Image from NASA: https://commons.wikimedia.org/wiki/File:Earth_Western_Hemisphere_transparent_background.png#filelinks

Remote Sensing

History

The goal of this section is to provide a general overview of the history of remote sensing science, Earth observation, and aerial photography collection to offer some context for the material that will be covered in this course.

Module Topics

1. Aerial imaging programs
2. Satellite-based remote sensing
3. Drones, microsatellite constellations, and other current trends
4. Professional societies, certifications, job market, resources, and software

2

These are the topics covered in this module.

Historic Overview

Aerial Photography

- 1858 = Gasper Felix "Nadar" Tournachon takes first aerial photograph of Paris from a hot air balloon
- 1860 = James Black takes aerial photograph of Boston from balloon
- 1906 = Aerial photograph from kite of San Francisco in wake of earthquake by George Lawrence
- 1903 = First flight by Wright Brothers

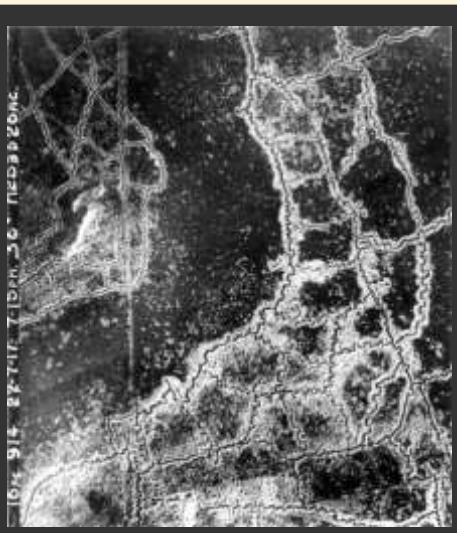
https://www.smithsonianmag.com/smart-news/this-picture-of-boston-circa-1860-is-the-worlds-oldest-surviving-aerial-photo-14756301/

http://robroy.dyndns.info/lawrence/landscape.html

4

The first aerial imagery predates manned air flight with fixed wing aircraft. The first images were collected from hot air balloons, kites, and even pigeons using film. This slide shows some of the first aerial images ever collected. With the advent of fixed-wing airplanes, we were able to have much more control over the data collection.

Aerial Photography



- 1908 = First aerial photograph from an airplane of Le Mans, France (Wilbur Wright and cameraman)
- World War I = Aerial photography implemented during war
- World War II = Continued use during war efforts

https://nzhistory.govt.nz/media/photo/trench-systems-somme

5

The first aerial image collected from an airplane was in 1908 over Le Mans, France by Wilbur Wright and a cameraman. Aerial photography was used extensively during the First World War for reconnaissance, as demonstrated by the provided image that highlights trench warfare. During the Second World War, aerial reconnaissance was even more extensive.

Aerial Photography

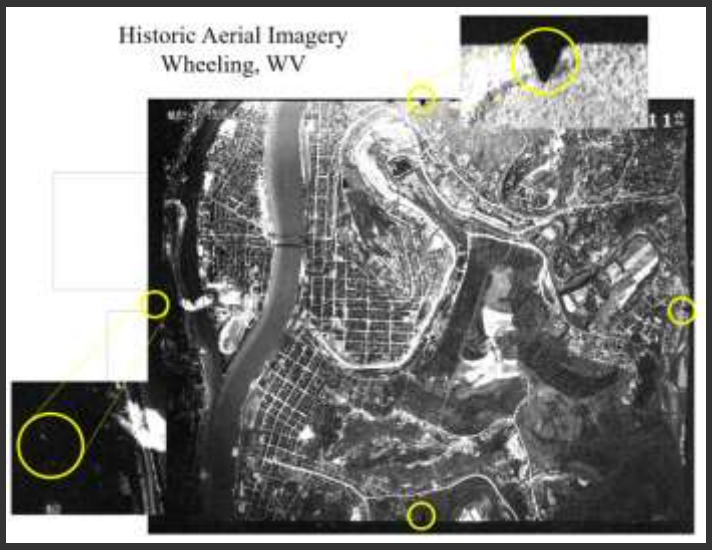
- 1950s = U-2 spy plane in use
- Post World War Era = Development of commercial aerial surveying

https://commons.wikimedia.org/wiki/File:Usaf.u2.750pix.jpg

6

After World War II and during the Cold War, spy planes, like the U-2, were used to collect reconnaissance data from a high altitude. Meanwhile, a civilian commercial aerial surveying industry developed that is still very active today.

Historical Images



7

I will now provide some examples of historic aerial imagery programs with a focus on the United States. This slide shows an example, historic aerial image of Wheeling, West Virginia as a single film exposure.

Historical Images

- National Archives
  - Still Pictures Unit – College Park, MD
- http://www.archives.gov/research/order/maps.html
- Limited on-line search
- Holdings:
  - Pre-1954 photographs (Late 1930's photos available for West Virginia)
  - Captured WWII photos
  - Declassified satellite images
- Vendors make copies for the public

8

This slide provides some example archives from which to obtain historic images.

Historic Aerial Imagery in West Virginia

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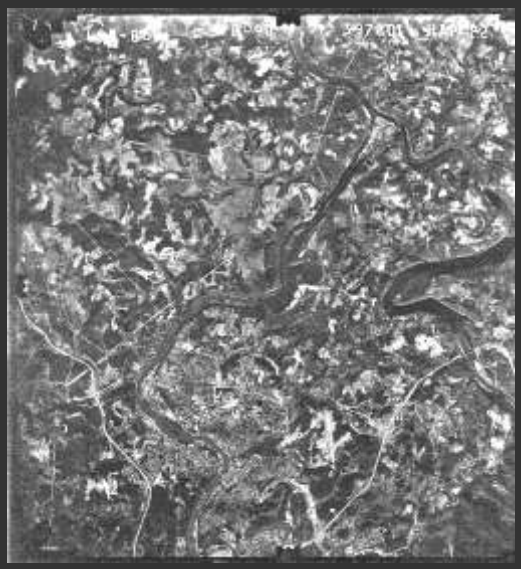
Information about historic photographs available across the state of West Virginia is made available by the West Virginia GIS Technical Center. All historic imagery is not currently digitized and georeferenced.

NHAP



National High Altitude Aerial Program

- 1980 to 1987
- Black-and-White at 1:80,000 scale

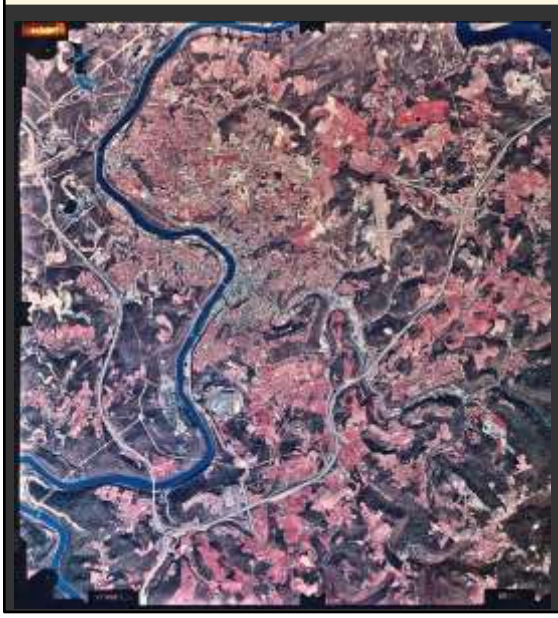
Panchromatic, 1:80,000

Morgantown, 1982

10

Some older imagery are provided by the US government. For example, the National High Altitude Aerial Program, or NHAP, collected data between 1980 and 1987. Black-and-white, panchromatic images were collected using film at a scale of 1:80,000. This slide provides an example of a panchromatic image of Morgantown, West Virginia collected in 1982.

NHAP



National High Altitude Aerial Program

- 1980 to 1987
- CIR at 1:58,000 scale

CIR
1:58,000
Leaf-Off

Morgantown, 1982

11

This slide provides another example of NHAP data as a CIR image. NHAP collected CIR data at a scale of 1:58,000. This is a leaf-off CIR film image of Morgantown, WV collected in 1982.

NAPP

National Aerial Photography Program

- 1987 to 2007
- CIR at 1:40,000 scale

CIR
1:40,000
Leaf-On

Morgantown, 1988

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The National Aerial Photography Program (NAPP) collected data from 1987 to 2007 and replaced NHAP. CIR data were collected at 1:40,000 scale using film. The example on this slide is from a leaf-on collection of Morgantown, WV completed in 1988.

NAPP

National Aerial Photography Program

- 1987 to 2007
- CIR at 1:40,000 scale

CIR
1:40,000
Leaf-Off

Morgantown, 1997

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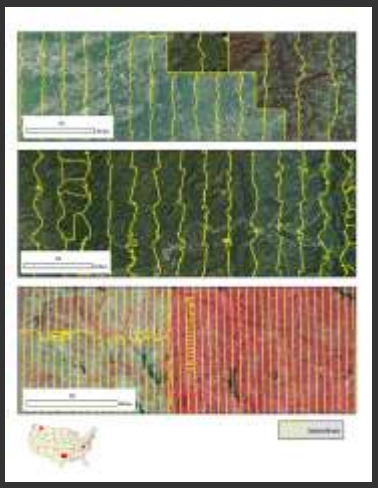
This slide provides an example of a 1:40,000 scale CIR film image of Morgantown, WV collected by NAPP in 1997.

National Agriculture Imagery Program (NAIP)



- 2003 to present
- State coverages
- Collected every three years (often more frequently)
- 3-band or 4-band
- 1 m cell size
- Growing season conditions

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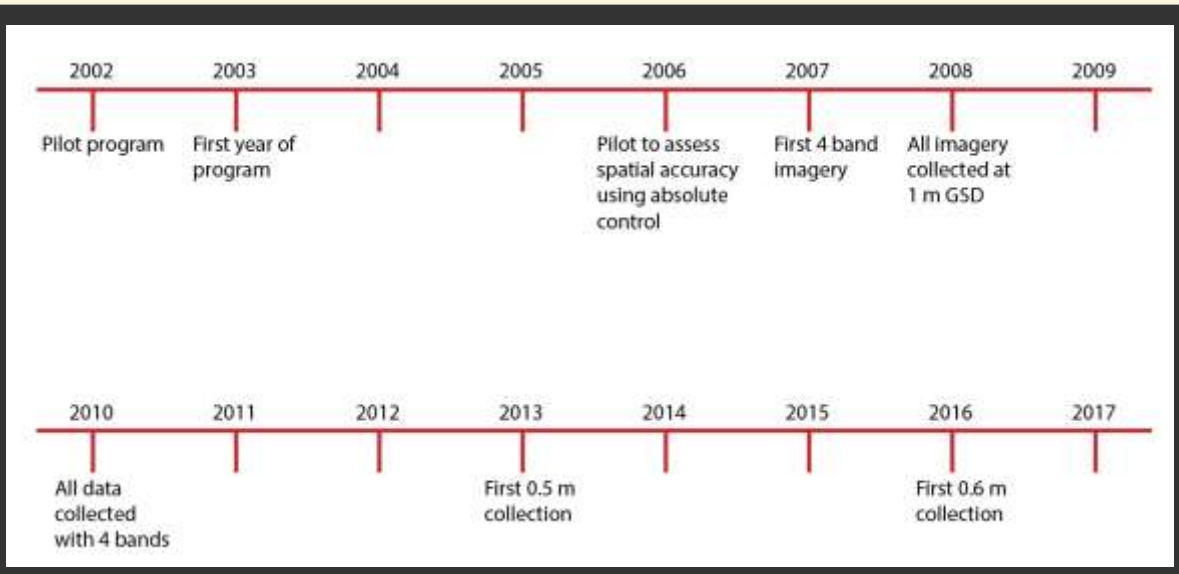
The most recent US government aerial imagery collection program is the National Agriculture Imagery Program, or NAIP. NAIP data are generally collected for entire states every 2 or 3 years. Older data were collected as 3-band true color images or 3-band CIR images. Recently, most data have been 4-band CIR images collected with digital sensors. NAIP data have traditionally been provided at a 1-meter spatial resolution. However, more recently higher spatial resolution data have been collected. These data are generally collected during the growing season and represent leaf-on conditions. This is because their primary purpose is for agricultural monitoring. Data are not commonly collected during the winter or during leaf-off conditions.

The imagery is generally made available as orthophotographs by USGS quarter quads or as compressed county mosaics.

NAIP Timeline



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This slide provides a general timeline of NAIP.

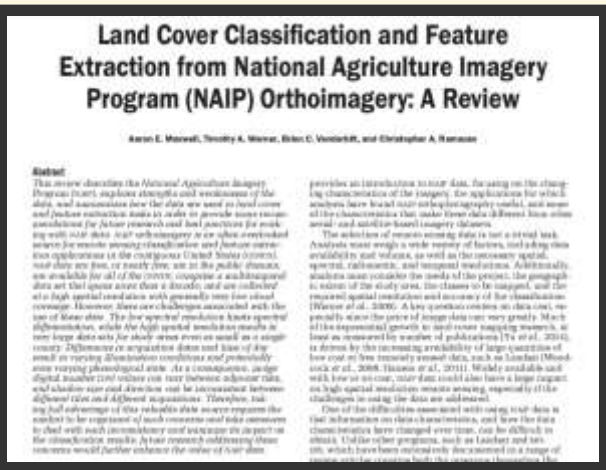
National Agriculture Imagery Program (NAIP)

https://www.fsa.usda.gov/programs-and-services/aerial-photography/imagery-programs/naip-imagery/

http://usdaonline.maps.arcgis.com/apps/MapTour/index.html?appid=445e3dfd16c4401f95f78ad5905a4cce&webmap=6d117f2ede424ace93917e2bc88202b3

This slide provides links to a story map that highlights the history of the NAIP program and a link to the NAIP webpage.

National Agriculture Imagery Program (NAIP)



Land Cover Classification and Feature Extraction from National Agriculture Imagery Program (NAIP) Orthoimagery: A Review

Aaron E. Maxwell, Timothy A. Warner, Brian C. Vanderbilt, and Christopher A. Ramezan

Abstract

This review describes the National Agriculture Imagery Program (NAIP), explores strengths and weaknesses of the data, and summarizes how the data are used in land cover and feature extraction tasks in order to provide some recommendations for future research and best practices for working with NAIP data. NAIP orthoimagery is an often overlooked source for remote sensing classification and feature extraction applications in the contiguous United States (CONUS). NAIP data are free, or nearly free, are in the public domain, are available for all of the CONUS, comprise a multitemporal data set that spans more than a decade, and are collected at a high spatial resolution with generally very low cloud coverage. However, there are challenges associated with the use of these data. The low spectral resolution limits spectral differentiation, while the high spatial resolution results in very large data sets for study areas even as small as a single county. Differences in acquisition dates and bias of the small in varying illumination conditions and potentially even varying phenological state. As a consequence, judging digital number (DN) values can vary between adjacent tiles, and shadow size and direction can be inconsistent between different tiles and different acquisitions. Therefore, taking full advantage of this valuable data source requires the analyst to be cognizant of such concerns and take measures to deal with such inconsistency and variation in order to optimize the classification results. Future research addressing these concerns would further enhance the value of NAIP data.

provides an introduction to NAIP data, focusing on the changing characteristics of the imagery, the applications for which analysts have found NAIP orthophotography useful, and some of the characteristics that make these data different from other aerial- and satellite-based imagery datasets.

The selection of remote sensing data is not a trivial task. Analysts must weigh a wide variety of factors, including data availability, user volume, as well as the necessary spatial, spectral, radiometric, and temporal resolutions. Additionally, analysts must consider the needs of the project, the geographic extent of the study area, the classes to be mapped, and the required spatial resolution and accuracy of the classification (Warner et al., 2009). A key question centers on data cost, especially since the price of image data can vary greatly. Much of the exponential growth in land cover mapping research, as [illegible] as measured by number of publications (Yu et al., 2014), is driven by the increasing availability of large quantities of low cost or free remotely sensed data, such as Landsat (Woodcock et al., 2008; Hansen et al., 2011). Widely available and with low or no cost, NAIP data could also have a large impact on high spatial resolution remote sensing, especially if the challenges in using the data are addressed.

One of the difficulties associated with using NAIP data is that information on data characteristics, and how the data characteristics have changed over time, can be difficult to obtain. Unlike other programs, such as Landsat and various, which have been extensively documented on a range of [illegible]

Maxwell, A.E., Warner, T.A., Vanderbilt, B.C. and Ramezan, C.A., 2017. Land cover classification and feature extraction from national agriculture imagery program (NAIP) Orthoimagery: A Review. *Photogrammetric Engineering & Remote Sensing*, *83*(11), pp.737-747.

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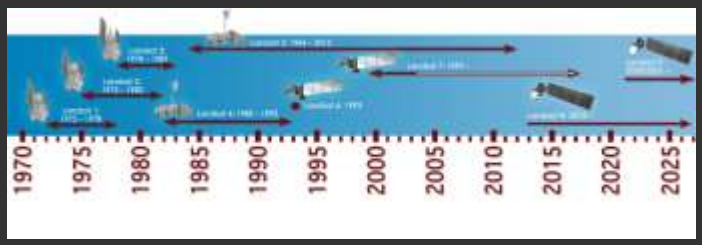
If you are interested in learning more about the NAIP orthophotography, I would recommend taking a look at this review article.

Commercial Imagery

There is currently a very active commercial aerial photography industry globally, which highlights the value of these data. It is now possible to collect images with pixels measuring only centimeters in size.

Landsat Mission

- MSS (Multispectral Scanner) = Landsat 1, 2, 3, 4, and 5
- Thematic Mapper (TM) = Landsat 4 and 5
- Enhanced Thematic Mapper Plus (ETM+) = Landsat 7
- Operational Land Imager (OLI)/Thermal Infrared Sensor (TIRS) = Landsat 8
- Operational Land Imager-2 (OLI)/Thermal Infrared Sensor-2 (TIRS) = Landsat 9



https://landsat.gsfc.nasa.gov/a-landsat-timeline/

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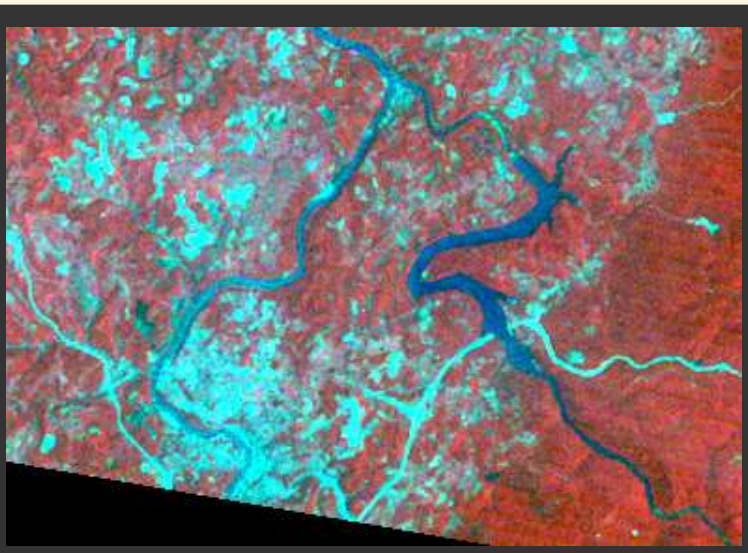
We will now provide a historic overview of satellite-based Earth observation. The first US Earth observation satellites were launched in the 1960s. However, regular, repeating collections didn't begin until the 1970s with the start of the Landsat missions. The Landsat program has been operational since 1972 with the launch of Landsat 1 that carried the Multispectral Scanner, or MSS, sensor.

At the time of this writing, Landsat 8 and Landsat 9 are still operational and providing data.

Landsat Multispectral Scanner (Launched 1972)



Morgantown MSS, June 21, 1975

1970s – Start of the Landsat Era; Scanner-based technology

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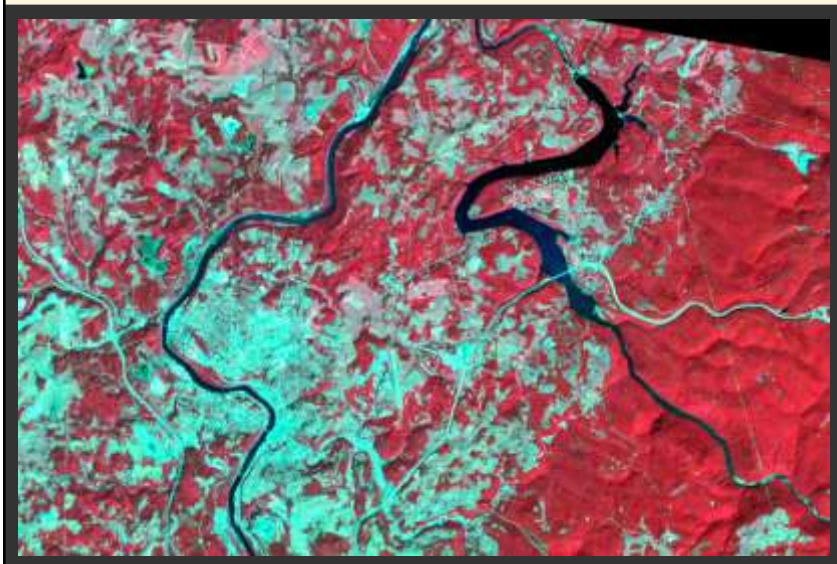
This is an example of an early Landsat Multispectral Scanner (MSS) image of Morgantown, WV from 1975.

Landsat Thematic Mapper (Launched 1982)



Morgantown TM, September 12, 1999

1980s - Landsat program privatized

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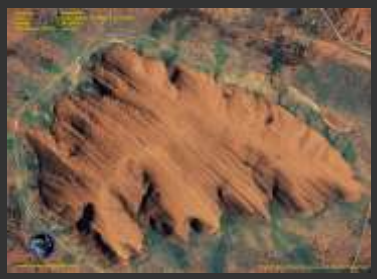
This image was collected with the Landsat 5 Thematic Mapper (TM) in 1999.

Commercial Sector

- 1999 = IKONOS
- 2001 = QuickBird
- 2009 = WorldView-2
- 2014 = WorldView-3



https://www.satimagingcorp.com/gallery/ikonos/

https://www.satimagingcorp.com/gallery/worldview-3/

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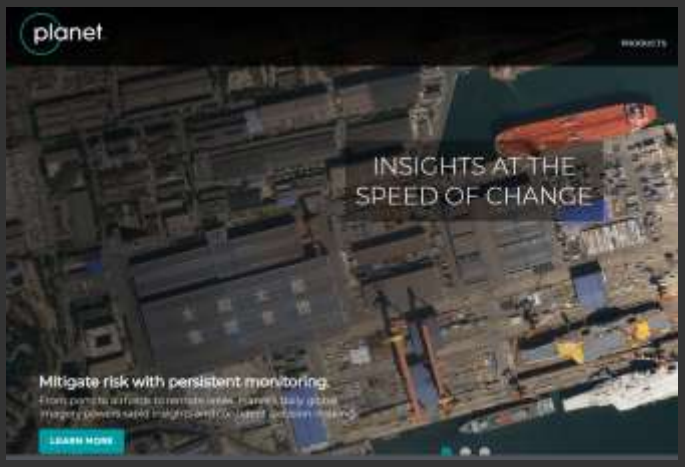
This slide highlights some high spatial resolution commercial satellites. IKONOS, which was launched in 1999, initiated the high spatial resolution, commercial, satellite-based Earth observation industry.

Microsatellite Constellations

- Planet Labs
- PlanetScope
  - 150+ Doves
  - 4 bands (R, G, B, NIR)
  - 3 m spatial resolution
  - 200 million km² per day
- SkySat
  - 21
  - 400 thousand km² per day
  - 5 bands (R, G, B, NIR, Panchromatic)
  - 0.8 m spatial resolution



https://www.planet.com/

23

High spatial grain and high temporal grain are being provided by launching constellations of microsatellites. For example, Planet Labs operates PlanetScope, which consists of over 150 doves or microsatellites. These satellites collected 4 band color infrared data at a 3-meter spatial resolution. Over 200 million square kilometers are collected per day. They also operate SkySat, which, at the time of this writing, consists of 21 satellites that collect color infrared data and a panchromatic band. Over four-hundred thousand square kilometers are collected each day.

Such projects are revolutionizing remote sensing.

UAVs

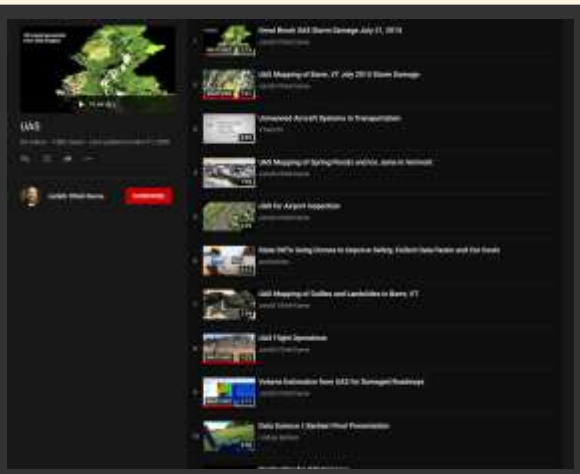
- Unpiloted Aircraft Systems (UAS)
- Unpiloted Aerial Vehicles (UAV)
- Drones

https://commons.wikimedia.org/wiki/File:Drone_im_Himmel_IMG_2423BE2.jpg

24

Drones or unpiloted aerial vehicles (UAVs) are changing the way we collect remotely sensed data over small study area extents. A wide variety of sensors are available that can be attached to drones including RGB cameras, CIR cameras, multispectral cameras, thermal sensors, hyperspectral sensors, and laser scanners. Collecting data from drone platforms has allowed for much cheaper data collection.

UAV Project Examples



Video series by Jarlath O'Neil-Dunne

https://youtube.com/playlist?list=PLG0a9U3eef7oQquIJC9I3p8reS_mk9_-k

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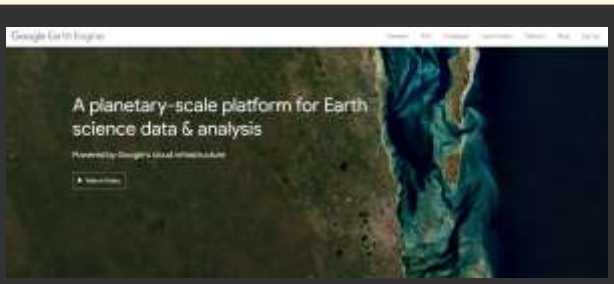
This slide provides links to a series of YouTube videos created by Jarlath O'Neil-Dunne relating to UAV data collection.

Geospatial Big Data

- Access data from the cloud
- Process large extents
- Analyze data time series



https://earthengine.google.com/

26

We now live in a world of big data. Geospatial big data allows for the processing and analysis of large volumes of data covering large spatial extents and/or time series. Cloud-based computer clusters allow for access to these large data volumes while also offering the necessary processing capabilities. Platforms such as Google Earth Engine, Microsoft Azure, and Amazon AWS has allowed remote sensing-based analysis and mapping to be scaled up and operationalized.

Geospatial Big Data

https://glad.umd.edu/projects/global-forest-watch

https://global-surface-water.appspot.com/map

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The provided links relate to projects that have used cloud computing and large volumes of moderate spatial resolution time series data to generate global maps of forest and water extent and change. Such projects have confirmed the operational value of remote sensing for Earth observation.

Video: Mapping Global Surface Water and Change

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Resources

In this last section, we want to highlight some useful resources for geospatial professionals and students.

Several professional societies support the geospatial profession including the *International Society for Photogrammetry and Remote Sensing*, the *American Association of Geographers*, and the *American Society for Photogrammetry and Remote Sensing*. In West Virginia, we have the *West Virginia Association of Geospatial Professionals*.

Many societies offer student discounts for dues and conferences.

AmericaView

- Remote Sensing education, outreach, and research
- Supported by USGS
- Supports state views

https://americaview.org/

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AmericaView is a project supported by the United States Geological Survey (USGS). AmericaView further sponsors individual state views, such as West Virginia View. These organizations support remote sensing education, research, and outreach across the country and within individual states.

This course material was generated with support from AmericaView.

Professional Certifications

- Offers GISP (Geospatial Information Systems Professional) Certification

https://www.gisci.org/

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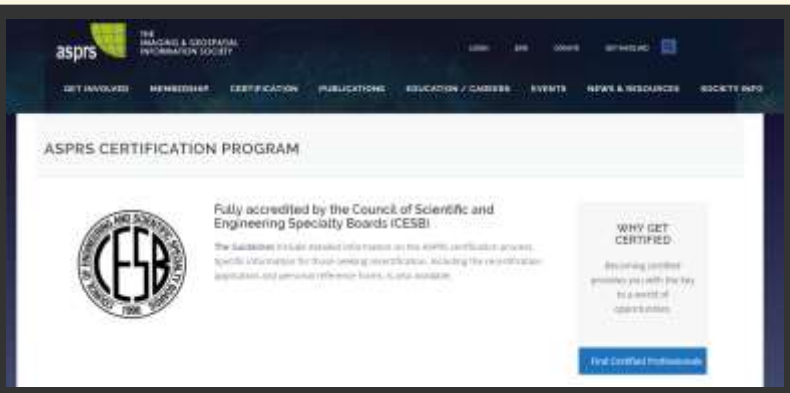
You can also obtain professional certifications.

I would recommend looking into the Geospatial Information Systems Professional Certification, or GISP, offered by the GIS Certification Institute.

Professional Certifications

- Certified Photogrammetrist
- Certified Mapping Scientist Remote Sensing
- Certified Mapping Scientist GIS/LIS
- Certified Mapping Scientist Lidar
- Certified Mapping Scientist UAS
- Certified GIS/LIS Technologist
- Certified Lidar Technologist
- Certified Remote Sensing Technologist
- Certified Photogrammetric Technologist
- Certified UAS Technologist



https://www.asprs.org/Certification

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There are other certification options. For example, the *American Society for Photogrammetry and Remote Sensing*, or *ASPRS*, offers many different certifications.

Geospatial Job Market

Job titles include:

- GIS Technician
- GIS Analyst
- Remote Sensing Analyst
- GIS Programmer
- GIS Web Developer
- Aerial Survey Technician
- Survey Technician
- Image Analyst
- Etc.

http://www.gjc.org/

https://www.gisjobs.com/

https://www.mygisjobs.com/

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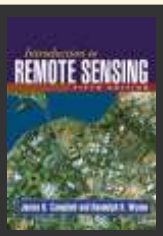
Here are some examples of geospatial job titles. I would recommend the GIS Jobs Clearinghouse, MyGISJobs.com, or GISJobs.com if you are job hunting.

Textbooks

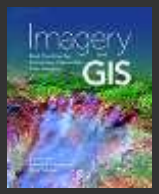
https://uk.sagepub.com/en-gb/eur/the-sage-handbook-of-remote-sensing/book230960

https://www.wiley.com/en-us/Remote+Sensing+and+Image+Interpretation%2C+7th+Edition-p-9781118343289

https://www.pearson.com/us/higher-education/product/Jensen-Remote-Sensing-of-the-Environment-An-Earth-Resource-Perspective/9780134897332.html



https://www.guilford.com/books/Introduction-to-Remote-Sensing/Campbell-Wynne/9781609181765



https://esripress.esri.com/display/index.cfm?fuseaction=display&websiteID=341&moduleID=0

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Several remote sensing textbooks are currently in publication. This slide provides links to the most commonly used texts.

Academic Journals (Remote Sensing)

- *Remote Sensing of Environment*
- *ISPRS Journal of Photogrammetry and Remote Sensing*
- *IEEE Transactions on Geoscience and Remote Sensing*
- *Applied Earth Observation and Geoinformation*
- *Remote Sensing*
- *Photogrammetric Engineering and Remote Sensing*
- *IEEE Geoscience and Remote Sensing Letters*
- *International Journal of Remote Sensing*
- *Remote Sensing Letters*
- *GIScience and Remote Sensing*
- *Canadian Journal of Remote Sensing*
- *Journal of Applied Remote Sensing*
- *Science of Remote Sensing*
- *Sensors*

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There are several academic journals focused specifically on remote sensing science. Currently, *Remote Sensing of Environment* and the *ISPRS Journal of Photogrammetry and Remote Sensing* are the leading journals in the field.

Academic Journals (Related)

- *International Journal of Geographic Information Science*
- *Computers & Geosciences*
- *Environmental Modeling and Software*
- *International Journal of Digital Earth*
- *ISPRS International Journal of Geo-Information*
- *Progress in Physical Geography*
- *Applied Geography*
- *Geographies*
- *Journal of Environmental Management*
- *Landscape Ecology*
- *Land*
- *Water*
- *Forests*
- *Geomorphology*
- *Earth Surface Processes and Landforms*
- *Journal of Spatial Science*

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Remote sensing-related studies are also published in journals supporting a broader audience or related disciplines, such as geography, GIS, geocomputation, environmental management, ecology, forestry, and geomorphology. This slide provides some examples.

Software

- ArcGIS Desktop/Pro — https://www.esri.com/en-us/arcgis/products/arcgis-pro/overview
- Erdas Imagine — https://www.hexagongeospatial.com/products/power-portfolio/erdas-imagine
- ENVI — https://www.l3harrisgeospatial.com/Software-Technology/ENVI
- QGIS/Orfeo Toolbox — https://qgis.org/en/site/ https://www.orfeo-toolbox.org/
- R — https://www.r-project.org/
- Python — https://www.python.org/
- MultiSpec — https://engineering.purdue.edu/~biehl/MultiSpec/
- TerrSet — https://clarklabs.org/
- eCognition — https://geospatial.trimble.com/products-and-solutions/ecognition

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Multiple software tools are available to work with and analyze remotely sensed data. Currently, Erdas Imagine, ENVI, and ArcGIS Pro are the leading commercial software packages. However, there are some free, open-source options including R, Python, and QGIS/Orfeo Toolbox.

In this course, most lab exercises will make use of ArcGIS Pro. However, we will provide examples in Erdas Imagine and QGIS/Orfeo Toolbox also.

This is the end of this lecture module.

Please return to the West Virginia View Webpage for additional content.

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Thanks! Hope you found this useful.