RECENT GLOBAL CHANGS IN GEOMATICS EDUCATION

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ABSTRACT:

Geomatics, composed of the disciplines of geopositioning, mapping and the management of spatially oriented data by means of computers, has recently evolved as a new discipline from the integration of surveys and mapping (geodetic engineering) curricula, merged with the subjects of remote sensing and geographic information systems. Geomatics has become open to value added applications in many other disciplines using spatially referenced data. The paper attempts to trace the historical roots of these developments, and to outline the challenges of the new discipline, as well as the consequences in educational requirements in the global scene. In the Central European Countries (Germany, The Netherlands, Scandinavia, Poland, Czechoslovakia, Austria, Switzerland, Yugoslavia) the need arose for the setup of cadastral administrations and a reorganization of agricultural practices for use of machines. This has led to the introduction of University degree programs in the Surveying and Mapping disciplines in the 1930's. The professional graduates formed a new workforce (in Germany of 8000 alone). Geodesy formed the scientific base of the discipline with application technologies such as surveying, photogrammetry and cartography also covered, as well as land administration and legal subjects. Due to the success of these ventures non European countries such as South Africa, Australia and Canada have also introduced these degree programs in the 1960's. Others like France, Spain, Nigeria, Zimbabwe, Malaysia followed in the 1970's and 1980's. The British and American influenced countries covered the Surveying and Mapping disciplines in graduate programs such as at University College London, and Ohio State University. The graduate programs accepted graduates in Civil Engineering, the natural sciences and geography. The specialization was possible in one field such as geodesy or photogrammetry, but a comprehensive orientation toward surveying and mapping was lacking. Since about 1960 a technological revolution has taken place in surveying and mapping technology: Angular surveys have been augmented by electronic distance measurement, and more recently by satellite positioning. Electronic computers were able to statistically analyse huge measurement sets. Photogrammetry has become an analytical discipline, competing in accuracy with ground surveys. Earth observation by satellites has made remote sensing an indispensable tool. Cartography relying on tedious graphic work has made way to computer graphics. Geographic Information Systems have permitted to organize spatially oriented data in data bases for the management of global, regional and local problems. The need for sustainable development has recently made obvious, that spatially referenced data constitute a needed infrastructure, to which all governments subscribe. Surveying and Mapping curricula have traditionally provided the vision for the provision, updating, management and dissemination of spatially referenced data. However, there is a need to upgrade the curriculum orientation to modern tools and to society's requirements. This is the reason why many programs have changed their name to "geomatics". It is time to rethink the needs, aims and contents of such a program. The paper analyses these in the light of present Central European experiences with a reflection on the requirements in other continents.

1. INTRODUCTION

ISPRS, since its creation in 1910 has been highly successful creating a scientific and professional international organization in the fields of imaging and image analysis. This would not have occurred unless there was a massive practical demand for its services in mapping.

Terrestrial surveys with a much older history have been the fundaments for determining size and shape of the earth, and of establishing country and continent wide reference networks. But only densely populated countries, small in area were able to build an area-coverage of accurate maps by terrestrial plane table surveys. For example, it has taken Germany in the 19th century about 100 years to do this at the scale 1:25 000. It needed the technology of photogrammetry to extend the topographic mapping coverage to the vast continents outside of Europe. This was demonstrated prior to World War II in the USA and in the Soviet Union, which by means of photogrammetry were able to map their huge countries in a 30 year period. Due to the nearly global military involvement during World War II this coverage was extended by photogrammetry to the conflict areas.

With the foundation of the ITC in the 1950's by Willem Schermerhorn in the Netherlands worldwide capacity building for photogrammetric mapping technology could begin, so that the not yet sufficiently mapped parts of the developing continents of Asia, Australia, Latin America and Africa could also be covered by adequate maps by this technology. The ITC now has a total of 15 000 graduates from 165 countries. It has been instrumental in establishing partner institutions in Asia, Latin America, and Africa. Starting from photogrammetry as a subject its emphasis has gradually changed to mapping applications. ISPRS has benefited from these established networks in expanding its influence from originally Europe and North America to the entire globe.

While aerial photographic interpretation became an important link between photogrammetry as a primary discipline for mapping to a great number of disciplines to collect thematic content, it was satellite imaging, starting with the American Landsat program in 1972, which integrated the multidisciplinary uses of remote sensing with those of photogrammetric mapping. There was once the danger, that satellite remote sensing operating with low resolution satellite sensors could go separate ways from photogrammetry as propagated by the space agencies. But the increased complexity with subsequent higher resolution sensors proved since, that the integration of photogrammetry and remote sensing was a wise move to overcome the various georeferencing problems.

There was yet another integration effort needed. It stemmed from the introduction of computer graphics into map production.

While photogrammetry and remote sensing were principal tools to acquire map content, the management of the data by geographic information systems, the analysis and visualisation of the data today forms an indispensable part of the geoinformation process. It does not make sense anymore to consider topographic and thematic mapping by photogrammetry and remote sensing separate from geographic information systems.
Althemore the tedious and costly local terrestrial survey methods have been augmented and surpassed by GPS positioning using navigational satellites. While formerly the geoinformation process could be separated into individual disciplines, such as surveying, geodesy, photogrammetry, remote sensing, and cartography of the analogue mapping era, different data acquisition methods such as terrestrial GPS-surveys, aerial photogrammetry, satellite photogrammetry, laser scanning, photointerpretation, digital processing of remotely sensed images now compete in quality and cost. Their application must be geared to the respective global, regional or local tasks.
For this reason it is not surprising that "geomatics", "geoinformatics" or "geoinformation" emerged as a new integrated academic discipline. To study the progress of the development is the task of ISPRS Commission VI.

2. WHAT IS GEOMATICS?

The content of what is now considered as "geomatics" is shown in fig. 1.

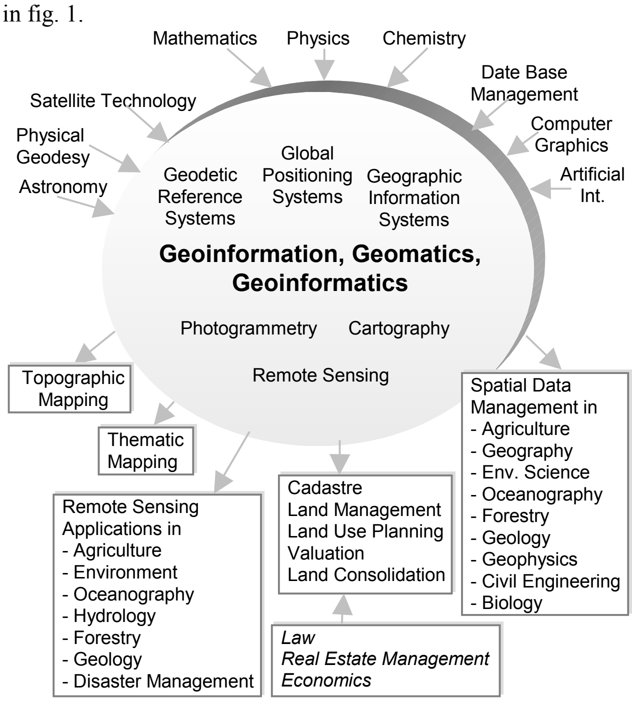

Fig. 1: Geoinformation, Geomatics, Geoinformatics

It embraces the subjects of geodetic reference systems, global positioning systems, geographic information systems, photogrammetry, remote sensing and cartography, as well as traditional surveying. It relies on theories of mathematics, physics, chemistry, astronomy, physical geodesy, and satellite technology. It is using tools of data base management, computer graphics, and artificial intelligence. Its application is in topographic and thematic mapping and spatial data management for a number of uses (agriculture, geography, environmental science, oceanography, forestry, geology, geophysics, civil engineering and biology). Special areas of professional and economic interest have traditionally been the cadastre, land use planning, land management, land valuation, and land consolidation.

To cover these tasks, an understanding of the principles of law, real estate management and economics is required.
While the methodologies for topographic and thematic mapping, for spatial data management and even for land registration and land management can be combined in a professional curriculum, it is clear that specific remote sensing applications and specific spatial data management issues require a thorough knowledge of the particular application field (e.g. agriculture, forestry or geology). It is impossible to combine all application disciplines into one curriculum. Thus geomatics should concentrate on a thorough understanding of theories and a coverage of the methodologies in which it has a chance to lead. But it is also required that it cooperates in a multidisciplinary manner with those, who have a better understanding of the particular application field. The specialized knowledge of the techniques of remote sensing and GIS is also required for graduates of these application disciplines. These can acquire it in special institutions, such as the ITC in graduate studies, which can, however, not substitute a professional orientation of geomatics.
The concept for a professional field, as expressed in fig. 1 for geomatics is not new. It was useful also some 40 years ago, when countries around the world began to develop surveying engineering curricula. Fig. 2 shows the "bubble chart" presented by A.C. Hamilton at the first Colloquium on Surveying Education in Canada, which was held in 1959 in Ottawa. On the basis of this chart a curriculum was devised at the University of New Brunswick for the field of "Surveying Engineering" in Canada.

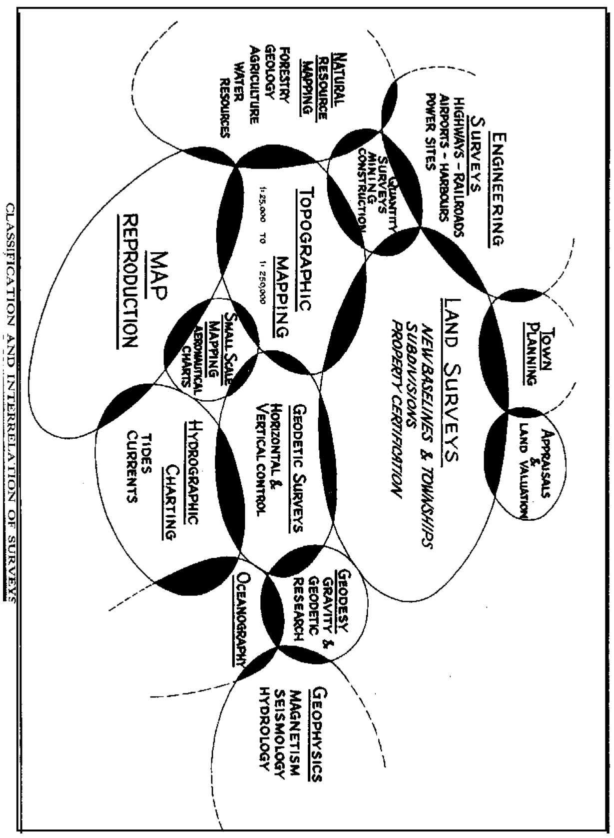

Fig. 2: A.C. Hamilton's Canadian Bubble Chart of 1959 for the classification and interrelation of surveys

3. HISTORICAL DEVELOPMENTS IN EDUCATION

Higher Education of today is believed to be linked to Universities. Surveying Engineering and Geomatics are predominantly taught at Universities. In this respect it might be appropriate to

review the history of what a University was to be. Some of the historical concepts still influence present day academic life.
A University is historically the product of the medieval European culture. The first universities in Parma, Bologna, Oxford, Modena, Perugia, Padova, Naples, Salamanca, Siena, and Paris originated as a reaction to the former schools of monasteries and cathedrals under religious domination to promote development of scientific knowledge. The early academic principles valid still today were academic honours, freedom of teaching and freedom from taxes. The first German University was established 1348 in Prague to be followed by that of Vienna (1365), Heidelberg (1386), Cologne (1388), and Leipzig (1409). The major faculties of these Universities were theology, law and medicine. A lower faculty, that of liberal arts covered such practical topics as grammar, dialectics, arithmetic, geometry, astronomy, and music. The Anglo-Saxon degree structure: "bacchalaureus", "licenciatus" and "doctor" was created at that time as well as the teaching division in "lections" and "disputations". The University consisted of the community of all who taught and all who learned.
The oldest American University, the one of Mexico City, is still very cognizant of these traditions. The early North American Universities, such as Harvard (and its offspring New Brunswick after US independence) were originally modelled after British University traditions.
In Central Europe the University movement became very political after the French Revolution as a reaction to the ruling nobility. The founder of the University of Berlin in 1809, Wilhelm von Humboldt, the brother of the South American explorer Alexander von Humboldt) expressed the aim of a University education by the ideal of humanity. He introduced the concept of unity between teaching and research, the belief of development of a personality by scientific argument, the autonomy of the University, the separation of school and University and the rejection of thought, that the University was preparatory for a professional career.
Contrary to this thought, engineering, as a practical career oriented discipline arose as a requirement of the mechanical age in the 1830's at schools, not Universities. The present University of Hannover originated in 1831 as an engineering trade school. In North America institutes of technology became important in the days, when the first railways spanning the continent were built.
In contrast to the tradition of the "Artes Liberales" at the Universities, where everyone could choose the study subject he wanted, engineering schools became career oriented with a specific obligatory educational curriculum, a tendency which in the meantime had also developed in some specific University disciplines such as medicine and law.
Engineering was firstly taught at military schools. When North American Universities at the time of land grants opened their doors to engineering, this type of education was called "Civil Engineering", from which later Mechanical Engineering, Electrical Engineering, Chemical Engineering, and finally Surveying Engineering separated.
In Central Europe the University concept changed around 1960, when the engineering Institutes of Technology (TH) were integrated into Universities merging them with the natural and social sciences.
At the University of Hannover (the former trade school) a first surveying course was given in 1831 by a collaborator of C.F. Gauss within civil engineering. At the University of New Brunswick Brydon Jack taught railway engineering in the 1860's with 80 % surveying content. In Hannover, the first institution to do so in Germany, a four to five year surveying engineering curriculum was introduced in 1930.
The separation of surveying engineering from military or civil engineering occurred at different times in different countries, in fact in some countries it still has not yet taken place. The reason for the separation is an existing national labour market for the field, which has been introduced by local economic situations, by law or simply by the initiative of professional groups or individuals. The aim of the education in surveying and mapping thus became to provide a basic workforce for a professional field.
In France, Britain, Russia, Spain, Italy, and the United States and even the Latin American countries surveying and mapping had military roots and motivations. Technical instruction in the required fields was done in-house in form of professional development. The Ecole Nationale des Etudes Géographique at IGN France is a relatively late starter following this career oriented schooling by a national mapping agency, which was formerly a military institution.
The following European countries have initiated surveying degree programs before the beginning of World War II:

- Germany
- The Netherlands
- Austria
- Switzerland
- Poland
- Cechoslovakia (Czech Republic and Slovakia)
- Yugoslavia (Serbia, Croatia, Slovenia)
- Denmark
- Sweden
- Finland
- Norway
- Hungary

The reason, why these countries found a sufficiently large labour market for surveyors was the task of an updated real estate cadastre introduced by law as a multipurpose cadastre and the new demands to restructure agricultural production by means of reallotment programs. In Germany alone there are now eight Universities with a five year academic surveying engineering orientation, supported by 15 technical academies to supply an annual workforce of 250 graduates at Universities and 800 graduates at the academies.
In the former Soviet Union mapping was declared as one of the priorities by Lenin, and in a planned socialist economy it became possible to create a specialized labour market for at least four or five specializations in the surveying and mapping field (aerial photography, photogrammetry, engineering surveys, cartography, land administration). MIIGAIK in Moscow became the largest educational institution in surveying and mapping in the world, with an annual student body of over 4000.
After China became socialist in 1949 the MIIGAIK model was introduced in Wuhan creating the Wuhan Technical University of Surveying and Mapping WTUSM in 1956 with student numbers surpassing those of the MIIGAIK. The Russian and the Chinese schools educated specialized professions for a government regulated activity.
In the United States of America the military agencies supported the establishment of a "Mapping and Charting Laboratory" at Ohio State University in 1953. Out of it grew a graduate program with the emphasis to take B.Sc. graduates in applied science (engineering, geography, mathematics, and physics) and to transform them within two to three years into a surveying and mapping career oriented individual. This was possible as most graduate students were already working in the field and were sponsored by their employers to take part in the course.
The philosophy of Ohio State University was very much like that of the ITC of The Netherlands with the advantage that OSU had a recognized University program at the start and ITC had to obtain gradual University recognition by the Dutch government.

The approach in Canada in 1959/60 was different. Civil Engineers, foresters and physicists had found employment in the surveying and mapping profession helping the development needs of the vast country. Prior to the creation of a Surveying Engineering program at the University of New Brunswick they had to go abroad for graduate specializations in geodesy and photogrammetry. There was a need for national professional tasks shown in fig. 2. Along with Laval University, which had a French speaking program for the preparation of Quebec Land Surveyors the University of New Brunswick program of 1960 became the model to set up further geomatics courses in the country (e.g. in Calgary). Such as model was also followed in South Africa (four Universities) and Australia (three Universities).
Technical cooperation with developing countries brought a cross-fertilization of ideas for education in surveying and mapping. The University of New Brunswick alone educated about 100 students from Nigeria sent on scholarship programs by the Canadian International Development Agency. For this reason many developing countries subsequently started their own surveying engineering or geomatics University programs such as Nigeria, Kenya or Malaysia supported by foreign aid.
The German Technical Cooperation Agency GTZ supported establishment of survey or geoinformatics degree programs in Zimbabwe and in India (Anna University, Chennai). In Europe finally Spain and Britain introduced new career oriented education programs in surveying and mapping, while in Italy photogrammetry still remains a special subject of Civil Engineering. On the other hand there are 90 000 persons licensed for surveying with high school graduation as minimal qualification.
Even in the USA, where prerequisites to be a surveyor are also very low, there are now 14 accredited surveying and mapping programs. While in Europe, Canada, Australia, South Africa, and Nigeria the course content covers the entire geomatics field, the coverage of certain aspects of the discipline differs from University to University as shown in fig. 3.

University	plane surveying	photogrammetry & remote sensing	survey computations	Geodesy & GPS	Cadastre	Cartography	GIS	land studies
Ohio State University	-			+	-	+		-
Oregon Inst. of Techn.	+					+		
Fresno		+		+				
U. of Maine			-					
Pomona		-						
Michigan Tech.								
Ferris State								
Texas A & M			-		-			-
Purdue U.								
Penn State U.			+				-	
New Mexico State U.						+		
U. of Alaska					+			
East Tennessee State							-	

\+ excellent coverage
\- poor coverage
empty space = adequate coverage

Fig. 3: Emphasis of U.S. Surveying and Mapping Programs (according to Steven Frank, FIG Congress 2002)

In Latin America emphasis in geomatics, or at least certain aspects of it like remote sensing has been placed on graduate programs at the diploma, the MSc., and even the Ph.D. level with examples of the Universities of Curitiba and Recife in Brazil and the Universities of Catamarca, Santiago del Estero in Argentina, and the Universidad del Zulia in Venezuela. The problem there is, that Argentina for example has a workforce of 4500 professionals in surveying and mapping, but only 0.5 % receive post-graduate education. The emphasis shared in Argentina by the Universities in Buenos Aires, Catamarca and Santiago del Estero must be on continuous education of professionals in short courses to widen their scope of activities.
In summary, the historical development of educational programs in geomatics is very heterogeneous from country to country. There are basically two problems: In countries where geoinformatics programs do not exist or where they are inadequately introduced, they need to be established for an eventually existing professional market. In countries, where geoinformation programs exist, they need to be modified according to pressures imposed by governments or society.

4. NEED FOR ESTABISHMENT OF GEOMATICS PROGRAMS, WHEN THEY DO NOT EXIST

The establishment of a program is warranted, if the knowledge to be transmitted is specific. This is the case for geomatics as described in chapter 2 of this paper.
The program must have recognition by the state, either for direct employment of graduates in the state agencies, or by establishing licensing bodies to regulate private practice.
The program, if it is to succeed, must be based on a scientific foundation. On the basis of the knowledge obtained a claim for a position in the labour market can be made.

5. NEED FOR RESTRUCTURING OF GEOMATICS PROGRAMS, WHERE THEY DO EXIST

5.1 The need for restructuring of geomatics program must be governed by the **labour market.**
A good example is the situation in Denmark, a country of an area of 43 000 km^2 with 4.2 million people and a workforce of about 900 professionals. Their percentages in employment areas have changed from 1967 to 1997 as shown in fig. 4.

employment sector	1967	1997
cadastre	70 %	20 %
planning	5 %	25 %
mapping	15 %	30 %
other	10 %	25 %

Fig.4: Employment Areas of Survey Professionals in Denmark 1967 and 1997 as shown by Enemark (FIG Congress 2002)

In Germany the current job market for a geomatics professional is shown in fig. 5.

employment sector	percentage
terrestrial surveying	40 %
geodesy	5 %
photogrammetry and remote sensing	5 %
GIS	30 %
land management	20 %

Fig. 5: Current German Job Market for Surveyors according to Witte and Heck (FIG Congress 2002)

In Germany, like in Denmark, the intake of graduates into state organizations (the cadastre) has diminished over the years, but a total of a professional workforce of about 8000 for Germany (for a country of 80 million inhabitants) has been maintained. Graduates increasingly went into value added GIS business. A ratio of 1 geomatics professional per 10 000 inhabitants seems to be a desirable figure expressing the demand.

5.2 Influences on Professional Recruitment by Governmental Measures

In a number of European countries higher education is free of charge, and a right to the citizen. This is the case in the Netherlands, Sweden, and in Germany. There is no pressure on the student to choose a particular field of study. He often does not choose a geomatics career because it sofar offers a low profile with less career opportunities. Due to a fuzzy content of the educational program and due to poor communication the number of student intakes has diminished from 40 per year to 10 per year at the TU Delft. The same trend is visible in Switzerland, Austria, and the southern part of Germany.

In Sweden, where the number of study places available is fixed by the government, the ratio of applicants is an indication of the desirability of a study field. Engineering science and geomatics only reaches a ratio of 1.4 applicants per study place, while economics reaches 2.6, medicine 3.8, law 4.5, and behavioural sciences 5.0. In Northern Sweden (KTH Stockholm) a ratio of only 1.0 was reached for geomatics, while the University of Lund in the South achieved a ratio of 2.0, mainly due to the fact that it has made the curriculum more attractive by adding real estate economics as a field of study. This enable the University of Lund to maintain a study number of 30 per year, which is a reasonable limit for a University offering such a program. If this number per year is any less there may be governmental pressure to close the curriculum down, as was the case in South Africa, where from four Universities previously only the University of Capetown has survived with their Geoinformatics course.

Another peculiarity is the University funding system introduced by the UK government to the British Universities. Political arguments started from the fact that 30 years ago only 10 % of the respective age group entered university. Now it is about 40 %, and the government wishes to raise this level to 50 %. One essential element to prevent mushrooming of mediocre Universities is the research assessment. According to the research assessments funds are distributed to the Universities resulting in the fact that the best Universities can afford a student to staff ratio of 5:1, and the Universities at the bottom end only of 22:1. This in part counteracts the relatively high fee structure at British Universities.

Another interesting development is in Russia. Since the central role of government with its planned economy has ceased to exist MIIGAIK and other specialized schools have to drastically restructure their curricula to a common, much broader field of geomatics.

In the countries of the European Union another restructuring necessity arose by the EU "Bologna Agreement of 1999", which prescribed the transferability of degrees for the countries of the Union. To introduce mobility a 3 degree structure B.Sc. (3 years), M.Sc. (2 years), and Ph.D. (3 years) was suggested as opposed to the German tradition of a 2 degree structure Dipl.-Ing. (4 to 5 years), and Dr.-Ing. (3 to 6 years). Due to the fact that in Germany higher education is under jurisdiction of the States, and that since the 1968 student revolution the Technical Academies wished to become Universities with a lot of state government support the Bologna declaration has caused a lot of confusion and resent in Germany. The outcome is still open.

5.3 Technological Influences

The last, but not the least reason for modifying geomatics curricula is the observation of the following technological trends.

Surveying has been subjected to automation. The field surveyor with a lot of technical skills and the ability to judge has been replaced by an operator controlled by hardware/software systems. The technical changes have not simply been a refinement of old techniques, but GPS and GIS operate on different principles. The subdivision of geomatics tasks in acquisition, processing, and presentation is no longer valid, as all tasks may be executed in a single integrated system.

Land management and regional and local planning has changed from a technical emphasis to social and environmental sustainability issues. Management and marketing have been added as new study areas.

What are still unsolved issues in geomatics technology? There is the transition from a 2D or 2 ½ D GIS to a 3 dimensional GIS, particularly for urban areas. There is the creation of a national data infrastructure to make natural and socio-economic data widely available through web-technology. There are user improvements in GPS-technology to reach cm-accuracy by modelling and transmitting corrections particularly for ionospheric influences.

What was formerly the case is still valid now: a University education must prepare graduate with intellectual versatility in which the graduation is only the first step in a lifelong learning process, as technologies develop further.

6. CONCLUSIONS

Depending on the economic and political situation of each country it is difficult to make general recommendations, except that it is wise to follow the trends expressed in United Nations Conferences on Environment and Development (UNCED Rio 1992) and Habitat II (Istanbul 1996) as well as its followup conferences. Within the context of the recommendations expressed there a graduate of geoinformatics has an important role to play for sustainable development. For he comprehends the basic theories, the methodologies of tools to be applied to monitor the earth's natural and social environment, and to react quickly in an analysis in case a catastrophic event might occur.

The closes application of geomatics technology, uncontested by any other group is in land administration. The security of access to land, to rights associated with it, and to introduce secured real estate as part of the capital market requires the establishment of a land records system, regulated by laws, which is within the scope of geomatics. The desolate state of land administration outside of Europe with only a few exceptions caused the World Bank to elect land management and land registration systems as one of its priorities.

With the rapid urbanization in the developing countries there are added motivations for the geomatics professional to become active in urban infrastructure planning and slum prevention. If geomatics can provide the tools, it only needs leaders in the field to introduce these tools for the betterment of conditions on this earth.

Only in areas, where no management of natural resources is required, where there is no economic growth, where land tenure is satisfactory, where there is no land taxation, where there is no need for land use planning geomatics is not needed. In the age of globalisation that leaves with exception of the polar icecaps and some deserts almost no areas on the planet.

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