INTRODUCTION TO GEOSPATIAL SYSTEMS
Syllabus

OVERVIEW
This introductory course explores remote sensing, geographic information systems (GIS) and the global positioning system (GPS) though visually-enriching presentations and labs.

REQUIREMENTS
This course has several requirements for full implementation. This includes access to a GIS program, GPS units, UAV's, photogrammetry software, laser range-finders and ground-penetrating radar systems. Additional details are located under "Assessment Details" at the end of this document.

TEXTS
Remote Sensing and Image Interpretation by Lillesand, Kiefer and Chipman, Sixth Edition or Above, Wiley (Strongly Recommended)

An Introduction to Geographical Information Systems by Heywood, Cornelius and Carver, Third Edition or Above, Pearson (Strongly Recommended)

GPS Made Easy by Letham & Letham, Fifth Edition, Mountaineers Books (Optional)

Outdoor Navigation with GPS by Hinch, Third Edition, Wilderness Press (Optional)

CALIFORNIA CONTENT STANDARDS ADDRESSED

ESS2.D
Weather and Climate. The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space. (HS-ESS2-2) (HS-ESS2-4)

HS-ESS3-2
Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.* [Clarification Statement: Emphasis is on the conservation, recycling, and reuse of resources (such as minerals and metals) where possible, and on minimizing impacts where it is not. Examples include developing best practices for agricultural soil use, mining (for coal, tar sands, and oil shales), and pumping (for petroleum and natural gas). Science knowledge indicates what can happen in natural systems—not what should happen.]

HS-PS4-2
Evaluate questions about the advantages of using a digital transmission and storage of information. [Clarification Statement: Examples of advantages could include that digital information is stable because it can be stored reliably in computer memory, transferred easily, and copied and shared rapidly. Disadvantages could include issues of easy deletion, security, and theft.]

DISCIPLINARY CORE IDEAS

PS4.B Electromagnetic Radiation
Atoms of each element emit and absorb characteristic frequencies of light. These characteristics allow identification of the presence of an element, even in microscopic quantities. (secondary to HS-ESS1-2)

ESS3.A: Natural Resources
Resource availability has guided the development of human society. (HS-ESS3-1)
All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors. (HS-ESS3-2)

ETS1.B: Developing Possible Solutions
When evaluating solutions, it is important to take into account a range of constraints, including cost, safety, reliability, and aesthetics, and to consider social, cultural, and environmental impacts. (secondary to HS-ESS3-2),(secondary to HS-ESS3-4)

PS4.A: Wave Properties
The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. (HS-PS4-1)

PS4.B: Electromagnetic Radiation
Electromagnetic radiation (e.g., radio, microwaves, light) can be modeled as a wave of changing electric and magnetic fields or as particles called photons. The wave model is useful for explaining many features of electromagnetic radiation, and the particle model explains other features. (HS-PS4-3)

CROSS CUTTING CONCEPTS

Structure and Function
The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (HS-ESS2-5)

Stability and Change
Much of science deals with constructing explanations of how things change and how they remain stable. (HS-ESS2-7)
Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. (HS-ESS2-1)

Influence of Engineering, Technology, and Science on Society and the Natural World
Modern civilization depends on major technological systems. (HS-ESS3-1),(HS-ESS3-3)
New technologies can have deep impacts on society and the environment, including some that were not anticipated. (HS-ESS3-3)
Analysis of costs and benefits is a critical aspect of decisions about technology. (HS-ESS3-2)

Energy and Matter
Changes of energy and matter in a system can be described in terms of energy and matter flows into, out of, and within that system. (HS-PS3-3)

Systems and System Models
Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales. (HS-PS4-3)

COURSE OUTLINE

UNIT#1: Introduction

Module 1 – Introduction to Geospatial Systems
Topics: Geospatial Systems, Remote Sensing, GIS, GPS, Applications (City Planning & Management, Business, Military, Law Enforcement, Environment, Preventing Hunger, Tracking Disease, Empowering People, Self-Driving Cars).

Module 2 – Satellites
Topics: Manufacturing, Satellite Manufacturing, Clean Rooms, Satellite Testing, Launch Vehicle, Launch Options, Sensors, Sensor Selection, Orbit Selection, Launch Site, Mission Control, Small Satellites, Space Debris.

UNIT#2: Remote Sensing

Module 1 – Introduction to Remote Sensing
Topics: Remote Sensing, EM Radiation, Units of Wavelength, Equation of Light, Planck Formula, EM Spectrum, Photons, Stefan-Boltzmann Law, Blackbody, Wein's Law, Atmospheric Window, Atmospheric Scattering, Rayleigh & Mie Scattering, Atmospheric Absorption, Earth's Energy Interactions (Incident Energy, Absorbed Energy, Reflected Energy, Transmitted Energy), Atmospheric Absorption Bands, Water Absorption Bands, Chlorophyll Absorption Bands,

Spectral Reflectance (Properties, Patterns, Curve, Water & Vegetation, Soil, Grass, Snow, Trees, Visible VS Infrared), Spectroradiometer, Temporal Effects, Spatial Effects, Active & Passive Sensors, Data Acquisition, Photography, Electronic Sensors, Spatial Resolution, Spectral Resolution, Radiometric Resolution, Temporal Resolution, Topography, Digital Elevation Model, Shaded Relief, 3D Perspective View, Reference Data, Time-Critical Measurements, Time-Stable Measurements, Initial Steps for Planning Remote Sensing Activities.

5E Handout

Module 2 – Photographic Systems
Topics: Advantages Over Ground Observations, Camera Description, Extraneous Effects, Vignetting, Colors, Color Film Photography, Filters, Absorption Filters, Wavelength Filters, Corrective Filters, Film Photography, Black & White Photo Production, Film Density, Characteristic Curves, Film Speed, Exposure Latitude, Radiometric Resolution, Black & White Films, Color Film, Color Infrared Film, Digital Photography, CCD VS CMOS, Aerial Cameras, Single-Lens Frame Film Cameras, Image Motion Compensation, Panoramic Film Cameras, Small-Format Digital Cameras, Large-Format Digital Cameras, Digital VS Scanned Film, Spatial Resolution of Film Camera Systems, Spatial Resolution of Digital Camera Systems, Aerial Videography, Analog Video Recording, Digital Video Recording, Aerial Videography Advantages & Disadvantages, Multiband Imaging.

Module 3 – Photogrammetry
Topics: Photogrammetry, Photogrammetric Activities, Vertical Photographs, Oblique Photographs, Camera Orientation, Relief Displacement, Orthophotos, Digital Orthophotos, Flight Line, Nadir Line, Stereo Pair, Overlap, Index Mosaic, Photo Coordinates, Photographic Scale, Large VS Small Scale, Aerial Photographs: Ground Coverage, Relief Displacement: Vertical Features, Parallax, Ground Control, Planimetric Maps, Stereoplotters, Photographic Mission Parameters.

Photogrammetry Lab

Module 4 – Visual Image Interpretation
Topics: Interpretation Process, Characteristics (Shape, Size, Pattern, Tone/Hue, Texture, Shadows, Site, Association, Resolution), Image Interpretation: Strategies, Inference Example: Buried Pipeline, Crop Calendar, Interpretation Keys, Selective Key, Elimination Key, Dichotomous Key, Image Interpretation: Temporal Aspects, Vegetation Changes, Soil Moisture Changes, Leaf-On and Leaf-Off, Image Scale, Image Interpretation Process – Approach, Classification System, Minimum Mapping Unit, Stereoscope, Land Use & Land Cover, Land Use Map, Land Cover Map, Land Use/Cover Mapping, USGS Classification, Level I Terminology (Urban or Build-Up Land, Agricultural Land, Rangeland, Forest Land, Water,

Wetland, Barren Land, Tundra, Perennial Snow or Ice), Geologic Mapping, U.S. Geological Map, Soil Mapping, Agricultural Applications, Forestry Applications, Tree Species Identification, Rangeland Applications, Water Resource Applications, Water Pollution Detection, Flood Damage Assessment, Lake Eutrophication, Urban & Regional Planning Applications, Wetland Mapping, Wildlife Ecology Applications, Archaeological Applications, Environmental Assessment, Natural Disaster Assessment, Landform Identification & Evaluation, Soil Characteristics, Land Use Suitability Evaluation, Image Interpretation for Landform Identification & Evaluation (Topography, Drainage Pattern & Texture, Erosion, Image Tone, Vegetation & Land Use), Sedimentary Rocks (Sandstone, Shale, Limestone), Igneous Rocks (Intrusive, Extrusive), Metamorphic Rocks.

Module 5 – Multispectral, Thermal & Hyperspectral Sensing
Topics: Multispectral Scanners, Across-Track Scanning, Along-Track Scanning, Mirror Scanning VS Linear Array, Thermal Scanning, Thermal Radiation Principles (Radiant VS Kinetic Energy, Blackbody Radiation, Radiation from Materials, Atmospheric Effects, Thermal Radiation Interaction with Matter), Atmospheric Effects, Interpreting Thermal Scanner Imagery, Thermal Scanners: Radiometric Calibration, FLIR Systems, Hyperspectral Sensing.

Module 6 – Earth Resource Satellites
Topics: Orbit Selection, Orbital Elements, LEO, Sun-Synchronous Orbit, Polar Orbit, MEO, High Earth Orbit, Geosynchronous Orbit, Geostationary Orbit, Highly Elliptical Orbit, Early History of Space Imaging (TIROS-1, MA-6, GEMINI 4, Apollo 9, Skylab), LandSats Overview, LandSat 1-3, LandSat 4-5, LandSat 6, LandSat 7, LandSat 8, Additional Earth Resource Satellites (OrbView-2, Terra, Aqua, NOAA-19).

Module 7 – Microwave & LIDAR Sensing
Topics: Microwave & Radio Waves, Microwave Sensing, Radar, Radar Applications, Soil Response, Vegetation Response, Passive Microwave Sensors, Microwave Radiometer, Types of Active Microwave Sensors, Non-Imaging Radar (Scatterometer, Altimeter, Doppler Radar), Imaging Radar (SLAR, SAR, ASAR), Shuttle Imaging Radar (SIR-A, SIR-B, SIR-C), LIDAR, LIDAR Applications, GLAS.

Laser Range-Finder Lab or Ground Penetrating Radar Lab
Remote Sensing Exam

UNIT#3: GIS
Module 1 – Introduction to GIS
Topics: Importance and Value, Site Selection, Applications (Government Planning, Commerce/Business, Environmental Management), Spatial Data, Attribute Data, Visualizations.

Module 2 – Spatial Data
Topics: Data, Modes & Dimensions, Maps, Scale, Points, Lines, Areas, Generalization, Spatial Referencing, Data Sources.

Module 3 – Raster & Vector
Topics: Spatial Data Models, Raster, Vector, Raster VS Vector, Spatial Data Structure (Raster & Vector), Pros & Cons (Raster & Vector.

Module 4 – Database Management
Topics: Advantages, Database Creation, Spatial & Attribute Link.

Module 5 – Data Input & Editing
Topics: Analog VS Digital Data, Data Input Methods, Scanning, Electronic Data Transfer, Data Editing, Detecting & Correcting Errors (Attribute Data, Spatial Data), Geocoding.

Module 6 – Data Analysis
Topics: Terminology, Measurements in GIS, Queries, Aspatial Queries, Reclassification, Buffering, Vector & Raster Buffer, Map Overlay, Vector Overlay, Raster Overlay, Network Analysis, Route Tracing.

Module 7 – Process Modeling
Topics: Types of Modeling, Process Model Classification, Mathematical Models, Forecasting, Modeling Problems.

Module 8 – Output
Topics: Output, GIS Map Design, Symbols, Legend/Key, Tables & Charts, Map Output Mistakes.

GIS Project
GIS Exam

<u>UNIT#4: GPS</u>
Module 1 – GPS
Topics: History of GPS, GPS Management, Control Segment, GPS Satellites, How GPS Works, Trilateration, Atomic Clocks, GPS Error, GPS Receivers, GPS Signals, Applications (Agriculture, Aviation, Earthquakes, Environment, Outdoor Activities, Roads & Highways, Surveying & Mapping, Time).

GPS Lab

ASSESSMENTS

5E Handout – 10%
UAV Photogrammetry Lab – 10%
Laser Range-Finder Lab OR Ground Penetrating Radar Lab – 5%
Remote Sensing Exam – 20%
GIS Project – 20%
GIS Exam – 20%
GPS Lab – 10%
Classwork/Participation – 5%

ASSESSMENT DETAILS

5E Handout - Provides an in-depth analysis of a particular topic/theme via the 5E Method (Engage, Explore, Explain, Elaborate, Evaluate). Topic: EM Spectrum

UAV Photogrammetry Lab – Students are to take at least 50 digital images of a particular area (e.g. small mountain, residential neighborhood) using a UAV, and then create a 3D image of the area using photogrammetry software. (Note: there are many UAV's on the market. Make sure yours is user-friendly and easily compatible for photogrammetry activities. Some UAV's market themselves as being useful for photogrammetry purposes, so do some research before buying. Also, free photogrammetry software is available, but again, make sure everything is compatible with everything else. Software is one of the primary determinants for the minimum range of pictures required to render a quality 3D image, so it's important to find out this information early on.)

Laser Range-Finder Lab OR Ground Penetrating Radar Lab – For the Laser Range-Finder Lab, having students demonstrate use and record distances to determine what variables might account for differential distances could be one option. For the Ground Penetrating Radar Lab, students could operate the machine and then incorporate findings into appropriate software. The goal of either is to ensure that students 1) understand the science behind the technologies utilized, 2) know how to use the equipment, and 3) can apply it towards a relevant application.

Remote Sensing Exam – Upon completion of the remote sensing unit, two exam questions can be asked to gauge comprehension. Allowing students to use their notes, they are to answer the following: 1) you are tasked with searching for a possible archaeological site several feet underneath the sand in a desert. What remote sensing system would you put together to achieve this? 2) There is a large forest fire that requires a constant updating of ground conditions. What remote sensing system would you put together to accomplish this? Each response should specify the platform (aerial, orbit), sensor(s) used, orbital selection (if applicable), and explain how their selections resolve the aforementioned questions.

GIS Project – Once students have a basic familiarity with whichever GIS program you are using, they will develop a GIS map that shows how to solve a particular problem. For example, students can identify (within a city) where the best location is to build a grocery store. Or, they can identify a location suitable for building a hospital. There are many options. To extend the project, after the map has been submitted to the teacher, students could then share their findings with the class.

GIS Exam – Students are provided a GIS map of a particular area (choose a small city area <10 square miles). For the entire class period, students are to analyze and select a location on the GIS map that would be ideal for building a parking structure. For a grade of "A" students should present to the teacher a GIS map with a key/legend showing AT LEAST SIX criteria (e.g. next to high-density housing, near a major highway, etc.) for which location is best for a parking structure. In addition to choosing seven criteria, assessment should include a two-paragraph response that justifies the criteria selected.

GPS Lab – Students are to acquire coordinates, record several points, and then integrate them into a GIS. There are many ways to do this. Several labs are available by searching via Google, but be aware that some of them are geared towards particular GPS units. As is the case with selecting a GIS program, consider all aspects before acquiring GPS units. Here is one example: http://geog.sfsu.edu/sites/sites7.sfsu.edu.geog/files/FieldLab1_GPS_Intro_0.pdf

RESOURCES

Photogrammetry UAV's
Some UAV's are more geared towards photogrammetric activities than others. Please see the following break-down to determine which UAV is most suitable for your purposes: http://www.dronezon.com/learn-about-drones-quadcopters/introduction-to-uav-photogrammetry-and-lidar-mapping-basics/

Estimated Minimum Cost Per: $1,350+

Free Photogrammetry Software

- Visual SFM: http://ccwu.me/vsfm/
- Python Photogrammetry Toolbox: http://184.106.205.13/arcteam/ppt.php
- Pix4D: http://www.pix4d.com/
- Arc 3D Webservice: http://www.arc3d.be/

Laser Range-Finder
Many can be found at Amazon.com and other popular shopping websites.

Estimated Minimum Cost Per: $100+

Ground-Penetrating Radar
Ground-penetrating radar (GPR) systems can be incredibly expensive, with the ground price starting out somewhere in the several thousands (if you're lucky). In addition, companies selling GPR systems require you to submit a quote, further wasting time. Consequently, you may want to consider renting a GPR system.

Estimated Minimum Cost Per: several thousand for handheld, low tens-of-thousands for full unit.

For an idea on how much it would cost to rent a GPR system, check out the following link: http://www.geo-app.com/rentals.html

Free GIS Software

- QGIS: http://qgis.org/en/site/
- Whitebox GAT: http://www.uoguelph.ca/~hydrogeo/Whitebox/
- SAGA GIS: http://www.saga-gis.org/en/index.html
- Grass GIS: https://grass.osgeo.org/
- gv SIG: http://www.gvsig.com/en
- Map Window: http://www.mapwindow.org/
- ILWIS: http://www.ilwis.org/
- GeoDa: https://geodacenter.asu.edu/software/downloads
- uDig: http://udig.refractions.net/
- OpenJUMP: http://www.openjump.org/
- DIVA-GIS: http://www.diva-gis.org/
- FalconView: https://www.falconview.org/trac/FalconView
- OrbisGIS: http://orbisgis.org/

GPS Units
Several different varieties can be found at Amazon.com and other popular shopping websites.

Estimated Minimum Cost Per: $100+

MINIMUM COST IMPLEMENTATION

To help provide a minimal cost scenario, assuming you have 30 students, here is a hypothetical breakdown of what it would cost to fully implement this course (note: this assumes you have acquired free photogrammetry & GIS software, and have chosen the laser range finder over the GPR).

UAV's for Photogrammetry Lab – Assuming a five-to-one ratio for students to use a UAV, you would need to acquire six UAV's at a minimum cost of **~$8,100**.

Laser Range Finders – Assuming a three-to-one ratio for students to use a laser range-finder, you will need to acquire 10 at a minimum cost of **~$1,000**.

GPS Units – Assuming a three-to-one ratio for students to use a GPS unit, you will need to acquire at least 10 at a minimum cost of **~$1,000**.

In total, the minimum implementation cost to fully execute this course (assuming all free software and choosing the laser ranger-finder lab over the GPR lab) will be at least **$10,100**.

If you still have questions, please contact: jweichman@elcamino.edu