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The field of Geomatics:
Scientific, Technological, Business and Infrastructural Aspects

By

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FOREWORD

Based on dr.polit dissertation in human geography, University of Oslo (2003): *Constructing Urban Technology – Producing Urban Space. The Case of Geomatics in the Transformation of Water and Road Infrastructures.*

CONTENTS

1 INTRODUCTION

The purpose of this paper is to explore a set of technological innovations that influence on the ways we perceive and use space and place. A rapidly growing subset of telematics or information and communication technologies (ICTs) is referred to as geographic information technology (GIT). This is computer systems and other "technological means for the collection, storage, analysis, and representation of geo-coded data" (Curry 1998: xii). However, this technological field has more recently been referred to as *geomatics*. The definition of geomatics are still evolving - and a matter of discussion that I return to later - but a short and wide working definition might be the knowledge, practice and technological artifacts related to the management of geo-referenced information.

In the following, I use the term *the field of geomatics* in a broad sense. It is a field constituted by social and institutional practices and relations including all actors, institutions, technologies and activities related to the use and production of geomatics in some sense. Moreover, such a field - whether local, national, regional or global in scale and scope - is embedded in and constituted by several technocultures. Thus, the complex character of the field of geomatics is strongly indicated. Geographic information and technology for gathering, analysing, exchanging, mapping and using this kind of information has been identified as a basic aspect of the complex processes of convergence between networked infrastructures.

According to John Pickles (1995b: vii), recent developments within this emerging field have implications for our understanding of nature and social life:

> "Over the past two decades the convergence of techniques for advanced computing and enhanced imaging has transformed the ways in which many of us think about and handle information. Together these technologies are now transforming our ways of worldmaking and the ways in which geographers and others think about and visualize the places, regions, environments, and peoples of the earth".

The past two decades have seen significant transformations in data handling, mapping capabilities and spatial representations. These changes have influenced upon many disciplines both inside and outside academia. With this development, new constellations of ideas, ideologies and social practices have also emerged.

In a broad sense, geomatics are a set of approaches to geographic information that can be situated within wider transformations of capitalism in late 20^{th} century:

> "as a tool to protect disciplinary power and access to funding; as a way of organizing more efficient systems of production; and as a reworking (and rewriting) of cultural codes - the creation of new visual imaginaries, new conceptions of earth, new modalities of commodity and consumer, and new visions of what constitutes market, territory, and empire" (Pickles 1995b: viii).

Thus, in addition to its aspects of a political economy of technical change, this field also represents "an emerging economy of the virtual sign, of cybernetics and cyberspace" (ibid.). This aspect of geomatics has been approached from a power/ knowledge tradition, critically focusing upon artifacts like maps as instruments and inscriptions of power (Harley 1988).

As Curry (1998) critically argues, for instance, there are very substantial limitations to what can be represented using geomatics technologies like geographic information systems. His general argument in this instance "focuses on the difficulty that the systems have in representing everyday practice…[When] we look at the representations of everyday practices produced using geographic information systems, for various reasons we have difficulty seeing what is represented *as* practices" (ibid.: 3). Part of this problem has to with the often obscure "relationship between the creator and the systems and their output" (ibid.: 3-4).

Notwithstanding such limitations, as Pickles (1995b: x) has observed, new technological possibilities for data handling and imaging are

> "fully naturalized as the next local and necessary step in the advance of science and society, and the stimulus to new ways in which individuals and groups can overcome the barriers of distance and enhance their abilities to exercise control over society, space, and the earth".

What is often observed, then, is that the dynamics of technological development and adoption tend to be legitimised by an ideology of progress. Unproblematised beliefs in the importance of technical advances across such fields as science, medicine, administration and logistics abound. Therefore, it is important to problematise the dynamic of technological development from more critical perspectives (Curry 1998).

The paper starts with a brief introduction to the discourse surrounding the field of geomatics (part 1.). The first central issue dealt with is the question of *how geomatics are defined* (part 2.). The second important issue dealt with is *what components geomatics consists of* (part 3.). The third critical issue dealt with is the question of *what purposes geomatics are used for* (part 4.). Finally, the chapter is summed up (part 5).

2 FOUR ASPECTS OF THE FIELD OF GEOMATICS[1]

In view of the aim of the present exploration, it is important to be critical when accounting for and assessing the different ways in which geomatics can influence on how we perceive and use place and space. It is also necessary to adopt a critical approach towards the rhetoric surrounding the problem solving capacity of geomatics while its purported positive contributions to society must be critically investigated. A recent inquiry into these matters is conducted in Samuelsen (2003). John Pickles (1995c) has illustrated why this is important by exposing the language of geomatics developers and practitioners. In their words, as caricatured by Pickles (ibid.: 23, original emphasis).

> "the new electronic technologies permit the rapid and extensive *surveying* of *new and more complete sets of data* at great *speed*, decreasing *cost*, and greater *efficiency*. The *technologica*l changes that make these *advances* possible also permit the *standardization* and *manipulation* of a variety of discrete data sets to *yield* new *spatially specific* sets of information that can be *codified*, and even *commodified*. This *control technology* and *knowledge engineering* require special *skills, knowledge*, and *training*. The *output* is in great *demand*, students can find good *jobs*, and government, military, and business *applications* provide challenges for the university researcher".

However, as Pickles point out, exponents and practitioners of geomatics make these claims hardly without any consideration of a broader context "of theorizing the changes in techno-logy and social relations, of epistemology and theories of science, or of the processes of the production, representation, and dissemination of information within which these processes operate" (ibid.). In light of this, the purpose here is to provide a brief but critical introduction to geomatics in terms of four aspects that characterise the field: the *technological*, the *scientific*, the *business* and the *infrastructural* aspects respectively.

2.1 Geomatics as a Technological Field

As noted earlier, the technological artifacts used in the social practice of geomatics - the transformation of the surface of the earth into spatial data - are computer systems and other "technological means for the collection, storage, analysis, and representation of geo-coded data" (Curry 1998: xii). As a rapidly growing subset of *information and communication technologies (ICTs)*, geomatics are thus involved in the complex processes of technological convergence between computing, telecommunication, broadcasting and imaging. One decisive factor in the development of geomatics technologies in general and *geographic information system (GIS)* in particular has been the recent advances in generic ICT, including computing power and *database management systems (DBMS).* The development of geomatics can be traced through three closely related technologies.

The first is the emergence of automated production of maps in the 1960s and 1970s. This area of geographic information handling by computers is called *computer-assisted cartography (CAC),* which includes the area of *computer-aided mapping (CAM)* and is related to the area of *computer-aided design (CAD)*. The second area of geographic information handling by computers is *remote sensing* with the related activity of *digital image processing.* A third related technology is the worldwide satellite system *Global Positioning System* (*GPS).* All these are distinct technologies in their own right, with much commercially available software, established literature and histories at least as long as that of GIS (Berry 1995).

[1] This part is partly based on Samuelsen (1998). For conventional introductions to the field, see Craglia and Couclelis (1997) and Clarke (1997). For more critical introductions to the development and use of geographic information technology both within the discipline of geography and in society at large, see Pickles (1995a) and Curry (1998).

As I show later in the paper (part 4) this set of technologies has a wealth of possible application fields. However, as Pickles (1995c: 23) has pointed out, the application of geomatics technologies must be viewed within "a wider context of theorizing the changes in technology and social relations". It is important to locate the possibilities, limitations, impacts of and influences on these emerging geomatics technologies within a broad political economy of social, technical and cultural restructuring. Geomatics are involved in technical change in specific contexts and influence on how we perceive and use space and place in various ways. This is the case, for instance, "in the discipline of geography, in the arena of production, in the use of advertising images, in the commodification of consumers, in the practice of war, in the governance of territory" (Pickles 1995b: viii) and, as in this inquiry, in the transformation of urban infrastructures.

The development and use of geomatics solutions implies high costs, a factor that has contributed to its emergence "above all as a tool and product that changes the way certain groups and organizations operate. That is, it is a technology (like all technology to one degree or another) closely tied to the concrete material and ideological needs and interests of certain groups" (Pickles 1995c: 3). Thus, the proponents of geomatics solutions to practical problems within various social, political and economic fields may use all sorts of rhetorical devices in order to embed their specific solutions in persuasive language. However, if geomatics technology "is not seen as a social relation, it is fetishised and aestheticised, the contingent nature of technical outcomes is overlooked, and the struggles waged over the choice and application of any particular technology are ignored" (Pickles 1995b: x). Thus, any claims to the positive contributions of geomatics to society must be seen as representing particular social, political and economic interests. If only briefly, the sociotechnical and political economic inquiries undertaken here can be seen as a contribution to taking into consideration a broader context when exploring the use of geomatics in city building.

2.2 Geomatics as a Scientific Field

During the last ten years, the scientific field of *geomatics* has emerged alongside terms like *geographic information science, geocomputation* and *telegeoprocessing.* These terms cover some of the same intellectual terrain and represent the overlapping and convergence of several disciplines like computer science, geography, information science, mathematics and statistics. The field of geomatics are characterised by emergent computer-based tools and techniques and the evolution of a strong and well-defined intellectual core in the science of map making. Geomatics, as a global scientific field constituted at local, regional and national levels, represent particular constellations of ideas, ideologies and social practices. Such characteristics make geomatics as a scientific field an interesting object of critical STI studies (Latour 1987). Although interesting, such an inquiry cannot be further pursued here. What is pursued, though, is a brief examination of the ongoing quest to define the field of geomatics, an effort returned to in part 2 below.

A few points should be emphasised here, however, particularly Pickles's point about the absence of "a wider context […] of epistemology and theories of science" in the presentations and discussions of geomatics (Pickles 1995c: 23). An enduring critique of geomatics science and practice - equally applicable to parts of transport geography and planning - is that it is based on assumptions derived from the positivist tradition (Smith 1992). As Pickles argue, authors within the field of geomatics "have grounded their analyses in terms of value-neutral observation, science as the mirror of reality, and theory as the product of data collection and testing" (Pickles 1995c: 17). The absence of a wider context for reflecting on the role of geomatics technologies, knowledge and practice in society is manifest in that proponents of geomatics "have not chosen to engage the disciplinary and social theoretic debates of the past two decades that address the intellectual, social, political and technological impacts of this form of instrumental action" (ibid.). This is in line with Curry's (1998) argument that the discipline of geography has paid remarkably scant attention to the field of geomatics.

Although the quest to define geomatics has been a long and still ongoing one, Pickles is of the opinion that the complex of technologies that is seen to enable geomatics-based science and practice “has been poorly defined within a language and framework that weakly reflects its impacts on issues such as individual autonomy, privacy, access, systems of governance, marketing strategies, and military tactics” (Pickles 1995c: 5). A pertinent question asked in this connection is whether the task of defining geomatics in this sense “is too important to be left only to the experts” (ibid.). This could and should be an issue of more general public concern.

Geomatics are now an issue in a range of fields like public policy, regional planning, business, the military, and private lives. Even if the effects of geomatics “are wide-ranging and the issues its application raises are important, [its] development and application […] have rarely been treated as having serious political and social implications” (ibid.). When the concepts, practices, and institutional linkages that underpin geomatics as a scientific field “remain largely unproblematized, naturalized as normal and reasonable ways of thinking and acting" (ibid.: 23), it is important to adopt a critical stance towards the problem solving capacity and purported positive contributions of geomatics to society.

This point is not least important in a field as wide ranging as city building where the sociomaterial structures that are developed with the help of actors from the field of geomatics can have impacts on the daily lives of millions of people. As pointed out in the foregoing chapter, in the pragmatic view technologies are always both problem solving and problem creating and the quest to define what the problem consist in and what qualify as a proper solution - whether based on geomatics technologies or not - is necessarily bound to be a socially biased power struggle between different stake holders and interest groups.

2.3 Geomatics as a Business Field

In parallel with these sociotechnical and techno-scientific aspects, we have the closely related emergence of what is now a fast-growing economic sector (Curry 1998). Geomatics technology has, as Pickles (1995c: 20) points out, “from its early days, been big business. Currently it is huge business, and the scale and scope of this business is not hidden in the marketplace”. This means that it is important to see geomatics “as a tool and an approach to geographical information within wider transformations of capitalism in the late 20th century […] and as a way of organizing more efficient systems of production” (Pickles 1995b: viii). This calls for seeing geomatics not only in a business and natural science perspective but also in a political economic perspective.

In their day-to-day operations, organisations of all sorts use and process large amounts of geodata. The information they derive from those data becomes one of the main components of their operational and financial outcomes. The great majority of these data are spatial in nature, that is, they refer to a particular geographic point or sector. The needs among organisations to acquire, manage and process geographic information are among the factors fuelling the growth of the geomatics industry. Other causes could be the comparative recency of geomatics, its rapid development, its problem solving ability and its commercial orientation. All in all there is a mix of factors that deserve closer critical scrutiny in a more detailed industrial analysis of the geomatics business.

During the latter years, the geomatics industry has been characterised by several trends (Clarke 1997). There have been rapid changes in technologies. Higher performance, lower priced product types have emerged. There has been more intense price and performance competition. Product cycles have been shortened. Software standards that make customers less dependent on specific hardware and software have evolved. Thus, it is acknowledged that geomatics have a large commercial potential and can contribute to solving socioeconomic and environmental problems.

However, it is important to be critical of the claims made by both suppliers and users of geomatics and ask questions about whose problems are identified, how they are solved, what the consequences are and who is paying. Approaching such issues critically takes us in the direction of identifying "a wider context of the processes of the production, representation, and dissemination of information within which" the practical processes of developing and using geomatics operate (Pickles 1995c: 23). The big business aspect of geomatics is important to bear in mind when systems suppliers are seen as potentially powerful actors in processes of city building through their involvement in transforming urban infrastructural spaces.

2.4 Geomatics as an Infrastructural Field

The last aspect of the field of geomatics dealt with here is less prominently featured in presentations of and debates on geomatics. However, field of geomatics can be seen to have an *infrastructure* dimension that relates to the fact that much information refers to specific places. Geographic information or spatial data is increasingly seen as an important resource for surveillance, control and management of society in ways that are more efficient than before (Graham 1999a). Management of networked infrastructures with geomatics-based tools presupposes that the spatial dimension of the infrastructures has been digitised. Thus, providers of geomatics systems have a clear interest in making urban networks subject to the increasing construction of geographic information infrastructures.

In acknowledgement of these possibilities, the development of Geographic Information Infrastructures (GII) or Spatial Data Infrastructures (SDI) - usually as part of more encompassing National Information Infrastructures (NII) - has entered the political agenda in many countries in the latter years.[2] Systematic building of such information infrastructures and the international standardisation of geodata are now prioritised tasks for both public and private actors. This is not least because the quality of the geodata infrastructure is very important for the development of new products and services based on spatial data. This means that business and control interests can be seen to converge at the level of national geographic information policy. With reference to policy, Pickles (1995c: 20) point out that since

> "electronic information technologies provide more information and assess across broader spans of space, they are presumed to be technologies that are liberating. Such a mythos of public benefit accruing to the ability to gain access to new and broader forms of data, and to represent this data spatially in a wide array of images, has been instrumental in the adoption of the new telematics within universities, planning agencies, environmental bodies, and the corporate and business world".

Partly through business push and partly through public information policy, geomatics has become an element in the extension of control, surveillance, monitoring and accounting systems, in the delivery of new services and in the support of new needs and responsibilities on the part of public and private agencies (Graham 1999a, Aurigi and Graham 2003). In such a situation, Pickles (ibid.: 22) argue, "it becomes crucial to ask how these technologies impact on the ways in which people interact with one another" in urban and in other social contexts.

[2] See Masser and Salgé (1997) on the European Geographic Information Infrastructure and Tosta and Domaratz (1997) on the US National Spatial Data Infrastructure.

3 THE QUEST TO DEFINE AN EMERGING FIELD

Having introduced the emerging field of geomatics in terms of some critical considerations related to four aspects, I now take a further step towards answering the main research question of this chapter. I do this by way of providing some insight into the quest underlying the issue of *how geomatics are defined*. In order to answer this question, the purpose of this part is to deal with several attempts at conceptualising and defining geomatics and a few related concepts. Since the 1990s, the multi- and interdisciplinary technological and scientific fields constituted by actors producing and using ICT for geographic information handling has been conceptualised in terms of geomatics. However, as pointed out earlier in this chapter as well as in chapter one, the definition of the concept of geomatics is still evolving and it seem to do so more or less confined within a relatively narrow scientific domain. I start by introducing several definitions of geomatics, continue with the concepts of geographic information technology, geographic information science, geocomputation and telegeoprocessing before summing up the discussion.

3.1 Defining Geomatics

In this part, I introduce a set of definitions of geomatics provided by university departments that early on have made efforts at shaping the self-understanding of the field. First, at the Department of Geomatics, University of Newcastle upon Tyne, UK, it is argued that geomatics has been quickly adopted world wide to refer to the variety of subjects that handle spatial data in digital form.[3] Previously, measurements were made in the landscape by surveyors and turned into maps by cartographers; plans of construction was made by engineers; information about pipelines and cables owned by utilities or about people who inhabited a local authority was held in paper records and on maps by clerks and archivists. Today, it is argued, the data is handled using computers, by professionals who are aware of the source, management requirements and possible uses of the data in a variety of contexts. The main point to be noted in this instance is the idea that a diverse set of activities are both transformed and integrated by the use of information and communication technologies.

Second, let us look at a definition provided by two Australian university departments, Spatial Information Science, at the School of Geography and Environmental Studies, University of Tasmania and the Department of Geomatics, University of Melbourne, respectively.[4] They both subscribe to a definition of geomatics as "a multifaceted profession concerned with the measurement, representation, analysis, management, retrieval and display of spatial data concerning both the Earth's physical features and the built environment". According to this view, geomatics has its roots in land surveying but now embraces much wider fields in measurement science and spatial information systems. The principal disciplines include the mapping sciences, land management, geographic information systems, environmental visualisation, geodesy, photogrammetry, remote sensing and surveying. This broad spectre of activities indicates the complexity of the field.

Third, at the Department of Geomatics, University of Melbourne, the practical dimension of geomatics is emphasised.[5] There, it is envisioned that modern geomatics professionals can be employed in a wide range of areas, including computerised mapping; satellite remote sensing for environmental monitoring; precise satellite positioning and navigation for offshore oil exploration; land development and computer based land information systems; cadastral surveying and land management; utility

[3] Web address: www.ncl.ac.ncl.uk/geomatics/geo_expl.html

[4] Web address: info.utas.edu.au/docs/geomatics_exp.html

[5] Web address: www.sli.unimelb.edu.au/about/multifaceted.html

management through geographic information systems; precise surveying for engineering construction; natural resource mapping and management; environmental planning; and industrial measurement using machine and robot vision systems. Thus, in this view, the concept of geomatics is seen to cover a variety of knowledge bases, material artifacts, practices and applications. Moreover, it is possible to see the contours of a technological system organised around the production, diffusion and use of technology for the measurement, representation, analysis, management, retrieval and display of spatial data.

Fourth, turning to the School of Geomatic Engineering, University of New South Wales, Australia, we see that geomatics are defined as

> "the modern scientific term referring to the integrated approach of measurement, analysis, management, storage and display of the descriptions and location of Earth-based data, often termed spatial data. These data come from many sources, including earth orbiting satellites, air and sea-borne sensors and ground based instruments. It is processed and manipulated with state-of-the-art (IT) using computer software and hardware".[6]

In this view, geomatics has applications in all disciplines which depend on spatial data, including environmental studies, planning, engineering, navigation, geology and geophysics, oceanography, land development and tourism. Thus, geomatics are seen as a basic component of the geoscience disciplines that use spatially related data.

Fifth, in the same vein, at the Department of Geodesy and Geomatics Engineering, University of New Brunswick, Canada, the discipline of Geomatics Engineering is seen to deal with "the practical, expert application of the sciences and technologies involved in acquiring, processing, integrating and portraying geographical information".[7] Here too, they consider geomatics to include a wide range of activities, from the acquisition and inquiry into site-specific spatial data in engineering and development surveys to the application of GIS and remote sensing technologies in environmental management. It includes cadastral surveying, hydrographic surveying, ocean mapping and is important within land administration and land use management.

In Norway, the situation in 1999 was that the widespread emergence of the concept of geomatics had not diffused much into the private business sector. However, the leading academic actors have acknowledged the term, namely Department of Mapping Sciences at the Norwegian Agricultural University (Revhaug 1998)[8] and Department of Surveying and Mapping at the Norwegian University of Science and Technology (Midtbø 1998).[9] In 1997, a committee suggested that the latter department should be restructured in order to offer geomatics as a line of study. This could also lead to a change in name to Department of Geomatics. The definition of geomatics underlying the work of this group resembles the definitions already introduced. Thus, the possible restructuring of the department follows the international trend. Whether this is done, however, is an open question subject to discussion at the Norwegian University of Science and Technology.

Having introduced a set of definitions of geomatics, a more detailed account of what the concept of geomatics contains is now due. First, however, I turn to a few other concepts that have emerged in recent years that further illustrate the range of activities of contemporary spatial sciences.

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[6] Web address: www.gmat.unsw.edu.au/whatis.html

[7] Web address: www.unb.ca/GGE/WhoAreWe/WhoAreWe.html

[8] Web address: www.nlh.no/geomatikk

[9] Web address: www.geomatikk.ntnu.no/

3.2 Related Concepts

In parallel with the emergence and diffusion of the notion of geomatics as a defining term for the technological and scientific fields discussed here, the concept of *geocomputation* has also emerged. Within the School of Geography at the University of Leeds, UK, The Centre for Computational Geography (CCG) has grown up as, in their own words, "a major new development".[10] The new centre aims to apply new computing techniques and resources to the solution of geographical problems whose magnitude and/or complexity have previously prevented much progress being made.

The CCG intends to exploit developments in High Performance Computing (HPC) to evolve existing and develop new computationally intensive approaches in the practice of geography. According to CCG, geocomputation represents the convergence of the disciplines of computer science, geography, geomatics, information science, mathematics and statistics. As we can see from this conception, geo-computation covers more disciplines than geomatics in that geomatics itself are included in the definition of this concept. Central within geocomputation is work on emergent computer-based tools and their application to spatial computation.

Areas of interest within geocomputation include: artificial intelligence (expert systems, neural and fuzzy modelling); fractals and chaos; visualisation, virtual reality and multimedia; process based modelling; developing distributed computing environments for geographical data processing; quality control techniques for data and models; exploratory data analysis and data mining; integration of geographical tools and techniques, particularly those requiring high performance computing; macro-modelling, micro-modelling and scaling; advances in Geographical Information Systems, particularly in the area of spatial analysis; cellular automata; statistical modelling (predictive and descriptive).

An additional concept that has come into use since 1998/99 is *telegeoprocessing*. This concept covers an area that emerges from the cross-fertilisation between Geographic Information Systems (GIS) and telecommunications technologies. Telegeoprocessing is seen as a new discipline based on real time spatial databases that are updated regularly by means of telecommunications systems in order to support online decision-making. Central within this area are solutions based on Global Positioning Systems (GPS) and all other technologies for sending data from sensors to GIS systems by means of wireless communications.

Main issues of focus among researchers in the discipline are; real time GIS, especially based on GPS; real time spatial data structures; real time graphics semiology; online Spatial Decision Support Systems; CASE tools for telegeoprocessing; visual languages and user interfaces; active hypermaps; sensors and radio-communications; multi-source fusion especially for updating; parallel and distributed GIS; interoperability in telegeoprocessing; geographic data interchange standards; GIS and internet working; visualisation and synoptics design; animated cartography; GIS and groupware; client-server architecture for GIS; distributed spatial objects; spatial knowledge engineering; and systems for spatial reasoning. Among novel applications of telegeoprocessing technology, much attention has been paid to domains such as urban planning; environmental planning; risk prevention; traffic management; fleet management; and geological information systems. Thus, the area covered by the term telegeoprocessing is rather comprehensive in terms of the knowledge bases drawn upon, the material artifacts used, the practices pursued and the fields of application.

Activities related to geographic information systems (GIS) have raised important issues for many disciplines. Goodchild (1992) takes this as a point of departure for developing a concept similar to

[10] Web address: www.ccg.leeds.ac.uk/

geomatics and argues that these issues have done much to remove the traditional isolation between photogrammetry, remote sensing, geodesy, cartography, surveying, and geography. To this list could be added computer science, operations research, spatial statistics, cognitive science, behavioural psychology and other disciplines with interests in the generic issues of spatial data.

Goodchild (1992) argues that these disciplines constitute *geographic information science* and that it makes more sense for the research community to decode the GIS acronym in this way, focusing on the fundamental issues of spatial data, rather than on the limited solutions offered by today's geographic information *system* products. As we can see from this conception, at the core of geographic information science we find the same disciplines as in geomatics. But in his elaboration of the term, Goodchild stays much closer to GIS (geographic information system) issues than is the case for geomatics, which is a broader concept.

According to Goodchild (1992), GIS as a scientific field is first and most clearly defined by geographic information. Here, *information* is taken broadly to encompass facts, data, knowledge and understanding, and *geographic* implies a specific tie to locations on the earth's surface. He defines the field of geographic information science as "the generic issues that surround the use of GIS technology, impede its successful implementation, or emerge from an understanding of its potential capabilities" (Goodchild 1992: 31).

Among the factors supporting the existence of a scientific field of geographic information are; the uniqueness of geographic data; a distinct set of pertinent research questions that can only be asked geographically; the commonality of interest in GIS meetings; the emergence of institutional infrastructures and communities for GIS; and a supply of books and journals. Among factors that could inhibit the field, Goodchild has noted the following; the level of interest depends on innovation; it is hard to sustain a multidisciplinary (rather than interdisciplinary) science; the core of the science - geography - is a social science tradition that has to some extent an antipathy to technological approaches (Goodchild 1992).[11] Further, Goodchild (1997: 591) has developed what he calls

> "a vision of the core of the field [consisting of] the study of geographic concepts; their role in human cognition; their formal representation in formal databases; their use in modelling, prediction and decision-making; the issues of the management and use of such databases; and their impact on society".

He has also noted that geographic information science involves both inquiries *using* GIS and inquiry *into* various issues of GIS. The first category refers to the vast range of applications of GIS. The latter category could be further divided in two kinds of activities, containing, on the one hand, technically oriented research to develop GIS and, on the other hand, inquiry into the use, and the contexts and implications of the use of GIS. This last category would include inquiries focusing on the two other categories, and as such, it is a kind of meta-research, reflecting on the day-to-day activity of GIS communities.

Typically falling within these *soft* areas are issues like, for instance, geographic data infrastructure and national information policy; GIS innovation, diffusion and implementation; business studies; and geographic information services. Concerning these areas, one observer thinks that "it is worth pointing out that to date the pool of researchers investigating these issues is relatively small compared with the technical or application-driven areas" (Craglia 1997: 2). As the community of inquiry has evolved,

[11] In a sense it is peculiar that Goodchild (1992) point out geography (as social science) as the core of a science of geographic information since the development of geomatics technologies has mainly been the domain of the mapping business and related technical fields. One should also remember Curry's (1998) claim that geomatics seem to have been of little interest to geographers.

there has been a marked shift in emphasis from technical issues towards economical, social, cultural, political and institutional issues, as exemplified by, for instance, the theoretical discussion of managing geographic information systems in Obermeyer and Pinto (1994). Thus, research within geographic information science has adopted a sociotechnical perspective more in line with the one used here. The primary driving force in this direction is the evolution of ever more application fields for geomatics. This has made geomatics a multi-billion dollar business. However, a necessary requirement for this development is the co-evolution of geographic information infrastructures.

3.3 Summing up

As a step towards answering the main research question of *what geomatics are*, the purpose of this part has been to deal with several attempts at defining geomatics and a few related concepts. This account has showed that there is a wide variety of definitions and conceptions of a scientific and technological field that, through the application of ICT, has not only been transformed but has also seen the emergence of completely new scientific fields. In order to sum up on the issue of defining geomatics, then, I turn to one of the first uses of the concept and a few arguments for why it came into use. In 1992, the Canadian Institute of Surveying and Mapping (CISM) became the *Canadian Institute of Geomatics (CIG)*. At the same time, the name of the Institute's quarterly publication was changed from CISM Journal ACSGC (formerly The Canadian Surveyor) to *Geomatica*. The official definition of geomatics by the Canadian Institute of Geomatics is the following:

> "Geomatics is a field of activities which, using a systemic approach, integrates all the means used to acquire and manage spatial data required as part of scientific, administrative, legal and technical operations involved in the process of the production and management of spatial information. These activities include, but are not limited to, cartography, control surveying, engineering surveying, geodesy, hydrography, land information management, land surveying, mining surveying, photogrammetry and remote sensing".[12]

Nichols (1997) argues that the conceptual change from *Surveying and Mapping* to *Geomatics* has been a response to a number of inter-related issues and opportunities.

First, there is a growing awareness that the surveying and mapping profession is in a period of tremendous change. Thus. It has been acknowledged that there is a need to re-examine its role in society (for instance, within environmental management, public administration and information management). Second, there is increased recognition of the impact that information and positioning technologies have on the profession and the need to broaden its role in developing, managing, and applying these technologies in order to expand opportunities for the profession. Third, it represents an opportunity to provide a solid scientific, mathematical and institutional foundation for the management and application of these technologies.

Fourth, it represents an opportunity to reach a wider audience, recognising that the users and applications of the technologies are important to, and often part of, the changing profession. Thus, it is acknowledged that surveying and mapping are part of the knowledge industries of the future and that these industries, accordingly, cannot be defined by conventional disciplinary boundaries. Fifth, it represents an opportunity to examine and improve educational programs better to prepare students for a dynamic and rewarding career.

These interrelated issues and opportunities are acknowledged among a growing number of the individuals, university departments, research institutes, public agencies and business organisations constituting the field of geomatics at a variety of local, national and global levels. In combination with

[12] Wed address: www.cig-acsg.ca/main/cigframe.html

the definitions reviewed above, these five points can serve as a relevant background to understanding the emergence, diffusion and application of the concept of geomatics at many locations on the map of the field of geomatics. Having provided the first part of the answer to the question of *what geomatics are*, I now need a more detailed account of the scientific and technological components that constitutes the field. I turn to this is the next part.

4 THE COMPONENTS OF GEOMATICS

As a further step towards answering the main research question, I also need to find out *what kinds of components geomatics consists of*. First, I explain how this knowledge has been collected and constructed. Thereafter, ten scientific and technological fields are focused upon. Finally, this part is briefly summed up.

4.1 Introduction

As pointed out in chapter one, the field of geomatics is constituted by both scientific and technological components. In order to answer the above research question, the purpose of this part is to briefly account for these components. Two sources of information have been used to construct this account. First, written material from various presentations of geomatics have been collected from firms and organisations and synthesised into the categories used below.[13] Second, on the basis of this representation of geomatics, the group of 22 persons active within the field of geomatics in Norway were asked what they considered the term geomatics to encompass in terms of *knowledge bases*, *practices* and *material artefacts*.[14] It should be noted that in dealing with this information I have not pursued the full range of a critical discussion of the issue that both these sources of information represent particular views on what science and technology are. The purpose here is to provide an overview and to indicate the multi- and interdisciplinary character of geomatics.

A basic feature encountered here is the multi- and interdisciplinarity that characterise much science and technology. According to the definitions accounted for above, a wide range of different scientific and technological components constitutes the field of geomatics. However, the separation of these components is not an easy task as they in practice are complexly intertwined and overlapping. In general, however, it can be said that these components together constitute a global field of geomatics. Inquiry into this global field can be conducted based on, for instance, MacKenzie and Wajcman's (1985: 3) argument that "the word 'technology' has at least three different layers of meaning". Following this, the components constituting geomatics can be presented in terms of first, their specific knowledge bases; second, their specific practices; and third, their main material artifacts. In general, these three aspects of geomatics science and technology have been shaped under time and place specific sets of conditions within the context where they have developed.

It should be pointed out that to view technology in this way, that is, as constituted by knowledge, practice and material artifacts, is completely in line with the pragmatic conception of technology outlined in chapter 2. Thus, this account of geomatics can be seen as informed by the pragmatic perspective although the full range of the six aspects of the pragmatic conception of technology is not drawn upon in this instance. It should also be noted that each of the sub-fields of geomatics identified here are potentially interesting cases in the tradition of critical social studies of science and technology. A full account of geomatics, then, implies the detailed inquiry into a range of issues in relation to every singe sub-field and activity. I cannot deal with such an extensive task here. A more thorough and critical discussion of this and the above mentioned issue falls outside of the research questions of this inquiry. Instead, I account briefly for the most important technological and scientific sub-fields underlying the activities within the field of geomatics. However, even if the account has to be brief it should useful to refer to the three aspects of technology noted above.

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[13] This material is mainly adapted from internet-based presentations of geomatics and related fields by firms and universities. The above seven www references are the main sources together with the US geomatics firm ESRI (web address: www.esri.com/).

[14] See Appendix 1 for list of people interviewed and Appendix 2 for interview guide.

4.2 Scientific and Technological Components of Geomatics

In this part, the following scientific and technological fields are focused upon: surveying, cartography, geodesy, hydrography and ocean mapping, photogrammetry, remote sensing, global positioning systems (GPS), geographic information systems (GIS), automated mapping/facilities management (AM/FM) and computer science.

4.2.1 Surveying

Concerning the practice of surveying, people have needed to measure and map the world about them since the beginning of recorded history. Ancient Egyptian hieroglyphics describe how priests would measure the fields on the banks of the Nile in order to calculate tax. The profession of surveying grew from this history. Surveying is used to define the extent of land features in small- and large-area databases. A surveyor may be involved in many different activities, something that illustrates the overlap with other fields of geomatics:

- *Cadastral surveyors* are involved in the legal definition of land ownership, boundary definition when land is subdivided, bought or sold and the project management, design and approval processes related to land development.
- *Engineering surveyors* are involved in the development of civil engineering projects such as dams, roads, and other structures. They measure and map the environment before the project being designed and approved and then they control the spatial accuracy of the project during construction.
- *Hydrographic surveyors*, usually associated with Marine Authorities, conduct mapping of sea floors, shipping channels, ports and other marine features.
- *Mine surveyors* are responsible for measuring and controlling mines, tunnels and other underground works.
- *Geodetic surveyors* use special techniques and tools to measure over long distances in order to provide the spatial control needed by cadastral, engineering, hydrographic and mine surveyors. They also provide information used to monitor large-scale phenomena like continental drift and sea level changes.

Thus, actors within the field of surveying are involved in a range of problem-solving activities throughout society.

Concerning the knowledge bases of surveying, it is a branch of applied mathematics that provides techniques and tools for determining the area of any portion of the earth's surface, the lengths and directions of the bounding lines, the contour of the surface and accurate delineation of the whole on paper.

Concerning the material artefacts used in the practice of surveying, to begin with actors used tools and instruments that were simple, laborious and not very precise. However, as technology advanced, the art and science of spatial measurement developed and now today's surveyors have at their disposal a wide range of instruments, tools, techniques and mathematical methods which they can use to measure, model and map objects ranging in size from the head of a pin to the whole earth. The technology includes, for instance, satellite positioning equipment (GPS), electronic theodolites and geographic information systems (GIS) together with computers to produce maps, plans and digital models of the physical world.

4.2.2 Cartography

Regarding the practice of cartography, it is concerned with the design and production of maps and in many ways is both an art and a science. A map is an information medium, an artifact for communication. An individual map contains a lot of information that is used in different ways by different individuals and organisations. It represents the means of locating ourselves in relation to the world around us. Maps are thus tools with many possibilities for application; from locating telephone wires under our streets, to displaying the extent of de-forestation in the Brazilian Amazon.

However, the mapped image of natural and social conditions is in a sense defining reality, not simply representing it. The modelled representation is actually an object of power and the constructors of maps are thus powerful, being able to define certain aspects of reality according to their purposes.[15] These purposes are often corporate or organisational rather than personal but are likely to represent the interests of certain groups of actors in society at the expense of others.

The map as an artifact has been in existence in much the same form for thousands of years. In the traditional form, it suffers from a number of problems. Firstly, maps are static and therefore difficult and expensive to keep up to date. This relates to a second problem, in that because they are static they loose flexibility, for instance, maps exist as discrete sheets and inevitably, your area of interest lies on the corner of four adjacent sheets. In addition, maps are often very complex and may require an expert to extract the particular data that are of interest. Equally important, maps are not objective representations of reality, free from value judgements and unaffected by the relationships of power within society. Instead, following a pragmatic understanding of artifacts and also geographers that work with maps as texts and objects in discursive practices, they are selective and value-laden constructed documents that embody the interests and values of particular groups at particular times.

Concerning the knowledge base of cartography, a cartographer must understand the mathematical techniques used to represent a solid spherical Earth on the flat surface of a map sheet. When designing a map, the cartographer must know how to use symbols to make complex spatial relationships clear and unambiguous. Further, the cartographer requires a detailed knowledge of the technical processes used to prepare a graphic design for printing.

Concerning the material artifacts used in the practice of cartography, it can be noted that traditionally the map was - and still is - an analogue, paper-based medium, produced with optical and mechanical instruments. In the late 1960s and early 1970s, software and hardware for automated map production was introduced although the products remained analogue and paper-based. This meant that the traditional knowledge base of the mapping craft had to be supplemented by ICT-based competence. From around 1970 there has been increasing interest in the mapping business for the potentials that ICT represents both as production technology for geodata, for design of products and for utilising the information by a variety of users.

By the 1980s, digital production of maps became the standard and today all map-production is automated and digitally based. Moreover, the material products of cartography are both analogue (paper, foil) and digital. Today, the knowledge base of geomatics-related activities is probably more dominated by ICT-based competence than by traditional knowledge of the mapping craft. Thus, for the last twenty years the industry of producing maps as an information and communication medium has gone through a transformation from analogue to digital processes and products.

[15] The constructors of maps operate within discourses that are more or less conscious of their power and influence on the construction of representations of the 'real' world.

4.2.3 Geodesy

Geodesy is concerned with the study of the size and shape of the Earth and its gravity field together with the variation of these features over time. Areas of study that require geodesy cover global problems such as monitoring vertical and horizontal movements of the earth, measuring change in sea level due to, for instance, the greenhouse effect, measuring variations in the rotation axis and rate of rotation of the Earth, to more local problems such as measuring the movements of bridges and the real-time alignment of roads and railway tracks. In their practice, geodetic surveyors use special techniques and technologies to measure over long distances. Their work is used to provide the spatial control needed by cadastral, engineering, hydrographic and mine surveyors. They also provide information used by scientists to monitor large-scale phenomena such as continental drift and sea level changes.

Moreover, geodesy frequently is used in geographic information management technology to establish a foundation in the form of base maps for other spatial data. Concerning its knowledge base, geodesy is a branch of applied mathematics that observes and measures the shape and size of the earth or a large part of its surface and the exact location of points on its surface. Today many of the fundamentals of geodesy are accomplished using advanced spatial technology such as the Global Positioning System GPS), Satellite Laser Ranging (SLR) and Very Long Baseline Interferometry (VLBI). These techniques are capable of measuring distances of some thousands of kilometres to a few millimetres accuracy.

4.2.4 Hydrography and Ocean Mapping

Based on the material collected, hydrography can be seen as the science of measuring and depicting those parameters necessary to describe the precise nature and configuration of the seabed, its geographical relationship to the landmass and the characteristics and dynamics of the sea. These parameters include bathymetry, tides, currents, waves, physical properties of seawater, geology and geophysics. The activity of doing hydrographic surveys with detailed exploration of water and waterside areas can include the following: water area depth mapping; waterside area altitude mapping; hydroacoustic profiling; inspecting underwater pipelines; searching for natural or artificial objects on the bottom; analysing water sediments; searching for objects within water sediment; hydrologic investigations; diving inspections; and photo/ video underwater shooting.

The primary use of the data collected and produced in this field is to compile marine charts and other graphic documents to facilitate and ensure safety of navigation for mariners in all the seas of the world and for use by others concerned with the marine environment such as ocean engineers, oceanographers, marine biologists and environmental scientists. Among the most important applications of hydrographic knowledge is its use in the planning of exploration and exploitation of marine resources, the determination of seaward limits of national jurisdiction and the delimitation of maritime boundaries.

Concerning the knowledge base and technology of hydrography, it draws on much the same as surveying, cartography and geodesy with the added challenge of doing surveying and mapping under water. Computer hardware and software for underwater mapping is a growing niche within the geomatics product spectre. In addition, navigation technology is important in order to stabilise surveying equipment installed in vessels.

4.2.5 Photogrammetry

Photogrammetry is the science of obtaining reliable measurements and maps from photographs. Just as with remote sensing, it is used whenever there is a need to measure an object or environment without contacting it. Thus, photogrammetry is often considered a special type of remote sensing. Sometimes the photographs are taken using very expensive, accurate and large film cameras mounted in aircraft; sometimes they are taken using inexpensive hand held cameras. Nowadays, digital cameras are often used instead of film cameras. Photogrammetry is also used to measure large structures such as dams, moving objects such as manufactured parts on a production line or objects that are in dangerous or inaccessible environments such as the deeply submerged parts of an offshore oil platform.

Moreover, just as with geodesy, photogrammetry frequently is used in geographic information management technology to establish foundations, like base maps, for other spatial data. Photogrammetric mapping techniques, which can produce a high level of accuracy based on survey control, are used commonly to gather the raw data needed to create base maps. Aerial photography is a mainstay in this science and improvements in material artifacts like camera types, lenses, film types and emulsions allows both higher flights and the production of photographs with better resolution, more precision and lower cost.

4.2.6 Remote Sensing

Remote sensing is a discipline that has evolved from photogrammetry. The practice of this field is to obtain information about an object or physical environment using data that has been acquired with technology that is not in contact with the object or environment. When information is needed about large parts of the Earth, aerial or space photographs, electronic scanners or sensors mounted on space satellites are often used. Sometimes these sensors are passive, that is, they receive and store signals that are being reflected or transmitted naturally from the Earth. Sometimes the sensors are active, that is, they emit a signal, such as for instance radar signals, which is then reflected back from the Earth and recorded.

The data produced are often represented as images that must be mathematically processed in order to turn the raw data into useful information. In the last two decades, actors within remote sensing have increasingly made use of digital technologies for collecting and processing spatial data. Moreover, the use of remotely sensed data acquired from satellites has also increased. Satellite remote sensing is used for many different applications, including three-dimensional mapping of land and sea surfaces, mapping of different types of land use and measurement and analysis of the health of natural and agricultural vegetation. Satellite images often also provide an important layer of data in geographic information systems.

4.2.7 Global Positioning Systems (GPS)

Over the past twenty years, knowledge of the shape of the earth has improved as a result of space programs and the development of earth satellites. One such program termed NAVSTAR - a military satellite system to support naval and aerial navigation - has contributed substantially to civilian geodetic surveying. The civilian application of this technology - known as the Global Positioning System (GPS) - uses a series or constellation of satellites of known position and earth-based satellite sensors or tracking devices. By simultaneously recording the position of multiple satellites by multiple sensors, computations can yield very accurate (within five centimetres) locational information for each sensor. By locating or moving the sensors throughout an area, a network of geographic coordinates can be established to support geodesy, surveying and photogrammetric mapping.

The Global Positioning System is used by geodetic surveyors to measure long distances, by hydrographic surveyors to map the position of boats at sea, by mining surveyors to map mining lease boundaries and its use by surveyors for cadastral and engineering applications are also increasing. Photogrammetrists use GPS on board aircrafts to measure the position of the aerial camera when acquiring photographs for maps. Moreover, GPS is an important tool for people gathering field data for entry into geographic information systems. Concerning the knowledge base of this field, the science and technology of satellites have established itself among the most prestigious of high-tech research and application over the past twenty years.

4.2.8 Geographic Information Systems (GIS)

Geographic information systems are computer systems capable of assembling, storing, manipulating and displaying geographically referenced information, that is, data identified according to their locations. Practitioners also commonly regard a total GIS as including operating personnel and the data that go into the system. Further, by some GIS is also regarded as the high-tech equivalent of the map. GIS provides the facility to extract the different sets of information from a map (roads, settlements, vegetation, etc.) and uses these as required. This provides great flexibility, allowing a paper map to be quickly produced that exactly meets the needs of the user. However, GIS goes further: because the data are stored on a computer, analysis and modelling of spatially referenced features and phenomena become possible. For example, one might point at two buildings, ask the computer to describe each from an attached database and then to calculate the best route between these.

Information collected in the field by surveyors or from aerial photographs, satellite images or using GPS is usually represented on some type of map. In the past, the printed map was the final product used to analyse the information and to make decisions. Nowadays, maps are stored as layers in a geographic information system. GIS are now being used to support decision-making in many different aspects of modern society, including geology, geophysics, marketing, medical research, land use planning, telecommunications planning, environmental management and so on.

Knowledge of cartography is important to anyone using a geographic information system to manage and analyse data, since decisions are often made based on information presented graphically to the computer screen or plotted onto paper. An ancient skill, cartography has contributed to GIS the general conventions used to produce map products. These general standards include accuracy and precision; map projection and co-ordinate referencing schemes; and the graphic appearance of the map through symbols, linework and annotation. Such cartographic conventions, as they have developed over time, continue to guide the construction of graphic data elements within a GIS database. Knowledgeable cartographers with access to GIS technology enjoy a greatly expanded ability to produce maps that effectively communicate geographic issues and ideas. The role of the cartographer's conventions cannot be ignored in developing GIS map products. Certainly, not every map has to be a work of art, but to be useful and communicative in problem solving, each map must adhere to the general principles of cartography.

4.2.9 Automated Mapping/Facilities Management (AM/FM)

In the utility world - electricity, gas, water, wastewater and telecommunication - the term automated mapping/facilities management describes a particular type of geographic information system that integrates non-graphic facilities management information into a database that is tied to facility maps. In some instances, the AM/FM system also stores the connectivity relationships between facilities, simplifying the creation of utility network models. Map production and facility inventory are among the most common uses of geographic information management technology by actors in the utility world. Utilities also use the technology for engineering, material control and inventory, troubleshooting, planning, construction, order dispatching, maintenance management, emergency response and financial and accounting functions. As main users of this type of technology, actors in the utility sector have been active in the development of GIS technologies since the mid-1970s.

4.2.10 Computer and Communications Science

Computer science provides the technologies for data capture, manipulation, storage and output. As such, the field of computer science encompasses hardware, machine processing capabilities, software development and computer programming languages. In the last several years, the technology has become better suited to the specific needs of geomatics. Processors are faster, the cost of processing is lower and the capabilities of the graphic devices are substantially improved. Better performance results from faster and higher-capacity storage media, higher-level query and programming languages and the incorporation of standards in operating systems and data communications. Organisations now can maintain large data bases in part because designs for both graphic and non-graphic data bases are more sophisticated, making access to large volumes of data easier, faster and less expensive.

As computer science progresses in its ability to code the logical and mathematical relationships that govern the processes used to associate and manipulate data, actors within geomatics software development are incorporating those improvements. Moreover, geomatics software and hardware developers have adopted specialized structures for managing non-graphic data. Confronted with databases of enormous size, computer scientists have developed approaches to data organisation such as quad tree structures to index and store data more efficiently. Other structures, such as network and relational databases, handle large arrays of data, building and retaining connectivity and relationships between data sets. Data-base management systems (DBMS) specialise in the storage and management of all types of data including geographic data. DBMSs are optimised to store and retrieve data and many GIS rely on them for this purpose. However, they do not have the analytic and visualisation tools common to GIS. In addition, data storage costs have fallen sharply and with the maturation of optical disk technology storage is probably becoming even less costly.

Advances in data communication and networking have expanded the flexibility of computer technology by moving away from centralised, mainframe configurations toward more distribution of processing power and data. Hardware advances have increased computer performance while reducing the size and dependency on strict environmental controls. Software developments have enabled complex networks using sophisticated communication protocols to transfer large volumes of data and, at the same time, provide the necessary error recovery and security demanded of computer networks. Continuing advances in data communication media have allowed greater flexibility in network configurations. High-speed, local-area networks and advances in remote communications techniques, such as digital telephone systems, microwave and satellite communications offer many options for creating computer networks. These changes also influence the practice and development of geomatics.

4.3 Summing up

The purpose of this part has been to establish knowledge of *what kinds of components geomatics consist of*. The answer to this question has been conceptualised in terms of three different layers of meaning of the concept of technology that applies to the sub-fields constituting geomatics, namely their specific knowledge bases; the practices within the sub-fields; and the main material artifacts.

Concerning the specific *knowledge bases* that constitute the field of geomatics, a truly multidisciplinary picture has been painted. Geomatics practitioners draw on a range of different scientific disciplines that all have in common the centrality of geo-referenced data and information in their production of scientific knowledge. Much of this knowledge production seems to be motivated by various control, surveillance, analysis and management purposes (Graham 1999a).

Concerning the *practices* that constitute the field of geomatics, the practitioners within the field span a broad spectrum of activities, many of which contribute to making geomatics what could be termed a science of action. This refers to the many tasks, often related to the collection of geo-referenced data, which has traditionally been fulfilled outdoors. In general, the processing of geodata seems to structure much of the activities within the field.

Concerning the *material artifacts* that constitute geomatics, these are all part of the complex processes of producing geo-referenced data and information. Whether stand-alone devices for surveying or integrated systems for satellite-based remote-sensing, the material artefacts are means of production in the processes of creating the data and information that is an input to the many control, surveillance, analysis and management tasks that engage the scientific and business practitioners within the field of geomatics.

Having provided the second part of the answer to the question of *what geomatics are*, I now need to establish a more detailed account of the various uses to which the geomatics knowledge, practice and material components just accounted for are put. In this way, I can also begin to address the question of *what role geomatics can play in transformations within urban infrastructural spaces*. I turn to this next.

5 THE APPLICATION FIELDS OF GEOMATICS

In order to answer the research question of *what purposes geomatics are used for* the aim of this part is to briefly outline the most important of the application fields. Focusing on this aspect of geomatics shows that a wide range of different actors across a variety of disciplines are involved. Moreover, geomatics technologies have extended the analogue, paper-based mapping functions it builds on to encompass new roles. Because of the wide range of application fields and the rapid development within this technology area, this part does not pretend to provide the ultimate overview of every possible task to which geomatics may be put. More modestly, the purposes are first, to provide enough material to contribute to answering the research question of this chapter and second, to provide relevant material that can serve as a background for the subsequent case studies.[16] Here, I briefly introduce the application of geomatics to natural, built and socioeconomic environments.

5.1 Introducing the Practical Use of Geomatics

With the introduction of digital technologies, the application areas of geomatics have been extended from static geographic and topographical data to dynamic built infrastructures and socioeconomic systems. At the same time, geomatics technologies upgrade the original mapping function to adapt it to the real-time needs implicit in mapping such changing systems. In addition, geomatics technologies adds to the descriptive mapping role other roles, such as system-monitoring and diagnostics functions which can tell how these systems are working and system-optimising functions which can suggest how to improve utilisation of system capacity etc. (Bernhardsen 1992). In the following I outline how geomatics can be applied to three main areas, following a functional distinction.

For a variety of reasons, including the specific application interests of early systems designers, the majority of geomatics technologies have been targeted at the processing of data relating to the physical environment, both natural and built. The natural environment application field represents some of the largest and longest established geomatics technology installations and probably represents the most common use of geomatics technologies today. The ability to conceptualise and measure the location of physical objects (for instance, roads, rails, buildings, rivers) according to some common co-ordinate system makes their spatial representation relatively unproblematic. This has led to a substantial commercial market for general-purpose systems, used by utilities, land-use managers, etc. With reference to the spatial dimensions of urban societies outlined in chapter 1, the application fields discussed here correspond more or less to what I have termed urban environmental space, urban physical space and urban infrastructural space.

However, more recently, there has been a substantial growth in the collection and use of geo-referenced data relating to the socioeconomic environment. Increasingly, accurate geo-demographic information is considered to be of considerable commercial value to a wide range of organisations. However, phenomena relating to people (for instance, unemployment and deprivation) are inherently more difficult to represent spatially, as it is not usually possible to define precise locations.[17] Geo-referencing is therefore frequently indirect and compatible, via geographic codes such as census areas or postcodes, although new data products are appearing which offer property-level geo-referencing.

[16] This overview is based on the same sources of information as in part 3.4. above.

[17] At least this is the case when applying a Euclidian conception of space as *absolute* or *relative*, as pointed out above. Again, this touches upon the complex issue of different spatial conceptions at work within fields that all claim to work with geographic information and representations of space and spatial relations. However, the issue of what conceptions of space that underpins the application of geomatics solutions within various fields lies beyond the confines of this inquiry.

This extension in application areas is accompanied by a diversification of the mapping role to involve a management function both in the natural and built environments. With reference to the spatial dimensions of urban societies just mentioned, the application fields discussed in connection to socioeconomic environments correspond more or less to what I have termed urban economic space, urban social and cultural space and urban political space. The resulting three broad categories of application fields, which overlap in various ways, are presented in table 1. Each of the three fields is focused upon in a little more detail below.[18]

Table 1. The Main Fields of Geomatics Applications

NATURAL ENVIRONMENTS	BUILT ENVIRONMENTS	SOCIOECONOMIC ENVIRONMENTS
Environmental services	Water and sewage utilities	Research and higher education
Forestry and land management services	Electricity and gas utilities	Wholesale and retail services
Agricultural services	Telecommunications services	Real estate services
Hydrography and ocean mapping	Transport and logistics services	Finance and insurance services
	The offshore oil industry	Mapping and geomatics services
	Defence services	Health and medical services

5.2 Geomatics Applied to Natural Environments

First, I take a brief look at geomatics applied within urban environmental space. In general, the application of geomatics technologies to natural resources entails less complicated mapping and diagnostic functions, involving systems that typically do not change rapidly. The most important fields included in the natural environments-category of applications are, inter alia; activities related to hydrography and ocean mapping; services connected to general environmental resources, forestry and land management and a range of more specifically agricultural services. Environmental services were one of the first areas of application for geomatics technologies, dating back to the late 1960s in Canada and the US (Marble 1990). Today, electronic networks based on geomatics play an important role in "the development of new capacities for collecting, analysing and distributing information on environmental conditions, remotely and in real time" (Marvin 1997: 192-3).

One early case was the Canada Geographic Information System (CGIS), begun in 1964, initially to handle information on agriculture, forestry, recreation, land use, watersheds, shorelines and census and administrative boundaries gathered by the Canada Land Inventory (CLI). Another early system concerned with environmental monitoring and land use was the Image Based Information System (IBIS) developed at the California Institute of Technology in the mid-1970s. A third case is the Global Resource Information Database (GRID), established by United Nations Environmental Program (UNEP) in 1985, as part of an overall effort to collect, manipulate and promulgate global environmental and natural resource data. This work - organised in eleven nodes distributed globally, with one in Arendal, Norway - is based on GIS, remote sensing, image processing and telematics (Bernhardsen 1992).

Within the field of forestry and land management, for instance, public and private foresters and land managers can be made more effective by providing them with methods and solutions based on geomatics. Relevant application fields are forest resource planning and history; land management

[18] Tables A1, A2, A3 and A4 in Appendix 3 provide more details of the application fields outlined in the next five parts.

planning and history; integration with rules-based systems; integration with relational database management systems.

5.3 Geomatics Applied to Built Environments

The second major area of application of geomatics is the built environment. It is within this application field we can begin to look for answers to the question of *what role geomatics can play in transformations within urban infrastructural spaces*. Moreover, this area of application also covers the constructions, installations and material structures that constitute urban physical spaces. In this context, a very large number of municipal tasks may be identified. The service functions connected to the dynamic infrastructures in this category involve a growing area of application for geomatics technology. Services connected especially to the broader dynamic telecom industry illustrate the ability of geomatics technology suppliers to adapt to the complicated demands of rapidly changing dynamic systems.

In areas such as telecom and transport logistics, it has become important that the mapping, monitoring, surveillance and control features prominent in the above application fields be extended to provide functions that can pinpoint system errors in infrastructure networks, diagnose these and prescribe remedies as well. This level of complication in turn heightens the need for greater collaboration between the geomatics suppliers and its users in development, training and maintenance. Included in the built environments-category of application fields are, inter alia; energy grids, transport systems, telecom nets and water and sewage networks.

5.4 Geomatics Applied to Socioeconomic Environments

Third, I take a brief look at geomatics applied within urban economic, socio-cultural and political spaces. This final category for geomatics technology-based applications involves more socially based networks, such as those connecting financial services and supporting health services. With the exception of higher education and health, which are mostly public services, this field of application is more relevant for private service providers, for instance in the fields of home teleservices, retail services, services connected to real-estate, financial services and services related to mapping and geodata. The geomatics applications in this category involve tools for planning and analysis within distributed systems of information relating to, for instance, insurance and retail markets (Birkin et al. 1996).

One common feature of the three main application fields outlined is their extensive pertinence to public and semi-public services. There are strong links to national (for instance, defence, education), regional (for instance, electricity, forestry) and municipal (for instance, water, waste) services. Included here are the public utilities that are based on networked infrastructures, such as waterworks, telecommunications and energy. A facet that reflects Norwegian conditions is the inclusion of the offshore oil industry, which is driven to a large degree by state-owned conglomerates. Local and regional governments are active users of geomatics technologies in a range of areas that bridge the three application fields, thus making them the largest single user group (Masser and Craglia 1997). Moreover, there is increased electronic interaction in the purchase and delivery of public services observed, for instance, in the trend towards virtual cities (Aurigi and Graham 2003).[19]

[19] The application fields could also be dealt with in terms of spatial scales or territorial boundaries, illustrated by the treatment of a range of applications *across* the three dimensions introduced here, within what Huxhold (1991) and Laterasse and Pauchard (1995), for instance, terms urban geographic information systems. A more general term in this connection is *urban and regional information systems*, a phenomenon that has initiated the Urban and Regional Information System Association (URISA). The two application fields focused upon here

5.5 Summing up

As a further step towards answering the main research question, the purpose of this part has been to establish knowledge of *what purposes geomatics are used for*. The answer to this question has been conceptualised in terms of three different environments to which geomatics are applied. Covering the domains of natural, built and socioeconomic environments, a wide range of practical uses of geomatics has been mapped. Even without aspiring to be anywhere near complete, it seems that most tasks related to the activities and practices within the various fields can be supported with some type of geomatics application. This could be partly due to the fact noted above that large portions of the data and information so central to the activities across the three user environments are geo-referenced in some sense.

There has been no space to go into any detailed assessment of the uses to which geomatics technologies are put except for a brief outlining of the fields of utilities and transport. Through highlighting these two fields within the built environments domain, I have provided the first elements of a partial answer to the research question of *what role geomatics can play in transformations of urban infrastructural spaces*. However, if a more detailed analysis and assessment were to be undertaken, the critical considerations made in part 3.2. would certainly apply.

Critical questions arise concerning who's problems are solved within the different fields, who's interests are represented, who benefits from the various types of uses, how the activities impact on the daily lives of citizens, who is financing the different activities, etc. In light of the big business aspects of the field of geomatics and the large costs involved in acquiring and using geomatics systems it seems that those already in powerful positions have an advantage over those in less powerful positions even if the potential usefulness of geomatics to these latter groups could be just as significant, like, for instance environmental activists and community groups. Having provided the third and last part of the answers to the question of *what geomatics are*, I can now sum up the overall results of the inquiries.

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and the two case studies conducted can thus be seen as cases of such urban and regional information systems.

6 SUMMING UP ON THE FIELD OF GEOMATICS

In chapter 1, I pointed out how two types of technological systems - telematics/geomatics and networked urban infrastructures - are involved in three complexly interrelated processes of transformation and convergence within urban infrastructural spaces. In this chapter - corresponding to the main part of the first phase of pragmatic inquiry - I have introduced the technological field of geomatics and thereby taken the first step in introducing this potentially transformative technology into urban infrastructural spaces. The purpose of this chapter has been to investigate in a more systematic and conceptual way the research questions of *what geomatics are* and *what role it can play in transformations of urban infrastructural spaces*. This has been a necessary step towards answering the overall research question of the dissertation. More specifically, I have treated the question of what geomatics are in terms of three issues: first, how it is defined; second, what components it consists of; and third, for what purposes it is used.

By drawing on the critical perspective of Pickles (1995a, 1995b, 1995c), I first introduced the technological field of geomatics. I think that an important lesson from this perspective concerning the treatment of geomatics is that the

> “discourses of 'social progress', 'technical advance', and 'the postmodern condition' must be situated within an analysis of the networks of power and systems of practice within which such discourses operate (and which they in turn partially constitute). If we are to make any claims about new technical capacities, users, and limitations, we need to be clear about the different ways in which technologies affect specific groups and regions, reconfigure social relations, and increase the potential for the exploitation of some for the benefit of others” (Pickles 1995b: xii).

Such issues are not the usual stuff of the presentations and discussion of geomatics in much of the available literature. There is an overly technical and instrumental bias to much that is written about geomatics and more sanguine treatments are in its place, not least within research that endeavour to understand social production of urban space, spatial transformation and changes in socio-spatial relations. In this instance, Pickles (1995c: 25) has argued that the emergence of geomatics

> “as both a disciplinary practice and a socially embedded technology represents an important change in the way in which the geographical is being conceptualised, represented, and materialised in the built environment”.

Through pursuing the three questions of this chapter, I have started to explore why and how geomatics are involved in these new ways of conceptualising, representing and materialising the geographical in the built environment, especially within utilities and transport infrastructures. The investigation shows that geomatics are “both a system for information processing and for the creation and manipulation of spatial images” and that it is “a technology which is diffusing rapidly through the apparatuses of the state and the organs of business” (ibid.).

By introducing geomatics at this stage of the inquiry, knowledge of *what geomatics are* has been established. This knowledge is integrated in the subsequent conceptualisations of urban infrastructure. In this conceptual work, I draw on critical social theory that can contribute to exposing “the ways in which the use of technology and its products reconfigure broader patterns of cultural, economic, or political relations, and how, in so doing, they contribute to the emergence of new geographies” (ibid.). In the next two chapters, then, conceptual inquiries are conducted into the technological networks that constitute urban infrastructural spaces, the ongoing social production and transformation of these networks and the potential role that geomatics can play in such processes.

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