THE UNIVERSITY SENATE OF MICHIGAN TECHNOLOGICAL UNIVERSITY

PROPOSAL 39-11

(VOTING UNITS: ACADEMIC)

"PROPOSAL FOR A MASTER OF SCIENCE IN INTEGRATED GEOSPATIAL TECHNOLOGY"

SUBMITTED BY THE:
SURVEYING ENGINEERING PROGRAM, SCHOOL OF TECHNOLOGY
SCHOOL OF FOREST RESOURCES & ENVIRONMENTAL SCIENCE
MICHIGAN TECH RESEARCH INSTITUTE (MTRI)

1. GENERAL DESCRIPTION AND CHARACTERISTICS OF PROGRAM

Sustainable development of a society depends greatly on the availability and reliability of geospatial data. Terabytes of multi-dimensional geospatial data and metadata are acquired using various sophisticated instruments such as global navigation satellite systems, aerial and satellite panchromatic hyper-spectral remote sensors, hi-precision optical-electronic surveying instruments, laser scanning systems, radar, sonar, etc. Data are used by scientists from many different disciplines such as engineering, geology, forestry, agriculture, social sciences, history, and political science to study diverse aspects of the Earth and human activity. All these disciplines use geospatial data and technology as a supplementary tool in their research, but *geospatial data acquisition and processing is a science in itself*.

The roots of geospatial technology are geodetic science, photogrammetry, cartography, surveying, topographic mapping, and thematic mapping. Combined with new technological developments in optics, electronics, and computing, these roots have produced a new blend of applied science – Integrated Geospatial Technology. Examples of recent applications of these technologies include: terrestrial and airborne laser scanning systems that are widely used to obtain 3D models of objects; high-resolution satellite imaging sensors that provide multi- and hyper-spectral video data which allow users to investigate spatial-temporal and physical properties of objects; and Global Navigation Satellite Systems that provide real-time and accurate geo-positioning and navigation data to define precise locations of objects on land and water, including man-made structures or natural features.

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 among different disciplines for more effective systems to gather, analyze, and interpret geographically referenced spatial data. Powerful new research and technological tools for addressing these problems require graduate-level training in the geospatial sciences.

In many cases, the same geospatial product, such as a Digital Terrain Model, can be created by different techniques. To achieve a goal, professionals need to reason and predict the spatial and semantic accuracy of the final product, compare different techniques and approaches, and estimate technological, financial, and manpower requirements. Planning the data acquisition process, balancing errors and accuracies, and combining and optimizing different technologies for data acquisition and adjustment requires professional knowledge integrated with skills spanning different aspects of *quantitative geospatial techniques and technologies.*

The proposed Master's Degree is designed for students from a variety of backgrounds for careers in surveying, photogrammetry, remote sensing, Light Detection and Ranging (LiDAR), terrestrial laser scanning industries, and for allied areas that require knowledge and understanding of the acquisition, processing, and analysis of spatially referenced data.

2. RATIONALE

Current trends in industry and government agencies indicate that a stable demand exists for geospatial technology within multiple disciplines. In academia, a growing number of faculty and graduate students are using geospatial data within a variety of fields. Active research programs, courses, and a growing number of graduate degrees incorporate the use of such data and information. The Master's Degree proposed here will support ongoing activities by facilitating interdisciplinary collaboration in graduate education, and will add value to Michigan Tech's current graduate offerings by providing a suite of courses in the area of Integrated Geospatial Technology.

The design of this proposed graduate program specifically addresses the following goals:

- Provide a flexible interdisciplinary structure to ensure the best positioning of its graduates in job markets.
- Allow for rapid response to the current demands of industry and foreseeable future trends.
- Incorporate state-of-the-art geospatial research and technology.
- Attract current students of Michigan Tech as well as students at other universities nationally and internationally.
- Promote flexibility in terms of staffing, research interests, practical expertise and modes of course delivery.
- Promote sustainable research infrastructure and staffing in the area of geospatial science and technology at Michigan Tech.

The proposed Master's Degree is viewed as the initial stage in the strengthening of geospatial science and technology at Michigan Tech.

3. DISCUSSION OF RELATED PROGRAMS WITHIN THE INSTITUTION AND AT OTHER INSTITUTIONS

Very few higher education institutions offer baccalaureate degree programs focused specifically on geospatial technology and GIScience *per se*. Berdusco[1] identified about 425 higher education institutions worldwide (about 260 in the US) that offer formal certificate, diploma, or degree programs in GIS and GIScience.

Of the 28 US 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.) Others offer baccalaureate degrees in 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

[1] Berdusco, B., Results of a Survey of Known Higher Education Offerings in GIS and GISci (2003), http://www.ucgis.org/priorities/education/GIS_Cert+Masters_Prog/Berdusco.htm

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.

A small number of US universities offer graduate degrees in separate quantitative geospatial disciplines such as Surveying (Purdue, University of Texas at Corpus Christi, Florida), Photogrammetry (Ohio State) and Cartography (Penn State, Kansas), but ***there is no*** university in the US offering Integrated Geospatial Technology.

4. PROJECTED ENROLLMENT

The Michigan Tech Surveying Engineering program's Advisory Board has expressed its support for establishing a graduate program in Integrated Geospatial Technology. The Board felt that there would be strong demand from industry for graduate students with the expertise that would be gained through participation in a certificate or Master's program.

We strongly believe that the unique structure of the proposed graduate program curriculum and the availability of online course delivery will attract additional non-degree seeking post-graduate students nationally and internationally.

When the program starts it is anticipated that the majority of students will be off-campus and enrolled in Plan C or taking courses as non-degree seeking students. Estimated student numbers for this group are 10-15. A smaller number, perhaps 3-5, will choose Plan B and do a project associated with their place of employment, but still be distance students. Best estimates for the number of Plan A students at startup is 2-3, all being supervised by faculty members in the Surveying Engineering program area. It is hard to estimate the steady-state enrollment but most likely it will be dominated by Plan C students, who will be self-supporting. It is also anticipated that the Plan A students will be self-supported.

5. SCHEDULING PLANS

The classes will be taught on the Michigan Tech campus and most of them will have the option for online delivery.

6. CURRICULUM DESIGN

MASTER OF SCIENCE PROGRAM:

Table 1 outlines options and requirements for the proposed Master of Science degree in Integrated Geospatial Technology.

Faculty members from any of the participating departments will be able to advise Plan A & B students as their schedules permit. Off-campus faculty members have also committed to advise students as needed. Any workload issues for faculty members outside of the School of Technology will be addressed in their home departments or organizations.

TABLE 1: MS DEGREE REQUIREMENTS

Program	Option	Coursework	Thesis Research	Report or Practicum	Total Credits
MS	Plan A	≥20	6-10		≥30
MS	Plan B	≥24		2-6	≥30
MS	Plan C	≥30			≥30

The Master's program is designed to represent the diversity within the body of knowledge that comprises Integrated Geospatial Technology. The specific set of courses a student takes to meet the requirements of the degree is meant to be flexible to allow a customized program that will satisfy specific research or project interests. It is assumed that each student will take at least 2 courses from at least 2 different areas and specialize in one area in order to understand the essence of integrated approaches to solving real life problems.

Tables 2, 3 and 4 provide examples of possible study plans; actual degree plans will vary and will reflect a customized plan of study developed by students in consultation with their advisor.

TABLE 2: PLAN A SAMPLE STUDY PLAN (24 COURSE CREDITS+9 RESEARCH CREDITS = 33 CREDITS)

Year 1			Year 2			Year 3		
Fall	Spring		Fall	Spring		Summer	Fall	Spring
FW 5810(2) SU 5020(3) SU 5800(1)	SU 5010(3) SU 5021(3) SU 5540(3) SU 5800(1)		SU 5043(3) SU 5540(3) SU 5800(1) SU 5999(1)	SU 5041(3) SU5999(1)		SU 5999(1)	SU 5999(3)	SU 5999(3)

TABLE 3: PLAN B SAMPLE STUDY PLAN

	Fall	Spring
Year 1	SU 5020(3) SU 5042(3) FW 5810(2) SU 5998(1)	SU 5010(3) SU 5021(3) SU 5540(3) SU 5998(1)
Year 2	SU 5020(3) SU 5800(1) SU 5930(3) SU 5998(2)	FW 5560(4) SU 5003(1) SU 5930(3) SU 5998(2)

TABLE 4: PLAN C SAMPLE STUDY PLANS (OTHER STUDY PLANS ARE POSSIBLE IN CONSULTATION WITH AN ADVISOR.)

	Geodesy			Remote Sensing/Imaging			GIScience	
	Fall	Spring		Fall	Spring		Fall	Spring
Year 1	FW 5540(4) SU 5003(1) SU 5020(3) SU 5041(3)	SU 5010(3) SU 5021(3) SU 5540(3)		SU 5002(1) SU 5020(3) SU 5930(3)	FW 5560(4) SU 5010(3) SU 5540(3)		SU 5003(1) SU 5020(3) SU 5041(3)	SU 5010(3) SU 5042(3) SU 5540(4)
Year 2	SU 5003(1) SU 5022(3) SU 5930(3)	FW 5560(4) SU 5023(3)		FW 5550(4) SS 5300(3) SU 5003(1)	SU 5043(3) SU 5540(3) SU 5800(1)		FW 5550(3) SU 5004(3) SU 5043(3)	FW 5560(4) SU 5800(1)

7. COURSE DESCRIPTIONS[2]

There are three groups of courses: A) required, B) core electives, and C) supporting electives. The required group consists of three courses (6 credits), an introduction to the geospatial field, research methods and a research seminar. The research methods course will be required for Plan A students and optional for Plan B & C.

The core electives group provides the set of major courses for the degree. The variety of courses provides flexibility for specific coursework selection depending on a student's area of specialization. For example, a student interested in pursuing an emphasis in Geodetics would be advised to take the Fundamentals of Remote Sensing (GE4250) course and the introductory one credit course (SU5003) combined with Computational Geosciences to fulfill a GIS component. As

[2] All courses with the exception of SU5998 and SU5999 are in the Michigan Tech undergraduate or graduate course catalogs.

another example, students interested in pursuing environmental geospatial applications might be advised to select FW5510, FW5540 and FW5560.

Supporting elective courses can be useful for tailored preparation of graduate students for specific career paths. This group includes courses in robotics and geoinformatics, which could serve the needs of a student interested in the aerospace industry; and courses in environmental policy and decision making for students seeking employment with governmental agencies.

The actual program of study for each student will be developed in consultation with an advisor and will be based on individual educational goals. Table 2 provides an overview of the schedule of course offerings and the associated instructors.

Table 5: Schedule of Course Offerings

	Notes	Course	Credits	Fall	Spring
Required Courses		SU 5010	3		Levin
	(Optional for Plan B & C)	FW 5810	2	Storer	
		SU 5800	1	PF[3]	PF
	(Required for Plan B)	SU 5998	Variable	PF	PF
	(Required for Plan A)	SU 5999	Variable	PF	PF
Elective Courses		SU 3540	4		Levin
		SU 4100	3	Levin	
		SU 4140	3	Levin	
		SU 5002	1	Shuchman	
		SU 5003	1	Brooks	Brooks
		SU 5004	3	Ternovskiy	
		SU 5020	3	Leick	
		SU 5021	3		Leick
		SU 5022	3	Leick	
		SU 5023	3		Leick
	(Alternate years)	SU 5041	3		Doytsher
		SU 5042	3	Doytsher	
	(Alternate years)	SU 5043	3		Doytsher
		SU 5540	3		Titarov
		SU 5930	3		Shuchman
		FW 5540	4	Falkowski	
		FW 5550	4	MacLean	
		FW 5560	4		Falkowski
		EE 5725	3	Tan	
		EE 5522	3		Roggeman
		GE 4100	4	Beske-Diehl	
		GE 4250	3		Carn
		SS 5300	3	MacLennan	
		SS 5350	3		Solomon

[3] PF is meant to indicate Participating Faculty members.

A. Required Courses

SU5010 Geospatial Concepts, Technologies and Data (3 credits), (Fall, Dr. Eugene Levin)
High-level review of geospatial data acquisition systems, sensors and associated processing technologies. Course considers geospatial metadata generation principles, interoperability, and major tools for manipulation with geospatial data. Course may help in transition of non-geospatial majors to geospatial field.

FW 5810 Research Methods in Natural Resources (2 credits) (Fall, Dr. Andrew Storer)
Overview of science and scientific research. The process of graduate education including choosing an advisor, selecting a research problem, writing a thesis proposal, scientific hypothesis testing, analyzing data, and communicating results through various media. **(Optional for Plan B & C students.)**

SU5800 Geospatial Master's Graduate Seminar (1 credit), (new course, Fall & Spring, participating faculty)
Student presentation of current geospatial research in a traditional seminar setting. Plan A students would be required to enroll in this course for at least their first three semesters.

SU 5998 – Graduate Practicum (Variable up to 6 credits, repeatable to maximum of 6 – Required for Plan B)
Advanced independent study for students in the Integrated Geospatial Technology Masters program. In consultation with student's advisor, develop and execute a project demonstrating capabilities in problem solving, communications, and decision making. The practicum can be done on campus or at the site of a Michigan Tech corporate partner.

SU 5999 - Master's Graduate Research (Variable up to 10 credits, repeatable to a maximum of 10 – Required for Plan A)
Research of an acceptable geospatial related problem and preparation of a thesis.

B. Elective Courses

SU5002 Infrared Technology, Sensors, and Applications (1 credit), (Fall, Dr. Robert Schuchman[4])
Infrared remote sensing fundamentals, current and future technologies, and applications are considered. Remote sensing for both civilian applications such as environmental resource mapping and military applications will be included.

SU 5003 Geographic Information Systems (GIS) Technology Fundamentals (1 credit) (Fall & Spring, Colin Brooks)
Course provides review of Geographic Information Systems applications and analysis and is intended for students who are not specializing in GIS. Includes core concepts such as data acquisition and management, topology, accuracy, metadata, output, quality control, analysis methods, new and traditional software options, web mapping, and GIS implementation/management for research and production.

SU 5004 Introduction to Geospatial Image Processing (3 credits) (Fall, Dr. Igor Ternovskiy)
Introduction to the basic concepts of image processing and understanding. Applications focus on preprocessing of satellite and aerial images, remote sensing, and image/video enhancement. This course will provide mathematical foundations and explore modern practical algorithms and methods.

SU5020 Data Analysis and Adjustments (3 credits), prerequisite SU3250(C) or equivalent (Fall, Dr. Alfred Leick[5])
Course explores fundamentals of mathematical error propagation theory including various observation equations, least squares adjustments, and Kalman filter methods. Blunder detection, decorrelation, and inversion of patterned and large matrices processes are considered. Involves analysis of position estimation deploying geospatial measurements.

SU5021 Geodetic Models (3 credits), prerequisite SU5020(C) (Spring, Dr. Alfred Leick)
Course provides solid geospatial background in geodetic reference frames: datums; geoids; and reference ellipsoids. 2D and 3D geodetic network adjustments are considered based on 3D spherical models.

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[4] Co-Director, Michigan Tech Research Institute (MTRI)
[5] Professor, Department of Spatial Information Science and Engineering, University of Maine; Adjunct Professor, Michigan Tech

SU5022 Positioning with GNSS (3 credits), prerequisite SU5020 or equivalent (Fall, Dr. Alfred Leick)
In depth study of GPS, GLONASS, Galileo, COMPASS satellite systems, theory, and processing of global positioning measurements. Strongly recommended for geospatial practitioners.

SU5023 Geospatial Positioning (3 credits), (Fall, Dr. Alfred Leick[6])
High-level summary of GPS-GAP courses. This course is intended for interdisciplinary graduate students who seek just ONE combination course in adjustments, geodesy and GPS (with emphasis on GPS/GNSS). Not available to students who have taken SU5020, SU5021, SU5022.

SU5041 Geospatial Data Processing (3 credits), (Fall, Dr. Yerach Doytsher[7])
Advanced data collection techniques; raster to vector; data conversion and map projections; topology; principles and application via advanced spatial analysis; advanced database structure; geo-database; geo-relational data model versus object-component data model; advanced 3D applications – vector and raster data model application; network analysis; linear referencing and conflation; geo-coding, GIS-CAD integration; web-based GIS innovations.

SU5042 Digital Cartography (3 credits), (Spring, Dr. Yerach Doytsher)
Spatial relations - topology, relations and relationships, directions and distances; hierarchy; generalization - vector (linear, polygonal, fractals) and raster; labeling - automatic name placement, text arrangement and deletion text; computational geometric algorithms - line intersection, polygonal relationships, grid model, route analysis.

SU5043 Topographic Analysis (3 credits), (Fall, Dr. Yerach Doytsher)
LiDAR measurements; DSM - data sources, accuracy analysis, quality control, vector data analysis; terrain representation and TIN; grid analysis - interpolation, visibility, filers (smoothing, edges, median); shading; merging overlapping DSMs; spatial analysis - spectral analysis shape analysis; automatic feature extraction from DSM.

SU 5540 Advanced Photogrammetry – Satellite Photogrammetry (3 credits) (Spring, Dr. Petr Titarov[8])
Fundamentals of spaceborne imaging systems relevant to topographic mapping. Imagery products: preprocessing levels and metadata. Specific methods of space photogrammetry. Review of contemporary spaceborne imaging systems and imagery products available. Airborne non-frame sensors and photogrammetric processing of the imagery.

SU5930 Synthetic Aperture Radar (SAR) Fundamentals and Applications (3 credits), (Spring, Dr. Robert Schuchman)
Review of radar concepts, applications of SAR (InSAR) data, types of available satellite/airborne systems, and data processing methods. Applications for creating topographic data, recognizing targets, classifying ice and vegetation, and oceans/large lakes will be presented based on real-world examples.

FW5560 Digital Image Processing: Remote Sensing Perspective (3 credits), (Spring, Dr. Michael Falkowski)
Presents the theory and quantitative procedures of digital image processing using remotely sensed data. Emphasizes image acquisition, preprocessing, enhancement, transformation classification techniques, accuracy assessment, and out-products. Discusses linkages to GIS. Also covers evaluating applications of the technology to current resource management problems via peer-reviewed literature.

SU3540 Geospatial Information Technology with Elements of Field Cartography (4 credits), prerequisite MA3710 (Spring, Dr. Eugene Levin)
Application of GIS technology methods for processing surveying data obtained in the field. Concepts of interoperability and metadata organization are considered. Includes map projection review and 2D and 3D cartographic data visualization.

C. Supporting Elective Courses

EE 5725 - Mobile Robotics & Multi-Robot Systems (3 credits) (Fall, Dr. Jindong Tan)
Introduction to mobile robotics and multi-robot systems. Introduce spatial description, mobile robot locomotion, kinematics, localization and mapping, motion planning and navigation. Topics in multi-robot systems include biological inspirations, control structure, inter-robot communication, learning in multi-robot systems, and modeling and analysis.

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[6] Senior Research Scientist, Michigan Tech Research Institute (MTRI)
[7] Professor, Civil and Environmental Engineering, Technion-Israel Institute of Technology
[8] Research scientist,

EE 5522 - Digital Image Processing (3 credits) (Spring, Dr. Michael Roggeman)
Image formation, enhancement, and reconstruction. Applications in medical imaging, computer vision, and pattern recognition.

FW 5540 - Advanced Terrestrial Remote Sensing (4 credits) (Fall, Dr. Michael Falkowski)
Remote sensing principles and concepts at the graduate level. Topics include camera and digital sensor arrays, types of imagery, digital data structures, spectral reflectance curves, applications and introductory digital image processing.

FW 5550 - Geographic Information Systems for Resource Management (4 credits) (Fall, Dr. Ann MacLean)
Use of geographic information systems (GIS) in resource management. Studies various components of GIS in detail, as well as costs and benefits. Laboratory exercises use ArcGIS software package to solve resource management problems.

FW5560 - Digital Image Processing: A Remote Sensing Perspective (4 credits) (Spring, Dr. Mike Falkowski)
Presents the theory and quantitative procedures of digital image processing using remotely sensed data. Emphasizes image acquisition, preprocessing, enhancement, transformation classification techniques, accuracy assessment, and out-products. Discusses linkages to GIS. Also covers evaluating applications of the technology to current resource management problems via peer-reviewed literature.

GE 4100 - Geomorphology and Glacial Geology (4 credits) (Fall, Dr. Suzanne Beske-Diehl)
The study of the processes, including fluvial, glacial, wind, mass movement, and wave action, shaping the earth's surface by erosion and deposition of geologic materials. Emphasizes the role of past and present climate. Field trips are a major component.

GE 4250 - Fundamentals of Remote Sensing (3 credits) (Spring, Dr. Simon Carn)
This course focuses on the basic physics behind above- surface remote sensing and remote sensing systems. Topics covered include: properties of the atmosphere, absorption and scattering of electromagnetic radiation, instrument design, data acquisition and processing, validation, and basic applications.

SS 5300 - Environmental & Energy Policy (3 credits) (Fall, Dr. Carol MacLennan)
An overview of environmental policymaking and politics in the U.S. Emphasizes policies regarding air and water pollution, toxics and hazardous waste. Discussion of rulemaking, enforcement, and administration of laws by EPA. Investigation of environmental politics on national and community levels, with focus on social movements and citizen participation.

SS 5350 - Environmental Policy Analysis (3 credits) (Spring, Dr. Barry Solomon)
The role of economic analysis in environmental policy, including a detailed review of the major tools that are used at the federal, state, regional, and local levels. Special emphasis on benefit-cost analysis and comparative risk analysis.

SU3540 Geospatial Information Technology with Elements of Field Cartography (4 credits) (Spring, Dr. Eugene Levin)
Application of GIS technology methods for processing surveying data obtained in the field. Concepts of interoperability and metadata organization are considered. Includes map projection review and 2D and 3D cartographic data visualization.

SU 4100 - Geodetic Positioning (3 credits) (Fall, Dr. Eugene Levin)
Introduces the instruments and procedures used in surveying projects that require a high order of accuracy. Discusses some conventional instruments and techniques but the greater emphasis is on GPS techniques.

SU 4140 - Photogrammetry (3 credits) (Fall, Dr. Eugene Levin)
Basic principles of photogrammetry and its role as a technology for spatial data collection. Use of photogrammetry in the fields of surveying, engineering, and geographic information management will be discussed.

8. LIBRARY AND OTHER LEARNING RESOURCES

The library has basic literature in the area of geospatial technologies but the following additional books and journals would be required.

LIST OF BOOKS (APPROXIMATE COST: $2,000)

1. *The ARRL Antenna Book*. Edited by R. Dean Straw. 21st ed: American Radio Relay League, 2007.
2. *Fractal Image Compression: Theory and Application*. Edited by Yuval Fisher. Springer-Verlag, 1996.
3. *Understanding GPS: Principles and Applications*. Edited by Elliot D. Kaplan and Christopher Hegarty. 2nd ed: Artech House Publishers, 2005.
4. Borre, Kai, Dennis M. Akos, Nicolaj Bertelsen, Peter Rinder, and Soren Holdt Jensen. *A Software-Defined GPS and Galileo Receiver: A Single Frequency Approach (Applied and Numerical Harmonic Analysis)*. Birkauser Boston, 2006.
5. Borre, Kai, and Gilbert Strang. *Linear Algebra, Geodesy and GPS*. Wellesley-Cambridge Press, 1997.
6. Diggelen, Frank van. *A-GPS: Assisted GPS, GNSS and SBAS*. Artech House, 2009.
7. Gonzalez, Rafael C., and Richard E. Woods. *Digital Image Processing*. 3rd ed: Addison-Wesley, 2007.
8. Goshtasby, Ardeshir. *2-D and 3-D Image Registration: For Medical, Remote Sensing, and Industrial Applications*, 2005.
9. Grafarend, Erik W., and J. L. Awange. *Linear and Nonlinear Models: Fixed Effects, Random Effects, and Mixed Models*. Walter De Gruyter , 2006.
10. Grafarend, Erik W., and Friedrich W. Krumm. *Map Projections: Cartographic Information Systems*. Springer-Verlag, 2006.
11. Grewal, Mohinder S., Lawrence R. Weill, and Angus P. Andrews. *Global Positioning Systems, Inertial Navigation and Integration*. 2nd ed: John Wiley, 2007.
12. Hoffman-Wellenhoff, Bernhard, Herbert Lichtenegger, and Elmar Wasle. *GNSS Global Navigation Satellite Systems: GPS, GLONASS, Galileo and More*. Springer, 2007.
13. Hofmann-Wellenhoff, Bernhard, and Helmut Moritz. *Physical Geodesy*. 2nd ed: Springer, 2006.
14. Jain, Ramesh, Rangachar Kasturi, and Brian G. Schunk. *Introduction to Machine Vision*. McGraw-Hill, 1995.
15. Leick, Alfred. *GPS Satellite Surveying*. John Wiley, 2003.
16. Misra, Pratap, and Per Enge. *Global Positioning System: Signals, Measurements and Performance*. Second ed: Ganga-Jamuna Press, 2001.

LIST OF JOURNALS (APPROXIMATE ANNUAL COST[9])

1. *GPS Solutions*, Springer, ISSN: 1080-5370 (Available through SpringerLink)
2. *Journal of Geodesy*, Springer, ISSN: 0949-7714 (Available through SpringerLink)
3. *Photogrammetric Engineering and Remote Sensing*, American Society for Photogrammetry and Remote Sensing (ASPRS), ISSN: 0099-1112 ($270/year)
4. *ISPRS Journal of Photogrammetry and Remote Sensing*, Elsevier Science, ISSN: 0924-2716 (Available through ScienceDirect)
5. *Surveying and Land Information Science*, National Society of Professional Surveyors, ISSN: 1538-1242

9. COMPUTING ACCESS FEE

A computer access fee[10] of $210 (2010-11) per semester will be required for students enrolled in this program and additional university Distance Learning fees may be required for on-line courses.

[9] From Ellen Marks, Library Director on 12/10/2010: "The library currently subscribes to most of the journals requested. One is only available in print (and it is in the collection). There is one for which we will request pricing once the program is approved but the need will not come close to the $12K proposed in the new degree/certificate proposal."

10. FACULTY RESUMES

MICHIGAN TECH

Colin Brooks (http://expertise.cos.com/cgi-bin/exp.cgi?id=1265087)

Michael Falkowski,PhD (http://forest.mtu.edu/faculty/falkowski/)

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

Ann MacLean, PhD (http://forest.mtu.edu/faculty/maclean/)

Robert Schuchman, PhD (http://expertise.cos.com/cgi-bin/exp.cgi?id=1289668)

Andrew Storer, PhD (http://forest.mtu.edu/faculty/storer/)

Surveying Engineering (Search in progress for a replacement faculty member - 2/21/2011)

INTELLIGENT OPTICAL SYSTEMS, INC.

Igor Ternovskiy, PhD (http://www.intopsys.com)

RACURS

Petr Titarov, PhD (http://www.racurs.ru)

TECHNION, ISRAEL INSTITUTE OF TECHNOLOGY

Yerach Doytsher, PhD (http://www.technion.ac.il/~doytsher/13.htm)

UNIVERSITY OF MAINE

Alfred Leick, PhD (http://www.gnss.umaine.edu)

11. DESCRIPTION OF AVAILABLE/NEEDED EQUIPMENT

The 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
- Arc GIS licenses (unlimited) (available via Michigan Tech)
- Carlson Civil Suite software (90 licences) $927,000
- SimWright StereoGIS softcopy photogrammetric workstation (5 licenses) $50,000
- Cardinal Systems VrMapping photogrammetric software suite (12 licenses) $120,000
- Chrysler PT Cruiser vehicle $6,700
- Small aerial UAV (in production with ME-EM aerospace student enterprise) $13,000
- RIEGL 3D Imaging Sensor LMS-Z210ii terrestrial LiDAR scanner $50,000

Total current assets are valued at $1,762,700.

[10] A proposal from the university CIO to remove all computer access fees starting July 1, 2011 is being considered.

The School of Technology and MTRI have all the necessary equipment and software licenses to start the proposed graduate degree program.

12. PROGRAM COSTS

The Graduate program may be started without additional costs since a portion of the distance learning tuition revenue will be used to support the external instructors. The plan is to have an agreement that pays the instructors a fixed amount per student with a cap on the maximum compensation per class. This means that classes with very low enrollment might not be offered if the instructor does not feel there is adequate compensation. Tuition revenue from classes with enrollment beyond the break-even point could possibly be used to subsidize low enrollment classes.

The majority of the courses for this program have been developed, and the remaining ones will be developed by participating faculty members who have agreed to do this at no cost. Any incidental development costs will be provided by the School of Technology. All participating faculty members have made commitments to offer their classes, with the exception for low enrollment as described above.

There are nine classes that could be taught on-line by external faculty members. On-line tuition revenue must pay for their salaries. All other faculty members are Michigan Tech employees who teach as part of their assigned workload.

Appendix A contains a spreadsheet with enrolment estimates and the corresponding revenue that would be generated for all courses. In addition it provides an estimate of the on-line tuition revenue, assuming the traditional 2/3 return, that would be available to pay the external faculty members. Using conservative enrollment estimates, approximately $88,000 would be available to allocate to the nine courses taught by external faculty members. A modest growth in enrollment is expected as the program matures which would result in a more positive financial outcome.

13. SPACE

Several shared graduate student offices will be required for full-time students (one room for each 5 students). In the event that a geospatial faculty member is hired as part the SFHI, an office in the School of Technology (EERC) might be needed in the future. Planned space for theses offices will become available in the EERC as the fifth floor renovations are completed.

14. POLICIES, REGULATIONS AND RULES

Admission Requirements:

Applicants must meet all requirements imposed by the graduate school at the time of application, and must follow the specified admissions procedures. For international applicants this includes submission of TOEFL or IELTS scores.

It is anticipated that applicants will come from various technical disciplines and will most likely have taken the appropriate foundation courses. To be specific all applicants must have:

- three college-level calculus courses,
- an object-oriented programming course,
- and college level physics.

In addition, a course in linear algebra is recommended.

The Admissions Committee, in making its final decision, will consider the combination of professional knowledge, academic excellence, letters of recommendation, and the Statement of Purpose, as well as English proficiency test scores of the applicant. Initially, this committee will be composed of two faculty members from Surveying Engineering, Dr. Eugene Levin and new faculty member who will be in place for Fall 2011; and two faculty members from the School of Forest Resources and Environmental Sciences, Dr. Michael Falkowski and Dr. Ann MacLean. Dr. Levin, together with the Dean of the School of Technology, will have responsibility for signing off on all required forms.

15. ACCREDITATION REQUIREMENTS

None.

16. INTERNAL STATUS OF THE PROPOSAL

Approved by: Dean's Council
Date: October 7, 2010

Approved by: Graduate Faculty Council
Date: December 7, 2010

Approved by: Faculty Senate
Date:

17. PLANNED IMPLEMENTATION DATE

Fall semester of 2011.

Revision History:

Version 1.0:

Document as approved by the Graduate Faculty Council.

Version 1.1:

Changed "Engineering Report" to "Report" in Table 1.
Updated course title of SS 5300 to reflect current usage.
Added the text in Section 14. specifying Admission Requirements, as presented at the December 7, 2010 Graduate Faculty Council meeting.
Added approval text and dates in Section 16.
Changed planned implementation date from 2010 to 2011 in Section 17.

Version 1.2:

Several changes throughout the document to address questions raised by Senate Curricular Policy Committee.

APPENDIX A: ESTIMATED ANNUAL REVENUES

I

			Tuition $/Credit	$625.00							
			Fall					Spring			
	Credits	Distance	Enrollment	Revenue	2/3-Model	Instructor		Enrollment	Revenue	2/3-Model	Instructor
SU 5010	3	Y		$0.00	$0.00			5	$9,375.00	$6,250.00	Levin
FW 5810	2	N	2	$2,500.00	$0.00	MacLean			$0.00	$0.00	
SU 5800	1	Y	2	$1,250.00	$833.33			2	$1,250.00	$833.33	
SU 5998	1	N	3	$1,875.00	$0.00			3	$1,875.00	$0.00	
SU 5999	1	N	2	$1,250.00	$0.00			2	$1,250.00	$0.00	
SU 3540	4	N		$0.00	$0.00			2	$5,000.00	$0.00	Levin
SU 4100	3	N	2	$3,750.00	$0.00	Levin			$0.00	$0.00	
SU 4140	3	N	2	$3,750.00	$0.00	Levin			$0.00	$0.00	
SU 5002	1	Y	5	$3,125.00	$2,083.33	Shuchman			$0.00	$0.00	
SU 5003	1	Y	3	$1,875.00	$1,250.00	Brooks		3	$1,875.00	$1,250.00	Brooks
SU 5004	3	Y	5	$9,375.00	$6,250.00	Ternovskiy			$0.00	$0.00	
SU 5020	3	Y	5	$9,375.00	$6,250.00	Leick			$0.00	$0.00	
SU 5021	3	Y		$0.00	$0.00			5	$9,375.00	$6,250.00	Leick
SU 5022	3	Y	5	$9,375.00	$6,250.00	Leick			$0.00	$0.00	
SU 5023	3	Y		$0.00	$0.00			5	$9,375.00	$6,250.00	Leick
SU 5041	3	Y		$0.00	$0.00			5	$9,375.00	$6,250.00	Doytsher
SU 5042	3	Y	5	$9,375.00	$6,250.00	Doytsher			$0.00	$0.00	
SU 5043	3	Y		$0.00	$0.00			5	$9,375.00	$6,250.00	Doytsher
SU 5540	3	Y		$0.00	$0.00			5	$9,375.00	$6,250.00	Titarov
SU 5930	3	Y		$0.00	$0.00			5	$9,375.00	$6,250.00	Shuchman
FW 5540	4	Y	5	$12,500.00	$8,333.33	Falkowski			$0.00	$0.00	
FW 5550	4	N	5	$12,500.00	$0.00	MacLean			$0.00	$0.00	
FW 5560	4	Y		$0.00	$0.00			3	$7,500.00	$5,000.00	Falkowski
EE 5725	3	N		$0.00	$0.00	Tan			$0.00	$0.00	
EE 5522	3	N		$0.00	$0.00				$0.00	$0.00	Roggeman
GE 4100	4	N		$0.00	$0.00	Beske-Diehl			$0.00	$0.00	
GE 4250	3	N		$0.00	$0.00				$0.00	$0.00	Carn
SS 5300	3	N		$0.00	$0.00	MacLennan			$0.00	$0.00	
SS 5350	3	N		$0.00	$0.00				$0.00	$0.00	Solomon
				$81,875.00	$37,500.00				$84,375.00	$50,833.33	

Introduced to Senate: 06 April 2011
Adopted by Senate: 20 April 2011
Approved by Administration: 27 April 2011
Approved by BOC: 29 April 2011
Approved by State: 03 June 2011