Towards the Development of a Strategy for a National Spatial Data Infrastructure

By

ABDULLAH M.R. AL-SHAHRANI

A thesis submitted to the University of Nottingham

for the degree of

Doctor of Philosophy

May, 2002

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DEDICATION

DEDICATED WITH GREAT LOVE, THOUGHTS AND PRAYERS TO MY FATHER, WHO PASSED AWAY ON SUNDAY 12TH SEPTEMBER 1999 (2/6/1420H), DURING THE FIRST YEAR OF THIS STUDY AND TO MY MOTHER, WHO PASSED AWAY ON THURSDAY 18TH FEBRUARY 1993 (27/8/1413H). MAY ALLAH BLESS THEM BOTH.

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TABLE OF CONTENTS

Acknowledgement	**iii**
Table of Contents	**v**
List of Figures	**xiii**
List of tables	**xvi**
List of abbreviations	**xvii**
Abstract	**xxvii**

CHAPTER 1 GENERAL INTRODUCTION

1.1	INTRODUCTION AND BACKGROUND	1
1.2	RESEARCH FRAMEWORK	2
	1.2.1 Definitions	2
	1.2.1.1 What is a Map?	2
	1.2.1.2 What is Spatial Data?	3
	1.2.1.3 What is a Geographic Information System (GIS)?	4
	1.2.1.4 What is a Spatial Data Infrastructure?	6
	1.2.2 Brief Historical Background of SDI	7
	1.2.2.1 Spatial Date Infrastructure Components	7
	1.2.3 Problems Researching a New field	8
	1.2.4 Research Structure	9
	1.2.4.1 Phase One	10
	1.2.4.2 Phase Two	11
	1.2.4.3 Phase Three	11
1.3	CONCLUDING REMARKS	12

CHAPTER 2 SPATIAL DATA SHARING

2.1	INTRODUCTION	13
	2.1.1 Definition	14

2.2	**SPATIAL DATA SHARING PERSPECTIVES**	14
	2.2.1 Objectives	15
	2.2.2 Benefits of Spatial Data Sharing	16
	2.2.3 Barriers to Spatial Data Sharing	17
	2.2.3.1 Organisational Perspective	17
	2.2.3.2 System Perspective	18
	2.2.3.3 Spatial Data Modelling Perspectives	18
	2.2.4 Spatial Database Heterogeneity	20
	2.2.4.1 Semantic Heterogeneity	22
	2.2.4.1.1 Situations Leading to Semantic Conflicts	24
	2.2.4.2 Syntactic Heterogeneity	25
	2.2.4.3 Schematic Heterogeneity	27
2.3	**METHODS OF RESOLVING HETEROGENEITY PROBLEMS**	29
	2.3.1 Shared Schema and No Context Mediation	30
	2.3.2 No Shared Schema and With Context Mediation	30
	2.3.3 No Shared Schema and No Context Mediation	31
	2.3.4 The OGC Solutions	32
2.4	**CONCLUDING REMARKS**	32
CHAPTER 3	**SPATIAL DATA STANDARDS**	
3.1	**INTRODUCTION**	34
	3.1.1 Definition	34
3.2	**EVOLUTION OF STANDARDS**	35
	3.2.1 Historical Background	35
	3.2.2 Categories of Spatial data Standards	37
	3.2.2.1 Spatial Data Transfer Standards	38
	3.2.2.1.1 Direct Data Conversion Among Systems	38
	3.2.2.1.2 Common Spatial Data Exchange Standards	40
	3.2.2.1.3 Classification of Transfer Standards	42
	3.2.2.2 Reference System	43
	3.2.2.3 Data Model	43
	3.2.2.4 Data Dictionary	44
	3.2.2.5 Data Quality	44
	3.2.2.5.1 Spatial Data Quality Characteristics	45
	3.2.2.5.1.1 Lineage	45
	3.2.2.5.1.2 Positional Accuracy	45
	3.2.2.5.1.3 Attribute Accuracy	46
	3.2.2.5.1.4 Temporal Accuracy	46
	3.2.2.5.1.5 Logical Consistency	46
	3.2.2.5.1.6 Completeness	47

	3.2.2.6 Metadata	47
	3.2.2.6.1 Metadata Standards	47
3.3	STANDARDISATION INITIATIVES	48
	3.3.1 National Standards Initiatives	49
	3.3.1.1 The U.S. Spatial Data Transfer Standard	49
	3.3.1.1.1 The organisation and structuring of digital spatial data	50
	3.3.1.1.2 Implementing SDTS thought profiles	50
	3.3.2 International Standards Initiatives	51
	3.3.2.1 International Organisation for Standardisation	51
	3.3.2.1.1 ISO/TC 211 Geographic Information/Geomatics	52
	3.3.2.1.1.1 The Aim of ISO/TC 211	52
	3.3.2.1.1.2 The ISO/TC 211 Working Groups	53
	3.3.2.2 CEN/TC 287	54
	3.3.2.3 DGIWG	55
	3.3.2.4 IHO	56
	3.3.3 Summary of Standardisation Initiatives	57
	3.3.4 Comparison of Standards	59
3.4	CONCLUDING REMARKS	62
CHAPTER 4	**CURRENT STATUS OF MAPPING ACTIVITIES IN THE KINGDOM OF SAUDI ARABIA**	
4.1	INTRODUCTION	64
	4.1.1 The Goal of the Survey Questionnaire	65
	4.1.2 Clarification	65
	4.1.3 The Invited Ministries and Organisations	65
	4.1.4 The Participants	66
	4.1.5 How fully was the questionnaire answered?	68
4.2	ANALYSIS OF RESULTS	69
	4.2.1 Section 1: Filtering Introduction	69
	4.2.2 Section 2: Digital Products	70
	4.2.3 Section 3: Geographic Information Systems	74
	4.2.4 Section 4: Conventional Maps	76
	4.2.5 Section 5: Users' Needs and Requirements	78
	4.2.6 Section 6: Geographic Information Exchange	79
	4.2.7 Section 7: The Development of a Strategy for a National Spatial Data Infrastructure in the Kingdom of Saudi Arabia	82
4.3	CONCLUDING REMARKS	83

CHAPTER 5 COMPUTER NETWORK AND WEB MAPPING SERVICES

5.1	**INTRODUCTION**	86
	5.1.1 Definition	87
5.2	**NETWORK COMPONENTS AND ARCHITECTURE**	88
	5.2.1 Types of Networks	88
	5.2.1.1 Local Area Networks (LAN)	89
	5.2.1.2 Wide Area Networks (WAN)	89
	5.2.1.3 The Internet Network	89
	5.2.2 Protocols	91
	5.2.2.1 The Open-System Interconnect Seven-Layer Model	91
	5.2.2.2 The Transmission Control Protocol and Internet Protocol (TCP/IP)	94
	5.2.2.2.1 Network Access layer	95
	5.2.2.2.2 Internet layer	96
	5.2.2.2.3 Host-to-Host layer	96
	5.2.2.2.4 Process /Application layer	96
5.3	**SERVERS**	97
	5.3.1 Types of server	97
	5.3.1.1 Internet Server	97
	5.3.1.2 Map Server	98
	5.3.1.3 Web Feature Server	98
	5.3.1.4 Other Specialised Servers Emerging From OGC	99
	5.3.2 Client-Server	99
	5.3.2.1 Client-Server Architecture	100
	5.3.2.1.1 One-Tier Architecture	100
	5.3.2.1.2 Two-Tier Architecture	100
	5.3.2.1.3 Three-Tier Architecture	101
5.4	**THE INTERNET**	102
	5.4.1 What is the Internet and who owns it?	103
	5.4.2 Internet services	104
	5.4.2.1 The World Wide Web	104
	5.4.2.2 Electronic Mail (E-Mail)	105
	5.4.2.3 File Transfer Protocol	106
	5.4.2.4 The Telnet Protocol	106
	5.4.2.5 Information Searching	107

5.5	**INTERNET-BASED GIS**	109
	5.5.1 Internet Services for GIS	109
	5.5.1.1 Raw Data Download	110
	5.5.1.2 Metadata Search	110
	5.5.1.3 Map and Image display	110
	5.5.1.3.1 Static map display	111
	5.5.1.3.2 Dynamic map browser	111
	5.5.1.3.3 Image Display	111
	5.5.1.4 Web-Based Spatial Query and Analysis	112
	5.5.1.5 Building GIS on the Internet	112
	5.5.2 Technologies Supporting Internet-Based GIS	113
	5.5.2.1 Common Gateway Interface (CGI)	114
	5.5.2.2 Application Programming Interface (API)	114
	5.5.2.3 GIS plug-ins	115
	5.5.2.4 GIS Helper programs	115
	5.5.2.5 Microsoft Active X	116
	5.5.2.6 Java	116
	5.5.2.7 The OpenGIS Consortium (OGC)	117
	5.5.2.8 Other Commercial Tools For Internet-Based GIS	119
	5.5.2.8.1 Intergraph	120
	5.5.2.8.2 ESRI	121
	5.5.2.8.3 MapInfo	123
	5.5.2.8.4 AutoDesk	123
5.6	**INTERNET SECURITY**	124
	5.6.1 What is Internet Security?	125
	5.6.2 Security Measures	126
	5.6.3 Firewalls	126
	5.6.4 Encryption	129
	5.6.5 Authentication	130
	5.6.6 Virtual Private Networks	130
	5.6.7 Computer Anti Virus	131
5.7	**CONCLUDING REMARKS**	132

CHAPTER 6 THE SEARCH FOR A SPATIAL DATA CLEARINGHOUSE MODEL

6.1	**INTRODUCTION**	134
6.2	**THE CLEARINGHOUSE**	135
6.3	**INITIATIVES**	136

6.3.1 Africa — 137
6.3.1.1 Kenya — 137
6.3.1.2 Ghana — 137
6.3.1.3 The Southern African Development Community — 137
6.3.1.4 South Africa — 138
6.3.2 The Asia-Pacific Region — 139
6.3.2.1 South Korea — 139
6.3.2.2 Japan — 140
6.3.2.3 Malaysia — 141
6.3.2.4 The PCGIAP — 142
6.3.2.4.1 The PCGIAP Structure — 142
6.3.2.4.2 The Asia and Pacific Spatial Data Infrastructure — 144
6.3.2.5 Australia and New Zealand — 144
6.3.2.5.1 The ANZLIC — 145
6.3.2.5.2 The Australian Spatial Data Infrastructure — 146
6.3.2.5.3 The Australian Spatial Data Directory — 147
6.3.3 Europe — 149
6.3.3.1 EUROGI — 149
6.3.3.2 The European Spatial Metadata Infrastructure — 150
6.3.3.3 Portugal — 150
6.3.3.4 The Netherlands — 151
6.3.3.4.1 Rave's Main Activities — 152
6.3.3.4.2 The Main Digital Spatial Data For The NGII — 153
6.3.3.4.3 The National Clearinghouse for Geographic Information — 153
6.3.3.4.4 The main components of the NCGI — 154
6.3.3.5 The United Kingdom — 155
6.3.3.5.1 Initiatives — 155
6.3.3.5.2 The National Geospatial Data Framework — 157
6.3.3.5.2.1 What is NGDF? — 158
6.3.3.5.2.2 NGDF Structure — 158
6.3.3.5.2.3 Progress of NGDF — 159
6.3.3.5.2.4 NGDF Activities — 160
1. Metadata Service — 160
2. The United Kingdom Standard Geographic Base — 161
6.3.3.5.3 The Charter of the UK Strategic Alliance — 161
6.3.4 South and North America — 162
6.3.4.1 Colombia — 162
6.3.4.2 Uruguay — 163
6.3.4.3 Canada — 164
6.3.4.3.1 The Canadian Initiatives — 165
6.3.4.3.1.1 The Delta-X System — 165
6.3.4.3.1.2 The Mercator Alliance — 167
1. Mercator I — 167
2. Mercator II Project — 169
3. Mercator III Project — 169
6.3.4.3.2 The Canadian Geospatial Data Infrastructure — 170
6.3.4.4 The United States of America — 172
6.3.4.4.1 Initiatives and Background — 173
6.3.4.4.2 The Federal Geographic Data Committee — 175
6.3.4.4.3 National Spatial Data Infrastructure Components — 176
6.3.4.4.4 The Clearinghouse Concept and Architecture — 178
6.3.4.4.5 Summary — 181

	6.3.5 The Global Spatial Data Infrastructure	182
	6.3.5.1 What is GSDI?	182
	6.3.5.2 The Aim of GSDI	183
	6.3.5.3 The GSDI Management Architecture	184
	6.3.5.4 The potential GSDI spatial data providers and users	184
6.4	**CONCLUDING REMARKS**	185
CHAPTER 7	**PROPOSAL FOR A SAUDI NATIONAL SPATIAL DATA INFRASTRUCTURE (SNSDI)**	
7.1	**INTRODUCTION AND BACKGROUN**	189
	7.1.1 Justification for Saudi NSDI	192
7.2	**SNSDI COMPONENTS**	193
	7.2.1 Institutional Framework	194
	7.2.1.1 Royal Decree	194
	7.2.1.2 National Committee for Geographic Information	195
	7.2.1.2.1 Implementation of RCGI	196
	7.2.1.2.2 Membership of the RCGI	196
	7.2.1.3 Organisational Framework	198
	7.2.1.3.1 Background	198
	7.2.1.3.2 General Commission for Survey and Mapping	199
	7.2.1.3.3 Human Resource Development	202
	7.2.1.3.3.1 Central Survey and Mapping Training Institute	202
	7.2.1.3.3.2 Role of Universities and Other Training Institutions	204
	7.2.1.3.3.3 Role of Research and Development	204
	7.2.1.3.4 Financial Resources	205
	7.2.1.3.5 Contracting and Procurements	205
	7.2.1.4 National Spatial Data Policy Document	206
	7.2.1.5 SNSDI Development Office and SNSDI Management Board	207
	7.2.1.6 Spatial Data User/Producer Community	209
	7.2.1.6.1 User/Producer Interfaces to GCSM	211
	7.2.2 Fundamental Spatial Data Sets	213
	7.2.3 Spatial Data Standards	215
	7.2.4 Technical Framework	216
	7.2.4.1 Saudi National Spatial Data Clearinghouse Architecture	216
	7.2.5 An Alternative Model for the SNSDI Institutional Framework	222

7.3	**SYSTEM DEVELOPMENT AND INPLEMEMTATION PHASES**	225
	7.3.1 SNSDI System Development	225
	7.3.1.1 Concept Phase	225
	7.3.1.2 Design Phase	226
	7.3.1.3 Implementation Phase	227
	7.3.1.4 Operation Phase	229
	7.3.2 SNSDI Security Policy	230
7.4	**CONCLUDING REMARKS**	230
CHAPTER 8	**FINAL SUMMARY AND CONCLUDING REMARKS**	
8.1	**INTRODUCTION**	233
8.2	**MAJOR FINDINGS AND SUMMARIES**	234
	8.2.1 Worldwide efforts	235
	8.2.2 Saudi NSDI	237
	8.2.3 Final Note	241
8.3	**FUTURE WORK**	241
	REFERENCES	243
	ANNEXES	257
	Annex I	258
	Annex II	281

LIST OF FIGURES

Figures	Page
Figure 1-1 Geographic Information System (GIS) conceptual framework.	5
Figure 1-2 The structure of a national spatial data infrastructure.	8
Figure 1-3 The research structure.	10
Figure 2-1 U.S. national spatial data infrastructure components-system perspective.	14
Figure 2-2 Differences in geometric representation due to differences in context.	19
Figure 2-3 Two basic structures for spatial data.	20
Figure 2-4 Example of a heterogeneous database system.	21
Figure 2-5 Raster map and raster topology source.	26
Figure 2-6 Data structure for vector map.	26
Figure 2-7 Possible situations for conflict in data representation.	27
Figure 2-8 Conceptual schemas of two applications.	28
Figure 2-9 Maintaining semantics at two contexts by mapping between their schemes.	29
Figure 2-10 Architecture of shared schema and no context mediation.	30
Figure 2-11 Architecture of no shared schema and with context mediation.	31
Figure 2-12 Architecture of no shared schema and no context mediation.	31
Figure 3-1 Categories of spatial data standards.	37
Figure 3-2 Transfer of spatial data using direct data conversion.	39
Figure 3-3 A common transfer format.	40
Figure 3-4 The role of data transfer standards.	41
Figure 3-5 The range of database transfer process.	42

Figure 5-1 General concept of the main components of the Internet network infrastructure.	90
Figure 5-2 Reference model for OSI-ISO.	92
Figure 5-3 The TCP/IP architectural model.	95
Figure 5-4 Client-server concept model.	99
Figure 5-5 General concept of the three types of tiers architecture.	101
Figure 5-6 Telnet architecture.	107
Figure 5-7 Typical system architecture for Internet-based GIS.	113
Figure 5-8 OpenGIS Consortium vision for spatial data connectivity.	118
Figure 5-9 GeoMedia web map architecture.	121
Figure 5-10 ArcIMS web map architecture.	122
Figure 5-11 AutoDesk three-tier client server architecture.	124
Figure 5-12 Firewall used in three-tier architecture.	127
Figure 6-1 An approximate conceptual model for the ASDD system architecture.	148
Figure 6-2 ANZLIC page concept.	149
Figure 6-3 Conceptual model for the NCGI system architecture.	154
Figure 6-4 The Architecture of Delta-X system.	166
Figure 6-5 The Delta-X server.	166
Figure 6-6 CGDI as supporting decision-making for sustainable development.	170
Figure 6-7 The complete CGDI.	172
Figure 6-8 Relationship diagrams of the essential activities of the NSDI in the USA.	177
Figure 6-9 The U.S. national spatial data clearinghouse architecture.	181
Figure 6-10 GSDI relationships.	183
Figure 7-1 King Abdulaziz's long and hard trip from Kuwait to Riyadh.	190
Figure 7-2 The strategic location of Saudi Arabia.	191
Figure 7-3 NCGI structure.	197

Figure 7-4 The General Commission for Survey and Mapping (GCSM) main components.	200
Figure 7-5 Saudi national spatial data collection and production framework.	201
Figure 7-6 Structure of the Saudi NSDI development office.	208
Figure 7-7 The user/producer perspective.	210
Figure 7-8 The user/producer interface with GCSM.	211
Figure 7-9 A model for Saudi national interoperable spatial data environment.	214
Figure 7-10 General concept of the Saudi National Spatial Data Network (SNSDN).	217
Figure 7-11 General concept of three-tier architecture for the SNSDI.	218
Figure 7-12 A conceptual model for the Saudi national spatial data clearinghouse.	220
Figure7-13 Spatial data co-ordination and integration.	224
Figure 7-14 Summary of the Saudi NSDI components.	224
Figure 7-15 The Saudi NSDI system development and management phases.	229
Figure 8-1 The structure and interrelations of the eight chapters and two annexes.	234

LIST OF TABLES

Tables	Page
Table 2-1 Semantic conflicts occur due to context definition, example 1.	23
Table 2-2 Semantic conflicts occur due to context definition, example 2.	25
Table 3-1 Comparison between translators and transfer standards.	41
Table 3-2 ISO/TC 211 family of standards.	54
Table 3-3 Spatial data transfer standards.	58
Table 3-4 Basic characteristic features of some national and international standards.	61
Table 4-1 Ministries and Organisations that received a copy of the questionnaire.	66
Table 4-2 Participants	67
Table 4-3 The total number of questions in each section and how many respondents.	68
Table 4-4 The respondents in each section and language used to answer the questionnaire.	68
Table 5-1 Identification of Protocol Layers as Defined by CCITT Standards X.21 and X.25 for the OSI-ISO.	94
Table 6-1 Member nations of the Permanent Committee.	143
Table 7-1 Recommended members of the NCGI.	197

LIST OF ABBREVIATIONS

Abbreviation	Meaning
ACM	Association for Computing Machinery
ACOA	Atlantic Canada Opportunities Agency
ADRG	Arc Digitised Raster Graphics
ADA	Ar Riyadh Development Authority (KSA)
ACSM	American Congress on Surveying and Mapping
AES	Advanced Encryption Standards
AGI	Association of Geographic Information (UK)
ALIC	Australian Land Information Council
ANSI	American National Standards Institute
ANZLIC	Australia New Zealand Land Information Council
API	Application Programming Interface
APSDI	Asia and Pacific Spatial Data Infrastructure
ArcIMS	Arc Internet Mapping System
ARPANet	.Advanced Research Projects Agency Network (US)
ASCE	American Society of Civil Engineers
ASCII	American Standard Code for Information Interchange
ASDI	Australian Spatial Data Infrastructure
A/NZ	Australia and New Zealand
ASP	Application Service Provider
ASPRS	American Society of Photogrammetry and Remote Sensing
BGS	British Geological Survey (UK)
BIIF	Basis Image Interchange Format
BSI	British Standards Institute
BSC	Binary Synchronous Communications
CAD	Computer Aided Design
CADRG	Common Arc Digitised Raster Graphics

CANARIE	CAnadian Network for the Advancement of Research, Industry and Education Inc
CCITT	Consultative Committee on International Telegraphy and Telephony
CCMC	Canadian Centre for Marine Communications
CCSM	Canadian Council on Surveying and Mapping
CD-ROM	Compact Disk Read Only Memory
CEN	Comité Européen de Normalisation
CIB	Controlled Image Base
CIRI	Centre International de Recherche en Infographie (Canada)
CGDI	Canadian Geospatial Data Infrastructure
CGI	Common Gateway Interface
CGM	Computer Graphics Metafile
CHS	Canadian Hydrographic Service
CNDG	Clearinghouse Nacional de Datos Geograficos (Uruguay)
CNIG	Centro Nacional de Informação Geográfica (Portugal)
CPU	Central Processing Unit
CSD	Civilian Survey Department (KSA)
CSDC	Commonwealth Spatial Data Committee (A/NZ)
CSDGM	Content Standard for Digital Geospatial Metadata (US/ISO)
CSMA/CD	Carrier Sense Multiple Access/Collision Detection
CSMTI	Central survey and Mapping Training Institute (KSA)
DARPA	Defence Advanced Research Projects Agency (US)
DBMS	Database Management Systems
DEM	Digital Elevation Models
DEMTS	Digital and Electronic Maps Transfer Standards
DES	Data Encryption Standards
DETR	Department of Environment, Transportation, and Regions (UK)
DFAD	Digital Feature Analysis Data
DGIWG	Digital Geographic Information Working Group (NATO)
DGN	DesiGN (Intergraph Microstation or GeoMedia design file format)

DIGEST	DIgital Geographic information Exchange STandards (NATO)
DIS	Draft International Standards (ISO)
DLA	Department of Land Affairs (SA)
DLG	Digital Line Graph
DNC	Digital Nautical Chart
DND	Department of National Defence (Canada)
DNS	Domain Name Service
DTED	Digital Terrain Elevation Data
DTM	Digital Terrain Model
DWG	DraWinG (AutoDesk drawing File Format)
DXF	Digital eXchange Format
EGII	European Geographic Information Infrastructure
ENC	Electronic Navigational Chart/Electronic Nautical Chart
ESMI	European Spatial Metadata Infrastructure
ESRI	Environmental Systems Research Institute
ETF	European Transfer Format
EUROGI	European UmbRella Organisation for Geographic Information
FAO	Food and Agriculture Organisation
FDDI	Fibre Distributed Data Interface
FDIS	Final Draft International Standards (ISO)
FGDC	Federal Geographic Data Committee (US)
FIPS	Federal Information Processing Standard (US)
FNC	Federal Networking Council (US)
FTP	File Transfer Protocol
GCC	Gulf Coorporation Council (KSA, Oman, United Arab Emerates, Qatar, The Kingdom of Bahrain and Kuwait)
GCSM	General Commission for Survey and Mapping (KSA)
GCSM-ID	General Commission for Survey and Mapping Internal Documents (KSA)
GDCS	General Directorate of Civilian Survey (KSA)
GDF	Geographic Data File

GDMS	General Directorate of Military Survey (KSA)
GEMET	GEneral Multilingual Environmental Thesaurus
GEPA	Ghanaian Environmental Protection Agency
GGDI	Global Geospatial Data Infrastructure
GIF	Graphics Interchange Format
GI	Geographic Information
GII	Geographic Information Infrastructure
GIS	Geographic Information System/Science
GML	Geography Markup Language/General Modeling Language
GPS	Global Positioning System
GSDI	Global Spatial Data Infrastructure
GUI	Graphic User Interface
HDLC	High Level Data Link Control
HMLR	Her Majesty's Land Registry (UK)
HTML	Hypertext Markup Language
HTTP	HyperText Transfer Protocol
IACG	Inter-Agency Committee on Geomatics (Canada)
IBM	International Business Machine
ICA	International Cartographic Association
ICDE	Colombian Spatial Data Infrastructure
ICEC	Ice Centre of Environment Canada
ICMA	International City/County Managers Association (US)
ICMP	Internet Control Message Protocol
ICSM	Intergovernmental Committee on Surveying and Mapping (A/NZ)
ID	Identification
IDeA	Improvement and Development Agency (UK)
IEEE	Institute of Electrical and Electronics Engineers
IESG	Internet Engineering Steering Group
IETF	Internet Engineering Task Force
IGC	Inter-tribal GIS Council (US)

IGMP	Internet Group Management Protocol
IHO	International Hydrographic Organisation
IMAP	Internet Mail Access Protocol
IMO	International Maritime Organisation
IMP	Interface Message Processor
IRC	Internet Relay Chat
ISCGM	International Steering Committee for Global Mapping
ISOC	Internet SOCiety
ISO	International Organisation for Standardisation
ISO/TC	International Organisation for Standardisation/Technical Committee
ISP	Internet Service Provider
IT	Information Technologies
ITC	International Institute for Aerospace Survey and Earth Sciences (the Netherlands)
ITRD	Information Technology Research and Development
JDBC	Java Database Connectivity
JPEG	Joint Picture Experts Group
JTC	Joint Technical Committee
JVM	Java Virtual Machine
KACST	King Abdulaziz City for Science and Technology (KSA)
KSA	The Kingdom of Saudi Arabia
LAN	Local Area Network
LAS	Logiciels et Applications Scientifiques, Inc. (Canada)
LBS	Location Base Service
LINZ	Land Information New Zealand
LIS	Land Information System
MACDIF	Map and Chart Data Interchange Format
MAFF	Ministry of Agriculture Fisheries and Food (UK)
MDIF	Map Data Interchange Format
MILNet	MILitary Network (US)

MIT	Massachusetts Institute of Technology (US)
MODA	Ministry of Defence and Aviation (KSA)
MOC	Ministry Of Communications (KSA)
MOMRA	Ministry Of Municipal and Rural Affairs (KSA)
MOP&MR	Ministry of Petroleum and Mineral Resources (KSA)
MSD	Military Survey Department (KSA)
MSGSI	Military Survey and Geographic Study Institute (KSA)
MSL	Mercator Systems Ltd (Canada)
MTOP	Ministerio de Transportes y Obras Publicas (Uruguay)
NaLIS	National Infrastructure for Land Information System (Malaysia)
NAC	National Association of Counties (US)
NACOM	National Action Committee on Ocean Mapping (Canada)
NAP	National Action Plan (the Netherlands)
NASA	National Aeronautics and Space Administration (US)
NATO	North Atlantic Treaty Organisation
NCGI	National Committee for Geographic Information (the Netherlands)
NCWCD	National Commission for Wildlife Conservation and Development (KSA)
NDI	Nautical Data International (Canada)
NFGIM	National Framework for Geographic Information Management (Ghana)
NGD	National Geospatial Database (UK)
NGDF	National Geographic Data Framework (UK)
NGII	National Geographic Information Infrastructure (the Netherlands)
NGIS	National GIS (South Korea)
NIMSA	National Interest Mapping Service level Agreement (UK)
NIST	National Institute of Standards and Technology (US)
NJUG	National Joint Utilities Group (UK)
NLIC	National Land Information Centre (South Korea)
NLIS	National Land Information Service (UK)
NLC	National League of Cities (US)
NLPG	National Land and Property Gazetteer (UK)

NMO	National Mapping Organisation
NMSDC	National Mapping and Spatial Data Committee (Malaysia)
NNTP	Network News Transport Protocol
NOAA	National Oceanographic and Atmospheric Administration (US)
NRCan	Natural Resources Canada
NRCS	National Resource Conservation Services (US)
NSDIPA	National Spatial Data Infrastructure Promoting Association (Japan)
NSDI	National Spatial Data Infrastructure
NSDP	National Spatial Data Policy (KSA)
NSGIC	National States Geographic Information Council (US)
NSIF	National Spatial Information Framework (South Africa)
NTDB	National Topographic Database
NTF	National Transfer Format (UK)
NVT	Network Virtual Terminal
ODBC	Open Database Connectivity
OGC	OpenGIS Consortium
OGDI	Open Geospatial Datastore Interface
OLE	Object Linking and Embedding
OMB	Office of Management and Budget (US)
OOPL	Object Oriented Programming Language
OS	Ordnance Survey (UK)
OSGB	Ordnance Survey, Great Britain
OSI	Open-System Interconnect
PCGIAP	Permanent Committee on GIS Infrastructure For Asia and the Pacific
PNG	Portable Natural Graphic
POP	Post Office Protocol
PP	Point Profile
PPP	Point to Point Protocol
PSMA	Public Sector Mapping Agencies (A/NZ)
QA	Quality Assurance

QC	Quality Control
RAD	Rapid Application Development (US)
R&D	Research and Development
RFP	Request For Proposal
RGF	Raster Graphic Formats
RIP	Routing Information Protocol
RMSE	Root Mean Square Error
RP	Raster Profile
RRSU	Regional Remote Sensing Unit (Zimbabwe)
SADC	Southern African Development Community
SAIF	Spatial Archive and Interchange Format (Canada)
SANG	Saudi Arabian National Guard
SASO	Saudi Arabian Standards Organisation
SAVD	Saudi Aramco Vertical Datum
SCECO	Saudi Consolidated Electric COmpany
SDI	Spatial Data Infrastructure
SDLC	Synchronous Data Link Control
SDO	SNSDI Development Office (KSA)
SDTS	Spatial Data Transfer Standards (US)
SDUPC	Spatial Data Users/ Producers Community (KSA)
SGML	Standard Generalised Markup Language
SIC	Survey Information Centre (KSA)
SINES	Spatial Information Network Enquirer Service (UK)
SMB	SNSDI Management Board (KSA)
S/MIME	Secure Multipurpose Internet Mail Extensions
SMTP	Simple Mail Transfer Protocol
SNCC	State NaLIS Co-ordinating Committee (Malaysia)
SNCGI	Saudi National Centre for Geographic Information
SNGIS	Saudi National Geographic Information Standards
SNIG	Sistema Nacional de Informação Geográfica (Portugal)

SNSDD	Saudi National Spatial Data Directory
SNSDC	Saudi National Spatial Data Clearinghouse
SNSDN	Saudi National Spatial Data Network
SNMP	Simple Network Management Protocol
SNSDI	Saudi National Spatial Data Infrastructure/ Strategy for a National Spatial Data Infrastructure (KSA)
SOAP	Simple Object Access Protocol
SPDFDM	Standard Procedure and Data Format for Digital Mapping (Japan)
SQL	Structured Query Language
SSL	Secure Socket Layer
STC	Saudi Telecommunication Company
SVF	Simplified Vector Format
SVG	Scalable Vector Graphics
TCP/IP	Transmission Control Protocol and Internet Protocol
TIFF	Tag Image File Format
TIGER	Topologically Integrated Geographic Encoding and Referencing System (US)
TVP	Topological Vector Profile
UCGIS	University Consortium for Geographic Information Science (US)
UCSB	University of California Santa Barbara
UDP	User Datagram Protocol
UKSGB	United Kingdom Standards, Great Britain
UNCED	United Nations Conference on Environment and Development
UNEP	United Nations Environment Programme
UNRCC-AP	United Nations Regional Cartographic Conference for Asia and the Pacific
UoD	Universe of Discourse
URISA	Urban and Regional Information Systems Association (US)
URL	Universal Resource Locator
USC	University of Southern California (US)

USGS	United States Geological Survey
USL	Universal Systems Ltd. (Canada)
UTM	Universal Transverse Mercator
VPF	Vector Product Format
VPN	Virtual Private Networks
VRML	Virtual Reality Modelling Language
WAN	Wide Area Networks
WAP	Wireless Application Protocol
WGS	World Geodetic System
WMI	Web Mapping Interface
WML	Wireless Markup Language
WWW	World Wide Web
W3C	World Wide Web Consortium
XML	eXtensible Mark-up Language

UNIVERSITY OF NOTTINGHAM

Abstract

Towards the Development of a Strategy for a National Spatial Data Infrastructure

By Abdullah M. Al-Shahrani

In today's world of ever advancing technology the time is precisely right for investment in the development and implementation of a national spatial data infrastructure. This implies that all spatial data presently scattered in different departments and organisations are co-ordinated and shared. In the Kingdom of Saudi Arabia there are a number of different mapping and Geographic Information Systems (GIS) activities being implemented within various government organisations, each with its own merits. Certain research and pilot projects have also been carried out aiming to provide help and recommendations with regard to spatial data sharing and to promote awareness of the importance of spatial data to the Kingdom's development. However, there is an urgent need for a consolidation of effort to avoid the costly mistake of duplication of work; hence the need for a unified national spatial data infrastructure.

This research aims to develop a conceptual framework for a strategy for a national spatial data infrastructure (SNSDI) including its main components. A proposal is presented for a Saudi national spatial data infrastructure (which happens to have the same abbreviation – SNSDI) to consolidate isolated mapping and spatial data efforts in the Kingdom of Saudi Arabia in place of the current practice of each agency acting independently.

This research project will hopefully provide a leadership role in developing a Kingdom-wide spatial data infrastructure.

CHAPTER 1
GENERAL INTRODUCTION

1.1 INTRODUCTION AND BACKGROUND

Maps are, without doubt, amongst the most ancient tools used by man as a means of communication. Since the beginning of his early activities on the face of the earth, man has tried to know more about his immediate surroundings. Eventually, he became more familiar with directions and bearings and drew lines on sand to show his travel routes and movements within his limited world. Later he used simple sketches to represent objects and features that were crucial to his life (Raisz, 1956). He carved stones, bones, wood and cave walls to show sketches and shapes representing the locations of natural resources, shelters, foods, water sources, hunting grounds and dangerous areas (enemies). These sketches, which were known before the discovery of alphabetic writing, represent a record of geographic information. This places maps amongst the oldest forms of communication (others are language and music) which mankind has invented (Rhind, 1997). Those lines and simple sketches soon began to be more complicated and took different shapes with regard to directions, angles, line lengths and weights. They were also taken a step forward from lines drawn on the ground, stones, bones, wood, etc to become lines drawn on clay plates containing figures and directional information of critical importance to navigation and transportation. In due time symbols were used instead of the sketches to identify natural and man-made features on papers, plates and other media (Brown, 1949).

Scientific and technological developments eventually enabled the use of aerial photography to portray such features more easily and accurately. The use of computers by the late 1960s led to the introduction of digital maps where all data and information shown on a conventional map (paper map) or aerial photography were converted to digital information stored on computer media. However, different organisations used different systems, methods and standards for the collection, processing and production of spatial data. This resulted in variations in internal contents, formats and structures, as well as other differences, which tended to be very complex and proprietary in nature, depending on the hardware and software applications used (Al-Shahrani, 2001a).

Significant initiatives and developments have taken placed in recent years to overcome these problems and ensure efficient spatial data collection, processing, manipulation and integration, as well as offering the possibility of making spatial data available to a rapidly growing number of users, and to other producers. This approach has attracted a great deal of interest in many spatial data communities and resulted in the introduction of many national, regional and international spatial data infrastructure initiatives throughout the world.

This chapter presents a general introduction and background to spatial data infrastructures and highlights the framework for this piece of research. Section 1.2 forms the main and most important part of this chapter. It defines maps, spatial data, geographic information systems and the term spatial data infrastructure, then briefly discusses the development of spatial data infrastructure work. It also identifies the research objectives and outlines the research structure. The chapter ends with concluding remarks in section 1.3.

1.2 RESEARCH FRAMEWORK

1.2.1 Definitions

1.2.1.1 What is a Map?

A map is most simply defined as a reduced drawing of the earth's surface or a portion of the earth's surface showing various representations, as seen from above, depicted at a given scale and in a given projection, printed on a flat surface (paper or any other similar material) showing natural and man-made features using special symbols and legends (Al-Shahrani, 1989).

This means that:

- A map is a miniature representation of our real world.
- A map shows the relationship between features (natural & man-made).

Conventional hard copy maps traditionally contain **spatial data** and non-spatial data (descriptive data, such as text or tabulated data that describe features or sets of data, such as geographic names, accuracy, co-ordinates, heights, etc). However, the latest advances in computer science and technology, space technologies and networks facilities introducing digital methods of data collection (mainly from digitising, scanning, photogrammetry, remote sensing and field survey) have become important sources for **digital spatial data** (Chou, 1997).

1.2.1.2 What is Spatial Data?

Many authors, writers, organisations, officials, etc have defined spatial data. The following are three examples that defined spatial data as:

1. Data tied to certain set of locations on the surface of the earth (Longley et al., 1999).
2. Data concerning objects or phenomena implicitly or explicitly associated with location relative to the earth (ISO/TC 211, 2002a).
3. Data that identifies the geographic location and characteristics of features (natural and man-made) and boundaries on the surface of the earth (Clinton, 1994).

We should not get too confused by the terms geographical or geographic information, geospatial information, geospatial data and spatial data, which have much the same meaning, although some authors prefer to use the term geospatial as, in principle, spatial might be taken to include information that is related to frames other than the surface of the earth, such as medical imaging of the human body (Longley et al., 1999). In this research the term spatial data will be used. Note, however, the difference between data and information as given by Masser (1997) where *information = data + metadata, or = data + context, or = data + meaning* (Masser, 1997).

Spatial data has found applications in many areas. It has the ability to relate the information on different activities and resources to a specific location on the surface of the earth, which can allow geographical monitoring or prediction of any changes. Spatial data is a complex, rapidly growing and important part of the information society and critical to solving today's complex environmental, economic and social problems.

If we take the economy as an example, Dr Geoff Robinson, former director general of the Ordnance Survey (OS) in Great Britain, quoted in his speaking notes in the Cambridge Conference July 1999, commented," *If I can refer to OS in Great Britain - consultants have recently advised us that £100 billion worth of Britain's GDP is underpinned by OS spatial data. So we are a fundamental contributor to Britain's economy*" (Robinson, 1999).

Spatial data is the main source of data for digital mapping, geographic information systems (GIS), Digital Terrain Model (DTM), Digital Terrain Elevation Data (DTED), Digital Feature Analysis Data (DFAD), Arc Digitised Raster Graphics (ADRG) and others. Use within a geographic information system (GIS) provides a good example to illustrate the importance of spatial data, so the next section defines and discusses geographic information systems in brief.

1.2.1.3 What is a Geographic Information System (GIS)?

The science associated with the use of geographic information system is termed " *Geographic Information Science (GIS)*" (Ratcliffe, 1999). However the abbreviation GIS is mainly used for Geographic Information System (GIS). In this research GIS refers to Geographic Information System (GIS), which can be defined by its system functionality, as follows:

"*A computer-based information system that enables capture, modelling, manipulation, retrieval, analysis and presentation of geographically referenced data*" (Worboys, 1995).

"*An organised collection of computer hardware, software, geographic data and personnel designed to efficiently capture, store, update, manipulate, analyse and display all forms of geographically referenced information*" (Chou, 1997).

"*A computer system for capturing, managing, integrating, manipulating, analysing and displaying data, which is spatially referenced to the Earth*" (McDonnell and Kemp, 1995).

Al-Shahrani defined GIS as "*a mix of hardware, software, human resources, procedures, policies and standards through which spatial data is captured, input, processed,* *manipulated, analysed, stored, retrieved and displayed in various methods and forms depending on the user's applications and requirements*" (Al-Shahrani, 2001a) in an attempt to include the trained people required to operate such a system. An alternative definition of geographic information systems is to say they are smart databases manipulated by a set of hardware, software and personnel.

A GIS has also been defined by its objective, e.g. "*a spatial decision-support system*" (Longley et al., 1999).

Figure 1-1 illustrates a conceptual framework of a geographic information system (GIS) based on the previous definitions.

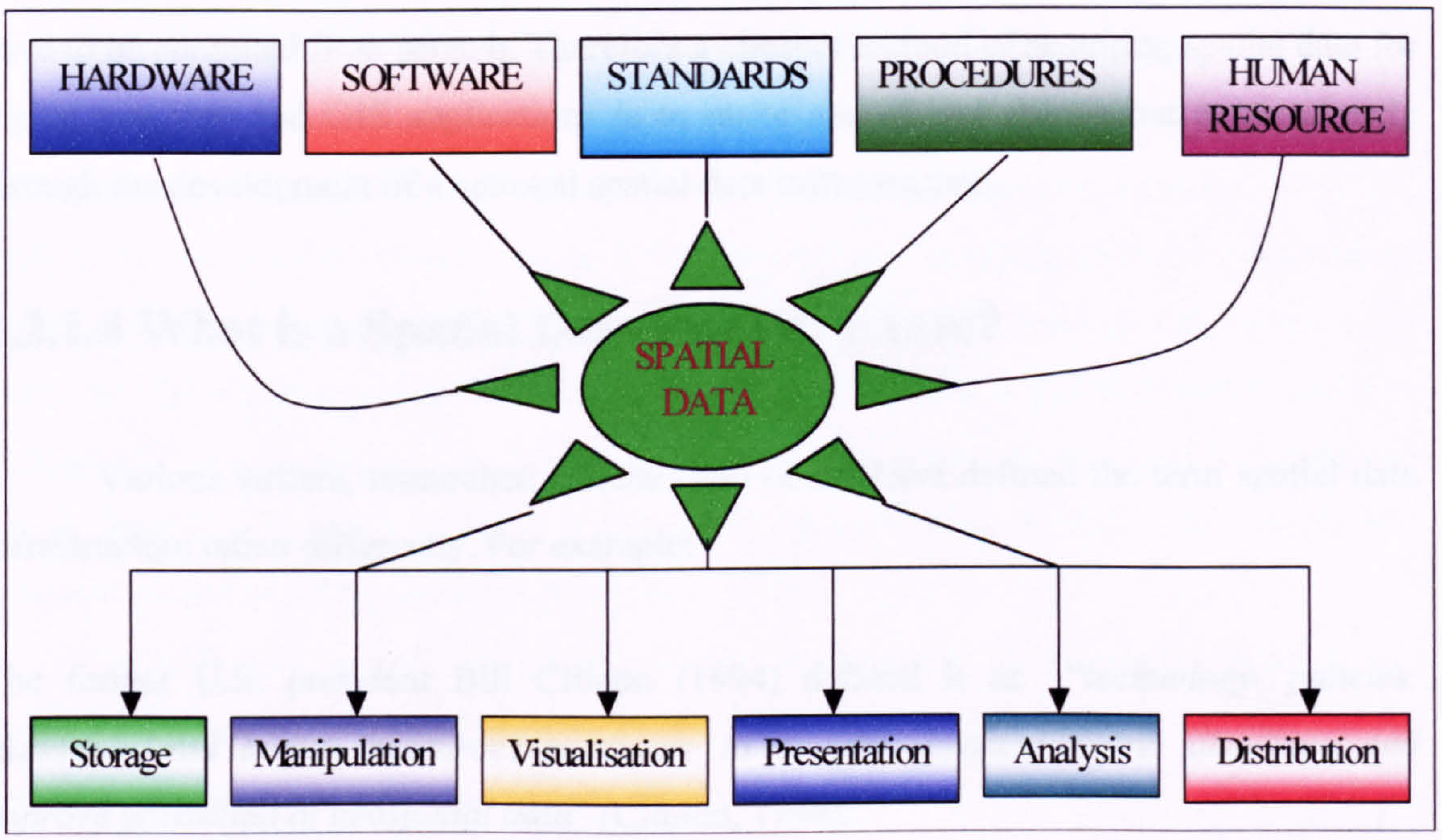


Figure 1-1 Geographic Information System (GIS) conceptual framework [Adapted from Chou, 1997].

Figure 1-1 shows that the spatial data are the central and main input component of any geographic information system (GIS). If we consider the large number of organisations in any nation who deal with digital mapping and GIS, we find that most of them have the hardware, software, human resources, procedure and other facilities. However they are missing the most important component, which is the spatial data. But if each organisation undertakes separate data acquisition ventures for its own needs without recourse to what exists already in other organisations, the result will be huge duplications of data, time, effort and money.

The original spatial data collection is the most expensive part of developing a GIS. As a result of researches, surveys and experience gained from practice, it has been concluded that around 75% to 85% of the total cost needed for the development of a commercially used GIS is spent on spatial data collection. The cost is mainly related to the capture of the geometric characteristics of the spatial features and may include the use of any of the traditional methods and sources such as field survey, aerial photography, satellite imagery, triangulation, data capture, cartography and digitisation or scanning of existing maps (Thapa and Bossler, 1992).

It is easily seen, therefore, that if accurate and up to date sources are available and accessible, developing the required GIS will only cost 15% to 25% as much, as if the data have to be compiled from scratch. Therefore a cheaper method of acquiring spatial data for digital mapping and GIS applications is to make use of and share what exists already through the development of a national spatial data infrastructure.

1.2.1.4 What is a Spatial Data Infrastructure?

Various writers, researcher, officials and others have defined the term spatial data infrastructure rather differently. For example:

The former U.S. president Bill Clinton (1994) defined it as "*technology, policies, standards and human resources necessary to acquire, process, store, distribute and improve utilisation of geospatial data*" (Clinton, 1994).

Radwan and Paresi (1995) defined an NSDI as *a "set of institutional, technical and economic arrangements to enhance the availability, reliability and accessibility of correct, up-to-date, to-the-point and integrated geo-information, timely and at an affordable price to support decision making processes related to a country's sustainable development*" (Radwan and Paresi, 1995).

On the other hand the U.S. Federal Geographic Committee (1995) defines it as a "*set of individuals, organisations, technologies and spatial data integrated to facilitate development and dissemination of spatial data and use of geographic information technologies*" (FGDC, 1995).

The study of spatial data infrastructure is a new subject that has emerged in many industrial and technologically advanced countries as a tool to help spatial data producers in both government and private sectors to standardise, organise and structure spatial data. An SDI should help users find what spatial data exists, in what condition, of what accuracy and quality and under what rules and regulations spatial data can be accessed and shared.

1.2.2 Brief Historical Background of SDI

The term Geo Information Infrastructure (GII) was used for the first time in Canada in the early 1980's, in connection with the creation of standards and exchange protocols for spatial data transfer between federal and provincial mapping agencies (Radwan, 1997).

In 1992, global environmental issues, such as the depletion of the ozone layer, were discussed at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, where it was agreed that reducing global environmental problems could be achieved through co-ordination among all the nations of the world. As a result of that meeting an action programme to address global environmental concerns (Agenda 21) was adapted. The Agenda 21 document highlighted the need for improved spatial data as a crucial tool for improving our understanding of the current status and temporal dynamics of the environment (Nebert, 2001).

In 1994, the former U.S. president Bill Clinton issued an Executive Order to co-ordinate geographic data acquisition and access in the USA, to form what was named the National Spatial Data Infrastructure (NSDI) (Clinton, 1994). This was the real start of national spatial data infrastructure activities.

Today many national, regional and international activities around the world are trying to consolidate and improve spatial data collection, production and distribution by developing and implementing a spatial data infrastructure.

1.2.2.1 Spatial Data Infrastructure Components

At the start, spatial data infrastructure was seen as entirely a technical issue, comprising standards for data definition, coding and exchange. But it became clear that standardisation would not be feasible without resolving institutional, fundamental data set and other technical and administrational issues concerning the right to access and share spatial data in a distributed environment (Clarke, 1996). Therefore a number of components for spatial data infrastructure were defined, as shown in figure 1-2.

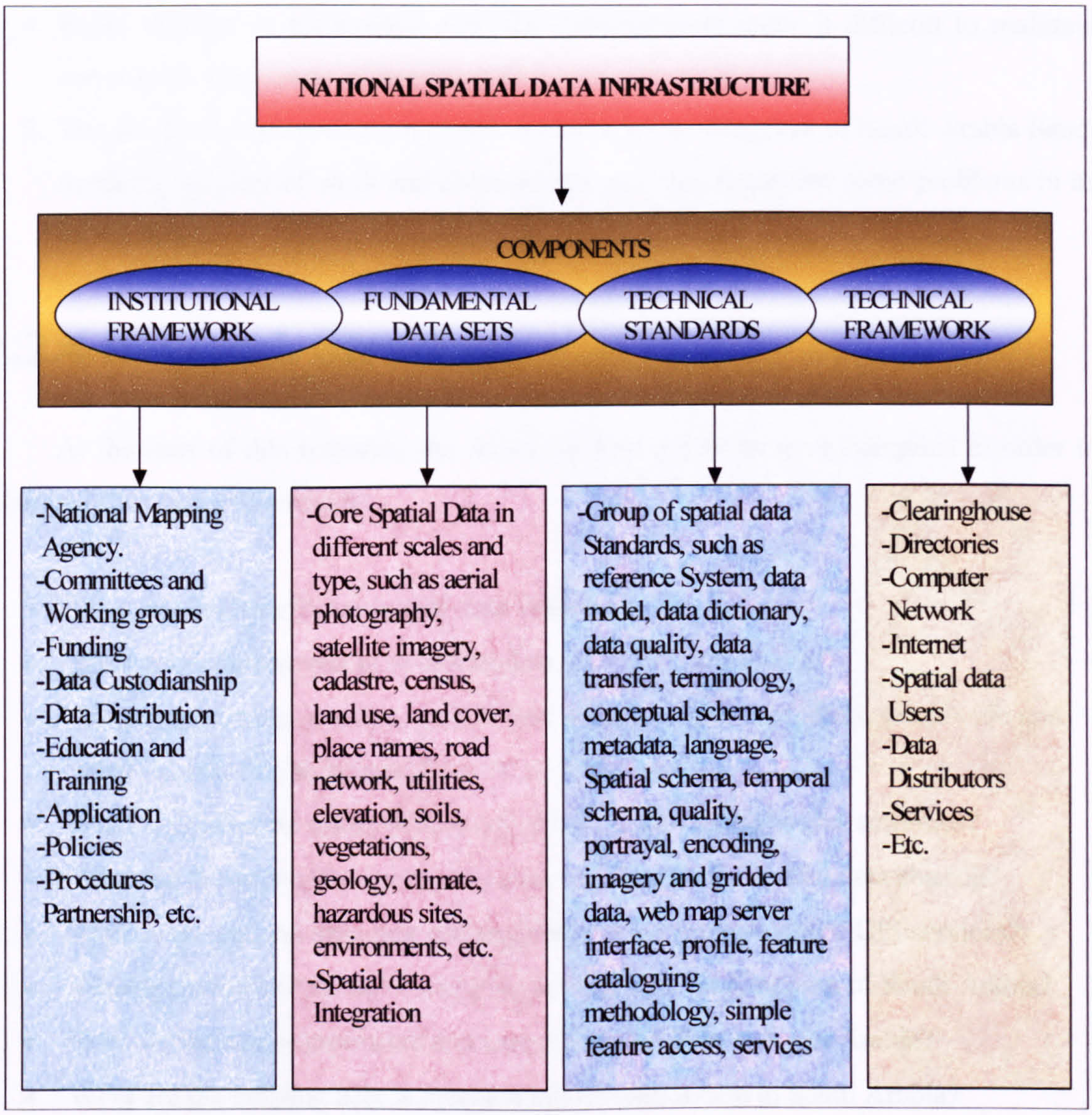


Figure 1-2 The structure of a national spatial data infrastructure.

1.2.3 Problems Researching a New Field

There were no major problems encountered in this research, but the following points are important:

1. The spatial data infrastructure concept is new and most of the initiatives are still under development.

2. The field was first recognised in 1994 and therefore most documents and references are relatively new.
3. Spatial data infrastructure is a broad subject covering many areas of endeavour.
4. Rapid changes in technology and SDI developments made it difficult to maintain currency in some parts of this research.
5. The practical implementation of this research in the Kingdom of Saudi Arabia Saudi needed great deal of work and commitment and may encounter some problems in its initial stages.

1.2.4 Research Structure

At the start of this research, the following key questions were compiled in order to plan and structure this research:

- What are the benefits of spatial data sharing?
- What is the current status of spatial data standards, worldwide?
- What is the current status of spatial data infrastructures initiatives, worldwide and what lessons can be learned from those initiatives?
- What is the current status of national spatial data clearinghouses activities?
- What are the appropriate computer network systems for spatial data sharing?
- What is the general structure and requirement for Internet-based GIS services?
- What is the current status of mapping activities in the Kingdom of Saudi Arabia?
- Who are the major producers and users of spatial data in Saudi Arabia?
- What are the existing access mechanisms of spatial data in Saudi Arabia?
- What are the main problems of data sharing and the consequences in Saudi Arabia?
- What is the impact of Saudi NSDI development on mapping organisations?
- What is the current status of information technologies and networks in the Kingdom of Saudi Arabia?
- What are the institutional, technical and other requirements needed for the development and implementation of an NSDI in the Kingdom of Saudi Arabia?

In order to find the answers to these key questions, the research was carried out in three different phases (subject areas), as shown in figure 1-3.

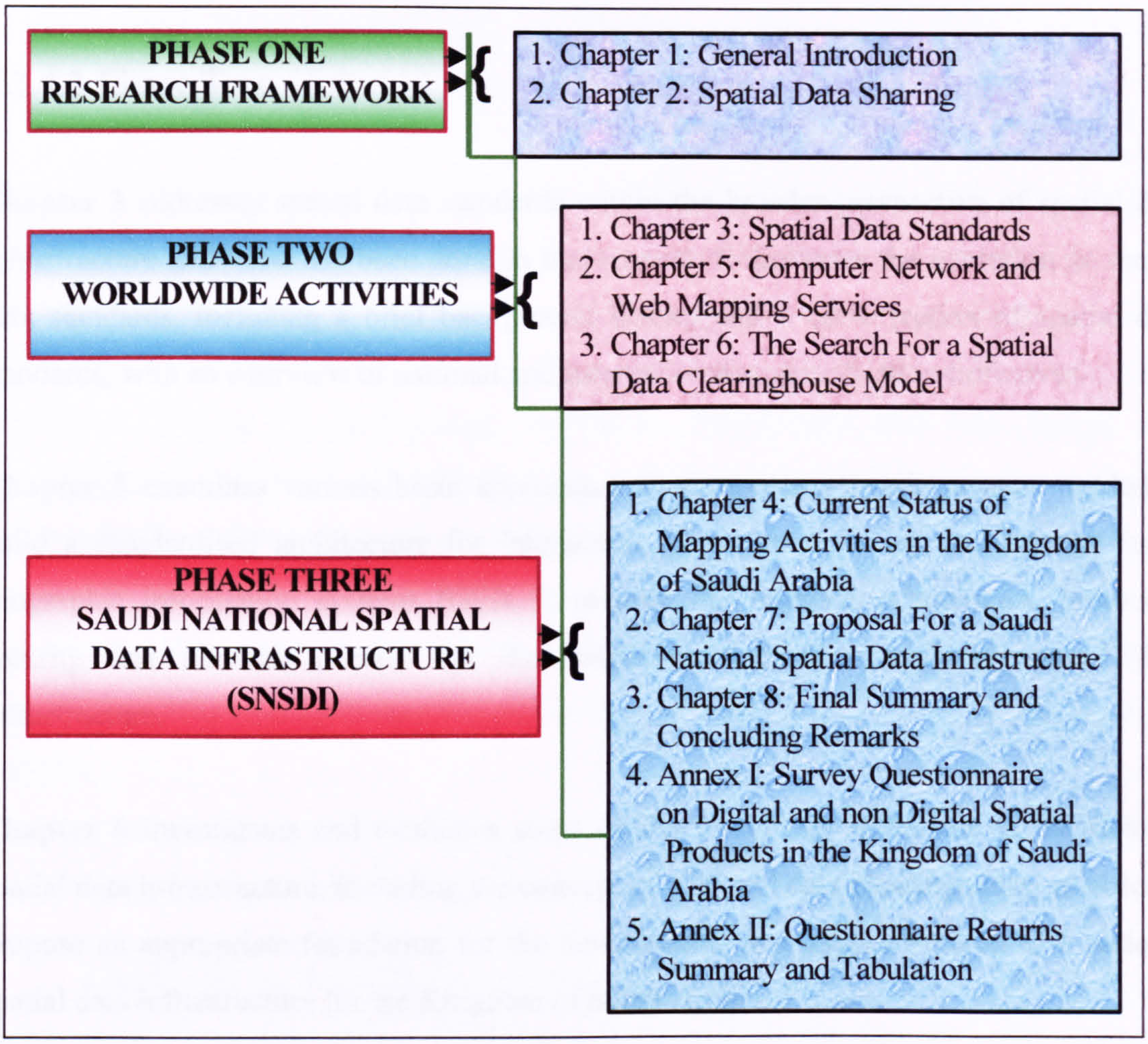


Figure 1-3 The research structure.

These three phases resulted in the eight chapters (including this chapter) of this research and its two annexes.

1.2.4.1 Phase One

Chapter 1 gives a brief history of the background of map-making from ancient maps to the latest digital maps and geographic information systems. Chapter one also sets out the framework for the research, as discussed above.

Chapter 2 discusses a number of spatial data sharing perspectives including objectives, benefits and problems of spatial data sharing. It examines some of the issues that make spatial data sharing difficult and highlights various methods that could be undertaken to facilitate spatial data sharing.

1.2.4.2 Phase Two

Chapter 3 addresses spatial data standards within the broader perspective of spatial data infrastructure and what has been done in that respect. It discusses the evolution of spatial data standards, including a brief background history and a classification of spatial data standards, with an overview of national and international standardisation initiatives.

Chapter 5 examines various basic approaches to computer network systems needed to build a standardised architecture for interactive spatial data sharing and Internet-based geographic information systems (GIS). It reviews the Internet technologies, protocols, security and services needed for the implementation of a national spatial data infrastructure.

Chapter 6 investigates and evaluates some of the worldwide initiatives in the field of spatial data infrastructure, including the concept of a spatial data clearinghouse, in order to propose an appropriate foundation for the development and implementation of a national spatial data infrastructure for the Kingdom of Saudi Arabia.

1.2.4.3 Phase Three

Chapter 4, annex I and annex II. Preparing a new groundwork for a national spatial data infrastructure and introducing it to the mapping organisations in the Kingdom of Saudi Arabia will bring a lot of changes, concerns and worries to these organisations. Therefore a requirements questionnaire (Annex I) was prepared and distributed to most of the Saudi mapping organisations. The questionnaire introduced the research and its objectives and contained sufficient questions to collect as much information as possible about the current status of mapping activities in Saudi Arabia and the producers and users needs and requirements. It also aimed to promote this proposed national spatial data infrastructure initiative. The questionnaire was distributed by the General Directorate of Military Survey (GDMS) to nineteen (19) ministries and organisations. The participants were given about six months to complete and return the questionnaire. A total of seventeen (17) questionnaires (89.5%) were returned. Annex II discusses, summarises and tabulates various replies. Chapter 4 presents an analysis of the results from the returned questionnaires, together with the general conclusions drawn from them.

Chapter 7 proposes an approach to the formulation and implementation of a Saudi national spatial data infrastructure (SNSDI) based on the information collected, discussed and compared in various chapters of this research. A discussion is also presented of the main components and building blocks for a Saudi national spatial data infrastructure (SNSDI), including the institutional framework, fundamental data sets, spatial data standards and technical framework. The chapter lays out conceptual, design, implementation and operation phases for the Saudi NSDI.

Chapter 8 briefly reviews the research with respect to the aim of developing a Saudi national data infrastructure, summarises the major findings and ends with brief concluding remarks.

1.3 CONCLUDING REMARKS

Spatial data are considered one of the oldest forms of human communication, pre-dating written language. Today, spatial data plays an important role in social, economic and environmental activities, as well as in security and in the defence of the nation-state. Spatial data is knowledge and knowledge is power.

The requirement to share spatial data among large numbers of users and producers raises the need to develop spatial data infrastructures. Applications of spatial data vary greatly from country to country; therefore, application of the spatial data infrastructure concept should vary as well. However, the main components of most of the worldwide national, regional and international spatial data initiatives are, in practice, identical and evolved around institutional issues, fundamental data sets, spatial data standards and technical frameworks.

This research explores the activities in, and the roles of, the main components of spatial data infrastructure work worldwide, then focuses on the development of a Saudi national spatial data infrastructure to integrate and share the large amount of spatial data scattered throughout geographically widespread archives.

CHAPTER 2
SPATIAL DATA SHARING

2.1 INTRODUCTION

One area that has attracted a lot of concern within the spatial data community is spatial data sharing. This chapter discuses a number of spatial data sharing perspectives and examines some of the issues that make spatial data sharing difficult and highlights various methods that could be undertaken to facilitate spatial data sharing. A significant proportion of a nation's infrastructure, economic development, social, environmental and other activities are heavily dependent on spatial data related applications. In spite of the importance of spatial data and its applications and the advances in the information technology, spatial data sharing still encounters major problems and does not advance as fast as computer software and hardware technology, owing to a lack of standards and mechanisms as well as the absence of an appropriate spatial data infrastructure. Sharing spatial data means a great many things to many people. It could imply the mutual exchange of information between two different application domains, but it could also imply exchange between various levels of government administrations and private sectors. Spatial data sharing, in general, could be done through non-commercial vertical relationships (example local, regional and national) and horizontal relationships by linking autonomous organisations or databases located in different geographic locations. To all intents and purposes spatial data sharing is partly vertical because of links between different levels of government administrations and the need to communicate with each other and partly horizontal due to participating organisations being independent cutting across disciplines (Passole, 1996).

To address these issues, section 2.2 forms the main and important part of this chapter. It highlights some of the spatial data sharing objectives, benefits and barriers. Then it discusses semantic, syntactic and schematic spatial data heterogeneities. Section 2.3 briefly discusses some of the strategies for resolving the problems identified in section 2.2, especially those arising from semantic heterogeneity. Global initiatives to overcome heterogeneity problems undertaken by the OpenGIS Consortium (OGC) are also briefly highlighted. Finally the chapter ends with concluding remarks in section 2.4.

2.1.1 Definition

Calkins (1992) defined spatial data sharing as the digital/electronic transfer of spatial data or information between two or more organisational units where there is independence between the spatial data producer and the prospective user. The transfer may be in the form of periodic bulk transfers, routine (daily, weekly, monthly, etc) transfers, or on-line access driven by individual transactions (Calkins et al, 1992).

However, nowadays, spatial data sharing means the creation and distribution of a well structured spatial data linked by a proper network to permit data from one source to be made available to others through a clearinghouse used by both the users and producers (Radwan et al, 1997).

2.2 SPATIAL DATA SHARING PERSPECTIVES

Successful evolution of spatial data sharing depends on high-level support, communication, co-operation and development of partnerships among spatial data users and producers, as well as agreements on the use of common standards. Success also depends on a proper plan and layout of an integrated system that enables access and sharing of spatial data (Coleman and McLaughlin, 1998). Figure 2-1 shows the spatial data sharing perspective in the United States of America as an example. The U.S. initiative will be covered in more detail in chapter 6.

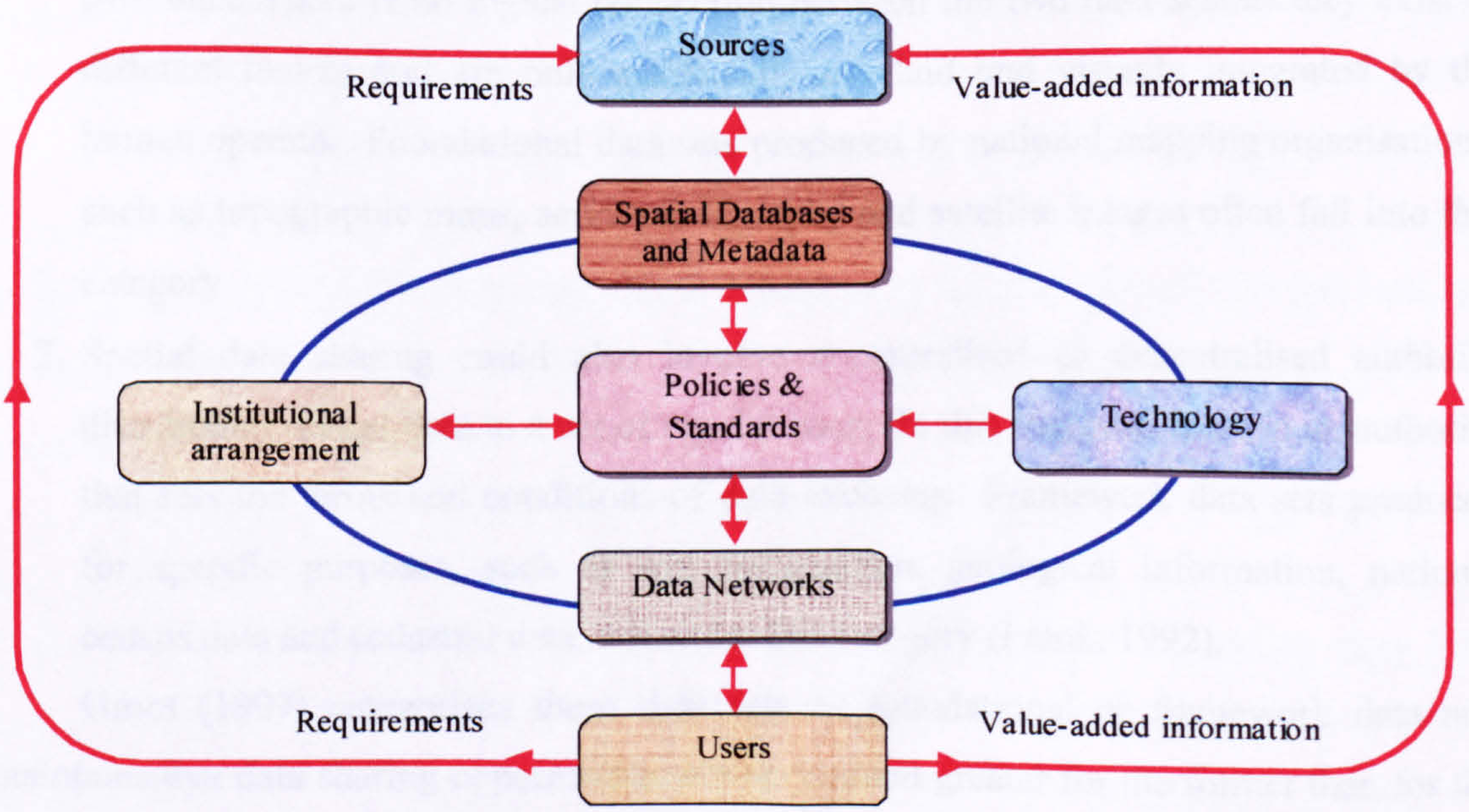


Figure 2-1 U.S. NSDI spatial data sharing perspective [Adapted from Coleman and McLaughlin, 1998].

2.2.1 Objectives

The overall objective for spatial data sharing is to create connections between widely dispersed spatial databases and users. Onsrud and Pinto (1995) indicated that three distinct situations require spatial data sharing between organisations:

1. Two or more organisations work together in the solution of a common problem. Data from one or more organisations, as well as expertise, are made available in a joint effort of problem solving. This is a non-routine situation and is solved on a case-by-case basis.
2. Inter-organisational systems, where organisations have a need for similar data so they develop procedures by which they can regularly share and exchange information.
3. Spatial data is structured and readily available to all interested users and producers through centralised or decentralised clearinghouse facilities. Sharing in this method is the most suitable and important method (Onsrud and Pinto, 1995).

Similarly, Frank (1992) gives two major different forms by which spatial data could be shared across organisational units.

1. Spatial data can be used as a backdrop on top of which the recipient presents his/her own data. There is no logical connection between the two data sets as they exist in different realms and are only graphically overlaid and visually integrated by the human operator. Foundational data sets produced by national mapping organisations, such as topographic maps, aerial photography and satellite images often fall into this category
2. Spatial data sharing could also involve a centralised or decentralised authority distributing spatial data to a set of regular users. In this instance, there is an authority that sets the terms and conditions of data exchange. Framework data sets produced for specific purposes, such as soil information, geological information, national census data and cadastral data, fall under this category (Frank, 1992).

Groot (1997) categorises these data sets as foundational or framework data and maintains that data sharing opportunities are very much greater for the former than for the later, which usually provides thematic information in a national context (Groot, 1997).

2.2.2 Benefits of Spatial Data Sharing

The availability of digital data capturing equipment, such as analytical plotters, soft copy photogrammetry, cartographic workstation, satellite image processing units, digitisers, scanners and GPS has increased the rate of digital spatial data collection and production and resulted in a large and growing volume of vector and raster data. Not only has the rate of spatial data collection and production increased, but also easy access to spatial data using new network technology, such as the Internet, has created a favourable atmosphere that allows spatial data to be shared and exchanged between organisations and users. This implies that users as well as producers can access a much wider range of spatial data from different organisations and sources in a better sharing environment than would be possible in a single user environment. Spatial data sharing provides access to additional data at a marginal or no cost. It is estimated that geographic information system operations that are able to share data between different organisations receive benefits at least four times greater than their costs (Radwan, 1997).

There are strong incentives for sharing spatial data. Different authors, in their analysis of the benefits of spatial data sharing from different sources, categorised the following benefits:

1. **Improvements in efficiency:** Spatial data sharing among organisations results in greater internal efficiency of operations due to less likelihood of duplicating works in creating and maintaining databases. Relatively cheaper access to existing accurate spatial data allows considerable reduction in time, effort and cost of data collection, production and maintenance. It permits organisational operations to be carried out more efficiently.
2. **Organisational effectiveness:** This is enhanced by the provision of new products and services. This may take place when an organisation makes use of available information through new sources. These changes help the organisation to improve and expand its services to clients and better monitor and enforce mandated programmes.
3. **Enhanced decision-making:** Enterprises stand to benefit by integrating data from various sources for improving decision-making. Some application areas, such as environmental management need information from different levels of government

and from different disciplines as well. The availability of such data enhances the chances of making good decisions (Onsrud and Pinto, 1995, and Radwan, 1997).

2.2.3 Barriers to Spatial Data Sharing

Many mapping organisations around the world usually undertake data acquisition ventures for specific purposes and within a certain application, using different software, hardware, standards, methods and different operators and supervisors with different experience. Spatial data is therefore collected and produced in different shapes, formats, structures, qualities, accuracies, completeness and managed by different database management systems, in different data models and under different rules and regulations. However, there is an urgent need for spatial data sharing across organisational boundaries, in spite of the above barriers. In general, the difficulties imposed on spatial data sharing may be viewed from three different perspectives: organisational, system and data modelling.

2.2.3.1 Organisational Perspective

Often, restrictions imposed by the internal regulations, directives and administrative policies in both government and private mapping organisations limit the release of spatial data for many reasons. The competition between organisations for leadership in the field of spatial data collection and production adds a serious obstacle to spatial data sharing (Moellering, 1996).

The data collected by some organisations are often seen as their property to be used solely by those organisations, who consider themselves to be the authority for such data. Besides, potential outside users may not have any idea as to the existence of such data. Furthermore, cost, legal issues, copyright and other obstacles may prevent the free flow of spatial data (Radwan, 1997).

Sharing of spatial data between organisations, in the Kingdom of Saudi Arabia for example, is minimal. Dr. Khalid Ankary, former Minister of Municipal and Rural Affairs (recently Minister of Higher Education in Saudi Arabia), indicated that the co-ordination between different ministries and organisations is minimal because information concerning existing networks is centralised at each ministry, for example proposed programmes and projects for expansion of the built up area. Traditionally most government offices have developed their own methods of data collection and storage as required for their own particular use. As these data are rarely accessible to other agencies, the data collected are mostly inconsistent and collected redundantly (Ankary, 1991).

2.2.3.2 System Perspective

Any two organisations using different hardware platforms, software systems and spatial data standards will tend to produce digital spatial data in different formats. Thus, sharing data requires conversion from one format to the other, sometimes with data loss, since there is no perfect union between the way two systems represent their data. Spatial data structures tend to be complex, more complex than for other kinds of digital data, because of the variety, shape and range of information they represent (Buehler and McKee, 1998). When data is stored in spatially distributed locations, a number of problems could arise that inhibit data sharing, because:

1. Each system is autonomous and under a separate and independent control.
2. Spatial data may be installed on different hardware platforms and may be run by different Database Management Systems (DBMS).
3. The database management systems may have different functionality and interfaces for access.

These situations lead to heterogeneity, which inhibits communication between systems and therefore makes spatial data sharing difficult.

2.2.3.3 Spatial Data Modelling Perspectives

Spatial data is abstracted from real world phenomena (e.g. roads, streets, farms, valleys,..) according to some application discipline, such as soil, relief, topography, hydrography, metrology, etc. The world of digital spatial data corresponds to a specific subset of reality viewed from different angles and different perspectives. Different applications have different views of reality and many different methods of abstraction. This is due to the fact that not all objects in the real world are relevant for all applications.

Similarly, not all attributes that specify the relevant properties of each object, such as road width or number of lanes, are relevant.

On the other hand, representation of data elements in an information system must take into account the role the objects play in the system and not their physical appearance in the terrain. Therefore geometric representation in different contexts could be different on account of the role the objects play. For example, a road may be regarded as a line object in a transportation database, as shown in figure 2-2 (a), while the same road may be handled as an area object in the cadastral database as in figure 2-2 (b). Therefore for a particular application, the set of objects that is relevant forms the application's context or view (Radwan, 1997).

a. Transportation Database1 b. Cadastral Database2

Figure 2-2 Differences in geometric representation due to differences in context [Adapted from Radwan, 1997].

Due to differences in context, spatial data sharing becomes difficult unless a mechanism is put in place for translating the data from one context to another. Within the same application domain, there could be different contexts depending on the views of the database designers. Consequently, both conceptual and logical models of any two systems may differ. Object definition and assignment of objects to classes as well as the representation of the objects in the database, depends on the particulars view of reality adopted.

It can therefore be stated that differences in the context worldview can be described as:

1. Differences in the geometric representation of the spatial objects.
2. Differences in the rules that assign objects to classes.
3. Differences in the class hierarchies and the attribute structure (Bishr et al., 1997a).

2.2.4 Spatial Database Heterogeneity

Molenaar (1997) indicates that thematic and geometric aspects of spatial data stored in an information system may be linked by two basic structures: the field based approach and the object oriented approach for representing the thematic and geometric properties of terrain objects. Figure 2-3 illustrates these two basic approaches.

In the field approach, the attribute values are linked directly to the position as occurs in levelling. In the object-based approach, however, both the geometric data (e.g. bounding rectangle of a house) and thematic data (e.g. number of rooms and owner) are linked together through the object that belongs to a class and has an identifier for a unique identification in the database. For example, a house can be defined by a unique identifier in the database (e.g. a house number and address). A basic difference between the two approaches is that in the field approach the terrain is treated as a collection of features described in a predefined continuous co-ordinate space, whereas the object based approach sees the terrain as discrete.

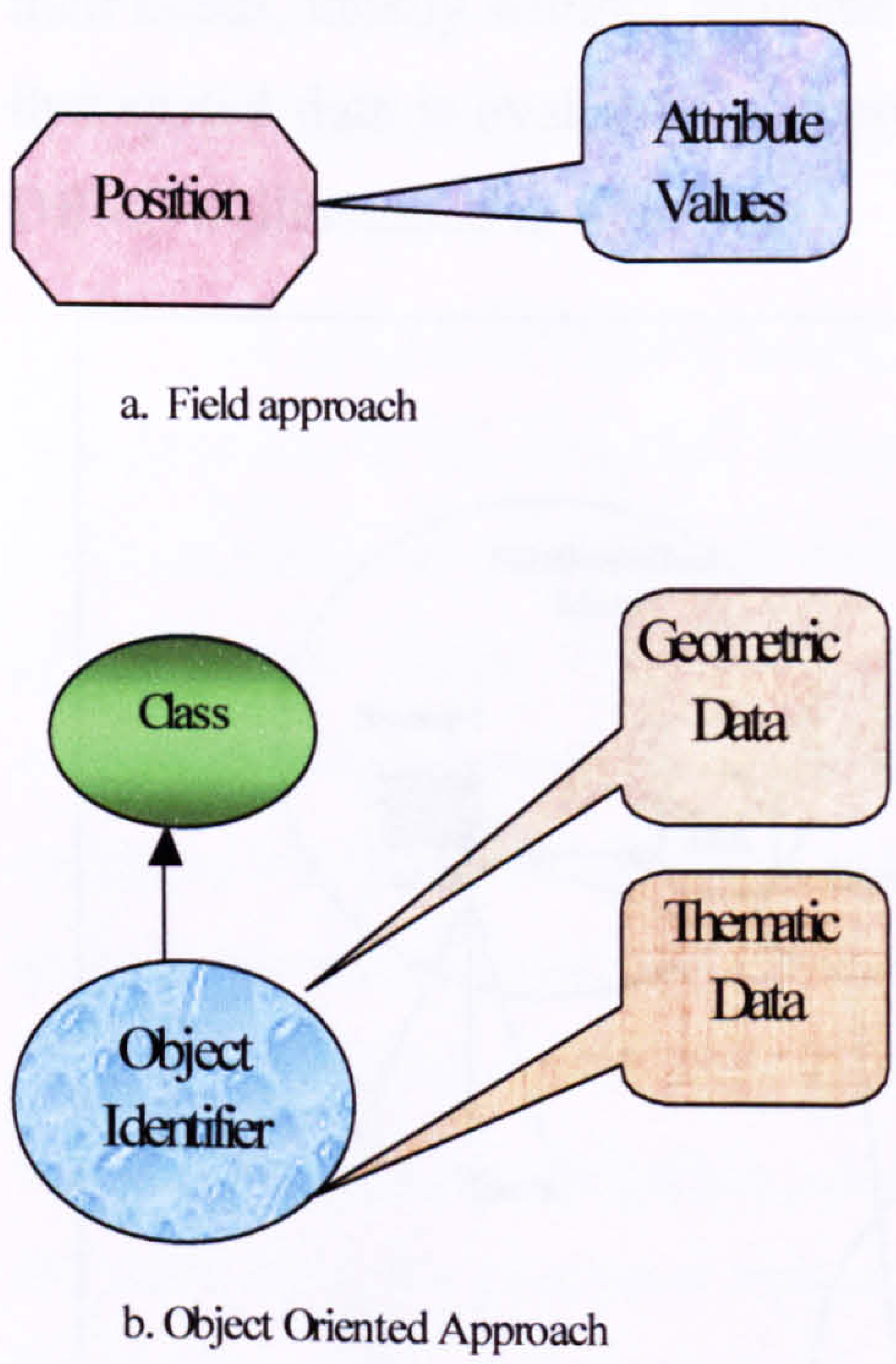


Figure 2-3 Two basic structures for spatial data [Source Molenaar, 1997].

In the object-oriented approach to data modelling, all conceptual entities are modelled as objects (Worboys, 1995). In this approach, the definition of objects to be represented in the information system is made primarily from a thematic perspective. Where the geometric aspects are considered necessary, a choice has to be made whether the objects should be represented as points, lines or area objects. The choice for the representation has to reflect the role the objects play in the information system, rather than their physical appearance in the terrain. The role, however, depends on the application and the level of aggregation of terrain description. A terrain feature with area dimension may be represented as a point in one application, while it is represented as an area object in another application, the two playing different roles in their respective applications. Object definition therefore differs from one application to the other. The abstraction and representation of features in an information system generally reflects reality only as seen in the context of the application.

Heterogeneity in databases basically results from those differences in context views of reality and the fact that autonomous organisations manage their data independently. One of the major effects of the emergence of a multiplicity of techniques for building proprietary databases is the existence of database heterogeneity. The availability of a variety of application software implies that users have a wider field to choose from to meet their needs, mostly without recourse to what choice other users would make. The result is that spatial data is available in many geographically distributed databases using different DBMS as illustrated in figure 2-4.

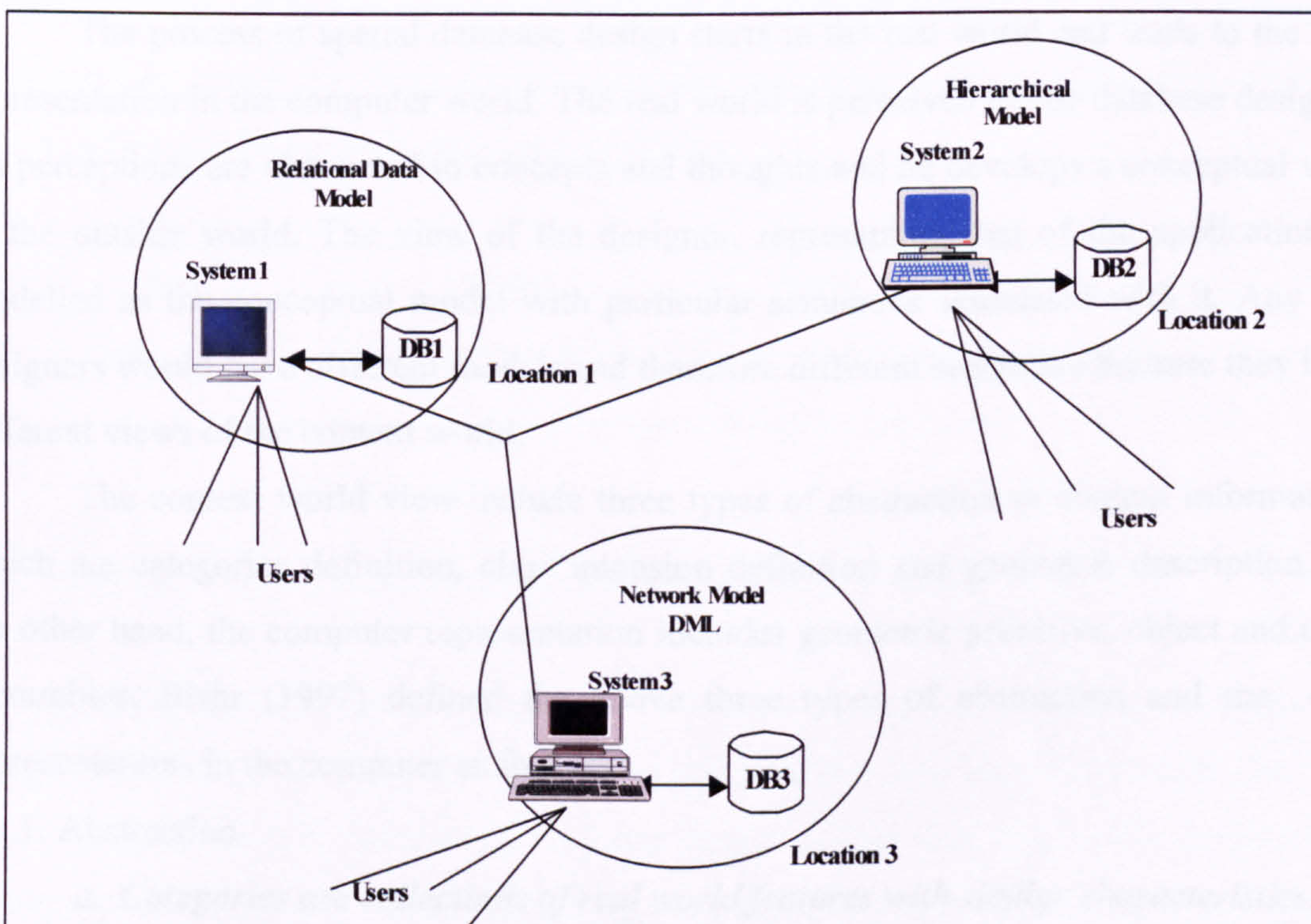


Figure 2-4 Example of a heterogeneous database systems [Source Hsiao and Kamel, 1993].

Different authors give different classifications for heterogeneity: Castellanos (1996) classifies heterogeneity among component databases into two types: system and semantic heterogeneities. System heterogeneity includes differences in hardware, operating systems, database management systems and communication protocols. Semantic heterogeneity, as will be discussed later, includes differences in the way real world is modelled in the databases, particularly in the schemas of the component databases (Castellanos et al., 1996).

Lee and McLaughlin categorised heterogeneity into lower and higher levels. Lower level heterogeneity covers hardware and operating systems while higher-level heterogeneity deals with data models (Lee and McLaughlin, 1991).

Bishr classified heterogeneity into three types: Semantic, syntactic and schematic (Bishr et al., 1997a). The following sections focus on the three aspects of heterogeneity, identified by Bishr, and highlight some major problems that could occur in a heterogeneous environment.

2.2.4.1 Semantic Heterogeneity

The process of spatial database design starts in the real world and leads to the data representation in the computer world. The real world is perceived by the database designer, his perceptions are abstracted in concepts and thoughts and he develops a conceptual view of the outside world. The view of the designer, representing that of the application, is modelled as the conceptual model with particular semantics associated with it. Any two designers would have different models and therefore different semantics because they have different views of the context world.

The context world view include three types of abstraction or context information, which are categories definition, class intension definition and geometric description. On the other hand, the computer representation includes geometric primitive, object and class hierarchies. Bishr (1997) defined the above three types of abstraction and the data representations in the computer as follows:

1. Abstraction
   a. *Categories are collections of real world features with similar characteristics.*
   b. *Class intention definition is the process of defining rules by which real world features are identified and associated with categories.*
   c. *Geometric description is the process of outlining specifications to assign geometric type to features as well as specifications to represent them in the computer.*
2. Computer representation
   a. *Geometric primitives are basic geometric elements which describe the geometry of spatial objects.*
   b. *Object are real world features.*

c. *Classes are computer representations of the categories which were defined in the context world view* (Bishr, 1997).

Semantic heterogeneity occurs mainly due to differences in context information. Semantic problems can be traced to differences about meanings, interpretations and intended use of the same or related data (Sheth and Larson, 1990). They arise when different terminology, names and values are given to similar data items in different databases. Semantic heterogeneity may also occur when a real world entity is given different meanings in related databases.

An example of conflict arising from differences in assigning objects to classes is illustrated in table 2-1. This table represents two databases that keep information on wells and ponds (applications A and B). Both the assumptions and criteria for assigning the object to classes differ and hence their contexts also differ.

Well	Pond
Area $\leq 25m^2$	$25m^2 \leq$ Area $\leq 50m^2$

a. Application A

Well	Pond
Area $< 50m^2$	Area $> 50m^2$

b. Application B

Table 2-1 Semantic conflicts occur due to context definition [Source Radwan, 1997].

In Application A, a distinguishing factor between a Well and a Pond is that the former has a surface area of up to $25m^2$, while the latter has a surface area ranging between $25m^2$ and $50m^2$. In Application B, however, a Well has an area of less than $50m^2$ while the Pond has an area greater than $50m^2$. Data sharing between these two applications needs to take into account the contexts and hence, the semantics of the data items. There is a need to indicate the conditions and assumptions under which classification (i.e. assignment of instances to classes) was made. This is necessary because what constitutes a pond in application A is not necessarily a pond in application B.

2.2.4.1.1 Situations Leading to Semantic Conflicts

Available literature gives a number of situations that can lead to semantic heterogeneity problems. Choi (1998) summarised the major types of conflicts, among which are the following:

1. **Domain incompatibility**: Arises when attributes of two objects have different domain definitions. For example:
   a. Naming conflicts: Semantically similar data items may be given different names (synonyms); and/or semantically different data items may be assigned the same name (homonyms).
   b. Data representation conflicts: Semantically similar attributes might have different data types or representation: for example, a value being an integer in one database and a string in another.
   c. Data scaling conflicts: Semantically similar attributes might be represented using different units of measure. For instance, the area of a parcel may be represented in 'sq. metres' in one database while another represents it as 'sq. feet'.

2. **Entity definition incompatibility**. This occurs when entity descriptors used by the objects are quite incompatible, even though the same type of entity is being modelled. Included in this category are:
   a. Database identifier conflicts: Semantically similar objects might have different identifiers, for example:
      Road1 (R1_ID, Name, type)
      Road 2 (R2_No, Name, type)
   b. Union compatibility conflicts: Semantically similar objects might be assigned semantically unrelated sets of attributes. For example, two schemes S1 and S2 both describing the same road could have two sets of unrelated attributes, for example:
      S1: (Road Name, width, max speed, max weight, type, transportation allowed).
      S2: (Road Name, type, last repaired, repaired type, maintaining office).

3. **Data value incompatibility:** Occurs when inconsistent data values are used to represent the same attribute in different databases (Choi, 1998).

Table 2-2 represents two separate databases with the same attribute, a farm named Al-Deerah. In database 1 the farm area is 120Km^2. In database 2, it is 110Km^2.

ID	Farm Name	Area
12345	Al-Deerah	120 Km^2

a. Database1

ID	Farm Name	Area
12345	Al-Deerah	110 Km^2

b. Database2

Table 2-2 Semantic conflicts occur due to context definition, Example 2 [Adapted from Radwan, 1997].

The detection of semantic heterogeneity can be a tough problem and it is even considered by some the most critical problem in data sharing (Castellanos et al., 1996).

2.2.4.2 Syntactic Heterogeneity

Syntactic heterogeneity is the difference in the thematic and the geometric representation as well as the topologic relationships of spatial objects (Bishr, 1997). Syntactic heterogeneity involves a coding of information such that it can be moved within a spatial database transfer system. It is also involves the representation of the geometry of terrain features as a point, line or area object, as well as the raster format of the representation. Systems have different particular ways of representing features. For instance one system may recognise an arc as made up of a number of connected edges whereas others may not; this constitutes a syntactic problem. The choice for the representation is based on the thematic aspect of the data. This can be done in either a raster or vector format. Figure 2-5 shows a representation of a raster map and its associated raster topology (Molenaar, 1991).

The representation of objects in a raster can best be done in a cell raster, as shown in figure 2-5. Each cell represents an area segment and hence this type maps is most suitable for the representation of area objects.

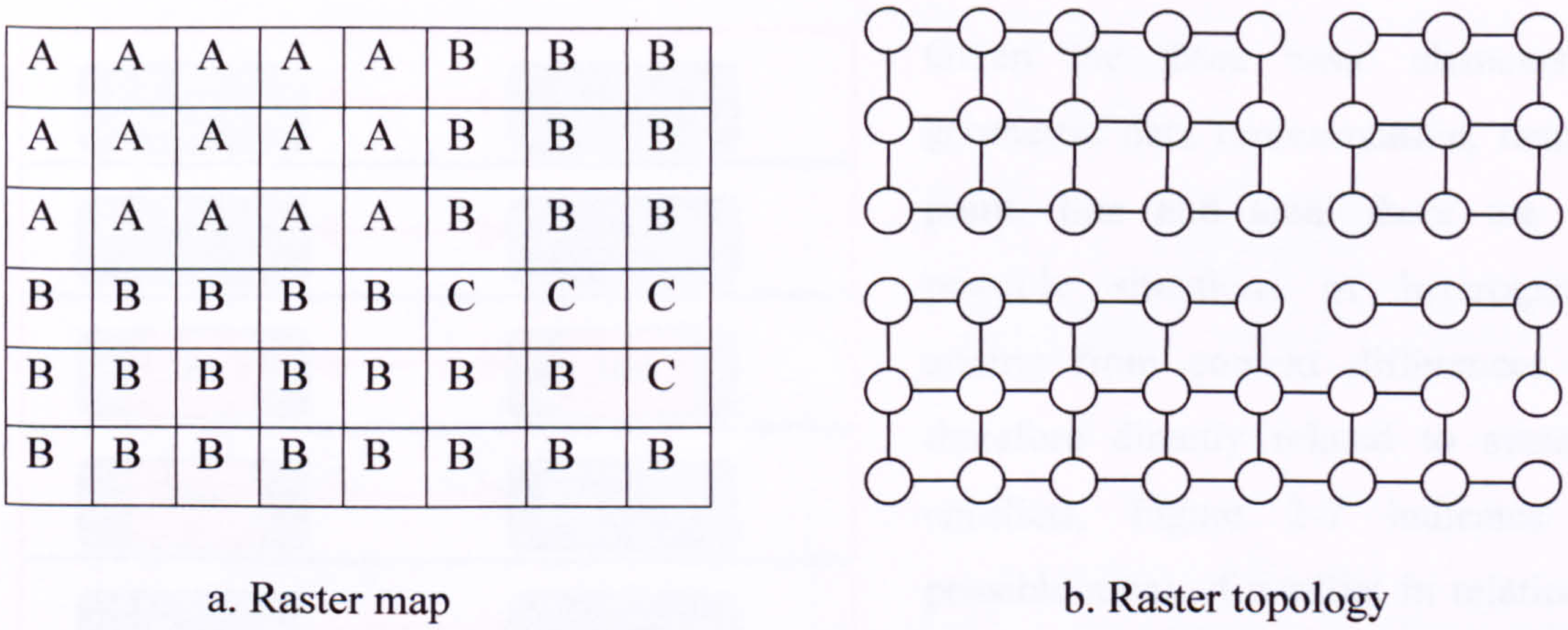


Figure 2-5 Raster map and raster topology [source Molenaar, 1991].

A vector structure represents linear characteristics of terrain features. A syntactical structure for vector maps of 2-D spatial objects, developed by Molenaar, is shown in figure 2-6. A 2-D vector map consists of six types of entities: three geometric types: nodes, edges and faces; and three geometric object types: point, line and area (Molenaar et al, 1997). All points used to describe the geometry of terrain features are treated as nodes.

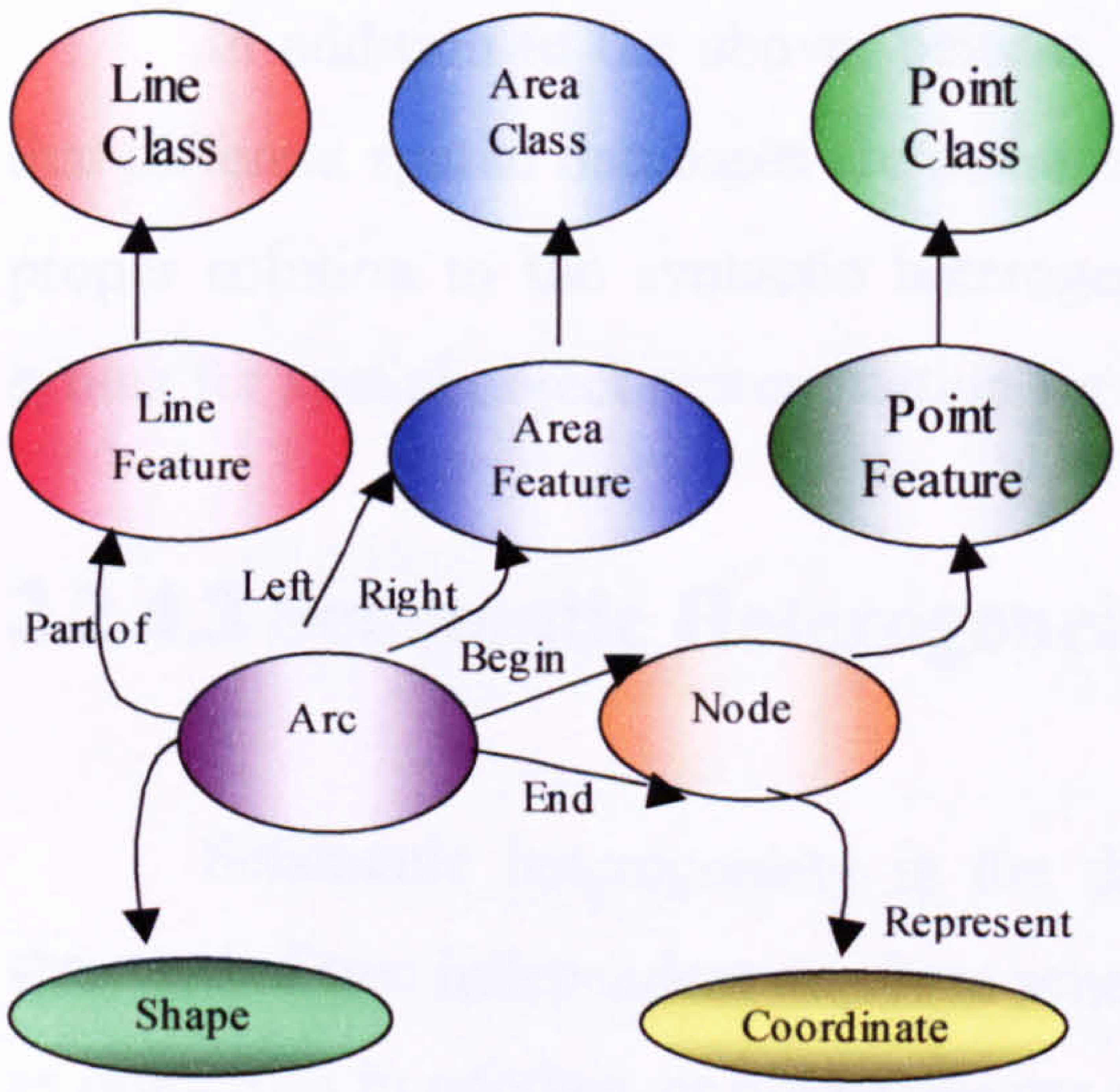
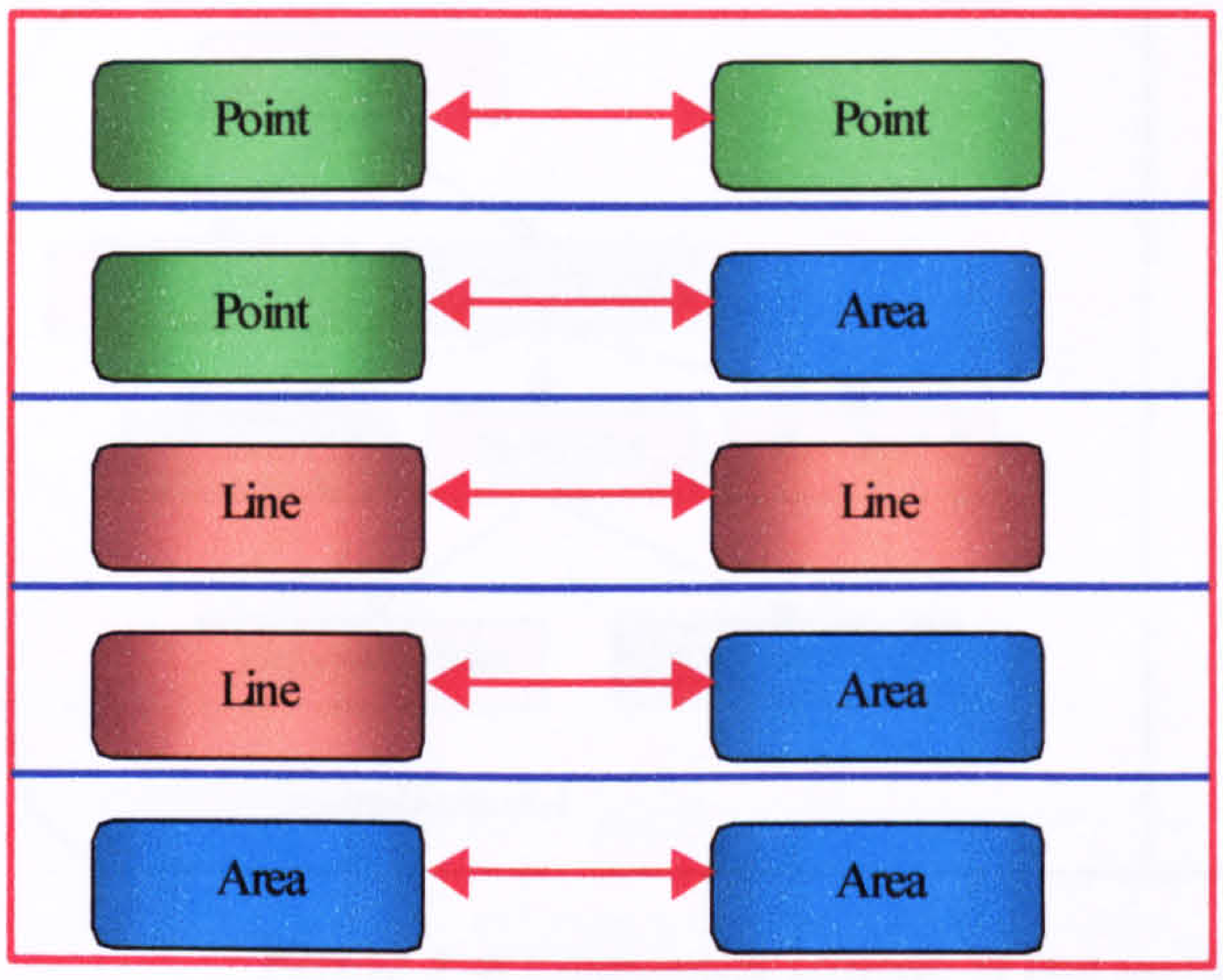


Figure 2-6 Data structure for vector map [Adapted from Molenaar, 1997].

Similarly, linear objects are represented as edges and their geometry by location, shape and length. An arc is therefore part of a line object. In the same way, the geometry of an area object is given by its boundaries.

Differences in object representation in different spatial databases constitute a syntactic problem, whereby is, the same real world object is represented by different geometric object types in related information systems.



Given the three basic elements of geometric data representation, namely, point, line and area, there are five possible situations of heterogeneity arising from context differences and therefore directly related to syntactic conflicts. Figure 2-7 indicates the possible areas of conflict in relation to vector geometry.

Figure 2-7 Possible situations of conflict in data representation [Adapted from, Radwan, 1997].

In addition to the above, besides, syntactic heterogeneity arises owing to the fact that different spatial databases are managed by different database management systems. A proper solution to the syntactic heterogeneity problem would be to provide a common syntax for spatial object representation for all databases (Bishr et al., 1997a).

2.2.4.3 Schematic Heterogeneity

Schematic heterogeneity is the difference in the class hierarchies and attribute structure of two independent database schemas. Objects in one database may be considered as properties in another, or object classes may have different aggregation or generalisation hierarchies, although they describe the same real world entities. Schematic heterogeneity can also be caused by relationships between objects being different from one database to another (Radwan, 1997).

Figure 2-8 represents two separate models of the feature class parcel. In (a) the industrial parcel has two subclasses: light industrial and heavy industrial. In (b) however, the light industrial parcel is considered as an attribute of the industrial parcel.

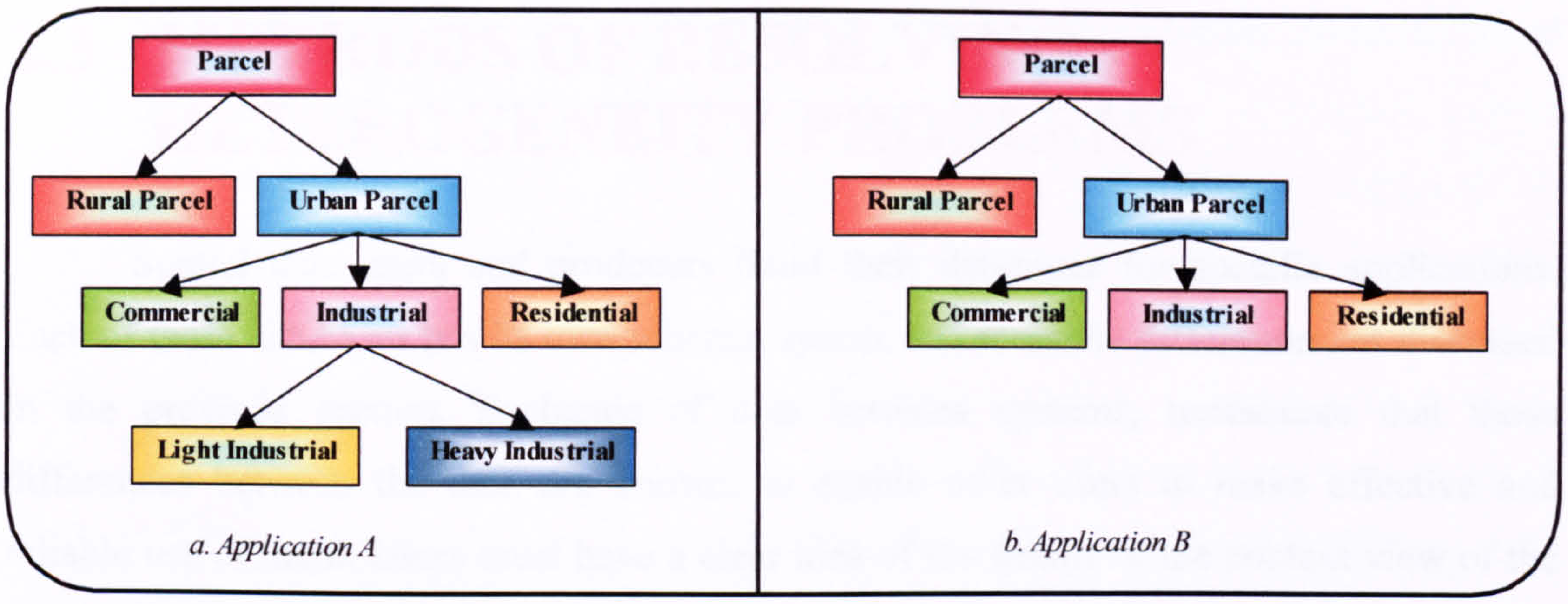


Figure 2 -8 Conceptual schema of two applications [Adapted from Radwan, 1997].

The class light industrial in (a) is an attribute for the class industrial parcel in (b). This situation leads to a schematic problem whenever the two applications are to exchange data. Schematic heterogeneity arises mainly because of differences in the data models used by different applications with different context views. A major consequence of this is incompatibility in abstraction level. This arises when two semantically similar entities are represented at different levels of abstraction. Two main results for this case are:

1. **Generalisation conflicts:** Two entities are represented at different levels of generalisation in two different databases, for example.

   Highway (ID, Name, type).

   Motorway (ID, Name, type).

   The first database uses the term "Highway" and the second database uses "Motorway".

2. **Aggregation conflicts:** An aggregation is used in one database to identify a set of entities in another database. For example:

   Block of Houses (ID, Average Area, Location)

   House (ID, Area, Location, Owner).

   A "Block of Houses" is a set of houses and an "Average Area in the Block" is the average (an aggregated function) area of a house.

The examples given above seek to highlight the fact that a difference in the view of reality is reflected in the way data is structured and also affects the meanings assigned to data items. It is obvious that for seamless data sharing, clients need to understand the concept and meaning of the terminology, the entities and their relationships in much the same way as the provider intends them to be in his application.

2.3 METHODS OF RESOLVING HETEROGENEITY PROBLEMS

Spatial data users and producers build their databases for specific applications. Each of these databases has its own schema, syntax and semantic differences, as discussed in the previous section. Exchange of data between systems, necessitate that those differences between the data are known, to enable other users to make effective and reliable use of them. Users must have a clear idea of the details of the context view of the data providers; but these are often known only to the designers of the respective systems.

An important step towards resolving heterogeneity problems in data sharing would be to resolve differences in schemas between user and producer systems, a schema being the description of the sharable spatial data. This may be achieved by mapping the respective schemas, as shown in figure 2-9.

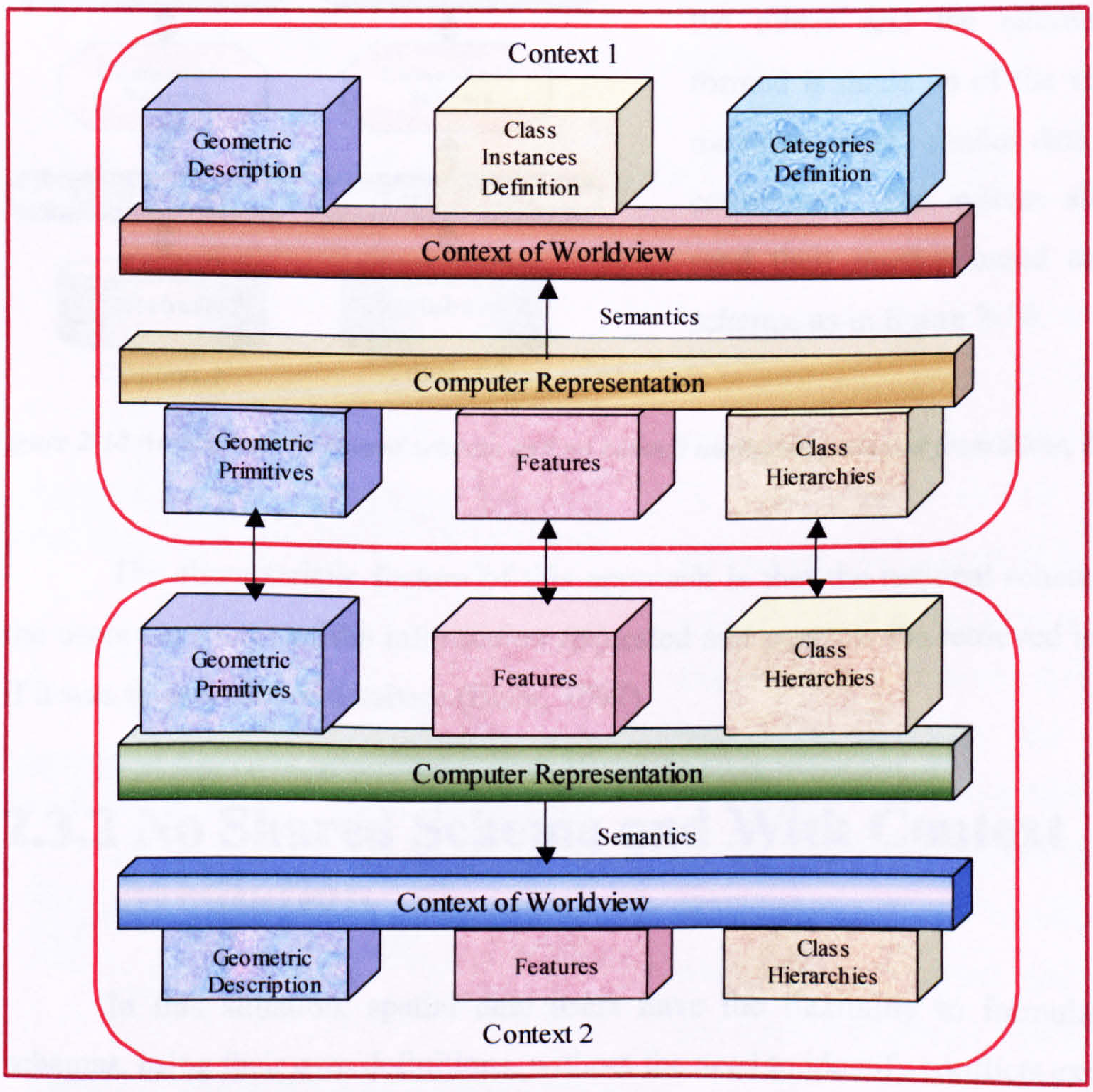
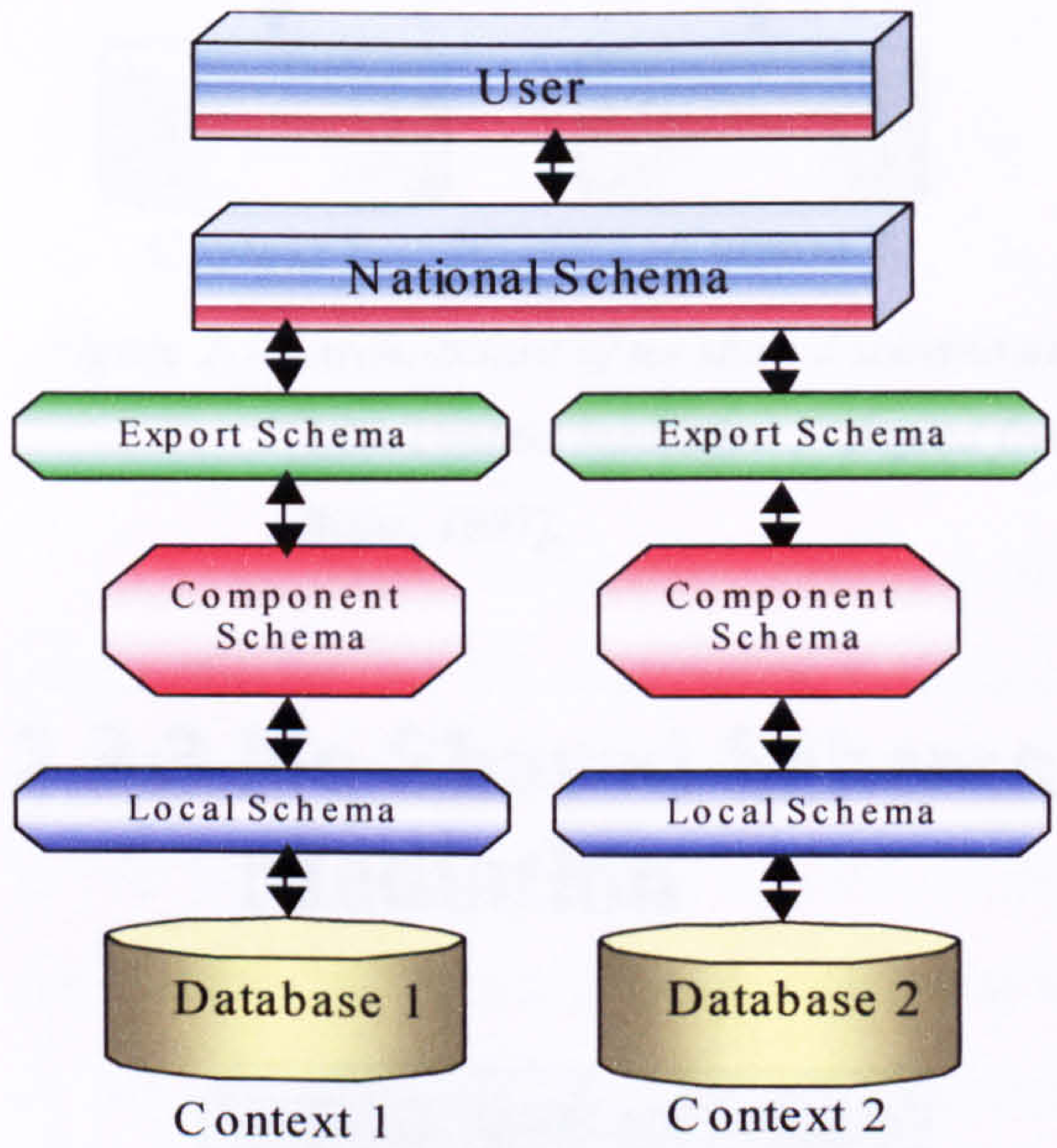


Figure 2-9 **Maintaining semantics at two contexts by mapping between their schemes [Source Bishr, 1997].**

Bishr identifies three basic approaches to resolving heterogeneity problems based on mapping of the schemas. These are:

1. Shared schema and no context mediation.
2. No shared schema and with context mediation.
3. No shared schema and no context mediation.

2.3.1 Shared Schema and No Context Mediation



This approach allows database designers to make available the export schemas of the component databases in order to describe the data. Each site is prepared to share with the others and the national schema so formed is made up of the views of all the members of the spatial data user/producer community. The system allows users to send their queries based on the national schema, as in figure 2-10.

Figure 2-10 Architecture of shared schema and no context mediation [Adapted from Bishr, 1997].

The characteristic feature of this approach is that the national schema hides from the users the source of the information requested and presents the retrieved information as if it was from a central database (Bishr, 1997).

2.3.2 No Shared Schema and With Context Mediation

In this situation, spatial data users have the flexibility to formulate their own schemas, using their own definitions, without the need to identify conflicts explicitly.

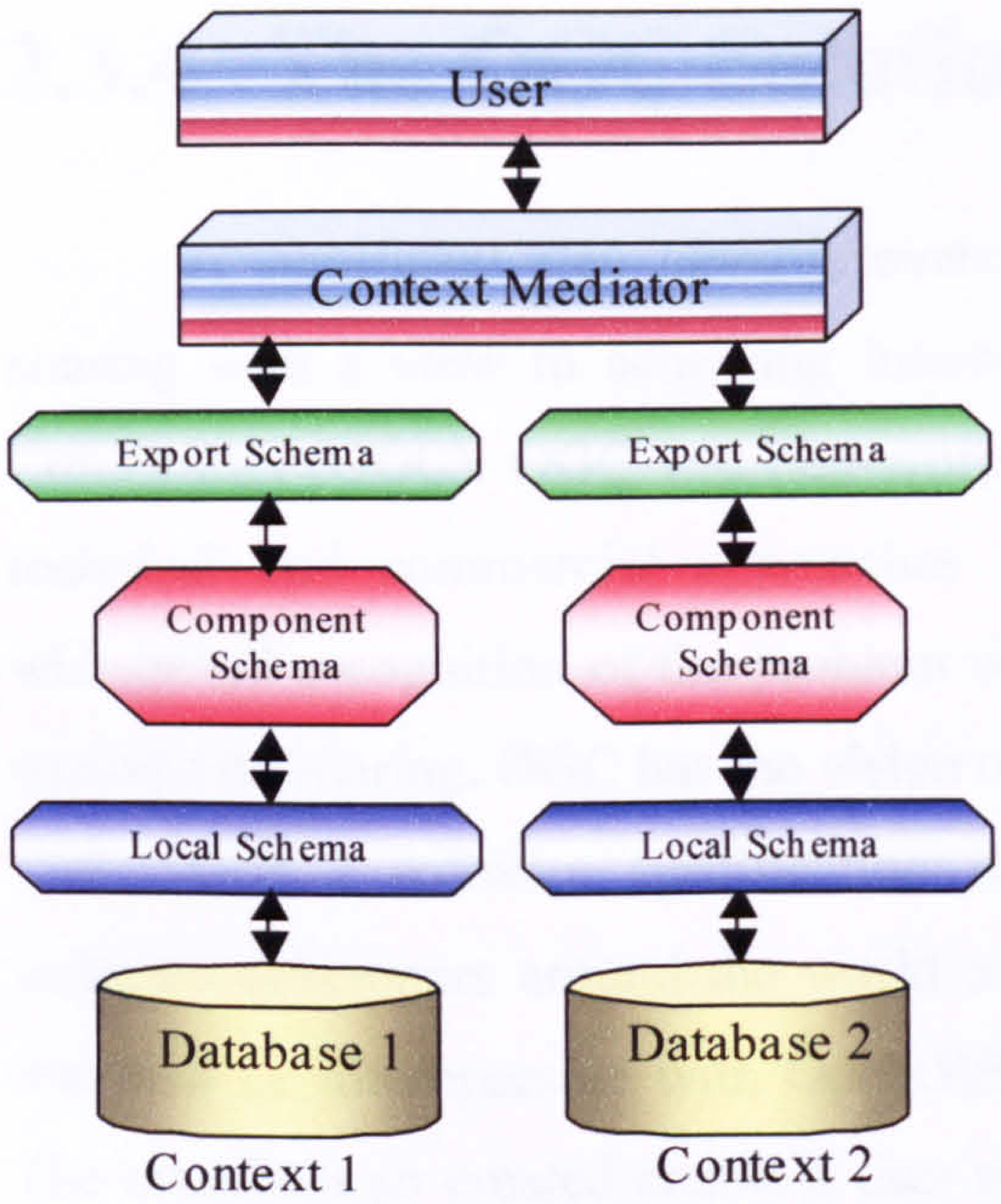


Figure 2-11 Architecture of no shared schema and with context mediation [Adapted from Bishr, 1997].

The context mediator, as shown in figure 2-11, handles context difference in the users' and the producers' resources. It compares the context of the user query with the context of the spatial data producer and processes the query in such a way that it is understood by the spatial data producer's context. The difference in naming conventions, units coordinate system, etc. is solved but the schematic problem remains unsolved. Intergraph GeoMedia products, which will be discussed in chapter 5, are an implementation of this approach (Bishr, 1997).

2.3.3 No Shared Schema and No Context Mediation

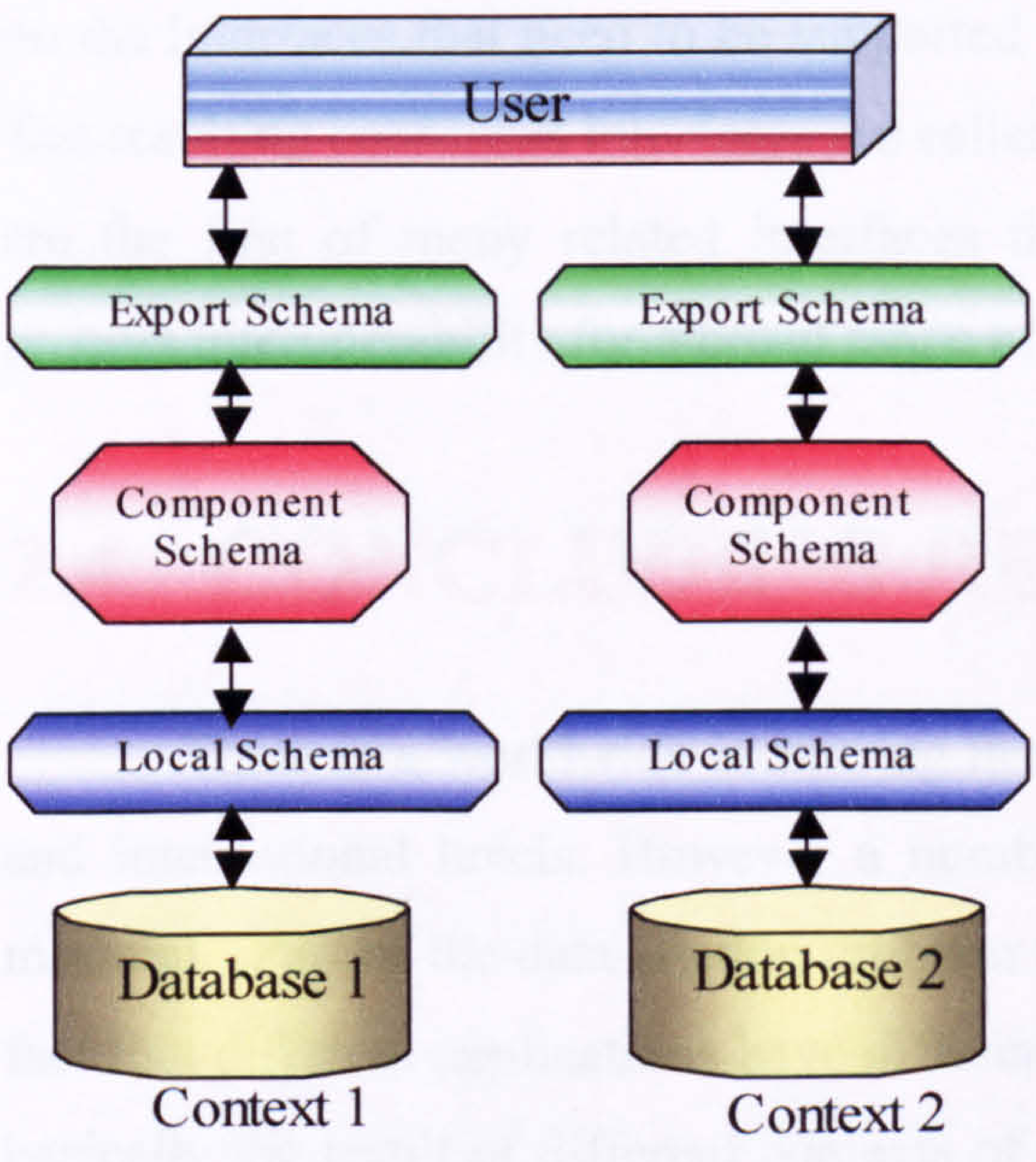


Figure 2-12 Architecture of no shared chema and no context mediation [Adapted from Bishr, 1997].

In this approach, spatial data users map their export schemas onto the spatial data producers' schemas, as shown in figure 2-12. This demands that the user know the schema and the context of the producers in order to detect and resolve any conflicts. In this approach it is assumed the user has the knowledge of who the spatial data producer(s) are. This method could only be applied in a closed system. In a distributed system with a large number of potential spatial data producers, this is impractical and difficult (Radwan, 1997)

2.3.4 The OGC Solutions

A significant step towards overcoming the heterogeneity barrier in spatial data sharing with a view to achieving interoperability is being carried out by the OpenGIS Consortium (OGC). OGC is a non-profit trade organisation founded in 1994 to promote technical and commercial approaches to interoperable geoprocessing in response to widespread recognition of the problem of non-interoperability and its negative impact on spatial data sharing. OGC has the vision of a national and global spatial data infrastructure.

OGC's software specification is the OpenGIS Specification, which will give software developers around the world a detailed common interface for writing software that will be interoperable with OpenGIS software written by other software developers. The interfaces so created enable a user to query a remote server on the Internet for some data, even though the data may have been acquired and processed in an incompatible system and managed by a different DBMS.

The chief difference between the OGC and other geospatial data exchange approaches is that the others treat exchange as a separate process, usually done "off line" or as a "batch" process. In OGC, access to data is performed in a process-to-process manner, in real time, within a single session, without the user being aware of it. To achieve this goal, OGC has gathered the consensus of the major software vendors and spatial providers on the interfaces that need to be supported in order to enable interoperability at this level. The resulting consensus interfaces are called "Simple Feature Access" interfaces, and these are the first of many related interfaces that require consensus, but deliver process-to-process interoperability for a broad range of spatial data services (OGC, 2000).

2.4 CONCLUDING REMARKS

There is a worldwide increasing need for spatial data sharing on national, regional and international levels. However a number of obstacles make spatial data sharing per minimal. Part of the data-sharing problem was attributed to heterogeneity arising from the fact that different applications have different views of reality. The differences in views are basically the result of different contexts of applications. Spatial data abstractions from the real world and subsequent structuring are therefore made with respect to the context view. Therefore, data representation in any two information systems, within the same application domain, could be different. This is because the representation has to be made in accordance with the designers' perception of reality, the role the objects play in the information system and each system's syntax, schema and semantics, rather than how objects appear in the real terrain. This has been so far the main technical problem of data sharing and has given rise to a need for the development and implementation of reliable and compatible spatial data standards.

Spatial data sharing requires standards to ensure that the sharers maintain the same view and understanding of their data. This has not been the case in the past in Saudi Arabia, and that the imposition of required sharing standards will ensure a commonality of view of all data in the Saudi national spatial data infrastructure model. Also as spatial data sources broaden from just maps to more general forms of spatial data applications, strict control will have to maintained to ensure such disparate data types are correctly portrayed.

CHAPTER 3

SPATIAL DATA STANDARDS

3.1 INTRODUCTION

This chapter takes a closer look at spatial data standards within the broader perspective of spatial data infrastructure and what work has been done in that respect. In the spatial data community, the development and implementation of standards is a major step forward for the collection, processing, modelling, production and integration of digital spatial data. Spatial data standards are certainly the key element to success in data integration, bringing together disparate data sets and promoting the use of information technology by reducing the initial effort and cost of solving the exchange of spatial data and facilitating the integration of data from different sources and system platforms (Guptill, 1999). Initially, the impelling force for the development and implementation of spatial data standards came from individual organisations in technologically and militarily advanced countries in effort to provide a mechanism for spatial data sharing between different non-communicating systems, which use dissimilar platforms, while preserving the meaning and quality of the original spatial data (Hogan and Sondheim, 1996). However, this growingly important area became the foundation for the new emerging national and international spatial data infrastructures and has been taken up by the national and international standardisation bodies.

Section 3.2 discusses the historical and classification evolution of spatial data standards. Section 3.3 provides a general overview of national and international standardisation initiatives, including a brief comparison of selected standards. The chapter ends with concluding remarks in section 3.4.

3.1.1 Definition

The glossary of the mapping sciences defines standards as a procedure agreed upon within a particular industry or profession as one to be followed in producing a particular product or result (Glossary of the Mapping Sciences, 1994). Similarly, the European standardisation technical committee defines a standard as a document, established by consensus and approved by a recognised body that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context (EUROGI, 1994). The International Organisation for Standardisation (ISO) defines standards as documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are fit for their purpose (ISO, 2001).

Spatial data standards, in general, involve mutual understanding, co-operation and agreement on common terms, names, procedures, policies, terminology, conditions, definitions and others that would enable data receivers to understand what they receive in much the same way as the spatial data producers intended the data to be viewed and to produce a product that satisfies both the producer and the user.

3.2 EVOLUTION OF STANDARDS

3.2.1 Historical Background

The field of conventional mapping is both one of the oldest scientific areas, as indicated in chapter 1, and an area where the need for standardisation has been recognised for hundreds of years (Østensen, 1996a). However for the last several decades, digital maps and geographic information have come to replace conventional maps and other data sources. The numbers of digital mapping and GIS installations have been increased, especially in government mapping organisations and a great deal of spatial data have been collected and produced. In the meantime databases have been designed and created to organise and manage spatial data. However, due to lack of proper standards, most digital spatial data were collected produced and stored in ways that suit the purpose for acquiring the data but which create data sharing obstacles and interoperability problems.

The growing recognition of spatial data as a national asset for sustainable development and infrastructure has resulted in considerable effort across the globe to facilitate spatial data sharing and the development of interoperable products. These attempts range from the development of software tools, defining standardised formats for the transfer and exchange of specific spatial data, to the development of comprehensive spatial data standards. Standards for digital spatial data began more than 30 years ago and focused on data transfer mechanisms.

Due to the fact that geographic information systems were created by governments, the first level of standards was developed and implemented under government mapping organisation authorities for their own products and for their suppliers and users. The type of standards adopted by this large part of the user community were generally referred to as *de facto* standards (McKellar, Beaulieu and O'Brien, 1995). Over the years there have been several generations of *de facto* standards. Some of them exist to this day. For example:

1. The U.S. Geological Survey (USGS) Digital Line Graph (DLG), which was used as their agency based standard.
2. The U.S. Census Bureau, Topologically Integrated Geographic Encoding and Referencing (TIGER) system line format standard, is used as their agency based standard to the present day.
3. The Map Data Interchange Format (MDIF) originally developed in Ontario by the Canadian Council on Surveying and Mapping (CCSM). It later became the Map and Chart Data Interchange Format (MACDIF).
4. The NATO DIgital Geographic information Exchange STandards (DIGEST).
5. The International Hydrographic Organisation (IHO) DX-90 transfer standards, which later became S-57 (Hogan and Sondheim, 1996).

However, the requirements and demands for interoperable spatial data forced the official standardisation bodies, whether national, such as the U.S. Bureau of Standards (later renamed the U.S. National Institute of Standards and Technology (NIST), the British Standards Institute (BSI), the Saudi Arabian Standards Organisation (SASO); or international, such as the ISO, to develop and endorse more or less general spatial data standards (Salgé, 1999). Also, as indicated in the introduction, the worldwide concept of a national and international spatial data infrastructure has created a need for general spatial data standards, which cover any, or at least a broad field of applications. The effort of developing general standards, referred to as *de jure* standards, is based on access to a reliable information technology foundation that facilitates the use of spatial data in a continually expanding context (Hogan and Sondheim, 1996). It should be noted that most of the *de facto* standards have been upgraded to *de jure* over a period of years.

3.2.2 Categories of Spatial data Standards

The categorisation of spatial data standards has been a diverse and protracted activity amongst spatial data communities in terms of the information technology used. It has also been the subject of discussion by many organisations, individuals, writers and researchers for some time and covers a wide range of research from data standards to programming languages. The spectrum of spatial data standards includes many spatial data activities, such as data acquisition, data modelling, data transfer, metadata, data classification and data quality. Newton (1992) categorised standards into four broad areas, as shown in figure 3-1 (Newton et al., 1992).

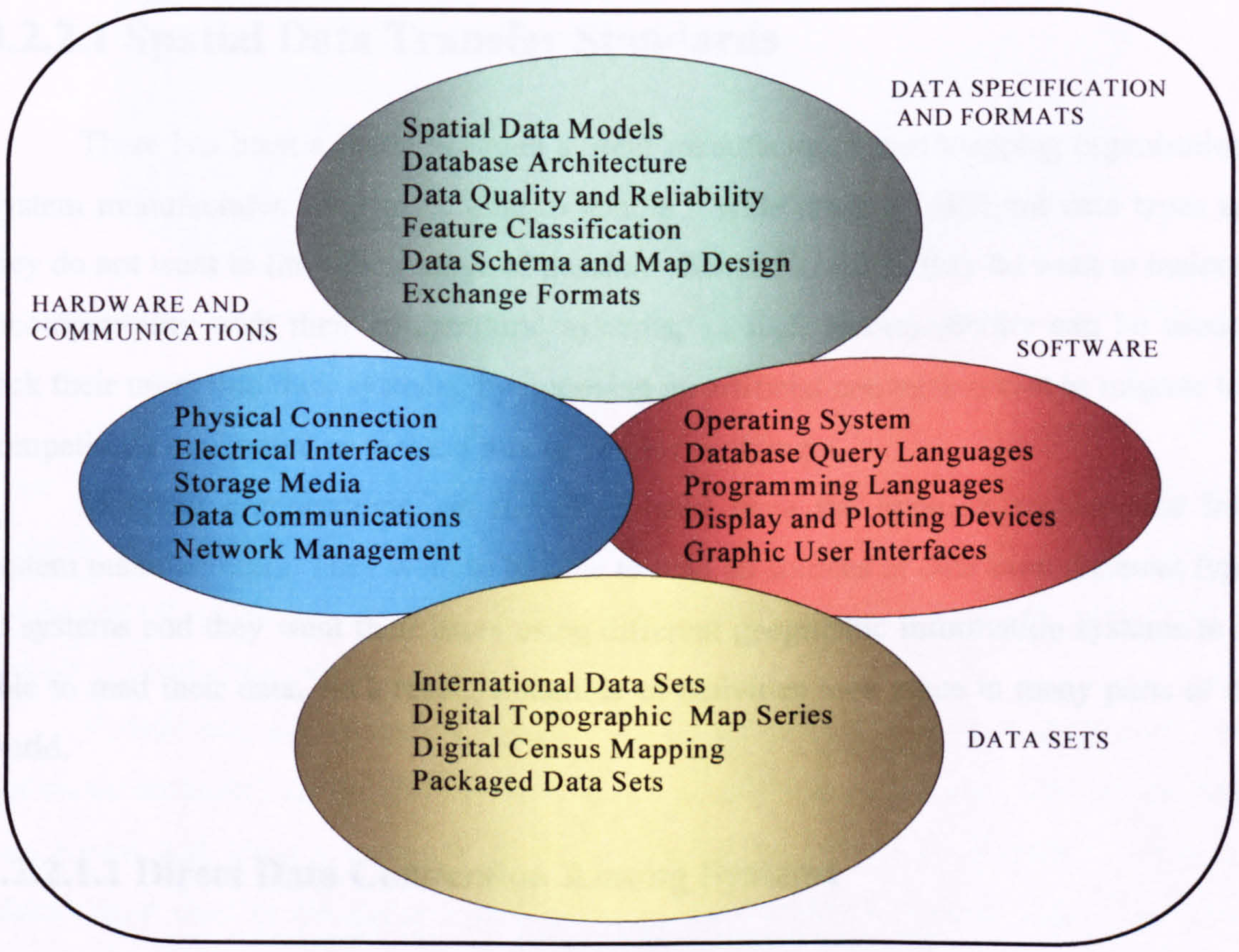


Figure 3-1 Categories of spatial data standards [Adapted from Newton et al., 1992].

Today there are many *de facto* and *de jure* standards at national and international or multinational levels. For example, the International Organisation for Standardisation (ISO), the Technical Committee 211 on Geographic Information/Geomatics (ISO/TC 211) is providing the framework for both national and international spatial data standards, whether *de facto* or *de jure* standards and will produce a broad band of spatial data standards, also the OpenGIS Consortium (OGC) is playing a big role in this field, meanwhile, Clarke (1996), in general, outlined the critical operational standards for an effective spatial data infrastructure as follows:

1. Data Transfer.
2. Reference System.
3. Data Model.
4. Data Dictionary.
5. Data Quality.
6. Metadata.

3.2.2.1 Spatial Data Transfer Standards

There has been a battle between system manufacturers and mapping organisations. System manufactures want to be able to handle a wide range of different data types and they do not want to limit their range of possible clients. However, they do want to maintain incompatibility with their competitors' systems, as such incompatibility can be used to lock their users into their systems, by imposing an artificial conversion cost to migrate to a competitor's equipment or to use a mix of vendor equipment.

Mapping organisations, on the other hand have the opposite requirement from system manufacturers. They want to be able to read all sources of data from different types of systems and they want their users using different geographic information systems to be able to read their data. As a result, a number of activities took place in many parts of the world.

3.2.2.1.1 Direct Data Conversion Among Systems

The initial attempts at spatial data sharing involved direct data conversion between small number of different GIS systems produced by different vendors, such as the Environmental Systems Research Institute (ESRI)'s Arc-Info and Intergraph's MGE, which necessitated file conversion from one system to another. The approach to data sharing was therefore to write *ad-hoc* interface programs or translators for each pair of communicating systems in a network (Radwan, 1997). To achieve data transfer between a large number of systems, as illustrated in figure 3-2, each system needs to develop software for the conversion of its data to each of the other systems with which it intends to share data. However, the development and maintenance of these programs is expensive in terms of time, effort and money. Besides, each time a new system emerges, all existing system authors must write new programs to accommodate it. The number of conversion programs, therefore, is of the magnitude of (n^2-n), where n is the number of systems.

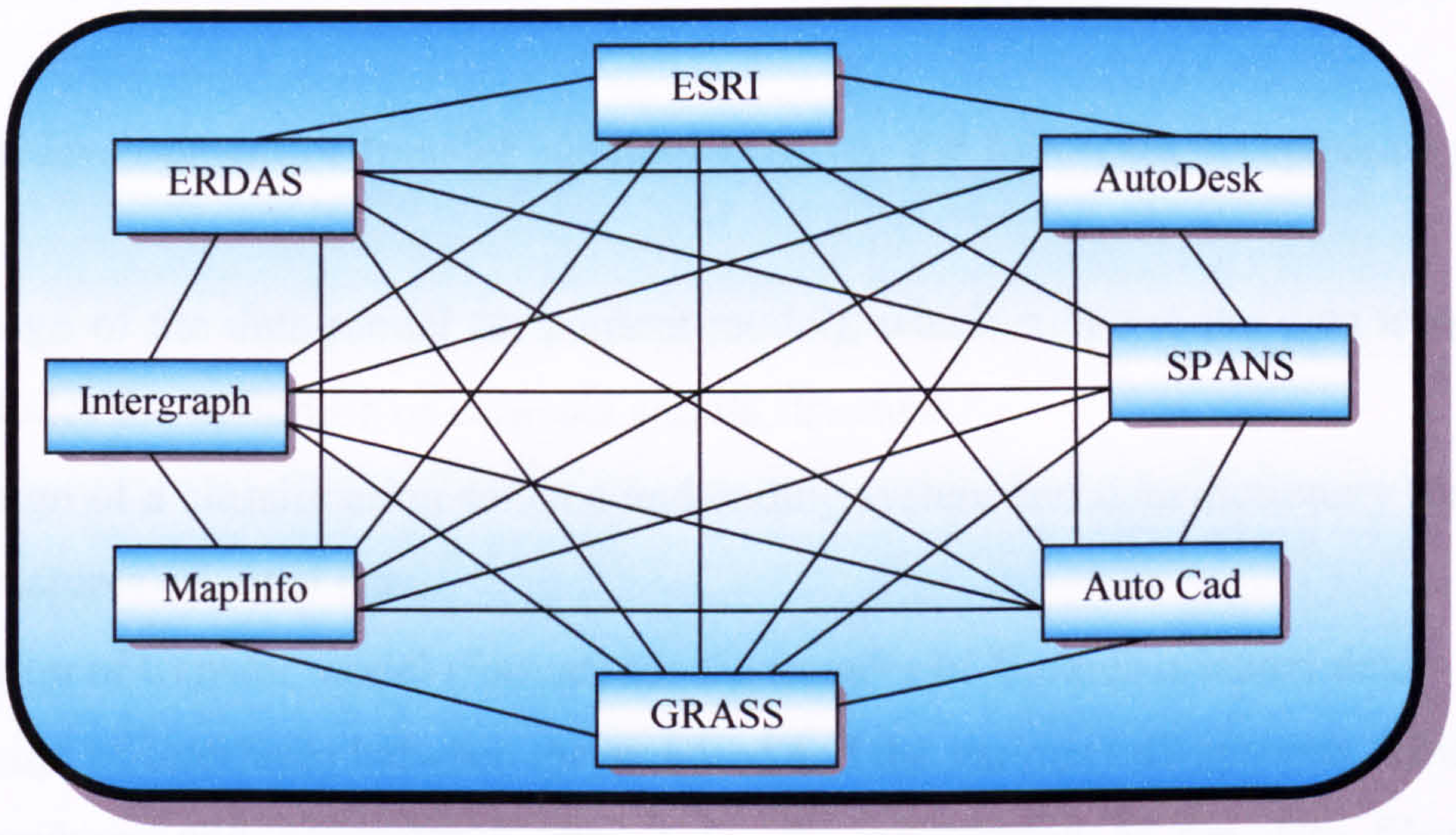


Figure 3-2 Transfer of spatial data using direct data conversion [Adapted from Ventura, 1991].

As a result, the development of direct translators between systems that want to share data is of limited value, especially when a large number of systems are involved. Nevertheless, interestingly, the survival of these limited pair-wise import/export functions has continued, owing to the failure of general conversion systems to convert adequately all aspects of competing data structures.

Further attempts at finding a solution to data sharing viewed data models and their associated semantics as the core problem. If all data providers and users could use the same data model and reach a common understanding of the meanings of entities, terms and relationships used in the general model, the problem could be solved. This is, of course impossible, because there exist many diverse applications to which spatial data can be applied. However, a number of common content models have been developed to enable distinct spatial data systems to communicate and remove a substantial amount of their differences.

3.2.2.1.2 Common Spatial Data Exchange Standards

Common spatial data transfer standards rely upon an agreed set of syntactic and semantic rules. The adoption of a spatial data transfer standard allows heterogeneous systems to share their data with other systems by making use of a common and agreed facility that represents and reflects the common model of the data used in participating systems.

The development of transfer standard involves the following components (Radwan, 1997):

1. Design of the data model (or content model), which supports the data transfer. This includes the definition of contents and its structure.
2. Design of a classification scheme and coding system and data dictionary for any type of features oriented data.
3. Design of transfer model (format) for the transfer of features oriented data.
4. Design of interfaces between the standard and the various GIS systems. This includes procedures and computer packages for the conversion of the data files in these systems to the standard format, and vice versa.

For an efficient utilisation of the data available, transfer standards should address characteristics of data quality, which will be discussed later in this section, and the way they are encoded. Common spatial data exchange standards imply an agreement on standard formats and definitions of a general content model for a particular application that caters for all participating systems, as shown in figure 3-3.

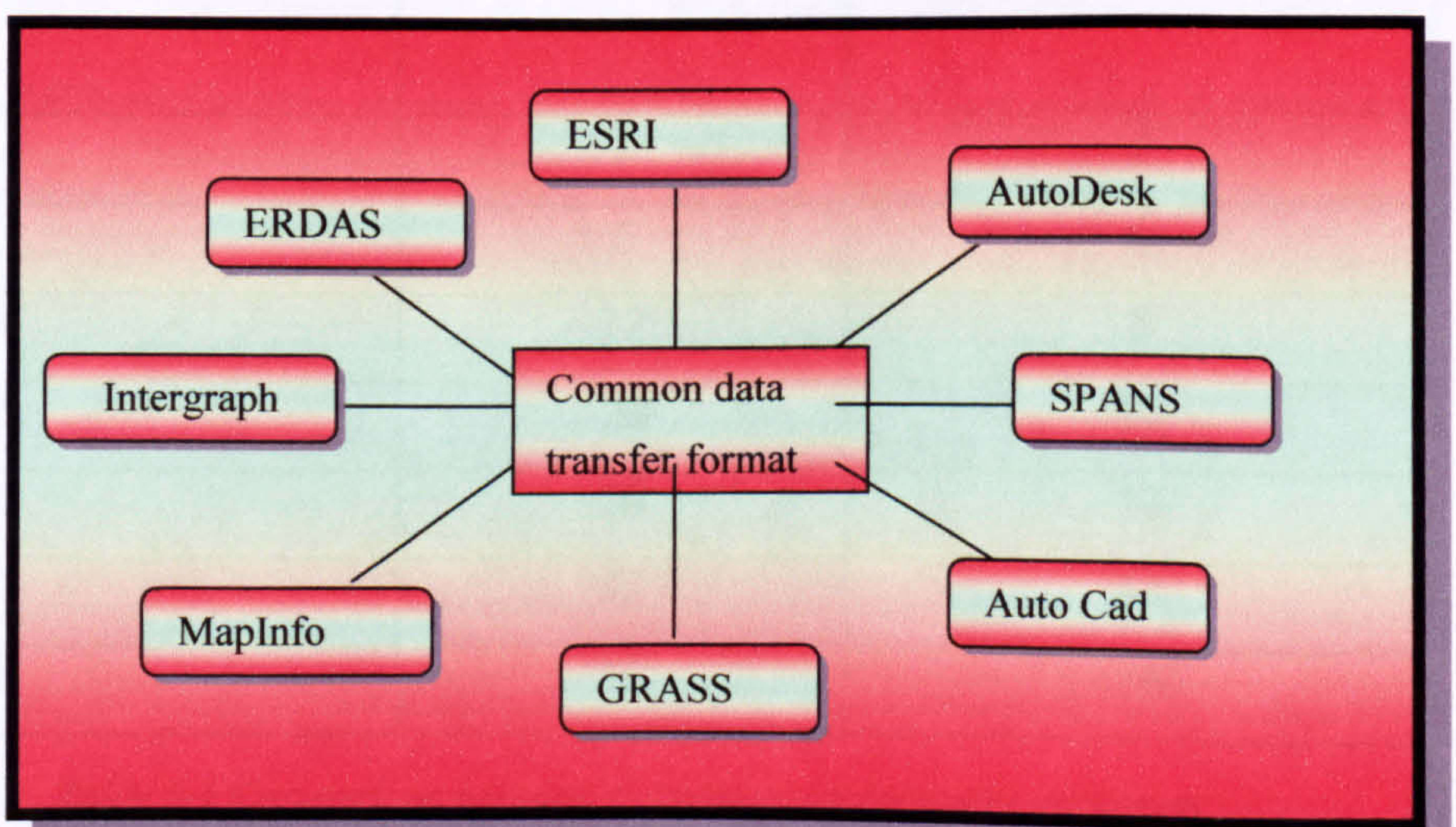


Figure 3-3 A common transfer format [Adapted from Ventura, 1991].

Adoption of a standard requires each participant to develop software that converts their data to the standard when exporting and another to retrieve needed data from it when importing, as shown in figure 3-4.

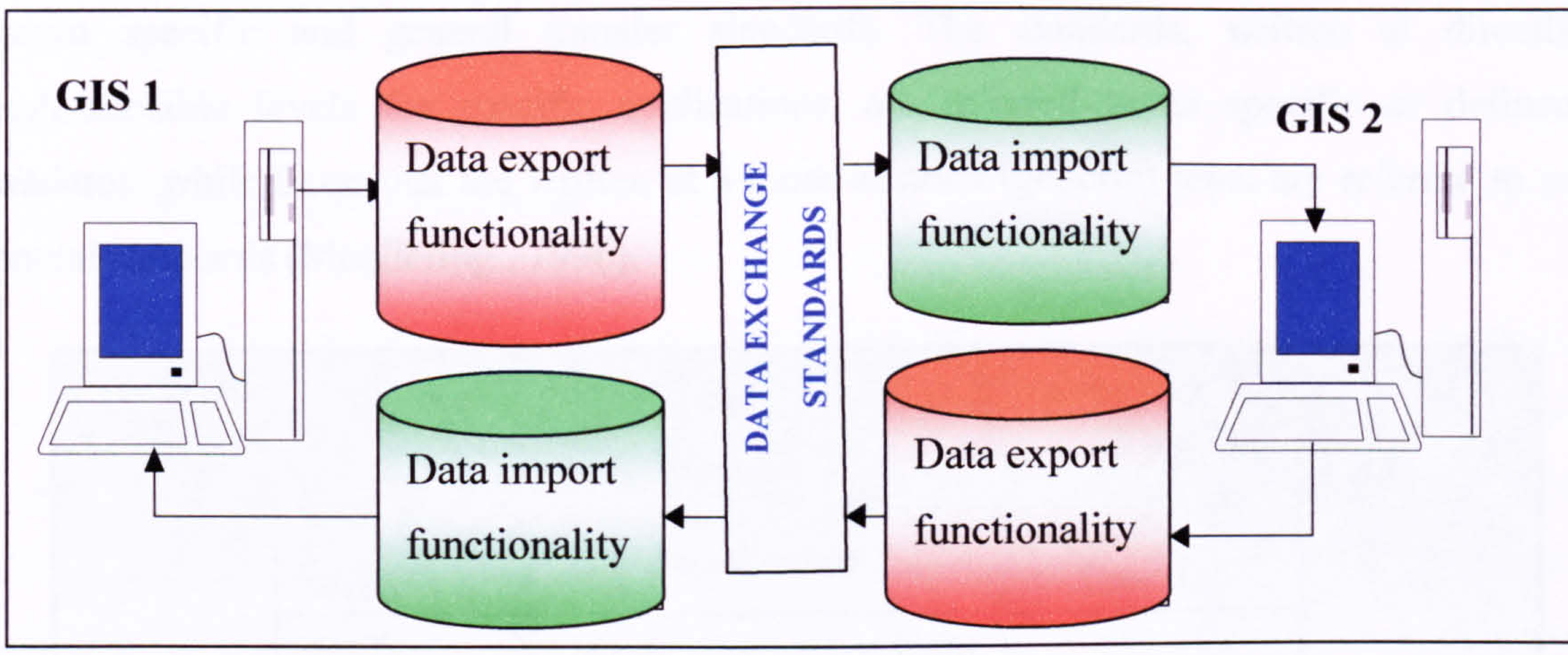


Figure 3-4 The role of data transfer standards [Source Cassettari, 1993].

Table 3-1 shows a comparison of the number of conversions between direct data conversion and common data transfer standards. It is clear that using transfer standards, the number of conversion routines is greatly reduced to 2n (by comparison with the situation in figure 3-2).

No. of conversions		
Number of systems	Translators (n^2-n)	Data transfer Standards (2n)
2	2	2
3	6	6
4	12	8
5	20	10
6	30	12
7	42	14
8	56	16

Table 3-1 Comparison between translators and transfer standards.

3.2.2.1.3 Classification of Transfer Standards

The design of spatial data transfer standards can vary widely, as shown in figure 3-5. According to Moellering (1996), spatial data transfer standards can be classified into system specific and general transfer standards. The standards, written at directly implementable levels for specific applications, are referred to as specific or defined standards, while those that are written at a more abstract (generic) level are referred to as general standards (Moellering , 1996).

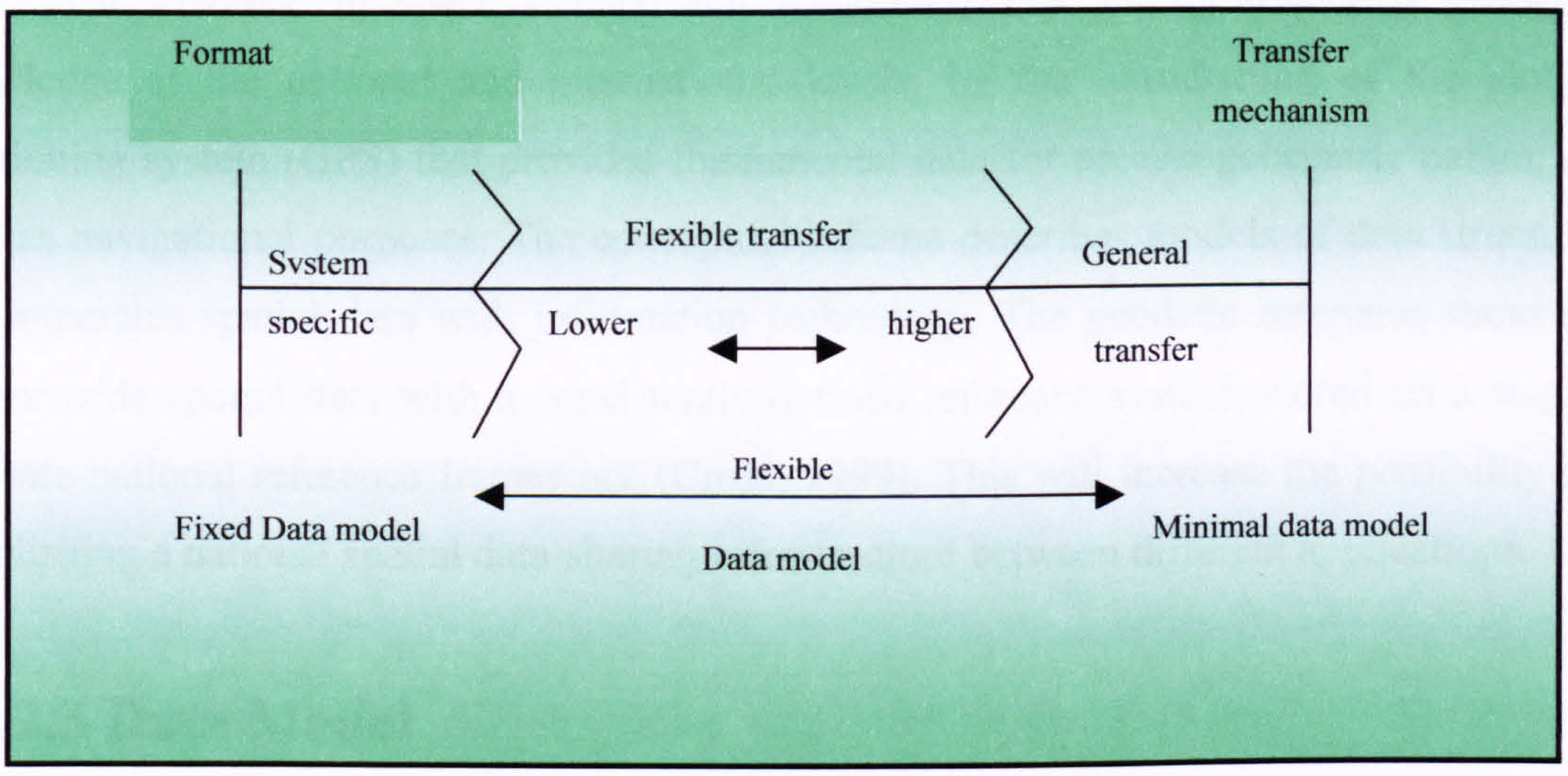


Figure 3-5. The range of database transfer process [Source Moellering, 1996].

A defined transfer standard is simply a transfer format with a fixed data model (system specific format), which in general is derived from production data formats. In contrast to general standards, defined standards are narrow in scope and cover a smaller range of application specific areas, such as environment, road traffic information, urban planning, utilities, nautical and navigational charts, hydro charts, etc. Spatial data producers have to restructure their data into the fixed data model, however, if a user's system does not share the same capabilities as the producer's system; otherwise, some parts of the spatial data will be lost during the transfer process. Both S-57 and DIGEST are primarily defined standards; near the left hand side of Mollering's chart (O'Brien, 2001).

On the other hand, general transfer standards use a flexible data model, work with a variety of applications and provide access to multiple data structures that may allow any kind of spatial data to be transferred, but do not guarantee interoperability. Table 3-3 and

3-4 illustrate some of the general transfer standards, such as those available in Canada, Netherlands, United Kingdom and United States of America. It should be mentioned that in between defined and general standards there are a range of transfer standards with a varying degrees of flexible data model, but as the flexibility increases the complexity of the standards increases as well (Moellering, 1996).

3.2.2.2 Reference System

The advance in space science and technology has greatly improved geodetic knowledge at the national and international levels, by the introduction of the global positioning system (GPS) that provides fundamental data for precise geocentric datum, as well as navigational purposes. The conceptual schema describes models of data structure and integrates spatial data with information technology. The geodetic reference standard will provide spatial data with a consistently defined reference system, stored on a single accurate national reference framework (Cross, 1999). This will increase the possibility of establishing a national spatial data-sharing infrastructure between different applications.

3.2.2.3 Data Model

A data model is a representation of real world phenomena and their relationships as spatial objects. There are three levels to a data model standard:

1. The conceptual data model, which provides a schema for the representation of the real world in the form of spatial data objects.
2. The logical data model (or data structure), which specifies how the relationships between various data sets are defined.
3. The physical data model (or file structure), which is implemented in the data transfer standard.

The data model also specifies the data generalisation process for a particular system. The scale might change the type of object that represents a given feature. A vector spatial data model, for instance, may represent roads as lines, forests as polygons and buildings as points. It is imperative that both data producers and users have a common understanding of the data model (McCullagh, 1999). However, as Lee and McLaughlin (1991) observe, researchers and developers have not yet been able to agree on a limited set of data models for spatial data that would satisfy all producers and users (Lee and McLaughlin, 1991).

3.2.2.4 Data Dictionary

A data dictionary standard is created based on the conceptual data model to provide definitions for spatial data and its components. For example, spatial features, e.g. roads, drainage, farms, sand dunes, etc are used for the creation of any spatial database. A feature may have associated with it one or more spatial attributes. The attribute specifies relevant properties of the real world feature, such as road class, number of lanes, surface and width. The attribute class may have a range of values that give the specific qualitative or quantitative measurements pertaining to a particular attribute. The value of a spatial attribute, as defined by ISO, is a spatial object - either a geometric object or a topological object - that describes one or more characteristics such as location, size, shape and spatial relationships to other spatial objects in the same 'real world'.

A spatial object can consist of a single geometric or topological primitive of 0, 1, 2 or 3 dimensions, or of a set of these. The data dictionary standard permits the level of topology within a 'real world' to be defined and specified by an application schema. It is essential that each database participating in the standard define its features in order to avoid confusion on the use of the spatial data (ISO/TC 211, 2002a).

3.2.2.5 Data Quality

The meaning of quality depends on the context in which it is used. The term quality is sometimes used to define the goal of producing error-free systems and products that meet user requirements (McCullagh, 1996). Consequently, quality assurance mechanisms are introduced into the development process to ensure that there are no deviations from requirements as development proceeds. Each stage of the development process is checked to ensure that errors are minimised (Hawryszkiewycz, 2000).

Spatial data quality standards can be descriptive, prescriptive or both. A descriptive data quality standard provides information and produces subschema for the quality characteristics of the spatial data. On the other hand a prescriptive data quality standard would define quality parameters for each characteristic, for a particular application (Clarke, 1996).

3.2.2.5.1 Spatial Data Quality Characteristics

Spatial data collection is an expensive business, as indicated in chapter 1. It is not only the most expensive part of spatial data activities, but also all the decisions made as a result of using the spatial data are based on the original (or primary) data collection. Many agencies and users resort to taking their base maps, complete with existing errors, and turning them into digital spatial data by either digitising or scanning (secondary data collection). The qualities of the new digital data are clearly determined by the quality of the original data. Hence, documentation of the original source of the data will enable prospective users to evaluate the data and determine its fitness for their use. Without thorough documentation for all data, the quality would remain unknown.

Thapa and Bossler (1992) as well as Veregin (1999) discuss the data quality characteristics or components that must be understood and documented, including lineage, positional accuracy, attribute accuracy, temporal accuracy, logical consistency and completeness.

3.2.2.5.1.1 Lineage

It is essential that the original source and reliability of the data, and all transformations and changes that have been applied, are known and documented, so that the overall quality of any resulting data set can be evaluated. Lineage refers to a description of the source materials from which the data were derived and the methods of derivation, including all transformations in producing the final digital data. The lineage must provide the transformation algorithm along with the computational steps taken to avoid round off errors. Lineage must also include the specific control points used, described with sufficient detail to allow recovery (Thapa and Bossler et al, 1992).

3.2.2.5.1.2 Positional accuracy

Positional accuracy or spatial accuracy (horizontal and vertical) describes the accuracy of the position of features in accordance with a dataset's product specification. It depends on the geometric data representation chosen (point, line or area). Error in a point is usually defined as the discrepancy between the actual measurement of the point and the value as defined by the specification. Error in a line or area position is far more complex to assess as Veregin (1999) states: "*metrics measurements are widely accepted for points* *entities, however widely accepted metrics measurements for line and area have yet to be developed*". There are a number of metrics that have been developed to summarise statistical error in spatial data sets. The most common accuracy measure is the Root Mean Square Error (RMSE). RMSE is computed as the square root of the mean of the squared error and used mostly to document vertical accuracy for Digital Elevation Models (DEM). There are no simple statistical positional accuracy measures for line and area as yet. The assessment methods for positional accuracy, in general, are made by comparison to an independent source of higher accuracy data or deductive estimates or internal evidence (Veregin, 1999).

3.2.2.5.1.3 Attribute Accuracy

Attribute accuracy or thematic accuracy refers to the accuracy of the thematic component. Attribute accuracy varies as a function of map scale and may be made either by deductive estimates, or map overlay, or based on a comparison between land cover classes assigned to certain selected points and the same classes observe on the ground, at these points (Thapa and Bossler et al., 1992).

3.2.2.5.1.4 Temporal Accuracy

Temporal accuracy of data is important and refers to the update or currency of spatial data. For example built up areas and roads in developing countries change very quickly. Therefore temporal accuracy is needed to keep spatial datasets both current and reliable (Veregin, 1999).

3.2.2.5.1.5 Logical Consistency

Logical consistency describes the degree to which data is stored in accordance with the structure of a dataset or the degree to which the correct encoding of feature attributes into a dataset are in accordance with a dataset's production specification. This includes the evaluation of attribute values and topological inconsistencies based on graphical or topological tests.

3.2.2.5.1.6 Completeness

Completeness indicates the relationship between abstracted features and the same features on the real world. It describes the degree to which all intended features attributes and relationships have been encoded into the maps or databases in accordance with the product specification (Thapa and Bossler et al., 1992).

3.2.2.6 Metadata

One of the key reasons that have been adduced for duplication of effort in spatial data collection and production, invariably leading to a higher cost for data, is a lack of information on existing or available data. The concept of metadata is not new and is familiar to most people who deal with maps. The map or chart legend information, such as publisher, date, scale, type, spatial reference and accuracy are pure metadata (Danko, 1999). Metadata systems are concerned with the documentation of data quality characteristics, but from the operational component view rather than being concerned with conceptual issues (Veregin 1999).

A collection of metadata records combined with data management and search tools forms a data catalogue. The use of metadata and a data catalogue helps to create an environment to accommodate user requests for spatial data. In order to make metadata easily read and understood by different disciplines, there should be a standard that provides a common set of terminology and definitions for the documentation of spatial data (Guptill, 1999).

3.2.2.6.1 Metadata Standards

Metadata standards are simply common sets of terminology and definitions that describe the origins of data, track the changes, and document spatial data, quality. For example, area covered, theme, format, content, data producer, context in which information was collected, condition of access, currency, accuracy, logical, consistency, restrictions, completeness, grid system, attribute values, lineage, media, coordinate system, projection, distributor, datum, all the transformation the data has undergone, as well as other relevant information. Metadata standards are complex and sometimes difficult to define. The level of detail depends on the purpose of the metadata. It can be used by the data producers internally to monitor the status of data sets, as well as externally to provide their data to potential users through a national clearinghouse.

Key developments in metadata standards are the ISO/TC 211 metadata standard (19115), the OGC metadata standards, the U.S. Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM), CEN European standard for metadata and others. However, most of these developments, especially the CSDGM, have merged with the ISO/TC 211 metadata standards.

Metadata provide the users with the necessary information they need to perform spatial data appreciation and evaluation and decide whether to use the data and save money and time or carry out new data collection work. The Federal Geographic Data Committee list the major uses of metadata and metadata standards as follows:

1. To help organise and maintain an organisation's internal investment in spatial data.
2. To provide information about an organisation's data holdings to data catalogues, clearinghouses, and brokerages.
3. To provide information to process and interpret data received through a transfer from an external source (FGDC, 1998).

Also Metadata may cover the following purposes:

1. Data cataloguing: - provides a summary of the content of data sets. Within an organisation, data cataloguing provides an inventory of all spatial data available. In the context of use of computer technology, it allows one to browse through the data to determine quickly whether it is potentially useful and worth further enquiry.
2. Data sharing: - metadata provides the necessary information about form, content and quality that enables users in different geographical locations to know of the existence or availability of data. This enhances data sharing and reduces duplication.
3. Internal documentation: - keeping track of what a dataset or database contains and how it is organised, maintained and updated (Yousefi, 1994).

3.3 STANDARDISATION INITIATIVES

Data sharing issues are of great importance to the spatial data community, as indicated in chapter 2. This is quite clear from the number of initiatives many countries and independent organisations, such as ISO/TC 211, have undertaken over the last two decades to establish standards for spatial data.

3.3.1 National Standards Initiatives

As shown in table 3-3, there are about seventeen national standards initiatives. In this section the United States' spatial data transfer standards (SDTS) is selected in view of the fact that available literature suggests that it has the potential to become a *de facto* world standard, customised where necessary to accommodate conditions peculiar to certain countries (Clarke, 1996).

3.3.1.1 The U.S. Spatial Data Transfer Standard

The U.S. Federal Geographic Data Committee (FGDC) was tasked, among others, to establish and implement standards for quality, content, metadata and transferability as well as the co-ordination of the collection of spatial data to minimise duplication. The metadata standard was briefly discussed in section 3.2.2.6.1 and in this section the U.S. Spatial Data Transfer Standards (SDTS) will be discussed.

The SDTS is approved as a Federal Information Processing Standard (FIPS 173) and is designed to support all types of spatial data exchange. It is a general modelling standard that has both a flexible data model and provides options for encoding data. SDTS provides the specification for the organisation and structuring of digital spatial data transfer, and the definition of spatial features and attributes. The purpose is to promote and facilitate the transfer of digital spatial data between dissimilar systems (McKellar, 1996). The objectives of SDTS are to:

1. Provide a common mechanism for transferring digital spatial data between dissimilar systems while preserving information meaning, minimising the need for information external to this standard.
2. Provide, for the purpose of transfer, a set of clearly specified spatial objects and relationships to represent world spatial entities.
3. Provide a transfer model that will facilitate the conversion of user-defined data to a standardised set of objects, relationship and information.

The standard is composed of six parts, Parts 1-3 are for the organisation and structuring of digital spatial data while Part 4–6 are added as profiles to allow for the exchange of particular types of data. The standard describes the underlying conceptual model and the detailed specification for the content, structure and format for exchange of spatial data (Moellering and Hogan, 1996).

3.3.1.1.1 The organisation and structuring of digital spatial data

SDTS allows the use of a wide range of Cartesian co-ordinates and geographic co-ordinates (ϕ, λ), UTM and U.S. plane co-ordinate systems.

PART 1: Logical Specification - consists of three main sections, which explain the SDTS conceptual model and SDTS spatial object types, the components of a data quality report and the layout of SDTS modules that contain all needed information for a spatial data transfer compliant with SDTS.

PART 2: Spatial Feature - contains a catalogue of spatial features and associated attributes. This part addresses the need for definition of common spatial feature terms to ensure greater compatibility in data transfer.

PART 3: ISO 8211 Encoding - explains the use of a general-purpose file exchange standard, ISO 8211, to create SDTS file sets.

3.3.1.1.2 Implementing SDTS through Profiles

Since the SDTS is designed to support all types of spatial data, implementing all the standards options at one time would be a monumental task and inefficient, so the standard is implemented through the use of profiles. The specification of a profile in SDTS reduces it to a defined interchange. Profiles balance two objectives of SDTS: to allow both encoding and decoding to be feasible and to ensure that all meaningful information is transferred.

The specific SDTS profiles are: Topological Vector Profile (TVP) (Part 4), Raster Profile (RP) (Part 5) and Point Profile (PP) (Part 6):

1. The topological vector profile is the first of a potential series of SDTS profiles, each of which defines how the SDTS base specification (parts 1,2, and 3) must be implemented for a particular type of data. TVP is the most mature profile with approval as an FGDC standard and as a Federal Information Processing Standard (FIPS) (Hackman, 1997). TVP limits options and identifies specific requirements for SDTS transfer of data consisting of topologically structured area and linear features.
2. The raster profile is for 2-D images and gridded rasters.
3. The raster profile is a modification of TVP and follows many of the conventions of that profile.

The main purpose of the profiles is to ensure a clearly defined subset of SDTS, related to just one data model and thus limit the available options so that translation software is much less complicated.

3.3.2 International Standards Initiatives

As shown in table 3-3, there are about six international standards initiatives. The discussion on standardisation initiatives commences with global issues involving the ISO through efforts at continental level, in the United States of America and Europe, and then examines individual countries initiatives. In this section, four important organisations or committees who have been involved in the development of various components of spatial data standards are selected.

3.3.2.1 International Organisation for Standardisation

The International Organisation for Standardisation (ISO) is a non-governmental organisation that was established in 1946 to develop worldwide standards to improve international communication and to promote smooth and equitable growth of international trade. It has national bodies in more than 100 countries all over the world. ISO is neither abbreviation nor acronym, but is taken from the Greek word iso, which means equal (Østensen, 1996a). ISO work results in international technical requirements that are published as international standards. All standards developed by the organisation are voluntary; no legal requirements force countries to adopt them. However, most countries and industries usually adopt and attach further significance to the organisation's standards, thereby making them mandatory.

The work of preparing international standards is normally carried out through ISO technical committees. ISO created a small number of standards that relate to geographic information before the advent of TC 211. In particular these are the standard for the representation of position in coordinates (ISO 6709), the standard for data base query of spatial data (ISO 13249-3 SQL/MM-Part 3) and the Basis Image Interchange Format (BIIF) from JTC1 SC24 (O'Brien, 2001). However the technical committee, ISO/TC 211 on geographic information/geomatics, was formed to build broad spatial data standards that will hopefully consolidate most of the national and international isolated standards presently in use around the world.

3.3.2.1.1 ISO/TC 211 Geographic Information/Geomatics

The ISO/TC 211 was established in April 1994 to define standards for geographic information/geomatics that were needed to support spatial data infrastructure and user requirements. The initiative for this committee came in 1993, from a Canadian proposal, which was circulated to the ISO member countries, for the formation of new technical committee in the field of geomatics. This proposal was based upon, among other things, the Canadian work within Digital Geographic Information Working Group (DGIWG).

ISO/TC 211 is composed of the national standardisation bodies from most countries all over the world. The current focus of the ISO/TC 211 is to enable interoperability between heterogeneous geographic information systems. It is arguably the most important body in the movement towards compatible spatial data standards.

3.3.2.1.1.1 The Aim of ISO/TC 211

The aim of ISO/TC 211, which was defined in the inaugural TC 211 meeting in Oslo in November 1994, is to establish a structured set of digital spatial data standards. These standards may specify, for geographic information, methods, tools and services for data management (including definition and description), acquiring, processing, analysing, accessing, presenting and for transferring such data in digital form between different users, systems and locations. The intention was announced to link to appropriate standards for information technology and data where possible and to provide a framework for the development of sector-specific applications using spatial data (ISO/TC 211, 1994).

3.3.2.1.1.2 The ISO/TC 211 Working Groups

The ISO/TC 211 started with five main working groups as follows:

1. Working group 1- Framework and reference model.
2. Working group 2 - Geospatial data model and operators.
3. Working group 3 - Geospatial data administration.
4. Working group 4- Geospatial services.
5. Working group 5- Profile and functional standards.

However during the 13th plenary meeting of ISO/TC 211, held in Adelaide, Australia, 22-26 October 2001 a number of resolutions were issued. The most important of these resolutions were:

The disbanding, as their work was complete, of:

Working group 1- Framework and reference model.

Working group 2 - Geospatial data model and operators.

Working group 3 - Geospatial data administration.

Working group 5- Profile and functional standards.

and the establishment of four new Working Groups.

Working Group 6: Imagery.

Working Group 7: Information communities.

Working Group 8: Location based services.

Working Group 9: Information management (ISO/TC 211, 2002b).

The ISO/TC 211 former and new working groups focused on the following thirty-five projects for standardisation, as shown in table 3-2

19101	Reference Model	19120	Functional standards
19102	Overview (Deleted)	19121	Imagery and gridded data
19103	Conceptual Schema Language	19122	Qualifications and certification of personnel
19104	Terminology	19123	Schema for coverage geometry and functions
19105	Conformance and Testing	19124	Imagery and gridded data components
19106	Profiles	19125-1	Simple feature access-Part 1:Common Architecture
19107	Spatial schema	19125-2	Simple feature access-Part 2: SQL Option
19108	Temporal schema	19125-3	Simple feature access-Part 3:COM/OLE Option
19109	Rules for Application Schema	19126	Profile-FACC data dictionary
19110	Feature cataloguing methodology	19127	Geodetic codes and parameters
19111	Spatial referencing by co-ordinates	19128	Web Map server interface
19112	Spatial referencing by geographic identifiers	19129	Imagery, gridded and coverage data framework
19113	Quality principles	19130	Sensor and data model for imagery and gridded data
19114	Quality Evaluation Procedures	19131	Data product specifications
19115	Metadata	19132	Location based services possible standards
19116	Positioning Services	19133	Location based services tracking and navigation
19117	Portrayal	19134	Multimodel location based services for routing and navigation
19118	Encoding	19135	Procedures for registration of geographical information items
19119	Services		

Table 3-2 ISO/TC 211 Families of standards [Source: ISO/TC 211, 2002a].

At the time of updating this chapter (January 2002) about fourteen (14) of the above projects have been approved as a draft international standards (DIS).

3.3.2.2 CEN/TC 287

The European Joint work goes back to the late 1980s, when the European national mapping organisations declared a need for a European Transfer Format (ETF). After years of co-operation and co-ordination among the European countries and due to the need for European spatial data standards, France proposed officially to the European Organisation for Standardisation (Comité Europeén de Normalisation, CEN) that it start working in the field of spatial data standards. In 1991 CEN agreed to take up this new work and formed a technical committee, TC 287 for this purpose. The first meeting of CEN/TC 287 was held in Brussels in February, 1992 and all the European Commission (made up of 22 members) are members (Østensen, 1996a).

The original goal of the CEN/TC 287 was to produce a family of standards aiming to bring a greater understanding of spatial data, harmonisation of concepts concerning sharing of spatial data, integration of spatial data and simplify the transfer between different systems in the 22 countries. Four CEN working groups handled standardisation within the committee and deal with issues pertaining to:

1. Framework for standardisation.
2. Models and applications.
3. Geographic information transfer.
4. Location reference systems.

CEN/TC 287 does not lay any restrictions on the use of particular referencing systems, as it recognises such basic concepts related to positional information as geodetic reference system, geodetic ellipsoid (Spheroid) and local co-ordinates (Salgé, 1996). It should be noted that CEN began before ISO/TC 211, but ISO/TC 211 later absorbed most of its work plan when, CEN/TC 287, due to financial difficulties, had to discontinue its work. The researcher discussed this issue, via E-Mail, with Francois Salgé, Director of European and International Activities IGN and chairman of the CEN/TC 287. He replied "the CEN/TC 287 has finished its work programme and is now dormant until ISO/TC 211 has delivered its results (2001-2003)".

3.3.2.3 DGIWG

Spatial data standardisation within the Northern Atlantic Treaty Organisation (NATO), for defence co-operation, started in 1983 using an informal group, which named itself the Digital Geographic Information Working Group (DGIWG). DGIWG's work has resulted in a series of military spatial data standards or NATO standards, which are now known as the DIGEST. Even though DIGEST was originally developed for military application to assist NATO in its operations, the intent of these standards has been to develop general public domain scientific standards rather than ones for purely military purposes. It grew from a simple data exchange standard to the establishment of a suite of direct use data products and the release of public domain software and tools for accessing spatial data. DIGEST is a 'defined' standard as it specifies one (or at most a few) ways to exchange sets of data through the components of DIGEST-A, DIGEST-B and DIGEST-C, which are different encoding of the same general model, that mostly handle vector data. DIGEST-D handles raster and matrix (image and gridded) data in alignment with the ISO basis image interchange format (BIIF) standard for imagery. Thus, a profile of a general standard could be created to correspond to a well-defined standard (Kottman, 1991). DIGEST allows a range of co-ordinates for spatial referencing including geographic and Cartesian co-ordinates and does not restrict the exchange of data between databases and systems.

3.3.2.4 IHO

The International Hydrographic Organisation (IHO) is an intergovernmental consultative and technical organisation established in 1921. IHO works together with the International Maritime Organisation (IMO) to support safety and efficiency in the sea navigation and protection of the marine environment. For over 75 years, the IHO has consistently worked towards the development of standards for hydrographic charts and related activities, so that mariners worldwide can share charts compiled by any member of the IHO. The standardisation of charts was achieved by adoption of the 'Chart Specifications of the IHO' at the 12th International Hydrographic Conference held in April 1982. However the key development of the IHO in the field of hydrographic digital spatial data standards was S-57 for the electronic navigational chart (ENC) as well as the transfer standards format, DX-90. IHO defines its ENC using the S-57 standard (IHO, 2001). S-57 standards work among other things as the object catalogue for spatial objects related to hydrography (Østensen, 1996b).

DGIWG has a similar requirement and has established a digital nautical chart (DNC) product based on the DIGEST standard. But DNC products use a different geometric and topological data structure (planar graph topology) and a different layering. However, both the IHO and the DGIWG have been working together for over ten years, trying to harmonise the differences between their standards. As a result, a significant move in the area of overcoming data sharing barriers has been achieved by the alignment of DIGEST to S-57 standards (Hume et al., 1998). The two standards are not identical;

however, the underlying models have been aligned, permitting conversion of data without loss of structure or information. The spatial schemas for both DIGEST and S-57 have been aligned, as have aligned metadata and feature catalogue object and attribute definitions. This work was completed in June 2000 and it is now possible to correctly produce DIGEST digital nautical chart (DNC) data from S-57 electronic nautical chart (ENC) data. In effect DGIWG and IHO have aligned their content models, but have not changed the implicit exchange format.

Both the DGIWG and IHO are altering their DGIWG and S-57 standards to make use of the ISO/TC 211 rules and schema to bring their standards closer together and minimise differences (O'Brien, 2001).

3.3.3 Summary of Standardisation Initiatives

The following table (table 3-3)summarises most of the worldwide standards initiatives (national and international) that have been developed.

No	Country(s)	Name of Standard	Acronym	Year	Authority	Official ID	Language of Documents
1	Australia	Australian Spatial Data Transfer Standard	AS/NZS 4270	1995	Standards Australia	Australian/New Zealand AS/NZS 4270	English
2	Austria	Austrian Interface for Digital Exchange of Geographic data	ONORM A2260	1994	Austrian Standards Institute	ONORM A2260	German
3	Canada	Spatial Archive and Interchange Format	SAIF	1995	Canadian General Standards Board	CGSBCGIS-SAIF cat. # CAN/CGSB.171.1-95	English
4	China	Data Exchange Format for Surveying and Mapping Information	DEFS	N/A	National Standards Bureau of China	N/A	Chinese
5	Finland	EDI Based geographic information service	JHS 111-119	1993	Julkisen hallinnon tietohallinnon neuvottelukunta	JHS 111-119	Finish and English
6	France	Traitement de l'Information Géographique Numérique: Echange de DonnéesInformatisé dans le Domaine de l'Information Geographique	EDIGéO	1992	Conseil National de l'Information Géographique	AFNOR:Z13-150 ISSN 0335-3931	French and English
7	Germany	Einheitliche Datenbankschnittstelle(EDBS)Für die Automatisierte Liegenschaftskarte(ALK) und das Amtliche Topographisch-Kartographische Informationssystem(ATKIS)	ALK/ATKIS-EDBS	1993	AdV	N/A	German
8	Israel	Israel Exchange Format '91	IEF91	1992	Survey of Israel	IEE91	Hebrew
9	Japan	Standard Procedure and Data Format for Digital Mapping	SPDFDM	1988	Geographical Survey Institute	N/A	Japanese
10	The Netherlands	Automated Data Processing-Interchange Format for Data of Objects Related to the Earth's Surface	NEN 1878	1993	Nederlands Normalisatie Institute	NEN 1878	Dutch and English
11	Norway	Co-ordinated Approach to Spatial Information	SOSI	1994	Statens Kartverk	SOSI Version 2.1	Norwegian, partial English translation
12	Russian Federation	Digital and Electronic Maps Transfer Standards	DEMTS 1.1	1995	Gosstandart of Russian Federation	GOST R 50828-95 State Standard	Russian (English Translation is under study)
13	South Africa	National Standard For The Exchange of Digital Geo-referenced Information	NES	1993	Coodinating Committee for the National Land Information system	NES v.2.0	English(Other official Language will be considered)
14	Spain	Norma de Intercambio de Cartografia Catastral	NICCa	1994	Centro de Gestión Cadastral y Cooperactión Tributaria	NICCa	Spanish
15	Switzerland	INTERLIS	INTERLIS	1991	Swiss Federal Department of Justice	INTERLIS	English, French German and Italian
16	United Kingdom	Electronic Transfer of Geographic Information	NTF	1992	British Standards Institution	BS 7567	English
17	United States of America	Spatial Data Transfer Standard	SDTS	1994	U.S. National Institute of Standards and Technology	1994	English
18	European Union	European Territorial Data Base	ETDB	1992	Comité Européen des Responsables de laCartographie Officielle	CERCO-ETDB	English
19	European Union	Full Description of the CEN/TC 287 Family of Standards	CEN/TC 287	Varies	Comité Européen de Normalisation	N/A	English ,French and German
20	European Union	Geographic Data File	GDF	1996	Comité Européen de Normalisation	CEN/TC 287	English ,French and German
21	NATO	Digital Geographic Exchange Standard	DIGEST	1991 (V1.0)	Digital Geographic Information Working Group	DIGEST	English
22	IHO	Transfer Standard for Digital Hydrographic Data	S-57	1996	International Hydrographic Organisation (IHO)	S-57	English
23	ISO	Geographic Information/Geomatics	ISO/TC211	——	Under development	Under development	English (maybe-other language)

Table 3-3 Spatial data transfer standards [Adapted from Moellering and Hogan, 1996 and ISO/TC 211, 2002a].

3.3.4 Comparison of Standards

In this section, a comparison is presented between seven of the best-known standards. They are:

1. SAIF (Canada).
2. NEN 1878 (The Netherlands).
3. NTF (United Kingdom).
4. SDTS (United States of America).
5. CEN TC 287 (European union).
6. DIGEST (NATO).
7. S-57 (IHO).

The comparison between the seven standards is carried out using the basic characteristics in table 3-3 and table 3-4 and based in part on Moellering and Hogan (1996):

a. All seven standards were independently developed and at different times(table 3-3).
b. They were documented in English Language (Table 3-3).
c. They have all been tested, with the exceptions of NEN 1878 and CEN/TC 287
d. They are all officially recognised, with the exception of CEN/TC 287.
e. Software for implementation is available for all except CEN/TC 287.
f. With the exceptions of DIGEST and S-57, all the standards are general standards, which allow different data types to be transferred.
g. All standards support spatial referencing, a conceptual data model, a conceptual data schema and a quality data model, except NEN 1878, which does not support a quality data model.
h. Data type:
   - In geometric/topological data type aspect, all standards support vector topology and spaghetti vector data types.
   - The raster data type (transfer in raster format) is supported by all, except NEN 1878.
i. Definitions of technical terms as well as that for entities, attributes and relationships are supported by all standards.

j. Implementation of general standards is done using profiles, except for SAIF, CEN/TC 287 and DIGEST. All standards contain descriptive information, except SAIF and CEN/TC 287.

k. SAIF, CEN/TC 287 and DIGEST support topological, object-oriented, hierarchical, relational and image data structure. NEN 1878 does not support an image data structure. . SDTS does not support object oriented and hierarchical data structure. S-57 does not support object-oriented and relational data structure. S-57 does not support a relational data structure.

l. All the standards have specifications for spatial reference systems as well as type of map projection used.

m. All data quality elements are supported in SAIF, SDTS, CEN/TC 287 and DIGEST. NEN 1878 supports lineage and positional accuracy. NTF supports lineage, positional accuracy and temporal accuracy. S-57 supports lineage, positional accuracy, completeness and temporal accuracy.

n. Metadata are defined in all standards.

o. The official documentation (papers) are available (with varied charges, except DIGEST which is free). On the other hand the Canadian (SAIF) and the U.S. (SDTS) standards can be accessed free through the Internet.

p. The technical description documentation (supplementary documents) are available for SAIF, NEN 1878, NTF, and SDTS. Also, user manuals/guides are available for SAIF, NEN 1878 and SDTS. Other supplementary documentation is available for all except IHO (Moellering, and Hogan 1996).

q. It should be noted that SAIF has been dropped as a national standard of Canada. It did not pass its reaffirmation vote, since it is used only by its developers in the Canadian province of British Columbia (O'Brien, 2001).

Table 3-4 summarises the seven selected standards and their characteristics.

Characteristics / Name of Standard(Country)	SAIF (Canada)	NEN 1878 (The Netherlands)	NTF (United Kingdom)	SDTS (USA)	CEN/TC 287 (European Union)	DIGEST (NATO(	S-57)IHO(
Copyright	Yes, Province of British Columbia	Yes, NNI	Yes, BSi	No	Yes, CEN	No	No
Official Recognition	Yes	Yes	Yes	Yes	No	Yes	Yes
Availability of official doc / Paper Price/ Internet price	Yes/ $22(Can) / free	Yes/ ƒ40.50/ No	Yes/ £132/ No	Yes/ $44..50/ free	Yes/not fixed/ No	Yes/generally free	Yes/ 650FF/ No
Availability of supplementary documentation and support: Technical description, User manual/guide, others Organisation of training Sessions, Training Materials	Yes, Yes, Yes Yes, In the internet	Yes, Yes, , Yes - / -	Yes, No, Yes Yes, Yes	Yes, Yes, Yes Yes, Yes	No, No, Yes No, No	No, No Yes No, No	No, No, No No, No
Available software for implementation	Yes	Yes	Yes	Yes	No	Yes	Yes
Type of standards(General or Specific)	General	General	General	General	General	—	General
Define the following concept in the transfer context: Spatial referencing, Conceptual data model Conceptual data schema , Quality model Generic term for real-world items, Generic term for digital representation of the real world items	Yes, Yes Yes, Yes Yes, Yes	Yes, Yes Yes, No Yes, Yes	Yes, Yes Yes, Yes Yes, Yes	Yes, Yes Yes, Yes Yes, Yes	Yes, Yes Yes, Yes Yes, Yes	Yes, Yes Yes, Yes Feature, Feature	Yes, Yes Yes, Yes Yes, Yes
On-line or telecommunication transmission	Yes	No	N/A	Yes	Yes	Yes	Yes
Use or Define language for: Data description, Query General exchange/Specialised exchange mechanisms	Yes, No Yes, No	No, No No, No	No, No Yes, No	Yes, No Yes, No	Yes, Yes Yes, Yes	Yes, Yes Yes, Yes	Yes/ No No/ No
Data types: Geometric/Topological aspect: Raster/grid Vector spaghetti, Vector topology, Topology only Semantic aspect: layer approach, object/feature approach Dimensional aspect: 2-D, 3-D Time data type/ User-defined data type	Yes Yes, Yes, Yes Yes, Yes Yes, Yes Yes/ Yes	No Yes, Yes, No Yes, Yes Yes, Yes Yes/ Yes	Yes Yes, Yes, No No, Yes Yes, 2½-D Yes/ Yes	Yes Yes, Yes, Yes Yes, Yes Yes, Yes Yes/ Yes	Yes Yes, Yes, Yes Yes, Yes Yes, Yes Yes/ No	Yes Yes, Yes, No Yes, Yes Yes, Yes No/ No	No Yes, Yes, No Yes, Yes Yes, No
Design approach: Hierarchical, Network, Relational Object-based, Object-oriented, Others	Yes, Yes, Yes Yes, Yes, –	No, No, No Yes, No, N/A	BS 7567 is based on internal data model independent of any particular DB system.	No, Yes, Yes Yes, No	No, No, No Yes, No, No	No, Yes, Yes No, Yes, No	No, No, No Yes, No, No
Query transaction defined	Yes	No	No	No	Yes	Yes	No
The standards contain: Descriptive information, Implementation through Profiles Encoding rules, Appendices	N/A, N/A N/A, N/A	Yes, Yes Yes, Yes	Yes, Yes No, Yes	Yes, Yes Yes, Yes	No, No No, Yes	Yes, No Yes, Yes	Yes, Yes Yes, Yes
Definition of technical terms	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Data Structure: Topological, Object-orient., Hierarchical Relational, Image, combination Other structure	Yes, Yes, Yes Yes, Yes, Yes No	Yes, Yes, Yes Yes, No, No Yes	Yes, No, Yes Yes, Yes, Yes No	Yes, No, No Yes, Yes, Yes Yes	Yes, Yes, Yes Yes, Yes, Yes No	Yes, Yes, Yes Yes, Yes, Yes, Yes	Yes, No, Yes No, Yes, Yes No
Transfer implementation used	ASCII	N/A	ISO8211,Simple Record	ISO 8211	N/A	ISO 8211 EDIFACT	ISO 8211
Spatial reference system(Co-ordinate): Polar, Cartesian, Geographic Geocentric, User-defined, Other co-ordinates	Yes, Yes, Yes Yes, Yes, Yes	Yes, Yes, Yes Yes, Yes, No	No, Yes, Yes Yes, No, No	No, Yes, Yes No, No, No	Yes, Yes, Yes Yes, Yes, No	Yes, Yes, Yes No, Yes, Yes	No, Yes, Yes No, No, No
Representation of height: As part of co-ordinates As attributes	Yes Yes	Yes Yes	Yes Yes	Yes Yes	Yes Yes	Yes Yes	Yes Yes
Projection name, Formula, parameters included In projection information transferred:	Yes/, No, Yes	Yes, No, No	Yes, Yes, No	Yes, No, Yes	To be determined (No enough inf)	Yes, No, Yes	No, No, No
Data quality elements: Lineage, Positional accuracy Attribute accuracy, Logical consistency Completeness, Currency	Yes, Yes Yes, Yes Yes, Yes	Yes, Yes No, No No, No	Yes, Yes No, No No, Yes	Yes, Yes Yes, Yes Yes(part of others)	Yes, Yes Yes, Yes Yes, Yes	Yes, Yes Yes, Yes Yes, Yes	Yes, Yes No, No Yes, Yes
Metadata defined, Metadata limited to quality information	Yes, No	Yes, No	Yes, No	Yes, No	Yes, No	Yes, No	Yes, No

Table 3-4 Basic characteristic features of some national and international standards [Adapted from Moellering and Hogan, 1996 and ISO/TC 211, 2002a].

3.4 CONCLUDING REMARKS

In the search for a suitable set of spatial data standards, the researcher found various worldwide initiatives and well established standards in this field. These initiatives and developments were undertaken primarily as a way of improving spatial data collection, production and distribution to a wider range of users. The initial development and implementation of spatial data standards started in countries with advanced information technology, such as the U.S. and Europe, to enable sharing of available fundamental spatial data sets and to facilitate the use of technology. The U.S. dominated these activities and its work has been recognised as pre-eminent in the world.

Standards for digital spatial data have addressed in the past the simpler problem of transfer format. Most of the spatial data standards initiatives were transfer standards. However, there has been a shift in the use of spatial data from simple transfer of data to more complex issues. The challenge now is not in data transfer, but in the structure of the spatial data. There is a need for Interoperable and compatible spatial data sets, as well to address institutional, administrational and technical issues in the establishment and maintenance of national and international spatial data infrastructures.

The major effort now is to create general and more universal standards in an environment that links the spatial data standards to good information technology standards. The emerging universal spatial data standards are defined and carried out by the ISO/TC 211. ISO/TC211 is developing versatile and flexible standards in most of the spatial data application domains and defining the standards that are required at national, regional and international levels.

The ISO/TC211 broad band standards should be used for the Saudi NSDI. If no national standards are introduced to the Kingdom of Saudi Arabia the drawbacks will be great. Spatial data users and producers will not be able to successfully share data, make a clearinghouse of any type, or know what is available in the Kingdom owing to disparate querying approaches and metadata provision. In the meantime the OGC standards are industry driven and may not be useful in a Saudi context by themselves. For Saudi Arabia to enter the world stage it must use the ISO/TC211 standards so that it can join the world in terms of data sharing and exchange in the future.

However, standards alone will not be enough to solve all the data sharing problems. It cannot ensure the free flow of spatial data from one organisation to another as well as to the users unless institutional, technical, administrational, policies, funding, co-operation, confidentiality, copyright and many other important issues are also addressed.

CHAPTER 4

CURRENT STATUS OF MAPPING ACTIVITIES IN THE KINGDOM OF SAUDI ARABIA

4.1 INTRODUCTION

Spatial data in the Kingdom of Saudi Arabia constitutes a valuable national resource that contributes to the development of the national infrastructure and to the country's economic growth. It has and will continue to have, a steady influence on the Kingdom's series of 5-year development plans (current and future) and the advancements made in the country's cultural, industrial and agricultural developments, the development of education, health care services, communications, telecommunications, transportation, road networks, environmental and tourism as well as other activities.

A large number of ministries and other government organisations, as well as ones in the private sector have, become involved with activities related to both spatial data and geographic information systems, but to consolidate their efforts and direct them to the optimum utilisation of existing (and future) spatial data, the development of a strategy for a national spatial data infrastructure in the Kingdom of Saudi Arabia is a pressing need, as indicated in chapter 1.

To guide the proposal of such a framework, the researcher formulated a requirement questionnaire. In August 2000 the questionnaire was distributed by the General Directorate of Military Survey (GDMS) to nineteen (19) ministries and organisations that produce and use spatial data. The participants were given until Monday, 25th December 2000 (about four months) to complete and return the questionnaire but, due to requests from some of the participants, the deadline for the completion of the survey was extended to the end of February 2001.

The main purpose of this chapter is to discuss, briefly summarise and analyse the various replies and draw general conclusions. Annex I contains the survey questionnaire text and annex II provides more detail and contains the tabulation of all the replies.

4.1.1 The goal of the survey questionnaire

The goal of the survey questionnaire was to gather as much information as possible about the availability, reliability and accessibility of digital maps, geographic information systems (GIS), conventional maps (paper maps), users' needs and requirements and the spatial data exchange activities presently underway in the Kingdom of Saudi Arabia.

The survey questionnaire also aimed to make the spatial data producers and users aware of this national spatial data infrastructure initiative and to get their feelings and feedback about the proposed strategy.

A subsidiary aim was to find a suitable mechanism for establishing co-operation and effective exchange of spatial data and expertise between data producers and users.

4.1.2 Clarification

When the term *organisation* is used in this chapter, it means the Section, Division, Department, Directorate, Establishment, Organisations, Ministry or any other name, of the representative who completed the survey questionnaire document.

4.1.3 The Invited Ministries and Organisations

Nineteen copies of the survey questionnaire were distributed to the following ministries and organisations (table 4-1).

No	Name of Ministry/Organisation	Name of Department, to whom the Questionnaire was Addressed
1	Ministry of Defence and Aviation and Inspectorate General (MODA)	General Director of Military Survey (GDMS)
2	Ministry of Petroleum and Mineral Resources (MOP&MR)	General Directorate of Surveying.
3	Ministry of Petroleum and Mineral Resources (MOP&MR) Saudi Aramco	General Manager of Saudi Aramco.
4	Riyadh City Municipality	The Municipal of Riyadh
5	Ministry of Municipal and Rural Affairs (MOMRA)	General Director of Surveying
6	King Abdulaziz City for Science and Technology (KACST)	Head of the Saudi Centre for Remote Sensing
7	Ministry of Interior	Deputy Minister of Provincial affairs
8	Ministry of Communications	Deputy Minister of Highway
9	Ar Riyadh Development Authority (ADA)	The Municipal of Riyadh, Head of ADA
10	The Ports Authority	General Director of the Port Authority
11	Ministry of Agriculture and Water	Manager of the Documentation and Information Centre
12	Ministry of Finance and National Economy.	Department of Census and Vital Statistics
13	Ministry of Education	General Directorate of Studies and Design
14	Saudi Telecommunication Company	General Manager of Riyadh District
15	The Saudi Consolidated Electric Company (SCECO).	General Director of the Saudi Consolidated Electric Company
16	General Presidency of Girls Education	President of Girls Education
17	National Commission for Wildlife Conservation and Development	Chairman of the NCWCD
18	Presidency of Civil Aviation	General Director Saudi Arabian Airlines
19	The Meteorology and Environmental Protection	President of the Meteorology and Environmental Protection

Table 4-1 Ministries and organisations that received a copy of the questionnaire.

4.1.4 The Participants

As a result of this survey, seventeen replies (89.5%) were returned. Two copies were received from KACST, one from the Space Research Institute and one from the Saudi Centre for Remote Sensing (GIS Centre), but these were amalgamated as they were very similar. The two agencies that did not complete the survey, were the Presidency of Civil Aviation-Saudi Arabian Airlines and the Department of Meteorology and Environmental Protection. No reason was given.

In order to make this chapter a reasonable length each participant is given an ID number to indicate the name of the ministry/organization, as shown in table 4-2.

Participant ID number	Name of Ministry/Organisation	Name of Department that Completed the questionnaire
1	Ministry of Defence and Aviation and Inspectorate General (MODA)	General Directorate of Military Survey (GDMS), Research and Development.
2	Ministry of Petroleum and Mineral Resources (MOP&MR)	General Directorate of Surveying.
3	Ministry of Petroleum and Mineral Resources (MOP&MR) - Saudi Aramco	Projects Support & Control Department – Surveying Services Division (SSD)
4	Riyadh City Municipality	Department of Names, Numbering and Aerial Surveying
5	Ministry of Municipal and Rural Affairs (MOMRA)	General Directorate of Surveying
6	King Abdulaziz City for Science and Technology (KACST)	Space Research Institute, the Saudi Centre for Remote Sensing–GIS Centre
7	Ministry of Interior	Not Given
8	Ministry of Communications	Service Coordination and Geographic Information System.
9	Ar Riyadh Development Authority	Urban Information System Department.
10	The Ports Authority	Department of Lighthouses and Marine Communications
11	Ministry of Agriculture and Water	Documentation and Information Centre
12	Ministry of Planning	The Department of Public Statistics, Mapping Unit
13	Ministry of Education	General Directorate of Studies and Design, Deputyship of buildings and school supplies.
14	Saudi Telecommunication Company	Riyadh Province
15	The Saudi Consolidated Electric Company (SCECO)	Geographic Information System and network design-Central Province
16	General Presidency of Girls Education	Not Given
17	National Commission for Wildlife Conservation and Development	Information and documentation Centre and Geographic Information System

Table 4-2: Participants.

4.1.5 How fully was the questionnaire answered?

Table 4-3 and table 4-4 summarise how the sections were answered.

Sections	**Total Questions**	**Number of Participants**	**% Answered**
Section 1: Filtering Introduction.	8	15	88%
Section 2: Digital Maps.	27	11	65%
Section 3:Geographic Information System.	25	12	71%
Section 4: Conventional Maps (paper maps).	15	12	71%
Section 5: Users' Needs and Requirements.	14	14	82%
Section 6: Digital Geographic Information Exchange.	16	16	94%
Section 7: The Development of a Strategy for a National Spatial Data Infrastructure in the Kingdom of Saudi Arabia	8	15	88%

Table 4-3: The total number of questions in each section and how many respondents.

ID	**Section One**	**Sec. Two**	**Sec. Three**	**Sec. Four**	**Sec. Five**	**Sec. Six**	**Sec. Seven**	**%**	**Language Used**
1	Y	Y	Y	Y	Y	Y	Y	100	A (T/E)*
2	Y			Y		Y	Y	50	A
3	Y	Y	Y	Y		Y	Y	83	E
4	Y	Y	Y		Y	Y	Y	83	A
5	Y	Y	Y	Y	Y	Y	Y	100	A (T/E)
6	Y	Y	Y			Y	Y	67	A (T/E)
7					Y	Y	Y	50	A
8	Y	Y	Y	Y	Y	Y	Y	100	A
9	Y	Y	Y	Y	Y	Y	Y	100	A (T/E)
10		Y	Y	Y	Y	Y	Y	83	A (typed)
11	Y	Y	Y	Y	Y	Y	Y	100	A
12	Y			Y	Y			50	A
13	Y				Y	Y	Y	67	A
14	Y	Y	Y		Y	Y	Y	83	A
15	Y	Y	Y	Y	Y	Y	Y	100	A
16	Y			Y	Y	Y		50	A
17	Y		Y	Y	Y	Y	Y	100	A
Total	**15**	**11**	**12**	**12**	**14**	**16**	**15**		
%	**88**	**65**	**71**	**71**	**82**	**94**	**88**		

Table 4-4 The respondents in each section and language used to answer the questionnaire (* A= Arabic, (T/E)=Technical Words answered in English).

4.2 ANALYSIS OF RESULTS

Each section of the survey questionnaire was analysed separately by calculating the percentage response to each item. The calculations of the percentages in all answers were performed as follows:

Total participants in each part of the question (whether Yes or No or any other) was divided by the total survey response (17). Missing value, termed Blanks (No Replies) was calculated by dividing the number of blanks by the total survey response (as illustrated in the first summary below). In the summaries given below, the percentages often sum to more than 100% as many organisations use or produce more than one type of product or service. For more details see Annex II.

4.2.1 Section 1: Filtering Introduction

A total of 15 ministries and organisations (88%) used the filtering introduction. The results of the analysis are:

1. The returns (as detailed below) indicated that 2 organisations out of the 17 participants (12%) are only users, 13 organisations (76%) are both producers and users and 2 organisations (12%)did not participate.

Total Survey Respondents: 17, Total participants in this Section: 15, Total Part. In this question: 15		
Users	**Both (Producers and users)**	**Blank (No Reply)**
12%	76%	12%

2. The types of digital products produced in the Kingdom of Saudi Arabia are as follows: Two organisations produce digital maps, 4 organisations produce conventional maps, 8 organisations produce both digital and conventional maps and 3 organisations did not participate.

Total Survey Respondents: 17, Total participants in this Section: 15, Total Participants in this question: 14			
Digital Maps	**Conventional Maps**	**Both**	**Blank (No Reply)**
12%	24%	47%	18%

3. Regarding geographic information capabilities, the responses showed that 10 organisations have GIS capabilities, 3 do not and 4 organisations did not participate.

Total Survey Respondents: 17, Total participants in this Section: 15, Total Participants in this question: 14		
Yes	**No**	**Blank (No Reply)**
59%	18%	24%

4.2.2 Section 2: Digital Products

A total of 11 ministries and organisations (65`%) participated in answering the digital products section. The results of the analysis are:

1. The returns indicated that 10 organisations produce raster data products, 9 organisations produce vector data, 1 organisation produces matrix, 1 organisation indicated other types of data and 7 organisations did not respond to this question.

Total Survey Respondents: 17, Total participants in this Section: 11, Total Participants in this question: 10				
Raster	**Vector**	**Matrix**	**Other**	**Blank (no reply)**
59%	53%	6%	6%	41%

2. In answer to what spatial data format is used, 6 organisations use DGN format, 4 use Arc Info, 4 use TIFF, 2 use Arc View, 2 use DXF, 2 use JPEG and 1 organisation uses each of the other formats.

Total Survey Respondents: 17, Total participants in this Section: 11, Total Participants in this question: 9				
DGN	**Arc Info and TIFF**	**Arc View, DXF and JPEG**	**Others**	**Blank (no reply)**
35%	24%	12%	6%	47%

3. A variety of digital products are produced in the Kingdom. The scales ranged from 1:1,000 to 1:2,000,000 and the areas covered varied from Riyadh City to the whole Kingdom. Also, the dates of the products ranged from 1990 to the present day.
4. The main identifiers of types and scales of digital products are as follows: 1 organisation indicated that their department (as listed in the question) identifies the type and scale of their products, 4 organisations indicated that the user does so, 6 organisations ticked both department and user and 6 organisations did not respond.

Total Survey Respondents: 17, Total participants in this Section: 11, Total Participants in this question: 11			
Department	**User**	**Both**	**Blank (No Reply)**
6%	24%	35%	35%

5. The main identifier of requirements and contents was as follows: 3 organisations indicated that their department (as listed in the question) identifies the requirements and contents of their products, 2 indicated the user, 4 ticked both department and user and 8 organisations did not respond.

Total Survey Respondents: 17, Total participants in this Section: 11, Total Participants in this question: 9			
Department	**User**	**Both**	**Blank (No Reply)**
18%	12%	24%	47%

6. The use of Quality assurance (QA) and Quality control (QC) in the digital production lines varied, 9 organisations said Yes, 6 organisations said No and 3 organisations did not respond. A very useful description of how quality assurance and quality control were performed was given by some of the participants. See Annex II (question 2.7, section two).

Total Survey Respondents: 17, Total participants in this Section: 11, Total Participants in this question: 15				
QA		**QC**		**Blank**
Yes	**No**	**Yes**	**No**	**(No reply)**
53%	35%	53%	35%	18%

7. In reply the question about in-house productions versus contracted, 11 organisations indicated that they produce their products in house, 6 indicated that they contrac all or some of their products and 6 organisations did not respond.

Total Survey Respondents: 17, Total participants in this Section: 11, Total Part. In this question: 11		
In-House Productions	**Contracted**	**Blank (No Reply)**
65%	35%	35%

8. The returns indicated that 6 organisations are using standards for their land and geodetic survey, photogrammetry, data transfer and printing, while 8 organisations are using standards for cartography, 5 organisations are using standards for quality assurance and quality control and 2 are using standards for Satellite images and for checking land use against maps on the production line. The results are good in general. They indicate that the main digital product activities were carried out based on

standards. The types of standards used range from homemade standards, to DIGEST, USGS, IHO and others. The following table summarises the results.

Total Survey Respondents: 17, Total participants in this Section: 11, Total Participants in this question: 10			
Activity	**Yes**	**No**	**Blank (No Reply)**
Land and Geodetic Survey	35%	30%	35%
Photogrammetry	35%	30%	35%
Cartography	47%	18%	35%
QA and QA	30%	35%	35%
Data transfer and Exchange	35%	30%	35%
Printing	35%	30%	35%
Others	12%	53%	35%

9. Regarding future plans for developing and using standards, 6 organisations had plan to develop standards, 4 indicated that they did not and 7 did not respond.

Total Survey Respondents: 17, Total participants in this Section: 11, Total Participants in this question: 10		
Yes	**No**	**Blank (No Replay)**
35%	24%	41%

10. In response to a question on their views and intentions with regard to the Kingdom of Saudi Arabia being a member of the International Organisation for Standards/Technical Committee for Geographic Information/Geomatics 211 (ISO/TC 211), 11 organisations indicated that they will adopt ISO/TC 211 standards and 6 organisations did not respond.

Total Survey Respondents: 17, Total participants in this Section: 11, Total Participants in this question: 11		
Propose to use ISO/TC 211 Standards	**Propose to use Other Standards**	**Blank**
65%	0%	35%

11. Geodetic Reference System used for digital products; 5 organisations use International Spheroid, 1 uses WGS 72, 7 use WGS84, 2 use others and 9 organisations did not respond to this question.

Total Survey Respondents: 17, Total participants in this Section: 11, Total Participants in this question: 8				
Int. Spheroid	**WGS 72**	**WGS 84**	**Other**	**Blank (No reply)**
29%	6%	41%	12%	53%

12. The Horizontal datum used for digital products were as follows: 1 organisation uses WGS 84, 7 use Ain Al Abd. Regarding the vertical datum, 5 organisations use Jeddah

72, 1 uses another (Saudi Aramco Vertical Datum, SAVD 78) and 10 organisations did not respond.

Total Survey Respondents: 17, Total participants in this Section: 11, Total Participants in this question: 8					
Horizontal			**Vertical**		
WGS 84	**Ain Al Abd**	**Others**	**Jeddah 72**	**Others**	**Blank (No reply)**
6%	41%	0%	29%	6%	53%

13. The availability of reproduction materials was as follows: 8 organisations indicated that they have reproduction materials, 2 said they did not and 7 organisations did not respond.

Total Survey Respondents: 17, Total participants in this Section: 11, Total Participants in this question: 10		
Yes	**No**	**Blank (No Reply)**
47%	12%	41%

14. The potential users of the digital products in the Kingdom were mostly confined to the department concerned.
15. Various hardware and Software is used to produce the digital products.
16. Product updates varied between daily to five years or more.
17. The majority of maps required an update period of one year.
18. The returns indicated that, 9 organisations have a digital geographic database, 2 did not and 6 did not respond. Types of digital geographic database used vary but mostly involve an Oracle based system.

Total Survey Respondents: 17, Total participants in this Section: 11, Total Participants in this question: 11		
Yes	**No**	**Blank (No Reply)**
53%	12%	35%

19. The maintenance of geographic data took various forms as follows: 6 organisations maintain hardcopy (paper maps), 7 maintain digital (CD-ROMs, diskettes..etc), 6 maintain databases; 5 have database management systems (DBMS) and 7 organisations did not respond.

Total Survey Respondents: 17, Total participants in this Section: 11, Total Participants in this question: 10				
Hardcopy (Maps, Charts, Co-ordinates, Reports, etc.)	**Digital (CD-R, Disks, High Density disks, Mag.Tape, etc.)**	**Database**	**DBMS**	**Blank (No reply)**
35%	41%	35%	29%	41%

4.2.3 Section 3: Geographic Information Systems

A total of 12 Ministries and organisations (71%) participated in answering the geographic information system (GIS) section. The results of the analysis are:

1. Regarding the number of GIS systems used, responses were evenly split; 6 of the organisations (35%) had one geographic information system and 6 (35%) had two geographic information systems. The geographic information systems used are mostly either Intergraph or ESRI or both.
2. The main uses of the geographic information systems varied.
3. The data formats used were mainly DGN or Shapefile
4. Geographic information systems were purchased between 1990 and 2000.
5. The returns indicated that, 10 of the organisation systems worked as part of a network (mainly LAN), 2 were standalone and 5 organisations did not answer.

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question: 12		
Yes	**No**	**Blank (No Reply)**
59%	12%	29%

6. On the co-ordination of the purchase of systems with other organisations; 6 organisations co-ordinated the purchase of their systems with other organisations, 6 did not co-ordinate and 5 did not answer.

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question: 12		
Yes	**No**	**Blank (No Reply)**
35%	35%	29%

7. The returns indicated that 10 organisations believed the system met their Departments' expectations, 2 did not believe so and 5 did not reply.

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question: 12		
Yes	**No**	**Blank (No Reply)**
59%	12%	29%

6. On the similarity of the GIS, 7 of the organisations were aware of similar GISs in other organisations, 4 were not and 6 did not answer.

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question: 11		
Yes	**No**	**Blank (No Reply)**
41%	24%	35%

7. The vast majority of the participants used the GIS for data collection, processing, management, analysis, display and output as detailed in the following summary.

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question depends on the activity as shown below.						
Activity	Yes	%	No	%	Blank	%
Data Collection	10	59	2	12	5	29
Data Processing	10	59	2	12	5	29
Data Management	12	71	0	0	5	29
Data Analysis	11	65	1	6	5	29
Data Display	12	71	0	0	5	29
Data Output	12	71	0	0	5	29
Others	3	18	9	53	5	29

8. Dates from which Digital Products (used for GIS) had been produced ranged from 1986 to 2000.
9. The main identifiers of the requirements and contents of the geographic information system products (department or users) were as follows: 2 organisations said their department, 4 said user, 6 ticked both and 5 did not answer.

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question: 12			
Department	**User**	**Both**	**Blank (No Reply)**
12%	24%	35%	29%

12. The main identifiers of types and scales of geographic information system products were as follows: in 3 organisations it was the department, in 2 the user, 4 ticked both and 8 did not answer.

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question: 12			
Department	**User**	**Both**	**Blank (No Reply)**
18%	12%	24%	47%

13. A variety of quality control and quality assurance procedures were carried out.
14. The returns indicated that 5 organisations experienced difficulties of one sort or another during the collection, processing, management, display or output of spatial data, 5 did not encounter any problems and 7 did not reply.

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question: 10		
Yes	**No**	**Blank (No Reply)**
29%	29%	41%

15. In answer to the question, 'do you have enough well trained Saudi personnel working in your department?' 5 organisations answer that they have well trained Saudi personnel, 7 indicated No and 5 did not participate. Most of the respondents indicated that they planned to recruit and train more Saudi personnel until all the vacancies were filled.

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question: 12		
Yes	**No**	**Blank (No Reply)**
29%	41%	29%

16. The returns indicated that 4 organisations were aware of similar geographic information products produced and maintained by other organisations, 6 were not aware of any and 7 organisations did not respond.

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question: 8		
Yes	**No**	**Blank (No Reply)**
24%	35%	41%

4.2.4 Section 4: Conventional Maps

A total of 11 Ministries and organisations (65%) participated in answering the Conventional Maps section. The results of the analysis are:

1. The future plans to produce digital maps and geographic information systems for organisations who did not have digital maps and GIS at present were as follows: 6 organisations said they have future plans for digital maps and GIS, 1 said No and 10 did not answer (they already have digital mapping and GIS capabilities).

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question: 7		
Yes	**No**	**Blank (No Reply)**
35%	6%	59%

2. Types of conventional products produced in the Kingdom included topographic maps, joint operation graphics, general maps, traffic and road maps, aerial photography and

cadastral maps. However, topographic maps dominated the products. The scale varies from 1:1,000 to 1:30,750,000 and the main area covered varies from an individual city to the whole Kingdom. The dates also ranged from 1970s to 2001

3. Two organisations produce their conventional products in-house, 1 organisation out-sources its products, 6 organisations have both in-house production and contractors and 8 organisations did not reply.

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question: 9			
Department	**User**	**Both**	**Blank (No Reply)**
12%	6%	35%	47%

4. Contractors used included firms from Saudi Arabia, Korea, Germany, Holland, French, Ireland and others.

5. The returns indicate that 10 organisations use some sort of standards, 1 organisation did not use any standards and 6 did not answer. The results are good in general, indicating that the main conventional maps are produced based on some standards. The types of standards used range from homemade standards to DIGEST, USGS, IHO and others.

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question: 11		
Yes	**No**	**Blank (No Reply)**
59%	6%	35%

6. Regarding the Geodetic Reference System used for the conventional maps, 5 organisations use International Spheroid, 1 uses WGS 72, 5 use WGS 84, 3 use others; however, 10 organisations did not answer. Some organisations use more than one reference system.

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question: 7				
International Spheroid	**WGS 72**	**WQS 84**	**Others**	**Blank (No reply)**
29%	6%	29%	18%	59%

7. The datums used for conventional maps were as follows: for the horizontal datum, 1 uses WGS 84, 6 use Ain Al Abd. For the vertical datum, 4 use Jeddah 72 and 11 organisations did not answer in relation to either horizontal or vertical data.

Total Survey Respondents: 17, Total participants in this Section: 11, Total Participants in this question: 11					
Horizontal			**Vertical**		
WGS 84	**Ain Al Abd**	**Others**	**Jeddah 72**	**Others**	**Blank (No reply)**
6%	35%	0%	24%	0%	65%

8. The availability of reproduction materials was as follows: 7 organisations said they are available in good quality and stored under perfect condition, 3 have no reproduction materials and 7 did not answer.

Total Survey Respondents: 17, Total participants in this Section: 12, Total Participants in this question: 10		
Yes	**No**	**Blank (No Reply)**
41%	18%	41%

9. Potential users of the conventional products were mostly confined to the respective departments.
10. The equipment used for conventional products varied, but was mostly Wild and Ziess.

4.2.5 Section 5: Users' needs and requirements

A total of 14 Ministries and organisations (82%) participated in answering the users' needs and requirements section. The results of the analysis are:

1. The main producers of maps and digital products currently used by other organisations are: 53% the Ministry of Defence and Aviation (MODA), the General Directorate of Military Survey (GDMS), 47% the Ministry of Petroleum and Mineral Resources (MOP&MR), 47% the Ministry of Municipal and Rural Affairs (MOMRA), 29% Ar Riyadh Development Authority (ADA), 12% the Ministry of Communication, 12% Riyadh City Municipality and 12% Al Farsi maps, 7% Ports Authority, 7% King Abdulaziz City for Science and Technology (KACST) 18% of the respondents did not answer this question.
2. Regarding the type of product being used, 9 organisations use paper maps, 8 use digital maps, 2 use other geographic information and 6 did not respond.

Total Survey Respondents: 17, Total participants in this Section: 14, Total Participants in this question: 11			
Paper Maps	**Digital Maps**	**Other GIS**	**Blank (No Reply)**
53%	47%	12%	35%

3. The returns indicated that 6 organisations plan to use GIS in the future, 1 had no plan and 10 did not answer.

Total Survey Respondents: 17, Total participants in this Section: 14, Total Participants in this question: 7		
Yes	**No**	**Blank (No Reply)**
35%	1%	59%

4. In response to the question, is requested geographic data received on time? 6 said Yes, 3 No and 8 did not reply.

Total Survey Respondents: 17, Total participants in this Section: 14, Total Participants in this question: 9		
Yes	**No**	**Blank (No Reply)**
35%	18%	47%

5. The type of products in use varied in scale from 1:500 to 1:3,000,000.
6. The primary use of geographic information was confined to the departments concerned.
7. Map scales preferred varied but were mainly very large scale.
8. The desired horizontal and vertical accuracy varied and appeared to be subjective. The contour and supplementary contours intervals also varied and appeared to be subjective.
9. The majority required most cultural features to be included for all the different scales.
10. Preferred image map resolution and type included land sat TM 30 metres resolution, Spot panchromatic 10m res., spot colour 20m res., the Russian sat. 5m res. and the Ikonos 1m resolutions.
11. Types of products used (by users) in the Kingdom varied and the dates ranged from 1976 to 2000.
12. Updating and preferred updating period varied from as needed to five or more years.

4.2.6 Section 6: Geographic Information Exchange

A total of 16 Ministries and organisations (94%) participated in answering the Geographic Information Exchange section. The results of the analysis are:

1. Sixteen of the participants exchanged geographic information with other organisations.
2. Thirteen organisations requested geographic data by official letter, 2 by agreement, 2 by phone, 2 by filling a form, 1 by email, 1 by other means and 1 did not respond.

Total Survey Respondents: 17, Total participants in this Section: 16, Total Participants in this question: 16			
By Official letter	**Agreement, Phone and Form**	**Mail or Other Means**	**Blank (No Reply)**
72%	12% Each	6% Each	6%

3. Requested data was identified as follows: in 12 organisations by co-ordinates, 11 by area of coverage, in 6 by main features, 4 by contents, 1 by cost and 2 did not answer.

Total Survey Respondents: 17, Total participants in this Section: 16, Total Participants in this question: 15					
By Co-ordinates	**Coverage**	**Feature**	**Contents**	**Cost**	**Blank (No reply)**
71%	35%	24%	6%	1%	2%

4. How are digital geographic data transferred to the users?

   3 organisations use ordinary mail, 2 use DHL, 2 use networks, 1 uses email, 10 use courier and 2 use other means (user pick up and formal delivery to user).

Total Survey Respondents: 17, Total participants in this Section: 16, Total Participants in this question: 14					
By Ordinary mail	**DHL and Networks**	**Email**	**Courier**	**Other Means**	**Blank (No reply)**
18%	12%	6%	59%	12%	18%

5. The media used for the receipt of data were as follows: 11 organisations use hard copy, 10 use CD-ROMs, 3 use Diskettes and 5 did not answer.

Total Survey Respondents: 17, Total participants in this Section: 16, Total Participants in this question: 12			
Hard Copy	**CD-R**	**Diskettes**	**Blank (No Reply)**
65%	59%	18%	29%

6. The majority indicated that there was no specific time frame for the exchange of digital products with other organisations; it occurs as needed.
7. Formats for the maintenance and exchange of data were said to vary, but the one were mainly MicroStation DGN, TIFF, Arc Info Shapefile AutoCAD, Arc Info Coverage, ASCII and JPEG as indicated in the following table.

Format	**Maintain**	**Exchange**
MicroStation DGN file	65%	53%
TIFF	53%	53%
Arc Info Shapefile	41%	29%
AutoCAD (DWG/DXF)	35%	47%
Arc Info Coverage	35%	18%
ASCII	29%	29%
JPEG	24%	24%
GIF (Graphic Interchange Format)	12%	12%
SDTS, SIF, DTED, CCITT, ADRG	6%	6%
DIGEST, Vmap, Others	6%	
HTML		6%

8. In response to the question, 'can organisations deliver geographic information on time?'; 14 indicated yes and 3 did not answer.

Total Survey Respondents: 17, Total participants in this Section: 16, Total Participants in this question: 14		
Yes	**No**	**Blank (No Reply)**
82%	0%	18%

9. The majority indicated that the data met the users' requirements under the following headings.

Total Survey Respondents: 17, Total participants in this Section: 16, Total Participants in this question depends on the term.						
Headings (Terms)	**Question 6.9 of section 3**					
	Yes	%	No	%	Blank	%
Completeness	11	65	2	12	4	24
Accuracy	11	65	2	12	4	24
Clarity	12	71	1	6	4	24
Currency	8	47	4	24	4	24
Data Format	11	65	2	12	4	24
Response Time	12	71	1	6	4	24
Quantity	11	65	2	12	4	24
Quality	11	65	2	12	4	24
Other-Specified	2	12	11	71	4	24

10. On the question, 'Do you find the current circumstances of exchanging information between organisations in the Kingdom of Saudi Arabia appropriate and efficient?' 1 organisation said yes, 13 organisations indicated that the current circumstances of exchanging information are not appropriate and not efficient and they suggested the introduction of some formal exchange mechanism, and 3 did not naswer.

Total Survey Respondents: 17, Total participants in this Section: 16, Total Participants in this question: 14		
Yes	**No**	**Blank (No Reply)**
6%	76%	18%

11. The majority of respondents anticipated expected that introducing a formal mechanism for geographic data exchange between organisations in the Kingdom will have positive effects by improving the quality of geographic data and knowledge, reducing duplication and saving time, effort and money. Thoughts on the main obstacles to the exchange of geographic data were fairly evenly spread across the response options, as shown in the following table.

Total Survey Respondents: 17, Total participants in this Section: 16, Total Participants in this question depends on each main obstacle.						
Main Obstacles	Yes	%	No	%	Blank	%
Data format	10	59	3	18	4	24
Data type	3	18	10	59	4	24
Currency of products	7	41	6	35	4	24
Media	4	24	9	53	4	24
Inconsistency and discrepancy	7	41	6	35	4	24
Unwillingness to exchange data	9	53	4	24	4	24
Cost	5	29	8	47	4	24
Hardware & Software Problems	6	35	7	41	4	24
Human resources	7	41	6	35	4	24
Others - Specified	1	6	12	71	4	24

4.2.7 Section 7: The Development of a Strategy for a National Spatial Data Infrastructure (SNSDI) in the Kingdom of Saudi Arabia.

A total of 16 Ministries and organisations (94%) participated in answering the section ondevelopment of a strategy for the a National Spatial Data Infrastructure (SNSDI) in the Kingdom of Saudi Arabia. The results of the analysis are:

1. All thought that the development of a strategy for a National Spatial Data Infrastructure in the Kingdom of Saudi Arabia initiative is an important idea and should be implemented (See final concluding remarks for more details).
2. The majority of the participants were willing to participate and be part of the SNSDI.

Total Survey Respondents: 17, Total participants in this Section: 16, Total Participants in this question: 15		
Yes	**No**	**Blank (No Reply)**
88%	0%	12%

3. Most of the participants were willing to make their geographic data available.

Total Survey Respondents: 17, Total participants in this Section: 16, Total Participants in this question: 14		
Yes	**No**	**Blank (No Reply)**
76%	6%	18%

4. Numerous suggestions and comments were made with regard to the questionnaire and the idea of the SNSDI ranging from wishing the researcher every success, through criticism of the format and layout of the questionnaire, to many very valuable comments.

4.3 CONCLUDING REMARKS

The results of this survey were very encouraging and valuable. Certainly the goals of the questionnaire were achieved and awareness of the needs and benefits of a nationwide spatial data-sharing programme for the Kingdom of Saudi Arabia was accomplished. The analysis of the survey shows that there are:

1. Large amounts of geographic information (digital and non digital) already available in the Kingdom of Saudi Arabia,
2. A variety of advanced hardware and software used,
3. Well developed GIS activities and capabilities,
4. Some geographic database management systems.

In general:

1. The participants were using a number of standard systems, and were maintaining required standards and accuracies.
2. The systems met most of the participants' expectations,
3. Most reproduction materials are available and stored under suitable conditions.
4. There are future plans for digital maps and GIS.
5. Quality controls and quality assurances are performed.
6. Common geographic data formats are used.
7. The users are involved in the identifications of product types, requirements and scales.
8. Most of the products were produced by the organisation (in-house).

All the participants want to use the ISO/TC 211 standards (through GDMS and this research project initiative) when it becomes available and fully support the development of a strategy for a national spatial data infrastructure in the Kingdom of Saudi Arabia.

The following are representative responses to illustrate what respondents thought about the proposed SNSDI initiative: "It is a must", "a great idea", "a national goal", "valuable to the Kingdom", "fruitful, innovative and worthy of much support and attention", "it should receive the highest and immediate attention to enable successful and speedy implementation", "it must be carried out as soon as possible", "it would support sound decision making based on geographic information and prevent duality", "we believe that the proposed SNSDI would give the country a main pillar in its development", "we look forward to seeing the idea executed for the common good", "the goals and objectives of the SNSDI should be drawn up and clearly stated", "all relevant parties must be allowed to effectively contribute to the building of the proposed database, looking forward to the realisation of this goal".

However, there are some geographic information using and producing organisations that are still in the development stage. It is clear from some of the answers that duplications in spatial data collections, the co-ordination and sharing of geographic data and insufficient availability of well-trained Saudi personnel are the most common problems. Also, some technical data integration and continuous updating difficulties were encountered. In the meantime a very small number of participants were confused by or did not understand certain questions, or the concepts were not fully understood (as can be seen from reading the summary of the replies).

Two organisation criticised the format and layout of the questionnaire, as follows:

1. "*This questionnaire is too big*". It is true that the questionnaire was quite lengthy, but this was necessary in order to collect as much information as possible about spatial data and its use within the Kingdom of Saudi Arabia.
2. "*Before writing the purpose of the questionnaire, page 2, there should have been 4-5 concentrated lines on the purpose of the study*". This comment is not wholly valid, because the introduction of the questionnaire Arabic document, which was distributed to the participants stated clearly the main goal of the study, but perhaps the respondents missed it, hidden amongst what is undoubtedly a very long document.
3. "*The GIS strategy in this questionnaire concentrates more on maps than other elements of importance to the strategy*". This comment may be correct, but the respondents did not state what they mean by other elements. Also, there is a similar comment that the questionnaire concentrates on maps and geographic information and gives no attention to satellite imagery. Satellite imagery is an important map source and will not be forgotten.
4. "*The questionnaire is too bulky with a lot of repetition*". Yes it is bulky, but as mentioned above, the purpose of the survey is to collect a lot of information. However, there are no repetitions! The filtering introduction introduces the concept of the

questionnaire. We need to collect information about digital products, GIS, conventional products, user needs, etc. So if the organisation produces only digital products, then it is not necessary to repeat the same answer in relation to conventional maps and vice versa. If they produce both digital maps and conventional maps and they use the same equipment then they should simply state "the same" as many organisations did. However, I welcome all these comments and would like to thank all those individuals and organisations, which participated in completing this, survey and helped in the process of this project.

Finally, it should be mentioned that the initial Saudi NSDI will be largely based on the developed infrastructure of mapping organisations - producers and users - but as the SNSDI progresses the needs of end users of maps and spatial data should be considered, particularly as the Location Based Service (LBS) market grows. This survey questionnaire will be the first of many, and certainly its content will swing in favour of addressing a more user based non-specialist community as time passes. The present set of questions are producer orientated, with users amongst the producer community and is therefore limited, but is based on the core users and producers in the Kingdom - those who will first make use of both clearinghouse and data sharing arrangements; those who will need to approve the primary stages of the SNSDI initiative if it is to succeed. Lessons learnt from this first set of survey questionnaire will have an impact on the types of future questions asked and the number of organisations and individuals polled.

CHAPTER 5

COMPUTER NETWORK AND WEB MAPPING SERVICES

5.1 INTRODUCTION

Computer network technology started to emerge in the early 1970s following the development of high-speed Local Area Networks (LAN). By the mid 1980s, the LANs and WANs were used widely to connect higher-performance workstations in host-base and standalone configurations (Coleman, 1999). Since then computer network technology has expanded and advanced so fast it has become an important part of the Information Technologies (IT) developed and has had a dramatic impact on our lives and work. At present, the Internet is revolutionising the globe and has become the main communicating tool at local, national and international levels. National and international contact, for example, can be made at the touch of a button using the Internet. During the past several years, hundreds of millions of users such as companies, government agencies, organisations and private people have joined and used the Internet; every day more and more people are joining. This in turn has affected the use and exchange of digital spatial data. Most early digital mapping and geographic information activities were isolated technologies; however, the advance in network technology gave spatial data producers and users the opportunity to communicate, exchange spatial data and interact with each other using the Internet. The Internet now forms a main component of any national spatial data infrastructure. Longley clearly stated the importance of network technology when he said, "*the computer is the network, and the network is the computer* " (Longley et al., 1999).

This chapter will examine various basic approaches to computer network environments and technologies needed to build a standardised architecture suitable for a national data infrastructure for interactive web mapping services and Internet-based geographic information systems.

Section 5.2 reviews network components and architectures including LAN, WAN, Internet network, protocols, the Open-System Interconnect (OSI) seven-layers model and the Transmission Control Protocol and the Internet Protocol (TCP/IP). Section 5.3 discusses servers including the Internet server, the map server, the web feature server, other special servers and the client-server model. Section 5.4 defines and presents a general view of the Internet and its services, including the WWW, email, FTP, Telnet, information browsing and searching, and GIS services. Section 5.5 reviews the evolution and services on the Internet in the field of geographic information systems, including raw data download, metadata, map display, Web-based spatial query and analysis, building GIS on the Internet, the technologies that support Internet services for GIS, including the Common Gateway Iinterface (CGI), the Application Programming Interface (API), GIS plug-ins, GIS helper program, active X, Java, the OpenGIS Consortium (OGC) and other GIS vendors' tools, such as Intergraph GeoMedia Web Map, ESRI Arc Internet Mapping System (ArcIMS), MapInfo MapXtreme and AutoDesk MapGuide. Section 5.6 gives an overview of Internet security, including firewalls, encryption, authentication, Virtual Private Networks (VPN) and computer anti viruses. Concluding remarks are presented in section 5.7.

5.1.1 Definition

A computer network, in general, is "*a collection of interconnected multiple types of computer systems, nodes, channels and protocols, which form a highway to exchange information and to enable online communications between local and remote computer systems and humans using certain physical media, such as telephone lines, co axial cables, twisted pair, fibre optics, microwaves, mobile phones, communication satellite, and so on*" (Tanenbaum, 1988). A computer network can be alternatively described as "*the software and hardware components used to implement a set of functions, well-defined interfaces and protocols that establish links between different types of computers and other devices on-line*" (Coleman, 1999).

Besides communication and exchanging data, a computer network is used for sharing hardware and software resources such as printers, scanners, digitisers, file servers, CD read and write disks, as well as software programs. Using a network to share resources reduces the cost of hardware and software, as well as increasing the integrity of specific datasets and the availability of high-quality facilities.

5.2 NETWORK COMPONENTS AND ARCHITECTURE

Most network nodes consist of packet switching elements, which are specialised computers that connect one host computer with another. These are called the Interface Message Processors (IMP). IMP was developed by the U.S. Defence Advanced Research Projects Agency (DARPA), based on transmission design (point-to-point or store-and-forward). Different types of IMPs have been developed (e.g. bridges, routers). All modern computer networks are based on packet-switching networks. The Consultative Committee on International Telegraphy and Telephony (CCITT) of the United Nations defines packet switching as transmission of data by means of addressed packets whereby a transmission channel is occupied only for the duration of transmission of the packet (Pretty, 1992). The packets are made of a series of bits, which contain the information. The maximum packet size is recommended to be 128 bytes, which is large enough that a high proportion of messages for interactive systems fit into one packet. If the data size exceeds the optimal size of packet, the message is broken into smaller packets. The broken packets contain linking and destination information that enables the receiving node to rejoin multiple packets in the right sequence to form the original message. Therefore, when a packet is transmitted from one computer to another computer or to a group of computers, it does not have to follow the same route, but can be forwarded through any available route and can wait in a node until transmission space is available. Sets of conventions have been established to control and maintain communication between different nodes (Man-Ho, 1998). These conventions contain a wide range of functions that are grouped into protocols, as discussed in section 5.2.2.

5.2.1 Types of Networks

This section will discuss three types of networks; Local Area Network (LAN), Wide Area Network (WAN) and, most importantly, the Internet Network.

5.2.1.1 Local Area Networks (LAN)

A Local Area Network is a computer network that physically or logically connects multi workstations, PCs, terminals, and other peripheral devices using a single cable or shared medium. The LAN usually covers a smaller area, which could be one building or group of buildings within a range of 1,000 metres, in general. It serves as the foundation of distributed computing technology. Most LANs are owned by a single organisation. The communication speed is relatively high (typically 10-100 Mbit/sec or maybe higher), using transmission media such as coaxial cables and fibre optics. The LAN uses standardised types of technology, including IEEE 802.3 (CSMA/CD or Ethernet), IEEE 802.4 (Token bus), IEEE 805.5 (Token Ring), and the American National Standards Institute Fibre Distributed Data Interface (ANSI- FDDI). Today, two technologies are typically used, Ethernet and Token ring (Coleman, 1999).

5.2.1.2 Wide Area Networks (WAN)

A wide area network is a computer network that spreads over large area, which could be a city, province, country, continent or the globe. WANs connect a collection of computer systems and a large number of LANs. Until the early 1990s, the communication speed of WANs was relatively slow, they did not offer real-time access between users, and could not move large amount of graphics data, such as digital maps, large files of spatial data and satellite images over long distances. Today, a typical WAN uses advanced technologies, transmission media, satellite-based networks and different protocols to offer high speed (10-45 Mbit or maybe higher), and is comparable to the speed of a LAN, but covers a much greater area (Man-Ho, 1998).

5.2.1.3 The Internet Network

The Internet network is a combination of worldwide networks of data servers and telecommunications links. It is a collection of many heterogeneous networks, that are physically separated, but linked together through special purpose computers (gateways) at specific points. Any network, such as a LAN or WAN, can be part of the Internet network, provided it adheres to a set of communication protocols, known as the Internet protocols (IP) (Amor, 2000), which will be discussed later in this chapter. Figure 5-1 shows a framework for the basic components of the Internet network infrastructure, consisting of nodes and channels that provide the basic communication tools.

Nodes can be classified into end-nodes and intermediate nodes. End nodes include servers and clients, such as the web server, map server and mail server. Clients, in most applications, are computers that are used to communicate with other nodes. Intermediate nodes are scaled down specialised computers used as a routers and bridges to forward traffic between network segments, and sometimes offer the possibility of filtering out certain requests and of restricting access to certain devices and sites within a network.

Channels are media for communication between nodes, which can be implemented by various kind of physical connections, such as co-axial cable, twisted pair, fibre-optic or telephone line, or by wireless connections, such as infrared transmission, microwave link, mobile phone and satellite (Amor, 2000).

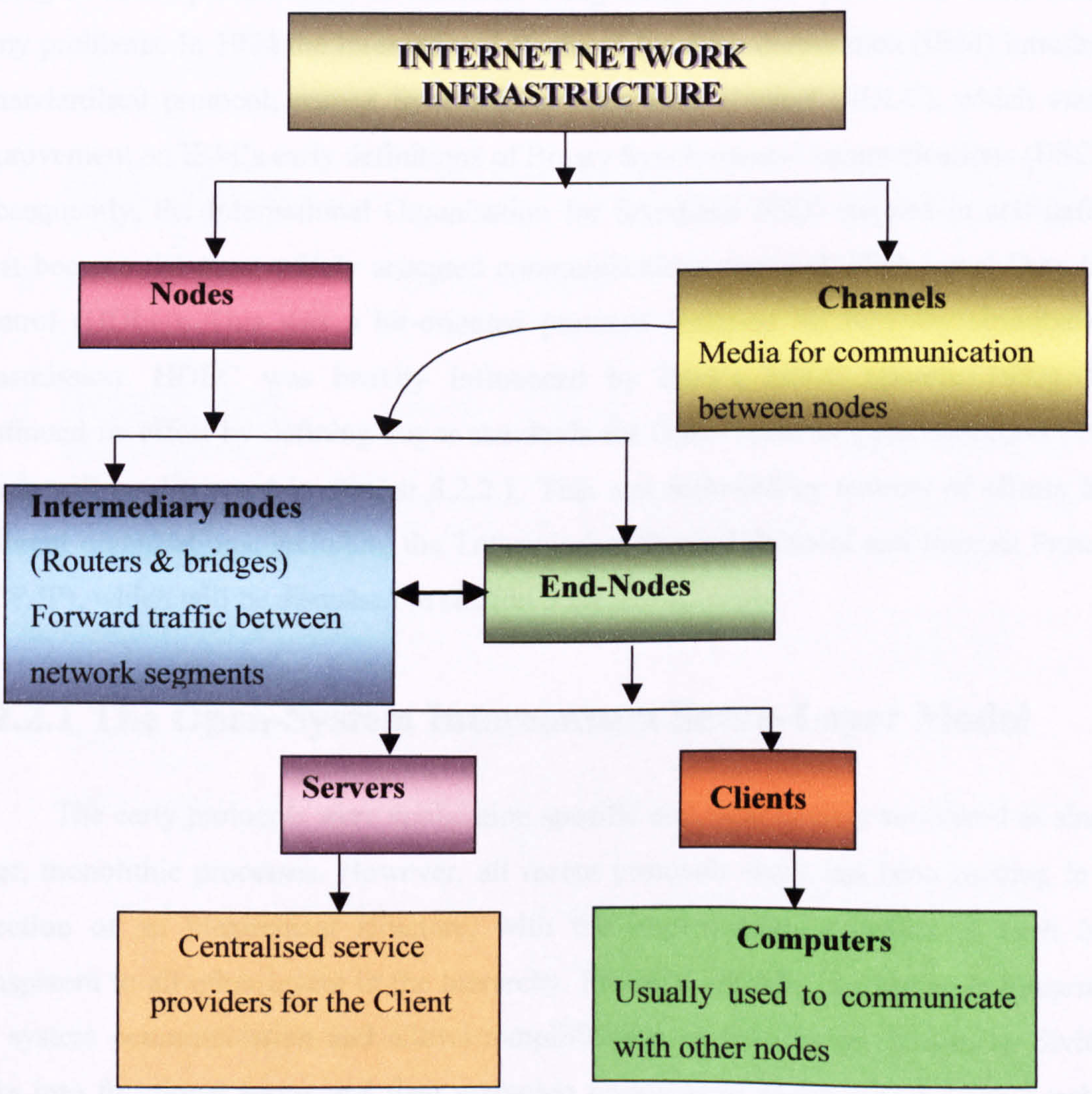


Figure 5-1 General concept of the main components of the internet network infrastructure.

5.2.2 Protocols

A protocol is a set of rules and conventions for handling the flow and exchange of information between different computing elements (nodes) across a network. Protocols define both how the information must be formatted for transmission and the series of commands and responses to be used in the exchange of data. Protocols are simply pieces of software that run on any node and state how each node of a network initiates, transmits, receives, addresses and splits the data into small packets to maximise the throughput, reduce the possibility of errors, loss or damage to data, reduce transmission failure and to maintain and terminate communications (Al-Shahrani, 1983).

For many years, protocols used in computer networks were not standardised, leading to the implementation of networks using many different protocols, which created many problems. In 1974 the International Business Machine corporation (IBM) introduced a standardised protocol, named Synchronous Data Link Control (SDLC), which was an improvement on IBM's early definitions of Binary Synchronous Communications (BSC). Subsequently, the International Organisation for Standards (ISO) stepped in and defined what became the most widely accepted communications protocol, High Level Data Link Control (HDLC). This was a bit-oriented protocol designed for two-way simultaneous transmission. HDLC was heavily influenced by IBM's SDLC (Booth, 1983). ISO continued its effort by defining major standards for Open Systems Interconnection (OSI), which will be discussed in section 5.2.2.1. This was followed by number of efforts from different organisations, including the Transmission Control Protocol and Internet Protocol (TCP/IP), which will be discussed in section 5.2.2.2.

5.2.2.1 The Open-System Interconnect Seven-Layer Model

The early protocols were application specific and were usually structured as single-layer, monolithic processes. However, all recent protocols work has been moving in the direction of an hierarchical structure, with the implementation details of each layer transparent to all other layers in the hierarchy. Protocol layering is a common framework for system communication and allows simplification of networking design, by dividing tasks into functional layers and then assigning protocols to perform each layer's task. A number of protocols exist to define different aspects of network communication and to ensure that communications and data handling are conducted effectively. The International Organisation for Standards (ISO) has defined the seven-layer protocol, as shown in figure 5-2, called the reference model for Open-System Interconnection (OSI-ISO). The open-system interconnection was originally developed by the Consultative Committee on International Telegraphy and Telephony (CCITT) of the United Nations. Each protocol is completely independent of the others as long as the inter-level interfaces are not changed. As the use of computer networks expands, particularly with the development of the Internet, a standardised architecture at all seven layers is necessary to achieve satisfactory operation and application flexibility. A protocol should define the type of connection. Data can be transmitted along a pre-planned path throughout the whole connection period, by point-to-point connection using a telephone line, or through any available path, depending on the condition of traffic.

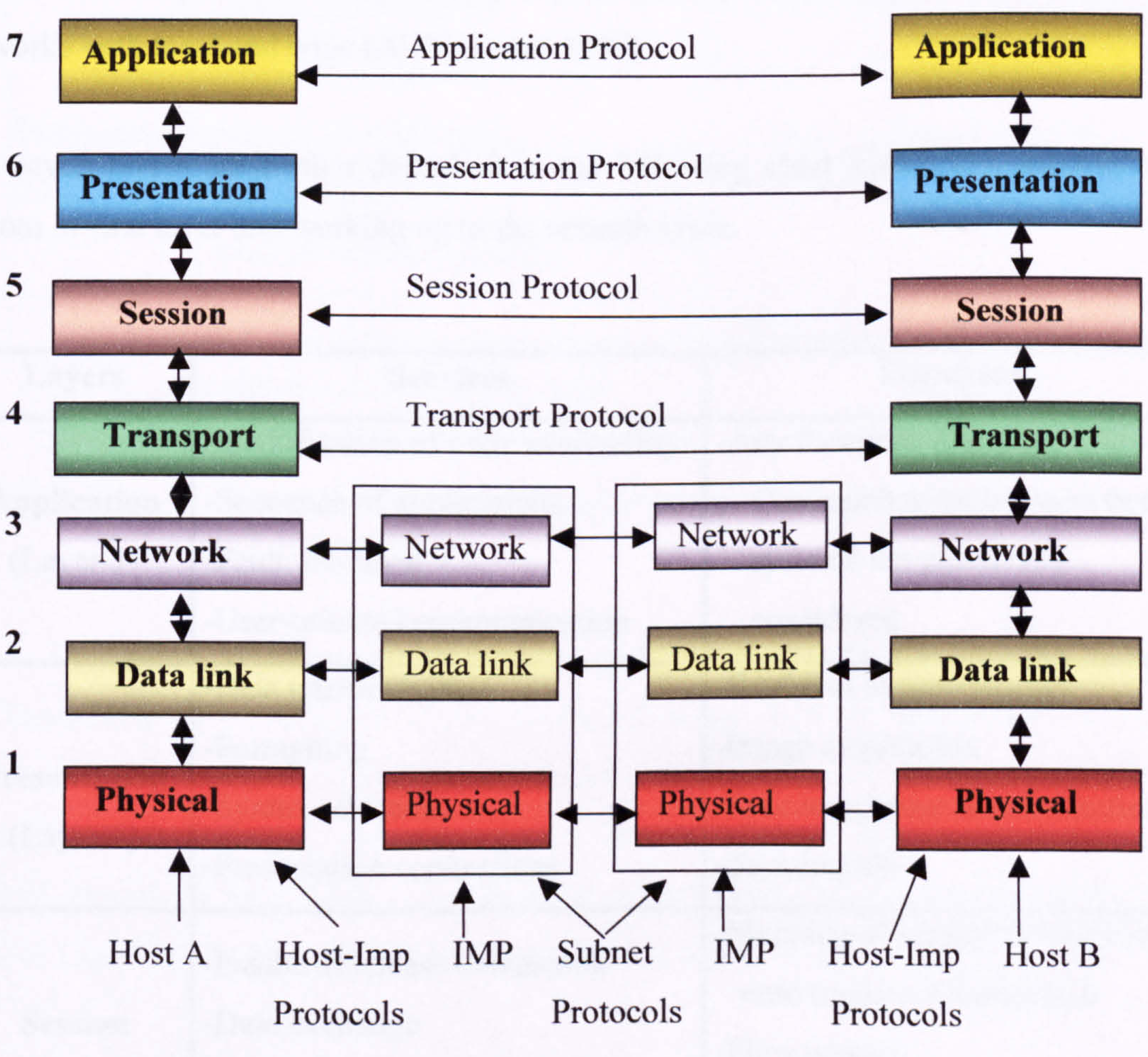


Figure 5-2 Reference model for OSI-ISO [Source Al-Shahrani, 1983].

At each layer of the OSI-ISO reference model, a given node in a network communicates with the same node in another network. All communication is supposed to remain at a particular layer at all times. However, since all layers are involved in every message, the communication at a particular layer is virtual. Physical communication via the communication medium occurs only at the first layer, and is managed by link-layer protocols of the second layer, which serves the higher layers. Layers are joined by interfaces, each of which defines how the lower layer serves the upper layer. Dividing the network into layers enables modification and replacement of certain layers without affecting the others, as long as the interfaces between the layers stay the same.

The seven layers formalise the functions required at each layer. By adhering to such a network design plan, a network designer can ensure that all required functions are performed. At the same time, the designer can simplify any future changes that may be needed and help assure compatibility (open system) at the higher levels with other networks both local and wide (Al-Shahrani, 1983).

The seven layers are further described in the following chart (table 5.1), starting at the bottom or first layer and working up to the seventh layer.

Layers	Services	Functions
Application (Layer 7)	-Identification of node availability -Sequence of applications -Fault tolerance -User-oriented communication	-Any functions implying Communication between two systems not previously considered
Presentation (Layer 6)	-Data transformation -Formatting -Syntax selection -Presentation connections	-Establish session request -Image negotiation -Special purpose transformation -Termination
Session (Layer 5)	-Establish/release connection -Data exchange -Interaction/exceptional mgmt -Interplant network protocol	-Mapping of session connection onto transport connection -Flow control

Transport (Layer 4)	-Endpoint Identifiers -Class of service selection -Data transport	-End-to end communication -Supervisory functions -Establishes a connection for data transmission
Network (Layer 3)	-Network address -Connection -Error notification -Sequencing	-Routing/switching -Segmenting -Blocking -Procedural means to exchange data between stations
Data Link (Layer 2)	-Service availability -Transmit delay -Capability to continue after component failure	-Error detection recovery -Identification and parameter exchange -Conveying data to network layer
Physical (Layer 1)	-Physical connections -Circuit identification -Fault notification -Medium interconnection	-Connection activation-electrical, repeaters, timing, raw bit stream

Table 5-1 Identification of protocol layers as defined by CCITT standards X.21 and X.25 for OSI-ISO [Source Al-Shahrani, 1983].

5.2.2.2 The Transmission Control Protocol and Internet Protocol (TCP/IP)

The Advanced Research Projects Agency Network (ARPANet) originally designed the Transmission Control Protocol and Internet Protocol (TCP/IP). The TCP/IP is a set of protocols that enable communication between different types of nodes, which are connected to the Internet, sometimes called Internet Protocol Suite, IPS (Amor, 2000). TCP/IP consists of four layers – the Network Access Layer, the Internet Layer, the Host-to-Host Layer and the Process/Application Layer, as shown in figure 5-3.

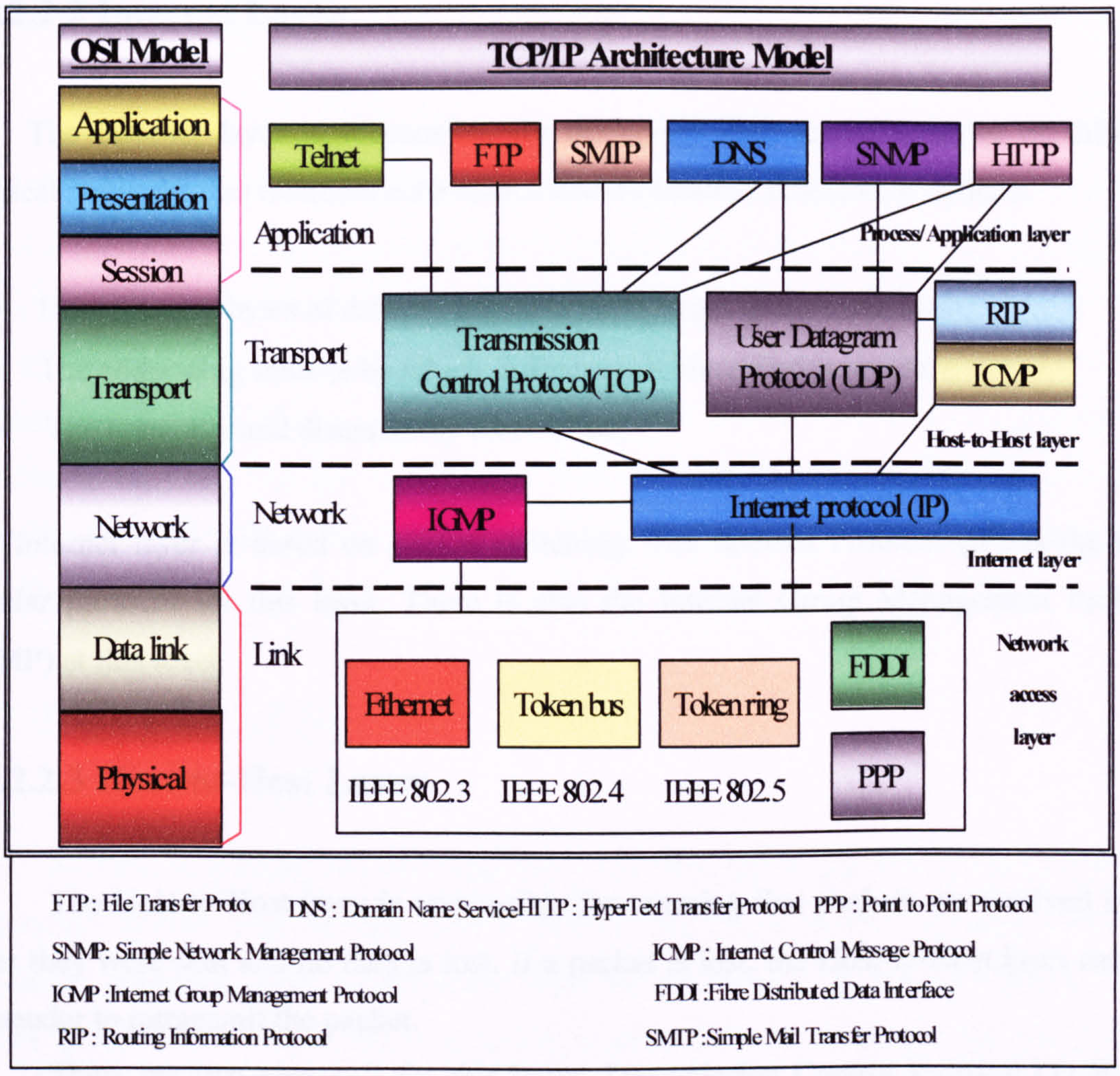


Figure 5-3 The TCP/IP Architectural model [Adapted from Man-Ho, 1998 and Amor, 2000].

5.2.2.2.1 Network Access Layer

The network access layer is responsible for delivering data over a particular hardware medium. Typical functions are to encapsulate an Internet Protocol (IP) datagram into packets transmitted by the network, and to map the IP address to physical addresses used by the network. Each packet contains not only data but also control information. The control information falls into general categories, addressing, error-detecting code and protocol control. The IEEE 802.3 (Ethernet), IEEE 802.4 (Token bus), IEEE 805.5 (Token Ring), the American National Standards Institute Fibre Distributed Data Interface (ANSI-FDDI, X39.5) technologies and the point-to-point protocol are used in this layer.

5.2.2.2.2 Internet Layer

The Internet layer is responsible for delivering data across a series of different physical networks that interconnect a source and destination machine. It defines:

- How bits and bytes of data are organised into larger groups (packets);
- The addressing scheme by which different machines find each other;
- The assembly and disassembly mechanism.

The Internet layer is based on packet switching. The Internet Protocol (IP) is the most popular protocol for this layer. There is also the Internet Group Management Protocol (IGMP) at this level.

5.2.2.2.3 Host-to-Host Layer

The Host-to-Host layer is responsible for ensuring that packets are received in the order they were sent and no data is lost. If a packet is lost, the Host-to-Host layer can ask the sender to retransmit the packet.

There are two protocols for this layer, Transmission Control Protocol (TCP) and User Datagram Protocol (UDP). There are also a Routine Information Protocol (RIP) and an Internet Control Message Protocol (ICMP).

5.2.2.2.4 Process /Application Layer

The Process/Application layer delivers data to the user. It decides what to do with data when it is transferred. The most common services for this layer are Telnet, File Transfer Protocol (FTP), Simple Mail Transfer Protocol (SMTP), Domain Name Service (DNS), Simple Network Management Protocol (SNMP), Hypertext Transfer Protocol (HTTP), and so on. Most Internet applications reside on this layer and specific protocols are required to enable the interaction between client and server such as the user's request, the server's processing and the server's reply. The HTTP is the primary communication protocol for the World Wide Web (WWW). It enables the transfer and display of text, graphics, animation, movie and sound (Man-Ho, 1998).

5.3 SERVERS

A server is a centralised service provider that offers services for many clients and users. It is a tool composed of several modules for accessing, bringing, merging, managing and sharing datasets from different resources, regardless of the format, type and location. Instead of storing datasets in a user's own computer, a server enables transparent multi-user access to share different datasets stored in a centralised location or probably several scattered locations residing on a network. The physical location of a server is generally not apparent to the user. The user can send a query to a remote server that has search engines and a database. The server then invokes the search engine, and the result is sent back to the user (Roman, 1999).

5.3.1 Types of Server

Servers, in general, can be categorised into three types: file server, data server, and application server. File servers enable remote multi-user access to files stored on designated hardware. Data servers make database functions available on a server. Some servers process and analyse the data before sending the results back to the client. Such servers are often referred to as application servers. The Open GIS Consortium (OGC) has developed a number of industry standards for GIS and spatial data servers. Lately the OGC and ISO/TC 211 signed an agreement to cooperate and ensure consistency between their standards. According to the OGC (OGC, 2001b), the most common servers used in GIS and spatial data today are:

5.3.1.1 Internet Server

An Internet server receives and routes messages to and from subscribers, and serves as an Internet gateway. Typical Internet servers are those serving as Internet service providers (ISPs) for private access to Internet services. Examples are email, HTTP, and access to browser applications.

5.3.1.2 Map Server

Map servers can produce a map (as a picture, a series of graphical elements, or as a packaged set of geographic feature data), answer basic queries about the content of the map, and tell other programs what maps can be produced and which of those can be queried further. The map server is implemented using a standard Web Mapping Interface (WMI) specification that allows it to understand a web mapping client's requests for capabilities and/or requests for service. A request for capability is issued by a client that asks the map server to reveal its abilities to select certain map layers, and to generate or resample map images to fit the client's needs. The Map Server can parse the client's request for particular layers and custom use the coordinate system, including size (number of pixels) and projection details, and can deliver a layer of information to the client that exactly fits other layers from different map servers on the client's screen (ISO/TC, 2002a).

5.3.1.3 Web Feature Server

The web feature server delivers General Modelling Language (GML) and eXtensible Mark-up Language (XML) encoded features from its feature store in response to Structured Query Language (SQL) from a client. It can also respond to a request for capability to determine support for the datum and projection requested by the client. Examples of web feature servers are:

Web Coverage Server - supports standard interfaces that allow it to calculate and encode coverage, and deliver them to the client, in response to the client's request for a specific coverage.

Catalogue Server - holds and indexes metadata records for (local or remote) data stores. The Catalogue server is useful for the discovery of useful information in the context of thousands or millions of potential sources of information. The metadata includes information on how to obtain the data stores of interest. The web feature server may be used to extract exactly the information desired.

5.3.1.4 Other Specialised Servers Emerging From OGC

There are many more specialised servers emerging from OGC, such as portrayal servers, location-based servers, GIS calculus servers, decision support servers, modelling servers, information community translators, repositories of feature type libraries, repositories of symbol libraries, repositories of symbolisation rules, coordinate transformation servers, language translator servers (including place names), route servers, real-time servers, geocoding and geopositioning servers, gazetteer servers. The list goes on and on (OGC, 2001c).

5.3.2 Client-Server

What is a client-server? Essentially any application that sends SQL requests across the network to a DBMS server can be called a client-server application. But the client-server model goes beyond database applications. Clients, in most applications, are computers used to communicate with another node, for example, a World Wide Web browser; also the definition can include any application, which can communicate with other servers. Server and client do not necessarily need to be different devices. Servers can be clients at the same time and vice versa. Figure 5-4 shows a conceptual model for client-server (Bishr, el al., 1997 b).

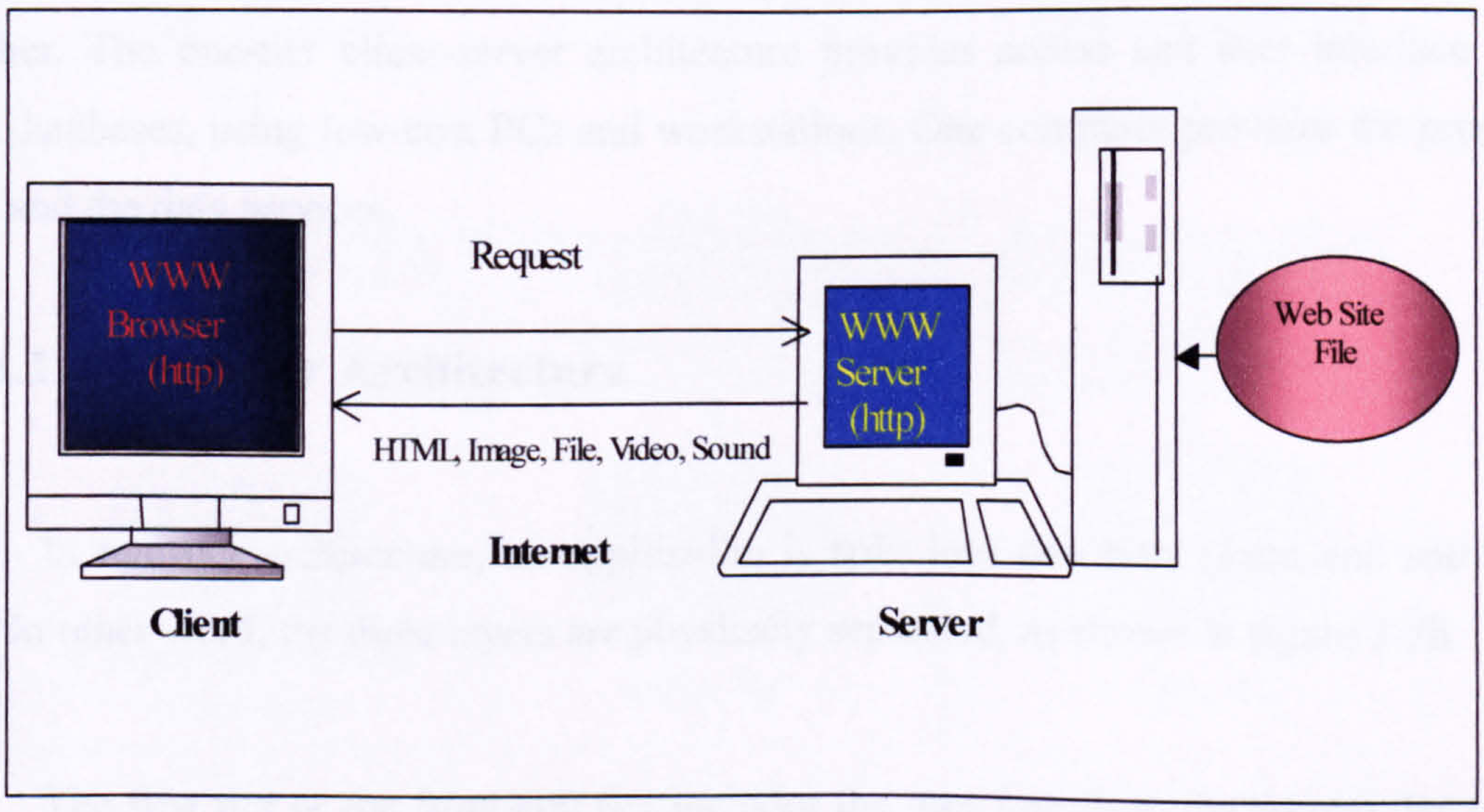


Figure 5-4 Client-server concept model.

5.3.2.1 Client-Server Architecture

Most modern network programming tools are based on client-server architecture. The client-server model provides the possibility of using many computer platforms, from small systems to large installations, and allows network configurations globally to share different spatial data and other resources. A client-server application typically stores large quantities of spatial data on an expensive, high-powered server, while most of the application program and user -interface activity is handled by client software running on relatively cheap personal computers. In this model a server(s), which resides somewhere on the network, enables clients (or workstations) to access and retrieve remote multi data, application software and, in some cases, more powerful computing resources (Coleman, 1999).

The industry has fashioned a number of broad client-server architectures that are currently known as *one-tier, two-tier, three-tier and N-tier* client-server architecture (N-Tier is four or more tiers). These models comprise several layers and have logical software partitioning, with each layer isolated and responsible for a separate task. The physical separation of those layers could be machine boundaries, process boundaries, or corporate boundaries, within a local or wide area network or the Internet (Roman, 1999).

5.3.2.1.1 One-Tier Architecture

In one-tier architecture, all the three layers, as shown in figure 5-5a, stay logically together. The one-tier client-server architecture provides access and user interface with main databases, using low-cost PCs and workstations. One computer provides the program logic and the data services.

5.3.2.1.2 Two-Tier Architecture

In two-tier architecture, an application is split into two tiers (front end and back end). In other word, the three layers are physically separated, as shown in figure 5-5b.

The first tier or the front-end tier includes the user interface; the second tier or the back end includes the data layer. The service layer is attached to either the front end or the back end (usually the front end, as shown in figure 5-5b). It is generally thought that the two-tier approach allows for rapid application development and offers good cross-platform portability (Amor, 2000).

5.3.2.1.3 Three-Tier Architecture

In three-tier architecture, the user interface layer, service layer and data layer are physically split into three respective physical tiers, with each layer isolated and running on its own machine, as shown in figure 5-5c. The three-tier client-server is considered a better architecture for large applications and implementations. It is generally considered to be more scaleable, reliable, extensible, maintainable and secure.

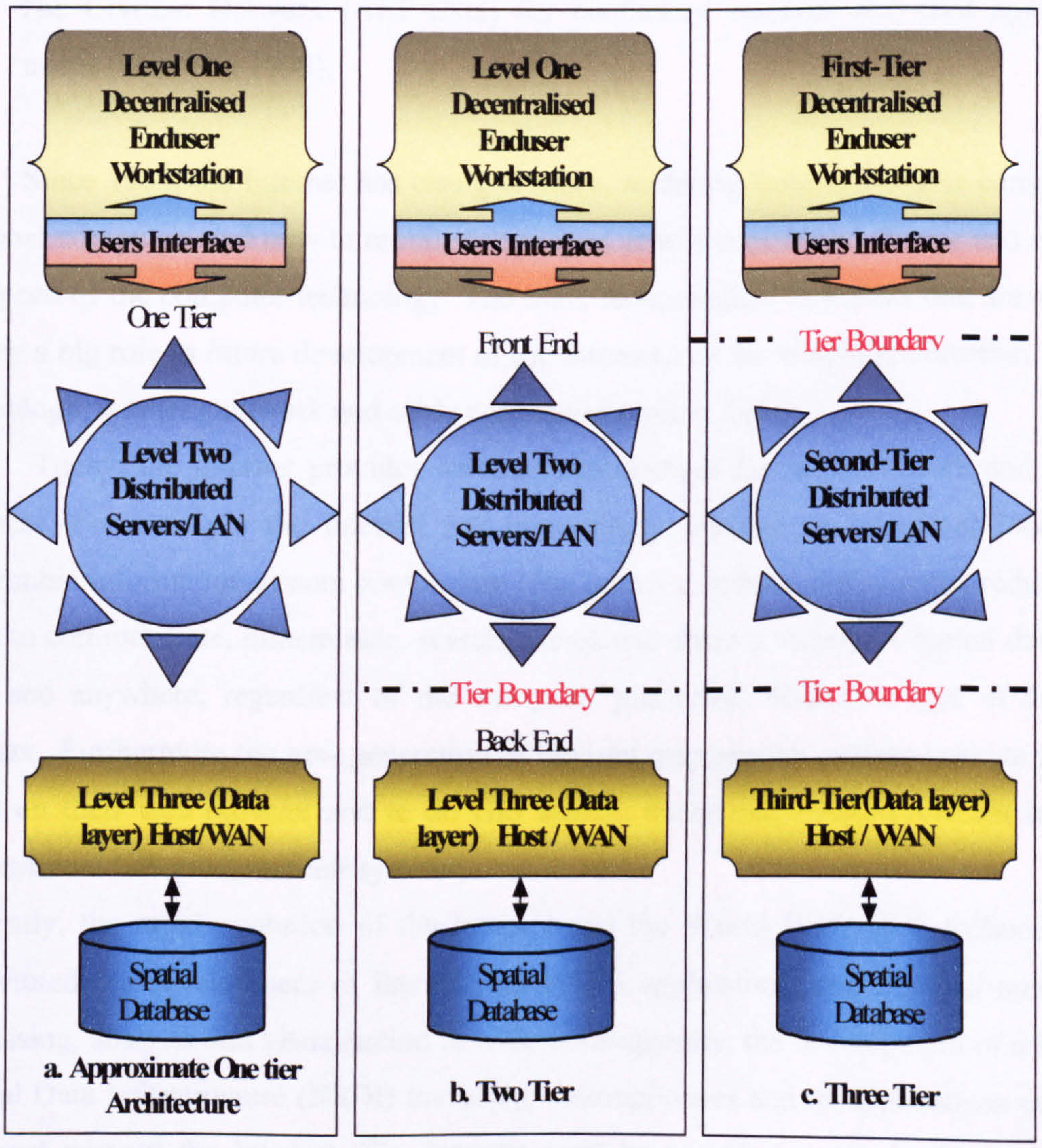


Figure 5-5 General concept of the three types of tiers architectures [Adapted from Coleman, 1999 and ESRI, 2000].

5.4 THE INTERNET

As a result of the activities of the U.S. Defence Advanced Research Projects Agency (DARPA), which started in the 1960s, a number of different distributed host computers were successfully linked in 1969, using the Advanced Research Projects Agency Network (ARPANet). Since then, computer networks have expanded and advanced. In 1972, a public demonstration of ARPANet was held and an electronic mail application was used. In 1980 TCP/IP was adopted as a defence standard and in 1983 the original ARPANet was split into two networks:

1. The Military Network (MILNet) used for military communications;
2. The Civilian Network (ARPANet) for continuing research and civil applications needs (Man-Ho, 1998).

Since 1983, the Internet has changed much, mutating from mainframe computers to personal computers and now to mobile telephones. It will continue to change and evolve at the speed of the computer technology. The main technological key areas that are expected to play a big role in future development of the Internet, are the telecommunication, satellite technology, wireless network and cable companies (Amor, 2000)

Today, the Internet provides services and changes the way we work and conduct business. For example the Internet has increasingly become an important tool in the geographic information system community. The Internet enables spatial data producers and users to communicate, disseminate, search, access and share a variety of spatial data at any time and anywhere, regardless of the computer platforms, distances, type of data, and formats. Furthermore the new generation of Internet map servers enables users to generate maps on their web browser and to do GIS search, query and analysis without installing conventional GIS tools on their systems.

Currently, the rapid evolution of the Internet and the World Wide Web technology has accelerated the development of Internet-based GIS applications and changed methods of processing, analysis and visualisation in GIS. Consequently, the development of a National Spatial Data Infrastructure (NSDI) including clearinghouses and its applications cannot be achieved without the Internet. The Internet must be regarded as the backbone and best means to link the spatial data community (Nebert, 1996).

5.4.1 What is The Internet and Who Owns It?

The Internet is an international network infrastructure consisting of many technologies, protocols, networks, services, a huge library of information, and interfaces. It does not belong to anyone in particular, although a very few organisations have an influence on Internet protocols, such as:

1. The Internet Engineering Task Force (IETF), an open international communities of companies, who research Internet standards and design and operate networks;
2. The Internet Engineering Steering Group (IESG), who manage the IETF technical activities and the Internet standards process (IETF, 2001);
3. The Internet SOCiety (ISOC), an organisation of experts on Internet policies and practices (ISOC, 2001);
4. The World Wide Web Consortium (W3C), a group (housed at MIT in Boston, USA) who developed HTTP, hypertext markup language (HTML), XML and other web standards built on the basic Internet standards (W3C, 2001).

The Internet networks are not connected directly to each other, but the Internet infrastructure uses backbones, which are information highways (high-speed connections) that connect separate network segments to each other, then connect sub networks (such as Modems, smart card, intranet, extranet and others) into the Internet network. The sub networks retain their own individual characteristics and the collections of the entire Internet networks appear as a single virtual network to the users (Amor, 2000).

The following four definitions best describe the Internet:

1. The Internet can be defined as "*an international network of dispersed local and regional computer networks used predominantly for sharing information and resources. Developed primarily for military and then academic use, it is now accessible through commercial on-line services to the general public*" (McDonnell and Kemp, 1995).

2. The Internet can be defined as "*a computer networking system that allows millions of computer users around the world to exchange information*" (Man-Ho, 1998).
3. The Internet is a "*network infrastructure, which consists of many networks that are built on certain standards, the Internet standards, which are used by all participants to connect to each other* " (Amor, 2000).
4. The National Coordination Office for Information Technology Research and Development (ITRD) agreed to the definition of the term "Internet" as follows;
"*Internet refers to the global information system that is:*

- *Logically linked together by a globally unique address space based on the Internet Protocol (IP) or its subsequent extensions;*
- *Able to support communications using the Transmission Control Protocol/Internet Protocol (TCP/IP) suite or its subsequent extensions and/or other IP-compatible protocols;*
- *Provides uses or makes accessible, either publicly or privately, high level services layered on the communications and related infrastructure described herein*" (ITRD, 2001).

From the above discussions and definitions, the Internet can be defined as computer systems inter-linked globally and logically to share and exchange information based on the Internet protocols and standards, especially the TCP/IP.

5.4.2 Internet Services

The following are some of the fundamental Internet services:

5.4.2.1 The World Wide Web

With the proliferation of World Wide Web site, there exist enormous stores of data all over the world. WWW is one of the most important services on the Internet. Searching the WWW for documents and data requires certain site information, such as names, addresses, and routes. A name specifies what an object is; an address specifies where it is; and a route indicates how to get there (path). An example is the Universal Resource

Locator (URL). The URL is a tool that localises a resource on the Internet. Most of the URL are in the form of http://www.xxx.yyy/zzz.nnn, where **http** is the type of protocol used for the connection, **www** is the name of the designated web server (even though there are many possible variations, it is standard practice to name the web server "www"), **xxx** is the name of the host or domain where the particular web page or information resides, **yyy** indicates the final suffix, known as the zone name, which shows the nature of the organisation, such as a company or commercial enterprise (.com) or organisation (.org) or government (.gov) or country (.uk), **zzz** is the directory path on the server and **.nnn** is the extension, for example .html, which indicates that the file is a hypertext markup language (Corfield et al., 1999). Besides WWW, there are other protocols that enable people to communicate via email such as post office protocol (POP), Simple Mail Transport Protocol (SMTP) and Internet Mail Access Protocol (IMAP); to chat online with Internet Relay Chat (IRC); and to participate in a news group with Network News Transport Protocol (NNTP). The success of WWW requires specific tools to handle and index this information so it can be easily accessed by users (Amor, 2000).

5.4.2.2 Electronic Mail (E-Mail)

Electronic mail is the first and most elementary service of the Internet, and for many users, the most useful service. One-can send/receive messages, text files, graphics, maps, spatial data, and so on. There are many email programs running on all kinds of computers and operating systems. All email programs are an implementation of the Simple Mail Transport Protocol (SMTP) and the Post Office Protocol (POP). The main components of electronic mail are:

1. A mail client-server, which can be set up for daily document exchange on the Internet. On the server side we can manage a database, define a command set and develop a program to automatically process this command set. For instance one can send a request for a document by using a predefined command set through the email, and a return email can be sent to the requester with a result based on the server-side search on the database.
2. A mail list server that has a database of one or several mail-list(s) containing all email addresses of members who have common interests in a certain field. They can

be connected to each other and can exchange their ideas about common fields of interest and provide comments on interesting issues (Man-Ho, 1998).

5.4.2.3 File Transfer Protocol

FTP enables any Internet user to move files from any web site to another one. Before the invention of the World Wide Web, FTP sites were very popular. FTP has limited functionality to get and to send files, but is fast and efficient for large data transfers such as graphic, video, and sound files. The transfer of GIS datasets often requires some compression mechanism due to the inherently large size of many GIS spatial data sets, especially raster data (Man-Ho, 1998).

5.4.2.4 The Telnet Protocol

The Telnet protocol stands for Telecommunications Network protocol, which provides a way for users to connect to multi computers or servers on the Internet. Telnet is a terminal-oriented remote log-in service that allows an end user to log into another remote computer by giving commands and instructions interactively to that computer, thus creating an interactive connection, where the local system becomes transparent to the user, who thinks that he is connected directly to the remote computer. The commands typed by the user are transmitted directly to the remote machine and the response from the remote machine is displayed on the user's monitor screen. Currently, end-users rarely use this service, because most sites are open to the public and most applications provide remote log in functions. However Telnet is largely supported by http. According to RAD data communication, Inc., Telnet is composed of three main principles:

1. Network Virtual Terminal (NVT), which is a device used by Telnet to enable a local computer to communicate with a remote machine.
2. The concept of negotiations, which is a mechanism that allows the user to set terminal parameters to values other than the default or to negotiate more sophisticated facilities.
3. A symmetrical view of terminals and processes that allows either the client or server to request a particular option as required, thus optimising the service provided by the other party.

Figure 5-6 illustrates the path of data in a Telnet remote terminal session as it is transmitted from the user's keyboard to the remote operating system. Adding a Telnet server to a timesharing system usually necessitates modifying the operating system (RAD, 2001).

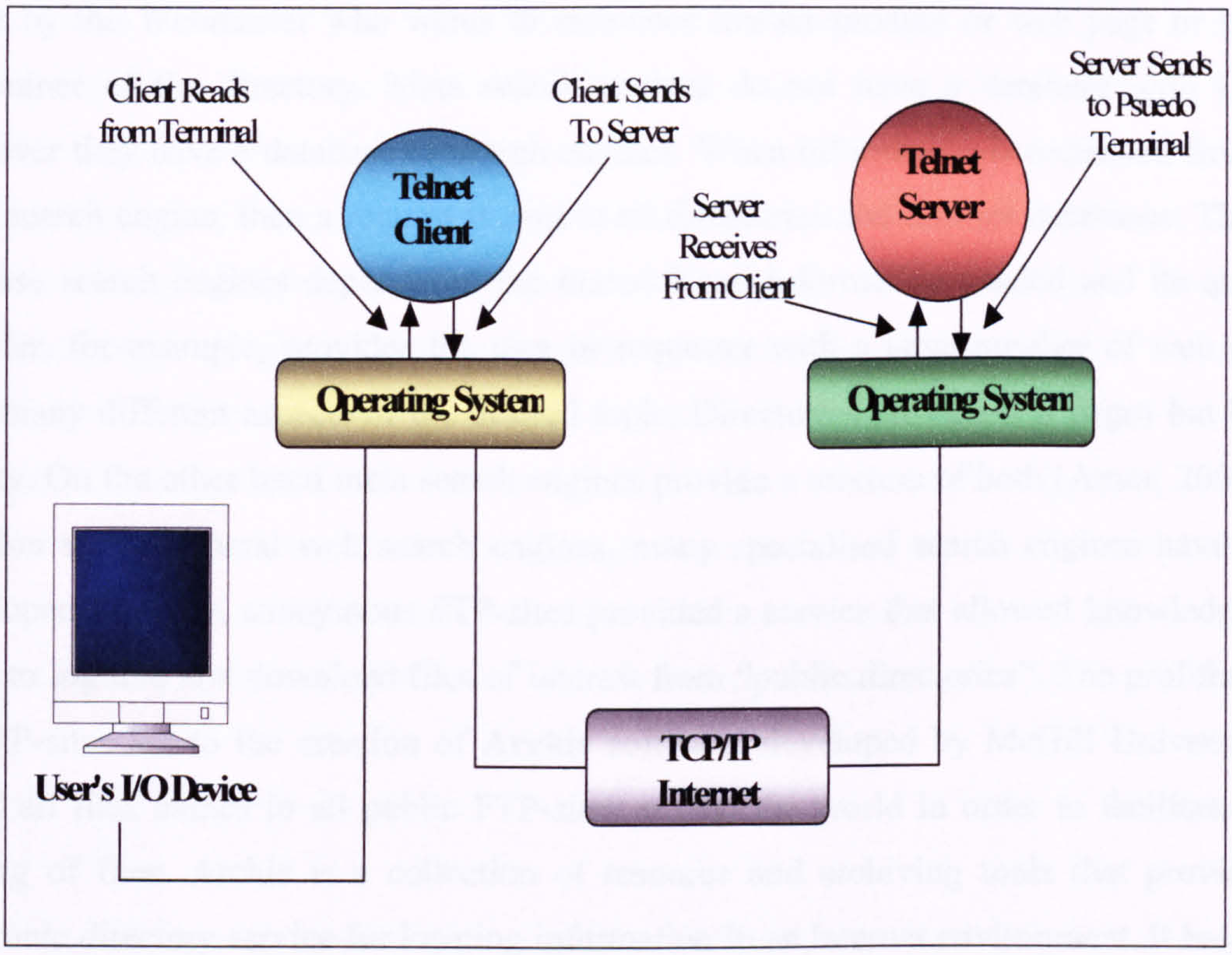


Figure 5-6 Telnet architecture [Source RAD, 2001].

5.4.2.5 Information Searching

Using the web browser to search the Internet for information is usually done by sending search criteria to the remote servers and databases, then the search results are sent back to the user. Some users just enter a keyword or abbreviation, and then the browser adds "http://" to the keyword and tries to find a web page. If nothing is found then it adds ".com" at the end and then "www" to be come http://www.keyword.com. Sometimes this process leads to correct web sites and good results, but sometimes it does not. This depends on what country the information resides in. For example, American companies often use ".com", and others may use it, but for instance companies in France use ".fr" instead.

Several different search engines and services have been developed over the past 10 years, for example, crawler, directories and meta search engines. Crawler was first created in 1993. It "crawled" from one web site to another and indexed everything it found by saving the contents of each web site into a huge database with URL, which users could query. The web directories contain a structured tree of information, which are entered either by the Webmaster who wants to announce his/her product or web page or by the maintainer of the directory. Meta search engines do not have a database with URLs. However they have a database of search engines. When information is requested from the meta search engine, then a request is sent to all directories and crawler databases. The use of these search engines depends on the material and information needed and its quality. Crawler, for example, provides the user or requester with a large number of web pages with many different aspects of the desired topic. Directories provide few pages but better quality. On the other hand meta search engines provide a mixture of both (Amor, 2000). In addition to the general web search engines, many specialised search engines have been developed. Initially, anonymous FTP-sites provided a service that allowed knowledgeable users to log into and download files of interest from "public directories". The proliferation of FTP-sites led to the creation of **Archie** software, developed by McGill University to index all files names in all public FTP-sites around the world in order to facilitate easy finding of files. Archie is a collection of resource and archiving tools that provide an electronic directory service for locating information in an Internet environment. It has been expanded to include the World Wide Web directories and resource listings, but does not provide any content-based searching.

In the meantime another program named **Gopher** was developed at the University of Minnesota as an Internet protocol for presenting menus of downloadable data. While Archie manages downloadable files in a database, Gopher manages files, documents and services on the Internet in a hierarchical menu system (Man-Ho, 1998).

Specialised search engines are good tools to find personal information, postal addresses, telephone numbers and emails. However, searching the Internet for information is still difficult for many users. Searching by keywords is the most common method of using search engines. However, a keyword may have more than one meaning, which could result in a huge volume of imprecise information. The method of browsing, on the other hand, takes a long time to find the relevant information. Directories such as Yahoo are trying to overcome these problems, but new paradigms of searching are needed, as well as software and tools, which are able to categorise web sites automatically. Today, most of the search engines come from the United States and focus on American English and culture. Therefore more multi-lingual and multi-cultural search engines, such as Altavista, Lycos, Google and EuroSearch, which present search results in several languages, are needed. Also search engines are very specific and cannot cope with multi database formats and file types. For example, text documents that are in special formats (such as postscript or Star office documents) are unreachable for many search engines. The same applies to scanned information and textural information from images and scanned maps. Therefore, there is a need to improve information searching mechanisms, to include different formats of text, documents, images, sounds and all other formats. It is necessary not only to improve the search engine technology, but also to improve the user interface. The use of natural language to access a database is needed, for example "Where can I buy a road map of Spain?" or " What are the digital maps that cover Kabul city (Afghanistan)?" or "How many spatial data web sites are there in the UK?" The answers to these types of questions can be found on the web, but the search engines are not able presently to understand the question. Also, the use of neural networks in the future may help to organise large, unstructured collections of information and allow more in-depth search (Amor, 2000).

5.5 INTERNET-BASED GIS

The Internet-based GIS, according to Peng (1997) is simply a network-centric GIS tool that uses the Internet as a major means to access, store and transmit spatial data and in some cases to conduct analysis and visualisation (Peng, 1997). There is little doubt that the success of national and international spatial data infrastructures is based on the success of the Internet technologies. Several attempts and activities have been undertaken to implement and deploy GIS services on the Internet, to enable a wide number of users to access and share spatial data and accelerate the adoption of Internet technology in the GIS field.

5.5.1 Internet Services for GIS

In general, Internet services for GIS can be grouped into five categories.

5.5.1.1 Raw Data Download

Spatial and non-spatial data can be transmitted from one computer or server to another using the Internet FTP, as can any other data file delivery service on the Internet. Spatial data is treated in a packaged form, such as ArcInfo export format, or a reformatted form, which is compliant to some national or international transfer standard such as the U.S. Spatial Data Transfer Standard (SDTS). A user who needs a raw dataset will first contact the search engine. The search services will provide the user with the necessary information about the availability of the data, the location of the data, the provider, the cost (if any)... etc. This service can only succeed when the client has the same GIS software installed, as shown in figure 5-7, as for the data set, and where there exists an efficient and organised metadata service, such as a clearinghouse. An exception could be the growing use of translators that allow GIS access to non-native format (Man-Ho, 1998).

5.5.1.2 Metadata Search

The GIS metadata search mechanism is a typical Internet search engine. However, it requires specific metadata content for spatial data sets, as discussed in chapter 3. The best example of the Internet metadata search service is the United States of America National Spatial Data Clearinghouse (NSDC) metadata managed by the Federal Geographic Data Committee (FGDC). The metadata mainly requires a text search capability, but allows a spatial query mechanism as well (FGDC, 2000). Another good and customer friendly metadata search service example is the AskGIraffe data locator in the United Kingdom (the National Geospatial Data Framework), which will be discussed in chapter 6.

5.5.1.3 Map and Image Display

There are a great number of different graphic formats used in hundreds of different programs, due to the lack of a single accepted standard in computer graphic field. Among those graphic formats, initially web browsers supported Raster Graphic Formats (RGF); Graphics Interchange Format (GIF) and Joint Photographic Experts Group (JPEG). GIF, developed by CompuServe, is designed primarily for on-line transmission and interchange of raster data, rather than as storage format for a file. JPEG format was developed to facilitate compression of large images with a high colour depth. The current technical trends for map and Images display are towards the visualisation of vector maps and the conversion of proprietary raster graphic format into Portable Natural Graphic (PNG) or JPEG format. Currently, several technologies have emerged to allow other types of graphic formats to be visualised on the web browser. Man-Ho (1998) categorised map display into three types as follows:

5.5.1.3.1 Static Map Display

This is the simplest mechanism that the Internet usually offers to the client, because this service uses pre-defined, pre-generated, and ready to display graphic files. All the server needs to do is to link the proprietary GIS graphic to web pages using HTML tags and their own identifiers (name of map file and its path) and put the image on the web server. GIS servers can also generate static PNG or JPEG map files using the snapshot technique to capture the graphic views generated from GIS tools displayed on the (possibly virtual) screen (Man-Ho, 1998).

5.5.1.3.2 Dynamic Map Browser

A dynamic map display service generates a fresh map on the fly based on the user's request. This service requires a GIS server component that can interact with GIS software installed on the server side. Based on the user's map production parameters such as theme, scale, feature colour and so on, GIS software draws a new map on the server machine, converts it into raster format such as GIF, JPEG, or into vector format such as Simplified Vector Format (SVF) or the more modern structured format for carrying graphics information, such as Scalable Vector Graphics (SVG), developed by the World Wide Web Consortium (W3C, 2001).

5.5.1.3.3 Image Display

Satellite Images provide a valuable source of data for map making and geographic information systems. Multispectral images are available in digital form on the web, and can be easily accessed, corrected (geometrically and systematically), enhanced, classified, analysed, and displayed. Internet real-time maps can be generated on the fly from remotely sensed data with the help of computer techniques. Also remote sensing data can be classified and overlaid on topographic maps using Internet-based GIS (Mather, 1999).

5.5.1.4 Web-Based Spatial Query and Analysis

Web-based spatial query and analysis is the most advanced Internet-based GIS service, which provides most GIS functions such as attribute queries, spatial queries, buffers, overlays, classification, and map display. Using an interface such as HTML forms or Java applets, users can interact with the server side database. However, more work is still required to provide all the necessary GIS functionality and perform more advanced applications on the Internet (OGC, 2001b).

5.5.1.5 Building and Requesting GIS

There are several ways to build a GIS on the Internet; most of them following the client-server model, discussed in more detal in section 5.3.2.

Figure 5-7 show a the typical system architecture for an Internet-based GIS. The Internet-based GIS requires specific software, which can interact with a GIS tool running on the server side. When a client makes a request for a map or spatial data, the request is sent over the Internet to the remote GIS server. The server interprets the request, and translates it into the internal code (query syntax or command with parameters) and invokes GIS service module functions by passing the message. GIS service modules control the GIS software to process the query or map production based on pre-defined procedures (Pleuwe, 1997).

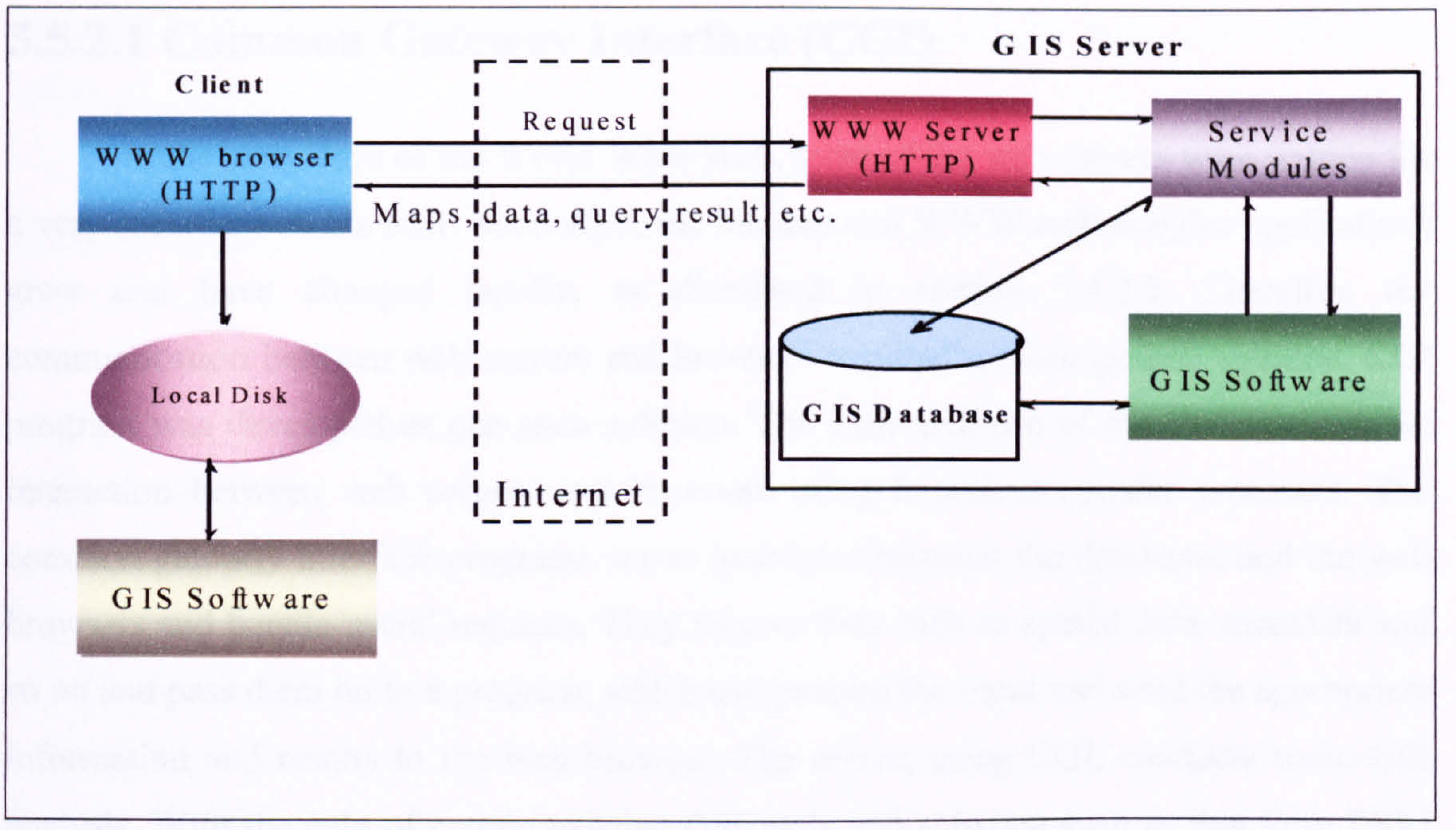


Figure 5-7 Typical system architecture for internet-based GIS [Adapted from Pleuwe, 1997].

5.5.2 Technologies Supporting Internet-Based GIS

The development of Internet-based geographic information system applications involves an integration of a HTTP server with geographic information system needs, using a Common Gateway Interface (CGI) by extending the browser functionality to support new data types and develop a cross-platform application using a mobile code system. There has been a growing integration of HTTP servers legacy systems, the Common Gateway Interface (CGI) and the server Application-Programming Interface (API). In order to enable GIS output to be visualised on a web browser, several technologies were also developed such as GIS plug-ins, GIS helper programs, and Active X. Java has been developed to provide client side processing and to provide more interactivity for the client. The World Wide Web consortium performed an evaluation of the current status of Java and their characteristics. Java is currently regarded as the most successful mobile code system (W3C, 2001).

The tools and technologies mentioned above, such as CGI, API, GIS Plug-in, GIS helper programs, Microsoft Active X, Java, OGC and other GIS commercial tools are discussed briefly as follows:

5.5.2.1 Common Gateway Interface (CGI)

In the early days of the World Wide Web, most of the web servers were written for a very specific web browser. Soon after, the Internet and WWW technologies applications grew and have changed rapidly, as discussed in section 5.4.2.5. Therefore the communication between web servers and browsers required a more general solution. CGI program was developed as one such solution. The main purpose of the CGI is to enable interaction between web servers and browsers using hypertext transfer protocols. The common gateway interface programs act as interfaces between the databases and the web browsers and handle users' requests. They receive data such as spatial data, metadata and so on and pass them on to a program, which can process the input and send the appropriate information and results to the web browser. The server, using CGI, conducts some GIS analysis. With the help of certain existing GIS tools and software such as that form ESRI and Intergraph (discussed later in this chapter) a full functionality can be achieved.

The CGI mechanism is quite easy to implement using almost all programming languages such as C, C++, Perl, Python, Java and so on. CGI is regarded as a *de facto* standard (Amor, 2000). However the CGI has some significant disadvantages concerning performance and functionality. Every interaction between the client and the server requires tedious routine workflow, the common gateway interface process, for execution of application, processing the request and translation of results (Man-Ho, 1998). It results in an excessive load for the server system and traffic on the Internet, especially in the case of simultaneous requests from multiple-users using slow modems. Providing interactivity to the user requires a lot of programming and coding effort for handling the many different customised pieces of a large and complex web site (Apostolopoulos et al., 2000).

5.5.2.2 Application Programming Interface (API)

In the client-server model, the client application usually communicates with the host or data layer through a database bridge. This database bridge or driver is called the API; it was developed for specific servers to overcome the performance and functionality drawbacks of the CGI. It works with different relational and object oriented databases, such as Open Database Connectivity (ODBC) and Java Database Connectivity (JDBC). The API includes most of the functions, that usually take place between the user's request and reply. The server API is five times faster than CGI. The disadvantage of it is the difficulty of building several APIs for each platform, for different web servers (Man-Ho, 1998).

5.5.2.3 GIS Plug-ins

Plug-ins are small applications, which add functionality to commercial applications, such as the Netscape browser or PhotoShop. Plug-ins can be installed in the web browser to extend its capability and functionality to support seamlessly spatial data access and to interact with other browsers, web pages and to support new data formats. Plug-ins enable users to interact with spatial data from their own web browser without installing traditional GIS tools. Some simple functionality such as zoom, pan and query can be built in plug-ins and performed locally. Visualisation of graphic data such as vector formats; 3D, Virtual Reality Modelling Language (VRML) and video, requires a specific plug-in for each format. For example, scalable vector graphics requires special plug-ins for visualisation. Implementation of VRML is usually by use of Cortona (Parallelgraphics) or CosmoPlayer (Sun Microsystems). The simplified vector format requires specific visualisation tools such as Vdraft Internet tools for SVF, AutoCAD drawing and DXF format (Amor, 2000).

Nowadays, even though most browsers support plug-ins, the Java and Active X solutions are overtaking the plug-in market, especially in the case of XML becoming the new basis for documents on the Internet (Eckstein, 1999). However, it will take some years before browsers do not require plug-ins. A new world standard for mobile phones, Wireless Markup Language (WML), which is similar to XML, was recently developed that may be more quickly effective (Kottman, 1999).

5.5.2.4 GIS Helper Programs

Helper programs are large applications software located in the user's local machine's GIS software. For example, ESRI ArcView can acts as a GIS helper program. When the web browser detects a spatial data type in an HTML page, it will automatically launch the appropriate GIS helper program and enable it to function locally.

The drawbacks of both plug-ins and helper programs are:

1. Both GIS plug-ins and GIS helper are platform dependent. Therefore, various types of plug-ins and helper programs need to be developed for different platforms.
2. Web users have to download various geographic information system plug-ins in order to manipulate different spatial data on the web. Since several geographic information system tools result in different data format visualisation of each data format requires its own specific plug-in.
3. Installation of various plug-ins occupies considerable space on the local machine.
4. If the user does not have helper programs, he/she cannot manipulate the data. These helper programs are quite big and expensive for general public users.

Fully functional platform independent GIS plug-in and GIS helper mechanisms are not yet available, but Java and Active X technology will soon make this possible (Man-Ho, 1998).

5.5.2.5 Microsoft Active X

Active X software is an Internet tool developed by Microsoft for including applications in HTML pages. Active X is used to create GIS controls and is built using the Object Linking and Embedding (OLE) standard to provide a common framework for extending the capability of Microsoft's web browser and Internet Explorer. Active X controls are components (or objects), which are embedded into a web page or other application to reuse packaged functionality to activate the Internet. If these objects are stored on the user's machine, the web browser can perform a designated function. If the user does not have those Active control components, the web browser will try to install those objects from another web site. Typical examples of GIS Controls are the MapObjects developed by ESRI, and GeoMedia developed by Intergraph (Korte, 2001).

5.5.2.6 Java

Sun Corporation developed the Java programming language and defined it as "*a simple, object-oriented, distributed, interpreted, robust, portable, high-performance, multi-threaded and secure architecture*" (Roman, 1999). Java has been used as a major tool for the implementation of interactive Graphic User Interface (GUI) and clearinghouse server modules; the graphic user interface allows users to search spatial databases and other datasets. Java is a successful technology tool that originated as a cross-platform development language, and has wide industry support. Java is an interpreted Object Oriented Programming Language (OOPL). It is a hardware independent language that runs on all major platforms. Java can embed executable code in a web page or a web server, which introduces the possibility of the development of a vast range of applications and transmission capabilities across a network executed on different platforms. It has powerful features of portability and safety and provides more interactivity to the web pages by allowing client side processing (W3C, 2001). Java has a number of component engines, such as enterprise beans, applets and servlets. Applets are portable Java programs that can be embedded (deployed) in a web page and servlets are request/response-oriented network components that can be used to increase the capability and functionality of a web server. Enterprise beans can be embedded in application servers. Java can run on a variety of computer platforms and operating systems by using the help of a unique standardised hypothetical computer, called the Java Virtual Machine (JVM), which is emulated inside the computer by a system specific program (Roman, 1999).

Finally, the CGI, API, Plug-ins, helper program, Active X control and Java technology can generally be used together depending on the purpose of the system and its application. Among those technologies, probably Active X and Java technology have more powerful features than others.

5.5.2.7 The OpenGIS Consortium (OGC)

Even with all the tools and technologies discussed above, there are still numerous non-interoperability spatial data because of issues discussed in chapter 2, which can be summarised as follows:

1. Issues related to data structures, geometry modelling and other matters of syntax. These are mostly proprietary problems due to different GIS vendors' use of different internal structures to define the basic geometry of geographic features.
2. Issues related to the Universe of Discourse (UoD); that is, on issues of semantics.
3. Issues related to the sharing process (Kottman, 1999).

These issues are regarded as serious obstacles in the field of Internet use of geographic information systems and spatial data. To solve this problem, many spatial data users, vendors, integrators, distributors, producers, as well as telecommunications, universities, government agencies, industries and others are joining the OpenGIS Consortium (OGC) membership to share potential solutions to interoperability of data. In this field, OGC initiated the OpenGIS project to provide a comprehensive suite of open interface specifications that enable developers to write interoperating components that provide transparent access to heterogeneous spatial data in a networked environment (OGC, 2001a).

The conceptual model in figure 5-8 reflects the broad coverage of the OGC activities.

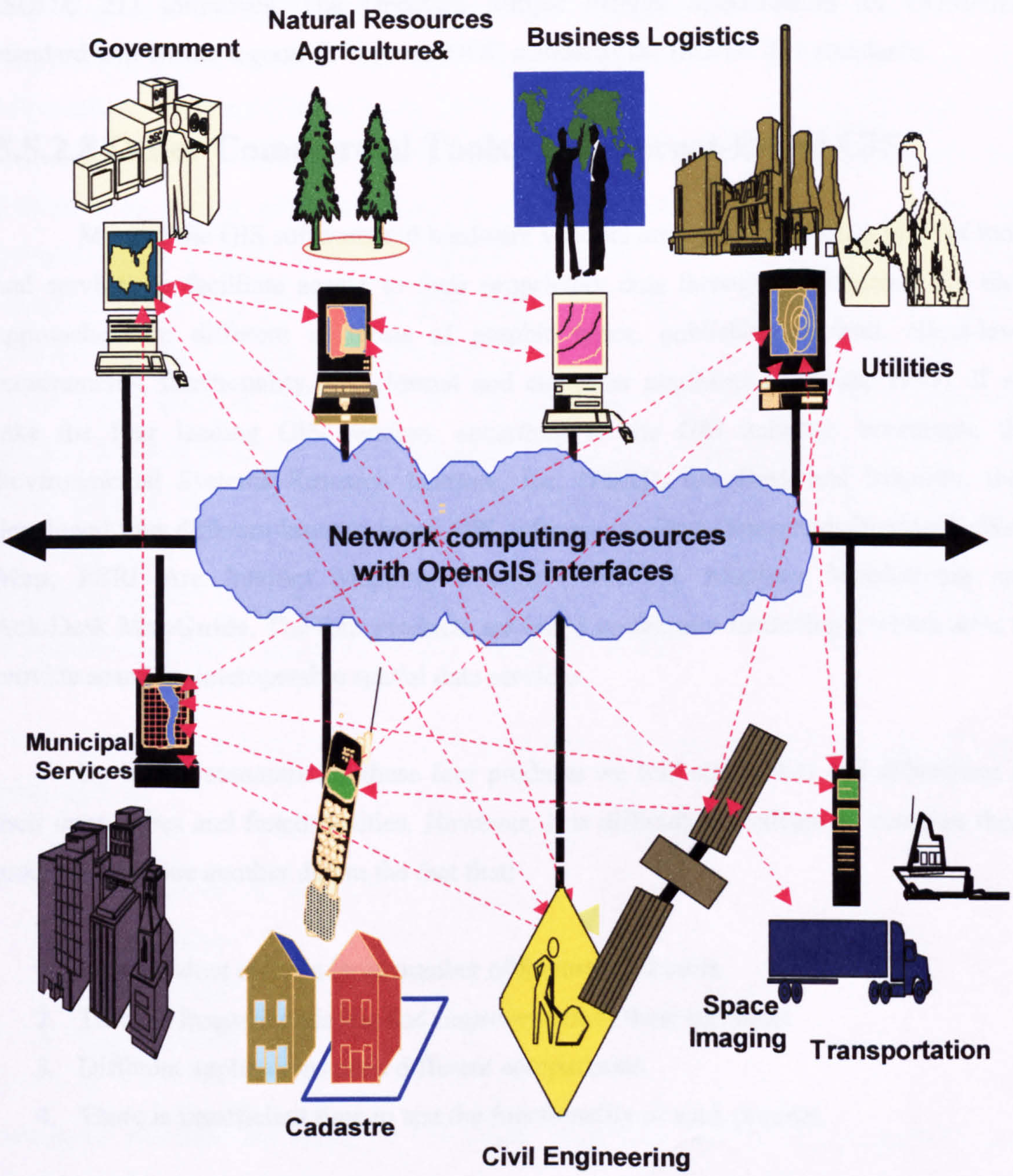


Figure 5-8 OpenGIS Consortium (OGC) vision for spatial data connectivity [Source Kottman, 1999].

The OpenGIS Simple Features Specification is a standard that supports storage, retrieval, query and update of simple spatial features and ensures control over interoperability, to help the producers of general open GIS and to allow interoperability between multi GIS vendors and users throughout the Internet. By using the OpenGIS Simple Feature Specification and Java development tools, any spatial data generated by specific GIS tools can be converted into a standard format.

Nowadays OGC works closely with the ISO/TC 211, see chapter 3 section 3.3.2.1.1 for ISO/TC 211 initiatives. The OpenGIS Simple Feature Specification for COM/OLE standard will ensure a good fit between OGC standards the ISO/TC 211 standards.

5.5.2.8 Other Commercial Tools For Internet-Based GIS

Most of the GIS software and hardware vendors are trying to develop Internet tools and services to facilitate access to their proprietary data through the Internet, but their approaches are different in terms of graphic types, publishing method, client-level requirements, functionality, data format and computer platforms (Radwan, 1999). If we take the four leading GIS vendors, according to the GIS industry: Intergraph, the Environmental Systems Research Institute, Inc. (ESRI), AutoDesk and MapInfo, they developed four different Internet-based GIS software products (Intergraph GeoMedia **Web Map**, ESRI Arc Internet Mapping System (**ArcIMS**), MapInfo **MapXtreme** and AutoDesk **MapGuide**. The four products are based on the new technology, which aims to provide seamless interoperable spatial data services.

By briefly summarising these four products we find similarities and differences in their approaches and functionalities. However, it is difficult to evaluate or compare these products with one another due to the fact that:

1. Each product offers a large number of features and tools.
2. There is frequent updating and improvement of these products.
3. Different applications need different comparisons.
4. There is insufficient time to test the functionality of each product.

However, the following brief discussion highlights some of the similarities and differences between the four products:

5.5.2.8.1 Intergraph

Intergraph GeoMedia Web Map is Microsoft Windows-based technology that enables visualisation, publishing, analysis and distribution of spatial data from multi sources over the Internet (Korte, 2001). It supports real-time links to spatial data clearinghouses with a simple interface that allows the users to navigate through large quantities of multiple spatial data in different formats (Intergraph, 2000). The GeoMedia Web Map reads MGE, FRAME, MGEDM, without translation or conversions as well as Microstation DGN, ArcInfo, ArcView, Field View, MapInfo, AutoCAD, Oracle and Microsoft Access data (Global Link, 1997). GeoMedia uses standard web browser tools, such as Microsoft Internet Explorer or Netscape Navigator to access spatial data. It gives flexibility to receive and create web mapping application facilities and provide data integration into a single client environment. GeoMedia Web Map allows users to build OpenGIS Consortium (OGC) compliant servers. For data storage, the user can choose between Microsoft Access, Microsoft SQL Server, or Oracle objects, depending on the size of the spatial database. GeoMedia web map offers command development using familiar, industry standard tools to build user applications in a way similar to Windows applications, in an effort to reduce the learning curve for new users who are already familiar with Microsoft applications, such as Word and Excel. Users choose the preferred language and programming environment based on their application requirements and current knowledge of industry-accepted programming tools (Intergraph, 2001b).

According to Intergraph (2001b), users work with standard Windows development tools, such as:

1. Visual Basic and Visual C++
2. PowerBuilder
3. Delphi, Excel, FoxPro
4. Access/Oracle Spatial

Intergraph extended the ability of GeoMedia Web Map browser and introduced other products, such as GeoMedia Professional and GeoMedia WebEnterprise. However, the objects are the same across the entire product line (Intergraph, 2001a). Figure 5-9 shows a rather simple view of the GeoMedia Web mapping process.

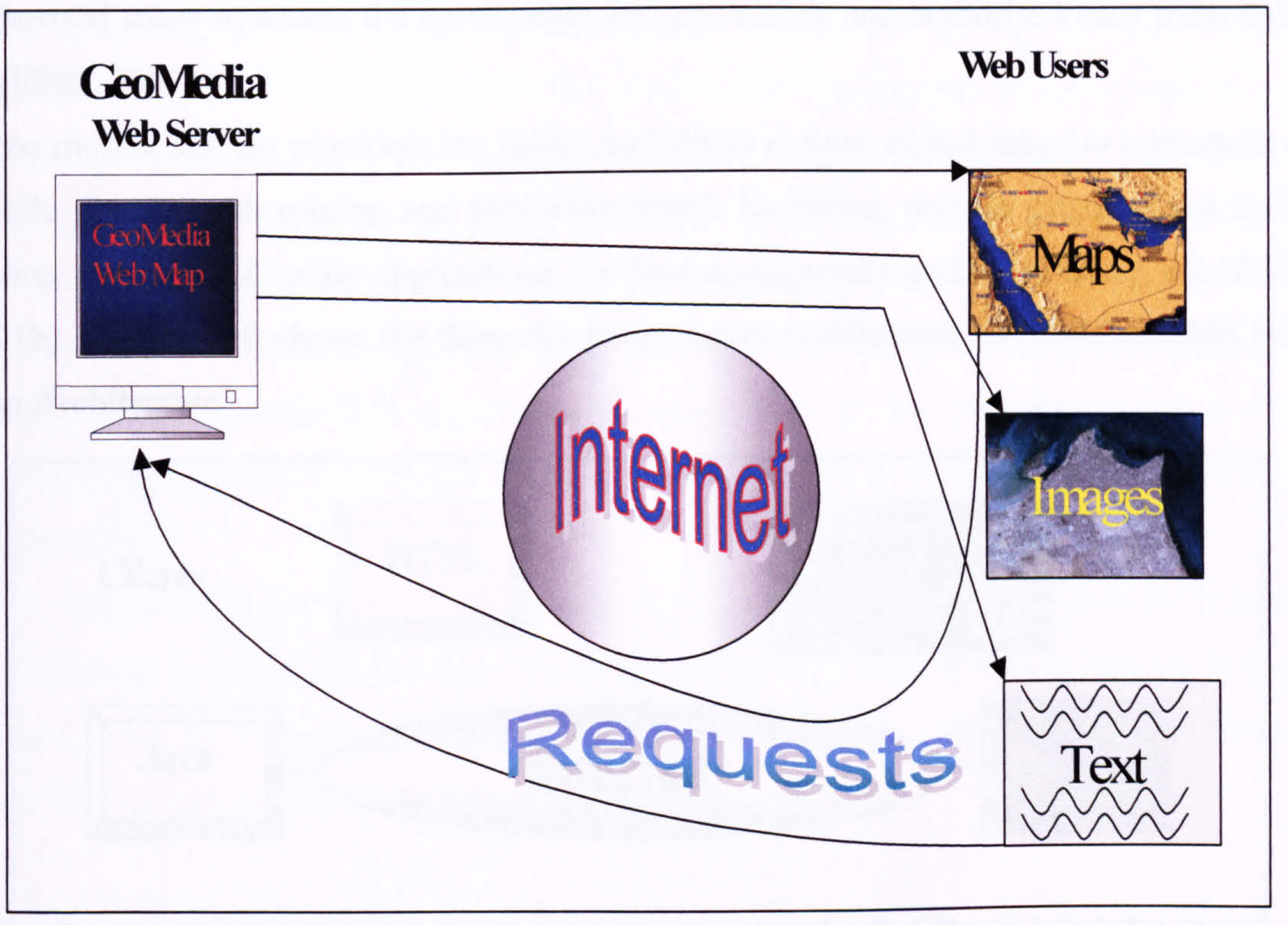


Figure 5-9 GeoMedia web map architecture [Adapted from Intergraph, 2000].

5.5.2.8.2 ESRI

The Environmental Systems Research Institute, Inc. (ESRI) developed the Arc Internet Mapping System (ArcIMS). ArcIMS is a framework that provides a common platform for the storage, exchange, real-time integration, analysis and distribution of web-enabled topologically structured spatial data and services over the Internet in a distributed environment that consists of both users and producers. ArcIMS forms the backbone of the ESRI Network (geography network) and provides data and services to the ESRI's ArcGIS system, which is a new comprehensive and integrated GIS solution (ESRI, 2000). The ArcIMS browser-based viewer and stand-alone ArcExplorer viewer offer tools for accessing and querying spatial and related non-spatial data and perform analysis. ArcIMS users can build custom Visual Basic and Visual C++ applications that use ArcIMS services (Korte, 2001).

ESRI recently developed a GIS extension to the standard XML, named ArcXML. ArcXML is a communication tool that offers a powerful way to customise ArcIMS applications. In addition, ArcIMS provides secure access to spatial data and services by controlling the security of certain web sites and performing user authentication, allowing authorised users to access the spatial data and preventing non-authorised uses from doing so (ESRI, 2001a).

Some mobile service providers are using ArcIMS to deliver digital maps to customers on mobile phones with routing and proximity search functions, provide personalised traffic reports and alerts, develop applications for fleet management and dispatching, etc (ESRI, 2001b). Figure 5-10 shows the three-tier client server architecture for ESRI ArcIMS Web Map Architecture.

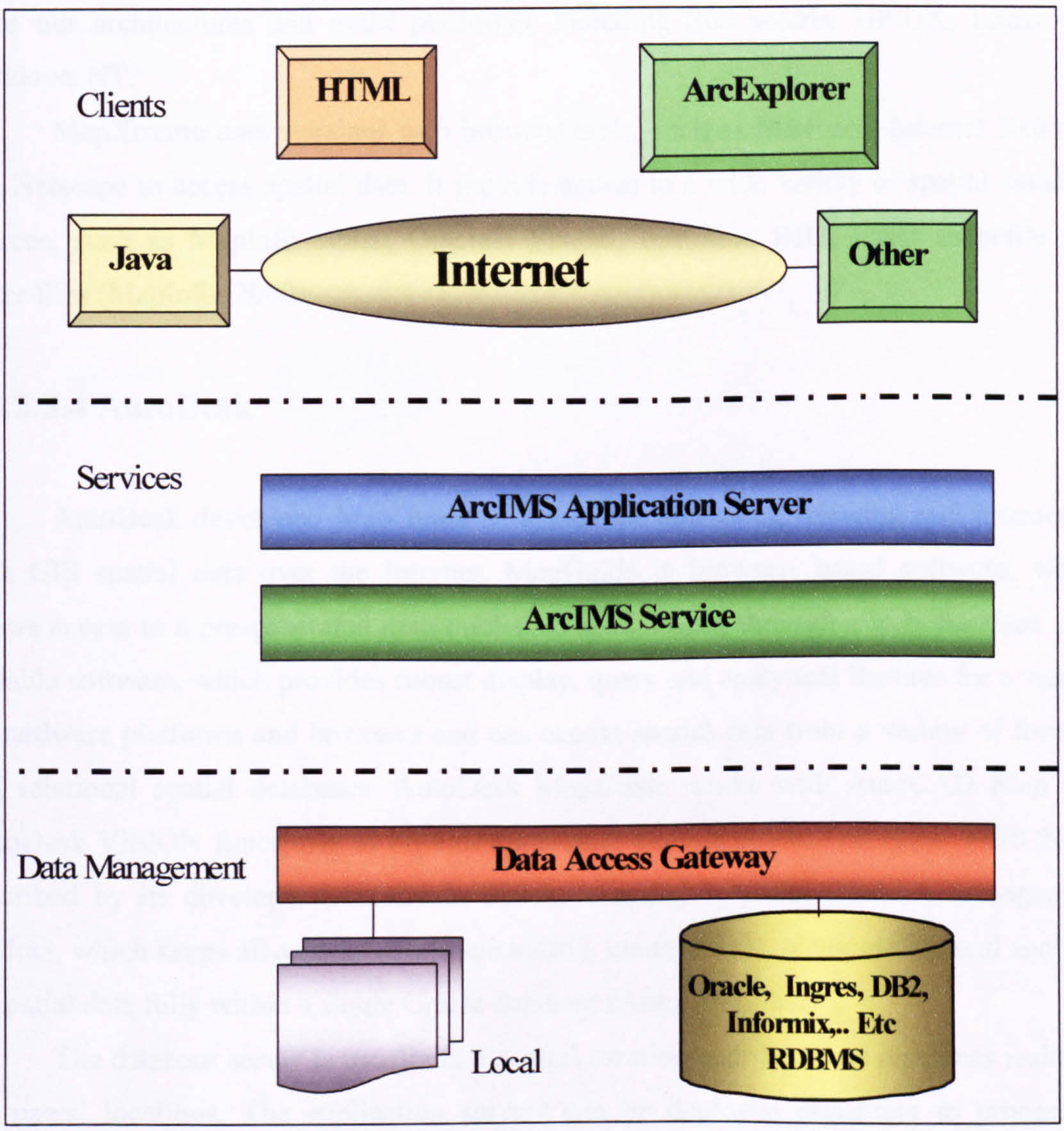


Figure 5-10 ArcIMS web map architecture [Adapted from ESRI, 2000].

5.5.2.8.3 MapInfo

MapXtreme is a 100% Java mapping application server for the Internet. MapXtreme provides a comprehensive list of powerful mapping functionality, such as map viewing, manipulation, thematic mapping functions, buffering, object (map) editing, draw layer, find, display, layer control, spatial selections, geocoding, extensive data base binding and sample data (MapInfo, 2001). It enables spatial data visualisation to discover new relationships and trends not apparent when viewing data using other tools. MapXtreme is scalable and compatible with major web and application servers and supports two tier and three tier architectures and multi platforms, including Sun solaris, HP/UX, Linux and Windows NT.

MapXtreme uses standard web browser tools, such as Microsoft Internet Explorer and Netscape to access spatial data. It provide access to a wide variety of spatial database sources, such as MapInfo tables, Oracle8i Spatial, Informix, DB2, ESRI shapefile and raster files (MapInfo, 2000).

5.5.2.8.4 AutoDesk

AutoDesk developed MapGuide as a tool for delivering, viewing and interacting with GIS spatial data over the Internet. MapGuide is browser- based software, which allows access to a pre-generated map published spatial data, through a web interface. It is scalable software, which provides robust display, query and analytical features for a variety of hardware platforms and browsers and can access spatial data from a variety of formats and relational spatial databases. AutoDesk MapGuide works with AutoCAD Map and AutoDesk VISION Enterprise to provide functional and operational services. VISION, as described by its developer (AutoDesk, 2000), is a major spatial database management product, which keeps all aspects of administration, management, manipulation and analysis of spatial data fully within a single Oracle database (AutoDesk, 2001).

The database server is usually in a central location and the client machines reside at the users' locations. The application servers can be deployed according to processing requirements and the size of the application. For organisations with large applications, a local application server is needed to process large complex transactions, but for small departments, which are spread over a province or state, a smaller number of servers at different locations are adequate (AutoDesk, 2000). Figure 5-11 shows the AutoDesk three-tier client server architecture.

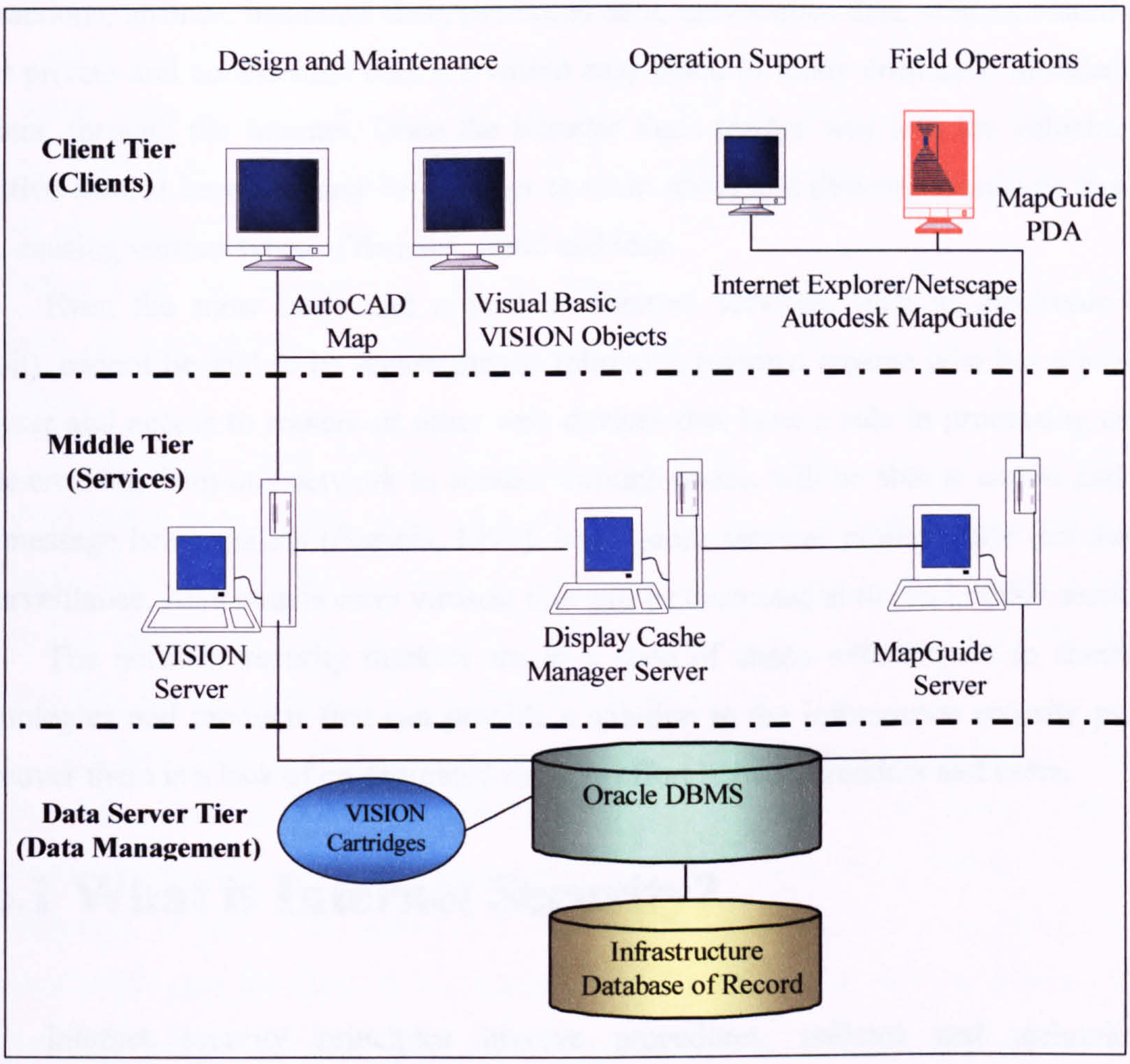


Figure 5-11 AutoDesk three-tier client server architecture [Source AutoDesk, 2000].

5.6 INTERNET SECURITY

The increasing demand for the use of the Internet raised awareness of the security problem for many people who had not recognised the real risk posed by the security challenges of the Internet. Communication and data transmission over the Internet is by default open and uncontrolled and within the reach of many intruders, hackers and criminals. Questions of confidentiality, integrity, availability, legitimate use and non-repudiation (validity) are serious problems of the Internet, if better security measures are not implemented (Amor, 2000). Many vendors, and sometimes users, claim that a system or network is secure. Unfortunately this is not true. We should ask such people, secure from whom and against what? (Schneier, 2000).

Internet security is a complex issue and growing a problem, with security hazards and challenges to many users. Every day, huge amounts of confidential spatial data, bank transactions, airlines, insurance data, personnel data, universities data, student records and other private and confidential data are within easy reach of many criminals, intruders and hackers, through the Internet. Once the intruder finds his/her way into the valuable and sensitive data, it becomes easy for him/her to roam about and destroy, change or steal the data, causing various types of damage, fraud and loss.

Even the most basic and ubiquitous Internet services, such as electronic mail (email), cannot be said to be secure for the following reasons: anyone who has a protocol analyser and access to routers or other web devices that have a role in processing emails while crossing from one network to another through nodes, will be able to access and read any message being mailed (Brosais, 1997). Intelligence services probably use this method of surveillance. Also emails carry viruses; this will be discussed at the end of this section.

The network security markets are in a state of chaos with respect to standards, technologies and products that can provide a solution to the information security puzzle. Moreover there is a lack of co-ordinated security effort between vendors and users.

5.6.1 What is Internet Security?

Internet security principles involve procedures, policies and technologies (hardware and software) needed to control and prevent unauthorised access to digital data. Security has the five major components, of confidentiality, integrity, availability, legitimate use and non-repudiation. The confidentiality level is set to stop unauthorised reading of a data or document, while integrity ensures that the data presented was not altered or deleted (sometimes by mistake) during processing and transmission. Availability means that the proper data can be accessed, by the authorised users, fast enough when it is needed (Schneier, 2000). Legitimate use means that non-authorised users should be prevented from accessing or using data or resources. Non–repudiation involves a trusted third party, who time-stamps outgoing and incoming data and communications and is able to verify the validity of a digital signature.

5.6.2 Security Measures

Many organisations (including survey and mapping organisations), companies, and government agencies, are sensitive about protecting their data and have introduced security systems. The design of a security system involves hardware and software components as well as physical security such as controlled doors, shields, cameras, guards, ..etc. It also involves policies and procedures. However security systems must be reasonable and well designed. An over-complex security system for unrestricted data will cost a lot and slow the system.

To protect valuable data, mainly from the Internet hazards, the first step should be the development of comprehensive procedures and policies for data security, internally and externally. These should state in detail the employees who will have access to each type of service provided by the Internet. It is also very important to educate the employees on their responsibility for the protection of the data and information.

The "site security handbook" issued by the Network Working Group, an Affiliate of Internet Engineering Task Force (IETF), gives a good account of the topics to be taken into consideration when an organisation gets ready to set its security policies. A security plan requires, as part of its arrangement, an estimation of the cost to be borne by the organisation in case the security arrangements are violated. Organisation officials at the highest levels should be involved in the process. It may be useful to hire a computer security expert to ensure system security; also, many of the Internet service providing companies may be consulted. Once the security procedures and policies are in place, then the organisation should evaluate available tools and technologies such as firewalls, encryption, authentication, Virtual Private Networking (VPN) and Anti-virus software and apply what is needed according to their security measures and requirements (Brosais, 1997).

5.6.3 Firewalls

Whenever the subject of Internet security is discussed, the minds of many people, especially companies and government agencies go to firewalls, in spite of the fact that firewalls do not solve all Internet security problems. A firewall is simply a divider or boundaries between private networks (Intranet), such as a LAN and WAN, and public networks, mainly the Internet (Schneier, 2000). The firewall receives incoming network packets at the network layer level and inspects all the packets and compares them against a set of rules and regulations provided by the organisation network supervisor (for example, the source and destination addresses of incoming packets). The firewall will pass packets which meet the rules and regulations, and reject all other traffic, which does not comply with the rules. Firewalls could consist of a variety of components, including hardware, software and services, and deal with multimedia traffic.

There are several ways to configure a firewall, depending on the level of security needed. There may be one or multiple firewalls, or multiple internal networks (Apostolopoulos et al., 2000). Although there would be no way of restricting access to the information on that web server, many organisations are definitely interested in stopping any tampering with the server's contents. Most security system providers are trying to protect web servers by providing legitimate access and by monitoring illegal activities (Brosais, 1997).

Figure 5-12 shows a firewall within three-tier system architecture. A firewall is usually installed between the user's interface (the first tier) and the application and database servers (the second and third tier) as shown in this figure.

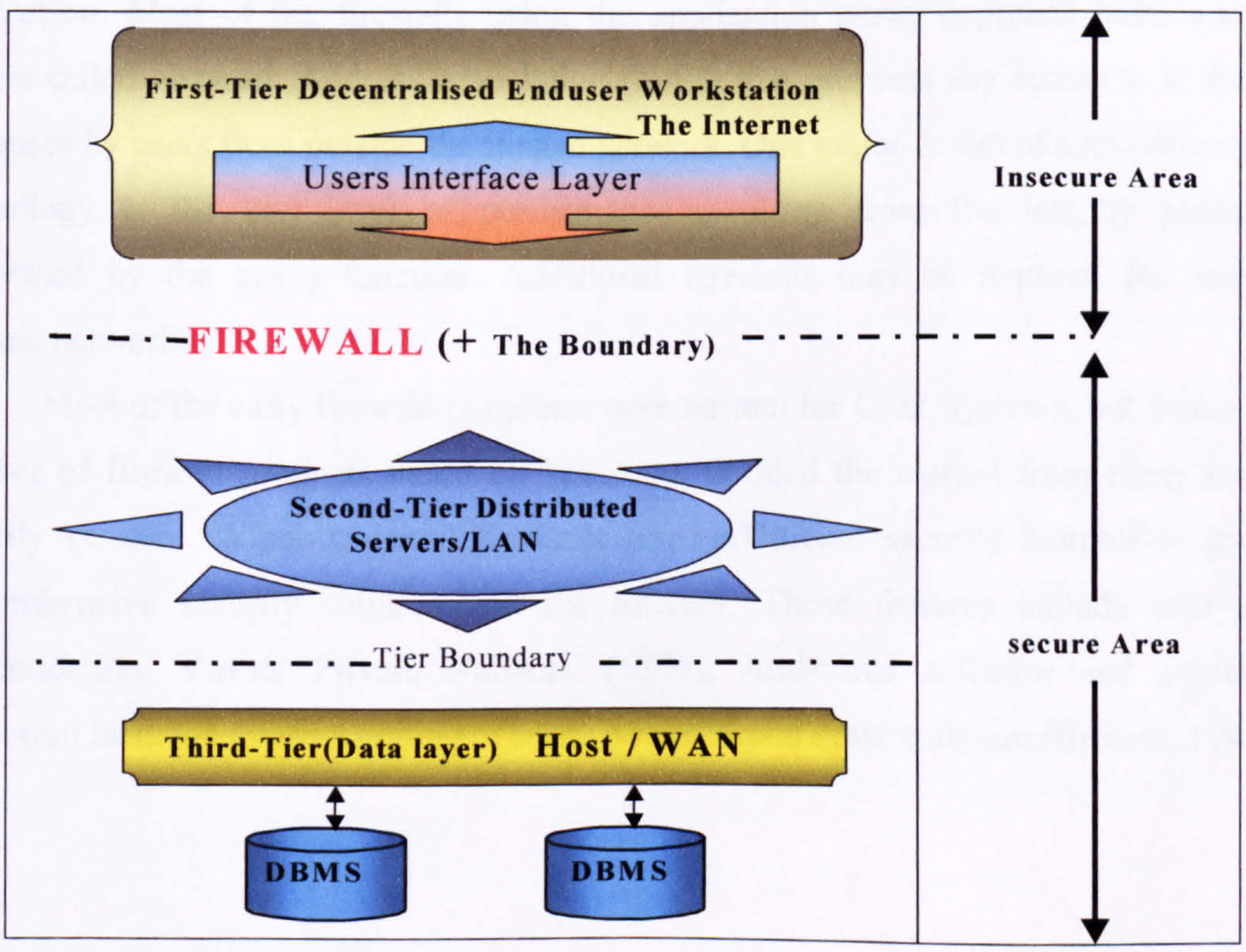


Figure 5-12 Firewall used in three-tier architecture.

Most firewall technologies in use today contain one or more of the three critical firewall elements, known as packet filtering, circuit proxy firewall and application proxy (Apostolopoulos et al., 2000). Packet filtering technology is relatively cheap, transparent to the user and has very limited effect on network performance, but the configuration of the packet filtering technology is a somewhat complicated process and requires an accurate knowledge of the web, the transfer protocols and, sometimes, requires knowledge of the application protocols. Configuration problems often lead to security vulnerabilities, which give an opportunity to computer hackers to gain access to organisation networks by changing the Internet Protocol (IP) addresses in the packet headers to other addresses acceptable to the local network. In the early days of network security, packet filtering used to perform the very basic function of checking each packet traversing the network. Today, packet filtering is smarter. Instead of checking each packet individually, the firewall keeps data and information about the state of the network and what packets are expected (Schneier, 2000). A more sophisticated and more secure system is the proxy technology (circuit proxy and application proxy). The circuit proxy is similar to packet filtering, but the circuit proxy forces all communications, whether client or server, to address all packets to the circuit proxy (Apostolopoulos et al., 2000). Application proxy software is capable of evaluating network packet to determine the authenticity of data relating to a particular application. Most of the firewalls using the application proxy approach have a special feature called Network Address Translation (NAT) that prevents any access to IP internal addresses by users from outside the trusted network. One major defect of application proxy technology is the low level of performance resulting from the lengthy processing performed by the proxy function. Additional firewalls may be required for sensitive internal networks.

Most of the early firewall programs were written for Unix Systems, but then a large number of firewall products based on Windows flooded the market from many Internet security vendors. Windows-based firewalls have additional security features to provide comprehensive security solutions on the Internet. These features include encryption, authentication, Virtual Private Network (VPN). Anti-virus software and sometimes protection from the malfunctioning of Java, Active X and other software (Brosais, 1997).

5.6.4 Encryption

Encryption is an important Internet security measure. Known modern encryption processes depend on the use of numerical values used as a public/print key. System encryption can be part of the Secure Socket Layer (SSL) and is widely used in web to server communications (between browsers and servers).

There are many types of algorithms or standards for encryption. For example the Data Encryption Standards (DES) used to be one of the most common algorithms, depending on the use of a symmetric key or secret key. The DES has been used since 1977 all over the world, in thousands of different products and applications (Schneier, 2000). Another example is the triple-DES, an updated version of the DES algorithm, which is used with more than one key.

The Secure Multipurpose Internet Mail Extensions (S/MIME) standards were introduced for the security of correspondence systems. They enable a secure exchange of emails and cover email encryption software (Brosais, 1997). On the other hand the Advanced Encryption Standards (AES) are more modern and advanced standards. According to Schneier (2000) AES will soon be the U.S. government standards encryption algorithm. These algorithms secure and protect privacy, such as emails, personnel computer file, important data and financial transactions (Schneier, 2000).

Not only does encryption ensure data confidentiality and privacy, but also it can be used to guard passwords and important data such as credit cards and bank transactions. All the data are encrypted by using the sender's key, ensuring the authentication of the sender, whereas the data are decrypted by using the recipient's key, ensuring the authentication of the recipient. It also enables a mechanism for the user authentication known as digital signature (Amor, 2000). The certifying authority in any organisation, which is formally responsible for delivering the public key to the user, could be set up by using digital certificates within the organisation or extending their use to include trusted partners. The certifying authority software providers are agencies or companies, trusted by a group of users, who are well known for their strict procedures for checking identities and identifying digital certificates. The X.509 standard is one of the best-known standards for identifying digital certificates (Brosais, 1997).

5.6.5 Authentication

As mentioned in section 5.6.3, firewalls stand between an organisation and the outside world to protect data from unauthorised outside users, check incoming and outgoing traffic, ensure legality and protect the organisation's systems and data. But if the organisation wants to allow certain users to have access to sensitive files and data on their systems through the firewalls, then they need to check the authenticity of the actual user. Authentication is defined as a set of procedures, which can positively identify the user and ensure that received and transmitted data were not altered, modified copied or deleted. Passwords are among the best-known procedures for user authentication, but it is well known that users frequently use passwords that can easily be guessed or figured out by experienced hackers.

5.6.6 Virtual Private Networks

Virtual Private Networks (VPN) are simply a secure connection over a public network, such as the Internet. The expression refers to remote access using the Internet Infrastructure to connect two offices (rooms) in an organisation or two different organisations to one another. Many firewalls products offer the possibility of virtual private networks. By using the remote access function, a remote user can contact the local Internet Service Provider (ISP) and get connected to his central network through the Internet. Certain standards were developed to facilitate remote access and connections through virtual private networks. For example, a standard developed by IETF under the name of IPsec or secure Internet protocol would permit the transfer of authentication and certification procedures from an Internet service provider to a server located somewhere on the Internet, say, at the head office of a company. This standard would enable VPN products to exchange public keys and encryption algorithms in order to prepare VPN sessions. Also, most VPN products and firewalls products support the IPsec standard. Consideration should be given to the fact that exchange susceptibility tests are still new and that the IPsec standard is still being developed. VPN networks and all encryption technologies are heavily dependent on the computer's Central Processing Unit (CPU) and could be the cause of low performance unless they are adequately designed and implemented (Brosais, 1997).

5.6.7 Computer Anti Virus

After protecting systems to prevent hackers, intruders and criminals from breaking into the networks, the looming risk of viruses is still a major problem threatening any system. Java applications and Active X, which enter a system when network users browse the Internet, can be a cause of virus attack. A computer virus is simply a string of computer code that attaches itself covertly to another file and attaches copies to other programs and infects and destroys files, programs and other resources. The first computer virus known was written in 1983 by Fred Colen, a University of Southern California (USC) student. He wished to prove his idea to a number of people who did not believe it was possible (Schneier, 2000). Nowadays there are estimated to be between 10,000 and 60,000 different viruses, with about six new or variant viruses appearing daily.

There are three types of viruses: file infectors, boot-sector viruses and macro viruses. The file infectors are the most common. They work by attaching themselves to executable program files. The boot-sector virus loads itself into memory when the computer first boots up and then infects all the hard disks, diskettes and any other disks that are placed in the drive and spreads into other systems. This worked well with Windows 3.1, but is less common with Windows 95 and upward. Macro viruses are written in scripting (macro) language and spread faster than other viruses, because data are exchanged more commonly than programs. Nowadays, the fastest spreading Internet viruses are macro viruses.

The propagation of viruses via email is new and will change every security measure, because email is everywhere and is not easily stopped, even at the firewalls. Email viruses became topical in 1999 with the Melissa Microsoft Word macro virus and the worm.exploreZip. For example, in the year 2000 the ILOVEYOU worm, and others, attacked very large numbers of systems, by using the email and spread across the Internet network using automatic e-mail features and mailing themselves to all the people listed in the infected host's email address book (Schneier, 2000). The ILOVEYOU virus is said to have infected about 10 million computers in a few hours. The anti virus companies release updates, but every day new types of viruses with new codes are developed, which makes it difficult to be secure. Finally, the following advice must be considered, especially for the Saudi National Spatial Data Infrastructure (SNSDI) chapter 7:

1. Any strange email should not be opened, unless proper procedures are taken.
2. Any computer, which is linked or used to access the Internet, should not contain any sensitive information or data files. It could be downloaded (from the computer to some where else) easily.
3. Important data should be saved on daily, weekly and monthly bases (three copies are recommended and should be saved in a different secured places).
4. Users should be aware of infected websites and not visit them, as virus or worms would spread and destroy their system.
5. Anti-virus software should always be updated.
6. Newly received floppy, zip disk, etc should be scanned before using it.
7. The use of credit cards and dispatching personnel information or address on the Internet should be minimised unless secure transmission is used.

5.7 CONCLUDING REMARKS

The Internet has become an important and a major part of computer networking technology. It is an essential communicating medium for the spatial data community and has changed the way of accessing, transmitting, conducting, analysing, visualising and sharing spatial data. The rapid development of the Internet and the World Wide Web (WWW) technologies has resulted in the Internet-based GIS. The current technology for Internet-based GIS application enables the successful implementation of a National Spatial Data Infrastructure (NSDI) and forms the backbone of any national spatial data clearinghouse. In addition, use of servers provides the ability to communicate with many computer platforms from small systems to a large installation and allows network configurations distributed across a nation or the globe to share different spatial data and other resources.

Several good tools and technologies have been developed to build and facilitate GIS applications on the Internet. Among those tools are the Common Gateway Interface (CGI), the Application Programming Interface (API), GIS Plug-ins, GIS helpers, Microsoft Active X, Java, and others. The OpenGIS Consortium (OGC) is the most innovating and technically competent consortium and offers very promising tools and features for interoperable Internet-based GISs in heterogeneous environments. Most GIS vendors have developed Internet tools and services for interactive GIS functions and Internet-based GIS following OGC guidelines. The Intergraph GeoMedia Web Map, ESRI Arc Internet Mapping System (ArcIMS), MapInfo MapXtreme and AutoDesk MapGuide products are considered the best four systems in this field. However, further work is required to provide all necessary GIS functionality and perform more advanced GIS analysis on the Internet. Moreover, the increasing demand for the Internet services increases the security hazards for many users. Intruders, hackers and criminals continually threaten the confidentiality, integrity, availability, legitimate use and validity of received and transmitted data. Therefore, high security awareness is needed and appropriate measures should be developed and implemented, provided that the level of security set is in accordance with needs, requirements and education of employees.

The Saudi NSDI should use the Internet network initially to promote the basic concept of an NSDI by means of web information pages and links to international good practice, and foster the formation of discussions groups amongst potential participants. The Saudi clearinghouse should only contain metadata during the first stage of the infrastructure project with spatial datasets supplied by the producers on their own servers. This will minimise the administrative load in setting up the national system compared with attempting to warehouse all the data at a national site or sites.

The initial metadata gateway will use the open Internet as a test vehicle for setting up a full scale clearinghouse while critical reliability issues of Internet network availability, speed and security are investigated. At the same time it should be possible to incorporate flexibly the feedback from discussion groups amongst the Saudi spatial data community to determine the best use of the Internet structure to access the spatial data clearinghouse and to decide on the number of nodes needed in a fully operational failsafe system.

Security is a major problem, both in terms of access to metadata and to the data themselves. One approach would be to rely on software security at the gateways, which can be very effective, but not perhaps to the professional hacker. Another growing alternative is to use either private lines or virtual private networks (VPNs) using high level encryption tunnels between sites. The latter is more computing intensive, but cheaper to implement and more flexible than secure private lines. The development of VPNs may be a very useful feature of the communication system within the clearinghouse.

CHAPTER 6

THE SEARCH FOR A SPATIAL DATA CLEARINGHOUSE MODEL

6.1 INTRODUCTION

The development and implementation of an international, national, and regional spatial data infrastructure, including clearinghouses, came as a result of the convergence of spatial data technologies, the internet network, mobile services, high level governmental support, the need to protect the environment and a desire to minimise duplication of effort in the expensive and time consuming collection, production and management of spatial data. The primary goals of creating a spatial data clearinghouse are to improve knowledge about current and future spatial data and to maximise the use of data and technology by co-ordinating and integrating a variety of spatial data from different sources, facilitating facilitate its access and sharing, and reducing the costs of its collection, production and maintenance by using common standards, policies, technologies and other facilities. Clearinghouses are an integral part of all spatial data infrastructures and therefore, in discussing spatial data infrastructure, it is appropriate to pay attention to the development of spatial data clearinghouses.

The main purpose of this chapter is to investigate and evaluate some of the worldwide initiatives in the field of spatial data clearinghouses in an attempt to learn the advantages and disadvantages of each initiative. This in turn will facilitate the formation of a proposal for the development and implementation of a national spatial data clearinghouse in the Kingdom of Saudi Arabia, which will be discussed in chapter 7. Section 6.2 defines and highlights some aspects of spatial data clearinghouses. Section 6.3 forms the main and most important part of this chapter. The search for a clearinghouse model tours the world, starting in the African continent; where four initiatives in Kenya, Ghana, the Southern African Development Community (SADC), and South Africa are briefly investigated. Then, the focus moves to the Asia and Pacific Region; where five initiatives in South Korea, Japan, Malaysia, The Permanent Committee on GIS Infrastructure For Asia and Pacific (PCGIAP) and the Australia-New Zealand region are discussed. After that five

European initiatives including the European Umbrella Organisation for Geographic Information (EUROGI), the European Spatial Metadata Infrastructure (ESMI), Portugal, the Netherlands and the United Kingdom are examined. Following Europe, the section reviews some of the North and South American initiatives, in Colombia, Uruguay, Canada and the United States of America. Lastly the Global Spatial Data Infrastructure (GSDI) is investigated. Section 6.4 contains concluding remarks.

6.2 THE CLEARINGHOUSE

The spatial data clearinghouse is the most important and essential component of any spatial data infrastructure. A national spatial data clearinghouse consists of four main components, spatial data, metadata, Internet and distributed interface and search tools (Masser, 1997). These have been discussed in previous chapters.

What is a Clearinghouse? - A spatial data clearinghouse can be defined (rather verbosely) as "*the creation of a centralised or decentralised (distributed) electronically connected network of servers located on the Internet, which contain metadata and detailed catalogue services that are collected in a standard format to facilitate query and consistent presentation across multiple participating sites that band together spatial data providers, custodians and distributors to promote their available digital spatial data and enable all users to search relevant spatial data nodes, determine what spatial data exist, find the data they need, evaluate the usefulness of the spatial data for their applications and obtain or order the data as quickly and economically as possible*" (FGDC, 1995).

Within any national spatial data clearinghouse, the role of data providers, data custodians and data distributors varies among countries and relevant organisations. A single site may perform all three roles, or the responsibilities for each role may lie with different locations and organisations. The creation of initial metadata is normally the responsibility of the spatial data providers. The provider defines most of the required metadata during the generation of the spatial data. Each data provider then describes the available data in an electronic form and provides these descriptions (metadata) to the network using a variety of tools. The responsibility for reviewing the initial metadata could be assigned to separate units within an organisation, or managed through external dedicated organisations. The maintenance and update of metadata differ according to policies and types of clearinghouses. For example in centralised clearinghouses, the clearinghouse administration is responsible for maintaining the centralised metadata, but in a distributed clearinghouse, each data provider is responsible for the maintenance of his or her local metadata.

Due to the continuous change in technologies, user access methods and modes, clearinghouse systems should be flexible and designed for maximum accessibility. Policies related to copyright, licences, fees, security, formats and other matters should be established. Existing policies and procedures should be extended, where possible, to avoid modifications and changes in the future. The development, implementation, maintenance and updating of a clearinghouse requires a considerable amount of money and effort, but it is worth it because of the benefits gained by avoidance of duplication and the consequent savings in time, money and effort.

A clearinghouse is heavily dependent on the manner of managing the metadata and communicating with different spatial data providers and the extent of services to be provided to the user community. In order to enable metadata to be easily read and understood by different disciplines, metadata standards that provide a common set of terminology and definitions for the documentation of spatial data should be developed and understood (training and practice) (Radwan et al., 1997). The main developer of metadata standards presently is the ISO/TC 211. Technical considerations including spatial data security, as discussed in chapter 5, should be addressed during the building of any clearinghouse. The protection of internal systems and networks, as well as the security of spatial data that is sensitive, for example, military spatial data or any other restricted data, needs to be assured; managers are responsible for protecting these organisational assets (Radwan, 1999).

6.3 INITIATIVES

Today, many national, regional and international organisations around the world are trying to develop strategies for spatial data infrastructure, including clearinghouses, as discussed in chapter 1. Examples of these activities are given below, but owing to lack of documentation and the fact that, in some cases initiatives are still in their early stages, the type and amount of information provided varies greatly:

6.3.1 Africa

There have been several efforts in Africa toward the development of spatial data infrastructure and directories or clearinghouses. Examples of these activities are:

6.3.1.1 Kenya

The United Nations Environment Programme (UNEP), headquartered in Nairobi, Kenya, supports a global directory of environmental spatial data, using UNEP software and a subset of the United States federal geographic data committee (FGDC) metadata elements (UNEP, 2000). This development is now in progress

6.3.1.2 Ghana

From 14-18 August 2000, staff from the United States of America, FGDC visited Ghana to co-host a comprehensive five-day workshop on "Managing Spatial Data for Development Planning in Ghana". Chartered under Ghana's multi-year Natural Resource Management Project, the National Framework for Geographic Information Management (NFGIM) initiative, hosted by the Ghanaian Environmental Protection Agency (GEPA), has made steady progress in raising awareness of the value of Spatial Data Infrastructure (SDI) and the need to facilitate collaboration on spatial topics across all sectors in Ghana. As a result of this workshop, Ghana has been provided with the training material, documentation, metadata and software tools necessary to implement a national spatial data clearinghouse (Reichardt, 2000).

6.3.1.3 The Southern African Development Community

The Regional Remote Sensing Unit (RRSU) was originally established in Harare, Zimbabwe for geographic information systems (GIS)-based applications in support of early warning for food shortages. The RRSU was funded and technically supported by the Food and Agriculture Organisation (FAO) of the United Nations and other donors. Initially the RRSU and its spatial data activities were not known and the original plan did not include the development of SDI. However, over the years, the RRSU has been recognised as one of the major spatial data-developing units in the Southern African region. In 1998, the RRSU was integrated into the organisational structure of the Southern African Development Community (SADC) and funded by the 14 SADC member countries (Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe) and other donors, with the aim of developing the spatial data infrastructure in the region; such development is now in progress (Nebert, 2001).

6.3.1.4 South Africa

South Africa is developing a national spatial data infrastructure in response to its needs for spatially referenced data to enable sound decision making, provision of services and other infrastructure (e.g. road networks, utilities). In 1997, the Deeds and Surveys branch of the Department of Land Affairs (DLA) dedicated resources to develop the National Spatial Information Framework (NSIF), South Africa's Spatial Data Infrastructure (SDI) initiative. The USA and Australian models, experience and software tools were used in building the SDI (NSIF, 2000).

The South African national spatial data infrastructure initiative has received good government support and is one of the most important activities in the African region. The NSIF spatial planning task team address and sponsor a number of activities, which include policies relevant to spatial data dissemination, setting standards to promote interchangeability, including accuracy standards for data collection, classification standards, metadata standards, a catalogue and a Spatial Data Discovery Facility (SDDF) to provide access to various spatial data by linking spatial data providers and users and to facilitate the exchange of spatial data using the Internet. The NSIF adopts the United States FGDC Content Standard for Digital Geospatial Metadata (CSDGM) and related software and will change to the ISO/TC 211 content standard once it is finalised.

Following co-operation between the NSIF and the Regional Remote Sensing Unit (RRSU) the NSIF set up a distributed SDDF system that includes about 3,000 records on spatial data holdings within both public and private sectors, in South Africa as well as the Southern African Development Community (SADC). As of April 2001, there were about 14 individual SDDF nodes on the Internet that provide digital spatial data covering much of the country, with a large number of metadata records allowing multiple queries of the spatial data through a single gateway. The primary digital spatial data themes that are commonly used and will be made available throughout the distributed systems include cadastral parcels and land ownership, topographic communications, urban areas, administrative and political boundaries, transportation networks, rivers and main dams, digital terrain models (DTM) and digital elevation models (DEM). The SDDF system provides several mechanisms for spatial data query. For example the SDDF presents the user with a map of South Africa, with tools to zoom in, zoom out, add to the map various spatial features, then view all the available databases (nodes) on the SDDF

However, while progress has been made in developing the South African spatial data infrastructure over the last four years, there are a number of obstacles that need to be addressed. These include the lack of a uniform policy across government organisations and agencies with respect to the pricing of spatial data and other conditions associated with its use; a spatial data sharing problem owing to the fear of some data providers over loss of control over their spatial data if it is shared, and the lack of investment in spatial data and associated technologies (Gavin, 2001).

6.3.2 The Asia-Pacific Region

6.3.2.1 South Korea

South Korea (the Republic of Korea) has carried out a number of research and development studies in the field of spatial data infrastructure (SDI) planning. According to Tschangho John Kim, the Government of South Korea established, in January 1994, the National GIS (NGIS) steering committee was established and created the following five functional committees:

1. The NGIS Coordinating Committee.
2. The NGIS Mapping Committee.
3. The NGIS Cadastral Committee.
4. The NGIS Standard Committee.
5. The NGIS R&D Committee.

In May 1994, another new committee called the NGIS Advisory Committee was created by the NGIS Steering Committee and 15 experts from the academic and the private sectors were appointed as members. The Advisory Committee was tasked to formulate and recommend a national GIS implementation plan and financial issues. Each functional committee also appointed its own committee members who recommend functional development and implementation programmes to the NGIS Committee for the national GIS (Kim, 1995).

In 1995, The South Korean National Land Information Centre (NLIC) was established by the Ministry of Home Affairs and tasked to collect and provide information about parcels registered in the Cadastral records using a computer network. The NLIC built a central database which stores cadastral data produced and updated by 15 Local Land Information Centres, which receive spatial data updates from 255 cities, counties and districts, Resident Registration data and Posted Land Price data, all provided by major participants through modems. The main participants in the NLIC include:

1. The Ministry of Home Affairs.
2. The Ministry of Construction and Transportation.
3. The Ministry of Agriculture, Forestry and Fisheries.
4. The National Tax Administration.

The NLIC is a centralised parcel-based land information system, which provides the means, using a parcel-based key identifier, to link to the whole data set provided by each participant. However, due to the lack of a national spatial data infrastructure and a lack of coordination and cooperation between the various spatial data providers, connection to NLIC is only allowed to local government offices. Therefore most of the spatial data sets are not accessible to the public and duplication of data collection and production exist (Man-Ho, 1998).

6.3.2.2 Japan

According to Imai (1999), the Japanese National Spatial Data Infrastructure Promoting Association (NSDIPA) was established, based on the Japanese Geographic Information System (GIS) academy initiative, at the time of the Great Hanshin Earthquake and presented to the Japanese central government. To support the NSDIPA initiative, the Japanese government decided to establish a liaison conference in the Councillor's Office on Internal Affairs, and a related committee in the Ministry of Construction and National Land Agency. The NSDIPA is a copy of the United States of America National Spatial Data Infrastructure (NSDI). The major private sectors have recognised the importance of the initiative and support it. The Japanese National Spatial Data Infrastructure (NSDIPA) has endorsed the creation of metadata and search facilities as part of its data infrastructure. In 1997, a test Clearinghouse was established in the Okinawa Prefecture with a Japanese language and web map-based query interface to search available spatial data across Japan. It is anticipated that NSDIPA will use the ISO/TC 21 standards and will become accessible through the OpenGIS Consortium (OGC) compliant catalogue services specifications as they become available (Imai, 1999).

6.3.2.3 Malaysia

In 1997, the Malaysian government issued a circular order calling for the establishment of the National Infrastructure for Land Information System (NaLIS). The NaLIS Co-ordinating Committee (NCC) was formed at the federal level under the chairmanship of the secretary general to the Ministry of Land and Co-operative Development. Also the State NaLIS Co-ordinating Committee (SNCC) was established under the chairmanship of the respective State Secretaries. Besides the two co-ordinating committees, the circular also established the National Land Information Clearinghouse (NLIC). The NCC consists of three sub-committees: the clearinghouse, the standards and metadata and the framework sub-committees. NCC was given the mandate to involve the Economic Planning Unit, the Malaysian Administrative Modernisation Planning Unit, the federal treasury, the Malaysian Institute of Micro-electronic Systems, the National Mapping and Spatial Data Committee (NMSDC) and the Ministry of Land and Co-operative Development. The private sector is also encouraged to participate in NaLIS activities.

The goal of the Malaysian national spatial data infrastructure initiative is to provide access to digital spatial data through the NaLIS clearinghouse nodes, similar to the U.S. FGDC clearinghouse model. However, NCC is also studying other models and the possibility of adopting them for Malaysia. The main digital spatial data being made available through NaLIS are geodetic, cadastral and topographic data, which are being produced by the department of survey and mapping. The acquisition of spatial data is co-ordinated by the NMSDC. The NMSDC is headed by the Department of Survey and Mapping and comprises various departments and agencies such as the departments of agriculture, forestry, the geological survey, the national remote sensing centre and the relevant academic institutions. NaLIS activities involve metadata and clearinghouse definition and the discussion of standards and core spatial data. The ISO/TC 211 suite of standards on geographic information and geomatics will be used as soon as it becomes available. NaLIS is still in the development and implementation stage and no specific cost structure has yet been developed or spatial data made available through the infrastructure. However, the Malaysian Government issued an order in February 1997 for copyright protection for all forms of digital survey and mapping data, as well as regulating the fees chargeable for the data (Tamin, 1999).

6.3.2.4 The PCGIAP

The Permanent Committee on GIS Infrastructure for Asia and Pacific (PCGIAP) was formed as a result of resolution 16 of the 13th United Nations Regional Cartographic Conference for Asia and the Pacific (UNRCC-AP), held in Beijing, China, in May 1994. The Committee was formally established at its inaugural formation meeting, held in Kuala Lumpur, Malaysia, in July 1995.

The aim of PCGIAP is to co-ordinate the development and implementation of a regional spatial data infrastructure that comprises fundamental spatial data, standards, institutional arrangements and access mechanisms, required to support activities undertaken by the nations of the Asia and Pacific region, to maximise their common economic, social and environmental benefits. It also ensures that spatial data users can acquire the data they need, even though the data are collected and maintained by different organisations (Abdul Majid, 1999).

6.3.2.4.1 The PCGIAP Structure

The PCGIAP operates under, and reports to, the UNRCC-AP. The United Nations defined 55 member nations of PCGIAP across the Asia and Pacific region as shown in table 6-1. The membership comprises directors of national survey and mapping organisations and equivalent national organisations in the Asia and Pacific region. Each nation nominates a single representative but may invite experts to meetings as advisors. The current membership of the Executive Board is China (chair), Australia (vice-chair), Japan (secretariat), Brunei Darussalam, Cook Islands, India, Iran, Malaysia, Philippines and the Russian Federation. The Executive Board meets annually and the following working groups carry out the projects:

1. Regional geodesy.
2. Fundamental Data.
3. Cadastral.
4. Institutional.

The private sector is involved in the development of the Asia and Pacific Spatial Data Infrastructure (APSDI) projects and in seminars that are being identified by PCGIAP (PCGIAP, 1998).

1. Afghanistan	15.Hong Kong, China	29.Marshall Islands	43.Samoa (American)
2.Armenia	16.India	30.Micronesia	44.Samoa (Western)
3.Australia	17.Indonesia	31.Mongolia	45.Singapore
4.Azerbaijan	18.Iran	32.Nauru	46.Solomon Islands
5.Bangladesh	19.Japan	33.Nepal	47.Sri Lanka
6.Bhutan	20.Kazakhstan	34.New Caledonia	48.Tajikistan
7.Brunei Darussalam	21.Kiribati	35.New Zealand	49.Thailand
8.Burma	22. North Korea	36.Niue	50.Tonga
9.Cambodia	23. South Korea	37.Northern Marianas	51.Turkmenistan
10.China	24.Kyrgystan	38.Pakistan	52.Tuvalu
11.Cook Islands	25.Laos	39.Palau	53.Uzbekistan
12.Fiji	26.Macau	40.Papua New Guinea	54.Vanuatu
13.French Polynesia	27.Malaysia	41.Philippines	55.Vietnam
14.Guam	28.Maldives	42.Russian Federation	

Table 6-1 Member nations of the permanent committee [Adapted from Godfrey et al., 1997].

6.3.2.4.2 The Asia and Pacific Spatial Data Infrastructure

The Australia - New Zealand model for spatial data infrastructures, which contain four core components: institutional framework, technical standards, fundamental datasets, and access networks has been accepted and Adopted by the Permanent Committee on GIS Infrastructure for Asia and the Pacific region (Holland, 1998). The PCGIAP plans to establish a distributed network of databases, linked by common standards and protocols to ensure compatibility between the related bodies in the region and contribute to the development of a more general global spatial data infrastructure for distribution and access - the Global Spatial Data Infrastructure (GSDI). A key element of the Asia and Pacific Spatial Data Infrastructure (APSDI) is the development of a spatial data directory system, which will contain metadata for the fundamental datasets, including policies and procedures for gaining access to the spatial data (Holland, et al., 1998).

The PCGIAP has plans to identify a range of distributed fundamental datasets, to include the following themes: geodetic control network, digital elevation data (DEM), drainage systems, transportation, populated places, geographical place names, vegetation, natural hazards, major administrative boundaries, topographic, hydrographic features and land use. Each dataset would be managed and maintained by custodians and may be linked electronically so that they appear, to the user, as a virtual database. The collection of fundamental datasets in the APSDI is the responsibility of PCGIAP member countries. The PCGIAP working groups for regional geodesy and for regional fundamental spatial data determine and propose the mechanisms for the co-ordination of data collection at the regional level. Data documentation and publications are expected to be made freely available over the Internet. No information or communication technology and standards have been formally adapted yet for APSDI. However PCGIAP is paying particular attention to standards development in ISO TC 211 and the Global Map project (PCGIAP, 1998).

6. 3.2.5 Australia and New Zealand

The Australian Land Information Council (ALIC) was inaugurated in January 1986 by agreement between the Australian Prime Minister and the heads of the State and Territory governments to co-ordinate the collection and transfer of spatial data between different levels of government and to promote the use of spatial data all over the Commonwealth. In November 1991, New Zealand became a full member of the Australian Land Information Council which was renamed the Australia New Zealand Land Information Council (ANZLIC) (Masser, 1998).

6.3.2.5.1 The ANZLIC

The Australia New Zealand Land Information Council (ANZLIC) is a co-ordinating arrangement between the national, state and territory jurisdictions of the two countries. This initiative has gained the support of both governments. The strategy behind the development and implementation of ANZLIC is to provide leadership in building a fundamental spatial data infrastructure to support Australia's and New Zealand's economic, social and environmental benefits by providing spatial data compatibility between the participating jurisdictions and minimising the barriers to spatial data sharing in the region, with the recognition of issues of privacy and confidentiality. ANZLIC also encourages industry participation in the development and implementation of spatial data infrastructure and promotes education and training as well as research and development (ANZLIC, 1998a).

The members of ANZLIC represent ten jurisdictions, namely:

1. The Commonwealth Spatial Data Committee (CSDC).
2. The eight members of the Australian states and territories.
3. Land Information New Zealand (LINZ).

The Commonwealth Spatial Data Committee (CSDC), for example, provides the capacity for integrating the views and interests of spatial data users within Australia's Federal Government. Each state and territory member of ANZLIC represents a co-ordinating body within their own jurisdiction, which provides co-ordination between the agencies that have responsibilities for the management of various spatial data types. ANZLIC maintains links with other related national co-ordinating bodies such as the Intergovernmental Committee on Surveying and Mapping (ICSM) and the Public Sector Mapping Agencies consortium (PSMA). ANZLIC plays an important role with respect to the development and implementation of the Australian Spatial Data Infrastructure (ASDI) by drawing all levels of government and the private sector together to identify the elements needed for the infrastructure, and to ensure that spatial data users get the data they need (ANZLIC, 1998b).

6. 3.2.5.2 The Australian Spatial Data Infrastructure

The main activities of ANZLIC toward the development and implementation of spatial data infrastructure can be grouped as follows:

1. The creation of an **institutional framework** to lead the development of the national spatial data infrastructure and to define priorities, policies, and management for building, maintaining and distributing spatial data and to strengthen the relationship between all levels of government and industry.
2. The development of the **technical standards** and guidelines necessary to define the technical characteristics of the fundamental datasets and enable the effective use and integration of spatial data. ANZLIC metadata guidelines, necessary to describe and identify spatial data sets, have been developed and implemented in many jurisdictions and organisations. ANZLIC will review other emerging spatial data standards, such as the ISO/TC 211 geographic information/geomatics standards series and specifications developed by the OpenGIS Consortium (OGC), and make recommendations with regard to their adoption as Australian and New Zealand standards. ANZLIC will also review the emerging ISO 19115 international metadata standard and revise the ANZLIC metadata guidelines to comply with it (ANZLIC, 2001).
3. The identification and prioritisation of **fundamental datasets,** which are produced within the institutional framework and comply fully with the technical standards. The collection of fundamental datasets is the responsibility of individual custodians. ANZLIC has identified a list of required fundamental datasets. According to Graham Baker, Executive Officer, ANZLIC in his reply to a survey (questionnaire) of national and regional spatial data infrastructure activities around the globe (conducted by Professor Harlan Onsrud, the University of Maine, USA) the required national datasets are:

a. *"Primary spatial data, such as the geodetic control network, the national geodetic database, the Australian Height Datum, the national geoid model, aerial photography and satellite imagery.*
b. *Administration data such as land parcels/cadastre, land tenure, street address, mining and petroleum lease boundaries and tenure, administrative boundaries, national and state boundaries, suburb/town/locality and local government, electoral boundaries, postcode, constraining or major Interests in land, feature names/place names.*
c. *Natural environmental data such as soils classification, vegetation classification, biodiversity regions, animals, earth's land surface, bathymetry, coastline (or marine and coastal boundaries), river catchment/drainage areas, streamlines and inland water bodies, geology, mineral resources, hydrogeology, oceanography, climate, and areas subject to natural hazard.*
d. *Socio-economic data such as census collection districts, demography, planning zones rural and urban land use.*
e. *Built environment data such as cultural features, aviation features, marine transport, road centrelines, rail centrelines, water supply, waste water, irrigation and drainage networks, electricity and gas networks, telecommunication network*" (Onsrud, 2000).

4. The development of a **clearinghouse network** to foster the integration of fundamental datasets into the network and make spatial data accessible to the community, in accordance with policies determined within the institutional framework, and to the technical standards agreed by all spatial data providers and users with due regards for privacy, and confidentiality (ANZLIC, 1998a).

6. 3.2.5.3 The Australian Spatial Data Directory

The Australian Spatial Data Directory was launched in 1998 with the help and support of the ANZLIC, through the Metadata Working Group. The ANZLIC vision for ASDD is for a network of distributed nodes that store the updated description of the spatial data (metadata) while core spatial data are stored in a distributed array of several local systems (databases). Each system is maintained by a recognised custodian and linked by administrative arrangements, standards and a distributed network so that consistent datasets and new data products can be readily assembled and shared. ASDD is considered a hybrid of centralised and distributed systems as shown in figure 6-1.

Prototype directory nodes have been implemented to promote the collection of metadata according to ANZLIC guidelines and to test the technology for a distributed clearinghouse system. Individual jurisdictions are well advanced in the development of their own directories, which comply with the ANZLIC metadata guidelines.

Among the jurisdictions, the Commonwealth is taking a lead in co-ordination of the ASDD and each member is implementing its own node. Currently there are more than 21 nodes within the directory. Australia is developing a web mapping capability and participated in the OGC Web mapping test bed initiative (ANZLIC, 2001).

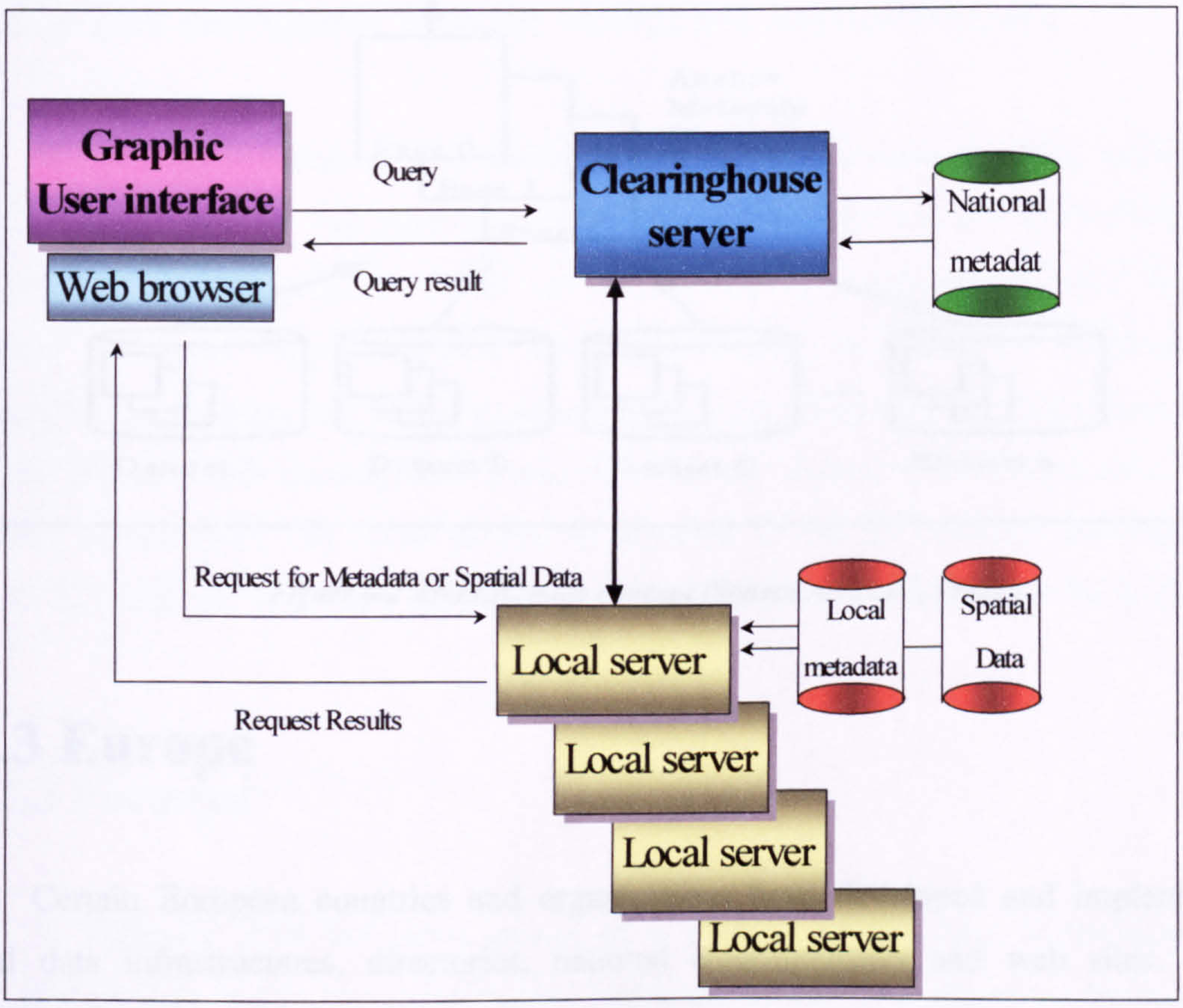


Figure 6-1 An approximate conceptual model for the ASDD system architecture[Source ANZLIC, 1998a].

Finally, ANZLIC has adapted a hierarchical "pages" concept as the basis for a national metadata framework where more general information is recorded at the highest level (Page 0) and additional information is recorded at lower levels (i.e. Page 1, Page 2), as shown in figure 6-2.

The highest level (Page 0) consists of a set of mandatory core metadata elements sufficient to allow a user to search and locate all relevant and available datasets, from national and state government agencies. Subsequent pages allow spatial data custodian organisations at the national, state, local government, academic, community or private industry levels to include additional information not required in Page 0 (ANZLIC, 1998a).

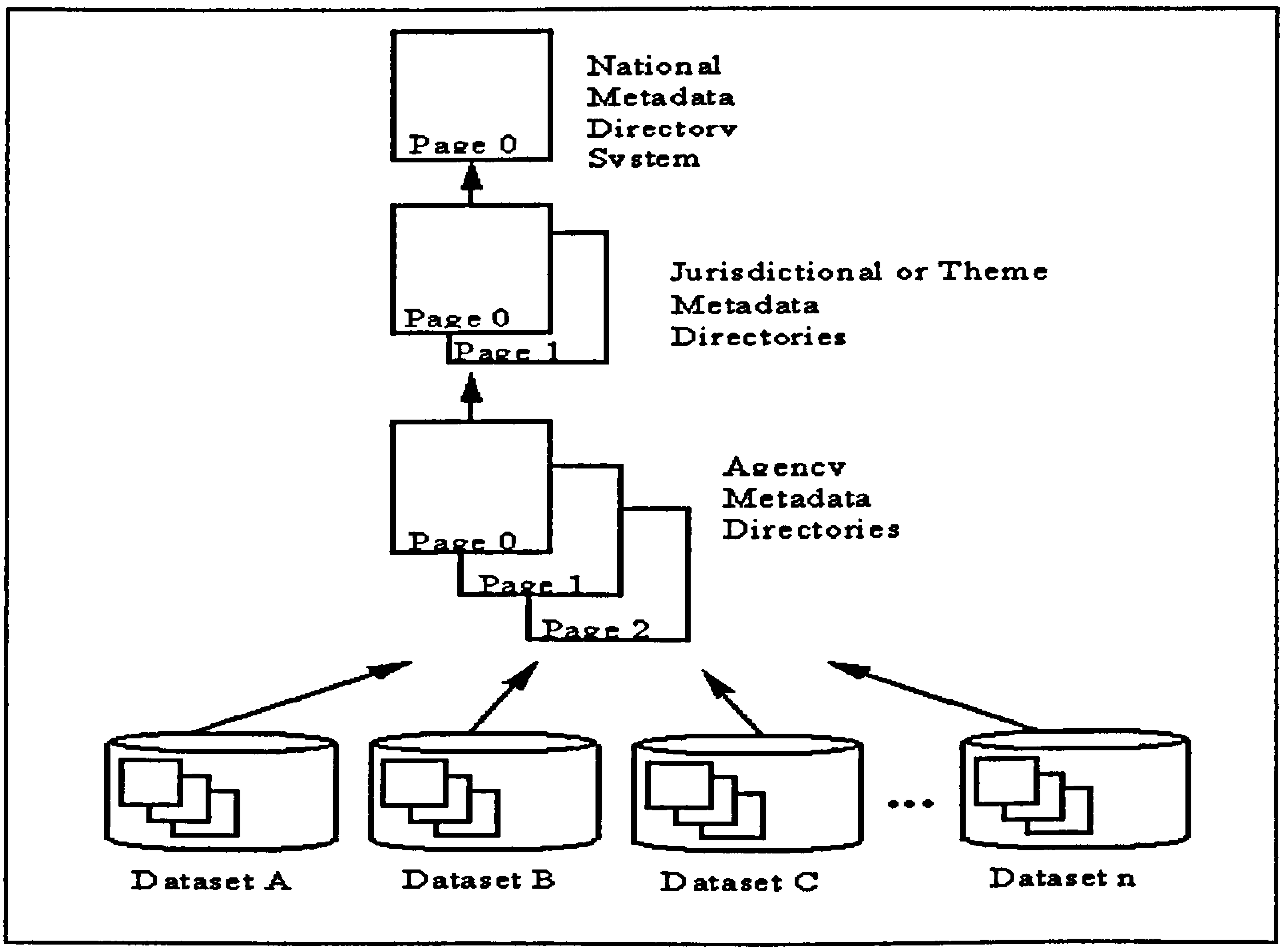


Figure 6-2 ANZLIC page concept [Source ANZLIC, 1998a].

6.3.3 Europe

Certain European countries and organisations have developed and implemented spatial data infrastructures, directories, national clearinghouses and web sites. The following are some examples:

6.3.3.1 EUROGI

In November 1993 the European Umbrella Organisation for Geographic Information (EUROGI) was established to provide geographic information accessibility throughout Europe by setting up and maintaining policies, regulations, standards, procedures, guidelines, and the requirement for co-operation and agreement between the European members (EUROGI, 1994). The aims of the EUROGI are to support the definition and implementation of a European spatial data policy, to facilitate a European Geographic Information Infrastructure (EGII), to provide communications between European members and support the implementations of local GIS throughout Europe, to improve spatial data exchange at the national and regional level and to encourage the development of spatial data clearinghouses (EUROGI, 1996). The EUROGI also represents the European view in the Global Spatial Data Infrastructure (GSDI) (Nebert, 2001).

6.3.3.2 The European Spatial Metadata Infrastructure

In 1998 the creation of a common data discovery infrastructure was initiated in most European countries. The most important initiative was the European Spatial Metadata Infrastructure (ESMI) project, which involves mapping organisations from Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Portugal, Spain, Sweden, the Netherlands and the United Kingdom. The ESMI provides a common research and development framework for the discovery of spatial data in the European Community. The ESMI project is expected to use the metadata developed by ISO/TC 211 and the OpenGIS Consortium (OGC) when they become available (ESMI, 1998).

6.3.3.3 Portugal

In February 1996 the development of a national spatial data infrastructure in Portugal started as a government initiative, under the Secretary of State for Science and Technology. In 1990 the spatial data infrastructure (Sistema Nacional de Informação Geográfica (SNIG)), was established by government decree. The National Centre for Geographic Information (Centro Nacional de Informação Geográfica (CNIG)) was created as a research agency of the Portuguese public administration and tasked to co-ordinate SNIG. The development of SNIG was slower than expected due to lack of available spatial data and the inadequacy of the computer technologies used by most of the spatial data providers (Nebert, 2001).

The Portuguese national spatial data clearinghouse, which was developed as part of the infrastructure, is a distributed electronic network with metadata as well as other procedures, policies and services that are intended to facilitate spatial data access through the Internet. SNIG's plan for the future is to have each data producer generate metadata each time a new dataset is created, according to a standard that will be managed and co-ordinated by CNIG. Future plans also include the development of web mapping services to explore spatial data in the country.

The policy for accessing the spatial data varies among the data providers. Some of the data providers make their data available in the public domain; others impose several restrictions on the access to and use of the spatial data. The digital spatial data being made available through SNIG cover all types of data that can be associated with the following fields: topographic, hydrographic, soils cartography, geological, forestry, land cover, urban planning, environmental, digital aerial photography and digital satellite imagery, geo-referenced data bases on air quality, water resources, hydrology and climatology, demography and housing, employment, electoral results, and cultural patrimony, among many others.

The private sector in Portugal is involved in the development of SNIG, but only in an indirect way, as private bodies are very often involved in spatial data project contracts for the government, where the ownership of the data remains within the government bodies (Onsrud, 2000).

6.3.3.4 The Netherlands

Most of the spatial data supplied in the Netherlands are from centralised services. The Minister for Housing, Spatial Planning and the Environment (VROM) is made responsible for national spatial data co-ordination on behalf of the Dutch government. The registration of land titles and large scale cadastral mapping are the responsibility of the Cadastre. The national topographic base map at the scale of 1:10,000 and smaller is the responsibility of the Topografische Dienst, which is part of the Ministry of Defence, although its employees are all civilians. The collection of statistics is in the hands of

Statistics Netherlands and real estate data is delegated to municipalities (there are about 650 municipalities in the Netherlands).

In 1984 the Dutch Council for the Real Estate Information (RAVI) was founded as an advisory body for the Minister for Housing, Spatial Planning and the Environment, on matters related to the operation of the Cadastre. Owing to the increasing computerisation of real estate and geographic information services in the early 1990s the RAVI was turned in 1993 into a consultative body comprising all public services and local authorities for all geographic information matters in the Netherlands (Masser, 1998). In March 1995 the RAVI took the initiative to launch the concept of the National Clearinghouse for Geographic Information (NCGI) with representatives from the co-ordinating minister, VROM, and other organisations. The aims of the NCGI are to make the existing spatial data in the Netherlands accessible to all users using metadata and the Internet, to stimulate the participation of all organisations in the spatial data community and increase awareness of the importance of spatial data and its infrastructure (RAVI, 1996).

6.3.3.4.1 RAVI's Main Activities

The RAVI mission is to develop a National Geographic Information Infrastructure (NGII) in the Netherlands. This plan incorporates a number of activities and topics, such as:

1. Participation in the European standards activities.
2. Participation in the ISO/TC 211 standards activities.
3. Development and implementation of metadata and metadata standards.
4. Development and implementation of geographic information standards.
5. Creation of a topographic database at the scale of 1:10,000 and other spatial data.
6. Development of a graphic user interface.
7. Development of a national clearinghouse for geographic information (NCGI) in the Form of a National Action Plan (NAP) Electronic Highway.
8. Registration of soil pollution.
9. Development of a copyright act and recording titles of geographic information to NCGI and other issues (RAVI, 2000).

6.3.3.4.2 The Main Digital Spatial Data For The NGII

The main digital spatial data identified as the fundamental data to build NGII and being made available through NCGI are:

1. Administrative spatial data, such as parcels of land in the automated cadastral register (AKR), the population registers that contain details about each individual citizen maintained by the Municipal Population Records (GBA), companies in the Chambers of Commerce Register (Handelsregister), and fundamental data sets for buildings (partly developed as the result of a tax-law for the assessment of real estate).
2. Nation-wide fundamental geometric/topographic data sets comprised of a Large Scale Base Map of the Netherlands (GBKN) and a database at a scale of 1:10,000.
3. Other fundamental data sets of the Netherlands, such as a land cover database (made by the Agricultural Research Department of the Netherlands (DLO-NL), land cover ecological database (made by the DLO- NL), a waterways data set (made by the survey department of the directorate general of public works and water management (Rijkswaterstaat)), a geology data set (made by the national geological survey (NITG-TNO)), an archaeology data set (made by the Institute for Archaeological Soil Exploration (ROB)), a cadastral map and other core data and thematic data sets (Onsrud, 2000).

6.3.3.4.3 The National Clearinghouse for Geographic Information

The National Clearinghouse for Geographic Information (NCGI) is a distributed network of organisations that produce, maintain and distribute spatial data using an electronic network (the Internet). The metadata service is a centralised system, which stores the metadata of all providers in a single clearinghouse server (Radwan, 1999), as shown in figure 6-3.

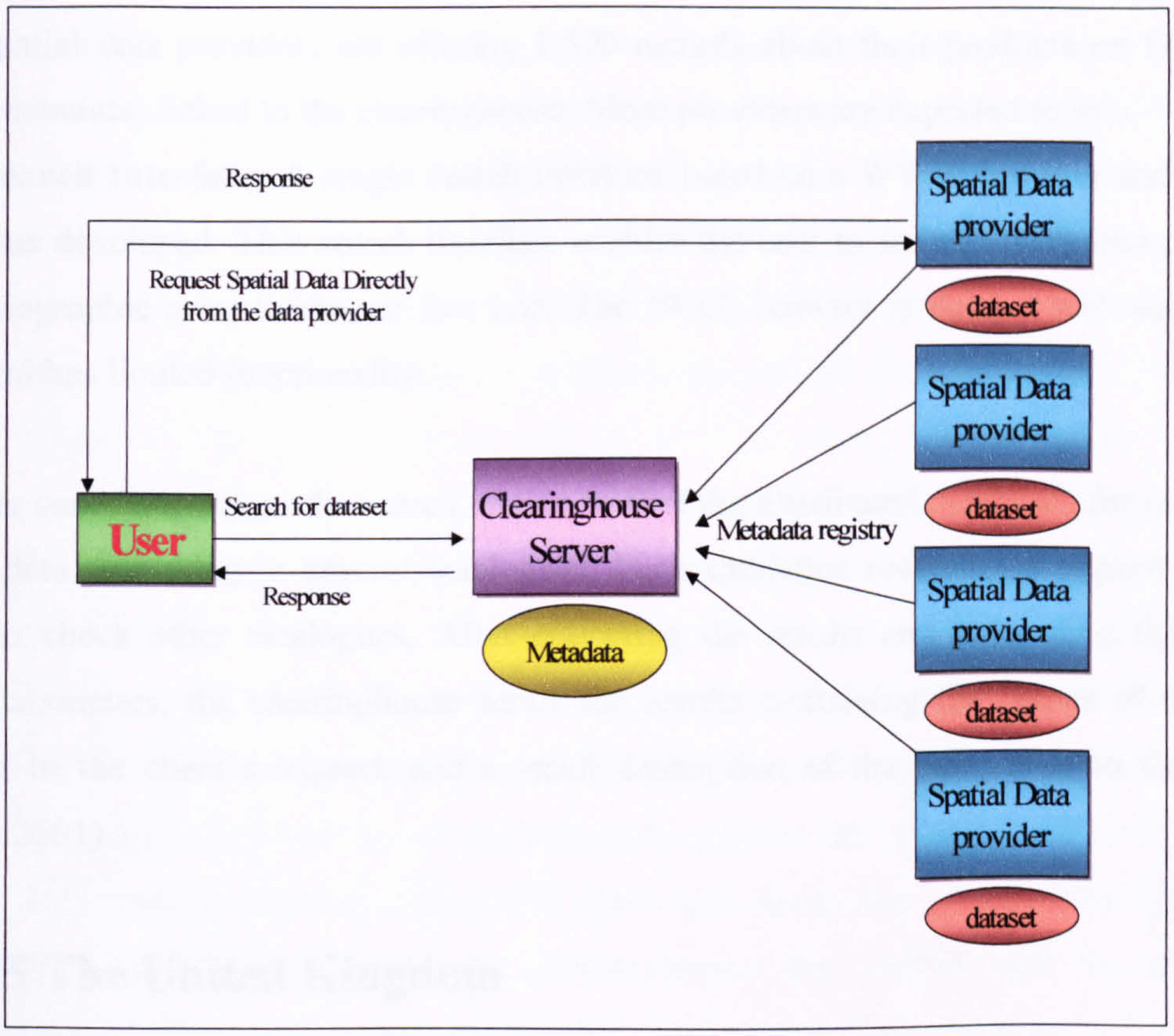


Figure 6-3 Conceptual model for the NCGI system architecture [Source Radwan, 1999].

6.3.3.4.4 The Main Components of The NCGI

The main components of the NCGI are:

1. **Metadata**; At the end of 1997 the first clearinghouse in the Netherlands was implemented with a metadata index called 'Idefix' - an Internet site through which users can access metadata and some spatial data. In 1998, the new organisation of the clearinghouse, the NCGI, was re-structured, the concept of the clearinghouse improved and the metadata system was changed into a system called GeoPlaza, which is more user-friendly. The European metadata standard CEN/TC 287 has been used from the beginning to support organisations in describing their spatial data (Radwan, 1999).

2. **Spatial Data;** At the time of writing this section (November 2001), more than 13 spatial data providers are offering 1,500 records about their products on GeoPlaza (metadata) linked to the clearinghouse. More providers are expected to join.
3. **Search Interface;** A single search interface based on a WWW browser and HTML was developed. This search interface enables the user to form a query based on the geographic area, theme, or free text. The NCGI browser is not yet well developed and has limited functionality.

The user sends a query to the search engine to find the distributed databases for requested spatial data, searching in several catalogues. Each catalogue receiving a request from a user can check other catalogues. After collecting the results and processing the user's query parameters, the clearinghouse sends the results containing the names of the data relevant to the client's request, and a small description of the data, back to the client (NCGI, 2001).

6.3.3.5 The United Kingdom

The United Kingdom of Great Britain and Northern Ireland consists of the union of England, Wales, Scotland and Northern Ireland with an area of 224,000 square kilometres and a population of 56.7 million. The United Kingdom is well covered with accurate and reliable digital maps at various scales. For example, the Ordnance Survey of Great Britain (OSGB) has completed the re-digitisation of topographic maps covering Great Britain, at the scale 1:50,000 since 1994, in partnership with the private sector. It has also completed the following digitisation of the following maps since 1995 (Masser, 1998):

1. More than 57,799 map sheets at the scale 1: 1,250.
2. More than 166,877 map sheets at the scale 1: 2,500.
3. More than 4,040 map sheets at the scale 1: 10,000.

6.3.3.5.1 Initiatives

The United Kingdom until recently did not have a national spatial data infrastructure (NSDI) or spatial data clearinghouse, despite the availability of an accurate geodetic network, a great deal of digital spatial data, the core of a digital national spatial database and great interest among many users and key players to develop a national spatial data infrastructure for the United Kingdom. Today, as much as 80% of the information collected in Britain is spatially referenced using, for example, national grid references and postcodes, which have evolved since the early 1960s as key data providing spatial references for many uses in Britain. But most of these spatial data are incompatible, cannot be combined, cannot be shared and are difficult and sometimes impossible to integrate (NGDF, 2000).

However, there have been a number of initiatives towards the development of a local and national spatial data infrastructure, although some of these initiatives are now obsolete:

1. In January 1989, the Association of Geographic Information (AGI) was formed, with a basic mission to promote and publicise the importance and benefit of geographic information and to help and represent the views of the entire spatial data user community. The AGI now has more than 7,000 members from government departments, the private sector, the utilities and the academic community.
2. In 1994 a joint working group of the Ordnance Survey of Great Britain, the Department of the Environment, Her Majesty's Land Registry (HMLR), the Valuation Office and the Local Government Management Board was set up to carry out a feasibility study and to develop a National Land Information Service (NLIS). As a result of the joint working group, the NLIS was developed as a joint initiative between central and local government. The aim of the NLIS is to provide estate agents with on-line land and property related spatial data held in different organisations in order to speed up and simplify the process of buying and selling properties. The Internet and the National Land and Property Gazetteer (NLPG) will also provide services to different data users, such as surveyors, estate agents, mortgage lenders, developers and insurers (NLIS, 2000).
3. The Ordnance Survey of Great Britain developed a Spatial Information Network Enquirer Service (SINES) that has been in full operation since 1994. The SINES is a simple metadata services that contain details of more than 600 spatially referenced databases held by more than 40 government agencies and related bodies. The initial concept of SINES was to provide useful information about the

availability of spatial data in Britain and where it is held, the creator and the contact address. It can be accessed by telephone, fax, or directly through the World Wide Web (WWW). Since July 2000, the SINES Service has been replaced by a new Metadata service, which will be discussed later in this section.

4. In 1995, the Ordnance Survey of Great Britain produced a document, which among its other objectives, plans to develop a National Geospatial Database (NGD), later named the National Geospatial Data Framework (NGDF). This aimed to link the Ordnance Survey national topographic databases to other distributed digital spatial databases held by other government agencies, such as the land and property information held by HM Land Registry, City Councils, Local Authorities, Coal Authorities, and the socio-economic data held by the Office for National Statistics, British Geological Survey, Environment Agency, Valuation Office and others (Masser, 1998).

6.3.3.5.2 The National Geospatial Data Framework

Following the Ordnance Survey's framework document, the National Geospatial Data Framework (NGDF) was launched as the National Geogspatial Database (NGD) initiative in 1995 at an Association for Geographic Information seminar. In June 1996, a well-attended seminar was held, at which participants discussed and agreed on the initiative guidelines. The outcomes of this seminar were presented at the Association for Geographic Information in 1996 (NGDF, 2000). Since then, there has been formal support and encouragement from British ministers for the government departments to work together ("joined up Government"). The Secretary of State for the Environment has asked the Ordnance Survey of Great Britain to take the lead in promoting more co-orporation between spatial data providers and users across the United Kingdom. The OS is also tasked to bring together all UK research and development initiatives into the main National Geospatial Data Framework (NGDF) programme.

In the meantime it has been argued that the success of the United Kingdom NGDF can only be achieved if common geographic information standards and metadata are developed, accepted and implemented by all participants, and commitment are gained from all participants to make all spatial data available and accessible through a common network. Therefore, following discussions between the Ordnance Survey and a large number of other interested parties in the United Kingdom, the NGDF Board (led by the Ordnance Survey), the NGDF Advisory Council (led by AGI) and the NGDF Task Force (working to the board) were established in 1996 (Masser, 1998).

6.3.3.5.2.1 What is NGDF?

As discussed above, the National Geospatial Data Framework (NGDF) is the name given to the United Kingdom geospatial data infrastructure, which is still under development. The aim of NGDF is to enable better awareness of spatial data availability, improve data quality, improve access to the data, integrate spatial data by using common geographic information standards and metadata and avoid duplication of spatial data. The NGDF is not a government executive order yet, but it is a co-operating agreement between different ranges of government departments, private sectors, academics, users and individuals (Masser, 1998). NDGF will not create a physical framework or deliver data sets, services or products, but it will help facilitate value-added data and services by enabling the combination of data from multiple sources (NGDF, 2000).

6.3.3.5.2.2 NGDF Structure

As discussed before, the NGDF Board was set up in 1996, when Dr David Rhind (Director General of Ordnance Survey at that time, now Vice Chancellor of City University, London) was appointed as the first Chairman of the NGDF Management Board (from 1996 to 2000). The NGDF Board is made up of the following organisations:

1. Association for Geographic Information (AGI).
2. British Geological Survey.
3. Central Information Technology Unit.
4. City of London University.
5. Her Majesty's Land Registry.
6. Interdepartmental Group for Geological Information.
7. Landmark Information Group Ltd.
8. Local Government Management Board.
9. National Joint Utilities Group.
10. Office for National Statistics

11. Ordnance Survey of Great Britain.
12. Ordnance Survey of Northern Ireland.
13. Property Intelligence Plc.
14. Registers of Scotland.
15. The Post Office.

On December 2000 a new Chairman of the NGDF Management Board was appointed. The new Chairman is Mr Len Cook, recently appointed as the UK's first national statistician and head of the Office for National Statistics (NGDF, 2000).

6.3.3.5.2.3 Progress of NGDF

The NGDF work programme was divided into two phases:

1. Phase one from 1996 to 2001. This phase concentrated on laying the foundations and setting up preliminary services.
2. Phase two from 2001 and beyond. The phase will concentrate on refining the services and encouraging wide participation.

The progress of these phases and the national geospatial data framework (NGDF) programme in general was initially slow, both due to lack of funds and resources to carry out the work and due to differences in opinion over the strategic direction for the programme. According to the NGDF Web site, the following events took place (NGDF, 2000):

1. In April 1998 a workshop was held in Britain to discuss and develop a strategy for the NGDF programme. The workshop resulted in the development of a strategic plan for NGDF for the United Kingdom.
2. In Autumn 1998, the Ordnance Survey of Great Britain managed to obtain funds under a National Interest Mapping Service level Agreement (NIMSA) to establish a central management team to manage the NGDF programme of work and to promote its implementation.
3. In January 1999, the Ordnance Survey of Great Britain managed to obtain funds from the Invest to save budget being provided by the treasury to help develop the

NGDF programme and to bring together more public service bodies together. With these funds NGDF is now in a position to realise its strategic goals.

4. In July 2000 the AskGIraffe Data Locator (metadata service) was launched by Minister Patricia Hewitt at a special event in London. Now AskGIraffe can be considered as a queryable spatial data clearinghouse.
5. On September 2000 the AskGIraffe Data Integrator (the United Kingdom Standard geographic base (UKSGB) service) was launched by Dr Robert Barr at the plenary session of the Association for Geographic Information Conference at GIS2000. The aim of this project is to link (using hotlinks) different organisations' web sites to provide a more integrated solution and enable the user to access data directly from the UKSGB Gateway and cross relate information between the different reference systems. (NGDF, 2000).

6.3.3.5.2.4 NGDF Activities

The NGDF programme has two major activities, which are currently underway. They are:

1. Metadata Service

The NGDF board have developed guidelines to promote the development and implementation of metadata that provide a consistent and simple method of documenting any spatial data resources in the United Kingdom. The development and implementation of the UK metadata system was carried out following extensive research into existing metadata standards, guidelines and workshop in which data producers were encouraged to compile metadata relating to their spatial data sets. The system is in line with the ISO/TC 211 metadata, the CEN/TC 287 Draft European Standard, the United States Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM) and Dublin Core - Online Computer Library Centre. At the time of writing this section (March 2001), 42-metadata elements have been identified as necessary for documentation at the discovery level. About 16 of those metadata elements will be mandatory for documentation and a further 7 are conditional, depending on the context; the remainder are optional. These compulsory elements cover title, theme, date, extent, access constraints, nature of the resource, how to obtain additional information and data supply

(NGDF, 2000). The metadata service is now using the AskGIraffe Data Locator. This service depends on the Internet and the metadata, which are submitted by each spatial data provider to one of a family of database nodes (servers) maintained by various spatial data providers located in England, Scotland and Wales for regional nodes and local government for community nodes (AskGIraffe, 2001).

2. The United Kingdom Standard Geographic Base

The NGDF is supporting the development and implementation of general geographic information standard. The UKSGB is an initiative that aims to supply spatial data providers and users with a geographic standard and consistent approach to commonly used spatial data in the United Kingdom. The UKSGB will be a good source for the NGDF programme and will improve the access, quality and consistency of spatial data in the UK (NGDF, 2000). At present the IOS/TC 211 is proceeding with the development of various digital geographic standards. Since the United Kingdom is a P-member of this committee, the ISO/TC 211 standards can be used and incorporated within the UKSGB.

6.3.3.5.3 The Charter of the UK Strategic Alliance

In January 2001, Vanessa Lawrence, the Director General and CEO of the Ordnance Survey of Great Britain, announced in a paper presented to the Seventh United Nations Regional Conference for the Americas (New York 22-26 January 2001) that "the Charter of the UK Strategic Alliance" will replace the NGDF. This replacement will involve most of the spatial data providers, spatial data integrators, hardware and software providers in the UK, application service providers and the Government in order for the UK NSDI to succeed. According to Lawrence, the Strategic Alliance's key members will be:

a. Data providers, which include the Ordnance Survey of Great Britain (OSGB), Her Majesty's Land Registry (HMLR), Improvement and Development Agency (IDeA), Ministry of Agriculture Fisheries and Food (MAFF), Office for National Statistics, GRoS and the British Geological Survey (BGS).
b. Data integration hub providers, such as the National Land Information Service (NLIS), the National Joint Utilities Group (NJUG) and Vodafone.

c. Geographic information system and imagery application providers, for example ESRI, LaserScan, MapInfo, AutoDesk, Oracle, ER Mapper, ERDAS and ZI maging.
d. Application service providers represented by Landmark.
e. The Government, including Department of Environment, Transportation, and Regions (DETR) and information age champions.

6.3.4 South and North America

6.3.4.1 Colombia

As a first step toward the development of a national geographic information network (RING) in the republic of Colombia, a national committee for the standardisation of geographic information was created in April 1997. The Colombian standards national body (ICONTEC) sponsors this committee. The RING initiative was a government, academic and private sector effort, which is co-ordinated by the Instituto Geografico Agustin Codazzi (IGAC). In July 2000 the RING preliminary initiative became the Colombian Spatial Data Infrastructure (ICDE) as a result of an agreement signed by the main spatial data providers and users. At the present time, IGAC is responsible for ICDE co-ordination and working to build the fundamental pillars of the ICDE (Borrero, 1999).

The aim of the ICDE is to create distributed spatial data directories (clearinghouses) linked by a network system that connects producers, administrators and users electronically, through the Internet. During 2000, ICDE installed two clearinghouse nodes based on training materials and software provided by the U.S. FGDC. The Colombian datasets consist of the following eight basic themes: ground control points, transportation, hydrography, cadastre, relief, vegetation and land use, administrative, political areas and geosciences. These basic data will be linked by a network using the Internet to provide the foundation required to developing multipurpose spatial data nation-wide. The government agencies are the main producers of spatial data and agreed to co-ordinate the collection of nation-wide of spatial data for the following small-scale maps at scales of 1:100,000, 1:500,000 and 1:25,000. And then create a seamless digital database from the result. All digital spatial data produced by government agencies will be available to the public, but all with copyright restrictions for any kind of use, whether commercial or not. Users are required to pay a fee to the producer (these fees range between 5% to 10%

of the production cost of the data being used). The purchase price depends on the data provider, the type of data and the number of licences required, etc. Analogue data sets are sold at a lower cost (1% to 5%) (Onsrud, 2000).

The agencies involved in collecting and co-ordinating spatial data in Colombia, are:

a. Instituto Geografico Agustin Codazzi (IGAC), in charge of producing and updating topographic maps, cadastral and agrological information.
b. Instituto de Investigaciones en Geociencias, Mineria Quimica (INGEOMINAS), in charge of geologic, geophysical and mining information.
c. Departamento Nacional de Estadistica (DANE), in charge of census information.
d. Instituto de Estudios Ambientales (IDEAM), in charge of environmental studies.
e. Empresa Colombiana de Petroleos (ECOPETROL), the national oil company.
f. Empresas Publicas de Medellin (EEPPM), the biggest utilities company in Colombia (IGAC, 2001).

The vision of the Colombian SDI is to incorporate metadata, clearinghouse, standards and core spatial data. They are examining the geographic information standardisation that is being developed currently by ISO/TC 211 (in which Colombia participates as an observer member) and the U.S. FGDC communications technology standards (Z39.50) (Borrero, 1999).

The main progress made so far is the development of the Colombian metadata standard NTC4611, which was developed jointly by private sector and public organisations, under the co-ordination of ICONTEC, based on the assessment and application of the United States FGDC, ISO/TC211 and European metadata standards elements.

6.3.4.2 Uruguay

Uruguay is developing a national spatial data clearinghouse (Clearinghouse Nacional de Datos Geograficos (CNDG)), which is a public service, operated by the private sector and co-ordinated by the Ministry of Transportation and Public Works (Ministerio de Transportes y Obras Publicas (MTOP)).

The aim of the clearinghouse is to provide digital spatial data, and 1:50,000 paper maps, as well as a GIS system for the ministry's own use. The primary digital spatial digital data being made available through the clearinghouse are digital cartography, original scale 1:200,000 and 1:50,000, with national coverage. These include hydrography, contour lines with 10m resolution, roads, political boundaries, vegetation cover, etc. Digital cadastral data from original scale 1:20,000, geological maps, land use, utilities network (electric, water, gas, telephone) are also made available. Access to some of these spatial data is being made available using the Internet and through the clearinghouse CNDG gateway, but very few are free, and the price is decided and fixed by the supplier. Moreover, some datasets are not intended for the general public, but are available only to the owners of the parcels. The Uruguay clearinghouse is adopting the U.S. FGDC metadata standards and Z39.50 (communicating and searching engine).

The Uruguay national spatial data clearinghouse is a co-operative project, which involves the following organisations:

1. The Ministry of Transportation and Public Works (MTOP)
2. National Telephone Company (ANTEL).
3. National Wastewater and Waterworks Company (OSE).
4. Milk producer (CONAPROLE).
5. Part of the Social Security System (CJJPU).
6. Ministry of Transportation and Public Works.
7. National Cadastre.
8. National irrigation co-ordination body (PRENADER).
9. Geology and Mining national administration body (DINAMIGE).

The clearinghouse is expected to co-ordinate all of these activities using standards (Lopez, 1999).

6.3.4.3 Canada

Over the last ten years or more the Canadian government agencies and private sector have developed a number of concepts and initiatives to create a Canadian geospatial data infrastructure (CGDI) to support, manage and improve the interoperability and accessibility of dispersed multiple digital spatial databases, using a wide range of methods and technologies. Current efforts are aimed towards the development and implementation of spatial data infrastructures including a spatial data clearinghouse. The Canadians call it a warehouse and it will be named warehouse in this section. The aim of the Canadian spatial data warehouse approach is to integrate and assemble multi-dimensional, multi-scale databases, including legacy data, satellite images, elevation data, feature data and other spatial data that are already available and reside in various computer environments throughout Canada. Another aim is to support the storage, processing, analysis, accessing of those spatial data within a continuous and seamless spatial data architecture using communications facilities (the Internet), and a distributed server architecture. The Canadian spatial data warehouse concept is driven by an open data access interface, where vector, raster, matrix and textual formats can be accessed through on-line network gateways, compliant with national and international industry and government standards (St. Laurent, et al., 1997).

6.3.4.3.1 The Canadian Initiatives

Owing to the availability of a large range of spatial data and a variety of GISs that reside on different systems with different data types, structures and formats, the Canadian government and private sectors carried out a number of initiatives, to develop and implement the Canadian geospatial data infrastructure (CGDI), including the spatial data warehouse:

6.3.4.3.1.1 The Delta-X System

The Delta-X concept was one of the first Canadian initiatives, developed by the Geographic Information Systems and Services Division of Geomatics Canada in the late 1980s. The Delta-X was a federated multi-database spatial information management system with a common integrated global conceptual schema definition, which was intended to create an infrastructure for GIS interoperability between different spatial data in a wide area network of heterogeneous spatial databases and to help spatial data users in identifying, accessing and sharing the source of data required for their applications (Allam, 1996).

As a major part of the Delta-X system, a spatial data warehouse and a metadata database were initiated. Also, a MetaView/GIS Spatial Browser (MV/GIS) was developed as a front end to the Delta-X to provide access to the metadata of various databases. The Delta-X system was developed before the Internet revolution; and it is based on a loosely coupled network of servers and clients that forms a LAN cluster. The clusters were connected to each other via a wide area network (WAN), which forms the backbone of the Delta-X system. Servers and clients can also be connected directly to the WAN or, via a dial-up line, to one of the servers. Delta-X performs multiple client-server roles as shown in figure 6-4 and 6-5.

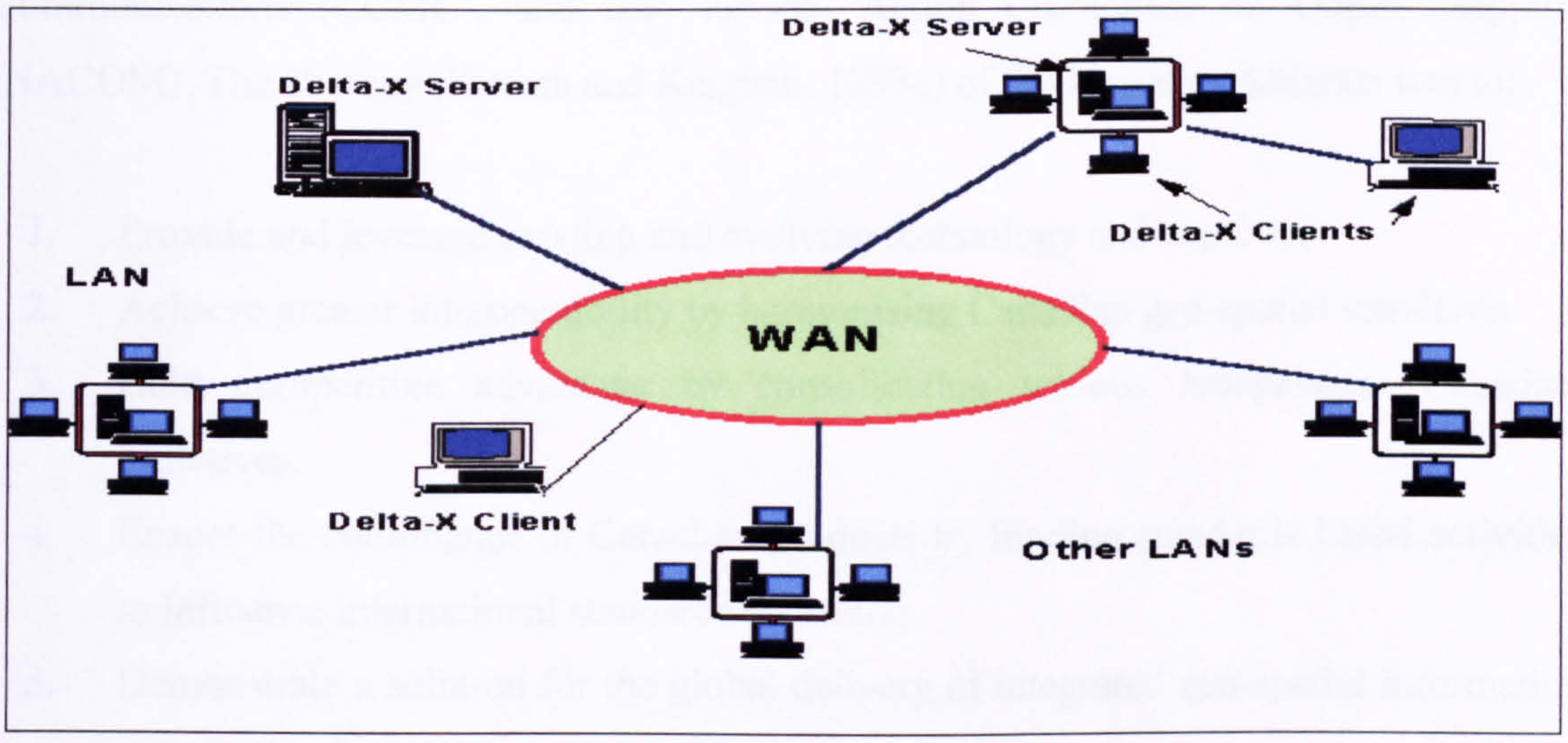


Figure 6-4 The architecture of Delta-X system [Source Allam, 1996].

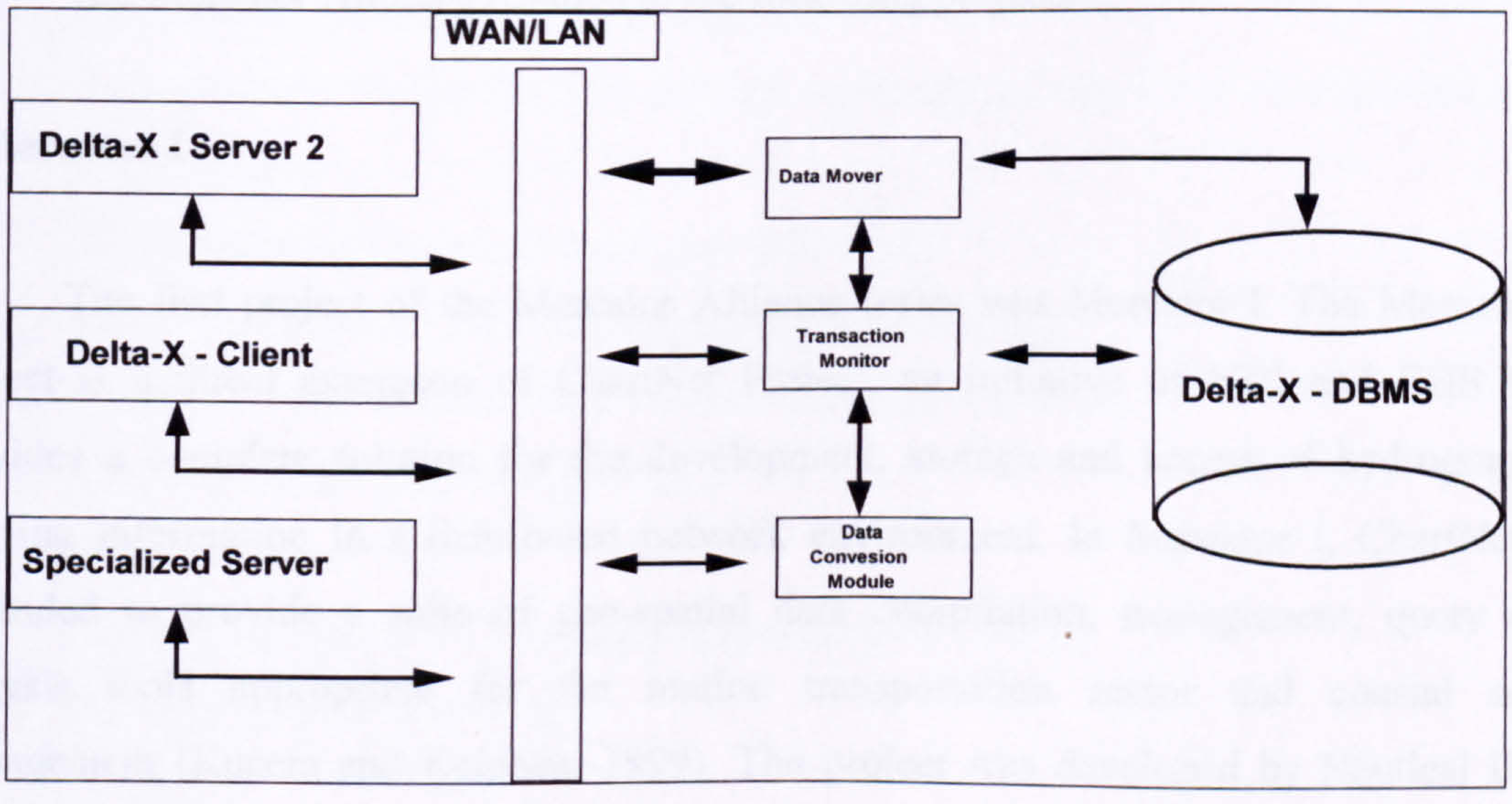


Figure 6-5 The Delta-X server [Source Allam, 1996].

6.3.4.3.1.2 The Mercator Alliance

The Mercator Alliance is a group of researchers, government agencies and private sectors that came together in 1996 to stimulate and co-ordinate the creation of a common spatial data management environment (infrastructure). The objective of the Alliance is to develop: spatial data products, spatial data standards, data warehousing, related software and contribute to the Canadian geospatial data infrastructure (CGDI) initiative. The development was funded by the Canadian Network for the Advancement of Research, Industry and Education Inc (CANARIE), the Canadian Hydrographic Service (CHS), the Atlantic Canada Opportunities Agency (ACOA), the Canadian Centre for Marine Communications (CCMC), and the National Action Committee on Ocean Mapping (NACOM). The strategy (Kucera and Keighan, 1998a) of the Mercator Alliance was to:

1. Provide and leverage existing and evolving technology and expertise.
2. Achieve greater interoperability by harmonising Canadian geo-spatial standards.
3. Gain competitive advantage by consolidating various independent Canadian initiatives.
4. Ensure the compliance of Canadian products by funding standards based activities to influence international standards evolution.
5. Demonstrate a solution for the global delivery of integrated geo-spatial information and applications.

The Mercator Alliance resulted in the following projects:

1. Mercator I

The first project of the Mercator Alliance series was Mercator I. The Mercator I Project is a direct extension of ChartNet Project, an initiative of NDI and CHS that provides a complete solution for the development, storage and access of hydrographic charting information in a distributed network environment. In Mercator I, ChartNet is expanded to provide a suite of geo-spatial data compilation, management, query and analysis tools appropriate for the marine transportation sector and coastal zone management (Kucera and Keighan, 1999). The project was developed by Nautical Data International (NDI) to co-ordinate the creation of a common geospatial data management environment, which included the following main objectives: the development of spatial data standards, networking protocols, connectivity tools, extensions to databases and human/machine interfaces and data warehousing. The development of the spatial data standards, as a critical component to the success of the infrastructure, was involved and influenced by national and international standards activities, such as SAIF, GIGEST, SDTS, S-57, ISO/TC211, ISO database standards (SQL3 and SQL/MM) and OGC interoperability (Kucera and O'Brien 1997).

The Mercator I project has been instrumental in the development of a common data model for S-57 and DIGEST to facilitate the encoding, storage, access and exchange of maps and charts (O'Brien, 1997).

The main participants in the Mercator I Project include:

1. Canadian Hydrographic Service (CHS).
2. Department of National Defence (DND).
3. Nautical Data International (NDI) - *Lead Contractor.*
4. Natural Resources Canada (NRCan).
5. Oracle Canada Research and Development Centre.
6. IDON Corporation.
7. Logiciels et Applications Scientifiques, Inc. (LAS).
8. Universal Systems Ltd. (USL).
9. Compusult Limited.
10. Ice Centre of Environment Canada (ICEC).
11. Canadian Network for the Advancement of Research, Industry and Education Inc (CANARIE).
12. Atlantic Canada Opportunities Agency (ACOA).
13. Canadian Centre for Marine Communications (CCMC).
14. National Action Committee on Ocean Mapping (NACOM).
15. Data Warehouse Technologies Ltd.
16. Holonics Inc.
17. Centre International de Recherche en Infographie (CIRI).
18. Mercator Systems Ltd (MSL).

2. Mercator II Project

The Mercator II project (MARINET) used Mercator I as a base to build upon. It was developed for marine purposes as a real-time system that assimilates information from a series of monitoring networks that can be used to plan for maximisation of shipping and hazard avoidance with a common theme of real-time computation and analysis. One of the Mercator II projects is MARINET which is a predictive system rather than reactive. MARINET goes beyond 2-D geographical space, which has been the focus of past projects, to 4-D space that includes time. MARINET will support the integration of diverse data formats within the same data store and demonstrate the benefits of a more efficient data management environment for accessing data from a large warehouse of multidimensional data. MARINET will also provide a uniform interface for external users while imposing no constraints on the data providers (Kucera and Keighan 1999).

3. Mercator III Project

Following the success of the first two projects (Mercator I and Mercator II), Mercator III was developed in 1997. The Mercator I and II data and concept were used as a base to extend other aspects of spatial data applications, but Mercator III is considered as the next generation of technologies and smart applications. It is intended to create virtual warehouse and knowledge-based methods and dynamic multimedia for the Canadian geospatial data infrastructure (CGDI). The projects were originally built for the Department of National Defence (DND) and the Natural Resources Canada, and then migrated to commercial application. Components of Mercator III project will provide services such as Dynamic Data Access through a multiscale spatial data warehouse giving users the ability to create new views or products dynamically as they come into demand. One of the Mercator III projects is the Integrated Multiscale Geospatial Data Warehouse Project, which links metadata content with stored procedures in a data warehouse environment to provide a means to create flexible, on-demand spatial information products (Kucera and Keighan 1998b).

6.3.4.3.2 The Canadian Geospatial Data Infrastructure

The Canadian geospatial data infrastructure (CGDI) is a government-driven project, led by the Inter Agency Committee on Geomatics (IACG), which was formed from 16 federal government agencies, as mentioned above. Most of the multi-spatial data collected as part of the Mercator projects and other government and private sector projects will be linked and integrated to be part of the Canadian geospatial data infrastructure. The aim is to create a Canadian geospatial data infrastructure to provide interoperability between different spatial data source and to support the exchange of data using the Internet, to reduce duplication of effort in collecting and producing spatial data, and more importantly to empower the economy, protect and enhance fisheries, wildlife and their habitat; ensure healthy and safe water, air, and land for all, manage and exploit water, forest, and mineral and natural resources, heritage and futures (3I, 2000). Figure 6-6 illustrates the vision of CGDI.

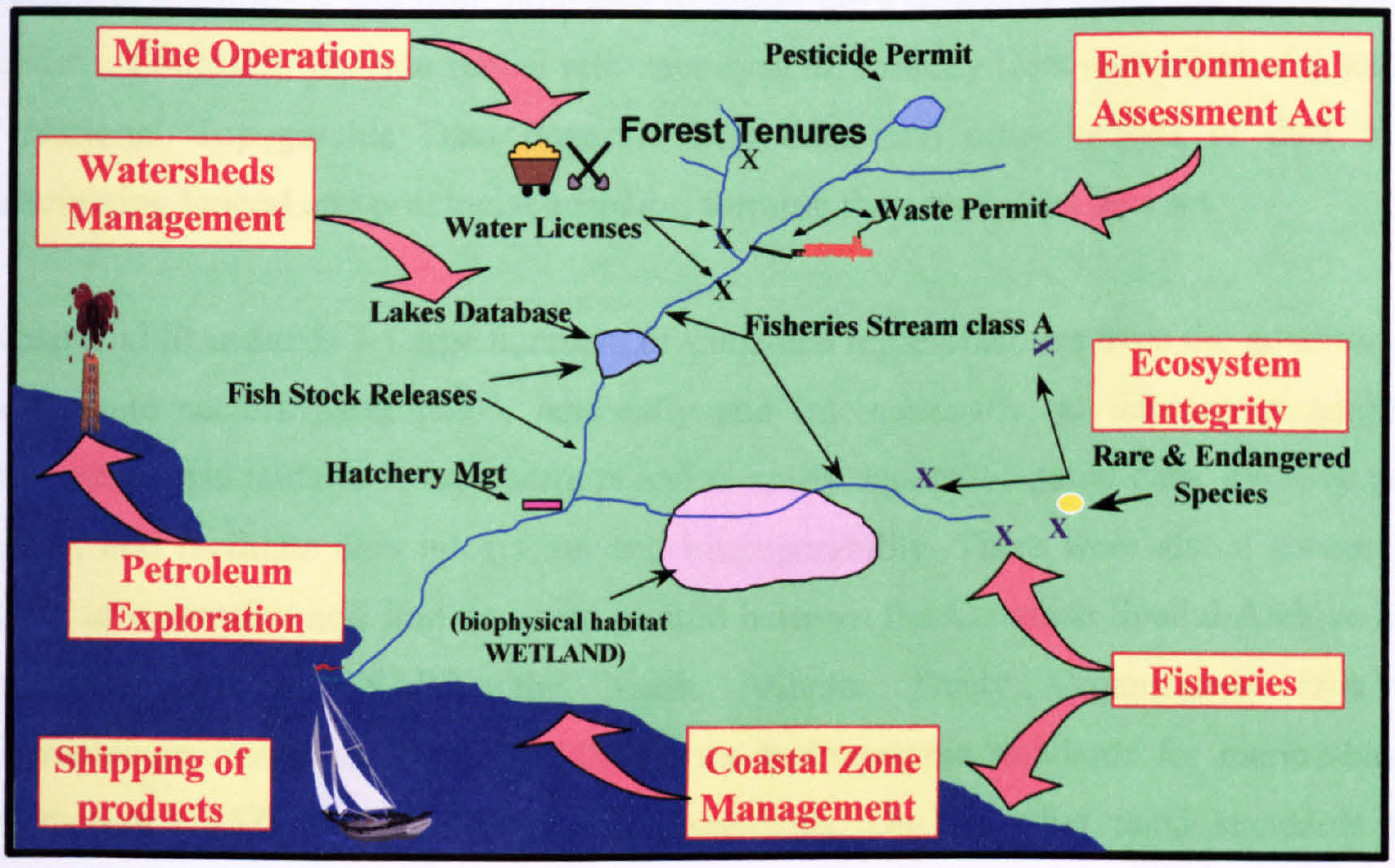


Figure 6-6 CGDI as supporting decision-making for sustainable development [Source Kucera and Keighan, 1998a].

The development and implementation plans of the CGDI over the next 10 years and beyond, as proposed by the Information Interoperability Institute (3i) team, will be as follows:

1. During the first two years CGDI will provide a bridge between the requirements of users and appropriate offerings of the providers of spatial data and information.
2. By the end of five years, CGDI should have considerable impact on organisations making use of it and be driving the organisational changes necessary for the efficient operation of the infrastructure.
3. By the end of ten years, CGDI should have become part of everyday life for all Canadians, from specialists to the general public.

To create the CGDI, the IACG used the following five thrusts (Kucera and Keighan1999):

Access to Spatial Data - The Department of National Defence and the Natural Resources Canada, in co-operation with other agencies and industry, developed key technical components for the CGDI to enable Canadians to access vast quantities of spatial data through the information highway using the Internet.

Framework Data - It has been proposed to group the Framework Data into three layers: Geodetic Control to provide spatial reference system, Primary Data comprised of a subset of National Topographic Data Base (NTDB) data, and other subsets of data from participating federal and provincial agencies, forming the core spatial data set.

Geospatial Standards – Large numbers of Canadian representatives from the government and private sectors participated, nationally and internationally, to develop geographic information standards to reduce barriers and simplify access to spatial data, improve data quality, and facilitate data integration and interoperability. There were also a successful efforts to harmonise and find common ground between the Canadian Spatial Archive and Interchange Format (SAIF), the North Atlantic Treaty Organisation (NATO) geographic/geomatics standards (DIGEST), the hydrographic standards for marine-based information (S-57) and the ISO/TC 211 standards. On the other hand standards for Metadata are also being developed.

Partnerships - To develop partnerships between various government agencies and industry, collaborative agreements and projects were established to collect spatial data, make it more widely available and create a large range of different spatial data applications.

Supportive Policy Environment - As more and more spatial data providers and users joined and understood the benefits of the infrastructure, the attitudes of many people changed and tensions reduced. This change in thinking made data access easier and encouraged a wide range of data providers and users to participate. Figure 6-7 shows the complete and integrated CGDI system.

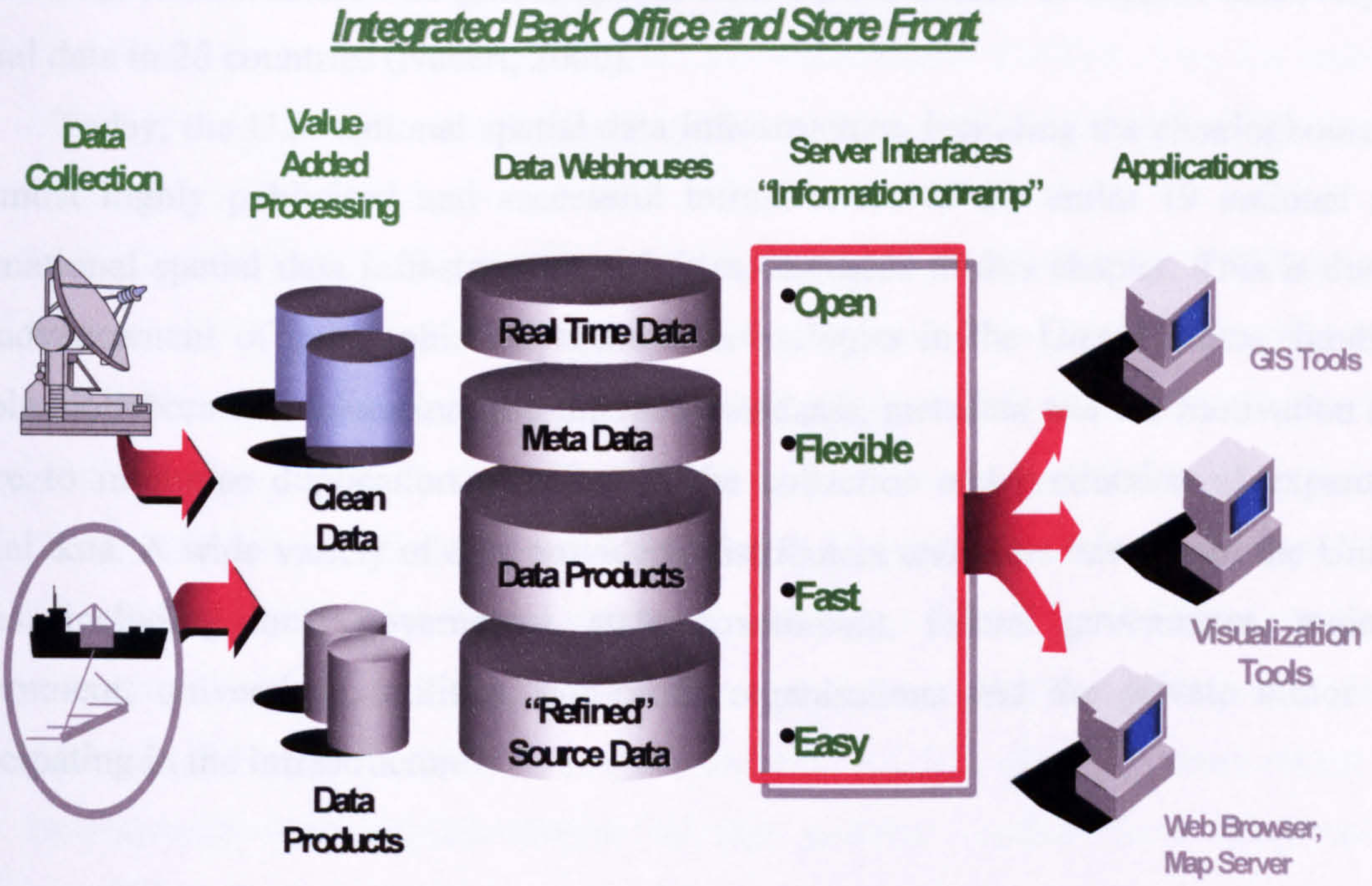


Figure 6-7 The complete CGDI ***[Source Kucera and Keighan, 1998a].***

The CGDI environment can be either central or distributed and will be accessible over the Internet network through Java and XML repository (catalogue) browsing tools.

6.3.4.4 The United States of America

Spatial data collection, production, management and dissemination in the United States of America is a multibillion-dollar business; the U.S. Federal government spends about 4 billion dollars a year on spatial data. However, many of these budgets may have been spent on duplicate collections of expensive digital spatial data that already exist. A critical national need to solve duplication problems, improve means for collecting and sharing spatial data was recognised by the former U.S. President Bill Clinton in Executive Order 12906 on the 11th April 1994. The Executive Order called for the establishment of a national spatial data infrastructure (NSDI) to support efficient collection, management, easy access to and sharing of digital spatial data and to facilitate new analysis to meet national needs. The Federal Geographic Data Committee (FGDC) established the national spatial data clearinghouse as a major component for the national spatial data infrastructure. The clearinghouse is a distributed network of spatial data procedures, managers and users linked electronically (FGDC, 2001). This clearinghouse is used in both the U.S. national spatial data infrastructure and global spatial data infrastructures to support discovery of spatial data in 26 countries (Nebert, 2000).

Today, the U.S. national spatial data infrastructure, including the clearinghouse, is the most highly publicised and successful infrastructure of the entire 19 national and international spatial data infrastructure activities discussed in this chapter. This is due to the advancement of geographic information technologies in the United States, funding, people, collaboration, education, the Internet, standards, metadata and the motivation and desire to minimise duplication of effort in the collection and production of expensive spatial data. A wide variety of data providers, distributors and users throughout the United States, including local government, state government, federal government, regional government, universities, utilities, non-profit organisations and the private sector are participating in the infrastructure.

6.3.4.4.1 Initiatives and Background

Over the last decade, thousands of organisations and individuals have contributed their ideas, efforts and research to break the barriers of spatial data sharing and to develop a nation-wide spatial data infrastructure. Examples include the clearinghouse project undertaken by the U.S. Geology Survey (USGS) that has now evolved into the NSDI clearinghouse operated by the FGDC, the Alexandria digital library project carried out by the University of California Santa Barbara (UCSB) and the GeoWeb project conducted at the University of Buffalo (Pleuwe, 1997).

The FGDC gaves a brief history of initiatives and activities towards the development of national spatial data infrastructure (FGDC, 1997a):

1. In 1990 the Office of Management and Budget (OMB) issued a revised circular A-16, which called for the establishment of an interagency co-ordinating committee, called the Federal Geographic Data Committee (FGDC), to develop a national digital

spatial information resource, with the involvement of federal, state, and local governments.

2. In 1992 FGDC initiated work on metadata standards and formed a liaison working group to communicate, investigate and co-ordinate between the FGDC and the private sector.
3. In 1993, former Vice President Gore's national performance review report called for the establishment of a national spatial data infrastructure (NSDI). Also the national GeoData policy forum and the work group on state and local partnership with the FGDC were established.
4. In 1994, the U.S. NSDI was officially launched by the Executive Order 12906 to co-ordinate the spatial data collection and management activities between governmental and non-governmental organisation. The order required that all federal agencies that produce spatial data should document new spatial data sets produced after January 1995 using the content standards for digital spatial metadata. The Executive Order 12906 defines NSDI as *"the technology, policies, standards, and human resources necessary to acquire, store, distribute, and improve utilisation of geospatial data"* (Clinton, 1994). The FGDC, local, state, regional and federal governments started the development and implementation of the national spatial data infrastructure immediately after the executive order and guidelines for implementing the clearinghouse were issued by the FGDC. In August 1994 the Open GIS Consortium (OGC) was founded to create interoperability specifications and open systems approaches to spatial data processing.
5. In 1995 the FGDC sponsored the national GeoData forum, which was held in Crystal City, Virginia. This meeting focused on building partnerships for the NSDI. In the same year, FGDC became a member of the OGC and the FGDC framework concept was approved as proposed by the working group's report.
6. In 1996, representation on the FGDC steering committee was broadened to include:
   a. International City/County Managers Association (ICMA)
   b. Inter-tribal GIS Council (IGC)
   c. National Association of Counties (NAC)
   d. National League of Cities (NLC)
   e. National States Geographic Information Council (NSGIC)
   f. University Consortium for Geographic Information Science (UCGIS)
   g. OpenGIS Consortium (OGC)

h. 31 State Co-operating Groups

7. In July 1996, a prototype for a clearinghouse node with geographic search capability was demonstrated at the Urban and Regional Information Systems Association (URISA) conference and pilot tested. By August 1996, approximately 200 clearinghouse server nodes, not all of them remotely searchable, were directly linked to the FGDC national spatial data clearinghouse. In February 1996, a review of the implementation of metadata in the clearinghouse was conducted throughout the community of spatial data users. The review concluded that a number of effective software tools to help in metadata collection and a refinement of the standard were needed to make implementation easier. In September 1996, the work began to refine the standard in co-ordination with the International Standards Organisation (ISO).
8. In 1997 it became evident that the NSDI original plan needed refinement. Therefore the FGDC published a new strategy for the NSDI. The new strategy was developed with broad input, not just from the federal agencies whose activities were the subject of the executive order, but from many other organisations, universities, private sectors and individuals.
9. In 1998, "*Geographic information for the 21st century: Building a strategy for the nation*" was published by the National Academy of Public Administration.
10. In 1999, the GeoData Alliance organisational initiative was established to build better relationships between organisations and to support the continuing development of the NSDI.
11. In 2000, the FGDC secretariat became increasingly involved in international standardisation efforts including acting as host secretariat for the global spatial data infrastructure.

6.3.4.4.2 The Federal Geographic Data Committee

The federal geographic data committee (FGDC) was designated as the leading body to promote the availability, quality, requirements, collection, development, use, access, sharing, and dissemination of digital spatial data through a searchable on-line system among government and non-government organisations (FGDC, 2001). The FGDC is chaired by the Department of the Interior and composed of the following 17 cabinet and executive level agencies:

1. Department of the Interior.
2. Department of Defence.
3. Department of Agriculture.
4. Department of Energy.
5. Department of Health & Human Services.
6. Department of Housing and Urban Development.
7. Department of Commerce.
8. Department of Justice.
9. Department of State.
10. Department of Transportation.
11. Department of Transportation.
12. Environmental Protection Agency.
13. Federal Emergency Management Agency.
14. Library of Congress.
15. National Aeronautics and Space Administration (NASA).
16. National Archives and Records Administration.
17. National Science Foundation.
18. Tennessee Valley Authority.

6.3.4.4.3 The National Spatial Data Infrastructure Components

The national spatial data clearinghouse is the central component of the NSDI architecture and was also specifically mentioned in the Executive Order 12906 document discussed above. To better understand and appreciate the role of the clearinghouse, it is important to understand the FGDC's major activities in creating the NSDI. Figure 6-8 shows the five components or activities. These components form the building blocks of the infrastructure.

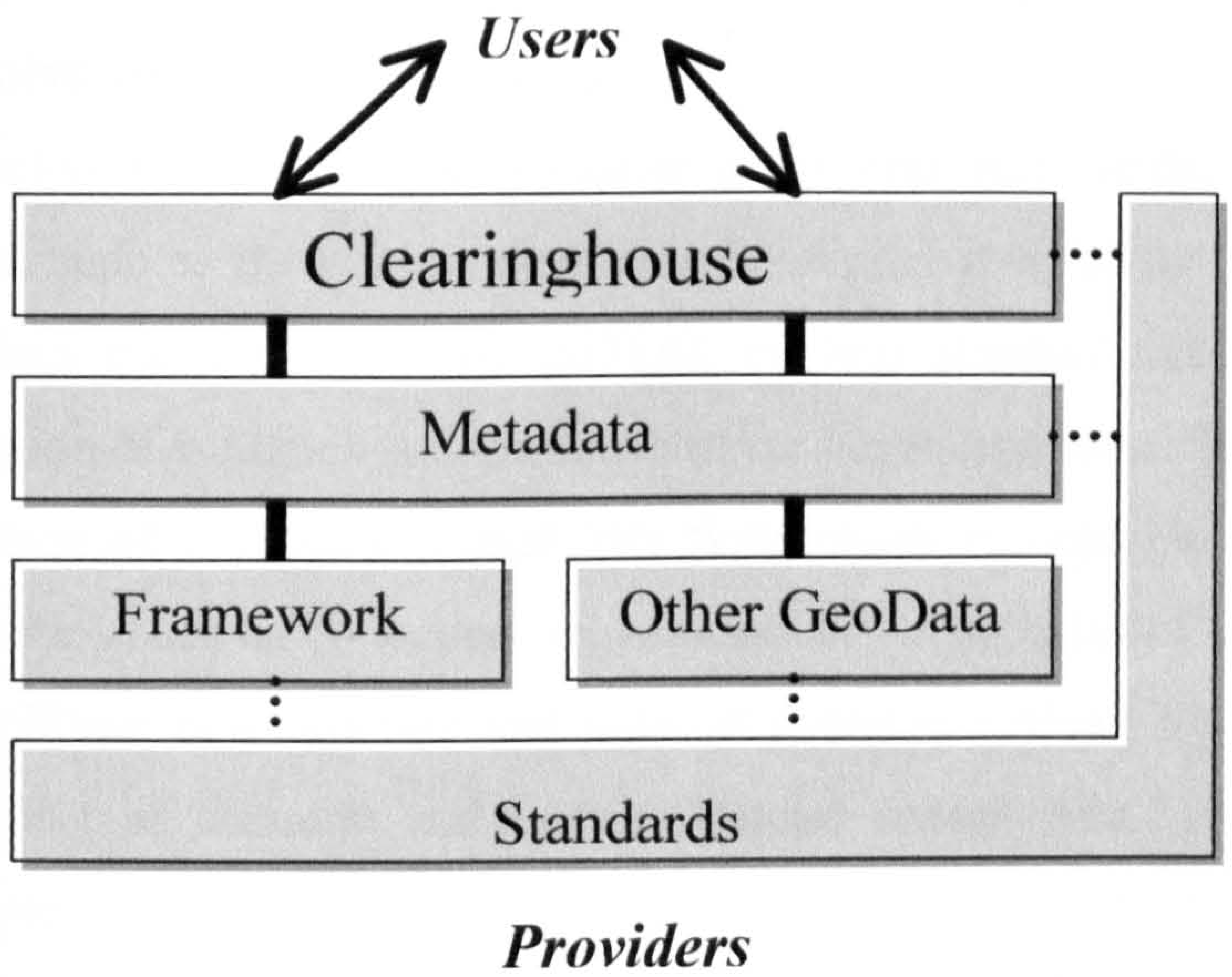


Figure 6-8 Relationship diagrams of the essential activities of the NSDI in the USA [Source Nebert, 2000].

The components being developed by members of the FGDC to create the NSDI can be summarised as follows:

1. The creation of a national spatial data **clearinghouse** with geographic search capability that provides the primary interaction between users and the spatial data.
2. The development of **metadata** to document the location of the spatial data, document the content and structure of the data, and provide the end-user with detailed information on its appropriate use. For example, the content and structure outline the information that must be included in a metadata record, which includes more than 220 items (composed of obligatory and optional items) that are intended to describe general digital spatial data adequately. These items are grouped into seven categories: identification information, data quality information, spatial data organisation information, spatial reference information, entity and attribute information, distribution information, and metadata reference information (Nebert, 2000). The metadata are stored on the clearinghouse nodes in a form of Hypertext Markup Language (HTML), eXtensible Markup Language (XML), Standard Generalised Markup Language (SGML), or text files, as discussed in chapter 5. Conversion tools are available for the data providers to convert and validate their

native metadata context into a CSDGM compliant metadata (e.g., ArcView metadata management system) (FGDC, 1999).

3. The development and implementation of several **standards,** including metadata standards, such as the content standards for digital geographic metadata (CSDGM), spatial data transfer standards (SDTS), content standards on cadastral data and classification of wetlands and the standard for vegetation classification.
4. The creation of a national spatial data **framework** to organise and improve spatial data activities such as collection, registration and integration of spatial data to reduce costs, facilitate new analysis and help in decision making by providing a readily available set of accurate and updated digital spatial data. The framework's key aspects are:
   a. Seven well known commonly used digital spatial data themes: geodetic control, elevation and bathymetry, hydrography, digital ortho-imagery, cadastral (land ownership information), transportation and government boundaries.
   b. Procedures, technologies and guidelines to support the integration and sharing of the digital spatial data.
   c. Institutional relationships and business practices to maintain and use the digital spatial data.
5. The U.S. national clearinghouse supports the discovery and access (through their metadata) of **other GeoData,** that do not conform to well known specifications and do not correspond to the seven framework themes, mentioned above, including unique scientific data, local maps, etc (Nebert, 2000).

6.3.4.4.4 The Clearinghouse Concept and Architecture

The United States of America is one of the largest country in the world, with a population of more than 250 million living on a land area of over 9,350,000 square kilometres (Masser, 1998). Owing to this vast size and based on various experiments conducted by the FGDC clearinghouse working groups, it was concluded that the national spatial data clearinghouse should be a decentralised system (distributed) of servers located on the Internet containing metadata that described available digital spatial data and using readily available web technology for the client-server architecture (FGDC, 2000).

The national spatial data clearinghouse contains a catalogue of locator records, spatial data, ordering mechanisms, map graphics for data browsing, and other detailed use information that are stored in the metadata entries. The spatial data being made available through the national spatial data clearinghouse are multipurpose vector and raster data that can be used for a large numbers of applications such as mapping, geographic information systems (GIS), land information systems (LIS) (cadastral application), statistical, image processing and so on. These spatial data may be stored at the site of the data provider or at clearinghouse server nodes throughout the country (Nebert, 1995).

The clearinghouse uses a variety of user interfaces with the same search capability and a common descriptive vocabulary (metadata), a common search and retrieval protocol and registration system for servers of metadata collections. The protocol used for the network search and retrieval is known as the American National Standard Information (ANSI) Z39.50 (ISO 23950) (FGDC, 1997b). It was initially developed by the library community and designed to support searching and retrieval of information (full-text documents, bibliographic data, images, multimedia) in a distributed client-server network environment. The Z93.50 protocol is independent of computer platform and permits migration from FGDC metadata to future international metadata being developed by the ISO/TC 211.

In general, spatial data can be searched using a single point-of-entry, or clearinghouse gateway, managed by the FGDC. At present, there are six gateways to access regional clearinghouse nodes. These gateways are located in Alaska Geospatial Data Clearinghouse (GDC), the EROS Data Centre (EDC) of the U.S. Geological Survey, ESRI-Redlands California, FGDC-Reston, the National Resource Conservation Services (NRCS) and NOAA Coastal Services Centre (CSC). All entry points or gateways have exactly the same lists of servers. The spatial data clearinghouse is implemented using a multi-tier architecture (see figure 6-9) as follows:

1. The first-tier (client) is realised by a traditional Web browser and native search client. The Web browser uses conventional hypertext transport protocol (HTTP) communications, whereas the native search client uses the ANSI Z39.50 protocol directly against a set of servers. According to Doug Nebert (U.S. geospatial data clearinghouse co-ordinator) a commercial Java-based clearinghouse client, "Metadata Browser," was released in September 1999 by MapInfo to provide

desktop access to the U.S. spatial data clearinghouse servers through a map and tab based search design.

2. The second-tier (gateway) architecture includes a World Wide Web to Z39.50 protocol gateway.
3. The third-tier (servers) architecture consists of Z39.50-compatible servers, which are implemented on top of XML document database or relational database systems, in which structured metadata are stored for search and presentation.

The Z39.05 protocol facilitates simultaneous query to several clearinghouse nodes, where the user builds a query and passes it to the gateway web server, then it is turned into requests to many clearinghouse servers. The query results are returned as HTML (or optionally SGML, XML, or text format) documents to the web client as titles of metadata entries that meet the search criteria. When the user selects one of the resulting headlines, he/she can access the metadata that resides on the clearinghouse node because each headline is linked with designated metadata by means of the Uniform Resource Locator (URL). If downloading of spatial data is allowed, the user can obtain the dataset in a pre-defined format using the file transfer protocols (FTP). The architecture required to make this work is described in the following figure.

Currently, the FGDC clearinghouse nodes allow users to make a query to five nodes simultaneously. This means, if a user does not know the appropriate node(s) to use, then the user will not find all the data unless he/she makes a query to all nodes. This limitation reduces the efficiency of finding the needed spatial data and adversely affects the query performance. However, a variant of a new Java search is being tested by the FGDC to permit search of the entire clearinghouse by selecting only servers to search based on geographic extent and FGDC metadata thematic "categories". In the meantime a new Java-based map search interface is being deployed at all FGDC gateways so the spatial data search can now be done by selection of place name, selection of a rectangular region on a map, or by co-ordinates, so the users will not need to decide which servers from over 240 to pick for the best possible results (Nebert, 2000).

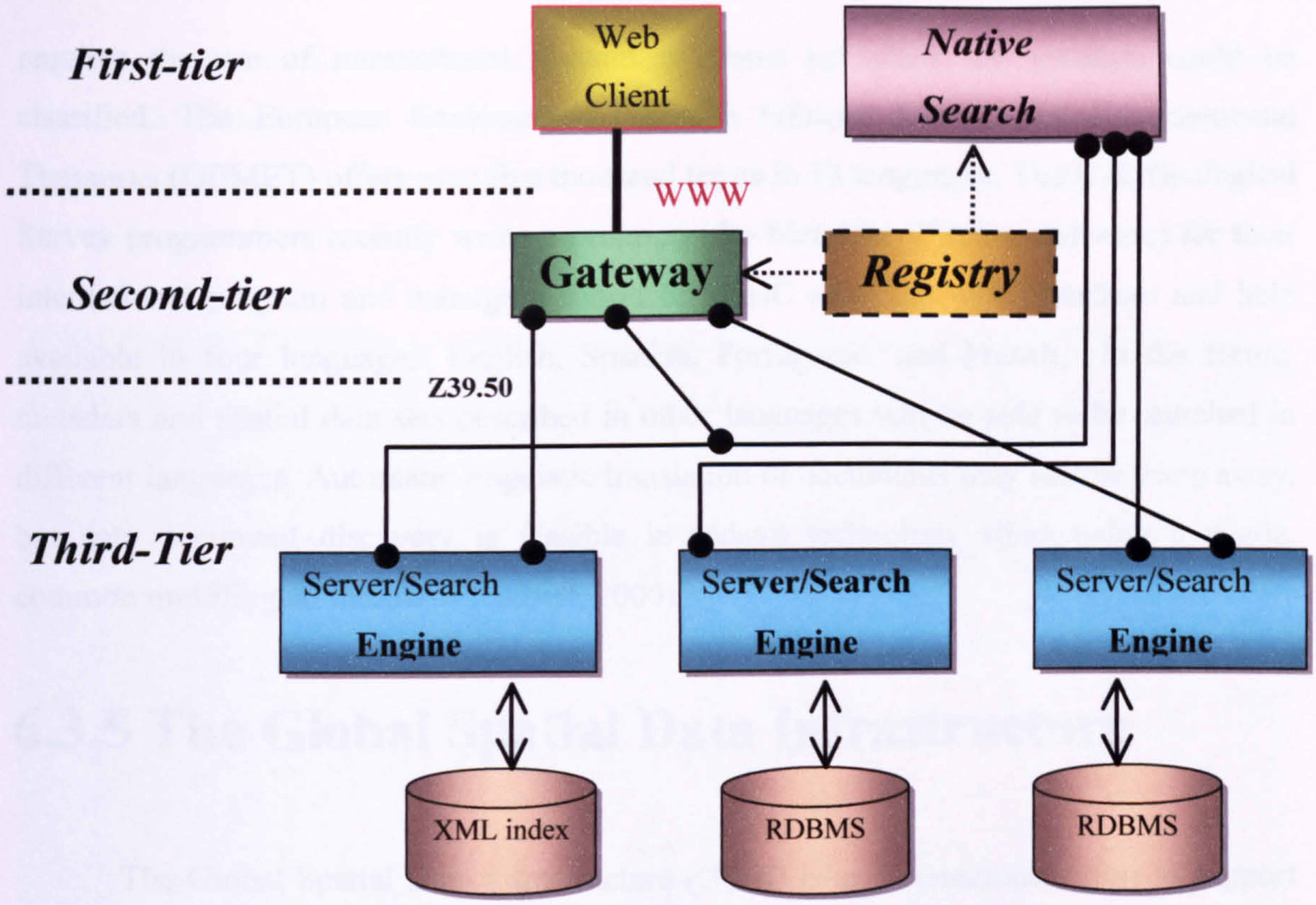


Figure 6-9 The U.S. national spatial data clearinghouse architecture [Source Nebert, 2000].

6.3.4.4.5 Summary

The U.S. national spatial data clearinghouse is in its sixth year of its development (1996-2001). During this period, the NSDI went through certain progresses and refinements to improve the infrastructure and the relationship between spatial data providers, distributors and users. NSDI in general is a successful infrastructure. It became a reality in the minds of not only many American people but also others worldwide. The clearinghouse employs a distributed architecture that permits search of a number of servers through a single interface. The distributed server architecture helps to avoid any single point of failure and potential overload that could happen with a more centralised clearinghouse. More and more organisations and individuals are joining and participating in this infrastructure and more server nodes have been implemented. Now there are more than 240 clearinghouse server nodes (January 2002) that provide data access, but this number does not include many other NSDI sites that are run by smaller units of a larger organisation. In addition, there is a migration toward treating metadata and data as interrelated and even being managed together within a single database. Searching spatial data using different languages is being considered by the FGDC. Multilingual search requires the use of international thesauri of terms by which all metadata could be classified. The European Environment Agency's GEneral Multilingual Environmental Thesaurus (GEMET) offers over five thousand terms in 13 languages. The U.S. Geological Survey programmers recently wrote a program (the MetaLite Window software) for their international program and manage a subset of FGDC metadata with interfaces and help available in four languages: English, Spanish, Portuguese, and French. In the future, metadata and spatial data sets described in other languages will be able to be searched in different languages. Automatic linguistic translation of documents may still be years away, but data document discovery is feasible in today's technology when using a single, common multilingual thesaurus (Nebert, 2000).

6.3.5 The Global Spatial Data Infrastructure

The Global Spatial Data Infrastructure (GSDI) is an international effort to support and promote compatible readily accessible global spatial data. The first initiative to create a GSDI cannot be exactly traced, but it can be concluded that the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil, in 1992, was the first step and main driver for the development of the GSDI. The Rio Summit discussed environmental deterioration and established the basis of a sustainable way of life in the next century (Agenda 21). The summit acknowledged that the availability of spatial data is critical for environmental decision-making and provides one measure to help protect the atmosphere and prevent pollution (Nebert, 2001). The GSDI held its first conference in Bonn, Germany, on 4-6 September 1996, where more than 60 representatives from the spatial data community around the world attended. In November 1996, an international seminar on global mapping was held in Santa Barbara, California, USA. The Santa Barbara Statement, prepared during this seminar, made a strong plea for the establishment of national and global mapping programs and the development of a global spatial data infrastructure (GSDI) (GSDI, 1999).

6. 3.5.1 What is GSDI?

The following definition of GSDI was adapted at the second GSDI conference, held in Chapel Hill, Northern Carolina, USA 19-21 October 1997: "...*The policies,* *organisational merits, data, technologies, standards, delivery mechanisms and financial and human resources necessary to ensure that those working at the global and regional scale are not impeded in meeting their objectives…*" (GSDI, 2000). Figure 6-10 defines GSDI visually.

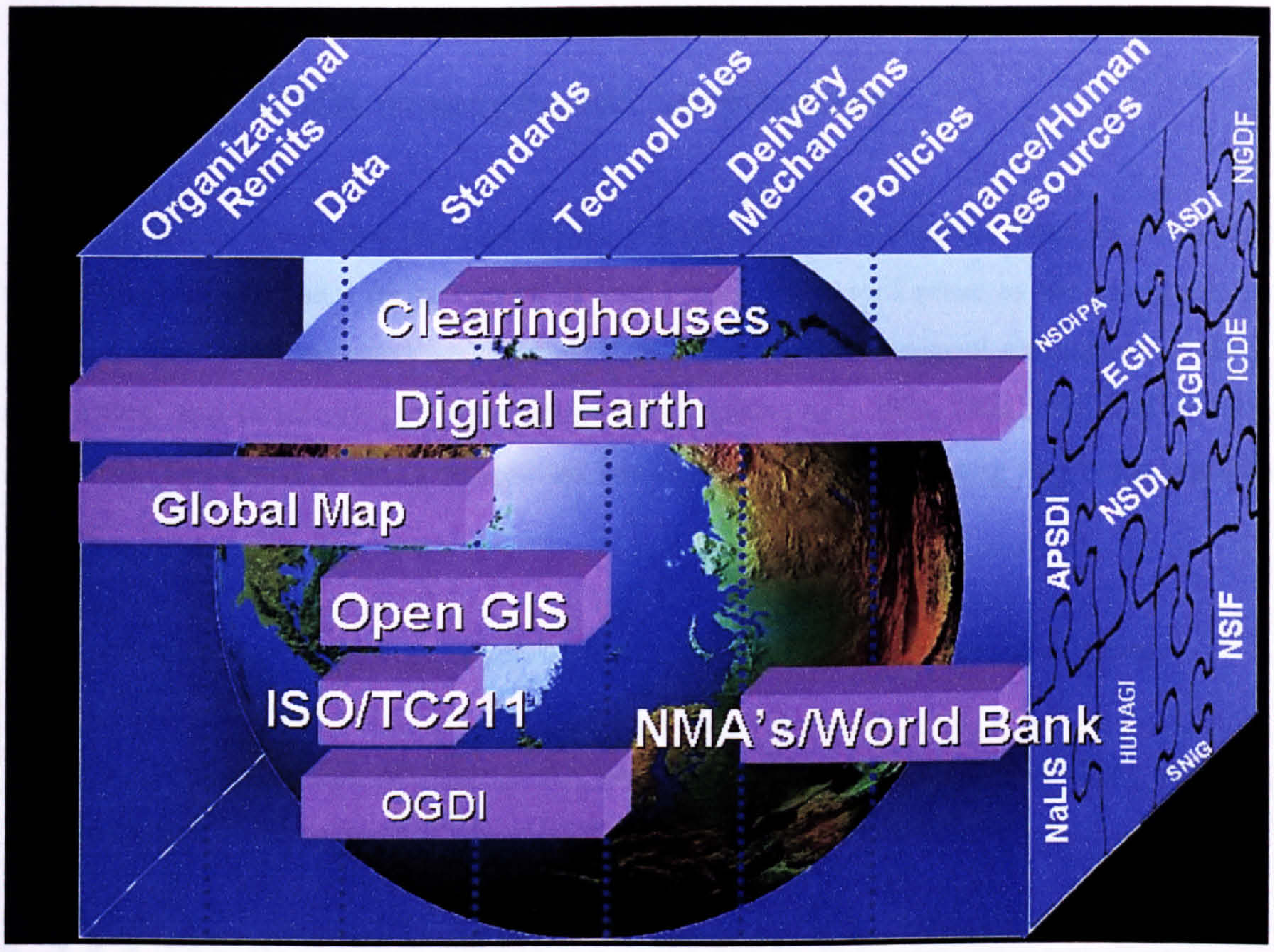


Figure 6-10 GSDI relationships [Source Reichardt, 2000].

6. 3.5.2 The Aim of GSDI

The primary goal of the GSDI is to discover and link local, national, and regional spatial data infrastructures into a global endeavour, and to highlight the need for multi-national co-operation to realise the promise of GIS technologies and spatial data in fostering sustainable development world-wide, through the implementation of globally compatible international spatial data infrastructures (GSDI, 2000). The aim of the GSDI will not be achieved without the development of common standards and metadata. Accordingly, GSDI, rather than develop its own geographic standards, identifies the best geographic standards being developed in national and international settings that can be applied at all scales of application, (such as the standards being developed by ISO/TC 211). In the meantime, the Technical Working Group of the GSDI is developing a dynamic electronic document that will assist countries and organisations in developing policies and technology that are compatible with national and global infrastructure initiatives (Nebert, 2000).

6. 3.5.3 The GSDI Management Architecture

The GSDI has a steering committee, comprising representatives from all continents to establish a permanent global umbrella organisation that will serve as the guiding body for the GSDI. This organisation is intended to bring together regional committee, national committee, and other relevant international institutions (e.g. ISO, OGC, ISCGM, ISPRS, ICA, etc). The GSDI steering committee has established the following two main working groups:

1. Technical working group, to advise the GDSI steering committee on technical issues.
2. Legal and economic working group, which comprises of a group of advisors for the GSDI steering committee on economic, legal, and funding issues.

6. 3.5.4 The Potential GSDI Spatial Data Providers and Users

There are a number of key players involved in GSDI activities, for example (Clarke, 1996):

1. The military (including Army, Navy and Air force).
2. The science and environmental communities.
3. The international development community.
4. National mapping organisations
5. Private sector.
6. Universities and education in general.

6.4 CONCLUDING REMARKS

There are a growing number of spatial data infrastructure initiatives throughout the world in recognition of spatial data's role as an essential national asset to serve economic growth, social and environmental interests; all heavily dependent on land related information. Most of the international, national and regional spatial data infrastructures (including clearinghouses) are government initiatives, for example the NSDI in the United States of America, the ANZLIC in Australia and New Zealand, the NCGI Netherlands, the SNIG in Portugal, The NaLIS in Malaysia, the NSIF in South Africa and the ICDE in the Republic of Colombia. On the other hand there are some initiatives that are driven by the private sector, for example the NGDF in the United Kingdom, the CGDI in Canada and the Uruguay clearinghouse (Nebert, 2001).

The worldwide initiatives discussed in this chapter (at the time of writing – November 2001) vary from a very basic idea or plan to very mature and successful spatial data infrastructures and clearinghouses. Most of the approaches of these initiatives are similar, despite differences in languages, institutions, technology, geographic information, users' requirements, etc. The U.S. national spatial data infrastructure (NSDI) is the most well known infrastructure and has been recognised as the leading spatial data infrastructure in the world. Most present SDI initiatives around the world use the United States of America NSDI as a model and incorporate many or all of its components. The other well-developed clearinghouses are the ANZLIC in Australia and New Zealand, the NCGI in the Netherlands, the CGDI in Canada and the NGDF (or now the Charter of the UK Strategic Alliance) in the United Kingdom.

The success of the U.S. national spatial data infrastructure was the result of high level support (The Executive Order 12906), availability of fundamental spatial data sets, funding, latest technologies, metadata standards, digital geographic information standards, a communications network (the Internet), expertise, and the involvement of powerful leadership (FGDC) that managed to stimulate co-ordinated and co-operative activities from the spatial data community to solve spatial data sharing problems, institutional issues and technical issues. The Charter of the UK Strategic Alliance is expected to be successful due to the small size of the country, the availability of good, reliable and comprehensive spatial data and the support of most of spatial data providers, spatial data integrators, hardware and software providers, application service providers and the Government.

The factors and components listed above must be given high priority when developing a strategy for a national spatial data infrastructure for the proposed Saudi national spatial data infrastructure. Most nations already produce digital spatial data and the ISO/TC 211 is developing metadata standards and a variety of digital geographic information standards, which can be used (perhaps with a small modification) by any ISO/TC 211 member. Also, the Internet network has become a worldwide major communication network, which can be used and accessed by anyone anywhere. Most, if not all, clearinghouses are now built on the Internet and use it as a backbone. Some components can be achieved easily, but others will need a lot of effort.

In the meantime the success of building and implementing a national spatial data infrastructure depends on the success of its clearinghouse. One of the most important issues to be considered in the development and implementation of a national spatial data clearinghouse is the metadata structure. The Clearinghouses architectures can be categorised into three different types:

The centralised clearinghouse, such as the Netherlands NCGI, stores the metadata of all spatial data providers in a single clearinghouse node. This type of service is normally easy to search, maintain, manipulate, update, monitor and control, because the description of the spatial data (the metadata) is stored in one place and managed by one management. It causes some burdens to the spatial data provider however, due to the fact that a different body not involved in spatial data collection, production and management manages the metadata system. Therefore, spatial data providers have to follow strict metadata protocols to describe their spatial data. Normally the spatial data has to be updated according to a defined plan to maintain currency, but update of the metadata requires complicated procedures by both the data provider and the metadata system management. Also, the centralised system is not usually searchable using the standard catalogue and clearinghouse techniques applied in the distributed systems. Centralised solutions can fit within a distributed framework. Purely centralised and isolated solutions do not promote regional or global search until they support common search protocols adapted by neighbouring nodes. The single centralised repository may be appropriate for the Netherlands (NCGI), but to stay current and usable in the European context, it would need to collaborate with other nodes in adjacent countries for a pan-European query to work in a distributed solution. But this would mean that NCGI would have to support common search protocols adapted by neighbouring European countries.

The distributed clearinghouse, such as is used in the USA, Canada, South Africa and the United Kingdom, is an open-market approach simply linking willing spatial data providers with interested users. In distributed clearinghouse systems architecture, most of the metadata is stored and managed by local data providers using nodes (servers) located on the Internet throughout the country or region. The distributed system requires each data provider to enter, manipulate, update, control and monitor his or her metadata. Searching for spatial data in a distributed clearinghouse is as easy as in a centralised clearinghouse, provided that the correct technologies, search software and a protocols are in place to allow sending multiple queries to several clearinghouse nodes at the same time.

The USA, Canada and Australia's clearinghouses employ the same search software, protocols and technologies, but their user interfaces vary in complexity. In fact, they are all moving to the same ISO metadata and linkage mechanism for global spatial data infrastructure (GSDI) compatibility. The burden of supporting metadata exists within distributed systems, but using new software such as ESRI's ArcCatalog this burden can be reduced in the distributed environment, where every spatial dataset holding site could become its own publishing node. The distributed system is considered more rigorous in its connection between the spatial data and the metadata system and has been applied successfully in e-commerce, data visualisation, and data access solutions. It also helps in avoiding common mode failure, or the potential overloads that plague some centralised clearinghouses.

The main benefits of a distributed clearinghouse system are:

1. Links between spatial data and metadata on the same system lead to current and even dynamic publication of metadata properties from the data.
2. The metadata are managed and supported by the spatial data provider, custodians or distributors, and tend to be more complete and correct than metadata sent away to a 'foreign' hosting service.
3. Distributed searches benefit from the power of the Internet, resulting in the ability to search millions of metadata records in a shared way by many machines, instead of inside a single enormous warehouse.

The hybrid clearinghouse, exemplified by the one in Australia, is a mixture of both centralised and decentralised clearinghouses to provide different levels of metadata to users. Basically any large-scale clearinghouse should have elements of centralisation and distributed (decentralised) management. In a hybrid clearinghouse, the metadata is stored in one place while details or other metadata are stored on several local servers at the sites of the spatial data providers. This hierarchy of the hybrid clearinghouse provides a more efficient search capability and gives the users the capability of comparing different datasets at the local and national level, but currency and update can be a problem.

Finally, it should be noted that with the advancement of computers, the power of the Internet, web site technologies, user interfaces, application programming interfaces, gateways, search engines, Java, XML languages and so on, the user will in the near future not notice difference between these three types of clearinghouses in the near future.

Due to the size of Saudi Arabia (over two million square kilometres) and the spread of the spatial data production, mainly between the Centre, East and West of the country, it is recommended that the distributed clearinghouse systems, as in the U.S. are used or the hybrid clearinghouse structure are used as a second choice. In the U.S. the decentralised model has worked well, after initial problems with server "holes" in the network. The U.S. approach has the benefit of being quite fault tolerant by having over 200 servers transparently acting as both data providers and in many cases mirrors. In Saudi Arabia similar conditions apply, although presently on a more limited scale.

The possibility of developing a hybrid system involving both government and industry must be left open, as a number of successful trials are under way in Europe and greater flexibility may result in the end, especially as the rate of technological change is not decreasing.

The plan for the Saudi spatial data clearinghouses will be discussed in chapter 7. However other systems which have become fully functional will be thoroughly investigated before the final model is developed.

CHAPTER 7

PROPOSAL FOR A SAUDI NATIONAL SPATIAL DATA INFRASTRUCTURE

7.1 INTRODUCTION AND BACKGROUND

The first Saudi Arabian State emerged in 1744 (1157 H) from an alliance between Imam Mohammed bin Saud, the ruler of Al-Dirriya, and the Islamic reformer Sheikh Mohammed bin Abdul Wahab. Under this alliance most of the Arabian Peninsula was brought under their control, however this unity was disrupted by an Ottoman invasion in 1811 (1226 H) ending the first Saudi Arabian state in 1817 (1233 H).

In 1824 (1240 H) the second Saudi Arabian state was founded when the Al-Saud family regained power under the leadership of Prince Torki bin Abdullah bin Saud, an ancestor of the late King Abdulaziz. The invasion of Riyadh, the capital city of the second Saudi state, by Mohammed bin Abdullah bin Rashid, ruler of Jabal Shamar, in the north of the Arabian Peninsula, brought the second Saudi state to an end in 1891 (1309 H). Imam Abdulrahman Al-Faisal Al-Saud withdrew from Riyadh to Kuwait with his family, including young son Abdulaziz and became guests of the Al Asubah Family (the rulers of Kuwait). However, young Abdulaziz decided to return to his family's land and restore the Saudi power again (Al-Assiri, 1996).

On January 15th, 1902 (Shawwal 5th, 1319H), Abdulaziz bin Abdulrahman Al-Faisal Al-Saud reclaimed Riyadh, after a long and hard trip from Kuwait to Riyadh (Figure 7-1) with about 60 fighters of his relatives and followers and very little in the way of food and weapons. This trip took about four months, but it was the cornerstone in the foundation of the third Saudi state, the modern Kingdom of Saudi Arabia (Al-Saud, 1999) that has just celebrated its centennial (100 years of building and unity) on January 22nd, 1999 (Shawwal 5th, 1419H).

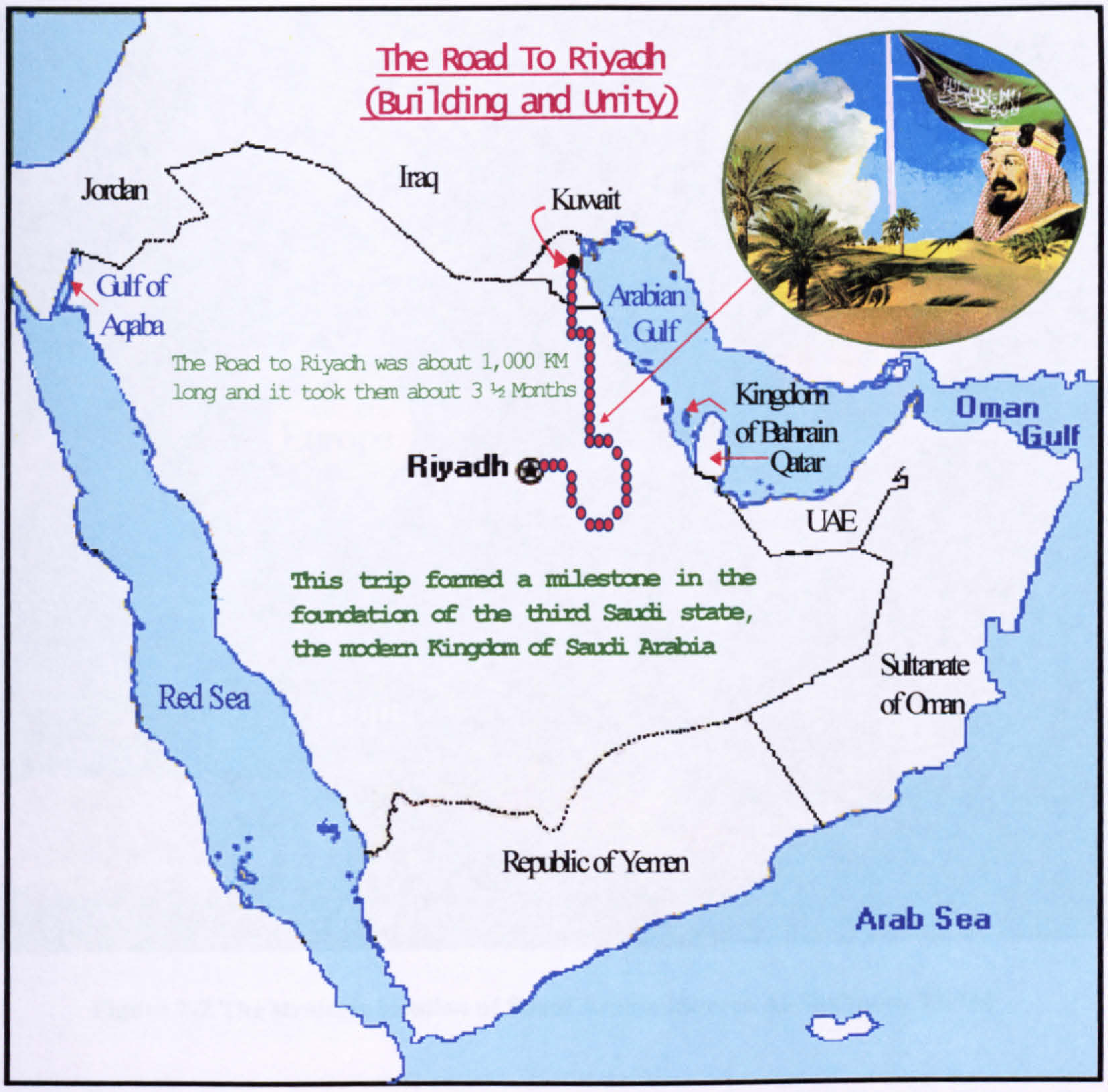


Figure 7-1 King Abdulaziz's long and hard trip from Kuwait to Riyadh [Source Al-Shahrani, 2001b).

The Kingdom of Saudi Arabia is located in the south western of Asia at the crossroads of Europe, Asia and Africa, as shown in figure 7-2. Saudi Arabia occupies four-fifths (*4/5*) of the Arabian Peninsula, which makes it the largest country in the Middle East. The founder of the modern Saudi Arabia, His Majesty King Abdulaziz, went to great effort to unify this vast land from the farthest northern limits of the peninsula to the southern precincts and from the Arabian gulf shores in the east to the Red Sea coast in the west to create a kingdom with an area of over two million square kilometres and external borders of about five thousand eight hundred kilometres.

As shown in figure 7-1, the Kingdom of Saudi Arabia is bordered in the north by Kuwait, Iraq and Jordan and in the south by Yemen and the Sultanate of Oman. In the east Saudi Arabia is bordered by the Arabian Gulf, United Arab Emirates, Qatar and the state of Bahrain and to the west by the Red Sea and the Gulf of Aqaba.

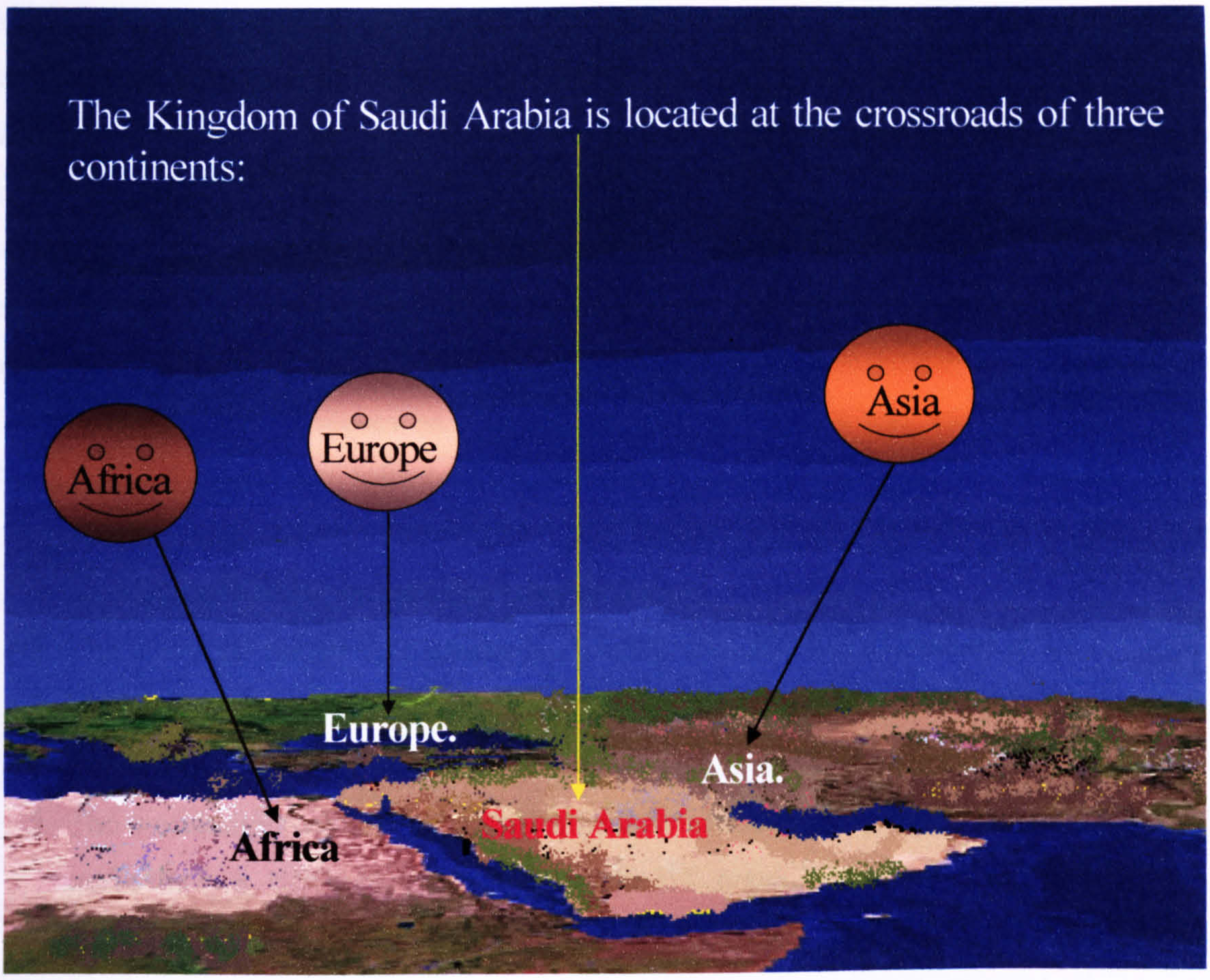


Figure 7-2 The strategic location of Saudi Arabia [Source Al-Shahrani, 2001b]

Saudi Arabia has a varied topography, ranging from the famous Empty Quarter (Rub al Khali) in the south-east (the largest continuous sand desert in the world), which also links to another large sandy desert, the Al-Nafud in the north of the country, to valleys, few lakes or permanent streams, and green and mountainous terrain rising to over 3,000 metres in the south-west. The topography of Saudi Arabia also contains salt flats, gravel plains and other types of terrain (Mughram, 1973).

A country with such vast area, long borderlines, unique topography and a regular pace of development and progress needs to pay close attention to spatial data and keep them high on its list of priorities. Just like any other area of vital national importance, spatial data in the Kingdom of Saudi Arabia are, therefore, receiving the close attention of government, but the Kingdom of Saudi Arabia lacks a national spatial data infrastructure. A Saudi national spatial data infrastructure is of critical importance to the well being of the Kingdom. National security and defence, the management of infrastructure, agriculture, healthcare, education, environment, industries, tourism, human development resources and many other vital aspects of national planning and services are supported directly or indirectly by spatial data. Therefore the development of a strategy for a national spatial data infrastructure in the Kingdom of Saudi Arabia, "the Saudi National Spatial Data Infrastructure (SNSDI)", is essential to facilitate the availability, accessibility and effective use of accurate, current and complete spatial data for use by all levels of government, private sector organisations and others, thus creating a partnership between all spatial data users and producers.

This chapter proposes an approach to the formulation and implementation of a Saudi national spatial data infrastructure based on:

1. Spatial data sharing perspectives and issues that highlighted the benefits and obstacles of spatial data sharing (chapter 2).
2. The universal spatial data standards, developed by ISO/TC 211 (chapter 3).
3. The current status of mapping activities in the Kingdom of Saudi Arabia (chapter 4).
4. The Internet network, tools and technologies (chapter 5).
5. The worldwide national and global spatial data initiatives, specially the factors that make the U.S. NSDI succeed as well as the UK strategic alliances, the ANZLIC in Australia and New Zealand, the NCGI in the Netherlands and the CGDI in Canada.
6. The researcher's experience and background and a review of the General Commission for Survey and Mapping-Internal Documents (GCSM-ID).

To address those issues and more, section 7.2 forms the most important part of this chapter. It discusses the main components of the proposed SNSDI, namely, the institutional framework, fundamental data sets, geographic information standards and the technical framework. Section 7.3 may be considered as laying down the building blocks for the implementation phase for the SNSDI. It highlights a development and implementation plans for SNSDI including concept, design, implementation and operation phases. Concluding remarks are found in section 7.4.

7.1.1 Justification for Saudi NSDI

At present many organisations in the Kingdom of Saudi Arabia collect and use spatial data, but this is mostly confined to their own departments and no agent is responsible for co-ordination of these activities or for enabling access and exchange of spatial data, nor are common spatial data standards used. Existing spatial data consists of conventional and digital products at various scales, types and formats. Small-scale complete digital map coverage exists for the Kingdom at 1:1,000,000 scale and at 1:2,000,000 scale. Also medium scale digital map coverage exists at 1:250,000 scale. Large-scale digital map coverage and geographic information systems exist for certain areas and main cities and villages at 1:25,000 scale and larger. Good and accurate geodetic and land information is available for the entire Kingdom at sufficient density to support mapping and national spatial data activities. Also, a national geographic names database exists for the whole Kingdom. On the other hand, and as indicated in chapter 4, there are conventional (hard copy) maps covering the whole kingdom at 1:50,000 scale and the updating and conversion of these to digital maps is in progress now. There are also hydrographic charts for the red sea, etc.

The digital and conventional products are not widely exploited in the user community. Current and future complex economic, social and environmental issues cannot be solved with this limited access.

The aim of the SNSDI is to exploit fully and enhance (not destroy or replace) existing national assets for the creation and exploitation of national spatial data infrastructure. The infrastructure builds on existing capabilities by providing coordination, prioritisation and central leadership so that spatial data can be widely accessible and sharable for the benefit of all users. The SNSDI will be the ultimate solution for the consolidation of isolated activities. It will avoid wasteful duplication of effort, time and money, simplify co-ordination and facilitate the establishment of the general and legal principles for partnership and co-operation in spatial data collection, donation, processing, integration, storage, distribution and sharing by many ministries, producers and users alike, no matter what types of hardware or software are used by each individual. For this purpose MODA has initiated, supported and funded this research to develop a strategy for defining and then implementing the SNSDI.

7.2 SNSDI COMPONENTS

The scope of the Saudi national spatial data infrastructure includes everything that enables the development, implementation, and maintenance of a national spatial data infrastructure, which serves the whole Kingdom of Saudi Arabia. It is based on the information collected, discussed, compared, and analysed in the previous chapters. The main Saudi NSDI components should include the following:

1. Institutional Framework.
2. Fundamental Data sets.
3. Spatial Data Standards.
4. Technical Framework.

These SNSDI components, as in all other successful worldwide national projects, are not independent activities, but complementary.

7.2.1 INSTITUTIONAL FRAMEWORK

The building of an institutional structure to co-ordinate and lead the development and implementation of a national spatial data infrastructure is essential. A national mapping body should be designated by the government as the leading body for the Saudi national spatial data infrastructure.

This research proposes the establishment of six specific new arrangements and institutional structures for the SNSDI and they are:

1. Royal Decree (High Executive Order).
2. National Committee for Geographic Information (NCGI).
3. Organisational Framework.
4. National Spatial Data Policy (NSDP).
5. SNSDI Development Office (SDO) and SNSDI Management Board (SMB).
6. Spatial Data Users/ Producers Community (SDUPC).

7.2.1.1 Royal Decree

The most important step to authorise and start the Saudi national spatial data infrastructure is to obtain a Royal Decree. The aim of the Royal Decree is to authorise and support the development and implementation of a national spatial data infrastructure in the Kingdom of Saudi Arabia and facilitates spatial data sharing and specifies the national mapping body to co-ordination this activity. The Royal Decree should state the goal of the Saudi national spatial data infrastructure and the responsibility of all the participating organisations, spatial data user/producer community and spatial data donors. The Royal Decree should also authorise the formation of a National Committee for Geographic Information (NCGI) from ministries and organisations that produce and use spatial data and encourage very positively spatial data access and sharing between all users and produces.

7.2.1.2 National Committee for Geographic Information

The most important step in the implementation of the SNSDI is the formation of a high-level body to provide co-ordination, leadership and authority at national level. The high-level body is termed the National Committee for Geographic Information (NCGI). The primary objective of the NCGI is to provide control, oversight and guidance to the development and implementation of the SNSDI, and to promote the efficient use and sharing of spatial data to prevent wasteful duplication of effort and yield high quality data for the benefit of all users in the Kingdom. NCGI supports domestic, military and civilian surveying and mapping activities, aids the use of spatial data and GIS and assists ministries, organisations, universities and researchers in their related spatial data activities. The NCGI should form alliance on specific topics and address national level issues within the scope of the national spatial data infrastructure, provide co-ordination and set policies for SNSDI execution in accordance with nationally agreed criteria.

The policies established by the NCGI would apply directly to the national mapping body and to other users and producers of spatial data in the Kingdom. The national mapping body should apply policies to prioritise its work in order to develop and implement the infrastructure as quickly, economically and simply as possible. Through adherence to national policy, the committee will arrive at national level spatial data policies and management criteria that are most beneficial to the Kingdom. This in turn will assist the national mapping body and the Saudi national spatial data infrastructure to receive guidance and funding. Adherence to spatial data standards by all members of the NCGI and the producer/user community will become a key and essential factor for the success of the Saudi national spatial data infrastructure.

7.2.1.2.1 Implementation of NCGI

Initially the NCGI will address start-up issues, such as an action plan, funding, staffing, standards, early implementation of spatial data products and design activities. Later, the NCGI will provide a forum for ensuring co-ordination between all organisations participating in the infrastructure, promote the SNSDI, encourage more producers and users to participate, attach priority to requirements for data and foster improvement to the infrastructure. The following are some of the main functions of the NCGI:

1. Promote the development and implementation of Kingdom-wide distributed spatial databases and network.
2. Promote interaction and spatial data sharing between users, producers and other authorities.
3. Encourage the development and implementation of spatial data standards, metadata standards, procedures and guidelines to enable spatial data to be shared.
4. Ensure that the SNSDI supports national security, national defence and emergency readiness.
5. Promote the establishment of central training institution and educational programs to support the SNSDI activities.
6. Promote technology development, knowledge transfer and spatial data analysis.
7. Provide a forum for discussion of financial matters.
8. Provide a national spatial data policy framework.

7.2.1.2.2 Membership of the NCGI

The membership of the NCGI should come from the government and non-government organisations, which make significant contributions to, or make significant demands upon, the national spatial data infrastructure. Members of the committee would be Deputy Ministers, or Assistant Deputy Ministers. The president of the national mapping body, who acts as a co-ordinator and advisor to the government on national spatial data matters, should chair the committee. Figure 7-3 shows the structure of the NCGI.

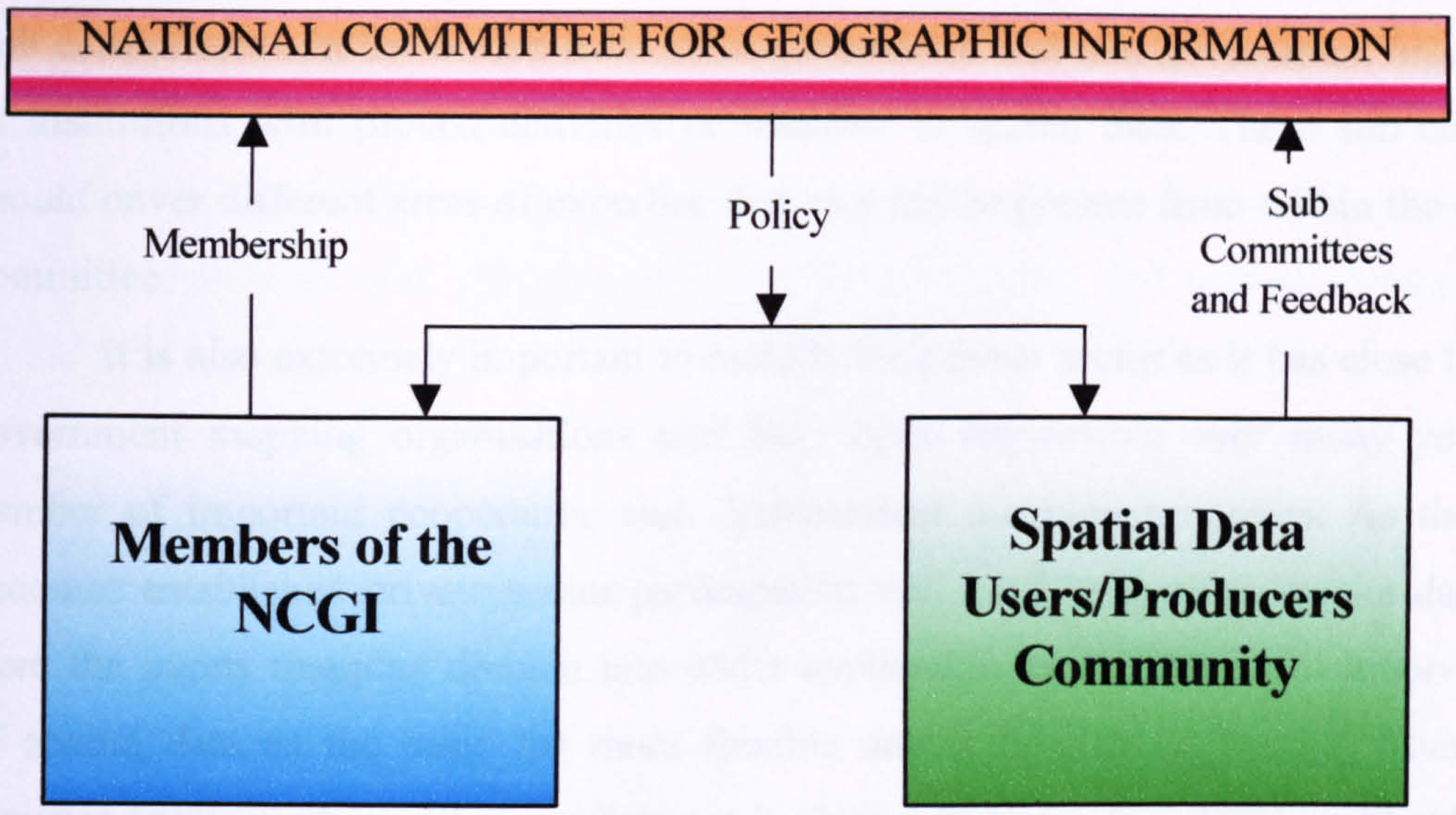


Figure 7-3 NCGI structure.

The bodies in Table 7-1 should be invited to form an executive committee. At its inception the membership of the executive committee should include main mapping and GIS producers as well as representatives from spatial data users and the private sector.

No	Name of Ministry/Organisation
1	Ministry of Defence and Aviation and Inspectorate General (MODA), General Commission for Survey and Mapping (GCSM).
2	Ministry of Petroleum and Mineral Resources (MOP&MR) and Saudi Armco.
3	Ministry of Municipal and Rural Affairs (MOMRA).
4	King Abdulaziz City of Science and Technology (KACST).
5	Ministry of Communication.
6	Ministry of Finance and National Economy.
7	Ministry of Planning/ census department.
8	The Meteorology and Environmental Protection.
9	Representative from the Private Sector.

Table 7-1 Recommended Executive members of the NCGI

Sub committees can be formed from other government and non government organisations or institutions with proven activities or interests in spatial data. These sub committees should cover different areas of expertise that may not be present from within the executive committee.

It is also extremely important to include the private sector as it has close links with government mapping organisations and has been responsible over many years for a number of important cooperative and independent mapping programs. As the SNSDI becomes established private sector participation will need to grow as spatial data moves from the purely mapping domain into wider application areas. These will involve the use of spatial data as the basis for more flexible arenas of display, varying from internet browser applications to other markets yet in their infancy such as location based services using Wireless Application Protocol (WAP) technologies. Similarly the user market will change and expand. At the moment only a small proportion of the Saudi population are directly concerned with the use of spatial data; in a few years the majority will expect to use web based interactive mapping. This will lead to a democratisation of the clearinghouse system and a large swing in the user base from organisational towards domestic consumption – as has already been seen in the U.S and Europe. As the market for spatial data develops so need for a wider range of spatial expertise will be required amongst the executive members of the NCGI.

7.2.1.3 Organisational Framework

7.2.1.3.1 Background

In 1990, the Council of Ministers completed a significant study to examine survey and mapping organisations in Saudi Arabia, to consolidate related spatial data activities that were being conducted by various ministries and organisations in the Kingdom. The Council of Ministers study concluded in the issue of Council of Minister Resolution Number 70, dated 22/04/1410 H (1990 G). This resolution recommended the consolidation of all government entities, which engage in mapping and surveying activities into one organisation (General Mapping Organisation). The resolution recommended that this organisation report to the Ministry of Defence and Aviation (MODA) and should be responsible for all surveying and mapping activities required by any government or non-government entity. The resolution indicated that the General Mapping Organisation should comprised of two main divisions, the Military Survey Department (MSD) and the Civilian Survey Department (CSD). The organisational structure of the National Surveying Organisation should also include a Survey Information Centre (SIC) responsible for the computer hardware and software required for geographic and survey information and organising, classifying and maintaining all data and reproduction materials.

On Monday 2nd Jamad awal, 1422 H (23rd July, 2001), the Council of Ministers, the Kingdom of Saudi Arabia, approved resolution 70 and issued Executive Order number 133 to transform the existing General Directorate of Military Survey (GDMS) into a national mapping organisation named "General Commission for Survey and Mapping (GCSM)" (GCSM-ID, 2001).

7.2.1.3.2 General Commission for Survey and Mapping

The General Commission for Survey and Mapping will be the organisation that brings the surveying and mapping activities of Saudi Arabia, military and civilian, under unified management and coordination. With its authority and capability, GCSM will co-ordinate and host the development and implementation of the Saudi national spatial data infrastructure. In this way, large and varied amounts of spatial data, much of which already exists in government organisations and elsewhere in the Kingdom, may be widely accessed and shared. GCSM is a component of MODA and will be divided into 3 directorates, in line with the Council of Ministers executive order:

1. The General Directorate of Military Survey (GDMS).
2. The General Directorate of Civilian Survey (GDCS).
3. The Saudi National Centre for Geographic Information (SNCGI).

The organisational structure of the Saudi National Centre for Geographic Information (SNCGI) should include the main national spatial data clearinghouse. In this way GCSM will assume a predominant role in developing a Kingdom-wide spatial databases and a leadership role in the SNSDI. The president of GCSM will ensure that the design and implementation of the GCSM and its systems satisfies the requirements of the SNSDI. GCSM will collect, produce, maintain and distribute national spatial datasets and ensure the modernisation of the mapping process necessary to support efficient exploitation of spatial data amongst all users that require it. The primary organisational components of GCSM are shown in Figure 7-4:

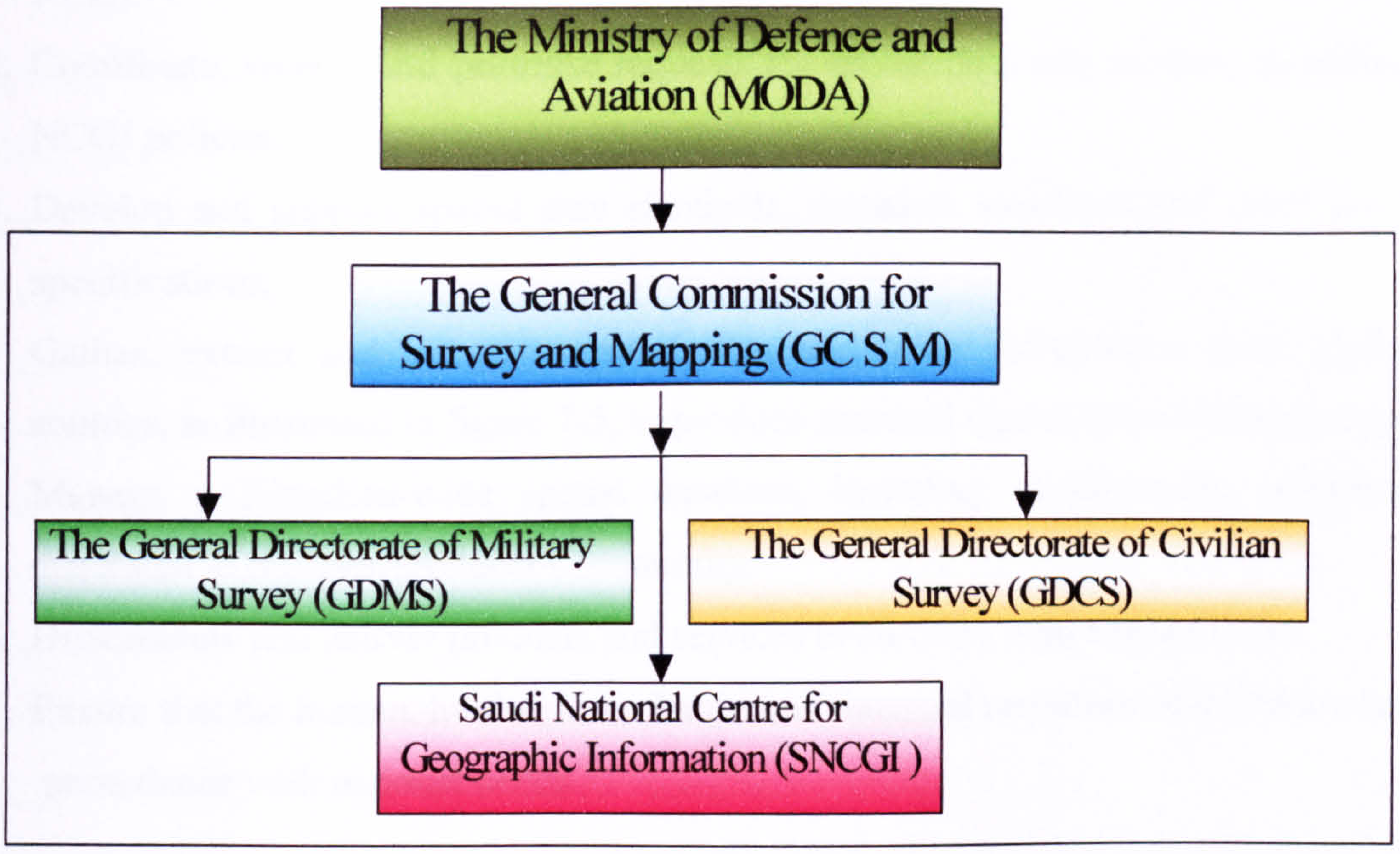


Figure 7-4 The General Commission for Survey and Mapping (GCSM) main components.

The General Directorate of Military Survey (GDMS) and the General Directorate of Civilian Survey (GDCS) will be tasked according to military and civil requirements and priorities. GCSM should start its activities with the main functions critical to the success of the overall SNSDI. GCSM will obtain available digital spatial data from other organisations and perform translation and processing into standard products, then integrate it into a multipurpose spatial database, generated by the SNCGI. The SNCGI will be a common resource and primary national focus providing spatial data products and services. These include the supply of conventional maps, digital maps, spatial data, coordinates, gazetteers, geographic names, satellite imagery, aerial photography and other resources, which will be shared by GDMS, GDCS and all other organisations and users. The SNCGI will be the home of the main "Saudi National Spatial Data Clearinghouse (SNSDC)" discussed later in this chapter.

Finally the GCSM, with the help of the NCGI, is required to undertake the following seven categories of activities:

1. Coordinate with the spatial data user/producer community and determine optimum use and development of resources for the SNSDI either directly or through the NCGI.
2. Coordinate, receive and prioritise requests for spatial data and services according to NCGI policies.
3. Develop and support spatial data standards, metadata standards and other product specifications.
4. Gather, extract and integrate spatial data and other information from different sources, as illustrated in figure 7-5, to produce standard digital spatial data products.
5. Manage a Kingdom-wide spatial database, including multipurpose information generated in the user/producer Community.
6. Disseminate and deliver products and services to all users who require them.
7. Ensure that the human, hardware, software and financial resources required are in accordance with national needs.

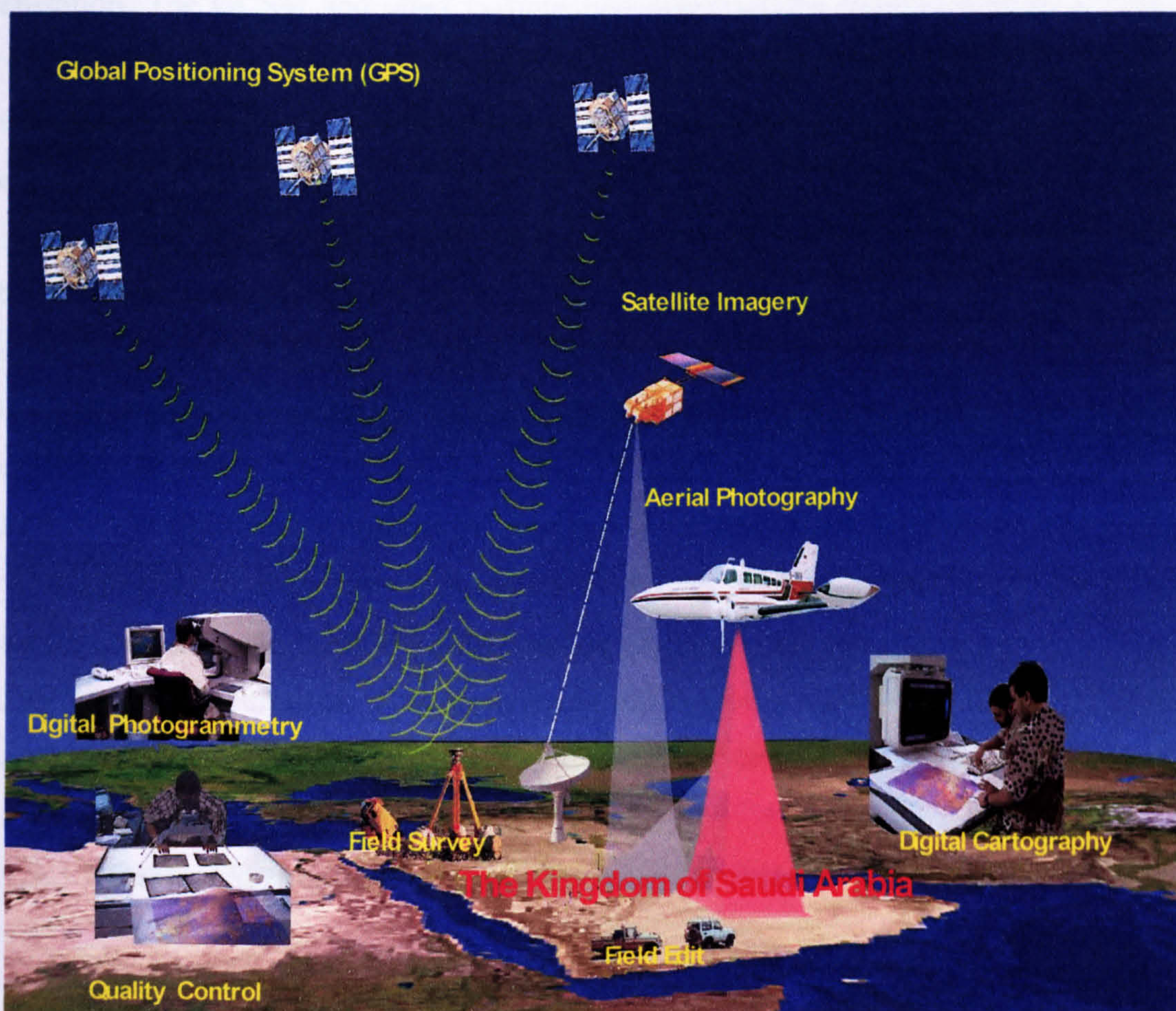


Figure 7-5 Saudi national spatial data collection framework.

7.2.1.3.3 Human Resource Development

The success of the Saudi national spatial data infrastructure depends directly upon the abilities and capabilities of the people who develop, implement, manage, supervise, maintain and operate the infrastructure. This includes a wide mix of managerial ability, technical skills and operators. Therefore, GCSM and other participating organisations must aggressively and pro-actively provide a plan, budget and institution to develop the human resources needed to manage, administer, operate and maintain the total SNSDI system. This should include also the human resources needed in the user/producer community for full exploitation of the spatial data products and services.

The NCGI, through its membership, should provide recruitment, educational and training policies and assistance, designed explicitly to develop the human resources necessary for the continued success of the SNSDI. Additionally, the NCGI should establish policies that promote career path development and reward professional growth within the organisation. The GCSM and other participating organisations should establish a Central Survey and Mapping Training Institute (CSMTI) and maintain a recruitment process that attracts qualified and motivated individuals. It should provide training for specific management and technical support, skills and operators needed for the SNSDI.

The SNSDI Development Office (SDO) requires upon its creation rapid staffing with dozens of individuals. The selected individuals must have, or quickly develop, strong technical, management and leadership abilities. These individuals will not only be the driving force behind the design, development and implementation of the Saudi national spatial data infrastructure system, but they will also be the future managers for future strategies. The first wave of career development activities should involve the selection of the best qualified of the present GCSM employees to form the cadre of the SDO. The vacancies created could be filled by promotion of junior members of the present GCSM and by outside recruitment. This process would continue until the SDO reaches full strength, completes it mission, and becomes the SNSDI Management Board (SMB).

7.2.1.3.3.1 Central Survey and Mapping Training Institute

There are presently a number of survey and mapping training facilities in Saudi Arabia. The most important one is the Military Survey and Geographic Study Institute

(MSGSI) in Riyadh. This specialised institute offers different courses at various levels and grants qualified graduates a diploma to work in most areas related to survey and mapping activities. This institute will certainly assist all survey and mapping organisations in the Kingdom of Saudi Arabia in maintaining career development plans for all staff, by coordinating and facilitating technical and management training courses and maintaining the necessary level of professional and technical staff. However, the institute curricula will be modified to cover more categories of professional and technical skills. These categories will include training on different aspects of GIS and spatial data collection, production, integration, dissemination, applying standards, metadata, research and development and others. The required training, knowledge, experience and how to obtain staff for each of these aspects must be carefully planned.

The required training, knowledge, experience and staff recruitment to achieve these objectives must be addressed by SDO and later by SMB. The range of courses should include, for example:

1. Training programmes for professional responsibilities for:
- Top decision makers and directors.
- Managers/supervisors.
- System programmers and analysts.
- Spatial databases administrators and analysts.
- Computer networking analysts.
2. Training programmes should also be designed for the following technical skills.
- Staff involved in the acquisition of all source materials of spatial and non spatial data, such as aerial photography, satellite images, existing maps, field surveys, geodetic survey, geographic names collection, reports and others.
- Staff involved in the data extraction from various sources, including enhancement of source documents, identification and extraction of spatial features, digitising, scanning, verification and integration of various data sets.
- Staff involved in the monitoring and quality control of spatial data production, including the analysis of spatial data requirements, design of production plans, testing of alternatives, optimisation, prioritisation and allocation of resources.
- Staff involved in the spatial data processes, including data enhancement, conversions and integration of various data sets, reformatting and restructuring, conversions and data modelling, storage and data dissemination.

- Staff involved in presentation and generation of various products, including cartographic enhancements and symbolisation, production of line maps, photo maps, digital files in specific data formats, special maps, reports, etc.
- Staff involved in spatial data analyses for various fields of applications.

7.2.1.3.3.2 Role of Universities and Other Training Institutions

In Saudi Arabia there are a total of eight universities granting Bachelor degrees in various disciplines. Some universities offer masters and doctorate degrees in certain specialties, including survey, mapping, GIS, etc. In response to any impact on Saudi human resources and the stimulus of the NCGI, universities should design and conduct courses and curricula specifically aimed at the professional and technical skills for a successful career in the digital spatial data sciences. The universities and institutions should actively recruit qualified students to enrol in these courses. Relevant university level courses, basic as well as advanced, must provide the students with an initial appreciation of and basic skills in spatial data handling and GIS theory. Specialised spatial data courses, whose main purpose is to provide manpower for the completion of spatial data and GIS operational tasks, also have major career development value. Some educational institutions abroad have already started to include spatial data infrastructure and GIS in their standard programmes. NCGI can build on this fact in the short term by encouraging ministries to send appropriate numbers of people to study abroad.

7.2.1.3.3.3 Role of Research and Development

A healthy Research and Development (R&D) activity is critical to the long-term success of the Saudi national spatial data infrastructure. Without research and development, the technology used by GCSM and other participating organisation would become inefficient, uncompetitive and uneconomical. Therefore, a research and development team should be established and tasked of maintaining the technical leadership of the SNSDI.

7.2.1.3.4 Financial Resources

It is very important that GCSM allocates part of its budget to start the SNSDI initial implementation. The authority to proceed with the implementation of the Saudi NSDI can be achieved in stages. The budget, likewise, will not be needed all at once. The GCSM, through the SDO, should provide funding profiles to reflect the stages and activities of the Saudi NSDI, including the development of a Saudi Centre for National Geographic Information (SNCGI). Based on the funding profile, the needed budget should be obtained. However, as the implementation phase is completed and spatial data become available a price should be introduced for spatial data to compensate for the charge of the SNSDI maintenance and operations. The question of what price this should be is important as if it is set too high no users will cooperate and the NSDI will die. Too low a price will place considerable costs for running and maintaining the system on the government. This has been overcome in the U.S. by the government sponsoring the entire system, and in the UK by the private sector taking the initiative. Both approaches have failings. The government funded system could lead – but in practice in the U.S. has not – to a depression of the private sector value added market because of the undercutting of the basic worth of data. In the private led model the perceived and actual danger is that only corporate users will be able to afford to be members. This is the case in most of the European systems, and very definitely in the UK where access to spatial data by the smaller (domestic, academic, etc) users has been very restricted. In Saudi Arabia a compromise system with the government paying for the basic infrastructure, and also subsidising use of basic data sets for general use might be envisaged.

7.2.1.3.5 Contracting and Procurements

The implementation of the Saudi national spatial data infrastructure will require the services of experts and contractors to provide consultation, computer hardware, software, communication network tools, training and other services. The procedures for selecting contractor(s) should be set forth in the RFP document. Different systems, including servers, graphic users interfaces, communication networks, protocols, programming interfaces, gateways, encoding, data security, integrity and so forth, are needed for the Saudi NSDI.

This system as a whole needs to be installed and integrated. Also the continuation of the operation and maintenance of system components based on a clear architectural approach should be considered.

7.2.1.4 National Spatial Data Policy Document

NCGI, in co-ordination with all participating organisations has the responsibility for proposing and implementing a national spatial data policy in a number of important subject areas. The policy requires careful drafting and negotiation. It is essential that the policy be circulated and agreed to by all the NCGI members, the participating organisations and the user/producer community before final publication, if they are to have the desired effect and be of substantial benefit to the users and producers. NCGI will, therefore, be required to coordinate for discussion and approval of different parts and sections of the national spatial data policy. The policy document should include guidelines on spatial data collection, production, access and sharing procedures, copyright, updating, pricing, security, privacy, education, training and any other issues needed to achieve a fully functional SNSDI. It also should include guidelines on what spatial data can be accepted in the clearinghouse, its accuracy, update, completeness, etc. It also should include information on metadata and how to find and fill the metadata forms (manually and electronically), software, communication network tools, maintenance and operation of the SNSDI. A pricing policy concerning the use of spatial data, clearinghouse service and the delivery of spatial datasets should be decided. The pricing should be set based on a cost-benefit analysis that provides provision for investment to the participants. Normally the government supports initial funding, however the pricing policy should consider the cost for SNSD system maintenance and operations. However, the NCGI may suggest free distribution of spatial data. A general policy for the allocation of priorities and resources for spatial data collection, integration, production and dissemination must be established, agreed by the NCGI, and included in the national spatial data document. The national spatial data policy must not be frozen, but will probably change as necessary. It is likely that these policies will require updating, modification and expansion as the SNSDI progresses.

The priorities, established by the national spatial data policy, must be observed and followed. The mechanism for appeal against too low priority must be stated in the policy document and understood. Many countries adopt quite sophisticated priorities programme in which availability or currency of a particular product is weighted.

In this way, a product whose priority is too low to permit production in a particular year will gradually in time gain a higher priority, sufficient to get it produced. The Policy should cover circumstances such as some local or national emergency, which would cause a delay or cancellation of the national spatial data infrastructure priorities in favour of some crisis period alternatives.

7.2.1.5 SNSDI Development Office and SNSDI Management Board

The SNSDI Development Office (SDO) is proposed to develop the infrastructure. The SDO can be formed from different ministries and firms along with experts and consultants from private sectors and other institutions. However, according to the Saudi Council of Ministers Executive Order number 133, the General Commission for Survey and Mapping (GCSM)) should administrate and manage SDO, up to the operation stage. The president of GCSM can either delegate or assume the position of director of the SDO. Under the leadership of GCSM, the SDO will be responsible for the design and implementation of the SNSDI system. This responsibility should include the delivery, installation, operation and readiness of hardware, software, operating procedures, funding and human resources. The SDO should ensure that parallel developments are coordinated, such as standards, metadata, provision of training, the productions of prototype spatial data, research & developments and the establishment of a users/producers interface. Also, SDO should control the performance, schedule and cost of developments. The SDO team should be drawn from GCSM, other participating organisations and consultant personnel. The SDO should include a wide variety of expertise including systems hardware and software engineers, production managers, system operators, facilities engineers, network analysts, etc. The proposed structure of the SDO is outlined in Figure 7-6.

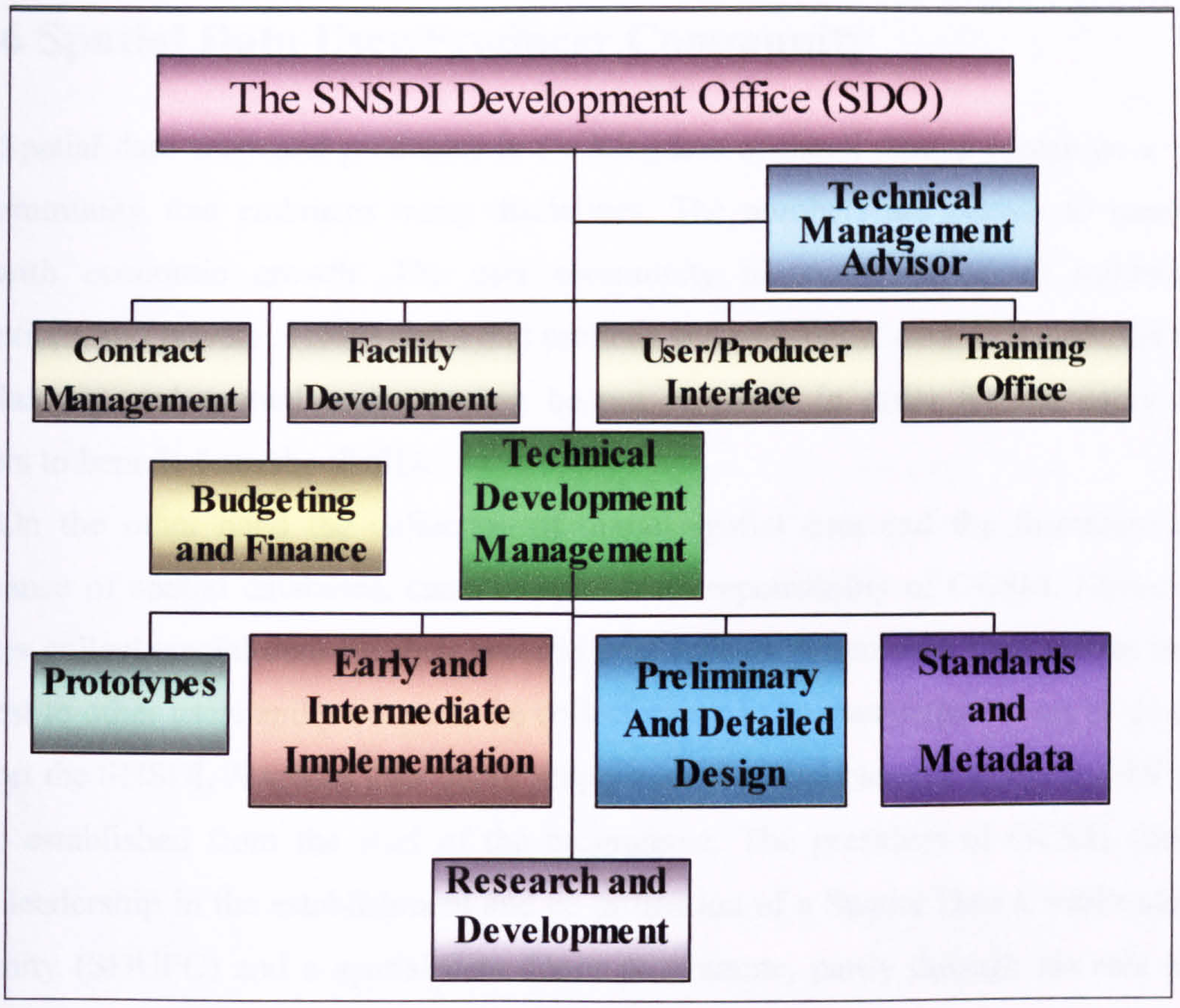


Figure 7-6 Structure of the SNSDI development office.

During the final implementation phase, which will be discussed later, the SDO will begin to be phased out and be replaced by a SNSDI Management Board (SMB) with the same staff and within GCSM. The SMB will manage the SNSDI beyond the final implementation phase (figure 7-15). Managers and supporting staff who had been assigned to SDO and have no position in the SMB will return to other positions in GCSM that directly support GCSM and the mission of SNSDI. The majority of these positions are in three rapidly expanding organisations within GCSM; the General Directorate of Military Survey (GDMS), the General Directorate of Civilian Survey (GDCS) and the Saudi National Centre for Geographic Information (SNCGI). Personnel can be added, when needed, to the SMB, from GCSM and other participating organisations to provide as much operational continuity of the SNSDI as possible. The SMB should be always at full complement and constant readiness, to operate, manage and update the SNSDI. The constant attention of this board is necessary to continue the operation, control costs and maintain balance in allocation of resources to various aspects of the infrastructure. Training continues to be a requirement, is paramount to the success of SNSDI and applies equally to new and existing staff.

7.2.1.6 Spatial Data User/Producer Community

Spatial data users and producers in the Kingdom of Saudi Arabia constitute a very large community that embraces many disciplines. The numbers are certain to increase along with economic growth. The user community is composed of all ministries, organizations and private sector groups that produce and use spatial data. It is essential that good planning and mutual understanding be put in place, in order for the users and producers to benefit from the SNSDI.

On the other hand the collection of digital spatial data and the formation and maintenance of spatial databases, cannot be the sole responsibility of GCSM. Numerous producers collect spatial data for their specific applications. When such data proves to be of interest to other users and producers, the collectors are to be encouraged to act as donors to support the SNSDI. A spatial data donor programme is a vital element of the SNSDI and must be established from the start of the programme. The president of GCSM should provide leadership in the establishment and co-ordination of a Spatial Data User/Producer Community (SDUPC) and a spatial data donor programme, partly through his role as a chairman of the NCGI and partly as the leader of the national mapping organisation and main provider of fundamental spatial data for the national spatial data infrastructure.

The aim of the spatial data user/producer community should be defined in the Royal Decree. The user/producer community should involve all organisations within the Kingdom of Saudi Arabia that produce and use spatial data and imagery. The SDUPC should interact through the NCGI to form a single voice concerning the national spatial data interests and thereby participate in the establishment of a consistent national spatial data policy, including priorities, co-ordination of products, education, spatial data standards, metadata standards and funds.

The responsibilities accepted by the user/producer community must be declared in the national spatial data policy document, which must express the precise role of this community in the overall infrastructure, including responsibilities for conforming to standards, for donating spatial data to the Saudi NCGI and for providing access to data held by other organisations through a metadata and catalogue. GCSM must have confidence in its relationship with the user/producer community and recognise that the functions and responsibilities of this community forms an important part in the overall SNSDI.

If full operational and economic benefits are to be gained from the creation of SNSDI, it is vital that mechanisms be in place by which user/producer community requirements are determined, nationally. This cannot be achieved solely by ensuring that digital spatial data and other products are in stock, nor by maintaining an accurate database to support spatial data and GIS activities. The potential users throughout the Kingdom of Saudi Arabia must be aware of the national spatial data infrastructure, its role, functions, products and capabilities. A positive approach must be taken to explain this new SNSDI's mission to the nation at large and to promote its function for the greater benefit of the Kingdom.

Figure 7-7 illustrates the user/producer perspective and their relationship to the NCGI.

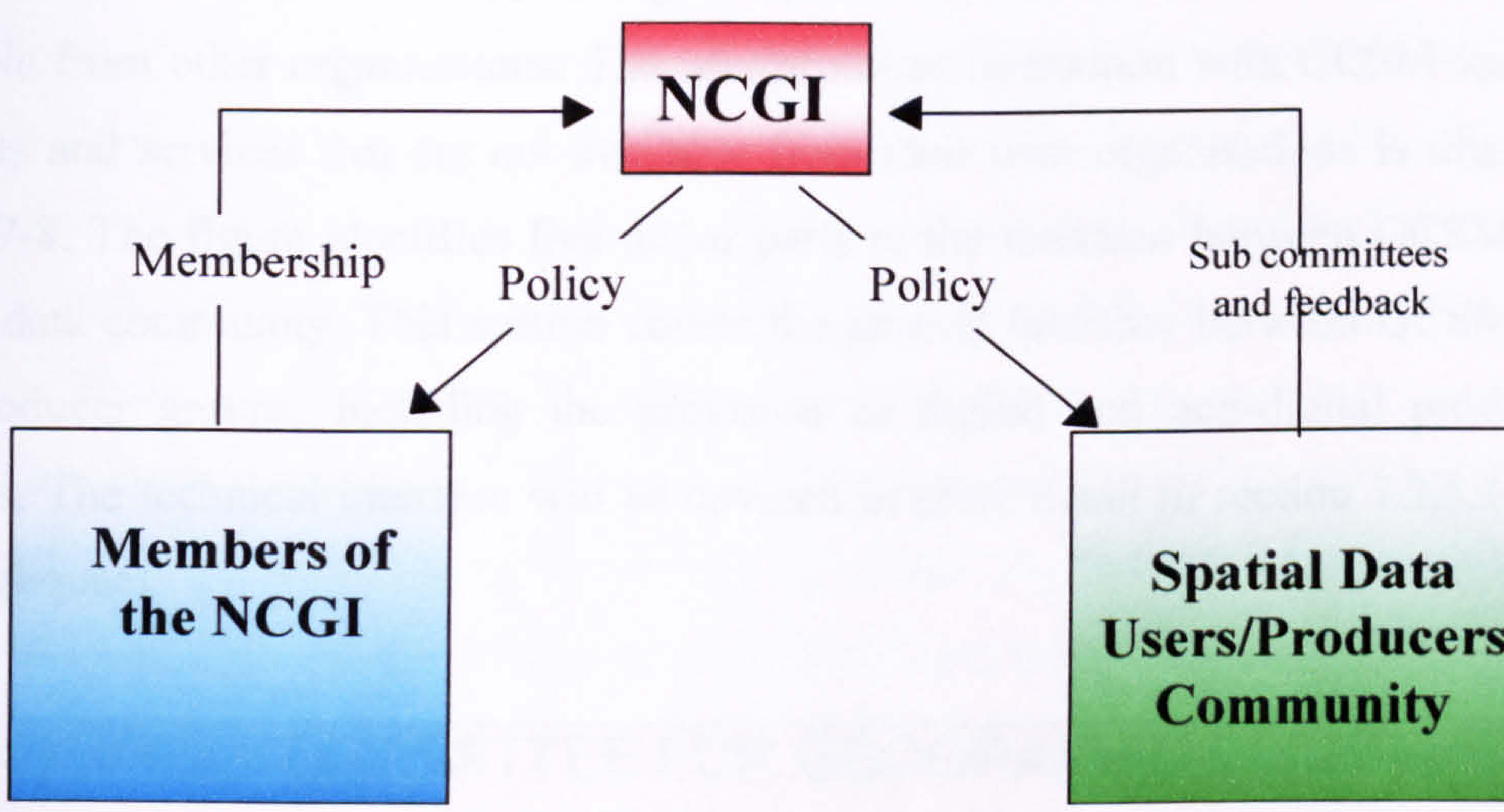


Figure 7-7 The user/producer perspective.

Users' requirements are not static; therefore GCSM and other spatial data producers must pro-actively identify future and emerging user requirements and provide the essential focus for national requirements to be identified and prioritised in accordance with the policies set by the NCGI. This activity must be promoted, especially in the early years of the implementation of the SNSDI, so that spatial data available anywhere may be made available elsewhere, subject to quality assessment, type, format and security restrictions on dissemination. This will be of great economic benefit to the whole SNSDI.

7.2.1.6.1 User/Producer Interfaces to GCSM

Users must know how to obtain spatial data, as well as aerial photography, satellite imagery, or any other source data and the various responsibilities accepted. For example, King Abdulaziz City for Science and Technology (KACST) should continue to hold responsibility for satellite imagery, whereas GCSM should remain the controlling authority for acquisition of all spatial data and aerial photography in the Kingdom and its processing, storage and copying under policy guidelines, the Ministry of Petroleum and Mineral Resources (MOP&MR) continue to maintain geological maps and information and the Ministry of Municipal and Rural Affairs (MOMRA) should continue to be in control of cadastral data. However GCSM should integrate, maintain and provide information about maps of various scales and types, digital spatial data as well as remote sensing data available from other organisations. The user/producer interaction with GCSM for specific products and services that are not available from their own organisations is illustrated in figure 7-8. The figure identifies five major parts to the interface between GCSM and the spatial data community. This section covers the general interface between GCSM and the user/producer groups, including the provision of digital and non-digital products and services. The technical interface will be covered in more detail in section 7.2.5.1 (SNSDI clearinghouse).

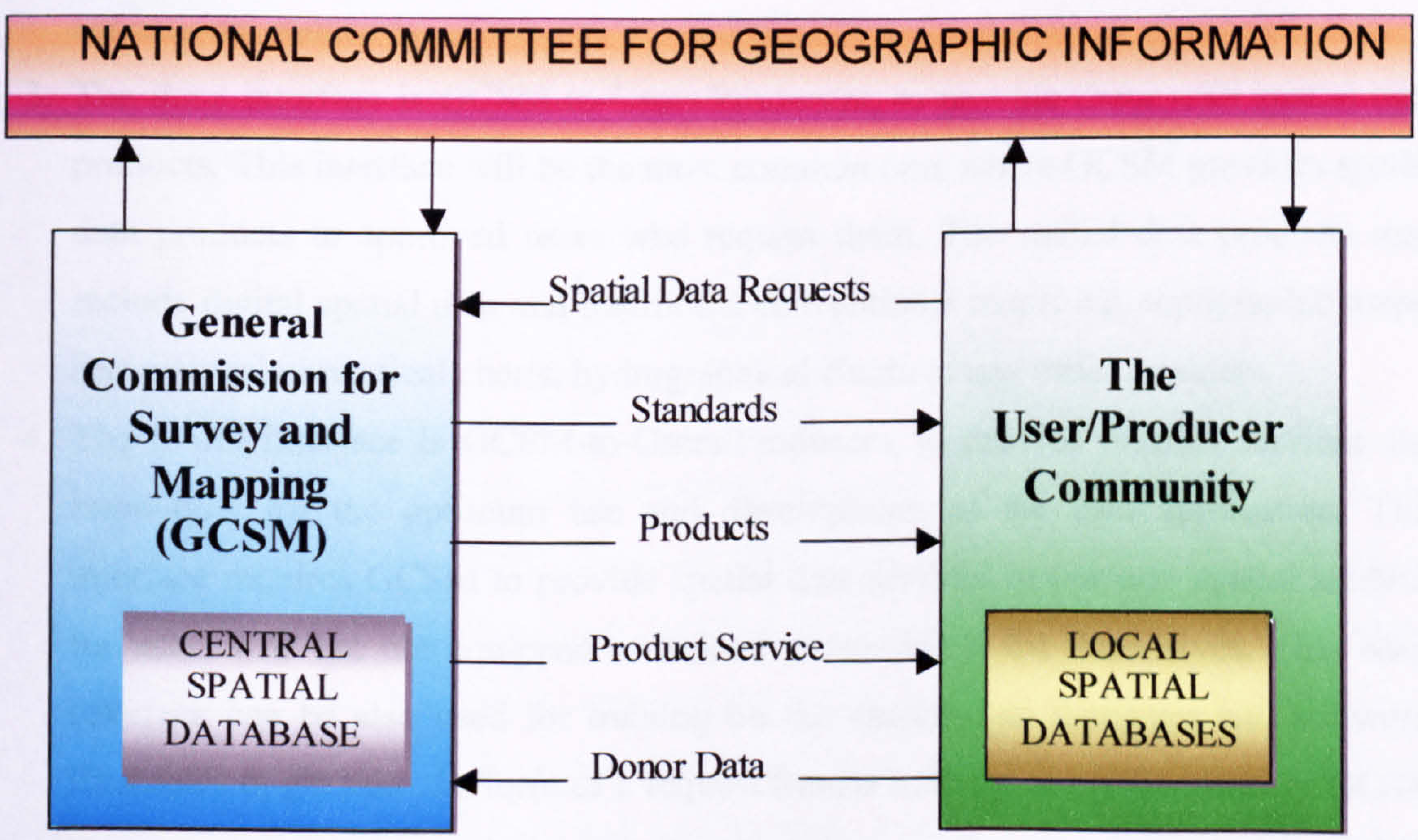


Figure 7-8 User/producer Interface with GCSM.

The administration interfaces between GCSM and the user/producer community can be described as follows:

1. The first interface is User/Producer-to-GCSM, where the community makes requests for standard spatial data products or any special GIS services. The request is received, checked and prioritised by the SDO using a formal policy and procedures set up by GCSM and the NCGI. Standard spatial data products that are already available in the GCSM are then provided to users. Requests for standard spatial data products not yet available in GCSM are fed into the prioritisation process. GCSM should also facilitate special *ad hoc* data sets or a product series conforming to a new standard. The special services requested may well include the production of complex presentations or detailed analyses based on varied spatial data held in the GCSM database as opposed to the mere reproduction of existing data. Through negotiations with its users, GCSM formulates new products and their specifications that more efficiently satisfy the mix of user requirements, taking into account the national need for integrated spatial data. In all of these activities, GCSM coordinates with the user/producer community and follows the national spatial data policy and the NCGI guidelines for the optimum use of the Kingdom's spatial data resources.
2. The second interface is GCSM-to-User/Producer, to set up a national spatial data and metadata standards authority under the Saudi Arabian Standards Organisation (SASO). This interface addresses the fundamental national needs for an authority to set national standards.
3. The third interface is GCSM-to-Users/Producers, to provide them with spatial data products. This interface will be the most common one, where GCSM provides spatial data products to approved users who request them. The spatial data products may include digital spatial data and traditional conventional maps; e.g. topographic maps, aeronautical or nautical charts, hydrographical charts or any other products.
4. The fourth interface is GCSM-to-Users/Producers, to provide product services and know-how for the optimum use and development of the user application. This interface requires GCSM to provide spatial data services or perform spatial analysis for users who are not equipped or trained to provide it for themselves. This basic interface can be also used for training on the spatial data hardware and software. Examples might take the form of a request from a military or civilian firm to GCSM to carry out terrain analysis, mission planning, road network analysis, wildlife protection planning, hazard assessment, etc. GCSM can either perform the service

and analysis through its own GIS capability, or by providing qualified GCSM personnel, who can be stationed temporarily at a user site, or by user personnel using assets at GCSM while under its supervision and training, or by contracting the needed services to qualified contractor or organisation.

5. The fifth interface is Users/Producers-to-GCSM, to offer GCSM some spatial data collected by the other organisation, which can be made available through the SNCGI to other parties. This interface is exemplified by an organisation that produces spatial data useful for other organisations. Rather than requiring the producer to set up a spatial data sharing mechanism, the design allows the producing organisation to donate the spatial data to the main SNSDI server at GCSM, thus avoiding either wasteful duplication elsewhere or attempts to share data in inefficient non-standard mechanisms and simplify the searching process for the users. Examples might be a city map or street names produced by MOMRA, geological maps produced by MOP&MR, or hydrographical charts produced or contracted by the Port Authority. When access to the spatial data is provided to GCSM, GCSM will integrate, maintain and provide Kingdom-wide access to a variety of spatial data for all approved users. Organisations that otherwise might have to capture the data, or that would be ignorant of important pertinent data, should have information as to its existence and access to the data itself through GCSM. It should be noted that GCSM can provide management of spatial data, without physically holding it, by acting as a "directory" to digital spatial data actually stored and administered elsewhere in the Kingdom of Saudi Arabia. To do this, GCSM should provide common metadata and catalogue to digital spatial data stored in other clearinghouse servers.

7.2.2 Fundamental Spatial Data sets

Chapter 4 revealed that there are huge volumes of digital spatial data in the Kingdom of Saudi Arabia, which have been collected or are about to be collected by different ministries and organisations, to be used for their own purposes and applications. By creating a common core spatial database framework with broad geographic coverage, as illustrated in figure 7-9, and making it available to all users in the Kingdom of Saudi Arabia through the proposed national spatial data infrastructure, duplication can be avoided. In most countries core spatial data includes both small scale and large-scale spatial databases (Masser, 1998).

The proposed fundamental Saudi spatial data should include standardised large scale, medium scale and small scale datasets, formed in and supported by the following themes and databases; the national geodetic database (including, field surveys, geodetic control network, gravity and magnetic information), topographic database, aerial photography/orthophotos database, satellite images/orthoimages database, national geographic names database, gazetteers, elevation/bathymetry, hydrography, marine and oceanography database, cadastral, transportation network, political boundaries, vegetation cover and classification, soil classification, data on education facilities, economic data, statistical data, photogrammetry, cartography, geology, mineral resources, petroleum, utilities network (electric, water, gas, telephone, telecommunication), province and administrative boundaries, biodiversity, climate, tourist information, areas subject to natural hazard, environmental data, aviation and aeronautical information, etc. The fundamental spatial datasets should also include other spatial data, which might not conform to well-known standards, as well as a directory for conventional (paper) products.

Figure 7-9 shows a proposed model for a Saudi interoperable spatial data environment with user interaction using the Internet, passing through an electronic front gate to prevent unauthorised access and data security as discussed in chapter 5.

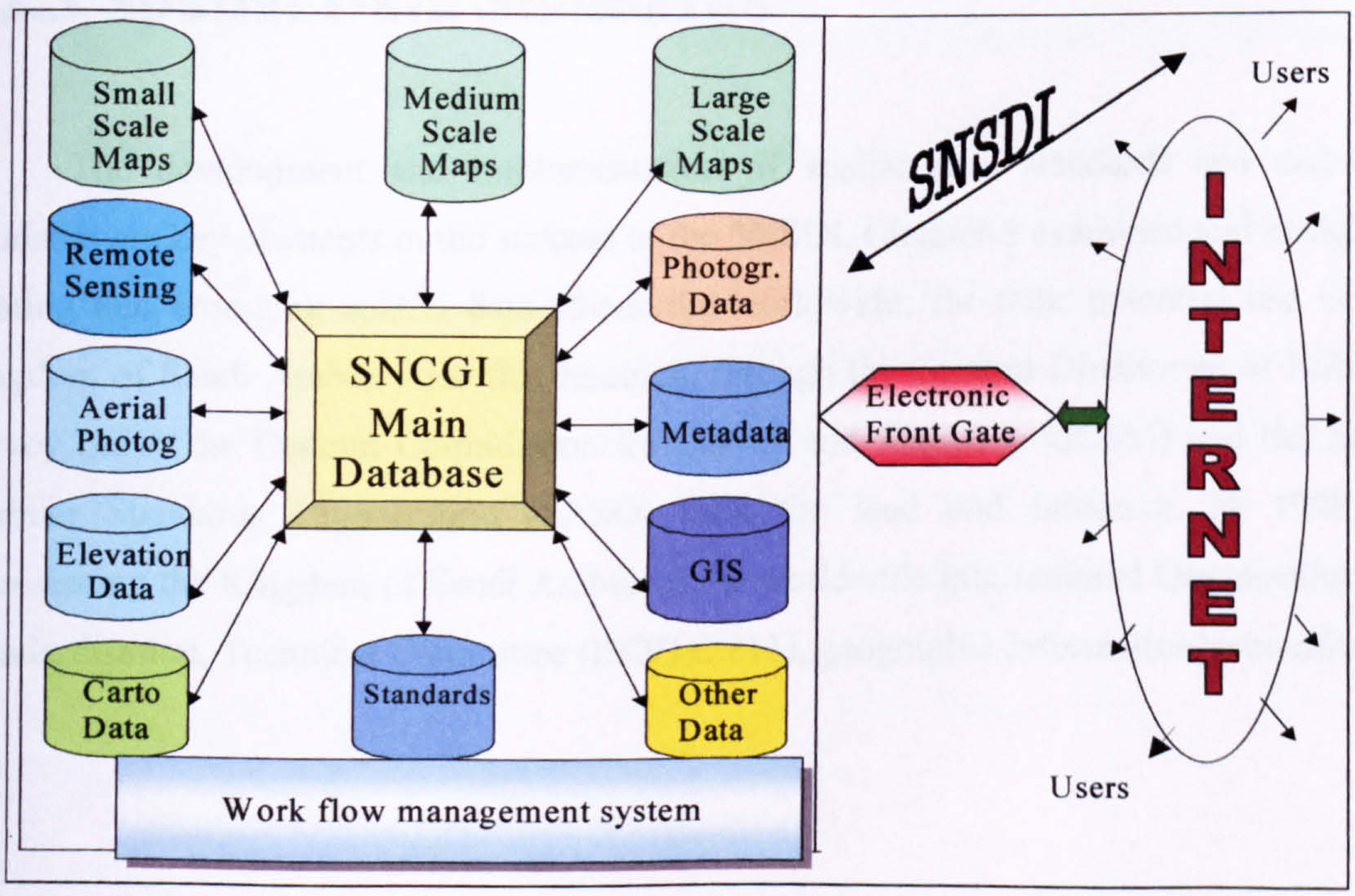


Figure 7-9 A model for Saudi national interoperable spatial data environment.

GCSM should design flexible spatial database schemas. The schemas should include detailed definitions of all the data types that can be stored and managed in the main Saudi NCGI, as well as other spatial databases. GCSM can make changes to the schema based on approval of the NCGI. Upon approval, GCSM has the capability to control the creation and revision of the schemas and other databases management and control systems.

The design of the database schema, quality control methods and other integrity and topological structures are to be determined during the SNSDI system design phase, which will be discussed later in this chapter. In order to ensure quality and integrity of the source data, GCSM should evaluate spatial data donated by other organisations to determine if it meets the requirements for use within the Saudi NCGI database. The evaluation criteria are specific to the nature of the source. The evaluation reports should be maintained in the source database.

Every spatial data product and database will have separate policies concerning updating, duration of archive and so on. This will depend mainly on the nature and value of each data set. Archiving digital spatial data products, as a back up for the on-line spatial data in the SNSDC, involves placing the data on durable media and storing the products in a safe and secure facility that is environmentally controlled and located away from the production facility.

7.2.3 Spatial Data Standards

The development and implementation of spatial data standards and metadata standards are key elements in the success of the SNSDI. Chapter 3 examined and evaluated existing and emerging spatial data standards, worldwide, for their potential use in the Kingdom of Saudi Arabia. Also this research, through the General Directorate of Military Survey (now, the General Commission for Survey and Mapping, GCSM) and the Saudi Arabian Standards Organisation (SASO) took the lead and initiative, in 1998, in representing the Kingdom of Saudi Arabia on the worldwide International Organisation for Standardisation, Technical Committee (ISO/TC 211), geographic information/geomatics.

The Kingdom of Saudi Arabia has now become a permanent member of ISO/TC 211. Rather than invent new spatial data and metadata standards the Kingdom of Saudi Arabia should adopt the ISO/TC 211 broad standards and modify them as necessary for the specific needs of the Kingdom and name it "the Saudi National Geographic Information Standards (SNGIS)". GCSM should play a critical role in nominating and co-ordinating the selected standards, which are most likely to be the ISO/TC 211 standards. This set of standards should be announced and enforced by GCSM in agreement with the NCGI policy and in co-operation and co-ordination with SASO to promote interoperability in both military and civilian communities and assist the commencement the SNSDI.

7.2.4 Technical Framework

The SNSDI will provide a fundamental framework for the development and implementation of technologies and technical capabilities and support. The main part of the technical framework will be a clearinghouse (the SNSDC) that will use a distributed network system to link all potential spatial data users and producers by a common network, a proven set of standards, procedures and policies to share and discover spatial data in Saudi Arabia and its condition, contents, structure and accessibility of the data.

7.2.4.1 Saudi National Spatial Data Clearinghouse Architecture

The proposed SNSDC assumes a distributed spatial data modular network to enable spatial data integration and facilitate access, process, ordering mechanisms, distribution and so on. The clearinghouse will provide high-speed physical links between all spatial data users and producers and can be achieved using the Internet and other local and wide area networks available within the Kingdom of Saudi Arabia, as shown diagrammatically in Figure 7-10.

Figure ***7-10 General concept of the Saudi national spatial data network (SNSDN).***

The Saudi national spatial data clearinghouse should be structured using a multi-tier model architecture. Figure 7-11 shows the proposed model, based on the OGC solutions discussed in chapter 5. This model architecture includes a first tier (client or user interface-level), a second tier (services and application-level) and a third tier (database-level). Each level is connected to the one above or below it using, wherever possible, standardised software interfaces and protocols. These standard software interfaces permit the connection of software in a highly distributed environment.

The first-tier represents the user and client software to access and integrate information provided through interfaces with application services and Web-based GIS processing services working on remote spatial data. This tier includes components such as a Web browser, search application and other users capabilities. The client tier employs interfaces and protocols such as the Hypertext Transport Protocol (http) over TCP/IP to access the Web Services in the next tier.

The second-tier in this architecture includes integrative services – services that can work with, combine, and process remotely accessed data from more than one source. Software which exists in this tier, generally known as an Application Server includes distributed World Wide Web (WWW) servers, gateways between http and other protocols (e.g. Z39.50, Simple Object Access Protocol (SOAP)), catalogues of data and services, and integrative application software that handles user requests and deliver processed information to the requesting user. This tier may include geo-processing facilities that can play an important role to search and integrate spatial data from different locations and perform certain operations, such as transformation, integration, symbolisation, overlay of different spatial data and deliver it to the user (Nebert, 2001). This tier is connected to the next one by standardised data access interfaces such as OpenGIS Simple Features SQL and the pending OGC Web Feature Services.

The third-tier provides access to data stored in distributed spatial databases. Access to this tier is provided through standardised data access methods. This tier includes data source and access services, spatial data, metadata, and catalogues.

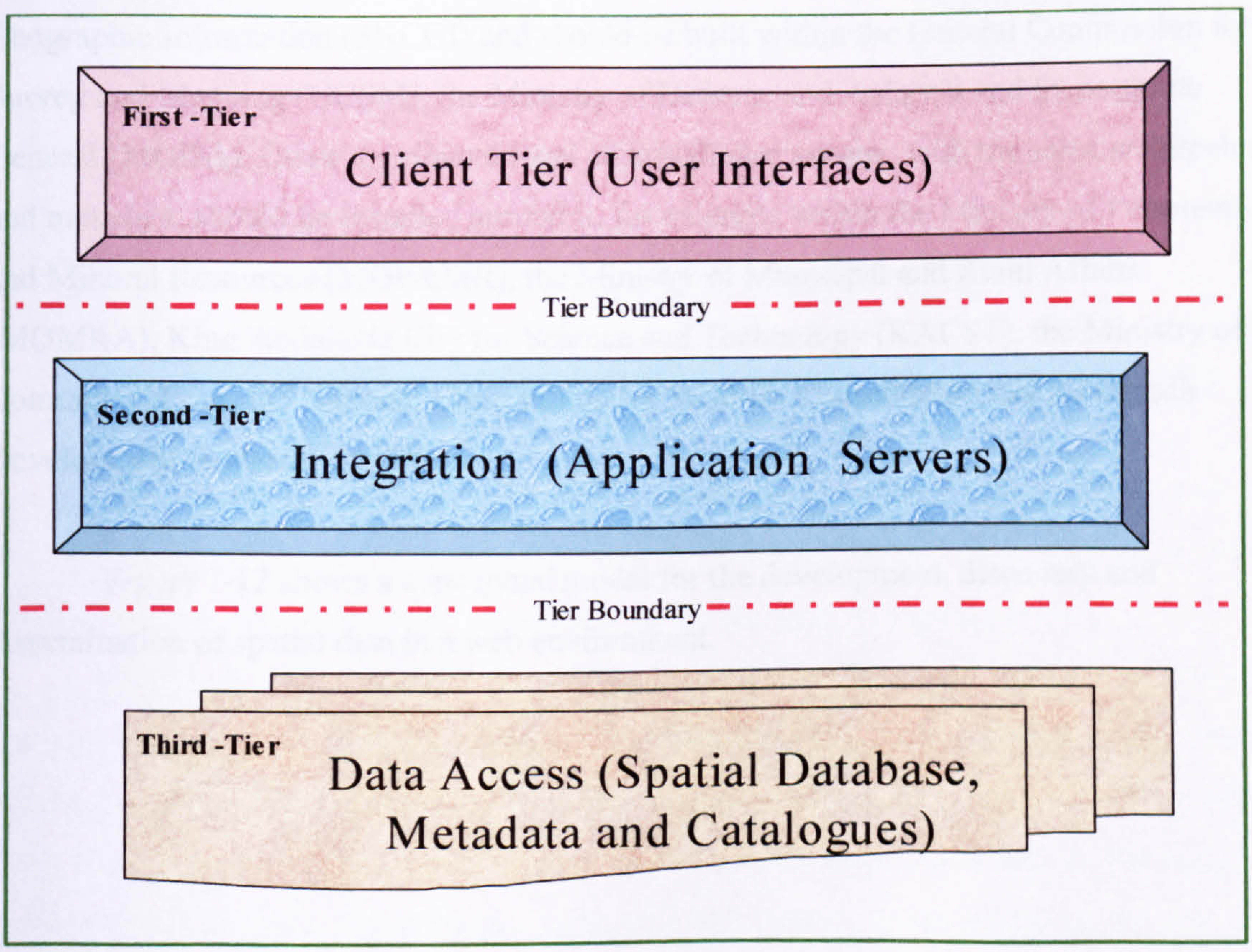


Figure 7-11 General concept of three-tier architecture for the SNSDC.

The metadata is one of the most important components of the SNSDC. The first step in developing and implementing the clearinghouse is to identify the relevant elements of the metadata based on the producer and user needs and requirements. Each spatial data producer or distributor will be required to describe their spatial data in an electronic form of documentation (metadata) and will publish these descriptions to the clearinghouse through the Saudi National Spatial Data Network (SNSDN) using standard methods and protocols. The metadata should describe all existing (and planned) digital spatial data and related data, in the Kingdom, precisely and concisely in order to provide the primary interface and interaction between spatial data users and producers and to facilitate spatial data discovery and sharing in a heterogeneous distributed environment. The metadata should include elements, capable of answering basic questions, which arise most commonly from the users. For example; "where can I locate certain type of spatial data, covering a specific geographic area, containing certain information, last update, cost and the access conditions?".

Metadata and spatial data, wherever possible, should be stored and maintained at the institutions responsible for their collection. As illustrated in figure 7-12, the main spatial data clearinghouse, with a national metadata, will be the Saudi National Centre for Geographic Information (SNCGI) and should be built within the General Commission for Survey and Mapping (GCSM), the Ministry of Defence and Aviation and Inspectorate General (MODA). Other distributed local clearinghouse servers, with the same architecture and metadata, should be installed around it, for example within the Ministry of Petroleum and Mineral Resources (MOP&MR), the Ministry of Municipal and Rural Affairs (MOMRA), King Abdulaziz City for Science and Technology (KACST), the Ministry of Communications, the National Commission for Wildlife Conservation and Ar Riyadh Development Authority (ADA).

Figure 7-12 shows a conceptual model for the development, discovery and dissemination of spatial data in a web environment.

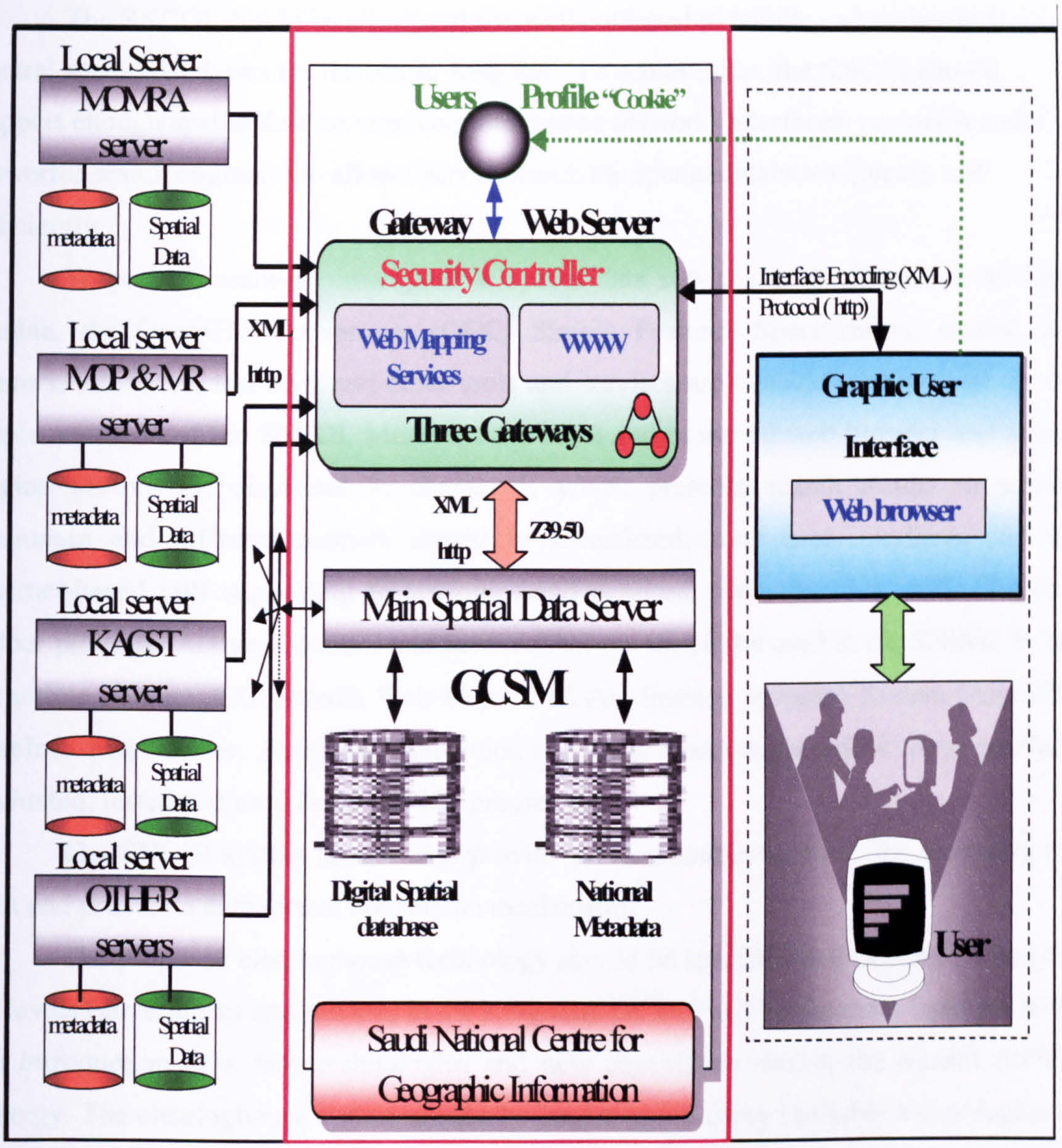


Figure 7-12 A conceptual model for the Saudi National Spatial Data Clearinghouse (SNSDI).

The interaction between the Gateway (controller), shown in figure 7-12, and the distributed catalogue services would probably use the ISO 23950 (ANSI Z39.50) protocol or http if an http implementation is standardised by the time of implementation.

SNSDI should anticipate the deployment of web mapping services in gateway environments or at the spatial data sites. The Web Mapping Services should take remote data and apply symbolisation rules to generate quick and detailed maps, as GIF or JPEG files, from raw data sources. Many users would benefit from the access to the maps as georeferenced pictures, though some users will still require direct access to the raw GIS data sources in their applications.

The SNCGI should be structured and well equipped to handle and maintain a central spatial databases for the whole Kingdom. To achieve that, the SNCGI should support enough spatial data servers, communication network, interfaces, protocols and a powerful search engine(s) to allow users to search the spatial databases quickly and efficiently.

To prepare seamless interoperable spatial data services in the Kingdom of Saudi Arabia, the OpenGIS Consortium (OGC) Simple Features Specification, spatial data servers, interfaces, test beds and other tools and services are considered important for the implementation of the SNSDI. Moreover the latest and powerful web browser and search engine technology, discussed in chapter 5, which presents search results in several languages and different formats should be considered. Also user interfaces and the Internet-based GIS supporting technologies and services, such the CGI, API, Plug-ins, helper program, Active X control and Java technology should be used in the SNSDI. In the meantime Intergraph GeoMedia Web Map, ESRI Arc Internet Mapping System (ArcIMS), MapInfo MapXtreme, AutoDesk MapGuide and other systems should be more carefully evaluated, tested and used as the SNSDI progresses.

The SNCGI system should also provide policies and procedures for accessing the data and provide a data format conversion mechanism.

The proposed clearinghouse technology should be specified and deployed widely at all levels (government and private) in the Kingdom. GCSM will be the main focal point for the introduction of a new technologies and new capabilities within the overall SNSDI strategy. The clearinghouse system should be implemented using available technologies to allow the user to access graphic and non-graphic datasets directly by using metadata standards. However the type and specification of the tools and technologies, needed for the SNSDC, must be stated clearly and in detail in the Request For Proposal (RFP), which should be prepared by GCSM in co-ordination with the NCGI and other participating organisations.

All clearinghouse servers within the Kingdom of Saudi Arabia should be logically identical and the search facilities should be capable of performing a single pass search of all servers instead of requiring the user to select server(s) from a list of ministries and organisations, or to search all servers one by one. The clearinghouse system should be capable of handling all users' queries by receiving queries and passing them to the gateway web server, where they will be processed and the user's authority (user name, password and other verifications) checked. The clearinghouse should be capable of building a users profile from this data and the queries themselves. Then, each server will simultaneously search its own metadata to find out whether it contains data meeting the user's search criteria. Each clearinghouse server may include metadata as well as the spatial data, or sometimes just the metadata. The clearinghouse gateway will then collect all results from each clearinghouse server and summarise and return them as Hypertext Markup Language (HTML) or Extensible Markup Language (XML) documents to the user as titles of metadata entries. When the user selects one of the resulting headlines, he/she will be able to access the full descriptive metadata entry. Reference to how the data can be accessed or mapped will be stored in the full metadata as one or Uniform Resource Locators (URL). The user may 'click' on these URLs to map or download the data. The clearinghouse query parameters, tools, accesses mechanism and downloading capabilities should be developed carefully and clearly stated and documented in the national spatial data policy document as well as the request for proposal document.

7.2.5 An Alternative Model for the SNSDI Institutional Framework

Section 7.2.1 discussed in detail the building of an institutional framework to co-ordinate and lead the development and implementation of a Saudi national spatial data infrastructure. It must be emphasised that a national mapping body is designated by the government to lead the development of the Saudi national spatial data infrastructure. This section also proposed the establishment of six specific new arrangements and institutional structures for the SNSDI. They were:

- Royal Decree (High Executive Order).
- National Committee for Geographic Information (NCGI).
- Organisational Framework.
- National Spatial Data Policy (NSDP).
- SNSDI Development Office (SDO) and SNSDI Management Board (SMB).
- Spatial Data Users/ Producers Community (SDUPC).

It is to be hoped that such an integrated approach with logically centralised control but with a distributed clearinghouse structure would be the most successful in the Saudi situation. If, for any reason, the above arrangements and models do not succeed, are delayed, or deemed inappropriate, then the following alternative model could be proposed. This alternative owes much to the UK system of private enterprise development of a disseminated spatial data approach where developments outside government lead to integration through business necessity and market development, with data warehouses and clearinghouses being constructed according to subject themes. This model allows mapping organisations access to all types of data from the individual providers classified according to their data types and format. For example, cadastral, topographical, geological, remote sensing, etc. Figure 7-13 outlines the co-ordination and integration of various modules and systems centred around a directory of all spatial data producers.

A client web server should be established and all spatial data producer are invited to list information about their products on the web, and the requirements and mechanisms to get those products. Then the users have to contact the spatial data holder directly and each organisation disseminate its spatial data separately. This process should include information about standardised and non standardised digital spatial data as well as conventional products and should provide a mechanism for converting any existing non standardised formats into standard or specific data formats based on the user's request. This alternative would be roughly equivalent to that presently being provided on a somewhat experimental level by the AGI initiative (AskGiraffe website) in the UK.

The critical problem with this alternative, which makes it the second choice for the Saudi situation, is the difficulty of controlling data currency and the management of the updating process for spatial data controlled by numerous different supplier systems. Adherence of all producers to the same standards might well be a serious problem. Also the chance of successful integration and utilisation of interoperable spatial data is more difficult owing to the decentralised and amorphous nature of the project, but this model is perhaps a more secure model for producers as they continue to be responsible for their own data. In contrast, the first proposal is more easily controlled and developed, and can be made directly beneficial to the whole Saudi population. The Royal backing also provides a very positive impetus to help development proceed as opposed to the somewhat "ad hoc" arrangements otherwise necessarily undertaken.

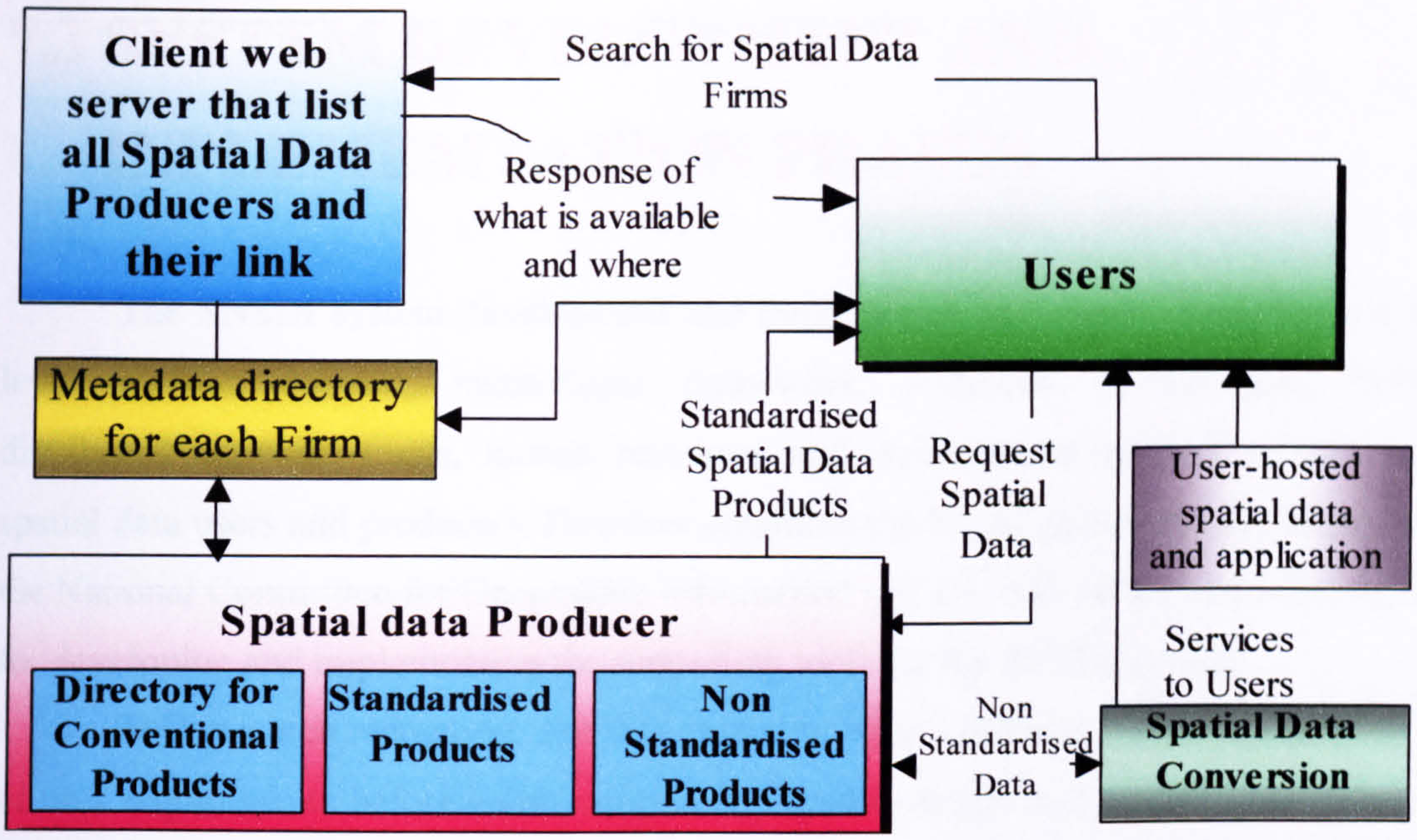


Figure7-13 An Alternative Model for the Saudi National Spatial Data Directory.

The following diagram (figure 7-14) summarises the components of the proposed Saudi national spatial data infrastructure in the first model.

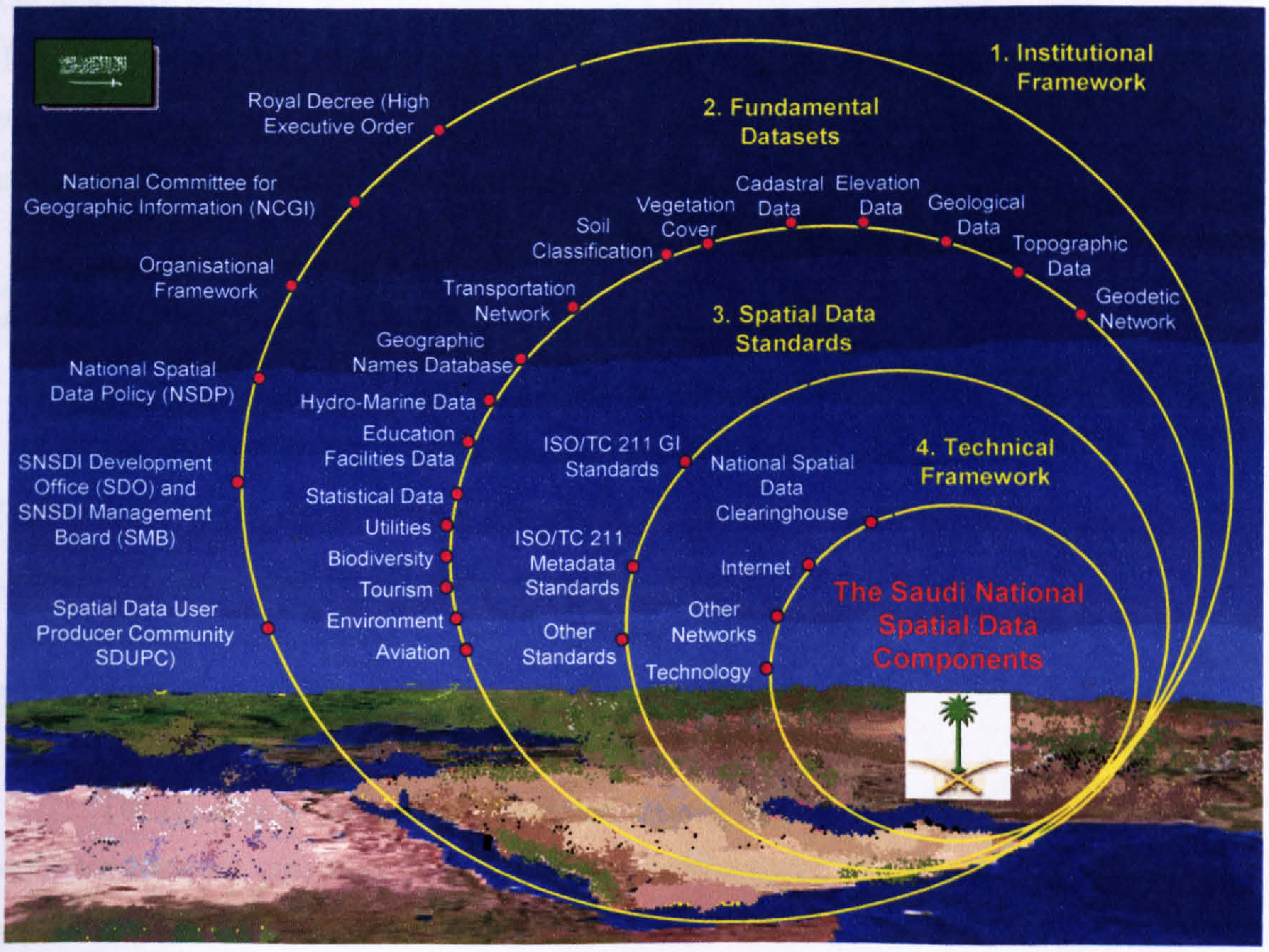


Figure 7-14 Summary of the Saudi NSDI components [Source: Al-Shahrani, 2001b].

7.3 SYSTEM DEVELOPMENT AND INPLEMEMTATION PHASES

The SNSDI system development and implementation process depends on a high-level decision support, institutional framework, standards, technologies, policies, distributed network, funds, human resources and development of partnerships among spatial data users and producers. However obtaining the Royal decree and the formation of the National Committee for Geographic Information (NCGI) will be the main driving force for developing and implementing the supporting tools for the SNSDI system.

This research recognises that it is crucial to have a full and complete understanding of user requirements before committing to any system design and implementation plan. It also recognises that users cannot state meaningful requirements in a vacuum. Many users, particularly those with no or little digital spatial data experience or facilities cannot articulate accurate requirements. Therefore, it is important to create prototype spatial datasets and develop pilot spatial data infrastructure capabilities, raise awareness and carry out demonstrations to help the users and assist them to state their requirements accurately. These efforts are termed early implementations and intermediate implementations phases, which will be developed in parallel with the system design activities and will be discussed, along with other phases, in the following section.

7.3.1 SNSDI System Development

The proposed Saudi national data infrastructure system development consists of four phases; the Concept Phase, the Design Phase, the Implementation Phase and the Operation Phase. An overview of each phase is discussed as follows:

7.3.1.1 Concept Phase

The concept phase defines the Saudi national spatial data infrastructure functional requirements and structure. It identifies the participating organisations, their roles and responsibilities and the way in which they relate to each other. This phase also identifies the functions that contribute to the overall infrastructure. The concept phase should produce a suite of documents, including development of standards-based RFP, to facilitate the acquisition of an appropriate SNSDI hardware and software system that collect, produce, integrate, manage, discover and disseminate the required spatial data. It is important that all participating ministries and organisations are involved in the planning and procurement of hardware and software, so that costs are minimised. The management of the concept phase should be handled by GCSM and other participating organizations, in close co-ordination with the NCGI.

7.3.1.2 Design Phase

During this phase, appropriate experts should prepare engineering designs and detailed plans for both a preliminary and a detailed design. Functional requirements should be refined and resources allocated for distributed network, hardware, software, operations and human resources. In this phase, also, the spatial data products, procedures, formats, spatial data standards, metadata standards, exchange standards to translate existing digital spatial data into the new required standard format, and other tools and service will be defined. GCSM and all other participating organisations should participate in all design functions and ratify the final documentation.

At the preliminary design level, the functional requirements should be traced to testable engineering requirements, then to a detailed design level. The detailed design activities should result in hardware and software specifications, operating procedures, detailed management plans, installation, testing and acceptance requirements. GCSM should manage the process of the design phase through co-operative efforts of other participating organisations, consultants, contractors and the user/producer community. A draft standards and prototype spatial data products document conforming to a draft standards should be prepared as an early implementation of the Saudi national spatial data infrastructure. Feedback on the draft standards and the prototype data should be gathered by hosting meetings and seminars that involve users and producers. The feedback should be in the form of:

1. User reactions to the draft standards and the prototype products in terms of data content, coverage, accuracy, format, structure, media, user friendliness and so forth.
2. Suggestions for improvement or alternative spatial data products.
3. Suggestions on the creation of a distributed versus centralised electronically

connected network servers and the location of each server.

Shortcomings discovered in the design process should be used to correct inadequate or inappropriate requirements and faulty engineering design or detailed design. The process should be iterated in the implementation phase.

7.3.1.3 Implementation Phase

The implementation phase is of major importance in providing feedback to enhance the design of the SNSDI system and strengthen the user/producer interface mechanisms. The implementation phase overlaps with the design and operation phases, as shown in figure 7-14 and is divided into three successive phases or stages, as follows:

1. The **early implementation (prototype)** phase, which consists of spatial data integration, of limited scope and complexity on selected framework categories, starts early in the design phase. The purpose of this phase is to promote and test spatial data sharing procedures, set priorities, guide the standardisation of spatial data products and their encoding, stimulate the growth of a user/producer community, establish metadata publishing and search services, spatial data access services and a user interface, provide an environment for the development of necessary human resources and provide feedback to the design process. Initial programmatic and technical coordination between various members of the user/producer community should be incorporated into the early implementation phase. The early implementation, as well as the design phase, should be built upon the existing GCSM and other participants' capabilities to minimise the costs and delays associated with new hardware, software and other new techniques and requirements and to demonstrate a readiness to start building the SNSDI. It is also noted that the SNSDI should be compatible with global standards wherever possible, to minimise cost in systems development, maximise compatibility with adjacent SDIs, and exploit commercial software solutions in lieu of constructing special solutions.

   The early implementation phase should also include the following activities:

   a. Identification of digital spatial data sets (standardised and non standardised) available in other organisations within the Kingdom of Saudi Arabia.
   b. Collection and integration of digital spatial data and metadata, donated by other organisations.

c. Conversion of the donated data set into standard structures and formats and creation of metadata for these data to document their data content and characteristics.

d. Distribution of a second prototype of the spatial data and metadata for user evaluation.

e. Promoting experimental and systematic use of the spatial data analysis in support of users' missions.

f. Assisting users to exploit the spatial data through the technology transfer, and other technical assistance.

g. Collecting user second feedback in the form of:
   - Suggestions for improvement in spatial data content
   - Suggestions for improvement in data structures and standards
   - Suggestions for improvements in spatial data user friendliness and utility.
   - Suggestions for improvement in the network and spatial data exchange procedures.

2. The **intermediate implementation** phase is associated with a steady build-up in the activities started in the early implementation phase and incorporates suggestions and lessons learned in the design phase. This phase includes testing of hardware, software, delivery, installation and small runs of the SNSDI system on a spatial data prototype. Prototype products, standards, tools, services, and an initial set of standardised products and techniques should be selected based on users' input and evaluations of the spatial data. During this phase the Saudi NCGI should start to disseminate and announce the availability of national spatial data through its Web-based Clearinghouse mechanisms.

3. The **final implementation** phase refers to the achievement of the full operating capability of the entire SNSDI system. This includes the construction of necessary facilities, final selection and installation of hardware, software, network, interfaces protocols, integration, training, recruitment, site acceptance, system testing and system initialisation. If several contractors are involved in the SNSDI system development, their equipment must be integrated in this phase according to the plans made in earlier phases. The implementation phase, as well as the transition, which will take place during the final implementation phase, will be managed by the SNSDI Development Office (SDO). This phase will also need to address issues of data privacy, security, fees, and internal and external access. The availability of

spatial data and metadata to the public in addition to participating government and academic organisations, for a fee or at no cost, may provide opportunities for economic development, analysis of development and planning alternatives, and other applications suited to helping to diversify the economy of the Kingdom.

At the end of the implementation phase, the benefits and capabilities of the SNSDI must be advertised widely in order to raise awareness and allow the SNSDI to benefit all users.

7.3.1.4 Operation Phase

The operation phase refers to the routine satisfaction of the users and producers requirement to access and share standard spatial data products and services rapidly and responsively through the Saudi national spatial data clearinghouse. This assumes that all previous phases and activities are properly executed and adequate levels of staffing, state of production, maintenance and dissemination of spatial data have been attained.

Receiving and integrating donated spatial data will continue during the operation phase. Also, system evaluation and training of personnel will continue to ensure the necessary long-term base of qualified Saudi staff and research and development activities. Figure 7.15 shows the system development phases and management stages under the guidance of the NCGI.

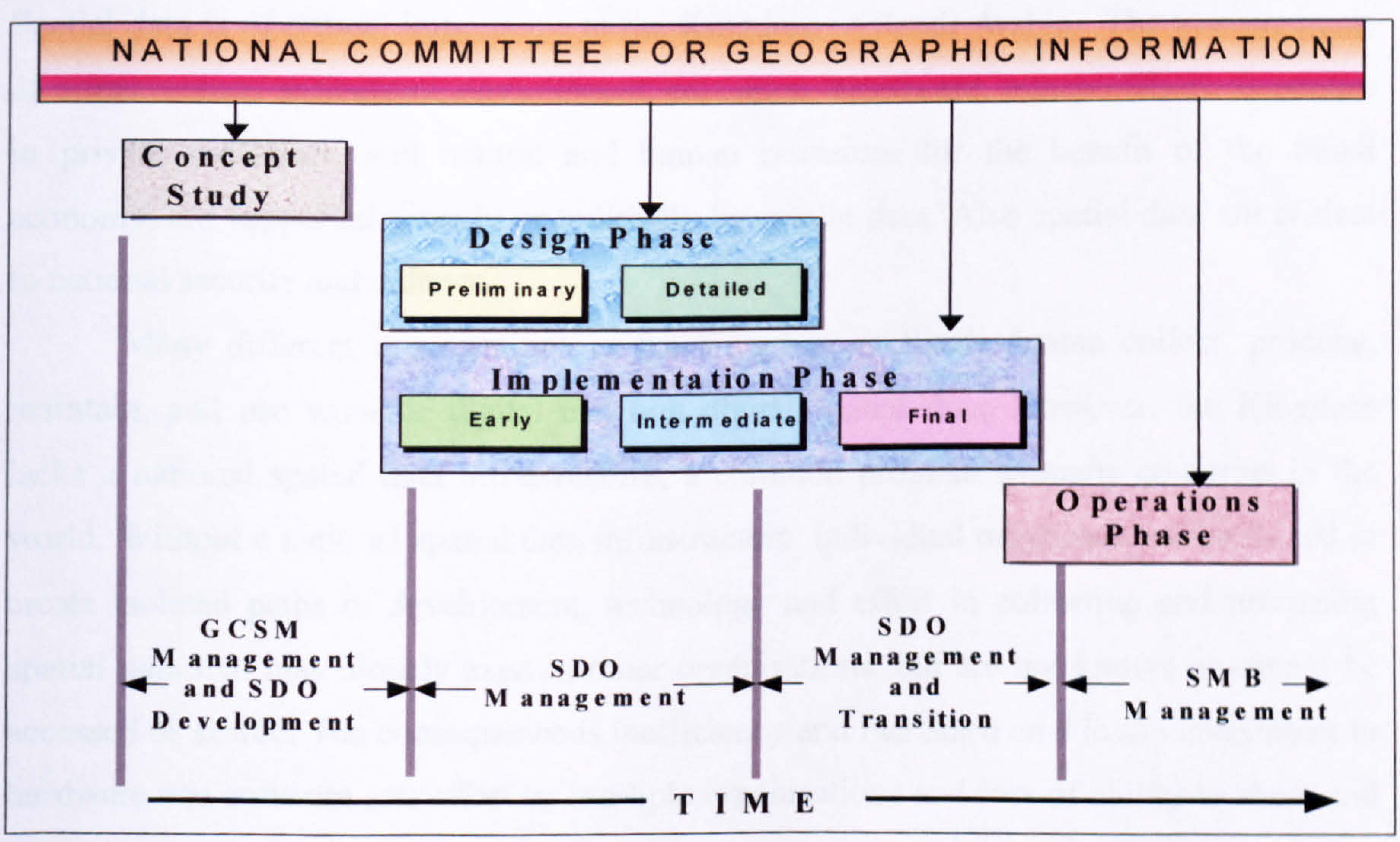


Figure 7-15 The SNSDI system Development and Management Phases

7.3.2 SNSDI Security Policy

By the nature of its work, GCSM will be the custodian of an enormous quantity of digital spatial data, critical to the SNSDI and to national security. The main database in the SNCGI will contain most of digital spatial data produced by GCSM and other participating organisations and therefore a clear policy for national spatial data security must be established to control and protect spatial data from unauthorised user access, e.g. by software, user name, password, firewalls, encryption, authentication and other means, as discussed in chapter 5. The security policy arrangement must also cover Virtual Private Networks (VPN) and physical security issues. The Saudi National Centre for Geographic Information, which contains the main national spatial database and the clearinghouse server at GCSM, must be installed in physically secure quarters in accordance with the security policy. The system must provide for safety against accidental loss of, and intentional damage to, subsystems or data. The same security policy must be applied also to spatial data and clearinghouse systems held by other participating organisations.

7.4 CONCLUDING REMARKS

Spatial data is of critical importance to the Kingdom of Saudi Arabia. The managements of infrastructure, agriculture, environment, education, healthcare, transportation, assistance to private industries, and natural and human resources for the benefit of the Saudi economy, are supported directly or indirectly by spatial data. Also spatial data are critical to national security and defence.

Many different organisations in the Kingdom of Saudi Arabia collect, produce, maintain, and use valuable digital and non digital spatial data. However, the Kingdom lacks a national spatial data infrastructure; a common problem to many countries in the world. Without a national spatial data infrastructure, individual organisations are forced to create isolated paths of development, technology and effort in collecting and producing spatial data that may already exist in other organisations, but are not known or cannot be accessed or shared. The consequence is inefficiency and increased cost in the investment in hardware and software and effort by multiple organisations and loss of ability to share and control spatial data. It is therefore necessary to co-ordinate all the Saudi efforts being made for spatial data collection, production, maintenance and dissemination through the development of a strategy for a national spatial data infrastructure (SNSDI). The SNSDI is designed to bring the benefits of spatial data and geographic information system technologies to the Kingdom of Saudi Arabia. The Kingdom now is in a unique and enviable position to establish the national spatial data infrastructure. Highly developed, low-risk technology is currently available; mature hardware, software and communication network tools have been extensively tested and implemented throughout the world and new processes and services are being developed, which can be easily adopted and incorporated into the SNSDI as it evolves.

This research appreciates and recognises the large digital spatial data assets that have been collected, produced and maintained within the CSMA, Ministry of Defence and Aviation (MODA), the Ministry of Petroleum and Mineral Resources (MOP&MR), the Ministry of Municipal and Rural Affairs (MOMRA) and King Abdulaziz City for Science and Technology (KACST), as well as other ministries and government and non-government organisations. These assets will be used as the nucleus of the Saudi national spatial data infrastructure.

Moreover, this research appreciates that the Council of Ministers Executive Order number 133, forming the General Commission for Survey and Mapping (GCSM), has been a big step towards the establishment of the SNSDI and will hasten the creation of the institutional framework and fundamental data sets required. It is envisaged that GCSM will assume a predominant role in developing a Kingdom-wide spatial data database and a leadership role in establishing a SNSDI capability in the Kingdom of Saudi Arabia. Building the first implementation of a national spatial data infrastructure for a country as large and extensive as Saudi Arabia is not an easy task. It is, rather, a task that requires high level government support, leadership, core spatial data, planning, co-ordination, co-operation, access mechanisms, including the privacy and security, communication links, technology, policies, procedures, standards, metadata, human resources, a positive partnership involving all spatial data users and producers in the Kingdom and critically, funds (from the government, industries, partnership and users).

The development of Saudi national spatial data standards and technical framework need serious efforts and work. The GCSM and other participating organisations, under the umbrella of NCGI should lead this and raise awareness of the SNSDI. This can be accomplished through publication, seminars, workshops, TV programs, general education and training processes. However, the educational institutions must also play an important role in promoting the infrastructure. Demonstration and pilot projects are a very effective way of promoting SNSDI. Joint ventures with manufacturers of software and hardware would invariably contribute to the promotion of SNSDI by demonstrating spatial data capabilities to users and producers.

CHAPTER 8

FINAL SUMMARY AND CONCLUDING REMARKS

8.1 INTRODUCTION

The quality of life of a nation depends to a great extent on that nation's ability to develop and maintain the components of its infrastructure, such as education, healthcare, electricity, water, gas, communication, telecommunication, road networks and so on. Currently a significant new component of infrastructure is emerging, which is the national spatial data infrastructure. A major challenge to developed nations is the viable integration of spatial data with existing social, economic and environmental activities. This integration can only be enabled through sound and informed implementation of a strategy for a spatial data infrastructure managed at a national level rather than individual or local levels.

This research was initiated in October 1998 to develop a theoretical strategy for a national spatial data infrastructure and was intended to be not only a piece of research for a PhD degree but also a practical plan to develop a real and comprehensive strategy for a national spatial data infrastructure for the Kingdom of Saudi Arabia in support of its needs and requirements to continue building and maintaining its other infrastructures. It is hoped that the new strategy presented here will overcome the deficiencies of the current mechanisms for spatial data sharing in the Kingdom, get individual organisations to work together and share common spatial data, thereby decreasing the overall investment in hardware, software data collection, production and avoiding wasteful duplication of effort, money and time.

This chapter draws the research to a conclusion; reviews the research in relation to the aims and objectives stated in the introduction given in Chapter 1 and highlights what the researcher has achieved in theoretical terms. Section 8.2 summarises the major findings, and the research ends with a note on implementation problems that leads to the potential for further research in section 8.3.

8.2 MAJOR FINDINGS AND SUMMARIES

This research project is probably the first initiative to investigate and evaluate all the main components of a spatial data infrastructure and summarise worldwide activities and initiatives in this field in an effort to develop the conceptual framework for a national spatial data infrastructure, and also present the proposed Saudi National Spatial Data Infrastructure (SNSDI).

Figure 8-1 shows an overview of the structure and interrelations of the eight chapters that forms this thesis, were chapter 1 and 2 set the thesis framework, chapter 3, 5 and 6 highlight and provide the spatial data standards, technical framework and institutional issues needed for the Saudi national spatial data infrastructure (chapter 7). In the meantime chapter 4 provides a framework for the Saudi spatial datasets.

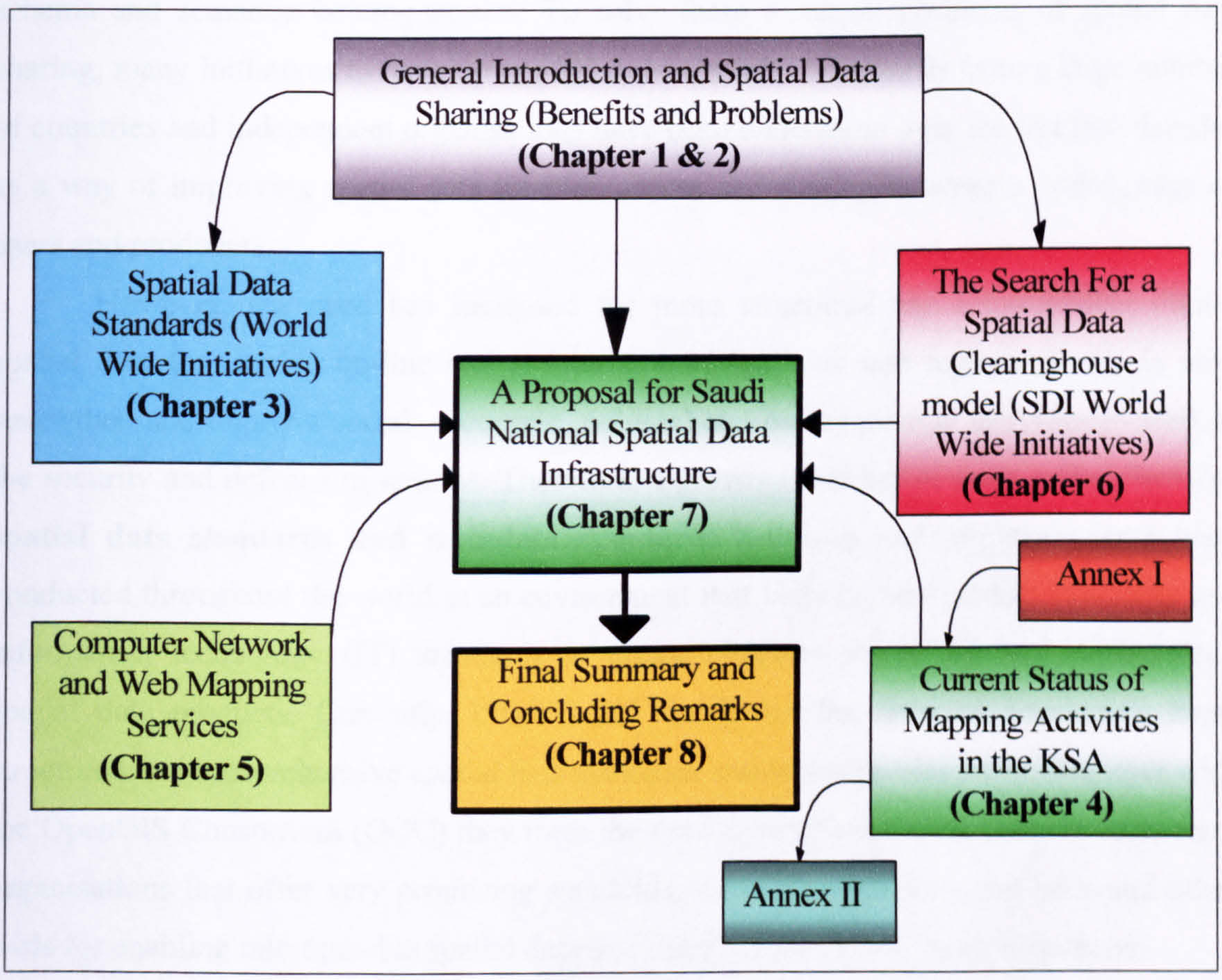


Figure 8-1 The structure and interrelations of the eight chapters and two annexes.

At the end of each chapter specific concluding remarks have been drawn in a summary. In this chapter a brief outline of those findings is presented as follows:

8.2.1 Worldwide Efforts

During the past three decades many worldwide survey and mapping organisations collect, produce and maintain digital spatial data independently and indifferent formats and structures. However, when the time was ripe to share and exchange spatial data, most of these activities have encountered serious formatting and structuring problems and obstacles, causing severe limitations in spatial data sharing and resulting in redundancy of data and increased cost for spatial data collection, processing, management, storage, analysis and updating.

Some of the data sharing problems were due to heterogeneity arising from the fact that different applications - and some people - have different views of reality (the real world), as a result of differences in contexts of application, each having its own syntax, schema and semantic heterogeneities. To solve these technical problems of spatial data sharing, many initiatives to develop **spatial data transfer standards** from a large number of countries and independent organisations have been undertaken over the last two decades as a way of improving spatial data transfer, access and sharing between a wider range of users and producers.

However, the need has increased for more structured and interoperable digital spatial data for sharing on-line and at international, national and regional levels to help strengthen and improve social, economic, political and environmental activities as well as the security and defence of nations. Therefore, a growing number of more comprehensive **spatial data standards and metadata standards** activities and initiatives have been conducted throughout the world in an environment that links the spatial data standards and information technology (IT) standards to create common structured and standardised spatial data products. Currently, ISO/TC 211 dominates the field of developing more structured and comprehensive spatial data standards and metadata standards. Together with the OpenGIS Consortium (OGC) they form the most innovative and technically competent organisations that offer very promising standards, interfaces, features, test beds and other tools for enabling interoperable spatial data activities in heterogeneous environments.

Moreover the United Nations Conference on Environment and Development (UNCED), held in Rio de Janeiro, Brazil, in 1992, which discussed environmental deterioration and established the basis of a sustainable way of life in the next century (Agenda 21) acknowledged that the availability of spatial data is critical for environmental decision-making and provides one measure to help protect the atmosphere and prevent pollution. This summit has been considered the first step in the development of **spatial data infrastructures.**

But most of the problems with spatial data over the years were associated with and inherited by the building of spatial data infrastructures. Foe example, heterogeneity problems, lack of spatial data standards and other various problems, have been mainly attributed to lack of funding, high level support, availability of reliable, accurate and updated digital spatial data sets, expertise, effective systems, policies, co-operation, technologies, communication networks and the commitments of spatial data producers to participate.

In addition there have been debates over charges imposed on spatial data by distributors and data custodians, legal issues such as copyright, security and most importantly, the tendency for some organisations to see spatial data as their own property, over which they have sole authority and their consequent unwillingness to share it freely with others. It is clear that installing a national spatial data infrastructure would not be feasible without resolving institutional, fundamental dataset and technical issues. Therefore most worldwide spatial data infrastructure initiatives grouped the main components of building an SDI into four items; spatial data standards, institutional frameworks, fundamental data set, and technical framework. These four components form the pillars of any SDI initiative.

Moreover, the current rapid development of the Internet, web mapping and World Wide Web (WWW) technologies and services has became an important technical issues to be considered in the development and implementation of a national spatial data infrastructures. The Internet has become the *de facto* communication medium for the spatial data user/producer community and has changed the way of searching for and sharing spatial data. Most, possibly all, proposed spatial data infrastructures around the world have now suggested the use of the Internet as a main backbone to enable the rapid and successful development and implementation of national spatial data infrastructure, to provide successful communication between multiple computer platforms from different manufacturers and to encourage many organisations to provide their spatial data to large numbers of users on the WWWW. Several good tools and technologies, thereafter, have been developed to build and facilitate spatial data and GIS applications on the Internet. Among those tools are specialised servers, Common Gateway Interface (CGI), Application Programming Interface (API), GIS Plug-ins, GIS helpers, Microsoft Active X, Java, and others. Moreover most GIS vendors have developed Internet tools and services for interactive spatial data functions and Internet-based GIS. Examples, the Intergraph, ESRI, AutoDesk and MapInfo. However, the increasing demand for the Internet services increases the security hazards for many data providers and users. Therefore, a number of issues concerning security awareness and appropriate measures have been discussed at the end of chapter 5.

Most present worldwide spatial data infrastructure initiatives (government initiatives, as well as initiative that are driven by private sectors), discussed in chapter 6, are similar in terms of their approaches and components and use the United States of America NSDI as a model. The U.S. national spatial data infrastructure has acted as a pioneer, is now well developed and has been recognised as a worldwide leader. The other well-developed initiatives are the ANZLIC in Australia and New Zealand, the NCGI in the Netherlands, the CGDI in Canada and the Charter of UK Strategic Alliance in the United Kingdom. However, the researcher expects the United Kingdom latest initiative (the Charter of the UK Strategic Alliance) to be one of the best NSDI because of the small size of the country, the availability of good, reliable and comprehensive spatial data at large, medium and small scales, as well as the support of most of spatial data providers in the UK, spatial data integrators, hardware and software providers, application service providers and the Government. It would be beneficial for the Saudi NSDI developers and decision makers to keep in close contact with the developers and institutions involved with those initiatives as well as the vendors and providers of related technologies and services.

Finally, it has been concluded that the success in developing and implementing spatial data infrastructure depends on the success of its clearinghouse. Clearinghouses are categorised into three different types (centralised, distributed and hybrid) each having its own advantages and disadvantages as discussed in chapter 6.

8.2.2 Saudi NSDI

The Kingdom of Saudi Arabia is a member of the worldwide digital spatial data community. It has been influenced by ongoing technological developments and follows similar paths in developing its digital spatial data capabilities as the rest of the world.

Saudi Arabia has carried out hundreds, if not, thousands of spatial data projects in support to its infrastructure and strategic plans, which resulted in a large volume of digital spatial data, non digital data, aerial photography, satellite images, geodetic data, geographic names and so on. Most of the available digital spatial data in Saudi Arabia were current, accurate and produced using a number of reliable spatial data standards. The data is maintained in a proper environment. It covers the whole Kingdom on medium and small scales and most cities on large scales.

There are also future plans to produce a variety of digital spatial data, including digital topographic maps at a scale of 1:50,000 covering the whole Kingdom. There are highly developed hardware, software and communicating networks available. Most importantly, all respondents to the researcher's questionnaire fully supported the development and implementation of a strategy for a national spatial data infrastructure in the Kingdom of Saudi Arabia, and willing to be part of it and wanted to use the ISO/TC 211 standards. On the other hand, the results of the survey questionnaire (chapter 4 and Annex I and II) indicated that as yet there are duplications in spatial data collection and production; the co-ordination and sharing of spatial data is per minimal.

All these factors highlight the Kingdom of Saudi Arabia's urgent need to implement the proposed SNSDI. Without a national spatial data infrastructure, the available spatial data will not be properly shared and managed on a national level and individual Saudi survey, mapping and GIS organisations will continue working separately, which will increased cost of spatial data collection and production and prevent users from accessing and sharing variety of different types of spatial data easily.

It is therefore proposed that a Saudi national spatial data infrastructure is developed and implemented to co-ordinate all the Saudi efforts being made for spatial data collection, production, maintenance and dissemination. The scope of the Saudi national spatial data infrastructure covers four main components; institutional framework, fundamental data sets, spatial data standards and technical framework, which form the building blocks for the development and implementation of the proposed SNSDI. To develop the Saudi NSDI two models have been proposed to build an institutional framework to co-ordinate and lead the development and implementation of a Saudi national spatial data infrastructure.

The first model discussed six specific arrangements and institutional structures for the SNSDI. They are: Royal Decree, National Committee for Geographic Information (NCGI), Organisational Framework, National Spatial Data Policy (NSDP), SNSDI Development Office (SDO) and SNSDI Management Board (SMB) and Spatial Data Users/ Producers Community (SDUPC). This model proposes that the General Commission for Survey and Mapping (GCSM) manage and control the SNSDI, in line with the Council of Ministers Executive Order number 133. The Executive Order gave GCSM a predominant role in developing a Kingdom-wide spatial data database and a leadership role in establishing a SNSDI capability in the Kingdom of Saudi Arabia.

However an alternative model is proposed. The alternative model suggested that the SNSDI can be developed within each mapping organisation and supported by a centralised directory for all spatial data producers. The metadata and spatial data would be maintained by the organisations separately according to data types and format (e.g., cadastral, topographical, geological, remote sensing, etc). The alternative model would be difficult to control, update, and manage. Also structured and interoperable spatial data integrations will be impossible, but it is more secure it terms of protecting a producer's data.

The alternative model could be proposed as an addition to the main model and is unlikely ever to be implemented on its own. But there may be situations where the main thrust of the SNSDI is assisted by private commercial developments. This should not be discouraged as long as the standards required for the SNSDI are maintained by other cooperating bodies.

It is therefore, recommended that the first model proposal is implemented for the building of the SNSDI and that the Saudi Council of Ministers issued Executive Order number 133, dated 23rd July 2001, be followed very closely. The Executive Order is a big step towards the implementation of the SNSDI and will support the creation of the institutional framework and fundamental data sets much more quickly and easily. In the meantime various systems, technologies, standards and communication networks and services discussed and analysed in this research are considered in the development and implementation of the proposed SNSDI. These include:

1. Worldwide effort and experience in the field of spatial data infrastructures and clearinghouses. It is recommended that the distributed clearinghouse systems, as in the U.S. be used as a first choice. In the U.S. the decentralised model has worked well, after initial problems with server "holes" in the network. The U.S. approach has the benefit of being quite fault tolerant through having over 200 servers transparently acting as both data providers and in many cases mirrors. In Saudi Arabia similar conditions apply, although presently on a more limited scale. The hybrid clearinghouse structure outlined in chapter 6 is recommended as a second choice.
2. The OpenGIS Consortium (OGC) efforts, specifications, spatial data servers, interfaces, test beds, and other OGC tools and services. However, the OGC standards are industry driven and may not be useful in a Saudi context by themselves.

3. The ISO/TC211 broad band spatial data standards and metadata standards so that Saudi Arabia can join the world in terms of data sharing and exchange in the future. If no nationally applied international standards are introduced to the Kingdom of Saudi Arabia the drawbacks will be great. Spatial data users and producers will not be able to successfully share data, make a clearinghouse of any type, or know what data might be available in the Kingdom owing to disparate querying approaches and metadata provision.
4. The Internet, the latest and powerful web browser and search engine technology, which present search results in several languages and different formats, as well as user interface and Internet-based GIS supporting technologies and services, mentioned above in section 8.2.1. These highly developed, low-risk systems and technologies are currently available and have been extensively tested and implemented throughout the world and would be easily adopted and incorporated into the SNSDI as it evolves. The Saudi NSDI should use the Internet network initially to promote the basic concept of an NSDI by means of web information pages and links to international good practice, and foster the formation of discussions groups amongst potential participants. The Saudi clearinghouse should contain only metadata during the first stage of the infrastructure project with spatial datasets supplied by the producers on their own servers. This will minimise the administrative load in setting up the national system compared with attempting to warehouse all the data at a national site or sites. The initial metadata gateway will use the open Internet as a test vehicle for setting up a full scale clearinghouse while critical reliability issues of Internet network availability, speed and security are investigated. At the same time it should be possible to incorporate flexibly the feedback from discussion groups amongst the Saudi spatial data community to determine the best use of the Internet structure to access the spatial data clearinghouse and to decide on the number of nodes needed in a fully operational failsafe system.
5. Security is a major problem, both in terms of access to metadata and to the data themselves. One approach would be to rely on software security at the gateways, which can be very effective, but not perhaps to the professional hacker. Another growing alternative is the use of either private lines or virtual private networks (VPNs) using high level encryption tunnels between sites. The latter is more computing intensive, but cheaper to implement and more flexible than secure private

lines. The development of VPNs may be a very useful feature of the communication system within the distributed clearinghouse nodes.

8.2.3 Final Note

This research provides a framework of ideas, components, benefits, techniques, awareness, and methods towards the development of a strategy for a national spatial data infrastructure designed for implementation within the Kingdom of Saudi Arabia. The research contains a large number of concepts and basic requirements for the implementation of a SNSDI. However, theoretical research alone will not be enough to build all the components of the infrastructure and solve all matters, as the field of building NSDI is very large and complex, especially for a country as large and extensive as the Kingdom of Saudi Arabia. It is, rather, a task that requires a great deal of effort, funds, human resources, co-operation and, most importantly, commitment from all spatial data producers and users in the Kingdom of Saudi Arabia.

Until now, most of the worldwide spatial data infrastructures initiatives are still at the theoretical and research stage. The theory expounded in this research must be put into a real world practical application to provide benefits and services to the modern Kingdom of Saudi Arabia and its people and enable the creation of Saudi national virtual spatial data communities.

Finally, the researcher has proposed that the Saudi national spatial data infrastructure is achievable from both technical and management perspectives. However, he feels that there will be a need to continue the research effort as discussed in the following section.

8.3 FUTURE WORK

The study of spatial data infrastructures is a new subject that has emerged in the last decade. There is an exciting and promising future for national spatial data infrastructures, which will be influenced by what the future challenging technologies bring to us. The vision of the Saudi national spatial data infrastructure should keep looking ahead and should go beyond the implementation and continue research and development works. At this time the following issues will need further research:

1. Continue the efforts to promote the SNSDI, first within the General Commission for Survey and Mapping (GCSM) and subsequently throughout various ministries within the government, to ensure the correct start towards the implementation of this initiative.
2. Design a general model for the SNSDI and complete the formalisation and funding of this initiative.
3. Evaluate and analyse spatial data networks and servers (nodes), especially fibre optics, portable communications, intelligent spatial data links, commercial spatial data servers, and neural networks.
4. Explore further the Location Based Services (LBS) and the issues attached to LBS, such as privacy and authenticity.
5. Investigate mechanisms and techniques that enable automatic update of medium and large-scale maps from high-resolution remote sensing data.
6. Develop a geodetic reference framework and explore differential GPS, active control systems, and real time GPS and what the impact of these technologies and services will be on the SNSDI.
7. Evaluate how will the SNSDI can take advantage of the growing capability of artificial intelligence, smart databases, and virtual reality.
8. It will be necessary to investigate further how spatial data and NSDI will change the way commerce is structured. What will be the effects on the "vertical domains" such as utilities, transportation, landscape architecture, urban planning, civil works, education, healthcare, training, etc? How can these disciplines take synergistic mutual advantage, through the medium of the SNSDI?
9. Expand the Saudi national spatial data infrastructure initiative to enable the creation of a Gulf Cooperation Council (GCC) regional spatial data infrastructure.

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ANNEXES

ANNEX I

SURVEY QUESTIONNAIRE ON DIGITAL AND NON DIGITAL SPATIAL PRODUCTS IN THE KINGDOM OF SAUDI ARABIA

I.1 INTRODUCTION

In the Kingdom of Saudi Arabia, there are a large number of different and isolated mapping, surveying, remote sensing and geographic information systems (GIS) activities within various ministries, other government organisations and in the private sector. This survey questionnaire was distributed to the main spatial data producers and users to collect as much information as possible about digital and non-digital spatial data in the Kingdom.

I.1.1 Clarifications

When we say department or organisation, in this questionnaire, it means the Section, Division, Department, Directorate, Establishment, Ministry or any other name of the organisation, which completed this questionnaire document.

I.1.2 Completion and Correspondence

Thank you for receiving this questionnaire and please note the following:

1. Fill in the sections of the questionnaire that apply to your department as clearly, accurately and completely as possible.
2. Write down any comments or suggestions that you may wish to include in this questionnaire.
3. Write down any relevant comments or suggestions you may have regarding the idea of building and implementing a strategy for national spatial data infrastructure (SNSDI) in the Kingdom of Saudi Arabia.
4. Provide citations of all documents, reports, materials, books, email addresses, or any other references, which were used to complete this questionnaire.
5. Please make sure that you return the completed questionnaire no later than 25/9/1421H (21/12/2000G). The estimated time to complete this questionnaire is about one hour and a half.
6. When you have completely answered the questionnaire please forward the entire document to the researcher or to the research and development section, General Directorate of the Military Survey (GDMS), Riyadh, Kingdom of Saudi Arabia.

7. If you have any questions, comments on this questionnaire or any useful information, please contact:

   A. The researcher:

Eng. Abdullah M. Al-Shahrani
E-Mail: Ashahrani@aol.com
Address: 115 East Acton Lane
London, W3 7HB
United Kingdom
Tel: 0044(0)2087461020 Home
Fax: 0044(0)2087460838 Home/Fax
Mobile: 0044(0)7887652030

   B. Any one of the contact persons at the General Directorate of Military Survey.

Eng. Mohammed Dalbouh
E-Mail: dalbouh@saudionline.com.sa
Address: P.O. Box 51860
Riyadh 11553
Tel: 014541200 ext.5225
Fax: 014563048

Eng. Eid Al-Mutairi
E-Mail: isxeam@hotmail.com
Address: P.O Box 87918
Riyadh 11652
Tel: 014567255, 3878, 2979
Fax: 014563048

I.1.3 Organisation Correspondence

In order to contact you or provide you with a response to your comments please complete the section below.

Name of Department :______________________________

Name of person(s), who completed this questionnaire:______________________________

Position(s): ______________________________

Address: ______________________________

Telephone: ______________________________

Fax: ______________________________

E-Mail: ______________________________

I.1.4 Some of The Ministries and Governments Organisations, Who Received Copies of This Questionnaire

Number	Name of Ministry/Organisation	Name of Department
1	Ministry of Defence and Aviation and Inspectorate General (MODA)	General Director of Military Survey (GDMS)
2	Ministry of Petroleum and Mineral Resources (MOP&MR)	General Directorate of Surveying.
3	Ministry of Petroleum and Mineral Resources (MOP&MR) Saudi Aramco	General Manager of Saudi Aramco.
4	Riyadh City Municipality	The Municipal of Riyadh
5	Ministry of Municipal and Rural Affairs (MOMRA)	General Director of Surveying
6	King Abdulaziz City for Science and Technology (KACST)	Head of the Saudi Centre for Remote Sensing
7	Ministry of Interior	Deputy Minister of Provinces affaires
8	Ministry of Communications	Deputy Minister of Highway
9	Ar Riyadh Development Authority (ADA)	The Municipal of Riyadh, Head of RDA
10	The Ports Authority	General Director of the Port Authority
11	Ministry of Agriculture and Water	Manager of the Documentation and Information Centre
12	Ministry of Finance and National Economy.	Department of Census and Vital Statistics
13	Ministry of Education	General Directorate of Studies and Design
14	Saudi Telecommunication Company	General Manager of Riyadh District
15	The Saudi Consolidated Electric Company (SCECO).	General Director of the Saudi Consolidated Electric Company
16	General Presidency of Girls Education	President of Girls Education
17	National Commission for Wildlife Conservation and Development	Chairman of the NCWCD
18	Presidency of Civil Aviation	General Director Saudi Arabian Airlines
19	The Meteorology and Environmental Protection	President of the Meteorology and Environmental Protection

I.2 QUESTIONNAIRE CONTENTS

1. Section one: Filtering Introduction.
2. Section two: Digital Products.
3. Section three: Geographic Information System (GIS).
4. Section four: Conventional Maps (paper maps).
5. Section five: Users' Needs and Requirements.
6. Section six: Digital Geographic Information Exchange.
7. Section seven: The development of a strategy for national spatial data infrastructure in the Kingdom of Saudi Arabia.

I.2.1 Section One: Filtering Introduction

For an easy and quick completion of this questionnaire, please read this section carefully. It serves as a guide that takes you directly to the sections relevant to your business and your area of interest.

1.1 Does your department produce maps spatial or geographic/ topographic/ geological/ land survey/ geodetic survey/ cadastral information/ aerial photography/ satellite imagery in any scale and format or are you a user of geographic products produced by another organisation or both? User Only [ ] Producer [ ] Both [ ].

1.2 If the answer to question (1.1) is "User Only", **go now to section five (I.2.2), and any appropriate part of section six (I.2.6) and seven (I.2.7).**

1.3 If the answer to question (1.1) is " producer or both producer and user", **complete this section (section I.2.1).**

1.4 What type of products are you currently producing?
Digital Products [ ] Conventional Maps [ ] Both [ ].

1.5 If the answer to question (1.4) is "Digital Products", **complete section two (I.2.2).**

1.6 If the answer to question (1.4) is "Conventional maps" **complete section four (I.2.4).**

1.7 If the answer to question (1.4) is "Both", **complete both sections two and four (I.2.4).**

1.8 Do you have a Geographic Information System or any of its capabilities?
Yes [ ] No [ ].

1.9 If the answer to question (1.8) is Yes, **complete section three (I.2.3).**

1.10 All participants, Please **complete sections six and seven (I.2.7).**

I.2.2 Section Two: Digital Productions

2.1 What type of digital products are you producing?

Raster [ ]
Vector [ ]
Matrix [ ]
Other [ ]

If other, please specify?______________________________

2.2 List all the spatial data formats used by your department?

____
____
____

2.3 List the Main Digital Products produced by your department (if you need more space please use a separate sheet).

Product Scale

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______
7. ______
8. ______
9. ______
10. ______

2.4 What areas do your products cover (you can use Co-ordinates, area or province name, title...)?

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______
7. ______
8. ______
9. ______
10. ______

2.5 Who identified the types and scales of your products?
Your department ☐ the user ☐.

2.6 Who identified the requirements and contents of your products?
Your department ☐ the user ☐.

2.7 In your production line, what type of quality assurance and quality control do you use?

______
______
______

2.8 Do you produce your products in-house, contracted or both?
In-house ☐ Contracted ☐ Both ☐.

2.9 If contracted, what is the name(s) of contractor(s)?

______
______
______

2.10 Are you using any standards or specifications for any of the following production steps (Please use tick (✓) for Yes and (X) for No in the appropriate box(s))?

Land & geodetic survey	☐
Photogrammetry	☐
Cartography	☐
Quality assurance and quality control	☐
Data transfer and exchange	☐
Printing	☐
Others	☐

If others, please specify?____

____

____

2.11 For the production steps ticked with (✓) in question (2.10), please indicate what standards and/or specifications are you using.

____

____

2.12 For the production steps ticked with (X) in question (2.10), please indicate if you have future plans to develop standards or use existing standards?
Yes ☐ No ☐.

2.13 If the answer is Yes, please indicate what is your plan and what standards or specifications are you planning to use or develop?

____

____

2.14 The Kingdom of Saudi Arabia became a permanent member of the International Organisation for Standards/Technical Committee for Geographic Information/Geomatics (ISO/TC 211), so do you want to use this committee's standards or other standards? ISO/TC 211 Standards ☐ Other standards ☐.

If other standards, please specify?____________________________________

____

2.15 What geodetic reference system are you using (please tick the appropriate box)?

International Spheroid	☐
WGS 73	☐
WGS 84	☐
Other	☐

If other, please specify? ______________________________________

____

____

2.16 What datum are you using, for both horizontal and vertical (please tick the appropriate box(s))?

Ain Al abd for horizontals ☐
Jeddah (1972) for vertical ☐
Others ☐

If others, please specify?____

____

____

2.17 Please list your product types and dates (If you need more space please use a separate sheet).

	Product type	Production date
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

2.18 Do you have the reproduction materials available? (i.e. individual feature separates or final colour negatives, plates...etc) Yes ☐ No ☐.

2.19 If Yes, please indicate the condition and quality of the reproduction materials:

____

____

2.20 Who are the potential users of your products?____________________________

____

____

2.21 In brief, what hardware are you using for?

1. Geodetic and land survey ______________________________________
2. Photogrammetry ____

3. Digital Cartography________
4. Reprographics________
5. Printing system________

2.22 In brief, what software are you using for?

1. Geodetic and land survey________
2. Photogrammetry ________
3. Cartography________
4. Reprographics________
5. Printing system________

2.23 How often do you update your products? (E.g. every year, every 2 years…etc)

____

____

____

2.24 How often do you prefer to have your products updated?________

____

____

2.25 Do you have a digital geographic database(s)? Yes ☐, No ☐.

If Yes, please explain what type of database: ________

____

2.26 In what form does your department maintain its geographic data?

Hardcopy (Maps, Charts, Co-ordinates, Reports, Etc).	☐
Digital (CD-R, Disk, High density disks, Mag. tape…etc)	☐
Database	☐
DBMS	☐
Others	☐

If others, please specify?________

2.27 If you have a Geographic Information System or any of its capabilities, please complete section three (I.2.3).

I.2.3 Section Three: Geographic Information System (GIS)

3.1 How many Geographic Information Systems(GIS) do you have?
Number of GIS [ ].

3.2 If you have more than one GIS, please fill one copy for each System used in your department?

3.3 What is the name and version (if applicable) of your GIS?__________

3.4 What is the main use for your GIS?__________

3.5 What Data formats do you use for your products?

3.6 When did your department buy this system? __________

3.7 Does this system work as part of a network(s) (such Local or Wide area network or Internet)? Yes [ ] No [ ].

3.8 If yes, please indicate the network(s)__________

3.9 Did your department co-ordinate, the purchase of this system (the hardware and software) with other organisation(s)? Yes [ ], No [ ].

3.10 If the answer is Yes, please list those organisations__________

3.11 Do you think the benefits of your system meet the expectations of your department?
Yes [ ] No [ ].

3.12 If the answer is No, please explain why not?__________

3.13 Are you aware of any other organization(s) in the Kingdom of Saudi Arabia that use the same geographic information system? Yes [ ], No [ ].

3.14 If the answer is yes, please list those organisations ______________________

____

____

____

____

3.15 Do you use your system for data: (please tick the appropriate box(s))?

Collection	[ ]
Processing	[ ]
Management	[ ]
Analysis	[ ]
Display	[ ]
Output.	[ ]
Other	[ ]

If other, please specify?______________________

____

____

____

____

3.16 How long have digital geographic products been produced in your department using this system?

____

____

3.17 Who identified the type and scale of your products? Your department [ ] the user.

3.18 Who identified the requirements and contents of your products?
Your department [ ] the user [ ].

3.19 In your production line, what type of quality assurance and quality control do you use?

____

____

____

3.20 Did you encounter any difficulty during data collection, processing, management, analysis, display or output? Yes [ ] No [ ].

3.21 If the answer is Yes, please explain the difficulties and your suggestions for the solutions.

____

____

3.22 Do you have enough well trained Saudi personnel working in your department?
Yes [ ] No [ ].

3.23 If the answer is No, what is your plan to train Saudi personnel?

____

____

____

3.24 Is your department aware of any other organisation(s) in the Kingdom that maintain geographic information system similar in type to the geographic information system maintained by your department? Yes [ ] No [ ].

3.25 If the answer is Yes, please list those organisations.

____

____

____

I.2.4 Section Four: Conventional Maps

4.1 Since digital products and geographic information systems are not your only product at this time, do you have future plans for digital products? Yes [ ] No [ ] .

4.2 If the answer is Yes, please clarify:___________________________

____

____

____

4.3 List the main conventional products produced by your department.

Product	Scale
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	

4.4 List the areas covered by your product (you can use co-ordinates, area or province name, title.).

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______
7. ______
8. ______
9. ______
10. ______

4.5 Do you produce your conventional products in-house, by contract or both?
In-house ☐ Contracted ☐ Both ☐.

4.6 If contracted, what is the name of the contractor(s)?______

4.7 Are you using any standards or specifications for your conventional products?
Yes ☐ No ☐.

4.8 If the answer is Yes, what standards or specifications are you using?______

4.9 What geodetic reference system are you using?

International Spheroid ☐
WGS 73 ☐
WGS 84 ☐
Other ☐

If other, please specify:______

4.10 What datum are you using (for both horizontals and verticals)?

Ain Al abd for horizontals ☐
Jeddah (1972) for verticals ☐
Others ☐
If others, please specify:______

4.11 How current is your product (If you need more space please use a separate sheet)?

Product type	Production date
1.	
2.	
3.	
4.	
5.	
6.	
7.	
8.	
9.	
10.	

4.12 Do you have the reproduction materials Yes ☐ No ☐.

4.13 If Yes, indicate their condition and quality:

______

______

______

4.14 Who are the potential users of your conventional product?______

______

______

______

4.15 In brief, what equipment are you using for your conventional products?

1. Geodetic and land survey: ______
2. Photogrammetry : ______
3. Cartography : ______
4. Reprographics : ______
5. Printing : ______

I.2.5 Section Five: Users' Needs and Requirements

5.1 Who produced the maps you are currently using?

a. General Directorate of Military Survey (GDMS) Ministry of Defense and Aviation (MODA). ☐

b. Saudi Geological Survey Department Ministry of Petroleum and Mineral Resources (MOP&MR) ☐

c. Department of Mineral and Natural Resources. Ministry of Petroleum and Mineral Resources (MOP&MR) ☐

d. Saudi Aramco Company Ministry of Petroleum and Mineral Resources (MOP&MR) ☐

e. General Directorate of Surveying. Ministry of Municipal and Rural Affairs (MOMRA) ☐

f. Ar Riyadh Development Authority (ADA). The Department of Urban and Environmental Development ☐

g. The Ports Authority. ☐

h. Ministry of Communications ☐

i. Others? ☐

If others, please specify______________________________

5.2 What type of maps and geographic information are you using?
Paper maps ☐ Digital products ☐ Other spatial data ☐.

5.3 If the answer is other spatial data, please clarify____________________

5.4 If your department is not presently using digital products, do you have plans for using it in the future?

Yes ☐ No ☐.

5.5 If the answer is Yes, please explain your plan ____________________

5.6 When you request geographic information, do you receive it on time?
Yes ☐ No ☐.

If the answer is No, please explain why____________________

5.7 What types and scales of maps is your department currently using?

Map Type		Scales Used
Topographic Line Maps	☐	________
Geological Maps	☐	________
Cadastral Maps	☐	________
Hydrographic Maps	☐	________
Orthoimage Maps (Aer. Photos) -Rectified	☐	________
Orthoimage Maps (Aer. Photos) -Unrectified	☐	________
Orthoimage Maps (Sat. Images) -Rectified	☐	________
Orthoimage Maps (Sat. Images) -Unrectified	☐	________
JOG Series Maps	☐	________
Others	☐	________

If others, please specify____

____

____

____

5.8 What are the primary uses of the geographic information in your department?

1. ____
2. ____
3. ____
4. ____
5. ____
6. ____
7. ____
8. ____
9. ____
10. ____

5.9 Which map scales do you prefer working with, and why?

____

____

____

5.10 Please complete the following table to indicate the desired vertical and horizontal accuracy, contour intervals, supplementary contours and map type that your department would require to satisfy your future needs.

Map Scale	Map Type	Horizontal Accuracy	Vertical Accuracy	Contour Interval	Supplementary Contours Interval
1:1,000					
1:2,000					
1:5,000					
1:10,000					
1:25,000					
1:50,000					
1:100,000					
1:250,000					
1:500,000					
1:1,000,000					
1:2,000,000					

Any additional Comments: ______________________________

Map Scale	Roads	Maritime Features	Water From Wells, etc	Pipe-lines	Dams/ Bridges	Terrain Types	Contours and Spot Hts	Developec Areas
1:1,000								
1:2,000								
1:5,000								
1:10,000								
1:25,000								
1:50,000								
1:100,000								
1:250,000								
1:500,000								
1:1,000,000								
1:2,000,000								

Any additional Comments: ______________________________

5.11 What cultural features are needed for your department (features to be printed on the maps)?

5.12 If you use image maps, please indicate the resolution which you prefer and type of images (coloured or black and white).

5.13 Please list the types and dates of products used by your department? (If you need more space please use a separate sheet).

	Product type	Production date
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		

5.14 How often are the maps used by your department updated? And how often would you prefer to have them updated? ____________________

____

I.2.6 Section Six: Spatial Data Exchange

6.1 List the organisations, with which your department is exchanging data.

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________
9. ____________________
10. ____________________

6.2 How are new data or products requested?

- By official letter ☐
- By agreement ☐
- By phone ☐
- By filling forms ☐
- By E-Mail ☐
- Other means ☐

If other, please specify ____________________

	Maintain	Exchange
ArcInfo Coverages	☐	☐
ArcView Shapefiles	☐	☐
Microstation DGN files	☐	☐
AutoCAD (DWG/DXF)?	☐	☐
GIF (Graphic Interchange Format)	☐	☐
SDTS (spatial data transfer standard)	☐	☐
SIF	☐	☐
TIFF	☐	☐
CIB	☐	☐
JPEG	☐	☐
DTED	☐	☐
DLG	☐	☐
Digest	☐	☐
Postscript	☐	☐
CGM	☐	☐
CCITT	☐	☐
HTML	☐	☐
VPF	☐	☐
Vmap	☐	☐
ADRG/CADRG	☐	☐
IGES	☐	☐
ASCII	☐	☐
Others	☐	☐

If others, please specify.______________________________

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____

6.7 Do you have any comment or observations concerning the exchange of data with other departments? Yes ☐ No ☐.

If the answer is yes, please explain ____________________________

____

____

6.9 Do you think your data meet the users expectations in terms of?

Completeness.	☐
Accuracy	☐
Clarity	☐
Currency	☐
Format?	☐
Response time	☐
Quantity	☐
Quality	☐
Other	☐

If other , please specify. ________________________________

6.10 If the answer is No to any part of the above question, please comment.

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6.11 Do you find the current circumstances of exchanging information with other organisations appropriate and efficient? Yes [ ] No [ ].

6.12 If the answer is No, what are your suggestions for the improvement of services?

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6.13 Do you expect the exchange of spatial data between organisations within the Kingdom of Saudi Arabia to have any effects? Yes [ ] No [ ].

6.14 Whether your answer is Yes or No, please clarify.

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4.15 In general, what do you think is the main obstacle to the exchange of spatial data among government organisations?

Data format	[ ]
Data type	[ ]
Currency of geographic products	[ ]
Media	[ ]
Inconsistency and discrepancy of data	[ ]
Unwillingness to exchange data	[ ]
Cost	[ ]
Hardware & Software Problems	[ ]
Human resources	[ ]
Others	[ ]

If others, please clarify ____

6.16 Do you have any final comments or suggestions regarding data exchange?

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I.2.7 Section Seven: The Development of a Strategy for National Spatial Data Infrastructure in the Kingdom of Saudi Arabia.

7.1 What do you think of the establishment of an SNSDI for the Kingdom of Saudi Arabia?

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7.2 Would you like to participate and be a part of this strategy? Yes ☐ No ☐.

7.3 If the answer is No, please explain why not.

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7.4 If the answer to question (7.2) is Yes, is your organisation willing to place your spatial data (or some of it) in the main Saudi spatial database directory, which is planned to be implemented as a part of the strategy (SNSDI)? Yes ☐ No ☐.

7.5 If the answer is Yes, please explain.

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7.6 If the answer to question (7.4) is No, can you provide written information about your spatial data and other related activities, so it can be used in the recommended Saudi National Spatial Data Directory (SNSDD)? Yes ☐ No ☐.

7.7 If the answer is Yes, please explain ______________________________

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7.8 Final Notes:

1. Please write any relevant comments or suggestions, you may have with regard to this questionnaire.

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2. Please write any relevant comments or suggestions with regards to this recommended strategy.

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3. Please provide citations of all documents, reports, materials, books, e-mail addresses, or any other references, which were used to complete this questionnaire.

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Finally, I would like to take this opportunity to express my gratitude, thanks, and appreciation to all those who participated in filling this questionnaire form and helped the researcher to complete the research successfully.

The Researcher

Abdullah Al-Shahrani

ANNEX II

QUESTIONNAIRE RETURNS SUMMARY AND TABULATION

This annex summarises and tabulates all the answers to the survey questionnaire, which contain the following sections:

A. Section One: Filtering Introduction

B. Section Two: Digital Products.

C Section Three: Geographic Information System (GIS).

D Section Four: Conventional Maps (paper maps).

E. Section Five: Users' Needs and Requirements.

F. Section Six: Digital Geographic Information Exchange.

G. Section Seven: The development of a strategy for national spatial data infrastructure in the Kingdom of Saudi Arabia.

However, as mentioned in chapter 4, in order to make this annex a reasonable length each participant is given an ID number to indicate the name of the ministries/organisations.

ID	Name of Ministry/Organisation	Name of Department who completed the questionnaire
1	Ministry of Defence and Aviation and Inspectorate General (MODA)	General Directorate of Military Survey (GDMS), Research and Development.
2	Ministry of Petroleum and Mineral Resources (MOP&MR)	General Directorate of Surveying
3	Ministry of Petroleum and Mineral Resources (MOP&MR) - Saudi Aramco	Projects Support & Control Department – Surveying Services Division (SSD)
4	Riyadh City Municipality	Department of Names, Numbering and Aerial Surveying
5	Ministry of Municipal and Rural Affairs (MOMRA)	General Directorate of Surveying
6	King Abdulaziz City for Science and Technology (KACST)	Space Research Institute, the Saudi Centre for Remote Sensing–GIS Centre
7	Ministry of Interior	Not Given
8	Ministry of Communications	Service Coordination and Geographic Information System
9	Ar Riyadh Development Authority	Urban Information System Department.
10	The Ports Authority	Department of Lighthouses and Marine Communications
11	Ministry of Agriculture and Water	Documentation and Information Centre
12	Ministry of Planning	The Department of Public Statistics, Mapping Unit
13	Ministry of Education	General Directorate of Studies and Design, Deputyship of buildings and school supplies

14	Saudi Telecommunication Company	Riyadh Province
15	The Saudi Consolidated Electric Company (SCECO)	Geographic Information System and network design-Central Province
16	General Presidency of Girls Education	Not Given
17	National Commission for Wildlife Conservation and Development	Information and documentation Centre and Geographic Information System

A. SECTION ONE: FILTERING INTRODUCTION

The filtering introductory sections were answered as follows (No refer to Participant ID):

1. Main activities of the ministries/organisations (producers, users or both).

Producer	User	Both
None	13, 14	1, 2, 3, 4, 5, 6, 8, 9, 11 (in the near future), 12, 15, 16, 17

2.Type of products produced.

Digital Maps	Conventional Maps	Both
6, 14	2, 12, 16,17	1, 3, 4, 5, 8, 9, 11(in the near future), 15

3. The Capabilities of Geographic information system (GIS).

Yes	No
1, 3, 4, 5, 6, 8, 9, 11(in limited bases), 51, 17	2, 14, 16

B. SECTION TWO: DIGITAL PRODUCTS

Each answer (summary of answers) in all the following sections has the same number as the question, for example 2.1 in this section is the summary of answer for question (2.1 What type of digital products are you producing?

2.1 Type of digital products, which are available in the Kingdom of Saudi Arabia.

Raster	Vector	Matrix	Other
1, 3, 4, 5, 6, 8, 9, 11, 14, 15	1, 3, 4, 5, 6, 8, 9, 11, 15	1	9 (Combination of Raster and Vector)

2.2 Spatial data formats used.

Format	ID	Format	ID
DGN	1, 3, 4, 5, 9 11	BMP	11
Arc Info	1, 8, 9, 11	DTED	1
Arc View	1, 9	ADRG	1

CRL	1	JPEG	3, 4
DXF	9, 11	CAD	8
DWG	11	ASCII	8
TIFF	1, 3, 4, 11	CARIS	10
LAN	11	Others	6
GeoTIFF	3		

2.3 Main Digital products (including scales, area covered and product date) produced in the Kingdom of Saudi Arabia (This summary includes replies to questions 2.4 and 2.17).

ID	Digital Products	Scale	Area Covered	Prod. Date
1	1. Topographic maps 2. Joint Operation Graphics (JOG) Air and ground versions 3. Map of Saudi Arabia 4. Planning charts 5. The provinces Map 6. OrthoImage Maps 7. Topographic maps 8.Digital Terrain Elevation Data (DTED) 9.Digital Feature Analysis Data (DFAD) 10.Arc Digitised Raster Graphics (ADRG)	1:25,000 1:250,000 1:2,000,000 1:1,000,000 Dif. Scales 1:100,000 1:50,000 1:250,000 1:250,000 1:250,000	Parts of KSA The whole KSA The KSA The KSA The KSA Parts of KSA Under production Parts of KSA Parts of KSA Parts of KSA	92-Now 1992-98 2001 1990-95
3	1. Planimetric and Topographic Maps 2. Planimetric and Topographic Maps 3. Planimetric and Topographic Maps 4. Plan and Profile	1:1,000 1:10,000 As needed	All Aramco operating areas; primarily in Eastern Province (about 120,000 square km).	Diff. Dates
4	1. Digital Maps of Riyadh City 2. Digital Maps of Riyadh City 3. Riyadh Maps Update 4. Satellite Image of Riyadh	1:1,000 1:25,000 1:1,000	City of Riyadh City of Riyadh City of Riyadh	1996 1996 1996 1999
5	1. Topographic Map 2. Topographic Maps 3. Topographic Maps 4. Topographic maps	1:1,000 1:2,500 1:10,000 1:20,000	All Cities and Villages in the KSA =	

	5. Ortho-photo Maps	1:10,000	=	
6	1. Different types of Satellite images are received at the centre's receiving station in KACST in Riyadh. 2. Jeddah Explorer, which contains the basic maps of the Jeddah City		The received images covers 5000 km diameter circle with an area of about 23 million sq. km, which covers all the middle east countries	Updated yearly 2000
8	1. The Road Network 2. Pavement elements of a road 3. Non-pavement elements of a road 4. Asphalt surface condition 5. Traffic accidents 6. Traffic counts	All type of Scales	All the KSA	2000 1999 2000 1999
9	1. City planning 2. Riyadh Explorer, which contains the basic map of the Riyadh City and some public facilities such as Ministries, hotels, hospitals, embassies, mosques, schools, police stations and civil defence stations etc. (GIS criteria: Version 1) 3. Geographic standards and spec.	1:1,000 1:2,500	The developed area of Riyadh representing an area of 1782 km^2. The extended limits of greater Riyadh City representing an area of about 4,000 km^2 will be covered later. The extension will include the developed areas of the Riyadh City and nearby villages. This will be carried out as part of the 2001/02-land use survey.	1999 2000 2000
10	Hydrographic charts	1:50,000 1:150,000	The Kingdom's Coastline and Seafronts.	
11	The products will differ according to the needs of each section or dept. of		Our target is to have a complete	

	concern, most importantly: The Land Department will have cadastral maps. The Forests and Pastures Department medium and small-scale maps. The water Deputyship will have a variety of map scales.		coverage of all Provinces in the Kingdom (13 Administrative areas).	
14	1. Cadastral maps showing the locations of the telephone network. 2. Cadastral maps showing the Locations of the telephone network.	1:1,000 1:10,000	All the exchanges within the developed areas of Riyadh Province. The primary highways in the KSA.	
15	Basic Maps of Riyadh City		Riyadh City	

2.5 The main identifier of type and scale of products (Department or Users).

Department	User
1, 3, 4, 9, 10, 14, 15	1, 3, 4, 5, 6, 8, 9, 11, 14, 15

2.6 The main identifier of requirements and contents products (Department or Users).

Department	User
1, 3, 4, 5, 9, 10, 14	1, 4, 5, 8, 9, 11

2.7 Quality assurance (QA) and quality control (QC) used in the digital production lines.

Quality assurance used in production		Quality control used in production	
YES	NO	YES	NO
1, 3, 5, 6, 8, 9, 10, 11, 14	2, 4, 7, 12, 13, 17	1, 3, 5, 6, 8, 9, 10, 11, 14	2, 4, 7, 12, 13, 17

2.7 (continued) Types of Quality Assurance and Quality Control used.

ID	Type of Quality assurance and quality control used
1	At each phase of production, starting from data collection in the field to the printing stage, the product is checked before it passes to the next phase. The checking procedures include both automatic (systems) checking and manual checking. In some cases the work has to go back to the field for field verification. After compiling each map sheet goes through several main QC checks, then separations for field editing, where quality, positional accuracy, completeness and other aspects are checked and verified. Then it returns to the office to apply all corrections and perform the final office QA. At the printing stage, the registrations, colours and other qualities are performed.

3	After Maps are compiled, they go through several preliminary QC steps. At this point the preliminary map sheet is sent to the field for field edit. After field edits, all corrections are applied and a final office QC is performed. QC includes both software data integrity checks and manuscript editing.
5	During the quality control phase, map sheets produced from aerial photographs are carefully checked to ensure conformity to the specifications stated and required by Ministry of Municipal and Rural Affairs (MOMRA). We also check the geographical locations of features by comparing measurements in reality to map measurements.
6	1. Image display on the screen. 2. Reading the information on the producing media.
8	A road survey was carried out using Global Positioning System (GPS) equipment. The survey was used to determine the accuracy of information. The accuracy of 90% of the data is determined at part of a metre and the accuracy of 10% of the data can be determined at + or – 50 meters. Samples of the data are compared with certain well-known geographic locations.
9	1. Ensure that product meets the requirements stated in the task order. 2. Ensure that colours and symbols are in accordance with the map legend. 3. There is a special Ar Development Authority (ADA) scale for each particular land use marked by a special colour. Scales are therefore checked to ensure correctness.
10	This is done in accordance with internal procedures based on the requirements of the IHO and other agencies of concern.
11	This will be determined by the concerned departments such as the land section, the forests section etc. This would typically include field verifications based on international standards.
14	Quality control procedures are conducted manually by checking each product before it is given out to contractors for production.

2.8 Contracted products against In-house productions.

In-house	Contracted
1, 3, 4, 5, 6, 8, 9, 10, 11, 14, 15	4, 5, 9, 11, 14, 15

2.9 Name of contractors used.

ID	Contractor
4	Not Named.
5	Asia Company of Korea, BKS, Terra, KLM Aerocarto Hunting, Hansaluftbuild, IGN.
9	e.g. The Riyadh Explorer. A contract was signed with Adaleel Information Systems Company whose job is to take care of development and production whereas Ar Riyadh Development Authority (ADA)'s role is to supply information and maps.
11	This shall be decided upon once the system becomes operational. We will probably start by contracting local companies until we begin to gain experience gradually. Our target is to become self-sufficient at the end of the day.
14	Rolita Company, Saudi Arabia.
15	Not named

2.10 Standards used for mapping production activities.

Activity	Yes	No
Land and Geodetic Survey	1, 3, 5, 8, 9, 11	4, 6, 10, 14, 15
Photogrammetry	1, 3, 4, 5, 9, 11	6, 8, 10, 14, 15
Cartography	1, 3, 5, 8, 9, 11, 14, 15	4, 6, 10
Quality assurance and quality control	1, 3, 5, 9, 11	4, 6, 8, 10, 14, 15
Data transfer and Exchange	1, 3, 4, 9, 11, 15	5, 6, 8, 10, 14
Printing	1, 3, 5, 8, 9, 11	4, 6, 10, 14, 15
Others	6. (Satellite images spec.) 9. (Land use spec. to check land use against maps)	1, 3, 4, 5, 8, 10, 11, 14, 15

2.11 Type of standards used.

ID	Standard
1	We use the specifications suitable for each product and compatible to the DIGEST specification. In the near future we will use the ISO/TC 211 standards as it become available through the Saudi Arabian Standards Organisation (SASO).
3	Geodetic Survey uses NGS Standards; Photogrammetry uses ASPRS Standards for accuracy and internal standards for GIS content, structuring, data modelling, etc. Data transfer standards use MGE/DGN. The Land Survey uses internal standards for map production and follows USGS for accuracy
4	Ministry of Municipal and Rural Affairs (MOMRA) specifications for feature table and categories are used.
5	The Ministry of Municipal and Rural Affairs (MOMRA) has specifications and standards for all the above steps (in summary 2.10) -of production but they cannot be easily described in a questionnaire like this.
6	There are special standards for the satellite images processing and production at the Saudi Remote Sensing Centre, KACST.
8	We use the specifications recommended in the "Map Design and Specification" compiled as part of the Ministry of Communications GIS Study conducted on behalf of the Ministry by British Aerospace Company.
9	Ar Riyadh development authority (ADA) has its own standard for checking land use against maps. i.e. quality is checked on logical grounds. For instance if an empty piece of land (no building on it) is found with a 3-5 storey building, this is obviously illogical or if a clay house has a height of 30 storeys, then this is illogical. It must be rejected and corrected. For digital mapping products, MGE programs are used to check the good quality and accuracy of graphics and that there is an attribute for every element. Transfer and exchange of geographical information: In this connection the standard available to ADA is DGN which applies to the international geographic standards of ISO/TC211
10	In accordance with IHO requirement S-57.
11	We will use the ISO/TC211 specifications as the Kingdom has joined membership of that committee. The specification is now being applied through the Saudi Arabian Standards Organisation (SASO).
14	Maximum accuracy of measurement to the nearest metre is required.
15	We have a constant list of codes and symbols that remain unchanged for the electric networks. Our new project for Riyadh City is based on Oracle databases with Spatial, which is compatible to all different GIS formats.

2.12 Future plans to develop standards or use existing standards

YES	NO
1, 3, 4, 5, 6, 11	8, 9, 10, 14, 15

2.12Standards or specifications planning to use or develop.

ID	Comment
1	The Ministry of Defence and Aviation and Inspectorate General (MODA), General Directorate of Military Survey (GDMS) is a member of the ISO/TC 211 and shall therefore adopt the set of standards and specifications being prepared by the above International Organisation once it is ready.
3	ISO/TC 211 standards. Depends on review and application of Aramco operations.
4	1. Kingdom wide Standardisation of GIS activities. Riyadh Development has taken the initiative in this direction by conducting a study and holding meetings. 2. This should preferably be handled by the Saudi Arabian Standards Organisation (SASO). 3. Once completed all parties concerned shall adhere to the standards.
5	The General Directorate of Surveying, being the central body of concern at the Ministry of Municipal and Rural Affairs (MOMRA) is trying to lay down the standards and Specifications for the transfer and exchange of geographical information. The aim is to establish consolidated procedures, specifications and standards as part of the information adopted by MOMRA to serve the sectors affiliated to it.
6	In relation to GIS, there is a plan for establishing consolidated specifications drawing on International GIS Standards (ISO/TC 211).
8	For the production steps marked No (in 3.10), our department is waiting for the action of competent authorities such as SASO regarding the approval of consolidated National Specifications and Standards for the exchange of Information through GIS Systems.
9	We do not have a plan as already indicated, but our intention is to adopt all the standards and specifications produced by ISO/TC 211 and approved by the Saudi Arabian Standards Organisation (SASO).
11	As part of the field study carried out in relation to the application of the proposed GIS, the Ministry will adopt the specifications established by Ar Riyadh Development Authority (ADA) where the Ministry staff have participated in the preceding discussions and attended training given on the specifications.

2.14 Views and intentions with regard to the Kingdom of Saudi Arabia being a member of the International Organisation for Standards/Technical Committee for Geographic Information/Geomatics 211 (ISO/TC 211).

Propose to use ISO/TC 211 standards	Propose to use other standards
1, 3, 4, 5, 6, 8, 9, 10, 11, 14, 15	None

2.15 Geodetic reference system in use.

International Spheroid	WGS 72	WGS 84	Others
3, 4, 8, 10, 11	10	1, 4, 6, 8, 9, 10, 11	5 (UTM)?, 10

2.16 Datum used.

Horizontal			Vertical	
WGS 84	Ain Al Abd	Others	Jeddah 72	Others
1	3, 4, 5, 6, 8, 9, 11		1, 4, 5, 6, 11	3 (Saudi Aramco Vertical Datum, SAVD 78)

2.18 Reproduction Material available for the digital products (This summary includes replies to question 2.19).

Yes	No	The condition and quality of the reproduction materials
1		All reproduction materials for our digital products are available in digital format and in excellent conditions, stored in the database.
3		Our primary deliverable is digital. If hard copies are required we print directly from digital file.
4		Stored under special storage conditions at fixed temperature.
5		In good condition
6		In respect to the satellite images. Information is stored on digital linear tapes - DLT
8		They are stored in a database in digital format.
	9	
10		In good condition.
11		
	14	

2.20 Potential users of the digital products.

ID	Potential user
1	1. All the military sectors affiliated to the Ministry of defence and aviation. 2. All the civilian agencies and other Armed forces. 3. Universities and Researchers.
3	Saudi Aramco Organizations.
4	Departments of the municipality and its branches.
5	The different sectors of Ministry of Municipal and Rural Affairs (MOMRA), government departments and private sector companies involved in roads, water supply, electricity and cleaning services along with consulting offices.
6	1. Satellite images are used by most government and private organizations. 2. GIS is expected to be used by service industries.
8	1. Ministry of Communications staff. 2. Some other organizations such as KACST.
9	1. Ar Riyadh Development Authority Departments 2. All government agencies and institutions involved in the development of Riyadh City or in serving it.

	3. Universities, private companies related to the execution of projects in Riyadh, individuals, and researchers.
10	Many different government departments, marine navigators and seaport users.
11	The entire Ministry of Agriculture and Water affiliates (Directorates and branches) as well as the Ministry's staff.
14	The only user is the department of network engineering and development and facilities development at the Saudi Telecommunications Company.
15	All departments in the Saudi Consolidated Electric Company for now. The digital map to be produced will be suitable for use by everybody.

2.21 Hardware used for digital products.

1. Geodetic and Land Survey

ID	Hardware
1	The Global Positioning System (GPS) equipment, total stations, theodolites (mainly Wild and Zeiss), distances measuring, leveling instruments-various classes.
3	GPS Receivers and NA-3003 digital level for geodetic survey. Trimble RTK GPS system, Leica TCA-1800 total station and differential GPS System (Omnistar). NA-2002 Digital level.
4	Total stations, GPS equipment, theodolites.
5	In the latest projects, land and geodetic survey depends on the GPS technology. Trimble equipment is used for this kind of work along with conventional survey equipment such as total stations, theodolites and balance equipment. Equipment is supplied by Wild.
6	GPS equipment.
8	Trimble differential GPS, Calcomp digitizer.
11	GPS equipment, total stations.

2. Photogrammetry

ID	Hardware
1	Intergraph IMA, DEC VAX and workstations, Dell workstations, Intergraph/Zeiss scanner PSII and various types of Wild and Zeiss digital and semi digital equipment.
3	Cessna citation aeroplane, RC-30 aerial camera mounted on PAV30 stabilizer, ASCOT system for AGPS data collection, DSW 300 Leica scanner.
4	Stereoplotters.
5	Scanners, type Zeiss are used for aerial photos while image stations of Intergraph are used for collecting three-dimensional images.
11	We cooperate with qualified government agencies of concern to obtain such products. We will not try to handle this at the Ministry except within very limited scope in the field of digital photogrammetry.

3. Digital Cartography

ID	Hardware
1	Intergraph Workstations TDs, Dell Pentium II and III PC Workstations, Compaq II, Micron and other image processing stations.
3	Image Station "Intergraph ZII" for data collection, Dell graphic workstation (620 Precision), IBM graphic workstations for data editing (Intellistation Z Pro).
4	Intergraph workstations TD7 2000
5	TD7 image station system of Intergraph is used for digital cartography along with sophisticated computers used for the cartographic enhancement of digital maps.
9	Workstation Hardware, MicroStation software, MGE, MGA
10	Intergraph charting system
11	Our plan provides for the obtainment of large and accurate digitizers for sectors and also for acquiring scanners.
15	NT-Workstation.

4. Reprographics

ID	Hardware
1	HP755 & 2500, Villa G rafx-XL50, Roland Hi-Fi jet, Optronics (Film Recorder), Tangent 5480 Scanner.
3	IBM Graphic Workstation (Intellistation Z Pro), Dell Graphic Workstation (620 Precision).
4	Intergraph Server, Intergraph TD7 Workstations, HP Brio PC's, 3 Com network, Eagle Scanner black and white, Large Format Colour Scanner (Colour Trac 3680).
5	During the early stages of mapping, we use versatec map plotter of Intergraph along with HP2500 & HP3500 plotters.
6	Digital equipment, SGI equipment.
9	HP plotters, MicroStation, Iplot, Arc View.
10	Intergraph charting system.
11	The plan anticipates the use of large plotters for vectors and raster.

5. Printing System

ID	Hardware
1	Man Roland and Speed Master for the final maps printings.
3	Electrostatic Versatec Plotter, Inkjet Large format Colorspan Plotter, LightJet 5000 for large format image production, HP 3500 Plotter, HP 750c Plotter, HP 600 Plotter.
4	HP 750C Plotter, HP 2500 CP postscript plotter, Epson Stylus Printer.
5	For Final map printing, we use: 1. Optronic Map Setter from Intergraph 2. Contact Copier 3. Dupont Processor

6	Complete development and printing labs, plotters, printers (HP), Kodak, printers, plotters, display maker.
8	HP 1050 C Plotter, HP 750 C, Calcomp Tech Jet 5336.
9	HP Plotters, MicroStation, I Plot, Arc View.
10	Intergraph Charting System
11	Different printers will be procured.

2.22 Software used for digital products

1. Geodetic and Land Survey

ID	Software
1	SDR 2000 for analysing, SOKIA for total stations, Trimble GPSurvey and Pathfinder, GeoMedia, MicroStation 95/SE.
3	Geodetic Surveys utilise, GPSurvey, Geolab, Geographic Calculator, Leica Level Reduction Program. Land Survey utilise, Trimble Survey Office (TGO), Gewogenius, MicroStation, Terra Survey Terramodular, StarLev, StarNet, and LandMark.
4	Win Comms Software for data transfer from cartridges and total stations.
5	Pathfinder Office, GPSurvey, Trimvac, Geolab, MapInfo, Liscad plus.
8	Trimble Software
11	We will be using the software supplied with the GPS and total station equipment.

2. Photogrammetry

ID	Software
1	NT Software- Pro 600 Helava & Socet set Helava (softcopy) IMA–Intergraph MGE and BC2 System.
3	ASCOT software, Flykin for AGPS data processing, Adobe Photoshop, ER-Mapper, Intergraph Mapping Suite (IMDZ).
4	MGE – Base Imager IRASC
5	For Aerial Triangulation: Bundall, Munjy, ISSBA, matchT, Bat B; for Aerial photos, we use PhotoScan program and ISPN program from Intergraph for the processing of three dimensional images.
11	We will use a few simple programs such as: Stereocorrelation in digital photogrammetry, aerial triangulation, DEM Generation, Ortho-Rectification.

3. Cartography

ID	Software
1	MicroStation 95/SE, IRASIC, MGE, various in-house software
3	MicroStation, Image Analyst, MGE and MGDM
4	MicroStation J, GeoMedia 3.0 Pro

5	We use the Intergraph MicroStation program together with support programs such as ISPN and MAYS for writing names in Arabic
8	Arc Info, Arc View.
9	MicroStation, MGE
10	Caris
11	Depends on what the GIS system will produce.
14	Intergraph's FRAM software
15	MicroStation

4. Reprographics

ID	Software
1	I Plot, CADScript, Photoshop, IRASIC
3	MicroStation, Image Analyst, MGE &MGDM
4	MicroStation J / SE, GeoMedia 3.0 Pro and MGE 7.0
5	We use MicroStation and IPlot
6	Special software for sat. image productions – PGS, image analysts software ER–Mapper, ERDAS, Photoshop, Arc Info, Arc View, MapInfo, GeoMedia, GeoMedia Pro.
9	MicroStation, MGE
10	Caris
11	Depends on what the GIS system will produce.

5. Printing System

ID	Software
1	MGE–map publisher
3	IPLOT, MicroStation, system manager from Picto Graphics.
4	I Plot 9.0 Server, I Plot Service Pack, On top of MGE and MicroStation.
5	For final printing, we use MicroStation, Iplot and SRIF. All operated by Intergraph Softcopy system.
6	PGS, ER-Mapper,ERDAS, Photoshop, Arc Info, Arc View and GeoMedia.
8	Arc Info and Arc View.
9	I Plot, Arc View and Plotting through-IRASC
10	Caris
11	Depends on what the GIS support software will produce and also on office software.

2.23 Digital products update period.

Annually	Two Years	Three Years	Four Years	Five Years	Six Years or more	When needed and whenever possible
6, 11	3, 9	8, 9	8	4, 9, 11		1, 5, 10, 14, 15 (daily)

2.24 Preferred Products update period

1 Year	2 Years	3 Years	4 Years	5 Years or more	As and when needed
3, 4, 6, 9, 11, 14	8	1		1, 11	5, 10, 15 (daily)

2.25 Digital Geographic Database held and types

Yes	No	Type Database
1		1. A database for the Kingdoms geodetic network information. 2. A database for the Kingdoms digital elevation data. 3. A geographic names database. 4. A database for topographic maps scale 1:250,000. 5. A database for topographic maps scale 1:50,000 (under development)
3		Saudi Aramco produces their own Base Maps for the company.
4		Oracle 8.0
5		Our current policy for the latest aerial photography projects is to produce digital maps and keep them for use in GIS applications. This was applied to the maps of Riyadh, the northern parts of Riyadh province and Madinah.
6		We plan to establish a digital geographic database using satellite images.
8		Oracle 8 DBMS
9		General Database
	10	
	11	In the near future will be developed (the design is ready and complete).
14		The telephone network information is stored in a geographic information database designed for the FRAM system.
15		Oracle–Spatial 8I

2.26 How is geographic data maintained?

Hardcopy (Maps, Charts, Co-ords, Reports etc.)	Digital (CD-R, Disk, High Density disks, Mag. Tape, etc.)	Database	DBMS	Others
1, 4, 5, 8, 9, 15	1, 4, 6, 8, 9, 11, 14	1, 4, 5, 8, 9, 11	1, 3, 5, 11, 15	None

C. SECTION THREE: GEOGRAPHIC INFORMATION SYSTEMS (GIS)

3.1 Numbers of geographic information systems (GIS) including the names and versions (This summary includes replays to question 3.2 and 3.3).

ID	No. of GIS	Name and Version
1	2	1. Arc Info (8.0) number of users 6 and Arc View (3.2) No of users 12. 2. GeoMedia Professional (3.0) and MGE number of users 1.
3	2	1. MGE/MGDM V.07.01 2. Arc Info and Arc View

4	2	1. MGE and GeoMedia 2. Arc/Info
5	1	MGE from Intergraph
6	2	1. Arc/Info (8.0), Arc/View 2. GeoMedia 4.0, GeoMedia Pro
8	1	Arc Info V 8.0.1 and Arc View V 3.2
9	2	MGE from Intergraph and Arc/View from ESRI
10	2	Caris Database Manager–2 systems
11	1	Either ESRI or Intergraph or both. The study for establishing such a system has been conducted, finalised and the plan is waiting to be implemented. The system designed will be semi-central. 25 branch centres will be connected to a main Centre covering the Kingdom of Saudi Arabia. Each centre will have its own peripherals and workstations.
14	1	Intergraph's FRAM system.
15	1	MGE - Oracle
17	1	Arc View 3.1

3.4 The main use for the GISs.

ID	Main uses
1	**GIS a (Maily ESRI)** 1. Use the different applications of GIS systems. 2. Carry out special projects such as the ministry of education project. 3. Terrain analysis and cross country movements 4. Build the Saudi Arabian topographic database for scale 1:250,000 maps (STDB 5. Build up the database for the basic topographic maps scale 1:50,000 maps (STD 2). 6. Training the staff in GIS. **GIS b (Maily Intergraph)** 1. At present it is used for a limited number of applications and for some studies. 2. Most of the MGE functions are used in production steps in the photogrammetry and digital mapping production phases. 3. The system was used for pilot projects and some demonstrations.
3	For Map Production and to make it available on-line for Aramco users.
4	1. Naming and numbering of streets and buildings. 2. Updating digital products. 3. Settlement of disputed boundaries of property and license. 4. Land Surveying
5	1. Area calculation 2. Elevation analysis 3. Built-up area analysis 4. Road network analysis 5. All the GIS services needed by Ministry of Municipal and Rural Affairs (MOMRA) for digital mapping
6	1. Establishing a geographic database. 2. Carrying out a number of projects.
8	Management and maintenance of roads.
9	Urban planning which involves land use, environment, transportation, housing, economy and social aspects etc.

10	Transfer of all information relating to navigational aids.
11	A wide range of applications is expected given the many applications needed by the ministry.
14	AutoCAD
15	1. To display locations of subscribers, plants and networks. 2. Monitor and keep record of network loads, types and distribution. 3. Study and estimate future loads.
17	1. Processing digital maps. 2. Data and information analysis.

3.5 Data formats used

ID	Formats
1	1. Arc Info Coverage and Arc View Shapefiles. 2. Intergraph format DGN
3	DGN MicroStation for Vector Data, TIFF, GeoTIFF and JPEG for raster data.
4	DGN; TIF:
5	DGN for graphics, Oracle for database, Visual Basic, Visual C and MDL for development
8	Arc Info Coverage, Shapefiles, ASCII files.
9	DGN; Shapefile
11	Not yet decided.
15	Oracle DB with Spatial

3.6 When were the systems purchased/upgraded?

ID	System	Date of Purchase
1	1. Intergraph MGE. 2. ESRI Arc Info and Arc View 3. Intergraph GeoMedia	1990 1998 2000
3	1. MGE/MGDM V.07.01 2. ESRI Arc Info and Arc View	1991 1991
4	1. Intergraph GIS 2. ESRI Arc Info	1996 1990
5	Intergraph MGE	1992
6	1. ESRI Arc Info and Arc View 2. Intergraph GeoMedia	2000 2000
8	ESRI Arc Info and Arc View	1996
9	1. Intergraph MGE 2. Arc View	1993 1996
10	Caris	1999
14	Intergraph FRAM system	1998
15	Pilot Project under development	
17	Arc View 3.1	1999

3.7 Does the system work as part of a network and if so, what type of network (This summary includes replies to question 3.8)

Yes	No	Type of Network
1		Local Area Network
3		Local Aramco Intranet
4		Local Area Network, 3 Com Cards and TCP/IP protocol
5		TCP/IP and Thin Net
6		Local Area Network
8		Local Area Network
9		Fast Ethernet (LAN) star topology
	10	
11		Details not yet determined.
14		Local Area Network
15		Company WAN using optical fibre network
	17	

3.8 Was the purchase co-ordinated with other organisations (This summary includes replies to question 3.10).

Yes	No	Organisations co-ordinated with
	1	
3		Some Saudi Aramco organisations
	4	
	5	
6		The General Directorate of Information.
8		1. Ministry of Defence and Aviation and Inspectorate General (MODA), the General Directorate of Military Survey (GDMS). 2. Ministry of Petroleum & Mineral Resources (MOP&MR). 3. Ministry of Municipal and Rural Affairs (MOMRA). 4. Ar Riyadh Development Authority (ADA). 5. King Abdulaziz City Science and Technology (KACST). 6. Plus departments of concern at the Ministry.
	9	
	10	
11		1. Ministry of Defence and Aviation and Inspectorate General (MODA), the General Directorate of Military Survey (GDMS). 2. Ministry of Municipal and Rural Affairs (MOMRA). 3. Ar Riyadh Development Authority (ADA). 4. King Abdulaziz City for Science and Technology (KACST). 5. King Saud University (KSU). 6. Ministry of Petroleum and Mineral Resources (MOP&MR).
14		Ar Riyadh Development Authority (ADA) who had past experience with the system.
15		1. Ministry of Defence and Aviation and Inspectorate General (MODA), the General Directorate of Military Survey (GDMS). 2. Ministry of Municipal and Rural Affairs (MOMRA). 3. Ar Riyadh Development Authority (ADA). 4. Riyadh City Municipality.
	17	

3.11 Do the benefits of the system meet the expectations of the department? (This summary includes replies to question 3.12).

Yes	No	The reasons for not meeting the expectations
1		
	3	The company just started recently to form a Corporate GIS.
4		
	5	1. Limitation of System 2. System is difficult to use
6		
8		
9		
10		
11		Hopefully they will.
14		
15		Hopefully they will.
17		

3.13 Is the Department aware of any similarity between their GIS and others in the Kingdom of Saudi Arabia? (This summary includes replies to question 3.14)

Yes	No	Organizations
1		1. Riyadh City Municipality. 2. King Saud University. 3. Ar Riyadh Development Authority.
	3	
	4	
	5	
6		1. Ministry of Communications 2. Ministry of Agriculture and Water 3. Ministry of Municipal and Rural Affairs 4. Riyadh City Municipality. 5. Department of Geological Survey. 6. Department of Meteorology and Environmental Protection.
8		King Abdulaziz City for Science and Technology (KACST)
9		1. Ministry of Defence and Aviation and Inspectorate General (MODA), the General Directorate of Military Survey (GDMS). 2. Ministry of Municipal and Rural Affairs (MOMRA). 3. Riyadh City Municipality. 4. Ministry of Petroleum and Mineral Resources-Saudi Aramco. 5. Saudi Consolidated Electric Company. 6. Saudi Telecom. 7. The Water Supply Department.
	10	
14		Ar Riyadh Development Authority (ADA)
15		1. New Project at Ministry of Municipal and Rural Affairs. 2. New project at Saudi Consolidated Electric Company (Western Region).
17		1. Ministry of Defence and Aviation and Inspectorate General (MODA), the General Directorate of Military Survey (GDMS). 2. Ar Riyadh Development Authority (ADA). 3. King Abdulaziz City for Science and Technology (KACST).

3.15 How is GIS used in the departments

ID →	1	3	4	5	6	8	9	10	11	14	15	17
Data Collection	Y		Y	Y	Y	Y	Y		Y	Y	Y	Y
Data Processing	Y		Y	Y	Y	Y	Y	Y	Y		Y	Y
Data Management	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Data Analysis	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y
Data Display	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Data Output	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Other	Y			Y*			Y					

* *Conversion of data from one system to another.*

3.16 How long have digital geographic products been produced in the Kingdom

1	3	4	5	6	8	9	10	11	14	15	17
Since 1990	Since 1991	Early 1991	Since 1996	Since 2000	Since 1996	Since 1986	Since 1999	Not Yet	Since 1999	Since 1999	Since 1998*

* *With the compilation of a digital map of the Red Sea Coast North of Jeddah to the Aqaba Gulf in co-operation with Japan International Co-operation Agency (JICA)*

3.17 Who identified product (This summary includes replies to question 3.18)

Requirements and Contents		**Type and Scale**	
Department	User	Department	User
1, 3, 4, 5, 6, 9, 10, 17	1, 4, 5, 6, 8, 9, 11, 14, 15, 17	1, 3, 4, 5, 6, 10, 14	1, 4, 5, 6, 8, 11, 15

3.19 What type of quality assurance and quality control is used

ID	**Quality assurance and quality control used in GIS steps**
1	1. There are quality control and quality assurances checks after each phase of the GIS preparation and production (same procedures as in number 2.7 above). 2. Also a thorough check of quality is made at the final phase.
3	Same as number 2.7 above.
4	1. Quality control check according to the scale of the map produced. 2. Following the Municipal and Rural Affairs (MOMRA) standards. 3. Checking against field data.
5	1. Elevation checks. 2. Symbology checks. 3. Cartographic presentation checks. 4. Level and graphic array validity analysis. 5. Field Checks. 6. Spelling and placement of names checks. 7. Various map production steps counter checking.

6	1. Checking to ensure the images co-ordinates. 2. Accuracy of information. 3. Making sure that the product meets the user requirements.
8	Same as number 2.7 above.
9	1. Verifying the place names. 2. Checking the control points. 3. Checking the map scale. 4. Matching the legend with the map contents.
10	Same as number 2.7 above.
14	Manual QC Procedure.
17	The NCWCD's GIS is just starting. The Red Sea Coast digital map was made in Japan after the initial data collection was completed by researchers from NCWCD and Japan.

3.20 Were there any difficulties encountered during data collection, processing, management, analysis, display or output? (This summary includes replies to question 3.21).

Yes	No	Difficulties Encountered
1		We still experience some technical problems especially in relation to the database we are using.
	3	
4		1. Sudden breakdown of systems and equipment. 2. The trained Saudi personnel leave to other agencies. 3. Expiry of consumables such as ink and printing paper.
5		1. Data integration problems due to MGE 2. Operating system conversion problems due to UNIX 3. MGE complex data handling problems
6		1. Obtaining information from other agencies. 2. Difference of specification from one agency to another. To overcome these problems we should co-ordinate activities and set up a National database after the approval of a consolidated GIS specification.
	8	
	9	
	10	
	14	
15		Data collection and verification and the continuous updating thereof.

3.22 Are enough well trained Saudi personnel working in the departments and what are the plans to train Saudi personnel? (This summary includes replies to question 3.23).

Yes	No	Explanation
	1	1. A number of Saudi employees have been recruited and are now at work. 2. We will continue to attract more people until all the vacancies are manned with concentration of specialized university and technical institute graduates
3		
	4	We don't have a plan. All we do is coordinate with the personnel department and authorised executives at the Ministry of Public Service.

		This delays recruitment.
	5	The existing plan aims at attracting qualified university and technical institute graduates and train them to operate the system in future.
	6	1. Attract specialised Saudis. 2. Maintain on the job training programmes. 3. Establish a specialised center of training.
	8	1. Recruit Saudi personnel as required. 2. Give them on-the-job training with the help of current personnel who are the system operators at the Ministry. 3. Send them for training at the Kingdom's Universities and overseas training colleges.
9		
10		
11		Hopefully, per our plan. Recruitment, Training at Universities and training in the Kingdom and Overseas.
14		
	15	Our programme for Saudisation is in good progress.
	17	We are Cooperating with the General Directorate of Military Survey (GDMS) to produce a digital map for the Ibex Sanctuary and the other sanctuaries with sufficient training for our staff.

3.24 Are departments aware of the maintenance of similar geographic information databases by other organisations in the Kingdom? (This summary includes responses to question 3.25).

Yes	No	The Organisation
	1	
	3	
4		The General Directorate of Military Survey (GDMS) and Ar Riyadh Development Authority (ADA).
5		Ar Riyadh Development Authority (ADA), Saudi Aramco, City municipalities affiliated with the Ministry of Municipal and Rural Affairs (MOMRA)
	8	
	9	
	10	
14		Ar Riyadh Development Authority (ADA)
15		The General Directorate of Military Survey (GDMS), Riyadh City Municipality, the Ministry of Municipal and Rural Affairs (MOMRA) and Ar Development Authority (ADA).
	17	

D. SECTION FOUR: CONVENTIONAL MAPS

4.1 Future plans for digital maps and geographic information systems (This summary includes replies to question 4.2).

Yes	No	The Plans
2		The General Directorate is currently working on a plan to acquire an integrated digital system. It would eventually scan all the conventional maps available at different scales and convert them into digital maps for future production.
5		The General Directorate of Surveying is now producing both digital and paper printed. This began in 1987.
8		Now we use digital maps and GIS systems. We also produce paper-printed maps using the GIS system available to the Ministry of Communication.
11		Plans in hand to start digital production.
15		The project will soon be awarded. Construction will start early 1422H.
	16	No plans
17		The plan is to first establish the GIS System and train our staff for future production of digital maps for all sanctuaries in the Kingdom.

4.3 List the main conventional (paper) products produced (This summary includes replies to questions 4.4 and 4.11).

ID	Conventional Products	Scale	Area Covered	Prod. Date
1	1. Topographic Maps 2. JOG (Air and Ground) 3. Map of the KSA 4. The Arabian Peninsula 5. Planning Charts 6. The Muslim World Map 7. Aerial photography 9. Others	1:25,000 1:250,000 1:2,000,000 1:3,000,000 1:1,000,000 1:30,750,000 1:120,000 Different s.	Parts of the KSA The KSA Parts of the KSA The KSA The KSA The Muslim World. The KSA Different area	92-Now 1992-98 2001 1987 1990-95 1992 1987-90 Dif. dates
2	1. Topographic maps 2. Topographic maps 3. Topographic maps 4. Topographic maps 5. Topographic maps 6. Topographic maps 7. Topographic maps	1:50,000 1:100,000 1:250,000 1:500,000 1:1,000,000 1:2,000,000 1:4,000,000	1,3,4 and 5 covered All of the Kingdoms provinces and governorates. 6,7 Covered KSA	Up to 1984
3	We only produce hard copy when proponents ask for it. Therefore, all the answers for this section (section 4) can be from digital mapping section (section 2)			

5	1. Topographic Map 2. Topographic Maps 3. Topographic Maps 4. Topographic maps 5. Ortho-photo Maps 6. Aerial photo project #101 7. Aerial photo project #102 8. Aerial photo project #103 9. Aerial photo project #104 10. Aerial photo project #105 11. Aerial photo project #106 12. Aerial photo project #107 13. Aerial photo project #108 14. Aerial photo project #109 15. Aerial photo project #110 16. Aerial photo project #112 17. Aerial photo project #113 18. Aerial photo project #115 19. Aerial photo project #116	1:1,000 1:2500 1:10000 1:20000 1:10000	All cities and villages in the Kingdom of Saudi Arabia. = = All cities in the KSA All cities in the KSA Taif and Jizan Makkah Al Mukramah Qassim/Hail & Makkah Arar The Eastern Region The Eastern Region Albaha Makkah/Madinah and Jouf Abha, Khamis Mushayt and Najran Madinah North Riyadh Province Riyadh City	 1976 1978 1979 1980 1982 1982 1984 1987 1992 1993 1995 1995
8	1. The Road Network 2. Pavement elements of a road 3. Non-pavement elements of a road 4. Asphalt surface condition 5. Traffic accidents 6. Traffic counts	All Different Scales	All Provinces in the Kingdom of Saudi Arabia.	2000 1999 2000 1999
10	Hydrographic charts (Navigational)	1:50,000 1:150,000	The Kingdom's Red Sea Coast and Seaports.	
11	The products will differ according to the needs of each section or department of The Ministry.		the target is to have a complete coverage of all Provinces in the KSA	
12	1. The KSA Provinces. 2. The KSA Provinces.	1:2,000,000 1:3,000,000	The KSA The KSA	update after eacl

	3. KSA Supervision areas of the 1993 Census and House count. 4. Al Farsi Cadastral maps Showing jurisdiction and the distribution of census. 5. The KSA Topographic maps showing borders of Provinces, governorates, as well as geographic names.	1:2,500,000 Various scales Various scales	The KSA Major Cities Various Area	activity
15	Basic Maps of Riyadh City		Riyadh City	
16	1. Map of the KSA. 2. Map of the KSA Provinces. 3. Map of the Kingdom's Roads. 4. Map of the Kingdom's most important oil fields. 5. Map of the Arab Gulf Countries. 6. Map of the Arab World. 7. Map of the Muslim World. 8. Maps of some Arab, Muslim and European Countries. 9. Map of Asia (Political) and Latin America (Natural and Political). 10. Map of the four seasons and the solar system.		The maps are distributed to the departments of education in the Kingdom's provinces and governorates who would in turn distribute them to schools for use in education. The maps have no reference value as regards international boundaries.	
17	1. Map of the Northern Sanctuaries. 2. Map of the Farasan Islands. 3. Map of the Ibex Sanctuary. 4. Map of Mahazat Assayd Sanctuary. 5. Map of Mahazat Assayd Sanctuary.	1:500,000 1:100,000 1:100,000 1:500,000 1:100,000	Al Jouf and Tabouk Farasan islands Al-Hariq, Al-Hilwa and Hotat Bani Tameem Al-Siyah, Al-Mowayh and Al-Khurma (Governorates).	1988 1990

4.5 Contracted conventional products against In-house productions.

In-house	Contracted
1,2, 5, 8, 9, 11, 12, 15	2, 5, 9, 11, 12, 15, 17

4.6 Name of Contractors used.

ID	Contractor
2	Asia Company, PASCO Company, plus some others.
5	Asia Company of Korea, BKS, Terra, KLM Aerocarto Hunting, Hansaluftbuild, IGN.
9	"Riyadh Explorer" was produced by local contractors – Addaleel Information Systems.
11	This will be decided upon once the system becomes operational. We will probably start by contracting local companies until we begin to gain experience gradually. Our target is to become self-sufficient at the end of the day.
12	Topographic maps in co-operation with the General Directorate of Military Survey. Al Farsi maps for jurisdiction of each census inspector.
15	Al Masdar Company (Saudi information system company and its Partner 'E-Spatial' an Irish Company).
16	1. Al Muayyad Printing and Publishing House. 2. Al Naqed International Advertising Agency.
17	The General Directorate of Military Survey (GDMS)

4.7 Standards used for conventional products and what standards (This summary includes replies to question 4.8).

Yes	No	Standard
1		1. The General Directorate of Military Survey (GDMS) prepared specifications adopted for some products. 2. International specifications for some products (DIGEST)
2		1. International Standards 2. Private Standards
5		Ministry of Municipal and Rural Affairs (MOMRA) has specifications and standards for all the above steps of production but they cannot be easily described in a questionnaire like this.
	8	
9		We use National and International Standards based on ISO/TC 211 specifications. We continue to update those standards as needed. Now we have a first version of the draft specifications for Riyadh City.
10		IHO Specifications.
11		We will use the ISO/TC 211 specifications as the Kingdom has joined membership of that committee. The specification is now being applied through the SASO.
12		Maps used in our department must give good resolution of the targeted area or place. E.g. named populated areas in villages and blocks in cities.
15		
16		The conditions and technical specifications required by the department include the quality of printing paper, printing method, types and quality of inks used, the number of colours and the arrangement of the source or map.
17		Same as those used by The General Directorate of Military Survey (GDMS)

4.9 Geodetic reference system in use for your conventional products

International Spheroid	WGS 72	WGS 84	Others
1, 2, 8,10, 11	10	1, 8, 9, 10, 11	5 (UTM)?, 9, 10

4.10 Datums used

Horizontal			Vertical	
WGS 84	Ain Al Abd	Others	Jeddah 72	Others
1	1, 2, 5, 8, 9, 11		1, 2, 5, 11	

4.12 Reproduction Material available (This summary includes replays to questions 4.13).

Yes	No	Reproduction material condition and quality
1		All reproduction materials for the conventional products are available. The quality differs between old and new materials, as the new materials are stored under perfect conditions and according to specifications.
2		Excellent condition. Format. Positive and negative film.
5		In good condition.
	8	Not hard copies, but digital format stored in the database.
	9	
10		In good condition and quality.
11		
	12	
16		Good condition
17		The reproduction material of the Northern Sanctuaries Map is available at the NCWCD but not in good condition. For the rest of the Sanctuaries the General Directorate of the Military Survey (GDMS) keeps the reproduction material.

4.14 Potential users of the conventional products.

ID	Potential user
1	All Ministries and Government Agencies as well as private organizations and researchers.
2	All Ministries and Government Agencies and government owned companies as well as privately owned companies, individuals and researchers.
5	All sectors of Ministry of Municipal and Rural Affairs (MOMRA) at municipalities, village clusters, water and sewage department, all government sectors,
8	1. Ministry of communication employees. 2. Other agencies, such as King Abdulaziz City for Science and Technology (KACST).
9	Individuals, companies, government institutions, planners and researchers.
10	Many different government departments, marine navigators and seaport users.
11	All the Ministry's affiliates (Directorates and branches) as well as the Ministry's staff.
12	Our maps are usually used within the department only for statistical purposes as we

	said. They are given to Statistical sections of concern whenever needed for field researches.
15	All Saudi Consolidated Electric Company Departments. The new planned map will be good for all civilian applications.
16	The Schools run by the General Presidency of Girls Education.
17	1. National Commission for Wildlife Conservation and Development Researchers. 2. Experts. 3. Rangers assigned to the Sanctuaries. 4. Air Control of the NCWCD aircraft.

4.15 Equipment used for conventional products.

1. Geodetic and Land Survey

ID	Equipment
1	Same as number 2.21 above (Digital products).
2	Levelling equipment and GPS
5	Same as number 2.21 above
8	Same as number 2.21 above
11	Same as number 2.21 above.
17	GPS Equipment.

2. Photogrammetry

ID	Equipment
1	Same as 2.21, plus various types of Wild and zeiss equipment and Aerial Cameras.
2	Analogue instruments such as A10, B8, B8s, A7 etc. Analytical Instruments-Planicom and ACI digitizer
5	Same as number 2.21 above
11	Same as number 2.21 above
17	We cooperate with the General Directorate of the Military (GDMS).

3. Cartography

ID	Equipment
1	Same as 2.21, plus various types of conventional equipment.
2	Manual Engineering tools
5	TD7 image station system of Intergraph is used for digital cartography along with sophisticated computers used for the cartographic enhancement of digital maps.
10	Same as number 2.21 above
11	Our plan anticipates obtaining a large and accurate digitizers and scanners.
15	NT - Workstation
17	We use manual techniques, but we are in the process of commissioning the GIS.

4. Reprographics

ID	Equipment
1	Same as 2.21, plus various types of conventional equipment.
2	Conventional Equipment
5	During the early stages of mapping, we use Versatec map plotter of Intergraph along with HP2500 & HP3500 plotters.
9	HP Plotters
10	Intergraph Charting System.
11	The plan anticipates the use of large plotters for vectors and raster.

5. Printing System

ID	Equipment
1	Same as number 2.21 above
2	Conventional Equipment
5	4. Same as number 2.21 above
8	Same as number 2.21 above
9	HP Plotters
10	Same as number 2.21 above
11	Same as number 2.21 above

E. SECTION FIVE: USERS' NEEDS AND REQUIREMENTS

5.1 Which agencies are the main producers for the maps currently in use within departments.

ID	Main Producing Agency
1, 7, 8, 11, 12, 13, 14, 16, 17	Ministry of Defence and Aviation, the General Directorate of Military Survey (GDMS)
1, 3, 5, 9, 11, 12, 16, 17	Ministry of Petroleum and Mineral Resources (MOP&MR)
4, 5, 9, 11, 12, 14, 15, 17	General Directorate of Surveying, Ministry of Municipal and Rural Affairs (MOMRA)
9, 11, 14, 15, 16	Ar Riyadh Development Authority (ADA)
16	The Ports Authority
8, 16	Ministry of Communications
9, 15	Riyadh City Municipality
9	King Abdulaziz City for Science and Technology (KACST).
11, 12	Al Farsi (private sector)

5.2 What types of products are being used? (This summary includes replies to question 5.3).

ID	Type of products
4, 5, 7, 8, 9, 11, 12, 15, 16	Paper maps
4, 5, 8, 9, 11, 13, 14, 15	Digital maps
15	Other (Plans for future use of satellite imagery)
16	Other (Geographical map featuring terrain, climate, mineral resources, population distribution, transportation and natural plants).

5.4 If department is not presently using Digital Maps and Geographic Information are there plans for future use (This summary includes replies to question 5.5).

ID	Future Plans
5	Our department is now producing digital maps intended for use with GIS applications
7	Our plan is to establish a GIS system.
11	We will soon start implementation of The Ministry of Agriculture and Waters GIS Project.
13	By cooperating with the General Directorate of Military Survey (GDMS) we hope to have our staff trained on this kind of mapping technique.
15	No explanation
17	Geographic Information System (Arc View 3) is still being developed.

5.6 When spatial data is requested, is it received on time?

Yes	No	Why spatial data were not received on time
5		
7		
	8	Coordination with the map producers is difficult. Some producers insist on the privacy of the information and refuse to pass it to other organisations.
9		
	11	Routine procedure and requests for approval. The basic problem is the non-existence of a law and specifications that would determine ways and means of tackling such transactions.
13		
14		
	15	No reason given.
17		

5.7 Type and scale of maps, which are currently in used.

ID	Type of Map used	Scales
5	Topographic Line Maps	1:25,000, 1:50,000, 1:250,000 &
7	Topographic Line Maps	1:500,000
9	Topographic Line Maps	1:50,000, 1:100,000: 1:500,000.
11	Topographic Line Maps	1:2,500
12	Topographic Line Maps	Different types
15	Topographic Line Maps	1:50,000 to 1:3,000,000
16	Topographic Line Maps	1;500, 1:1,000, 1:2,500, 1:5,000,

17	Topographic Line Maps	1:10,000 According to needs
9 16 17	Geological Maps Geological Maps Geological Maps	1:10,000 According to needs
5 7 8 11 12 16 17	Cadastral Maps Cadastral Maps Cadastral Maps Cadastral Maps Cadastral Maps Cadastral Maps Cadastral Maps	1:1,000 and 1:20,000 1:1,000,000 and 1:2,000,000 Any scale as specified Different Depends on City size and density According to purpose
10 17	Hydrographic Charts Hydrographic Charts	1:50,000 and 1:150,000
4 5 7 9 11 12 14 15 16 17	Orthoimage Maps (Aerial Photos)–Rectified Orthoimage Maps (Aerial Photos)–Rectified Orthoimage Maps (Aerial Photos)–Rectified Orthoimage Maps (Aerial Photos)–Rectified Orthoimage Maps (Aerial Photos)–Rectified Orthoimage Maps (Aerial Photos)–Rectified Orthoimage Maps (Aerial Photos)–Rectified Orthoimage Maps (Aerial Photos)–Rectified Orthoimage Maps (Aerial Photos)–Rectified Orthoimage Maps (Aerial Photos)–Rectified	1:1,000 1:5,000 and 1:10,000 1:1,000,000 1:1,000 / 1:2,500 Different 1:50,000 According to purpose
4	Orthoimage Maps(Aerial Photos)–Unrectified	1:1,000
4 5 11 17	Orthoimage Maps (Sat. Images)–Rectified Orthoimage Maps (Sat. Images)–Rectified Orthoimage Maps (Sat. Images)–Rectified Orthoimage Maps (Sat. Images)–Rectified	Spot Panchromatic As needed Different
4 5 8 9	Orthoimage Maps (Sat. Images)–Unrectified Orthoimage Maps (Sat. Images)–Unrectified Orthoimage Maps (Sat. Images)–Unrectified Orthoimage Maps (Sat. Images)–Unrectified	Spot Panchromatic As needed Resolution: 10 metres Resolution: 10 metres
	JOG Series Maps	
9	Others	Plans approved by Riyadh City Municipality for new quarters in the city.

5.8 What are the Primary uses of the Maps and Geographic Information?

ID	Primary Uses
4	1. Naming and numbering Streets and buildings. 2. Settlement of disputes (boundaries, property ownership, and licenses). 3. All other work requiring land surveying.
5	1. Identify ownership, their boundaries, and areas. 2. Settle property disputes by providing map data. 3. Town planning and organization studies.
7	All the studies and research efforts relating to the "law of governance in the provinces"

8	1. Maintenance of roads 2. Operation of roads 3. Traffic safety 4. Other administrative and managerial works relating to roads.
9	1. Planning 2. Analysis 3. Conducting exploratory studies 4. Future forecasts 5. Drawing of policies 6. Administrative boundaries 7. Decision making
10	They are mainly used for marine navigation.
11	1. Agricultural land 2. Soil 3. Water 4. Forests 5. Pastures 6. National Parks 7. Desalination 8. Crops, fertilizers and treatment 9. Directorates and branches 10. Meteorology and Meteorology Stations 11. Agriculture guidance 12. Livestock quarantine 13. Silos and Grains
12	1. Location of populated places, routes leading to them and the difficulty and ease of access to those places. 2. Identify the boundaries of cities, villages and other named features and locations. Also providing details of cities at block level. 3. Maps of the department are used as an assistant factor in conducting statistical researches, population, and economic censuses as a quick means of reading the required statistical research unit. 4. Distribution, organization and follow up of field work and monitoring the work progress. 5. Assess to figure out the manpower and other needs required for each area of supervision including means of transportation and communication. 6. Identify the boundary limits, defining the locations of different field workers.
13	1. Locating the Educational facilities 2. Establish a strategy for the distribution of educational facilities within cities and neighbourhoods. 3. Determine the standard for the provision of school services. 4. Selection of optimum location for placing schools with a view to educational environment consideration. 5. Selecting optimum locations for rented school buildings. 6. Selecting optimum locations for private schools. 7. Determining the type of service and school building size based on density of population.
14	Determining the boundaries of exchanges and cabins for residential areas receiving service or targeted for future service.
15	Specify the locations of subscribers, plants and networks.
16	1. Showing natural features and how they differ from one another.

	2. Showing the population distribution and variety of religious affiliations around the world. 3. Showing the distribution of economic activities; namely mining, livestock and agriculture. 4. Showing the different types of transportation routes, nationally and internationally.
17	1. Field Surveys. 2. Study of Sanctuaries. 3. Establishing new Sanctuaries. 4. Air and Ground Control. 5. National Commission for Wildlife Conservation and Development Researchers and experts.

5.9 Which map scales are preferred and why?

ID	Preferred Scales and the Reasons
4	1:1000, 1:5000, 1:25000
5	The General Department of Surveying is recognised as one of the main map producers in the Kingdom. It produces maps at scales of 1:25,000 or larger that are needed by municipalities and other government departments.
7	No specific scale, the scale is selected in accordance with the needs.
8	No specific scales.
9	We prefer 1:1,000 for the following reasons: 1.Enables the accuracy required to compile a basic consolidated digital map of Riyadh City. 2.Facilitates map production at different scales. 3.The scale is easy to use by the parties involved in the operation and maintenance of Riyadh such as Saudi Consolidated Electric Company, Saudi Telecom, The Water Supply Department and the Municipality.
10	The scales are selected as needed. The scales used now are 1:50,000 and 1:150,000.
11	1. Cadastral 1:250 to 1:1,000 2. Non-Cadastral 1:10,000 to 1:500,000
12	1. Maps of geographic names (1:50,000 scale) for areas with numerous populated place names where it would be easy to show names and identify the boundaries of governorates and administrative areas on those sheets. 2. City maps. Depends on the size of city and density of population. The need also depends on the resolution of the boundaries of blocks within the cities and towns.
13	1:5,000 and 1:10,000 for clarity and easy recognition of cultural features and their locations on maps.
14	1. 1:1,000 – Clearer and easier to read during network construction. 2. 1:10,000 – Important reference for arriving at locations and locating work sites. 3. 1:20,000 – Used for exchange cables (exchange service area). 4. 1:50,000 – Used for the entire area cables (involving several exchanges).
15	1:1000, 1:2500, 1:10,000, 1:20,000, and 1:50,000.
17	This would normally depend on the type of study needed, e.g. for detail studies, we prefer larger scales such as 1:50,000 or larger. For more general studies smaller scales are preferred such as 1:250,000 or smaller.

5.10 Desired vertical and horizontal accuracy, contour intervals, supplementary contours and map type that organisations would require to satisfy their future needs (ID in brackets).

Map Scale	Map Type	Horizontal Accuracy	Vertical Accuracy	Contour Interval	Supplem. Contours Interval
1:1,000	(4)-Digital (5) (9)-MOMRS Spec. (11)-MOMRS Spec. (14)-Survey	(5)-0.15m (9)-0.15m (11)-0.15m (14)	(4)-0.20m (5)-0.20m (9)-0.20m (11)-0.20m	(4)-5m (5)-1m (9)-1m (11)-1m	(4)-1m
1:2,000	(5) (9)-MOMRS Spec. (11)-MOMRS Spec. (12)-City map (14)-Survey	(5)-0.30m (9)-0.30m (11)-0.30m (14)	(5)-0.40m (9)-0.40m (11)-0.40m	(5)-2m (9)-2m (11)-2m	
1:5,000	(5) (9)-MOMRS Spec. (11)-MOMRS Spec. (12)-City map (13) (14)-Survey	(5)-0.60m (9)-0.60m (11)-0.60m (14)	(5)-0.80m (9)-0.80m (11)-0.80m	(5)-5m (9)-5m (11)-5m	
1:10,000	(5) (9)-MOMRS Spec. (11)-MOMRS Spec. (12)-City map (13) (14)-Survey	(5)-1.5m (9)-1.5m (11)-1.5m (14)	(5)-2m (9)-2m (11)-2m	(5)-10m (9)-10m (11)-0m	
1:25,000	(1)-Topo. Digital (1)-Topo. Printed Map (4)-digital (5) (9)-MOMRS Spec. (11)-MOMRS Spec. (14)-Survey	(1)-8.5m (1)-12.5m (5)-10m (9)-10m (11)-10m (41)	(1)-2.2m (1)-5m (5)-15m (9)-15m (11)-15m	(1)-10m (1)-10m (4)-20m (5)-20m (9)-20m (11)-20m	(1)-5m (1)-5m
1:50,000	(1)-Topo. Digital (1)-Topo. Printed Map (8)-Topographic (11)-GDMS specs (12)-Topographic (14)-Survey (17)-Topographic	(1)-17m (1)-25m (8)-10m (11)-25m (14)	(1)-3.7m (1)-10m (11)-10m	(1)-20m (1)-20m (8)-5-10m (11)-20m (17)-10m	(1)-10m (1)-10m (11)-10m (17)-5m
1:100,000	(11)-GDMS specs				
1:250,000	(1)-Digital (1)-Printed Map	(1)-85m (1)-125m	(1)-22m (1)-25m	(1)-50m (1)-50m	(1)-25m (1)-25m

	(8) -General Map (11)-GDMS specs (17)-Topographic	(8)-200m (11)-125m	(11)-25m	(11)-50m (17)-50m	(11)-25m (17)-25m
1:500,000	(11)-GDMS specs (12)-Topographic (17)-Topographic			(17)-50m	(17)-25m
1:1M	(11)-GDMS specs (12)-Topographic (17)-Geological				
1:2M	(11)-GDMS specs (12)-Topographic			(11)-200m	(11)-50-100m

5.10 (continue) Additional comments:

ID	Comments
12	1. For cadastral maps of cities, we usually care for street and block details, as only those are relevant to our fieldwork. 2. We usually use them to show names of population-related names. Therefore the scale is selected in accordance with the density of population related names.

5.11 What cultural features are needed for departments (features to be printed on the maps)?

Map Scale	Roads	Maritime Features	Water From Wells etc	Pipe-lines	Dams Bridges	Terrain Types	Contours &Spot Hts	Developed Areas
1:1,000	4, 5, 8, 9, 11, 14, 15, 16	5, 11, 15	4, 5, 8, 11, 16	4, 5, 8, 11, 14, 15, 16	4, 5, 8, 9, 11, 15	4, 5, 8, 11, 15, 16	4, 5, 8, 9, 11, 15	4, 5, 8, 9, 11, 14, 17, 20
1:2,000	5, 8, 11, 12, 15	5, 11, 15	5, 8, 11, 12	5, 8, 11, 15	5, 8, 11, 12, 15	5, 8, 11,12, 15	5, 8, 11, 15	5, 8, 11, 12, 15
1:5,000	4, 5, 8, 9, 11, 12, 13, 15	5, 11, 15	4, 5, 8, 11, 12	4, 5, 8, 11, 15	4, 5, 8, 11, 12, 15	4, 5, 8, 9, 11, 12, 12, 15	4, 5, 8, 9, 11, 15	3, 5, 8, 9, 11, 12, 13, 15
1:10,000	5, 8, 11, 12, 13, 14, 15	5, 11, 15	5, 8, 9, 11, 12	5, 8, 9, 11, 12, 14, 15	5, 8, 11, 12, 15	5, 8, 11, 12, 13, 15	5, 8, 9, 11, 13, 15	5, 8, 9, 11, 12, 13, 14, 15
1:25,000	4, 5, 8, 11, 15	11, 15	4, 8, 11	4, 8, 11, 15	4, 8, 11, 15	4, 5, 8, 11, 15	4, 5, 8, 11, 15	4, 5, 8, 11, 15
1:50,000	5, 7, 8, 11, 12, 14, 15, 17	11, 12, 15, 17	7, 8, 11, 12, 17	8, 11, 12, 15, 17	8, 11, 12, 15, 17	5, 7, 8, 11, 12, 15, 17	5, 8, 11, 12, 14, 15, 17	5, 7, 8, 11, 12, 15, 17
1:100,000	5, 7, 8, 11, 12, 15	11, 12, 15	7, 8, 11, 12	7, 8, 11, 12, 15	7, 8, 11, 12, 15	5, 7, 8, 11, 12, 15	5, 11, 12, 15	5, 7, 8, 11, 12, 15

1:250,000	5, 8, 11, 12, 15, 17	11, 11, 15, 17	11, 12, 17	8, 11, 12, 15, 17	8, 11, 12, 15, 17	5, 11, 12, 15, 17	5, 11, 12, 15, 17	5, 8, 11, 1[illegible] 15, 17
1:500,000	5, 7, 8, 11, 12, 17	7, 11, 12, 17	7, 11, 12, 17	8, 11, 12, 17	7, 11, 12, 17	5, 7, 11, 12, 17	5, 7, 11, 12, 17	5, 7, 8, 11, 12, 17
1:1,000,00	7, 8, 11, 12	7, 11, 12	7, 11, 12	8, 11, 12	7, 11, 12	7, 11, 12	7, 11, 12	7, 8, 11, 12
1:2,000,00	7, 8, 11, 12, 17	7, 11, 12	11, 12	8, 11, 12	7, 11, 14	7, 11, 12	11, 12	7, 8, 11, 12, 17

5.11 (Continued) Additional comments

ID	Comments
7	The limits of administrative jurisdiction between provinces, the limits of administrative jurisdiction between governorates and districts and the locations and names of governorates and districts.
11	Other features are used, such as forests (Woodlands), Pastures, Public Parks, Cultivatable lands, Soil. Note maritime features are used if and when needed
12	Locations of girls schools, school clinics, fire stations, police stations.
15	Electric Power Lines

5.12 Preferred images in terms of resolution, type of images and colour or B&W.

ID	Comments
4	Spot Panchromatic (10m resolution)
5	We use satellite images of the French Satellite Spot (10m res.), the US Satellite Landsat (30m res.), the Russian Satellite (5m res.) and the US Satellite Ikonos (1m res.)
8	We use images from the Spot Satellite with a 10m resolution, which is preferred by our department. The images used are black and white.
9	Now we use 10m black and white, We prefer a resolution of 1 metre in colour.
11	All images are needed and usable because of the variety of applications. Spot, black and white, Colour (10m, 20m), TM 7 or 5 bands (30m), IRS black and white, plus all bands (5m), Ikonos black and white, plus all bands (1m, 4m)

5.13 List of types and dates of products used by organisations.

ID	Product Type	Production Date
4	Digital maps, Aerial photographs and Satellite Images of Riyadh City (see number 2.3 above)	1996-1999
5	Mainly aerial photography as indicated in number 4.2 above	1976-1995
8	The Road Network and road service maps	1999-2000
10	The products are updated as and when needed.	
11	1. 1:1,000 2. 1:2,5000	Various dates
12	1. 1:50,000 2. 1:250,000	1979 – 1988 1981

	3. 1:500,000 4. 1:2,000,000 5. 1:3,000,000 6. City Maps	1981 – 1991 1987 1987 Different dates
14	Accurate Aerial Surveying	1 year from update
15	Aerial Photos (current use)? Aerial Photos (prospective use)?	1983 1995
17	Aerial Photographs of the Red Sea Coast.	1998

5.14 How often are maps updated, and preferred period for updating.

ID	Comments
5	As and when needed.
7	1. Maps are updated as need may arise. 2. We prefer to have them updated when a new data is added or upon the deletion or revision of data.
8	Updated every 1 to 4 years. Preferred to be updated every year.
9	Now they are updated every 5 years. For the future, we would prefer to have them updated each year.
10	As and when needed.
12	Within the unit, maps are updated after each field research in order to match the changes seen in the research specimen.
13	This depends on what we receive from the general directorate of military Survey (GDMS) but we believe their products are up to date and updated every five years. We prefer to have them updated at 5-year intervals.
14	At present the products are updated each year or at two years' interval maximum. The interval should be one year.
15	As needed. Prefer annual.

F. SECTION SIX: GEOGRAPHIC INFORMATION EXCHANGE

6.1 Departments exchanging geographic data.

ID	Departments exchanging with
1	1. Different Sectors of the Armed Forces. 2. Ministry of Education. 3. Ministry of higher education. 4. Ministry of Communications. 5. Ministry of Information. 6. Ministry of agriculture and water. 7. Ministry f Hajj. 8. King Abdulaziz City for Science and Technology (KACST). 9. King Saud University. 10. King Abdulaziz University. 11. King Fahad University. 12. The National Commission for Wildlife Conservation and Development 13. Riyadh City Municipality.

2	1. Ar Riyadh Development Authority. 2. Ministry of Communications. 3. King Abdulaziz City for Science and Technology (KACST). 4. Ministry of the Interior.
3	1. Internal to Saudi Aramco only. 2. No information exchange with non-Saudi Aramco Organizations.
4	1. The Ministry of Municipal and Rural affairs (MOMRA) 2. The General Directorate of Military Survey (GDMS) 1:25,000 & 1:50,000 maps for some parts of Riyadh City and only as hard copies.
5	1. Ar Riyadh 'Development Authority (ADA) 2. Ministry of Agriculture and Water 3. Ministry of Communications 4. Ministry of Interior 5. King Abdulaziz City for Science and Technology (KACST). 6. Saudi Telecom Company 7. Saudi Consolidated Electric Company 8. Universities of the Kingdom 9. Ministry of Petroleum and Mineral Resources.
6	1. The General Directorate of Military Survey (GDMS). 2. Ministry of Petroleum and Mineral Resources. 3. Ministry of Municipal and Rural affairs (MOMRA) 3. Riyadh City Municipality. 4. Ministry of Agriculture and Water. 5. Ministry of Communications.
7	The General Directorate of Military Survey (GDMS).
8	1. Ministry of Municipal and Rural affairs (MOMRA). 2. King Abdulaziz City for Science and Technology (KACST).
9	1. Riyadh City Municipality 2. Riyadh Water and Sewage Department 3. Saudi Consolidated Electric Company 4. Saudi Telecom 3. The Ministry of Municipal and Rural affairs (MOMRA). 5. Saudi Aramco. 6. Ministry of Petroleum and Mineral Resources (MOP&MR) 7. The General Directorate of Military Survey (GDMS). 8. Chamber of Commerce 9. Ministry of Agriculture and Water 10. King Abdulaziz City for Science and Technology (KACST). 11. King Saud University
10	The General Directorate of Military Survey (GDMS).
11	1. All departments, sections, branches and directorates of the Ministry of Agriculture and Water. 2. The General Directorate of Military Survey (GDMS). 3. King Abdulaziz City for Science and Technology (KACST). 4. The Ministry of Municipal and Rural affairs (MOMRA). 5. Ministry of Communications. 6. Ministry of Petroleum and Resources. 7. Other related agencies.
13	The General Directorate of Military Survey (GDMS).
14	1. Municipalities. 2. The General Directorate of Military Survey (GDMS).

15	1. Riyadh City Municipality.
16	1. Ministry of Education. 2. King Abdulaziz City for Science and Technology (KACST).
17	1. The General Directorate of Military Survey (GDMS). 2. King Abdulaziz City for Science and Technology (KACST). 3. The Department of Meteorology & Environmental Protection.

6.2 Means of requesting geographic data.

Means	ID
By official letter	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 14, 15, 17
By Agreement	8, 13
By Phone	7, 9
By filling in forms	3, 9
By email	9
Other means	16

6.3 How the requested data is identified.

Identified by	ID
Co-ordinates	1, 2, 3, 4, 5, 6, 7, 9, 10, 11, 13, 17
Area of Coverage	1, 3, 4, 5, 6, 7, 8, 9, 11, 14, 15
Main Features	1, 4, 6, 8, 11, 15
Contents	1, 3, 7, 11
Cost	11
Other means	

6.4 How the digital geographic data is transferred to the users.

Transferred by	ID
Ordinary mail	6, 15, 17
DHL	6, 9
E-Mail	8
Network (Local or Wide area network)	3, 14
Courier	1, 2, 4, 5, 6, 9, 11, 13, 15, 17
Other means - Specified	3-User picks up. 10-By formal delivery to user

6.5 Media used for receipt of data

Media used	ID
Hard Copy	1, 2, 3, 4, 5, 6, 8, 9, 11, 14, 15
CD-ROMs	1, 3, 4, 5, 6, 8, 9, 11, 15, 17
Diskettes	1, 4, 8
Xbyte	5

6.6 Frequency of exchanging digital products with other organisations.

Frequency	ID
Daily	
Weekly	9
Monthly	15
Quarterly	8
Annually	6
As needed	1, 3, 4, 5, 8, 11, 13, 14, 15, 16, 17
Other - Specified	1-Each request is different from others and it is difficult to specify a time. There is generally no specific time frame for these requests.

6.7 Format used to maintain and exchange the digital geographic information.

Format	Maintain	Exchange
Arc Info Coverage	1, 4, 6, 8, 11, 13	6, 8, 11
Arc Info Shapefile	4, 6, 8, 9, 11, 13, 17	1, 6, 8, 9, 11
MicroStation DGN file	1, 3, 4, 5, 6, 9, 10, 11, 13, 14, 15	1, 3, 4, 5, 6, 9, 10, 11, 15
AutoCAD (DWG/DXF)	4, 5, 8, 10, 11, 13	1, 4, 5, 6, 8, 9, 10, 11
GIF (Graphic Interchange Format)	10, 11	10, 11
SDTS (Spatial Data Transfer Standards)	11	11
SIF	8	8
TIFF	1, 3, 4, 5, 6, 8, 9, 10, 11	1, 3, 4, 5, 6, 8, 9, 10, 11
CIB		
JPEG	3, 5, 9, 11	3, 5, 9, 11
DTED	1	1
DLG		
Digest	1	
Postscript		
CGM		
CCITT	9	9
HTML		5
VPF		
Vmap	1	
ADRG/CADRG		
ADRI	1	1
IGES		
ASCII	3, 4, 5, 8, 9	3, 4, 5, 8, 9
Others - Specified	5-(MOS, RLC, RLE, RGB, EPC, CIT)	

6.8 Can Organisations deliver geographic information on time?

YES	NO	Comments
1,2,3,4,5,6,7,8,9,11,13,14,15,17		

6.9 In the participants' view, does the data meet the users expectations in terms of the given items?

Items	YES	No
Completeness	1, 3, 4, 5, 6, 8, 9, 11, 13, 15, 17	2, 14
Accuracy	1, 2, 3, 4, 5, 6, 9, 11, 13, 15, 17	8, 14
Clarity	1, 2, 3, 4, 5, 6, 8, 9, 11, 13, 15, 17	14
Currency	1, 3, 5, 6, 11, 13, 15, 17	4, 8, 9, 14
Data Format	1, 3, 4, 5, 6, 8, 9, 11, 13, 15, 17	14
Response Time	1, 2, 3, 4, 5, 6, 8, 9, 11, 13, 14, 17	15
Quantity	1, 2, 3, 5, 6, 8, 9, 11, 13, 14, 17	4, 15
Quality	1, 2, 3 (To some extent), 4, 5, 6, 9, 11, 13, 14, 17	8, 15
Other-Specified	1–In many cases we receive requests for update coverage of 1:50,000 map for certain areas where we only have old maps. 8–The product available now meets the user requirements for quality but it does not cover all the areas in demand. The Department is now planning to update and compile the latest digital maps to meet the user requirements.	2, 3, 5, 6, 9, 11,13, 14, 15, 17

6.10 Why did not the data meet the users expectations?

Terms	ID	Comments
Completeness		
Accuracy	8	Since the available land surveys are too old, new and more accurate surveys are being made.
Clarity		
Currency	2 4 8 9	Due to lack of funds the maps are not updated, therefore they do not include some of the recently constructed features. The maps were produced more than 15 years ago. No comment As the road network is too extensive, it is difficult to make the land surveys at short intervals. All users would want to have the information supplied by us to be more up to date than it is.
Format	2	Lack of digital mapping system
Response Time		
Quantity	4	No comment
Quality	3 8	To some extent the GIS requirements are evolving. Although the quality control (QC) meets the original requirements, QC is evolving to meet the evolving requirements. In the past, no advanced technology was available for carrying out the land surveys. State of the art technology like differential GPS is now used to ensure good quality work.
Other - Spec.	4	No comment

6.11 Do you find the current circumstances of exchanging information between organisations in the Kingdom of Saudi Arabia appropriate and efficient? (This summary includes replies to question 6.12).

Yes	No	Thoughts
	1	If the proposed Central Surveying and Mapping Agency is approved and if the proposed SNSDI is developed, we will be in an excellent position to handle this role.
	2	For paper printed maps the present system is OK. Digital data and digital maps are not available to the department now. We believe that a network is needed for speedy exchange of data among government departments.
	3	Lack of standards, no coordination, and no centralization. A centralized GIS body to encourage standardization, data sharing, and cooperation would improve the value of GIS data.
	4	An exchange network should be established to connect all the departments and agencies using geographic information. This would ensure a speedy access to information and a speedy exchange thereof. It is also important to use security systems to protect the information against damage or leakage.
	5	We suggest : 1. That communication among government institutions should be easy and avoid unnecessarily difficult procedures. 2. Those Government institutions are connected to a computer network in order to facilitate the transfer of available data from one to all other partners.
	6	Establish a national GIS database based on consolidated specifications through which data information can be exchanged under certain regulations and controls.
	8	All parties of concern must use consolidated standards and specifications for the exchange of information.
	9	Through the Internet
	10	We need a work team who must meet on regular periodic basis to review the latest developments at all agencies and organizations of concern and the information needs and requirements of all.
	11	1. Issue of a law enabling easy exchange of information for both the user and producer and handling problems of information security. 2. Sorting out classified and non-classified information and user classes. 3. Using electronic communication systems for the immediate transfer of information through networks. 4. Establishing consolidated standards and specifications for all users. 5. Documentation of information as regards quality, temporal dimension, copyrights. Fees could be levied to cover the cost of maintaining and updating information.
	13	1. Flexibility and mutual confidence among the agencies of concern is needed. 2. The information must not be restricted to one department or agency. Free access should be allowed for all at any time. 3. We must preferably have a product for the market offered for sale.
14		
	15	1. Establish a comprehensive network linking all producers and users together. Alternatively, the information can be provided through Internet and email so that updating can be made automatically and continuously.
	17	A coordination committee involving all departments of concern must be appointed. The proposed committee should meet on regular periodic basis to discuss developments and problems.

6.13 Expectations that the exchange of spatial data between organisations within the Kingdom of Saudi Arabia will have an effect (This summary includes replies to Question 6.14).

ID	Expectations
1	The expected impact will be positive, as it would reflect on product giving better quality products. It would also make data exchange easier, stop duality and save time, effort and money.
3	That might affect producing departments as follows: 1. Require additional resources. 2. Identify duplication of effort. 3. Be viewed as a threat by some organisations. 4. Increased efficiencies 5. Improved knowledge levels.
4	1. Quick access to information would positively affect the quickness and integrity of decision making. 2. Swiftness of the exchange of information. 3. Avoiding unnecessary duplication of effort and cost. 4. Easy update and early delivery of data to users.
5	No
6	No change expected. It could not have a negative effect on the work performance of the department. It would rather save time and money.
8	It may be necessary to divert intensive efforts to the goal of having uniform standards for the transfer of data shared by all users for a smooth exchange of data among them.
9	Reducing costs, time economy, standardisation, elimination of repetition of work, improving quality of products, consistency and integration among agencies of concern.
10	No – It would improve and facilitate the overall performance.
11	The exchange in itself should have no problem but it must be accompanied by a clear-cut plan on who should have the power to decide on updating the information, such as roads are the work of the Ministry of Communications but the decision to add them to maps should come from a national committee. The Ministry of Agriculture should similarly take care of its own information. The same should apply to municipalities, GDMS, KACST, etc.
13	The decision-making strategy will become clear to executives in the government agency or department of concern.
15	It would cut the costs, eliminate repetition, consolidate efforts and provide the latest information in the shortest possible time.
17	We believe that a shared transfer and exchange of geographic information would help each individual party to make use of the efforts of other parties and minimise the wasting of resources in repeated efforts. It would also help with the quicker completion of work.

5.15 In general, what is thought to be the main obstacle to the exchange of spatial data among government organisations? (ID 13 shows grading in brackets, may be out of 10?).

Obstacle	ID
Data format	1, 4, 5, 6, 9, 10, 11, 13(8), 15, 17
Data type	9, 13(6), 17
Currency of geographic products	3, 5, 6, 9, 11, 13(5), 15
Media	5, 10, 13(7), 15
Inconsistency and discrepancy of data	3, 4, 5, 9, 11, 13(9), 15
Unwillingness to exchange data	3, 4, 6, 8, 9, 10, 11, 13(4), 15
Cost	3, 9, 13(2), 15, 17
Hardware & Software Problems	5, 10, 13(1), 14, 15, 17
Human resources	3, 5, 10, 11, 13(3), 15, 17
Others - Specified	1 – The obstacles have more than one factor but there is essentially a lack of coordination among the different agencies of concern.

6.16 Additional comments on how to exchange geographic data in the Kingdom.

ID	Comments
1	We suggest that all agencies of concern in the Kingdom should adopt the international digital geographic information standards being developed by (ISO /TC 211) now that the Kingdom has become a full member of this committee. The expected set of standards would make the exchange of information easier and remove all obstacles in future.
2	The primary issue is the data itself and the willingness of effective resources to cooperate.
4	1. Steps should be taken to set up a centre or organisation, which will have central control of network transfer and exchange of data. 2. The exchange procedure should be protected. 3. Using the latest and most advanced satellites in the acquirement of images and making them available to users.
6	Establish consolidated specifications.
8	It may be better to establish a common geographic information system shared by all parties, which can also be used by the parties for the exchange of information.
9	1. Absence of relevant policies, ordinances and regulations. 2. Some users are not connected to the Internet. 3. Lack of Standards and specifications. 4. Users are not informed on what information is available to other agencies or organizations, which can be useful to them.
13	If the information is put in an exchange network, it will be easily accessible for all and there would be no need for formal correspondence in this case.
15	1. All agencies and organisations of concern should meet to discuss the subject and come up with a common agreed version. 2. A formal Royal decree should then be issued to all parties to abide by the commonly agreed version.

G. SECTION SEVEN: THE DEVELOPMENT OF A STRATEGY FOR A NATIONAL SPATIAL DATA INFRASTRUCTURE IN THE KINGDOM OF SAUDI ARABIA.

7.1 Thoughts on the development and implementation of a Strategy for National Spatial Data Infrastructure (SNSDI) in the Kingdom of Saudi Arabia.

ID	Thoughts
1	The idea is innovative and worthy of much support and attention as it constitutes the first step on the right way to building a National GIS System which can serve all civilian and military sectors in the Kingdom. The matter should receive highest and immediate attention to enable speedy implementation. All parties should co-operate in this effort.
2	We believe that the establishment of SNSDI will be useful and a positive step for the common good. It can also help the concerned departments each in their own field of activity
3	It is a great idea, and when its achieved it could be valuable to the Kingdom. This idea needs support at very highest level to be successful.
4	This is a good idea and must be carried out as soon as possible as it would save a lot of wasted effort and money. It would support sound decision-making based on geographic information and prevent duality in decision making as it provides for an integrated geographical information.
5	We believe that the proposed SNSDI would give the country a main pillar in the Country development. We look forward to seeing the idea executed for the common good.
6	An essential idea to benefit from all geographic information and reduce cost. The Space Research Institute is interested in this idea.
7	The idea is good and fruitful.
8	We think this is a good idea, which will help with removing many difficulties in the establishment of GIS systems in different organisations including the exchange of information and the consolidation of standards and specifications.
9	Very good idea but it needs a great effort and continuous co-ordination among the different parties. The goals and objectives of the SNSDI should be drawn up and clearly stated. All relevant parties must be allowed to effectively contribute to the building of the proposed database. Individual organisations must be allowed to work in their respective areas of speciality as long as they do not clash with the other organisations in goals or strategies.
10	We look forward to the realisation of this goal.
11	This is a great aim; we name it the national spatial database.
13	This is a national goal for which we must all work together. We believe that The General Directorate of Military Survey (GDMS) is most qualified to undertake this effort as it has much to its advantage.
14	Very good idea and must be supported.
15	It is a must.
17	This is a good and constructive idea that could result in a dramatic shift for both users and producers. It can also help with the organisation of work.

7.2 Willingness to participate and be part of this SNSDI (This summary includes replies to question 7.3).

YES	NO
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 17	

7.4 Willingness to provide geographic data or information about their data on the Saudi Nat. Spatial Data Clearinghouse (SNSDC) on the Internet, (This summary includes replies to question 7.5).

Yes	No	Willingness and comments
1		There are huge volumes of basic geographical information covering the KSA available in digital format. Such information can be useful to many government sectors and organisations and could become the nucleus of a National GIS. The General Directorate of Military Survey (GDMS) has no objection to include this information as part of the proposed SNSDC.
2		We have no objection to the publication of non-confidential geographic information, which can be useful for researchers and other information users.
4		We can contribute part of the unclassified geographic information
5		
6		We can provide information such as satellite images etc., offer technical support and participate in establishing a national network.
	7	
8		We can include some of the Ministry of communication geographic information in the GIS database of the proposed GI centre.
9		1. Publish and distribute the basic city map with full details. 2. Consolidate the GIS standards and specifications. 3. All parties involved should be connected to a speedy information network for easy access and utilisation of the huge volume of information made available. 4. It is necessary to establish a complete set of metadata related to geographic information.
10		The available information will be released on request.
11		As mentioned already, this issue must be the work of a specialised committee who should identify and sort out the information into classified, unclassified and highly strategic information, which can only be circulated within very restricted limits. I repeat, the proposed effort is very large and needs to be carefully legalised under guidance of specialist technical committees.
13		The Ministry of Education deals with educational, building facilities, teachers and students. If all the information is available to the employees it becomes easy to save time and effort. In order to secure free access to all information on the Ministry so that the users will come to know the work method adopted by the Ministry of Education and that the Ministries needs and requirements will become clear.
14		Yes
15		We agree to place any information available to us that are useful to the other parties in the proposed network.
17		This would boost the cause of data and information exchange, eliminate the problem of repeated work efforts and allow better coping with latest developments in the field.

7.8 Final Comments

1. Relevant suggestions or comments by the participants with regard to the questionnaire.

ID	Comments
4	1. We wish the scholar every success. 2. When the questionnaire data are analysed it is hoped that the final result will be sent to us for our perusal.
6	The questionnaire concentrates on maps and geographic information and gives no attention to satellite imagery, which are essential for mapping.
8	1. Some of the questions mostly concentrate on map production. 2. Some questions are similar. 3. It would have been better to include an English version of the questionnaire.
9	1. Set up specialised and branch committees to discuss technical matters resulting from the establishment of an essential data base for the Kingdom and its different cities. 2. Government institutions and departments of concern must be connected to a site on the Internet to exchange geographic information and expertise. 3. Set up qualified training centres to qualify local manpower in the field.
10	We wish you every success.
11	This questionnaire is too big. It would have been better if: 1. Before writing "The Purpose of the Questionnaire" page 2, there should have been 4-5 concentrated lines on the purpose of the study. 2. The GIS strategy in this Questionnaire concentrates more on maps than other elements of importance to the strategy. The Questionnaire is too bulky with a lot of repetition. Many people would find it difficult to respond properly. Some agencies or departments may fail to respond either because of the size of the questionnaire or because it is sometimes unclear.
13	We wish you all success.
15	Kindly send us a copy of the study when concluded

3. Relevant suggestions or comments by the participants with regard to the SNSDI.

ID	Suggestions and Comments
1	We wish the researcher every success.
4	1. We recommend that a specialised national centre of geographic information is established for the Kingdom of Saudi Arabia. 3. An effective mechanism should be established for data security and to stop hackers.
6	We heartily wish you success.
8	1. The responsibility for establishing the proposed strategy should preferably be managed and overseen by King Abdulaziz City for Science and Technology (KACST) 2. We suggest the creation of an independent body to oversee the development of the strategy. This body should involve permanent members representing organisations that have or plan to have GIS systems. It is suggest that the establishment of the strategy should be made as soon as possible. As the technology used in GIS systems continue to change very fast, it may be difficult, in the future, to reach agreement on the consolidation of standards and

	specifications because of the variety of GIS systems and the disparities between them.
9	We suggest that the proposed strategy be built on a decentralised rather than centralised basis and that all parties shall be allowed to take part in the formational and advisory activities on the national, provincial and city levels.
11	It is thought that your subject for the proposed strategy should need 3 or 4 PhD dissertations and not just the one. If it is treated as a single subject it would be very generalised, hence less useful. The dissertations suggested are as follows: 1. Maps and mapping information, map types, their validity, production and handling etc. through a national centre of exchange, updating and maintenance of maps. 2. Databases, their types, encryption, contents and the exchange of their contents, whether they are relational or object-orientated and how to establish a matching standard code etc. 3. Communications and networks. This alone is an extensive subject, which can have a drastic influence on the whole idea.

3. Citations of documents, materials, reports, bulletins, emails or any other references that were used by the participants to complete the survey.

ID	References used
4	1. MOMRA Standards. 2. TERRA Survey Standards. 3. Intergraph Standards.
8	1. British Aerospace GIS Study – User Requirement Report. 2. British Aerospace GIS Study – User requirement – Executive Review. 3. British Aerospace GIS Study – Map Design and Specification Report. 4. British Aerospace GIS Study – Functional Requirements and GIS Evaluation Criteria. 5. British Aerospace GIS Study – Development Programme
9	1. Ar-Riyadh Explorer (CD-ROM) 2. Ar Riyadh Development Authority Draft Standards
11	The detailed field study for the development of geographic information system (GIS) for the ministry of Agriculture and Water.
15	We will be glad to receive you in our office and show you what we have.