Master of Science Degree in Applied Geospatial Information Science

An Inter-Disciplinary Degree at Michigan Technological University

General Program Description and Characteristics
This is a proposal to create a Master of Science Degree in Applied Geospatial Information Science. The program will be an inter-disciplinary program with the Graduate School providing oversight. Courses contributing to this graduate degree are currently offered by the School of Forest Resources and Environmental Science, School of Technology (Surveying Engineering), the Department of Geological and Mining Engineering and Sciences and the Department of Mathematics. The program is open to any graduate student who has completed a Bachelor’s Degree.

Course work will be designed and developed to meet the needs of graduate students who wish to develop an expertise in one of two areas of geospatial information science- geographic information systems (GIS) or terrestrial remote sensing. The degree will be a thesis (Plan A) or project report (Plan B) and require 30 credit hours beyond the bachelor’s degree. A coursework option (Plan C) will not be included because students in this degree program will develop an expertise in geospatial information science in party by applying their “classroom knowledge” in their specialization area via research or management project. Students will work in basic research, applied projects, and/or internships with groups involved in applied geospatial information science such as the Michigan Tech Research Institute (MTRI).

The program will be administrated by the two units involved in teaching the core courses: School of Forest Resources and Environmental Science (Maclean) and the School of Technology (Levin).

Rationale
Applied geospatial information science builds on the technologies of GIS, remote sensing and digital image processing, photogrammetry, and cartography to provide an integrated approach of measurement, analysis, and management of the descriptions and locations of earth-based data, often termed geospatial data. The proposed program will be a highly quantitative degree program that will instruct students in remote sensing, GIS, photogrammetry, and cartography using many technologies including airborne and satellite sensors, as well as ground based instruments. While the above-mentioned technologies are often thought of as tools to answering research questions in a particular field, the sciences associated with these technologies and the interpretation of geospatial data is what this degree will emphasize. Geospatial information science has many applications in disciplines which depend on spatial/temporal data including forestry, volcanology, environmental studies, atmospheric sciences, wildlife management, civil and environmental engineering, geology, geophysics, surveying, archaeology, and regional planning to name a few.

The US Department of Labor has predicted that jobs in the various fields of applied geospatial information science will increase by 20% by 2015. Currently, there is a shortage of qualified
personnel to fill these open positions, particularly those with a strong quantitative background. Furthermore, the worldwide market for applied geospatial information science technologies has enormous potential. Estimated at $5 billion in 2001, the market is expected to have annual revenues of $70 Billion by 2015. Therefore, graduates with advanced degrees in applied geospatial information science are needed to meet the needs of this expanding market.

**Related Programs**
The degree will provide a formalized program for students conducting quantitative applied research in GIS, remote sensing, image processing, global positioning systems and geodetic science. In the past and currently, participating students have been enrolled in various departments and schools across campus including Forest Resources and Environmental Science, Geological & Mining Engineering and Sciences, Computer Science, Social Sciences, Biological Sciences and Civil & Environmental Engineering. There have been numerous requests for an Applied Geospatial Information Sciences Degree to emphasize GIS, remote sensing, image processing, global positioning systems or geodetic science as the main focus of the student’s course work and research.

There are no other Applied Geospatial Information Science Programs in the State of Michigan. The University of Michigan, School of Natural Resources and Environment offers a degree in Environmental Informatics. This program emphasizes methods and skills using computational and analytical techniques to solve environmental problems, as well as considering the science-social issues of these problems. Students in this program incorporate GIS and remote sensing into their particular research area, and are not required to take any geomatics courses, leaving a gap in their GPS and photogrammetry expertise. Quantitative depth is limited to only one required course in Natural Resource Statistics.

Michigan State University offers a Master of Science in GIS as a non-thesis degree that emphasizes applications of analytical techniques in the field of geography. Students are trained in advanced technologies such as remote sensing, geographic information systems, cartography, and geospatial analysis. The degree is aimed toward professionals who want to acquire expertise in research techniques, but who may not necessarily wish to eventually pursue a PhD. This program is appropriate for persons with interest, but not necessarily strong training, in the geographical sciences.

The University of Wisconsin-Madison has discontinued their graduate program in Photogrammetry and recently suspended their program in Environmental Remote Sensing. They do offer a one-year non degree program in GIS as a capstone certificate through the Department of Geography.

The University of Minnesota (Twin Cities) offers a Masters of Natural Resource Science and Management with a track in Assessment, Monitoring, and Geospatial Analysis.

**Projected Enrollment**
Based on the current job market and the need for qualified personnel, it is anticipated the program will have 10 – 20 students enrolled.
Scheduling Plans
Initially classes will be taught on the Michigan Tech campus. However, it is anticipated that as the program grows and offered courses expand, that there will be remote long distance and/or web delivery of some courses. Some courses will have a field component as well.

Curriculum Design
Students, enrolled in the program, will be required to complete four core courses in Geospatial Information Sciences, and one upper level statistics course with the additional courses taken from the list of electives.

Required Cores Courses (18 credits)
- FW5540 Advanced Terrestrial Remote Sensing (4 credits)
- FW 5550 Geographic Information Systems for Resource Management (4 credits)
- FW 5560 Digital Image Processing: A Remote Sensing Perspective (4 credits)
- SU 4140 Photogrammetry (3 credits)
- MA4710 Regression Analysis (3 credits)
  OR
- MA 4720 Design and Analysis of Experiments (3 credits)
  OR
- FW5411 Applied Regression Analysis (3 credits)

Elective Courses (3 credits minimum)
- FW4170 GPS Field Techniques (1 credit) - currently taught as a special topics course
- FW5411 Applied Regression Analysis (3 credits) – if not taken as a core course
- FW5421 Regression with the R-Environment for Statistical Computing (1 credit)
- GE4150 Natural Hazards (3 credits)
- GE5250 Advanced Computational Geosciences (3 credits)
- MA4710 Regression Analysis (3 credits) - if not taken as a core course
- MA4720 Design and Analysis of Experiments (3 credits) - if not taken as a core course
- MA4730 Nonparametric Statistics (3 credits)
- MA5740 Advanced Sampling Methods (4 credits)
- MA4750 Applied Multivariate Methods (3 credits)
- MA5791 Categorical Data Analysis (3 credits)

Research (Thesis or Report) (6-9 credits)

Library and Other Learning Resources
Critical learning resources exist primarily on line. There is adequate access to the peer-reviewed literature via the VanPelt Library, online tutorials and classes such as those offered by the Environmental Systems Research Institute (developers of ArcMap) and other sources too numerous to list.

Computing Access Fee
Computing is a key component of this program. Students will be using computers extensively and will have 24/7 access to the Spatial Analysis Teaching Laboratory located in room 139 of the
Forest Resources and Environmental Science Building and the computing facilities maintained by the Surveying Engineering Program. Maintaining these labs with adequate computing and software resources is critical to the program. Students will be charged the normal computing fees for the School of Forest Resources and Environmental Science’s or School of Technology’s computing fees for each semester they are enrolled.

**Faculty Resumes**
Ann Maclean (attached)
Eugene Levin (attached)

**Description of Needed Equipment**
No special equipment is needed for this program.

**Program Costs**
We are requesting support for .5 of 1 technical support person to maintain and update the software need to support this program. Software licenses needed for this program should be supported centrally.

**Space**
No additional space is needed

**Policies, regulations and rules**
There will be no additional policies, regulations, or rules for this program beyond those mandated by the Graduate School

**Accreditation requirements**
None

**Planned Implementation Date**
As soon as approved
Ann L. Maclean  
Associate Professor

School of Forest Resources and Environmental Science  
Michigan Technological University  
1400 Townsend Drive  
Houghton, MI 49931-1295  
(906)487-2030  
amaclean@mtu.edu

Education
M.S. Forestry, University of Wisconsin, Madison, Wisconsin, 1984.
B.S. Forestry, Michigan Technological University, Houghton, Michigan, 1976.

Employment
Associate Professor (1993 - present), Remote Sensing/Geographic Information Systems, School of Forestry and Wood Products, Michigan Technological University, Houghton, Michigan, 49931.
Assistant Professor (1986-1993), Remote Sensing/Geographic Information Systems, School of Forestry and Wood Products, Michigan Technological University, Houghton, Michigan, 49931.
NASA Trainee (1983 to 1986), Goddard Space Flight Center, Greenbelt, Maryland.

Peer-Reviewed Publications


**Book Chapters**


**Video Produced**

Maclean, A and T. DeBruyn. 1999. Education Video of Black Bears for Primary Grade School Children.

**Publications Edited**


Peer-Reviewed Report

Non-Referred Publications


Ann L. Maclean


Externally Funded Research


Professional Memberships
American Society for Photogrammetry and Remote Sensing
Past Associate Editor for Photogrammetric Engineering and Remote Sensing (1997-1999)
Past Director of the Geographic Information Systems Division (1995-97)
Past Chair of the Education Committee (1993-1995)
Past Chair- Space Imaging Digital Imagery Award
Current Manuscript Reviewer
Eugene Levin
Assistant Professor

School of Technology, Surveying Engineering
Michigan Technological University
1400 Townsend Drive
Houghton, MI 49931-1295
(906)487-2446
elevin@mtu.edu

Education

Ph.D. Photogrammetry, State Land Organization University, Moscow, Russia 1989
M.S. Astro-Geodesy, Academy of Engineers in Geodesy, Aerospace, Survey, and Mapping, Novosibirsk, Russia, 1982

Professional Experience

MICHIGAN TECHNOLOGICAL UNIVERSITY, Houghton, Michigan 2007 – present
Assistant Professor, Graduate Program Development Coordinator

Work on MTU Geospatial Initiative encompassing new undergraduate two Master and one Ph.D degrees along with development of Integrated Geospatial Technology Research Center.

► Teaching 4000 level courses:
   SU4140 Photogrammetry
   SU4100 Geodetic Positioning

► Teaching 3000 level courses:
   Lab for FW3540 GIS course

Development of the new 5000/6000 level courses for new degrees: BS Geospatial Technology and MS/PhD in Integrated Geospatial Technology.

► Member of Ph.D committees.
► Work on publications and Research Grants submission

AMERICAN GNC, Simi Valley, California 2006 – 2007
Program Manager

Responsible for the design and development of products in the fields of UAV-based moving target surveillance and tracking, image processing, automation in photogrammetry and remote sensing, mapping, GIS, LIS, robotics, navigation, guidance and control, integrated navigation systems, embedded software, modeling and simulation.

► Developed 4D GIS system for moving targets tracking, prediction and visualization. Performed system demonstration at Armament Research and Development Engineering Center (ARDEC). System encompasses UAV image processing, computer vision, geospatial reasoning and efficient 3D visualization.
Oversaw development of Web-based Remote Sensing technology within NASA Stennis center research program. System integrates multi-tier client server architecture and advanced neural network based hyperspectral satellite image processing algorithms.

Developed algorithms for man-made terrain features extraction from oblique aerial and terrestrial imagery.

Work with outsourcing development team in Taiwan.

FUTURE CONCEPTS, La Verne, California 2005 – 2007

GIS Manager

- Developed architecture for the mobile Incident Command Center multi-tier GIS technology
- Supervised GIS development in-house and in overseas.

DIGITAL MAP PRODUCTS, Costa Mesa, California 2005 – 2006

Lead Photogrammetrist

Consulted with Marketing and Business development on scope, feasibility and requirements. Actively promotes creativity and open discussion throughout the organization. Assisted in creating company culture that respects diversity and differences of opinions.

- Involved in work with software engineering team members to design and development of object oriented systems that use and enhance Digital Map Products API, using C++, Java, JavaScript, HTML, XML, XSLT.
- Integrated real-time fleet management (GPS/RFID/GPRS) functionality into Web-GIS services.
- Technically directed team efforts. Research and adaptation of the new tools, languages and techniques
- Prepared SBIR and BAA proposals for NASA, DoD and Homeland Security federal government agencies.
- Oversaw aerial and satellite imagery data workflows in LandVision and CityGIS products.

PHYSICAL OPTICS CORPORATION, Torrance, California 2000 – 2005

Senior Scientist / Team Leader Geospatial Technology

Principal Investigator and Project Manager on several award-winning government programs. Heavy involvement in several POC government contracts (automatic target recognition, photogrammetry, and mapping). Software development outsourcing in Russia. Prepare scientific proposals for USAF, NGA, NASA, and NSF.

- Developed a new approach of target-recognition based on fusion of photogrammetry and catastrophe-theory image processing.
- Designed a proposal-level system for automated change detection. Developed algorithms and technology for flight-simulation database generation based on aerial and satellite imagery.
- Created multi-level frame technology for DTED generation based on exploration of Russian satellite imagery for NGA.

Eugene Levin

NESS TECHNOLOGIES, Tel-Aviv, Israel 1996 – 2000
Chief Photogrammetry Analyst

Served as a key member of the Military Photogrammetric Intelligence system development team. Oversaw algorithm and software development for a large defense project. Developed algorithms of geometrical solutions for non-standard photos (oblique, panoramic, CCD and other sensors), including customization for stereo-visualization on Intergraph stations and GIS applications for analytical Phototriangulation.

- Developed airfield ground traffic control (AGTC) GIS application for military/civilian airport uses.
- Introduced algorithms and applications to BEZEQ (Telephone company of Israel) based on MicroStation GIS for graphical representation of wave propagation modeling.
- Developed technologies on automated quality assurance for GIS based projects.
- Completed a training course on processing of Russian satellite images (SOVINFORMSPUTNIK Company, Tel-Aviv, Israel, 1998).

Manager – Department of Land Registration and GIS

Managed a group specialized in software development of topographic and cadastral data digital processing. Introduced technological lines of air photos and image processing for Land Registration. Coordinated group’s legal issues (including merchandising contracts, employment terms, loan agreements, and real estate purchases).

- Located equipment suppliers throughout Europe and USA, and carried out technical and financial analysis of tenders. Conducted negotiations and concluded project planning.

OMSK AGRICULTURAL ACADEMY, Omsk, Russia 1989 – 1995
Lecturer / Senior Lecturer / Associate Professor

Created lectures and practical courses in GIS Image Processing and Basic of Remote Sensing for post-graduate students specialized in Land Organization and Geodesy. Created software to support practical course in Digital Image Processing

- Instructed a training course and summer field practice in Image Interpretation for Topographic Mapping.
- Supervised graduate students on diploma projects. Consulted Ph.D. thesis students on research investigations of scientific opponents.

RESEARCH INSTITUTE OF APPLIED GEODESY, Novosibirsk, Russia 1982 – 1985
Software Engineer

Designed low-level API for data obtaining field systems, including adjustment computations. Developed algorithms and applications for online generation of DTM-based on-field surveying systems. Introduced products for gravimetric measurement automation.

Eugene Levin

Selected Publications
A “SIGHT-SPEED” HUMAN-COMPUTER INTERACTION FOR AUGMENTED
GEOSPATIAL DATA ACQUISITION AND PROCESSING SYSTEMS, In: Still U et al
(Eds) PIA07. International Archives of Photogrammetry, Remote Sensing and Spatial

HUMAN CENTRIC APPROACH FOR GEOSPATIAL DATA FUSION IN HOMELAND
DEFENCE AND SECURITY APPLICATION SCENARIOUS, accepted by SPIE Defense
and Security Symposium, E Levin, G Gienko, A Sergeev. , submitted to SPIE Defense and
Security Symposium, Orlando, FL , March 2008

Eye movement analysis in visual inspection of geospatial data, (E Levin, G Gienko)

EYE-TRACKING FOR STEREOSCOPIC GEOSPATIAL IMAGE ANALYSYS (Alex
Sergeev, Eugene Levin, Gennady Gienko), submitted to XXI congress of ISPRS, Beijing
China, July 2008

Geometric approach to multisensor, multiresolution image fusionProceedings of ASPRS
Annual Conference , Baltimore 2005 (E. Levin, G. Guienko)

Development of Analytical Photogrammetric Networks Based on Russian Satellite Imagery
Proceedings of ASPRS Annual Conference ,Denver 2004 (E. Levin, P.Salamonowiz, G.
Gienko, V Chekalin)


Open source data to improve geometric accuracy of IKONOS Geo images
Proceedings of ASPRS Annual Conference, Anchorage 2003 (E. Levin, G. Guienko)

Geographic information to support vision-based approaches for GPS-independent
autonomous navigation
Proceedings of ASPRS Annual Conference, Anchorage 2003 (E. Levin, G. Guienko, A.
Zhranovsky)

Multilevel frame method for phototriangulation and digital elevation model generation
Proceedings of ASPRS Annual Conference, Anchorage 2003 (E. Levin, V. Chekalin)

Flexible simulation strategy for modeling 3D-cultural objects using multi-source remotely

Eugene Levin

Catastrophic approach to satellite imagery utilization on network-based flight simulators

Eye-tracking in Augmented Photogrammetric Technologies
Aspects of satellite imagery exploration in GIS-based command and control real-time technologies

GIS-based UAV real-time path planning and navigation

Externally Funded Research

**USAF:** Analytical Manifold Modeling for Dynamic Planning and Execution.
*Phase I*, F30602-01-C-0117, 04/01/01-01/01/02, ~$99,992
*Phase II*, F30602-02-C-0132, 09/25/02-09/24/04, ~$744,280, Principal Investigator and Project Manager

**NAVY:** Look-Measure Analyze Toolset for Image processing and GIS
*Phase I*, N00039-020-C-2203, 05/30/02-11/30/02, ~$99,992, Principal Investigator and Project Manager.

**NGA (former NIMA):** Multi-level Frame Technology for Digital Elevation Data Generation.
*Phase I*, NMA401-02-C-0005, 04/11/02-10/11/02, ~$99,976
*Phase II*, NMA501-03-C-0011, 09/25/03-09/24/05, ~$499,973, Principal Investigator and Project Manager

*Phase I*, NBCHC050111, 06/01/05-12/01/05, ~$99,999

**US Army:** 4D GIS-based Virtual Reality for Moving Target Prediction and Visualization
*Phase I*, W1SQKN-06-C-0014, 01/05/06-06/05/06, ~$99,999, Project Manager.
*Phase II*, W1SQKN-06-C-0202, 08/30/06-08/30/08, ~$729,952, Principal Investigator and Project Manager.

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**Eugene Levin**

**Research Interests**

Sensors. Methods of high-resolution remote sensing.
Image-processing. Automated feature extraction from aerial and satellite imagery.
Remote sensing and GIS: data fusion.
GIS-oriented image analysis.
Spatio-temporal datamining
Knowledge Extraction
Autonomous GPS-independent navigation.
Photogrammetry of aerial and high-resolution satellite imagery.
Digital image processing and GIS in applied geosciences.
Remote sensing and environmental engineering.

Professional Memberships
- American Society for Photogrammetry and Remote Sensing (ASPRS)
- The International Society for Optical Engineering (SPIE)
- Member of Editorial Board of the “GPS Solutions” journal published by Springer-Verlag, Heidelberg, Germany
MTU Geospatial Initiative for Sustainable Development and Environmental Stewardship

BACKGROUND

**Geospatial** is a term widely used to describe the combination of spatial information software and analytical methods with terrestrial or geographic datasets. The term is often used in conjunction with geographic information systems, surveying engineering and geomatics. Sub-disciplines in geospatial sciences and technologies are: geodesy, land surveying, photogrammetry, cartography and GIS.

**Geospatial technologies** employ Earth observation systems, global navigation satellite systems, laser and radar imaging sensors, optical-electronic measurement systems, computer geovisualization and analysis systems, mathematical and statistical data processing, real-time data acquisition networks, wireless and Internet technologies.

**Geospatial workplace:** 175,000 people are employed in the “U.S. remote sensing and geospatial information industry” (Mondello, Hepner, and Williamson, 2004).

**Geospatial enterprise:** NASA estimated that the U.S. “geospatial technology” market would generate $30 billion a year by 2005—$20 billion for remote sensing, $10 billion for geographic information services (Gaudet, Annulis, & Carr, 2003).

**Geographic information science is a research enterprise.** Research-based, multidisciplinary graduate education in GIScience prepares students to master the technical, analytical, business, and interpersonal competencies needed to play leading roles in research and development, system analysis and design, and application development (Saalfeld, 1997).

**Insufficiently rigorous undergraduate programs.** Duane Marble published an influential critique of the “low-level, non-technical” character of GIS education in undergraduate degree programs. “Existing GIS education fails to provide the background in GIScience that is necessary to meet the needs either of the users of GIScience technology or of the scientific community engaged in basic GIScience research and development” (Marble, 1999, p. 31).

MISSION STATEMENT

Considering the need for an increased professional pool in the field of Geospatial Technologies, the department of Surveying Engineering envisions its ultimate goal by developing a highly skilled workforce, well educated and equipped to lead the development of Geospatial Information Technology on the cutting-edge scientific and technological level.

Our goal will be accomplished by integrating three substantial environments: expert-led, self-paced, and collaborative efforts through achievement of the following objectives:
1. Consolidate (integrate) geospatial capabilities throughout MTU institutions by establishing the **MTU Geospatial Consortium**
2. Reinforce research in Geospatial sciences, technologies and applications
3. Strengthen and expand undergraduate and graduate programs in Geospatial sciences and technologies

We believe that the overall goal and objectives are very much in line with the MTU Strategic Plan for sustainable development.

To address these goals and objectives the Surveying Engineering department in the School of Technology proposes to create an Inter-disciplinary Geospatial Task Force (IGTF) to develop a framework for the MTU Geospatial Initiative by establishing an **Integrated Geospatial Technology Center of Excellence (IGTCE)** at MTU.

**Rationale.** The primary purpose of establishing of this Inter-disciplinary Geospatial Task Force is to facilitate an interactive dialog. Interested stakeholders throughout MTU subdivisions will promote and collaborate on future trends and issues in Geospatial sciences and technologies that address the MTU strategic development plan and also develop the work plan for implementation of IGTCE.

**The successful outcome** of the Geospatial Task Force will be based upon a coalescence of the needs and directions of a diversified group of research, teaching and service subdivisions of MTU working together in their respective communities to develop a pragmatic approach for establishing and successive implementation of the MTU Geospatial Initiative for Sustainable Development and Environmental Stewardship.

**RESEARCH, EDUCATION AND CONSULTANCY**

IGTCE structure is based on three closely tightening components: research, education and consultancy.

**Research.** MTU innovative Strategic Faculty Hiring Initiative makes it possible to attract world-class researchers and faculty to establish MTU Integrated Geospatial Technology Center of Excellence for research in applied geospatial sciences, technologies, emergency surveying and mobile mapping. The center will play the key role in development of the cutting edge geospatial sciences and technologies and will bring MTU at the leading position as the world-class excellence research institution.

**Education.** Teaching at undergraduate, masters and doctoral levels is an inherent part of the MTU Geospatial Initiative. The teaching component comprises of the following programs:

1. BS in Surveying Engineering (existing)
2. BS in Geospatial Technologies (to be developed)
3. MSc/MEngg in Integrated Geospatial Technologies (to be developed)
4. MSc in Geospatial Applications and GIS (to be developed)
5. PhD in Geospatial Sciences (to be developed).

**Consultancy.** MTU holds high-end processional surveying and measurement equipment and professionally certified faculty and staff capable to provide professional consultancy to MTU subdivisions and external customers in land surveying, industrial surveying, first response and
emergency surveying, mobile mapping, GPS mapping, cartographic mapping, map design, geospatial data compilation and analysis.

Increased support for programs like IGTCE is needed to increase the capacity of research-based graduate education, which in turn is needed to “rebuild the top of the pyramid” – effective and cutting edge research in geospatial sciences and technologies.

**GEOSPATIAL WORLD IN MORE DETAILS**

**Fundamental Geospatial sciences:** theory of the Earth shape, geodynamics, global positioning systems, mathematical cartography and projections; planetary and outer space spatial sciences

**Applied Geospatial sciences and technologies:** Earth observation systems, optical, laser and radar imaging sensors, GPS networks and systems, wireless and mobile data collection technologies, spatial data visualization, distributed geo-networks and data repository, geospatial data compilation, updating and fusion, automated image classification and feature extraction, geospatial data mining, knowledge and expertise elicitation and transfer, industrial surveying, emergency response surveying, land surveying and land tenure.

**Size of the geospatial enterprise.** There is little question that the geospatial information enterprise is large and growing. Absent a standard industry definition, however, estimates of the size of the enterprise have varied. Technology market research firm Daratech (2004) estimated that worldwide sales of GIS software, services, data, and hardware totaled $1.84 billion in 2003. Daratech predicted that total revenues increased nearly 10 percent in 2004.

The American Society for Photogrammetry and Remote Sensing’s (ASPRS) survey of the “remote sensing and geospatial information industry” led it to estimate 2001 industry revenues at $2.4 billion, and to predict growth to more than $6 billion by 2012 (Mondello, Hepner, & Williamson, 2004). The National Aeronautics and Space Administration (NASA), in consultation with the Geospatial Workforce Development Center at the University of Southern Mississippi, estimated that the U.S. “geospatial technology” market would generate $30 billion a year by 2005—$20 billion for remote sensing, $10 billion for geographic information services (Gaudet, Annulis, & Carr, 2003). This most optimistic prediction, based on an expansive conception of the geospatial information industry that includes remote sensing, GIS, and global positioning system technologies, has since been adopted by the U.S. Department of Labor (U.S. Department of Labor, n.d.).

**Size of the geospatial workforce.** Because of the varied definitions, broad scope, and rapid evolution of the geospatial enterprise, reliable information about the size and composition of the geospatial workforce is difficult to obtain (Ohio State University, 2002). A few telling estimates do exist, however. ASPRS estimates that about 175,000 people are employed in the “U.S. remote sensing and geospatial information industry” (Mondello, Hepner, and Williamson, 2004).

Environmental Systems Research Institute (ESRI), which along with Intergraph accounts for nearly half of the worldwide GIS software market, estimated in 2000 that 500,000 individuals in the U.S. use its software products as part of their jobs, and that some 50,000 individuals work as full-time GIS specialists (Phoenix, 2000). Longley and colleagues estimate that there are some four million GIS users worldwide, working at some two million sites (Longley, Goodchild, Maguire, & Rhind, 2005). Whatever the actual size of the geospatial information workforce, everyone seems to agree that there are too few qualified workers available to support the industry’s growth.
Geographic information science is a research enterprise. GIScientists lead research and development efforts at GIS software firms, government agencies, and in universities. Academic GIScientists are also responsible for recruiting, training, and mentoring the next generation of researchers who will advance the capabilities of geospatial technologies in the future. Research-based, multidisciplinary graduate education in GIScience prepares students to master the technical, analytical, business, and interpersonal competencies needed to play leading roles in research and development, system analysis and design, and application development (Saalfeld, 1997). Graduate education can also promote adoption of spatial analysis and geographic modeling among the various disciplines that employ geospatial technologies.

Insufficiently rigorous undergraduate programs. In 1998, Duane Marble published an influential critique of the “low-level, non-technical” character of GIS education in undergraduate degree programs (Marble, 1998, p. 28). “Existing GIS education,” Marble claimed, “fails to provide the background in GIScience that is necessary to meet the needs either of the users of GIScience technology or of the scientific community engaged in basic GIScience research and development” (Marble, 1999, p. 31). Unlike students in the early days of GIS education, when the primitive state of the technology necessitated programming skills, Marble pointed out that latter day students and some instructors believe that all one has to do to become a GIS professional is to master the standard functions of commercial off-the-shelf (COTS) software. Thus, graduates are no longer prepared “to make substantial contributions to the ongoing development of GIS technology” (Marble, 1998, p. 1). Advanced knowledge and skills in computer and information sciences are needed more than ever, he argued, to realize the full potential of GIS&T.

Formal education at the undergraduate level: Four-year institutions. Very few higher education institutions offer baccalaureate degree programs focused specifically upon Geospatial technologies and GIScience per se. Berdusco (2003) identified about 425 higher education institutions worldwide (about 260 U.S.) that offer formal certificate, diploma, and degree programs in GIS and GIScience. Of the 28 U.S. universities listed as offering undergraduate degree programs in GIS, all but four in fact offer B.A. and B.S. degrees in geography (nineteen programs), Earth science, environmental science, natural resources, or forestry, with concentrations, specializations, tracks, or undergraduate certificates in GIS, GIScience, cartography, and related topics. For the same reasons that the geospatial workforce is diffused among many industries in every employment sector, geospatial activities tend to be widely dispersed and poorly coordinated on four-year college campuses. Within academic programs, courses involving geospatial technologies are often positioned as intermediate or advanced technical specialties with prerequisites and class size limits that pose barriers to enrollment.

WHO IS WHO IN GEOSPATIAL WORLD

Key state agencies: National Geospatial Intelligence Agency (NGA), USGS, NASA, DHS, the Transportation Security Administration (TSA).

Key US universities: Ohio State University, Purdue University, University of California Santa Barbara, University of Mississippi in Oxford.

Key world universities: International Training Center in Geospatial Sciences and Earth Observation Systems (Netherlands), Institute for Photogrammetry (Germany), Graz University of Technology (Austria), Salzburg University (Austria), Swiss Federal Institute of Technology (Switzerland), Moscow University for Geodesy and Cartography (Russia), Siberian State Geodetic
Academy (Russia), Wuhan Technical University (China), The Hong Cong Polytechnic University (China), Curtin University of Technology (Australia), Royal Melbourne Institute of Technology (Australia), University of Otago (New Zealand), University of Nottingham (UK), University College London (UK).
MTU Geospatial Initiative at Glance

Establish a world-class internationally recognized educational and research programs in Geospatial Science and Technology at MTU

Reinforce research in Geospatial science, technologies and applications by establishing Integrated Geospatial Technologies Institute (GeoTech)

Strengthen and expand education in Geospatial science and technologies by establishing new interdisciplinary undergraduate and graduate programs

Geographic Information Science and Technology: Body of Knowledge

Developed by University Consortium for Geographic Information Science, 2006, 159 pages

Ten Knowledge Areas:
- Analytical Methods
- Conceptual Foundations
- Cartography and Visualization
- Design Aspects
- Data Modeling
- Data Manipulation
- Geocomputation
- Geospatial Data
- GI & T and Society
- Organizational & Institutional Aspects

Education in Geospatial Technologies

- There is a concern in professional society about unregulated academic certificate programs and insufficiently rigorous undergraduate and graduate programs (GIS & T BoK, 2006).

- Many universities across the US offer degrees, certificates and courses in GIS and Remote Sensing

- Few universities in the US offer different components of Geospatial Technologies:
  - Surveying: Purdue, UTexas at Corpus Christi, UFloida
  - Photogrammetry: Ohio State
  - Cartography: Penn State, Kansas

- There is no university in the US offering education in Integrated Geospatial Technologies as a specialty
Success story: International Training Centre (Netherlands)

The International Institute for Geo-Information Science and Earth Observation was established in 1950 and is usually referred to as ITC because of its original name, the International Training Centre for Aerial Survey.

Key figures for 2006:
- 1364 newly registered students
- 555 degrees/diplomas/certificates awarded
- 9 degree courses, 7 diploma courses, 15 short courses, 6 refresher courses, 15 joint educational courses, 5 distance education courses, 35 tailor-made courses
- 66 registrants for the graduate programme
- 45 advisory activities
- 236 staff, which includes 16 full professors

MTU strength and emphasis in GISc

Geospatial data in Natural Science
- Geology
- Forestry
- Environmental studies
- Atmosphere studies
- Water resource management
- Sustainability studies
- Climate studies
- Archeology
- Geograpy
- Social science
- etc

Geospatial technologies
- Earth Observation and Imaging Systems
- Global Satellite Navigation Systems (GPS)
- Geodesy
- Topographic Engineering
- Land Surveying
- Industrial Surveying
- Photogrammetry
- Aerial and Satellite Image Analysis and Interpretation
- Cartography
- etc

Geoinformatics in Engineering and Computing
- Imaging sensors
- Robotics
- Navigation
- Wireless
- Computer networks
- Database management
- Data representation and transfer
- etc

Degrees in Geospatial Science, Technologies and Informatics

Academic Degrees by MTU Geospatial Initiative (Delivery Timetable)

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>BS Geospatial Engineering</td>
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<tr>
<td>MS Geospatial Integrated Geospatial Technology</td>
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<tr>
<td>MS Applied Geospatial Information Science</td>
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<tr>
<td>MS Geoinformatics</td>
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</tr>
<tr>
<td>PhD Applied Geospatial Science</td>
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<td></td>
<td></td>
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<tr>
<td>PhD Geoinformatics</td>
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</tr>
</tbody>
</table>

Faculty and staff, directly (full time) involved in GI Science and Technologies

2007: 4 faculty + 1 adjunct faculty + 1 staff (part time?)
2008: 6 faculty + 2 adjunct faculty + 1 staff (full time)
2010: 10 faculty + 2 adjunct faculty + 1.5 staff

Faculty number is approximate and will depend on the number of courses offered and teaching workload model.
1. General description and characteristics of program.

Sustainable development of the society very much depends on availability and credibility of geospatial data. Terrabytes of geospatial data and metadata about the Earth are acquired using different sophisticated sensors and instruments such as global navigational satellite systems, aerial and satellite panchromatic and hyperspectral remote sensors, hi-precision optical-electronic surveying instruments, laser scanning systems, radars, sonars, etc. These data help scientists from many different disciplines such as geology, volcanology, forestry, agriculture, social sciences, demography, history and politics to study diversity aspects of the Earth and human phenomena. All these disciplines use this data and technologies as a supplementary tool in their research, but geospatial data acquisition and processing is an applied science and technology by itself.

The roots of these technologies are laid in geodetic science, photogrammetry, cartography, surveying and topographic and thematic mapping. Featured with new technological development in optics, electronics and computing, these roots emerge into a new blend of applied science – integrated geospatial technologies. Terrestrial and airborne laser scanning systems are widely used to get 3D models of object, high-resolution satellite imaging sensors provide multi- and hyper-spectral video data which allow the user to investigate spatial-temporal and physical properties of objects on the earth, ocean and atmosphere; Global Navigation Satellite Systems provide real-time accurate geo-positioning and navigation data to define precise location of objects not only on the land surface, but any features on and in the water, including man-made and wildlife creatures tracking.

There is a large and growing need for scientists and engineers with advanced training in the geospatial technologies. In particular, there is a recognized need in different disciplines to gather, analyze and interpret geographically referenced spatial information and data. Powerful new research and technological tools for addressing these problems require graduate-level training in the geospatial sciences for their effective use.
In many cases, the same geospatial product, for example Digital Terrain Model, can be created by different techniques. To achieve the goal, the professionals need to predict and reason spatial and semantic accuracy of the final product, compare different techniques and approaches, estimate technological and financial efforts as well as manpower. Planning data acquisition process, balancing errors and accuracies, combining and optimizing different technologies for data acquisition and adjustment require truly integrative, professional knowledge and skills in different directions of quantitative geospatial techniques and technologies.

The proposed Masters program seeks to educate students from a variety of backgrounds for careers in the surveying, photogrammetric, remote sensing, LIDAR and terrestrial laser scanning industries, and for allied areas that require a knowledge and understanding of the acquisition, processing and analysis spatially referenced data.

The degree program will offer two general options – Master of Applied Science and Master of Engineering with the emphasis on thesis and coursework respectively.

The Masters degree in Integrated Geospatial Technologies is sough as an inherent component of the integrative MTU Geospatial Initiative, the educational part of which comprises the following components:

1. BS in Surveying Engineering (existing)
2. BS in Geospatial Engineering (to be developed at School of Technology)
3. MSc/MEng in Integrated Geospatial Technologies **(the current proposal)**
4. MSc in Applied Spatial Information Sciences (inter-departmental program being developed by School of Forestry and Environmental Resources in co-operation with School of Technology and School.
5. MSc in Geoinformatics (proposed inter-departmental program to be developed in co-operation with EE/EM/ME)
6. PhD in Geospatial Sciences and Geoinformatics (proposed inter-departmental program to be developed in co-operation with SFER/EE/EM/ME)

All degrees will be implemented in the frame of the MTU’s Multi-disciplinary Integrated Geospatial Technology Center(Institute) of Excellence (IGTCE), which is aimed on establishing geospatially-centered research environment and providing world-class knowledge and expertise for multi-disciplinary research in Environmental and Biological, Geosciences, Sustainable Development and Social Sciences, Information and Data Management Technologies.

2. **Rationale.**

Current trends in technologies, industry and government agencies indicate stable demands for multi-disciplinary knowledge. In academy, a growing number of faculty and graduate students are using geospatial data and MTU is not an exception. Active
research programs, courses, and a growing number of graduate degrees based on the use of such data and information already exist. This initiative is to build on this critical mass of effort by developing a new, inter-disciplinary degree program in the Integrated Geospatial Technologies. The initiative is based on the following statements

- The Graduate Program is designed as a flexible inter-disciplinary structure to ensure the best positioning of the graduates on job markets.
- The Graduate program should respond to current demand of industry and foresee future trends
- The Graduate program should reflect state-of-the-art geospatial research and technologies
- Proposed program is challenged to attract students of MTU and other universities nationwide and internationally as integrated geospatial education option
- Inter-disciplinary structure of the program allows certain courses to be included into other degrees program at MTU
- Inter-disciplinary approach provides flexibility for the School in staffing, research interests, practical expertise and modes of course delivery
- The graduate program is sought as an important component for developing sustainable research in Geospatial sciences and technologies at MTU

3. Discussion of related programs within the institution and at other institutions.

Very few higher education institutions offer baccalaureate degree programs focused specifically upon Geospatial technologies and GIScience per se. Berdusco (2003) identified about 425 higher education institutions worldwide (about 260 U.S.) that offer formal certificate, diploma, and degree programs in GIS and GIScience.

Of the 28 U.S. universities listed as offering undergraduate degree programs in GIS, all but four in fact offer B.A. and B.S. degrees in geography (nineteen programs), Earth science, environmental science, natural resources, or forestry, with concentrations, specializations, tracks, or undergraduate certificates in GIS, GIScience, cartography, and related topics.

For the same reasons that the geospatial workforce is diffused among many industries in every employment sector, geospatial activities tend to be widely dispersed and poorly coordinated on four-year college campuses. Within academic programs, courses involving geospatial technologies are often positioned as intermediate or advanced technical specialties with prerequisites and class size limits that pose barriers to enrollment.

The only few US universities offer graduate degree in separate quantitative geospatial disciplines such as Surveying (Purdue, UTexas at Corpus Christi, Florida), photogrammetry (Ohio State) and Cartography (Penn State, Kansas), but **there is no** university in the US offering the Integrated Approach to Geospatial Technologies.
4. Program commercialization strategy

4.1 Projected enrollment.

The Surveying Engineering program’s Advisory Board meeting (October 12th 2007) has expressed its support in establishing such a program and reassured that there is a strong demand from the industry and administrations in graduates both with Master of Sciences and Master of Engineering options.

There are five students at Surveying Engineering program already expressing their interest in enrolling the Master’s degree program. We anticipate that within three to five years the program will have 10 to 15 students on campus and 15 to 20 students on their workplace.

We strongly believe that the Masters program will attract diversity of students due to the integrated approach and the nature of the courses. Students can find attractive the variety of courses in cartography and photogrammetry where 40-60% of professionals are traditionally female.

4.2 Program expansion strategy

Integrated Geospatial Technology graduate program will be unique in the United States. Therefore we expect the traditional MTU sources of applicants to be supplemented with those of multiple government agencies and industries. Non-traditional sources which will require marketing efforts include:

- Intelligence Government Agencies: NGA, CIA, TSI. In particular the NGA supports university programs and research. The structure of NGA academic initiatives is reproduced on Figure bellow

![NGA Structure](image)

Engaging NGA will require a significant marketing effort. We expect support from Interdisciplinary Studies Institute (ISI) to actively participation in member organization of NGA and other federal agencies.

- Aerospace Industry: nowadays most of the major companies in this industry are involved in geospatial projects and therefore need specialist in integrated geospatial technology and research.
- The example of ITC (Netherland) indicates that there is a need in geospatial education internationally. Therefore contacts with relevant UN universities
may result in involvement of an international component in proposed program.

The most efficient way to approach these new markets is participation in high-level geospatial intelligence symposiums such as GEOINT (http://www.geoint2008.com/). A booth at such high-level forums can be an efficient mean of getting more students enrollment. The Institute for the Application of Geospatial Technology at Cayuga Community College, Inc. (IAGT) (http://iagt.org/) is an example of successfully using Geoint for promoting Geospatial training and education for the Intelligence Community. We expect help from the graduate faculty to prepare MTU’s presence in this kind of events.

5. Scheduling plans (Extension, Evening, Regular).

The classes will be taught on the MTU campus and partly delivered online. Some courses will require fieldwork; non-thesis option courses will have the internship component as well.

6. Curriculum design (refer to format of degree audit form). Indicate subject areas to be used for Departmental GPA calculation.

Table 1 outlines options and requirements for both degrees (Master of Applied Science and Master of Engineering) where students should earn 30 credits total including 12 or more credits for 5000-level courses.

<table>
<thead>
<tr>
<th>Program</th>
<th>Option</th>
<th>Course work</th>
<th>Thesis research</th>
<th>Course research</th>
<th>Engineering report</th>
<th>Engineering practicum</th>
<th>Total credits</th>
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</thead>
<tbody>
<tr>
<td>MAppSc</td>
<td>Plan A</td>
<td>12</td>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>MAppSc</td>
<td>Plan B</td>
<td>18</td>
<td></td>
<td>12</td>
<td></td>
<td></td>
<td>30</td>
</tr>
<tr>
<td>MEng</td>
<td>Plan C</td>
<td>21</td>
<td></td>
<td>3</td>
<td>6</td>
<td></td>
<td>30</td>
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<tr>
<td>MEng</td>
<td>Plan D</td>
<td>21</td>
<td></td>
<td></td>
<td>3</td>
<td>6</td>
<td>30</td>
</tr>
</tbody>
</table>

The program is designed to represent the diversity of the Body of Knowledge in Integrated Geospatial Technologies. It is assumed that each student will study a key course component and then specialize in a certain direction to understand the essence of integrated approaches in solving real life tasks.
Table 2. Courses in Integrated Geospatial Technologies Master degree program

Notes: GS course code stands for GeoSpatial
+ stands for course development
@ first time course introduction
* course regularly offered

<table>
<thead>
<tr>
<th>Course title</th>
<th>Title</th>
<th>cr</th>
<th>l-r-p</th>
<th>prereqisites</th>
<th>Avail. courses and credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>GS4010</td>
<td>Geospatial concepts, technologies and data</td>
<td>3</td>
<td>3-0-0</td>
<td>+ @ * * * *</td>
<td>9 19 28 31 38 45</td>
</tr>
<tr>
<td>GS5020</td>
<td>Data analysis and adjustments</td>
<td>3</td>
<td>2-0-1</td>
<td>SU3250 @ * * * *</td>
<td></td>
</tr>
<tr>
<td>GS5021</td>
<td>Geodetic models</td>
<td>3</td>
<td>2-0-1</td>
<td>GS5020 @ * * * *</td>
<td></td>
</tr>
<tr>
<td>GS5022</td>
<td>Geospatial positioning</td>
<td>3</td>
<td>2-0-1</td>
<td>GS5021 @ * * * *</td>
<td></td>
</tr>
<tr>
<td>GS5030</td>
<td>Earth observation systems and technologies</td>
<td>3</td>
<td>3-0-0</td>
<td>+ @ * * * *</td>
<td></td>
</tr>
<tr>
<td>GS5031</td>
<td>Digital processing of geospatial imagery</td>
<td>4</td>
<td>1-2-1</td>
<td></td>
<td>+ + @</td>
</tr>
<tr>
<td>GS5032</td>
<td>Geospatial image analysis and interpretation</td>
<td>3</td>
<td>0-2-1</td>
<td>+ @ * * * *</td>
<td></td>
</tr>
<tr>
<td>GS5033</td>
<td>Algorithms and programming in applied geospatial image analysis</td>
<td>4</td>
<td>1-2-1</td>
<td></td>
<td>+ + @ *</td>
</tr>
<tr>
<td>GS5040</td>
<td>Analytical and digital photogrammetry</td>
<td>4</td>
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<td>GS5041</td>
<td>Advanced photogrammetry and applications</td>
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<td>GS5040 + + @ *</td>
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<tr>
<td>GS4050</td>
<td>Cartography and Geographic Information Systems</td>
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<td>1-1-1</td>
<td>GS4200 + @ * *</td>
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<tr>
<td>GS406</td>
<td>Advanced geospatial technologies and applications</td>
<td>3</td>
<td>3-0-0</td>
<td>GS4010 + @ * * *</td>
<td></td>
</tr>
<tr>
<td>GS4200</td>
<td>Advanced geospatial practicum</td>
<td>3</td>
<td>0-2-1</td>
<td>GS4010 + @ * *</td>
<td></td>
</tr>
</tbody>
</table>
7. New course descriptions.

**GS 4010 Geospatial concepts, technologies and data**

a) Fundamental spatial concepts (Euclidean space, geometry of space, topology of space, network spaces, metric spaces);
b) Geospatial concepts (coordinates, projections and transformations); c) Fundamental measurement concepts (2D and 3D measurements, errors of measurements and their analysis);
d) Fundamental geomodeling concepts (reducing Earth objects to formal descriptions; the modeling process, objects and fields in geospatial modeling); e) Geospatial source information and media (images, drawings and maps);
f) Geospatial measurements (measuring location, distance, area and volume);
g) Geospatial data collection (statistical and spatial data sampling, resolution, accuracy and scale, data generalization and abstraction);
h) Geospatial data acquisition techniques (measurement and imaging technologies);
i) Maps and mapping technologies (land surveying, topographic mapping, aerial surveying and photomapping, cartographic mapping);
i) Geospatial data and metadata formats and visualization (use, storage and distribution, Network and mobile technologies for geospatial data acquisition and use).

**GS 5020 Data analysis and adjustments**

Errors, stochastic and mathematical models, quadratic forms, linearization and variance-covariance propagation of multi-dimensional nonlinear functions, least-squares algorithm of observation equations, position estimation using surveying and GPS vector measurements; review of statistics and linear algebra. Error ellipses and ellipsoids, propagation of estimated quantities, a priori information on parameters, adjustment of implicitly related observations and parameters, mixed model, condition equation model, sequential solutions, testing conditions on nonlinear parametric functions. Geometry of least-squares, definition of network coordinate systems, singularities, probability regions, minimal and inner constraints, invariant quantities, multivariate normal distribution, relevant statistical tests, type I/II errors, internal and external reliability, absorption of errors, blunder detection, decorrelation, inversion of patterned and large matrices, numerical aspects; Kalman filtering.

**GS 5021 Geodetic Models**

Conventional celestial and terrestrial references frames, geodetic datum, geoid, ellipsoid of revolution, geodetic coordinates, height systems, 3D geodetic model and modeling observations, reduction of observations, observation equations, partial
derivatives, 3D network adjustments, height-controlled 3D networks, GPS vector observations, review of spherical trigonometry and spherical harmonic expansions. Geodesic line on the ellipsoidal surface, geodesic curvature, differential equations of the geodesic, direct and inverse solutions, 2D network adjustment on the ellipsoidal surface, partial derivatives, reduction of observations, traditional horizontal and vertical networks in surveying and geodesy; in-depth review of differential geometry. Conformal mapping of the ellipsoidal surface, meridian convergence, point scale factor; State Plane Coordinate systems, Transverse Mercator, Equatorial Mercator, Lambert Conformal with one or two standard parallels, polar azimuthal, and UTM; reduction of observations, computations on the conformal map and relation to the surface of the earth; review of complex variables.

GS 5022 Geospatial Positioning
ITRF and ICRF references frames and transformations, tectonic plate motions, precession, nutation, polar motion, rotational and atomic time scales, GPS time scale, normal orbits, Kepler's laws and equation, topocentric satellite motions, visibility, perturbation of satellite orbits, solar radiation pressure, impact of asymmetry of gravity field and earth's flattening; GPS, GLONASS, Galileo and COMPASS satellite systems. Pseudorange and carrier phase observables, satellite time, relativity, broadcast and precise ephemerides, range iteration, receiver and satellite clock errors; singularities, tropospheric refraction and absorption, impact of the ionosphere, solid earth tides, ocean loading, satellite antenna offset, phase windup correction, closed form solutions; Kalman filter; timing, mapping of the spatial and temporal variation of the troposphere and ionosphere. Differenting observables in space and time, common-mode error reduction, geometry-free solutions, widelaning, cycle slips, constraint solutions, integer ambiguity estimation, LAMBDA, antenna calibration, multipath on pseudoranges and carrier phases, spatial vector networks, differential corrections, global data collection and maintenance, GPS services.

GS 5030 Earth observation systems and technologies
Optical radiation models (electromagnetic spectrum and EM radiation, interaction of EM radiation with atmosphere and surface objects); Sensor models spatial, spectral and temporal resolution; spatial and spectral response; sampling and quantization; geometric and radiometric distortions; topographic and sensor effects); Correction and calibration (sensor and image calibration; geometric image displacement and distortions); Reference surfaces and ground control points (surveying and georeferencing); Image geometric correction: (rectification and orthorectification); Earth imaging technologies (comparative study of terrestrial, aerial and satellite imaging sensors)

GS 5031 Digital processing of geospatial imagery
Data models (photographic and digital imagery; photo digitalization; sampling and quantization; image presentation in digital form; univariable image statistics, statistical measures of image quality); Spectral and spatial transforms (image enhancement; convolution and filtering; Fourier transforms; scale-space transforms and rectification); Image correction and enhancement (sensor and image radiometric calibration; noise reduction, atmospheric correction); Geospatial imagery data: presentation, compression, storage and distribution
GS 5032 Geospatial image analysis and interpretation
Image informative properties (content, resolutions, generalization and scale)
Visual information: quantitative and qualitative approaches; measuring of information);
Image media (photographic and digital presentation); Visual image interpretation (image interpretation keys);
Image information extraction (indices and objects); Computer-assisted image analysis (pixel-based and object-based approaches)
Pixel-based classification (approaches to multispectral image classification) Object-based classification (feature extraction approaches);
Accuracy of image analysis and interpretation; Trends in image and visual data mining.

GS 5033 Algorithms and programming in applied geospatial image analysis
Images, arrays, and matrices (Algebra of vectors and matrices, eigenvalues and eigenvectors, vector derivatives, image statistics, Parameter estimation, Hypothesis testing and sample distribution functions, Bayes' Theorem and classification, Ordinary linear regression);
Transformations (The discrete Fourier and wavelet transforms, principal components, Maximum noise fraction, spatial correlation, convolutions, filters, and fields, linear filters, wavelets and filter banks, Gibbs-Markov random fields); Image Enhancement and Correction (Lookup tables and histogram functions, High-pass spatial filtering, panchromatic sharpening, Topographic correction, Image-image registration);
Supervised Classification (Maximum a posteriori probability, training data and separability, maximum likelihood classification, Gaussian kernel classification, Neural networks, postprocessing, evaluation and comparison of classification accuracy, hyperspectral analysis); Unsupervised Classification (Simple cost functions, fuzzy maximum likelihood estimation clustering, including spatial information, the Kohonen self-organizing map); Change Detection (Algebraic methods, principal components, post-classification comparison, multivariate alteration detection, decision thresholds and unsupervised classification of changes).

GS 5040 Analytical and digital photogrammetry
Introductory Concepts (Photogrammetric Systems, Photogrammetric Applications and Products, Sources of Photogrammetric Information, History); Elementary Photogrammetry (Perspective projection, image coordinate system, relief displacement, parallax and stereo, image overlap, epipolar planes and lines); Photogrammetric Sensing Systems (Physics of remote sensing – electromagnetic energy, optics, sensing, image quality, imaging geometries, image motion compensation, frame camera, camera calibration, active sensors, platforms for photogrammetric Sensing); Mathematical Concepts in Photogrammetry (Perspective geometry, sensor modeling in aerial and satellite imagery); Resection, Intersection, and Triangulation (Single –photo-projection, relative and absolute orientation, block triangulation and adjustment, self-calibration, evaluation of block adjustment); Digital Photogrammetry (Digital imagery and digital image processing, image resampling, image compression, digital image measurement, computer vision and computer graphics); Photogrammetric Instruments); Hardcopy and softcopy based systems; Photogrammetric Products (Hardcopy and digital photogrammetric products, GIS, 3D photogrammetric products, products accuracy and quality assurance); Close-Range Photogrammetry (Instruments and software for close-range photogrammetry, mathematical models for close-range photogrammetry, calibration procedures, applications of close-range photogrammetry); Analysis of Multispectral and Hyperspectral Image Data (Statistical pattern recognition and classification, feature reduction and spectral transformation, multiSpectral Data); Active Sensing Systems
(Radar imaging fundamentals, the radar equation, SAR processing and geometry model, introduction to IFSAR, LIDAR.).

**GS 5041 Advanced photogrammetry and applications**

Procedures for large-area point measurement (Block adjustment of independent models, bundle block adjustment, satellite positioning for point determination, aerial triangulation with GPS support, effects of earth’s shape and the distortions of national coordinate systems); Special Features of Digital Photogrammetry (Automatic fiducial marks location, measuring image coordinates of natural features, Special features in relative orientation, and special features in aerial triangulation); Quality control and detection of errors (Accuracy control (inner, relative, absolute, block), least-squares adjustment with and without random errors, data snooping, robust procedures, reliability checks for photogrammetric standard procedures, variances estimations for observation groups); Photogrammetric Engineering Applications with cases study: Large scale aerial triangulation, Photogrammetric Cadastral Surveys, Buildings Reconstruction from non-metric images, Forensic photogrammetry. Photogrammetric Measurement and Visualization of Surfaces (Digital orthophotos, digital stereo-orthophotos, surface visualization by means of digital orthophotos, 3D photomodels, automatic definition of object Surfaces); Photogrammetric capture and visualization of Dynamic Phenomena (Motography with photographic cameras, the spatio-temporal system, visualizing phenomena and dynamically visualizing static objects); Calibration of Photogrammetric systems (Concepts of calibration, calibration procedures, calibration of various types of camera).

**GS 4050 Cartography and Geographic Information Systems**

Cartography and maps; the map as an interface to GIS; Geospatial Data acquisition (methods and techniques; vector and raster data and file characteristics; deriving data from existing maps; control and accuracy in cartographic data). Cartography and the cartographic communication process; Map functions and map types. Maps and the nature of GIS applications (map scale and GIS applications Geospatial, thematic and temporal comparisons of cartographic data). Mathematical cartography and map projections. Measurements from maps (fundamentals of cartometry); statistical mapping and cartographic generalization. GIS and cartographic mapping: requirements for cartographic component in GIS packages. Desktop mapping, map production and distribution; updating geospatial data. Map making and visualization of spatial data in natural, geo- and social sciences

**GS 4051 Cartographic modeling and Geospatial Data Visualization**

Cartographic visualization (presenting geospatial data); graphic variables (location, value, hue, size, shape, spacing and orientation); geospatial data (perceptual and cognitive limitation); geospatial data (Graphic and display limits); representing geospatial data uncertainty and temporal dependence; visualization of multidimensional data on 2-dimensional displays designing maps and multimedia cartographic products; visual information and multimedia techniques (internet, web and digital media) multimedia cartography (geospatial data and hypermaps); cartographic design and implementation strategies for cyber-cartography; internet GIS and web-mapping technologies; geography markup language
GS 4060 Advanced geospatial technologies and applications
Advanced geoinaging technologies (Aerial and terrestrial lidars for surveying and industrial applications; UAV and robotics imaging systems; non-topographic and close-range photogrammetry; videogrammetry; surveying and photogrammetry for homeland security, surveillance and military applications; augmented geoinformation systems and technologies); wireless, internet and mobile mapping and geospatial technologies; geospatial data compilation, conflation and updating; distributive and corporative data networks; security, legal and copyright issues in geospatial data. Geospatial data visualization (visual modeling and data presentation, spatio-temporal immersive visualization, autostereoscopic 3D vision, tactile data sensing and management (touchtable, datawalls etc.); current trends in global navigation satellite systems; emerging trends in advanced surveying technologies.

GS 5061 Special Topics in Integrated Geospatial Technologies
Specific topics individually tailored to the students expressing a specific interest and having access to particular technologies, instruments and data, which are not available at MTU.

GS 4200 Advanced geospatial practicum
Advanced study and extensive practical training in modern software packages according to student’s specialization. The student should take training in at least two software packages from the following list (software packages is subject of availability):
   a) Carlson Software (surveying)
   b) Trimble Geomatics Office (GPS and data adjustment)
   c) ENVI/eCognition (geospatial image analysis and recognition)
   d) ArcGIS/MapInfo/GRASS (generic GIS and cartography software)
   e) VrMapping, StereoGIS, Photomodeller (softcopy photogrammetry)
   f) PCIGeomatics/ERMapper (geospatial data software suits)
   g) Skyline TerraBuilder, TerraExplorer (3D visualization of geospatial data, cybercartography)

GS 5200 Engineering Report
Course work study on engineering subjects within selected specialization stream. Designed for Masters of Engineering degree (option C).

GS 5310 Advanced Engineering Practicum
Advanced senior engineering practicum in industry or government on engineering subjects within selected specialization stream. Required comprehensive report. Designed for Masters of Engineering degree (option D).

GS 5500 Graduate Research
Supervised research in selected specialization stream conducted in partial fulfillment of the requirements for MAppSc degree according to the student’s tailored Masters of Applied Science degree plan (options A & B).
8. Library and other learning resources.

The library has basic literature in area of geospatial technologies, but it is anticipated that the program will require some extra funds to update and extend existing resources.


Initially each student will pay the Computing Access Fee to general computer lab in the School according to the department’s policy. Eventually, with establishing of the Center for Integrated Geospatial Technologies and dedicated Geospatial Laboratory, the program may have its own fee.

10. Faculty resumes (a web site link is sufficient).

Eugene Levin, PhD (http://www.tech.mtu.edu/Faculty_Pages/Eugene_Levin.html)

Rober Liimakka, MSc, PhD candidate (ABD) (http://www.tech.mtu.edu/Faculty_Pages/Rob_Liimakka.htm)

Alfred Leick, PhD (www.gnss.umaine.edu)

Gennady Gienko, PhD (http://www.geo.fio.usp.ac.fj)

The MTU Geospatial Initiative anticipates that the faculty will be expanded by secured strategy minimizing risks by means of simultaneous development undergraduate Geospatial Engineering degree. Besides that Initiative match MTU strategic plan therefore in the future other faculty expansion and development programs may support the growth of program.

11. Description of available/needed equipment.

School of Technology has been teaching surveying engineering and photogrammetry for over 20 years. In terms of equipment the School of Technology already has the following capital assets to support the new program:

- Trimble GNSS RTK system $60,000
- Trimble S6 total stations (4 pcs) $96,000
- TSC2 wireless data collectors (4 pcs) $10,000
- Leica DN Digital Levels (10 pcs) $30,000
- Trimble Geomatics Office (90 licenses) $400,000
- Carlson Civil Suite software (90 licenses) $927,000
- SimWright StereoGIS softcopy photogrammetric workstation (5 licenses) $50,000
- Cardinal Systems VrMapping photogrammetric software suite (12 licenses) $120,000
- Chevrolet PT Cruiser vehicle worth $6,700

Total current assets are valued in $1,699,700.
Surveying and GPS component of the Masters program is currently covered with sufficient equipment and software. The photogrammetric component will require purchasing dedicated high-end workstations for stereoscopic image analysis and measurements (5 PC). The image analysis and cartographic component will require dedicated cartographic and geovisualization software.

A Minimal Risk (30 credits) program can be delivered without additional investments of the equipment.

Full-volume (45 credits) program development and course delivery will require purchasing the following equipment:

- 5 High-end dual-processor photogrammetric workstations with stereoscopic screens and shutter-glasses ($10,000)
- Geo Server
- 1Gbit local network
- 15 dual screen PCs
- A0 plotter
- A3 flat bed scanner
- laser color printer
- overhead projector
- computer lab furniture

12. Program costs, years 1, 2, and 3. (Additional information may be requested by the Senate Finance Committee.)

The MTU Geospatial Initiative anticipates as a safe strategy that the new faculty lines will be opened simultaneously with the proposed new undergraduate Geospatial Engineering program. We expect that new faculty will develop and teach both graduate and undergraduate courses. In addition the extramural research funding generated by the current and expected new faculty members will help in providing a sustainable development of the program.

Estimation of faculty growth is provided in section 17.

The risk mitigation strategy with projected rollout and start-up costs calculation are given in section 18 of the current proposal.

Positive acceptance of MTU Geospatial Initiative by MTU top-administration, departments of Socials Sciences, Geology, Forestry, Cognitive Sciences, Electrical Engineering, MTRI makes us confident that one of the next years Sustainable Development strategic plan will be devoted to Geospatial technologies.

13. Space.

The Geospatial Technologies program requires establishing dedicated teaching laboratory and office space for graduate students and new faculty.
• Geospatial Laboratory (to accommodate 15 dual screen PCs, 5 Photogrammetric Workstations, 1 Server, A0 plotter, A3 scanner and 6 cartographic workbenches): 800 sq ft (approx)

• Surveying and Geodetic Laboratory (winter lab classes) adjunct to Surveying equipment storage room: 450 sq ft + 150 sq ft (approx)

Office space:

• for new faculty: 3 offices 100 sq ft each

• for graduate students: 5 offices 100 sq ft each (shared between 10 students)


Not applicable.

15. Accreditation requirements.

Not applicable.

16. Internal status of the proposal.

Approved by:

17. Planned implementation date.

A draft for the Masters in Integrated Geospatial Technologies program development and delivery schedule is outlined in section 6, Table 2 and summarized in Table 3 below.

Table 3

<table>
<thead>
<tr>
<th>Master program in Integrated Geospatial Technologies</th>
<th>Course development and delivery schedule</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>courses</td>
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<tr>
<td></td>
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<td>2008 spring</td>
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</tr>
<tr>
<td>fall</td>
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<td>2009 spring</td>
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<td>2010 spring</td>
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<tr>
<td>fall</td>
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<td>2011 spring</td>
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<tr>
<td>total</td>
<td>4</td>
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18. Risks mitigation strategy, rollout plan and start-up cost calculation

Understanding the complexity of risks for the Michigan Tech related to the implementation of the proposed graduate program, the School of Technology proposes the following risk mitigation strategy:

- Program start with minimal faculty lines openings based on minimal 30 credits rollout plan;
- To secure investments we propose that the graduate program and the undergraduate program in Geospatial Engineering, which will be supported by the same 4000 level courses and will be given by the same faculties, start at the same time;
- Development of the full volume 45 credits coursework will be secured after a successful 30 credit period marketing strategy and by extramural research funding created by current and new-hired faculties
- Interdisciplinary Research Center/Institute for Geospatial Technology’s uniquely combination of education and research can be considered as another factor securing risks of program strategy.

Preliminary calculation of the start-up rollout plan is presented in Table 4. The calculation assumes a graduate tuition is $545 per credit in graduate level and $300 for the undergraduate level. For the simplicity of calculation it is assumed that all courses are being offered on an annual basis for both the graduate and undergraduate degrees. In start-up cost calculation is assumed also the fully loaded cost of a faculty member of $110,000 per year. It follows from Table 4 that in order to cover the opening of the 2 new faculty lines, which are necessary for the minimal 30 credits program implementation, an enrollments of 139 students in undergrad programs and 10 students for proposed graduate program is needed. The current surveying engineering enrollments exceed 50 students; therefore an additional increase of 89 students in connection with the new Geospatial Engineering undergrad program seems to be a realistic goal. We already have 5 students willing to start graduate education in the fall of 2008. Ten graduate students will make the proposed program a “zero profit”. Two faculty lines are secured by the new undergrad program. With 7% of the undergrad students deciding to rollout into the proposed graduate level program will create a self-sufficient situation.

Start-up cost calculation given above is certainly just preliminary and it is modeling numerically the “worst of the worst” situation, when none of research funds will be delivered by geospatial faculties. Relying on average MTU proposals winning rate of 67% we are confident that real-life situation will be more favorable for the program. It assumes that new-hired faculties will submit and win research grants supporting graduate students. For example, if all the faculties mentioned above will deliver $100,000 research funding per year proposed graduate program can become mostly independent from undergraduate financially. Furthermore, this situation as optimistic will open capability of the additional faculty lines to support both graduate and undergraduate programs. This is our view of sustainable development of geospatial research and education in Michigan Tech. We believe that extramural research funds and program’s national and international expansion strategy described in section 4 will make it profitable for Michigan Tech.
<table>
<thead>
<tr>
<th>Table 4</th>
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<tbody>
<tr>
<td><strong>Surveying/Geospatial Engineering undergraduate and graduate Roll out plan</strong></td>
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<td></td>
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<tr>
<td>credits in program</td>
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<tr>
<td>years in program</td>
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<tr>
<td>credits, coursework</td>
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<tr>
<td>credits, thesis</td>
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<td>credits, per year</td>
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<tr>
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<tr>
<td>faculty load lecturing, per year</td>
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<tr>
<td>cost balance, per program $</td>
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<tr>
<td>cost balance for both programs $, total</td>
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</table>
Proposed change in Graduate School policy regarding definition of outside examiner for non-departmental and interdisciplinary Ph.D. program committees

Proposed By: Engineering (Environmental) (EPD2) Non-departmental Ph.D. Degree Program Faculty Committee represented by Judith Perlinger (Chair)

Current Policy: Current University policy (http://www.gradschool.mtu.edu/catalog/phd.htm) states that for interdisciplinary and non-departmental programs, the outside examiner on PhD examining committees may not be affiliated with the interdisciplinary or non-departmental program:

Proposed Change in Policy: Allow Graduate Faculty members affiliated with a non-departmental or interdisciplinary program to serve as outside examiners on committees of students who are not in the same administrative home department.

Proposed Revised Policy (used Track Changes):
“The Examining Committee will be appointed by the Graduate School in consultation with the department chair. The committee will consist of at least four members of the graduate faculty. At least one of these will be from outside the student's administrative home department. The primary advisor, or a co-advisor who serves as chair of the committee, must be from the student's home department. For interdisciplinary and non-departmental programs, the outside examiner may be affiliated with the interdisciplinary or non-departmental program but not with the student’s administrative home department. A person external to Michigan Tech may be appointed as an ad hoc member of the Graduate Faculty <http://www.gradschool.mtu.edu/policies/gradfaculty_policy.html> to serve as the outside examiner. Persons who are not members of the Graduate Faculty may not serve as voting members of doctoral examination committees.”

Rationale:
- According to Dean Huntoon, the purpose of the external member is viewed as twofold: 1) it gets people from across campus to learn about what is going on outside of their primary disciplinary focus; 2) it ensures that programs do not become isolated from the rest of the university and do not take actions that might jeopardize Michigan Tech’s reputation for quality in graduate education. There is no reason that faculty committee members of interdisciplinary/non-departmental degree programs who are outside a student’s administrative home department cannot serve this purpose;
- The primary defining feature of a member of an interdisciplinary/non-departmental faculty committee is serving or having served as advisor of a student in the program. Student advisory committees should be able to benefit from having outside examiners who are or have become affiliated with a non-departmental/interdisciplinary program as a result;
- Outside examiners who are affiliated with the interdisciplinary/non-departmental degree program can bring expertise that other outside members cannot provide unless the affiliated individual were to serve as an additional member of the committee, with the difficulties this imposes due to scheduling conflicts.
Graduate Student Orientation – Fall 2008

Our goal is to strengthen our commitment to academic integrity and responsible conduct for research by including some basic training in these areas during orientation.

Proposed schedule (week of August 25th):
- **Afternoon 1 (optional/required?):** General introduction to Michigan Tech and the Graduate School. Plenary talks (about 45 minutes) followed by round table discussions on topics of interest to new students (living in Houghton, how to succeed as a graduate student, how to select an advisor, etc.). **Case studies would be distributed for review before second session.**
- **Afternoon 2 (required):** Plenary discussion on academic integrity and responsible conduct of research followed by small group discussion of basic case studies (how to cite literature, plagiarism, acceptable levels of collaboration in courses)
- **Thursday and Friday afternoons are proposed.** The MUB ballroom is available both afternoons and presents no known conflicts for programs.

Known conflicts:
On January 24, 2008, all Graduate Program Directors, Graduate Program Assistants, GFC and GSC were asked about their plans for fall orientation. Peace Corps (Forestry) students are off campus at the Ford Forestry Center for 12 weeks, and will need to be accommodated separately.

Programs with orientation before August 25th:
- International Students (August 22nd)
- Chemical Engineering

During the week of August 25th:

<table>
<thead>
<tr>
<th>Monday</th>
<th>Tuesday</th>
<th>Wednesday</th>
<th>Thursday</th>
<th>Friday</th>
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<tbody>
<tr>
<td><strong>8-noon</strong></td>
<td>GTA (International I)</td>
<td>Civil Eng</td>
<td>GTA (Domestic)</td>
<td>MEEM GTA (International II)</td>
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<td>Electrical Eng.</td>
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<td>Environmental Eng. Science</td>
<td>Environmental Eng. Science</td>
<td>Environmental Policy</td>
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<td><strong>Lunch</strong></td>
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<td>GTA (Domestic)</td>
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<tr>
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