

**Course: SURE 440****Advanced Photogrammetry**

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<b>Credits:</b>	3 Hours
<b>Contacts:</b>	2 Lecture (T,R 12:00-12:50 Swan 207), 3 Lab Hours (T, R 8:00 – 10:50 Swan 201) per week
<b>Course Description:</b>	This course acquaints the student to advanced photogrammetric concepts that are normally encountered in photogrammetric practice. Topics include an introduction to analytical photogrammetric principles, concepts of the bundle adjustment, principles of advanced sensors, orthophotography, and principles of digital photogrammetry.
<b>Course Prerequisites:</b>	SURE 340, SURE 373
<b>Course Outline:</b>	The official course outline for this course can be located at the SURE 440 web site as well as on the FerrisConnect SURE 440 site.

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<b>Required Textbooks:</b>	Elements of Photogrammetry, 3 <sup>rd</sup> edition, by P. Wolf and B. Dewitt, McGraw-Hill
<b>Course Web Site:</b>	Reference materials, mandatory supplemental reading, assignments, instructor messages and other information are provided through the SURE 440 web page and Ferris Connect site for this course. Daily reference is mandatory.
<b>Reference Textbooks:</b>	<ol style="list-style-type: none"><li>1. Introduction to Modern Photogrammetry, E.M. Mikhail, J.S. Bethel, and J.C. McGlone, John Wiley.</li><li>2. Manual of Photogrammetry, 5<sup>th</sup> edition, J.C. McGlone, E.M. Mikhail, and J.S. Bethel, American Society for Photogrammetry and Remote Sensing</li><li>3. Digital Photogrammetry, T. Schenk, TerraScience.</li><li>4. Photogrammetry, 2<sup>nd</sup> edition, Karl Kraus</li><li>5. Analytical Photogrammetry, S. Ghosh, Pergamon Press.</li><li>6. Analytical Photogrammetry, ENG 431 Lecture Notes by A. Habib, <a href="http://dprg.geomatics.ucalgary.ca/index.php?option=com_content&amp;task=view&amp;id=103&amp;Itemid=22">http://dprg.geomatics.ucalgary.ca/index.php?option=com_content&amp;task=view&amp;id=103&amp;Itemid=22</a></li></ol>

<b>Required Materials:</b>	Some form of memory device such as a USB memory stick, external hard drive, etc.
<b>Reference Materials:</b>	Students should visit the SURE 440 web page to find material for this course. The URL for the web site is: <a href="http://www.ferris.edu/faculty/burtchr/sure440.html">http://www.ferris.edu/faculty/burtchr/sure440.html</a> . The site contains links to additional pages like the Syllabus (which contains links to the lecture notes), Assignments, Glossary of Terms, Questions that have appeared on past exams, Term Paper Topics, and Pictures. Additionally, some of this material will also be shown on FerrisConnect along with additional information if needed.
<i>Other suggested or supplemental materials</i>	None

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**Faculty: Prof. Robert Burtch**

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Office Hours:

Alt. Phone:  
Alt. Email:

Day	Times	Day	Times
Monday	9:00 – 9:50 AM	Tuesday	4:00 – 4:50 PM
Wednesday	9:00 – 9:50 AM	Thursday	2:00 – 2:50 PM

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**Student Learning Outcomes**

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Students satisfactorily completing this course will achieve/complete/demonstrate...:

1. Be able to transform coordinates from one system to another using the 3-parameter, 4-parameter, 6-parameter, 8-parameter, and polynomial transformation models.
2. From first principles, will be able to derive the formula for the Helmert (4-parameter) transformation.
3. Be able to apply corrections to photo observations including lens distortion, atmospheric refraction, and earth curvature.
4. Be able to explain in writing the differences in First-Order, Second-Order and Third-Order theory in analytical photogrammetry.
5. Be able to describe in writing the physical concept described in the collinearity condition equation.
6. From first principles, will be able to derive the observation equations for Case I, Case II, Case III, and Case IV Single Photo Resection and Orientation.
7. Be able to write a program to adjust a set of photo observations for Single Photo Resection and Orientation.
8. Be able to describe in writing the advantages and limitations with direct sensor orientation.
9. Be able to describe in writing the physical interpretation of the observation equations utilized in airborne GPS specifically and mobile mapping systems in general.
10. Be able to perform a small mapping project including both creating an orthophoto and vector map using available software in the laboratory.
11. Be able to identify in writing the rectification principles of orthophotography.
12. Be able to filter digital data for enhancement purposes.
13. Be able to describe in writing the first principles of image correlation and matching, including advantages and disadvantages of the different approaches.

## Course Assessments

Course assessment will be performed using examinations, homework, and laboratory exercises. The course assessment will also include a student project at the end of the course and a research paper that will be presented to the class during the last week of the semester.

## Course Policies

<b>Attendance:</b>	<p>I understand that each student may upon occasion need to be away from class due to illness or other important matters. The following policy recognizes these life issues but at the same time reflects the real world need to be present in class in order to learn and share your learning with others in the class.</p> <p>Each student will be allowed to miss up to 4 classes, either lectures or lab, without penalty. These absences may be for any reason and do not require giving me an excuse. A student who is absent a fifth time will be required to withdraw from the course if this absence occurs during the withdrawal period of the semester. If this absence occurs after the withdrawal period the student will receive a failing (F) grade in the course. The four absences a student may have represents nearly 10% of the meeting dates and far exceed any absence policy that would exist in business, industry or other professional areas. All laboratory absences must be made up during the semester.</p> <p>Exceptions to the Attendance Policy (Verification of all exceptions is necessary):</p> <ol style="list-style-type: none"><li>1. A University-sponsored event in which an excused absence from the Vice President for Academic Affairs office is given.</li><li>2. Death of a family member or close personal relation (friends, neighbors).</li><li>3. Extended hospitalization (this does not apply to a visit to the health center because of a cold or other illness).</li><li>4. Jury duty or being subpoenaed to testify in a court case.</li><li>5. Dangerous weather conditions in which driving is considered by local authorities to be unsafe (for commuter students).</li></ol>
<b>Assignments:</b>	<p>Homework and lab assignments will be submitted to the FerrisConnect web page for this class. Use the SURE 440 assignment template provided on the course web page. Send the assignments as attachments. Use the following naming convention: <i>last_name – assignment number</i>. For example, for lab 1 the file will have the file name: burtch – lab 1. Note that your last name is in lower case and that there are spaces around the hyphen and also before the number.</p> <p>A cover sheet will be included with each assignment identifying the assignment, student name, and the class.</p> <p>Assignments will be typed, unless the work requires numerical solutions. It is</p>

	<p>assumed that you can put together a correctly structured assignment, free of technical and spelling errors. Assignments with more than 4 combined spelling or grammar errors will be returned to be rewritten. I will require any student that is found to have significant deficiencies in their writing to use the services of the University Writing Center in an effort to improve such deficiencies to a satisfactory level.</p> <p>When graphical output is required for an assignment, the output should be properly identified and located in the appropriate part of the assignment. If the graphical output is being done by hand, it must be drawn using a straight-edge and appropriate templates. Label all parts of the graphic as appropriate.</p> <p>Work that is submitted in hand-written form must be prepared on engineering paper in pencil. Corrections will be erased or placed above the incorrect values that will be stuck out with a single line through the error. Use only the front side of the sheet. Always include units in the answer and highlight the answer by either underlining it, placing a box around the answer, or by using a highlighter. When you have answers that are less than 1, always begin the number with a zero. For example, .471 shall be written as 0.471. When writing angles, minutes and seconds must always have two units, excluding any decimal portion. If a minute or second contains only single units, i.e., 4 minutes, 7 seconds, the number shall be preceded by a zero. In this case the angle shall be written as 04' 07". Unless otherwise stated, all angles will be presented in degrees, minutes and seconds format. Use common sense in portrayal of significant figures. Each assignment will be submitted in a report folder. Unless otherwise stated, only one assignment per folder will be accepted. See a sample at the end of this syllabus.</p> <p>Lab reports will consist of a least 3 main parts:</p> <ol style="list-style-type: none"><li>1. Purpose of the lab written in your own words.</li><li>2. Procedure. In this section succinctly identify the procedures employed in the lab and your results.</li><li>3. Conclusion. This section will consist of a discussion of the lab in general and upon your results in particular. Such items of importance might be the validity of the lab, limitations of the results, possible sources of errors that might affect the results, items you might have done differently, special problems encountered, etc.</li></ol> <p>For term paper requirements and speech guidelines, see the following web page: <a href="http://www.ferris.edu/faculty/burtchr/trm_papr.html">http://www.ferris.edu/faculty/burtchr/trm_papr.html</a>. The topic for the paper must be approved by the instructor. A topic will be submitted to the faculty member at the end of the second week. The proposal will be a short paragraph explaining the topic being proposed and the approach taken to research the topic. For a list of possible topics, see: <a href="http://www.ferris.edu/faculty/burtchr/sure440/topics.html">http://www.ferris.edu/faculty/burtchr/sure440/topics.html</a>.</p>
<b>Behavior:</b>	It is essential that everyone in this class establish a mutual respect amongst each other in this class. Therefore, there are a few simple rules that you will be asked to adhere to; most of these can be defined as good manners. These

	<p>rules are:</p> <ul style="list-style-type: none"><li>• Class starts on the hour so please make every effort to arrive on time by planning ahead for any contingencies.</li><li>• Class lasts for 50 minutes so do not begin to pack up your books and other items early. This is very distracting to me and your fellow students. You are expected to participate throughout the entire class period.</li><li>• Turn off all cell phones, pagers, PDA's, and other electronic devices before class. If there are extenuating reasons, please see me.</li><li>• During the lecture, feel free to ask questions, but refrain from conducting personal conversations. Again, this is very disruptive.</li><li>• Sleeping, eating and reading newspapers are not allowed in class. While in class the student is expected to pay attention and participate in this class and not finish work for another class during this class periods.</li><li>• Come to class prepared. Instructional material students should not be without include, as a minimum, writing material, computer disks and calculators.</li><li>• Students are expected to check the web page for this course weekly and students are responsible for all material on this web page along with textbook and other readings.</li><li>• When you leave the classroom, please pick up after yourself. Try to leave the room cleaner than when you found it.</li></ul>
<p><b>Exams and quizzes:</b></p>	<p>The exams will be primarily Multiple Choice and True/False tests. This will constitute about 60-80% of the exam, depending on the topics covered in the exams. The remaining parts of the exam will contain Short Answer questions as well as mathematical problems.</p> <p>Students absent from class for a test must make arrangements to take the exam prior to the next class meeting. Failing to do so will result in a grade of 0%. It is the student's responsibility to call me to set up a time to make up the test. Missing quizzes will not be made up outside of class. This course may have a cumulative final exam.</p> <p>Final examination schedule guidelines from the Registration and Academic Guide:</p> <p><i>In the event that three or more final examinations are scheduled on the same day during the examination week a student may elect to take only the first and last of those regularly scheduled on that day. Such election by the student to the affected instructor must be made no later than two weeks prior to the exam date. It will be the responsibility of the student to present authentication to the instructor of the course affected. The rescheduled exam will then be taken on another day during the examination week as arranged by the course instructor and the student.</i></p>

<b>Ferris Connect:</b>	Ferris Connect site must be referenced daily by students for access to instructor messages and course information.
<b>Grading Percentage:</b>	<p>Student performance is based on 3 general groups: exams/quizzes, term paper/presentation, and assignments. Weight for each may vary based on the category. Generally, mid-term exams have a weight of 100 points while the final exam is generally around 150 points. Quizzes, if given, are usually assigned a weight of 10 points. Assuming exams only, if the total number of points is 350 and you scored an 85, 72, 137, then the number of points for exams/quizzes is <math>(85 + 72 + 137)/3.50 * 0.60 = 50</math>. The term paper is based on a letter grade (A, B, C, D, F) which are then converted to a numeric grade of (95, 85, 75, 65, 50) respectively. The assignments will have varying weights, depending on the particular assignment. The weights for the term paper/presentation and assignments are computed in a similar fashion as the exams. The final breakdown for the course grade is as shown below:</p> <p>60% from exams and quizzes 20% from term paper and presentation 20% from assignments (lab assignments, homework, project, and readings) 100% TOTAL</p> <p>The course grading scale is:</p> <p>90 – 100% - A Range 80 – 89% - B Range 70 – 79% - C Range 60 – 69% - D Range 0 – 59% - F Range</p>
<b>Integrity:</b>	All of your assignments must be developed independently. Cheating of any type will result in loss of credit or more serious consequences.
<b>Student Responsibilities:</b>	<p>When conducting field work, students must wear safety vests. In all cases, be aware of traffic. There is no reason why measurements need to be conducted in traffic. Be aware of your surroundings at all times.</p> <p>Assistance in this course is available to help you with academic and other difficulties you may be experiencing. It is your responsibility to seek help.</p> <ol style="list-style-type: none"> <li>1. Office hours – I will be happy to work with you during regularly scheduled office hours.</li> <li>2. Pre-scheduled assistance outside of normal office hours (as my schedule permits).</li> <li>3. Meet with your Academic advisor.</li> <li>4. Meet with an educational counselor. College Educational Counselor – Vordyn Nelson x 2890, JHN 200</li> <li>5. The ACADEMIC SUPPORT SERVICES CENTER offers free tutoring and assistance for test anxiety, study skills, writing skills, exam preparation, content reading, personal growth, and classroom skills. The Center is located in Room 1017 of the Arts and Sciences Commons Buildings and they can be reached at 591-3543.</li> </ol>

## Course Schedule

Date	Lecture Topic	Preparation	Assignment
Week 1	Introduction: Understand course objectives, grading policy, etc.; Review of basic concepts in photogrammetry		Lab 1 (4 weeks – Review of LPS)
Week 2	Transformations, affine transformation, polynomial transformation	Lecture Notes Appendix C	Homework 1
Week 3	Transformations in three dimensions	Lecture Notes Appendix C	Homework 1
Week 4	Corrections to photo coordinates: interior orientation, film deformation, lens distortion, atmospheric refraction, earth curvature	Lecture Notes Chapter 4	Homework 2 Lab 2
Week 5	Collinearity condition, coplanarity equation, linearization of collinearity equations	Lecture Notes Appendix D	Lab 3 (4 weeks)
Week 6	Mid-Term Exam #1, October 8		
	Numerical resection and orientation	Lecture Notes Chapter 11	
Week 7	Numerical resection and orientation	Lecture Notes	
Week 8	Principles of aerial triangulation	Lecture Notes Chapter 17	
Week 9	Principles of airborne GPS triangulation and direct sensor orientation with emphasis on mobile mapping	Lecture Notes Chapter 17	
Week 10	Orthophotography: creation of orthophotos, rectification, advantages and disadvantages	Lecture Notes Appendix E	Lab 4 (3 weeks)
Week 11	Principles of laser scanning for mapping	Lecture Notes	
Week 12	Mid-Term Exam #2, November 19		
	Digital photogrammetry; basic principles of DPW, scanners and digital cameras	Lecture Notes Chapter 15	Lab 5 (3 weeks)
Week 13	Image processing: principles of human vision, resampling, compression, geometric corrections	Lecture Notes Chapter 14	Homework 3
Week 14	Image processing: filtering, image transformation and programming with images	Lecture Notes Chapter 14	Homework 4

Week 15	Digital photogrammetry: image correlation and matching, principles of computer vision, Hough transform, object recognition	Lecture Notes Chapter 14	
Week 16	Final Exam – Tuesday, December 15, 12:00 – 1:40 PM		

**Final Note:**

**I reserve the right to make needed and appropriate adjustments in this syllabus.**

### Sample Format for Homework Assignments

The following pages will show how a typical assignment should be completed, whether solving the problem by hand or using Mathcad. Always show the formulas when applicable and highlight the answer. Briefly identify the steps involved in the solution.

Drawings should be used when appropriate. Use a straight edge, compass and/or template when drawing figures. Label all pertinent elements of the drawing.

The question that is answered in the next two pages is:<sup>1</sup>

1. The distance measured between two points on a map to a scale of 1:62,500 is 29.05 mm. The distance measured between the images of these same two points on a vertical photograph taken with a lens having a 152.14 mm focal length is 54.81 mm. Both points lie at an elevation of 240 ft. as determined from the map. Compute the flying height for the photograph.

The first page is the hand solution while the second is the Mathcad solution.

<sup>1</sup> Moffitt, F., 1967. Photogrammetry, 2<sup>nd</sup> edition, International Textbook Company, Scranton, PA.

SAMPLE HOMEWORK

NAME

1/1

1) GIVEN:  $S_M = 1:62,500$   
 $ab_M = 29.05 \text{ mm}$   
 $f = 152.14 \text{ mm}$   
 $ab_P = 54.81 \text{ mm}$   
 $h = 240 \text{ ft}$

FIND H.

SOLUTION:  $S_P = \frac{f}{H-h} \Rightarrow H = \frac{f}{S_P} + h$

$$S_P = \frac{ab_P}{AB} \Rightarrow AB = \frac{ab_P}{S_P}$$

$$S_M = \frac{ab_M}{AB} \Rightarrow AB = \frac{ab_M}{S_M}$$

$$\therefore \frac{ab_P}{ab_M} = \frac{S_P}{S_M} \Rightarrow S_P = \frac{ab_P}{ab_M} S_M = \frac{54.81 \text{ mm}}{29.05 \text{ mm}} \left( \frac{1}{62,500} \right)$$
$$= \frac{1}{33,125.8}$$

then,

$$H = \frac{f}{S_P} + h = \left( \frac{152.14 \text{ mm}}{\frac{1}{33,125.8}} \right) \left( \frac{1''}{25.4 \text{ mm}} \right) \left( \frac{1'}{12''} \right) + 240'$$
$$= \underline{\underline{16,775'}}$$

22-141 50 SHEETS  
22-142 100 SHEETS  
22-144 200 SHEETS



### Sample Format for Using Mathcad in Assignments

Given:	$S_m := \frac{1}{62500}$	Scale of map
	$ab_m := 29.05\text{mm}$	Distance on map
	$f := 152.14\text{mm}$	Focal length of camera
	$ab_p := 54.81\text{mm}$	Distance on photo
	$h := 240\text{ft}$	Elevation of two points

What is H?

Solution:

$$S_p := \left( \frac{ab_p}{ab_m} \right) \cdot S_m$$

$$S_p^{-1} = 33125.8$$

Scale of photo is 1:33,125.8

$$H := \frac{f}{S_p} \cdot \left( \frac{1\text{in}}{25.4\text{mm}} \right) \left( \frac{1\text{ft}}{12\text{in}} \right) + 240\text{ft}$$

$$H = 16775 \text{ ft}$$