

EPFL



Image processing for Earth Observation

Welcome
Devis TUIA



■ École polytechnique fédérale de Lausanne

EPFL, fall semester 2025

Welcome to the image processing for Earth Observation course

- First of all, some introductions are in order.
- I am Devis, I come from Ticino, I run the ECEO lab in Sion
- With me, the hosts for the semester will be



Emanuele



Robin



Valérie



Filip



Manon



Jan

We will talk about images that look like that



We will talk about images that look like that



We will talk about images that look like that



The IPEO course

- Aim: introduce the students to general concepts of remote sensing image processing
- No satellite design nor missions planning
- We focus on **optical** remote sensing of the Earth by satellites
 - Remote sensing of other planets => have a look at Space Minor courses
 - Remote sensing active (radar and SAR) => A. Berne - Remote sensing Bachelor course
 - Remote sensing from aerial platforms => photogrammetry course

The IPEO course learning objectives

- At the end of this course you will know about
 - Remote sensing systems & existing spaceborne platforms
 - List main applications using Earth observation data
 - Know current limitations & foreseen developments of spaceborne EO
 - Design a remote sensing workflow to get a geospatial product (e.g. a land cover map)
 - Use image processing & machine learning to extract relevant information

The IPEO course

rough table of contents

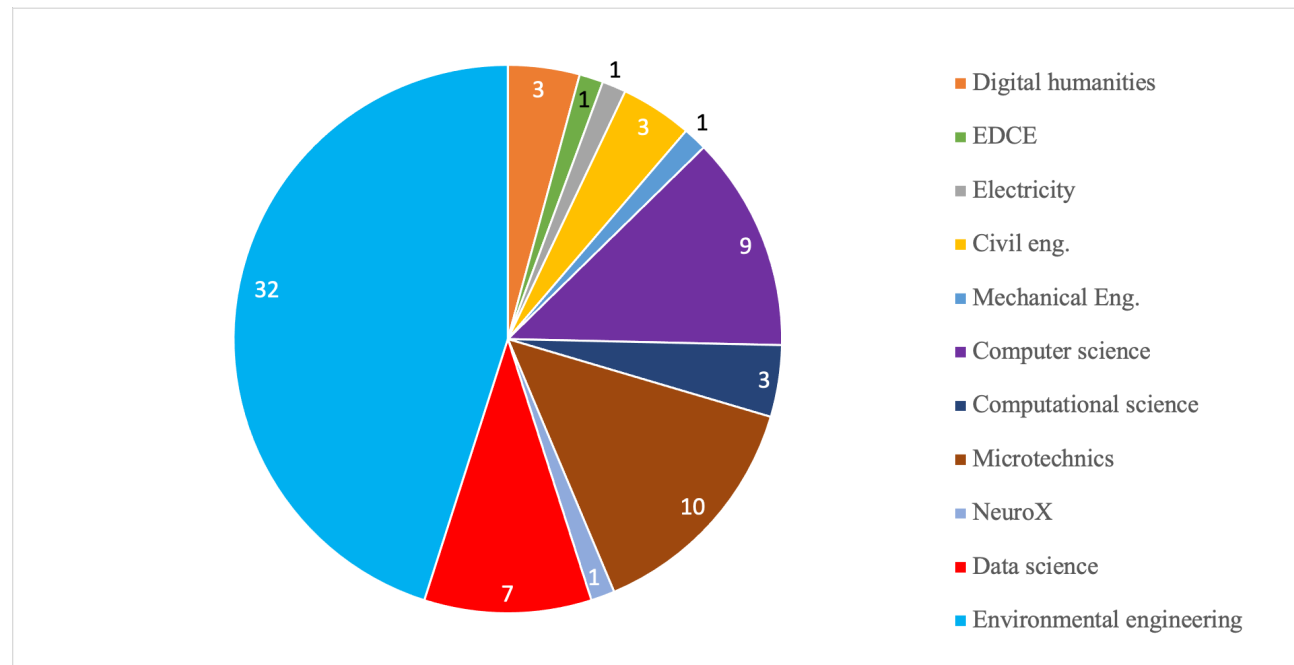
1. Intro on imaging sensors & python programming
2. Information extraction
 - Vegetation indices
 - Spatial context and indices
3. Image classification with machine learning
 - Feature – then – classify approaches
 - Deep learning

Week-by-week schedule on moodle!

IPEO administration

■ Elective master course

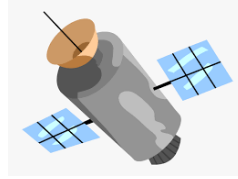
- Environmental sciences and engineering master
- Civil and environmental doctoral program
- Space technology minor
- Urban planning and territorial development minor



IPEO administration

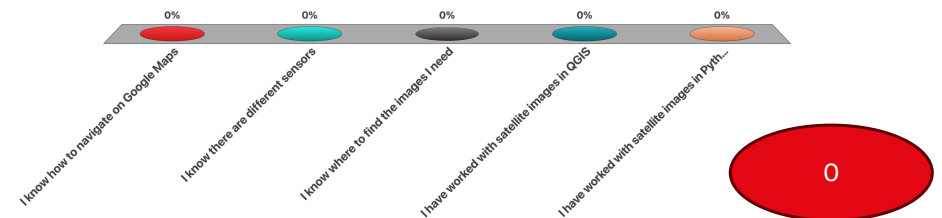
- 4 credits ECTS
- 4h / week,
 - +1-2h of work from home
 - ~50% lectures
 - ~50% exercises and project (Python-based)
- Room: INF3 (here)

You and satellite images



URL: tpoll.eu
Session ID: ipeo23

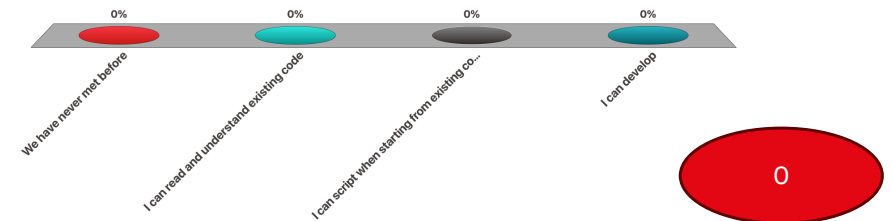
- A. I know how to navigate on Google Maps
- B. I know there are different sensors
- C. I know where to find the images I need
- D. I have worked with satellite images in QGIS
- E. I have worked with satellite images in Python



You and Python

URL: tpoll.eu
Session ID: ipeo23

- A. We have never met before
- B. I can read and understand existing code
- C. I can script when starting from existing code
- D. I can develop

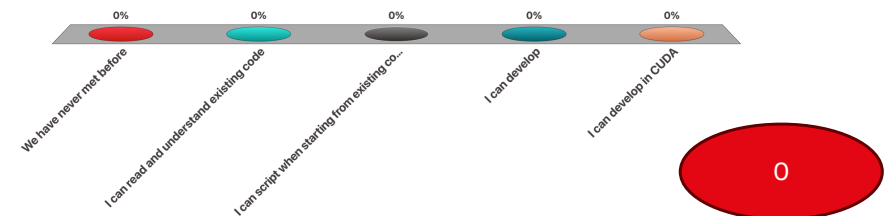


You and PyTorch



URL: tppoll.eu
Session ID: ipeo23

- A. We have never met before
- B. I can read and understand existing code
- C. I can script when starting from existing code
- D. I can develop
- E. I can develop in CUDA



IPEO evaluation

- 1 written evaluation, with theoretical questions and short calculation exercises
 - 50% of the grade, exam **on 28.11.2025**

- 1 project to be provided at the end of the semester, composed of a final report (10 pages) and appendix (code, etc)
 - 50% of the grade

IPEO logistics moodle

- <http://moodle.epfl.ch>
- Course: “Image Processing for Earth observation” (ENV-540)
- Inscription code: empty enrollment key
- On moodle:
 - Schedule
 - Lecture slides
 - Exercises
 - References & readings
 - News and communications
- Slack channel: ipeo-2024.slack.com (invitation link on moodle)

What we do

- We provide **starting concepts** in the lectures
- We provide help in the computer room when you are severely blocked
- We provide (detailed) **explanations** for understanding
- We provide the **solution of the expected model one week after**

What we do not do

you are 71. So:

- We do not answer questions if you haven't even tried
- We are not there to give the solution away, we're helping you to find it
- If we are busy with your colleagues, interact with your neighbours (they might have a solution for you)
- We do not accept any kind of disrespect or harassment in the classroom

- This course has been strongly inspired by:

The course “Imagery of Territory” by D. Tuia, © EPFL, 2012-2014

The course “Remote Sensing of the Earth by Satellites by M. Borgeaud, © EPFL, 2009

- Remote sensing image processing (M&C)

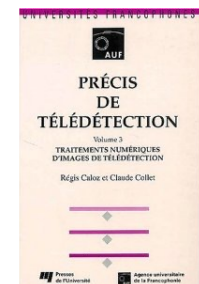
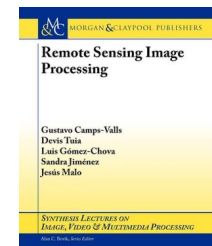
Camps-Valls, Tuia, Gomez-Chova, Jimenez, Malo

available at: <http://www.morganclaypool.com/>

- Précis de télédétection, Vol 4 (Presses du Québec)

Caloz and Collet

En français!



What is Earth observation?

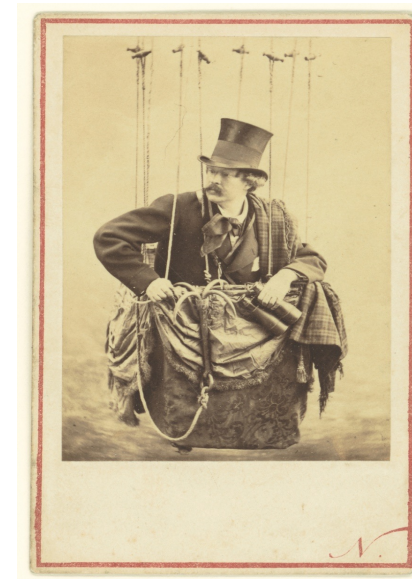
A bit of history

Defining Earth observation today

The EO system (and what we cover in IPEO)

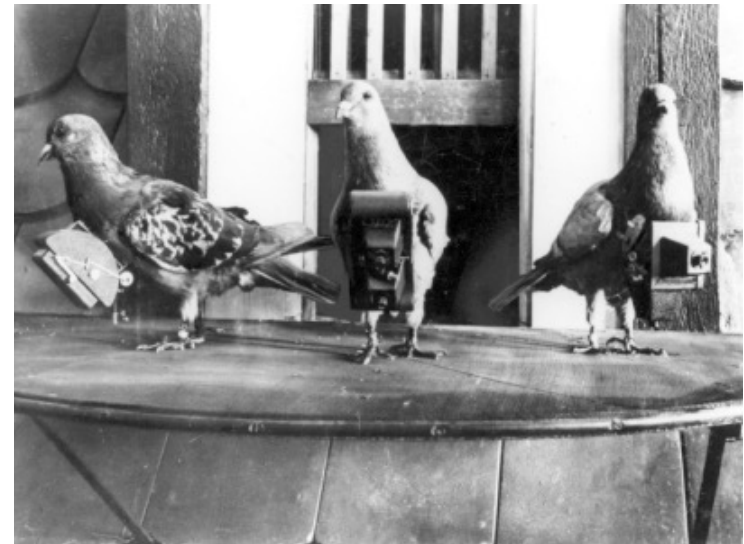
A bit of history

1858: First aerial image by Gasper Felix Tournachon "Nadar"



A bit of history

1902-1914: Aerial images by The Bavarian Pigeon Corps



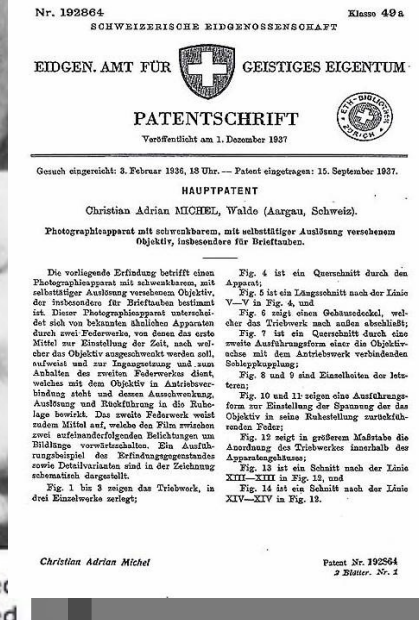
A bit of history

1902-1914: Aerial images by The Bavarian Pigeon Corps

In pictures: World's hero pets

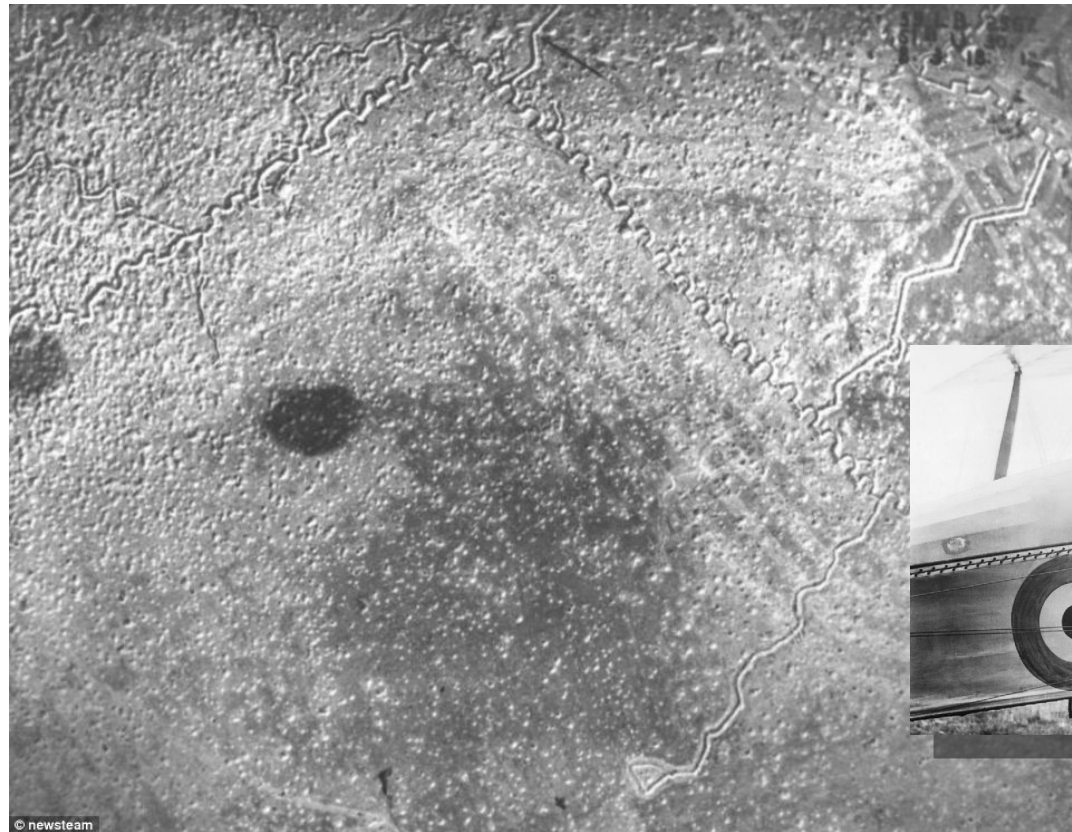


Other animals not buried at Iford but which have received the Dickin medal include GI Joe, a pigeon which prevented troops in an Italian village from becoming victims of 'friendly fire'.



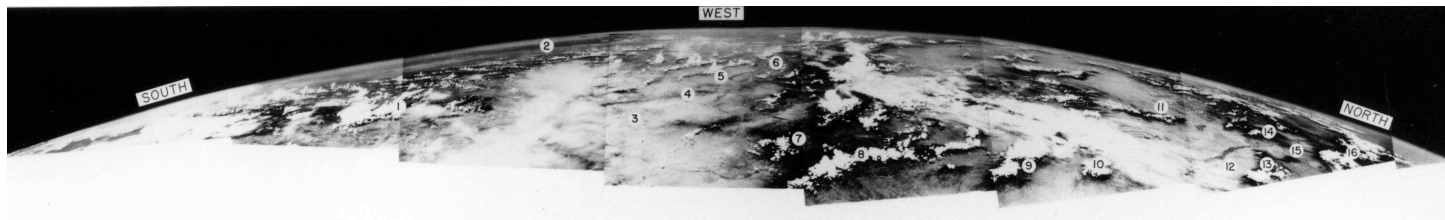
A bit of history

1914-1918: Aerial imagery for military purpose during WWI



A bit of history

1946: First images from space using V2 rocket launched from US



- | | | | | |
|-----------------------|--------------------------|-------------------------|---------------------|-----------------------------|
| 1- MEXICO | 3- LORDSBURG, NEW MEXICO | 6- SAN CARLOS RESERVOIR | 9- SAN MATEO MTS. | 12- ALBUQUERQUE, NEW MEXICO |
| 2- GULF OF CALIFORNIA | 4- PELONCILLO MTS. | 7- MOGOLLON MTS. | 10- MAGADALENA MTS. | 13- SANDIA MTS. |
| | 5- GILA RIVER | 8- BLACK RANGE | 11- MT. TAYLOR | 14- VALLE GRANDE MTS. |
| | | | | 15- RIO GRANDE |
| | | | | 16- SANGRE DE CRISTO RANGE |

ROCKET FIRED AT WHITE SANDS PROVING GROUND, JULY 26, 1948

DISTANCE FROM CAMERA TO HORIZON-700 MILES

AREA SHOWN APPROXIMATELY 800,000 SQ. MILES

DISTANCE ALONG HORIZON-2700 MILES

INSTRUMENTATION AND PHOTOGRAPHY BY APPLIED PHYSICS LABORATORY OF THE JOHNS HOPKINS UNIVERSITY FOR THE BUREAU OF ORDNANCE, U.S. NAVY

A bit of history

1960: military, 2000s commercial



Keyhole satellite



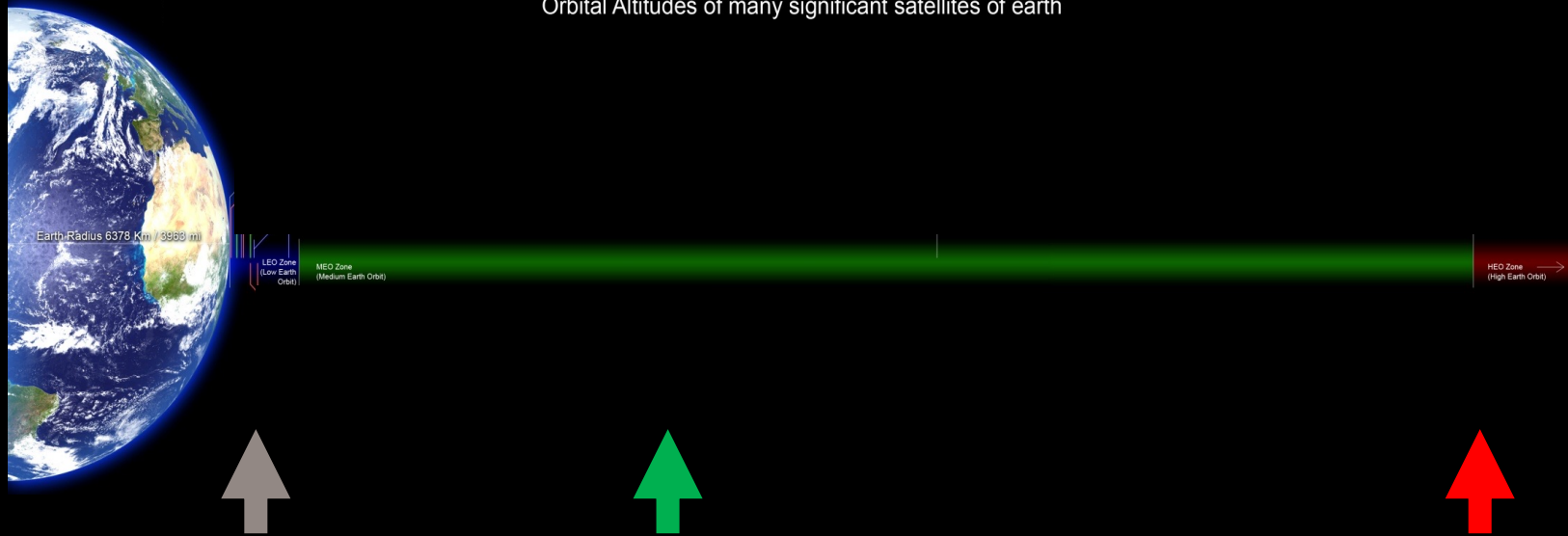
Quickbird satellite

The place of Earth observation in the... near solar system





Orbital Altitudes of many significant satellites of earth

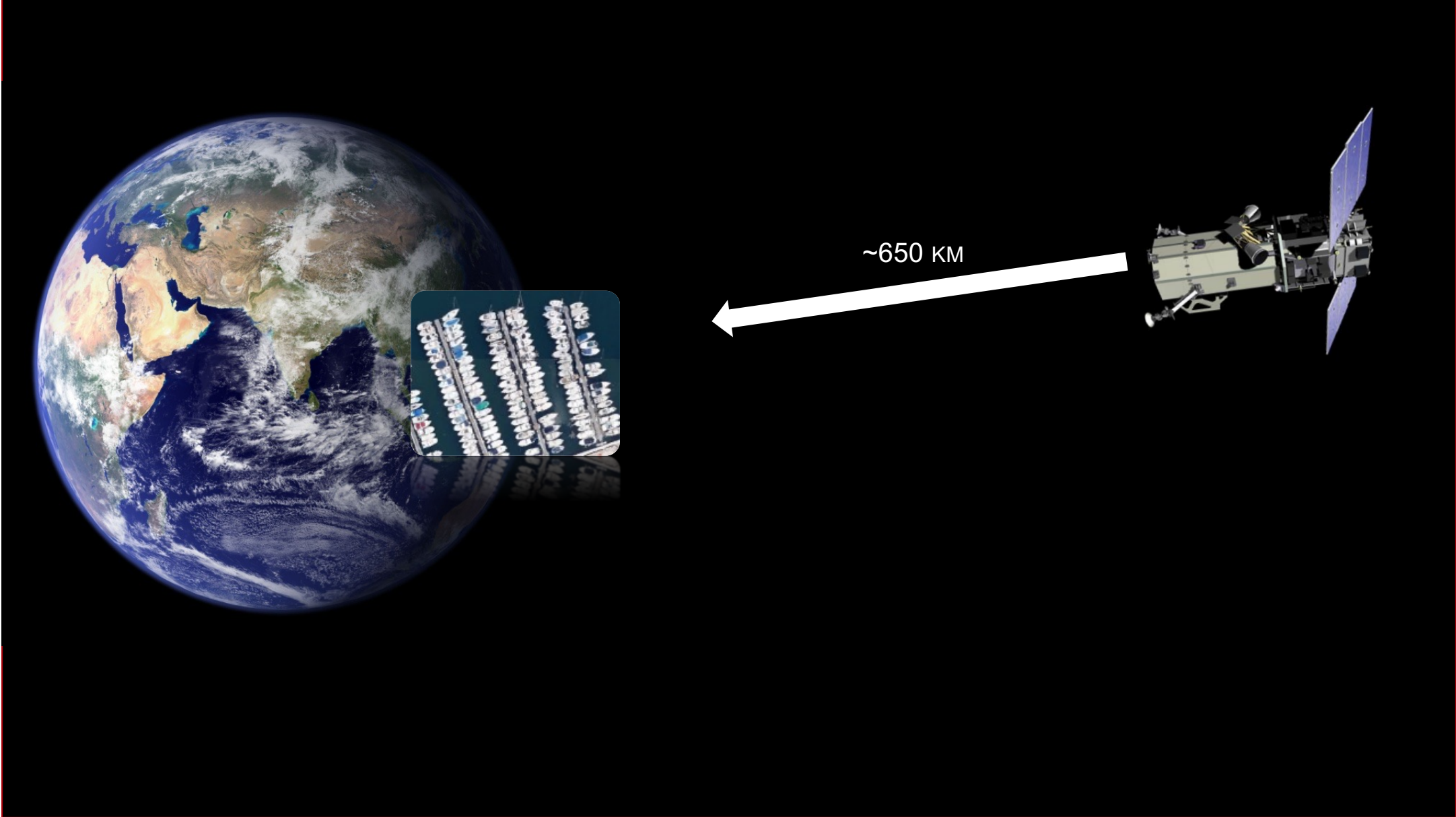


< 2'000 KM
LOW EARTH ORBIT

MEDIUM EARTH ORBIT

> 36'000 KM
HIGH EARTH ORBIT
(GEO-STATIONARY)

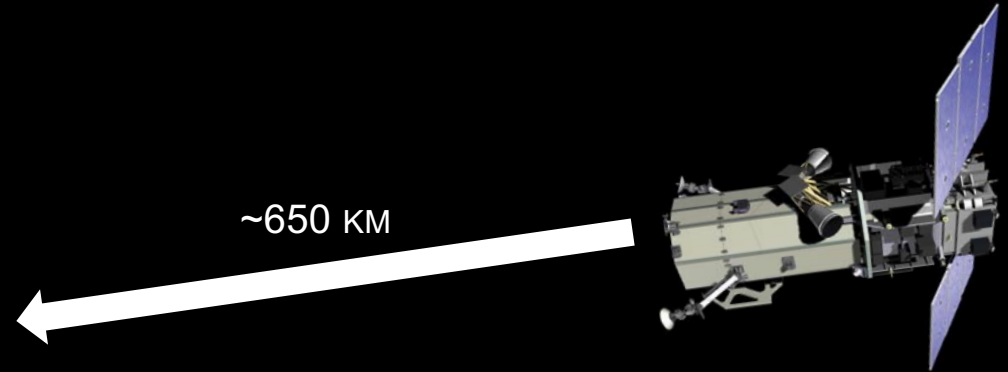




~650 KM



~650 KM

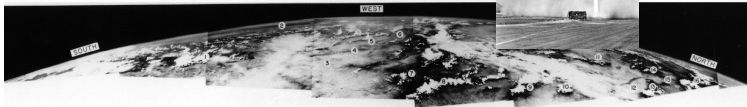


~650 KM



Earth observation past-present-future

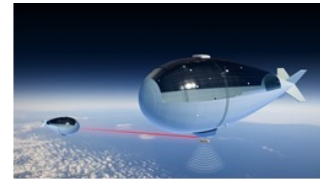
1902-1914: Aerial images by The Bavarian Pigeon Corps



ROCKET FIRED AT WHITE SANDS PROVING GROUND, JULY 16, 1948
 AREA SHOWN APPROXIMATELY 800,000 SQ. MILES
 DISTANCE FROM CAMERA TO HORIZON-700 MILES
 DISTANCE ALONG HORIZON-2700 MILES

1- MEXICO	3- LOSOSBURG, NEW MEXICO	4- SAN CARLOS RESERVOIR	5- SAN MATEO MTS.	6- ALBUQUERQUE, NEW MEXICO
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	12- GILA RIVER	13- BLACK RANGE	14- MT. TAYLOR	15- VALLE GRANDE MTS.
			16- RIO GRANDE	17- SANGRE DE CRISTO RANGE

PHOTOGRAPHER AND PHOTOGRAPHER BY APPOINTED PERIODS LIBRARY OF THE JAMES HAYES UNIVERSITY FOR THE BUREAU OF MINERALS, U.S. GEOLOGICAL SURVEY



Thales Aliena Space



Airbus



What is Earth observation?

A bit of history

Defining Earth observation today

The EO system (and what we cover in IPEO)

Image processing for Earth Observation

- For some time, people called it *remote sensing*
- In that case, it means observing from a distance
- So working from a PC is also remote sensing

- In this course, we want to focus on one object of interest: Earth.



http://www.fas.org/irp/imint/docs/rst/Intro/Part2_1.html

Image processing for Earth Observation

- Here we mean observing Earth using digital sensors.
- We deal with electromagnetic radiation
- We deal with satellites, aircrafts or drones

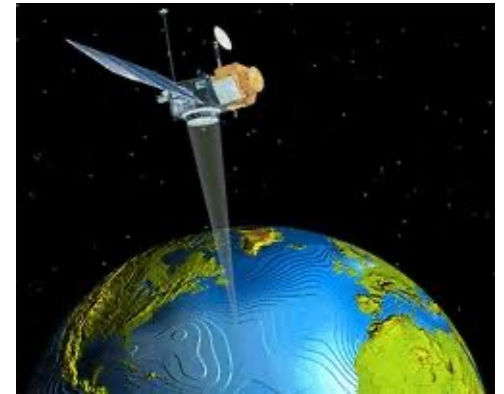
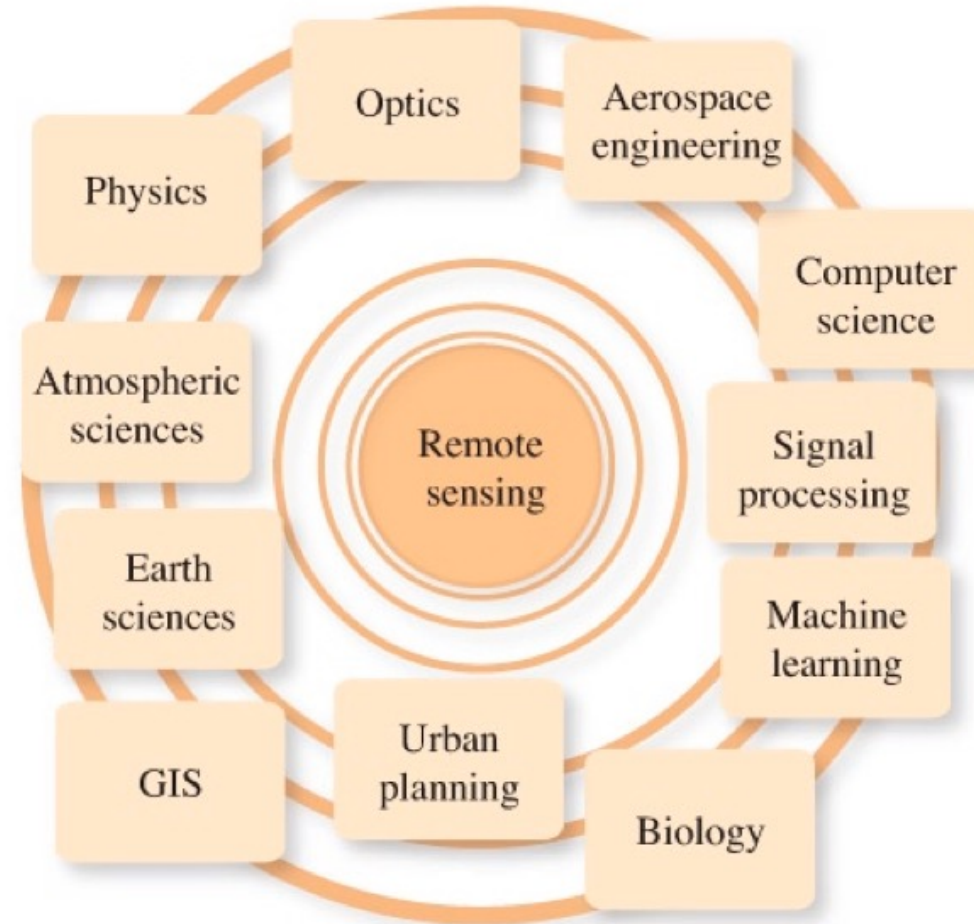


Image processing for Earth Observation

- We can use EO for
 - Monitoring and modelling the processes at the surface of Earth
 - Obtain quantitative measures and estimations of geo-bio-physical variables
 - Identify materials
 - Describe and track changes

An interdisciplinary field



An interdisciplinary field

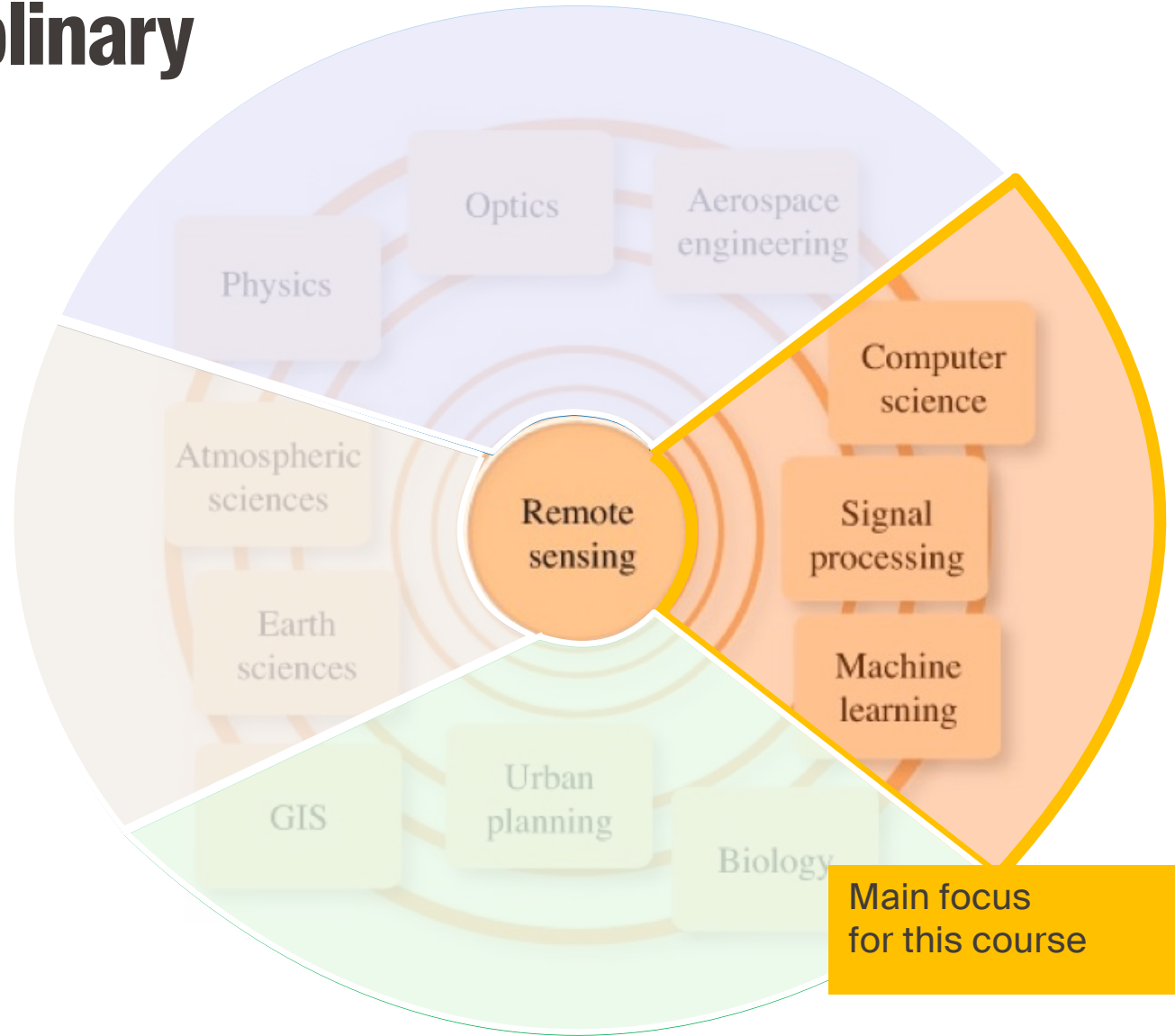


Image processing for Earth Observation

- EO is relevant in a number of domains
 - Geology, geomorphology (minerals identification, landslides)
 - Topography, cartography (thematic maps, landuse)
 - Agriculture (crops monitoring, phenology, yield estimation)
 - Forestry (trees mapping, height, DBH estimation)
 - Hydrology (detection of floods, reservoir modeling, water quality)
 - Cryospheric sciences (ice charting, roughness)
 - Planning (3D reconstructions, scenarios)
 - Forensics (proofs of events, 3D scene reconstruction)
 - Insurances (damages estimation, verification of claims)
 - ...

Image processing for Earth Observation

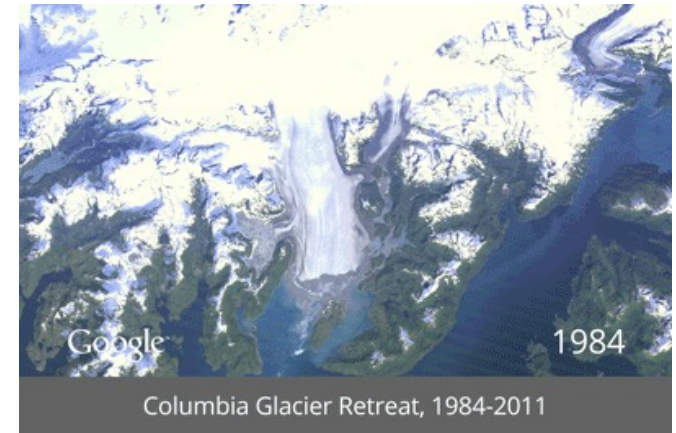
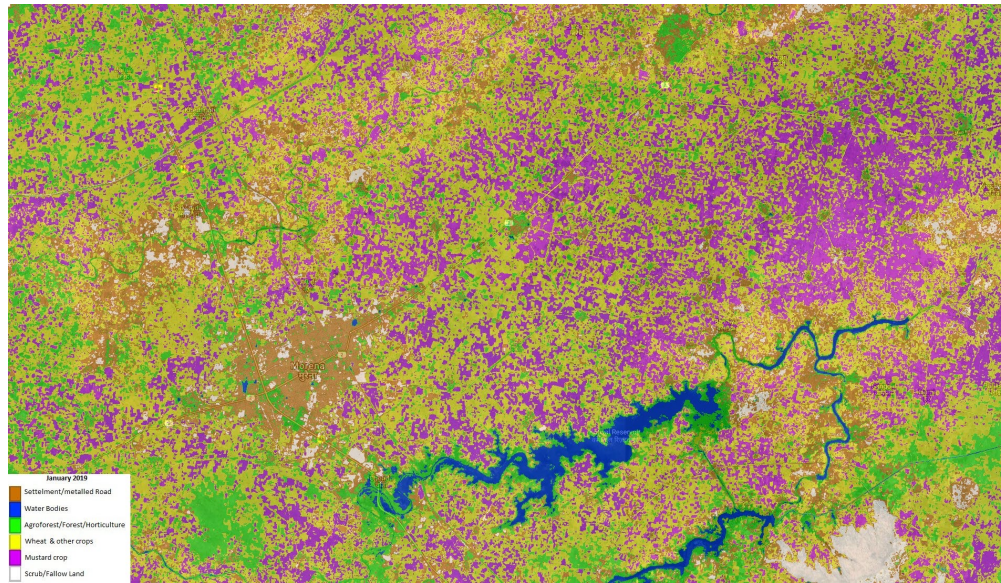
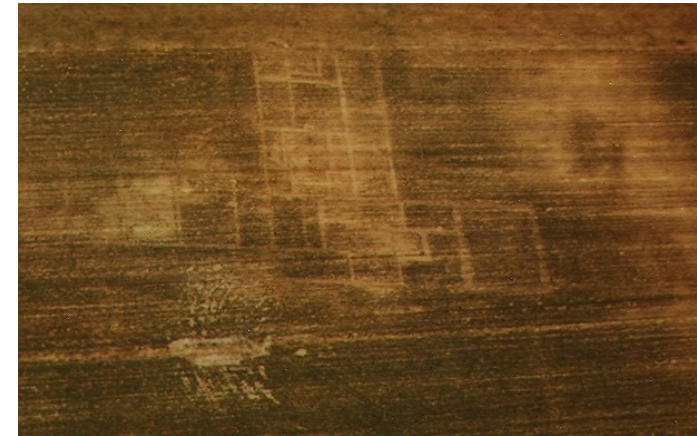


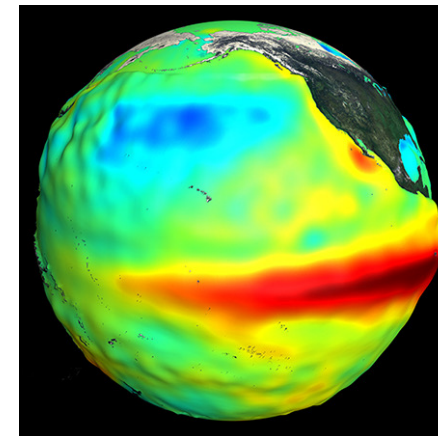
Image processing for Earth Observation



Agricultural land use in Madhya Pradesh




Digital archaeology



Sea surface temperature (el Niño)

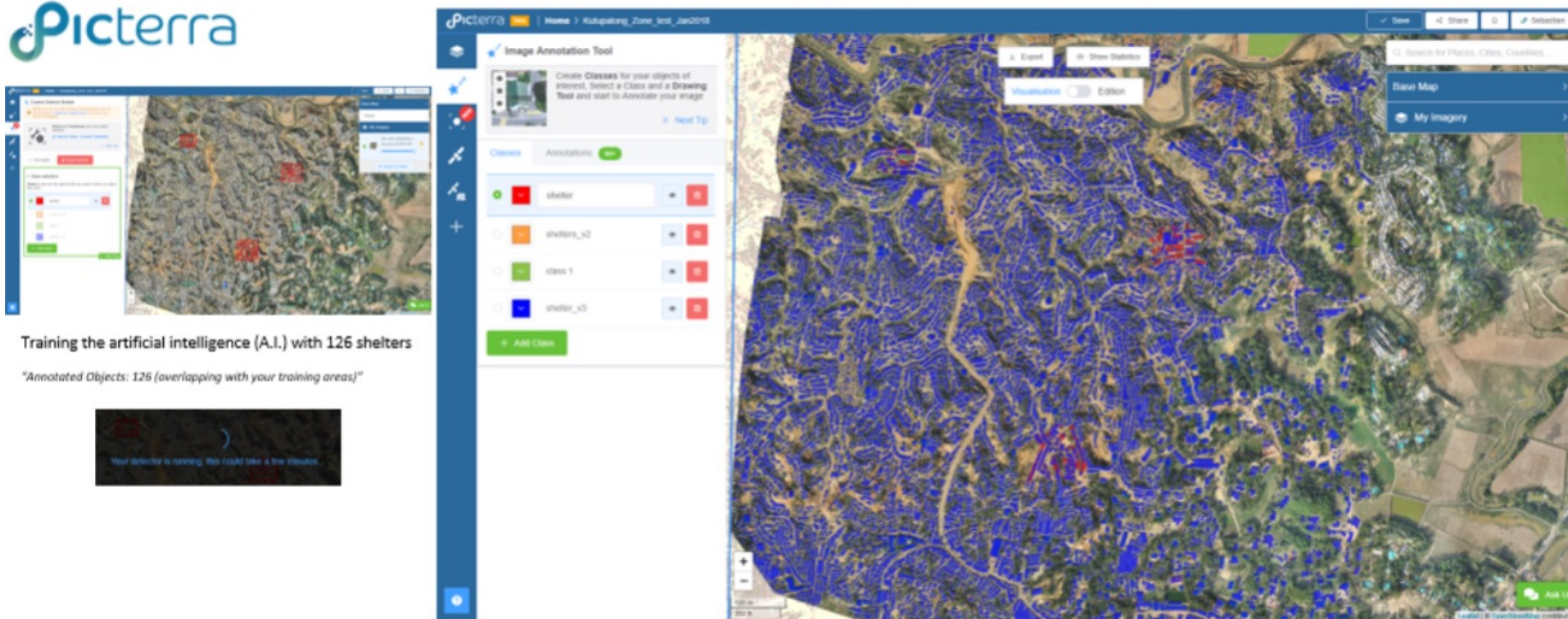
Image processing for Earth Observation

USE OF DRONES AND GIS TO SUPPORT
ROHINGYA REFUGEE EMERGENCY RESPONSE IN COX'S BAZAR, BANGLADESH



 NPM
 THE UN MIGRATION AGENCY

Artificial intelligence and machine learning based on UAV (drone) imagery



Training the artificial intelligence (A.I.) with 126 shelters

"Annotated Objects: 126 (overlapping with your training areas)"

Picterra A.I. platform detected automatically more than 26.000 shelters inside the 2.5km² test area.

INTERNATIONAL ORGANIZATION FOR MIGRATION – JANUARY 2019

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Image processing for Earth Observation

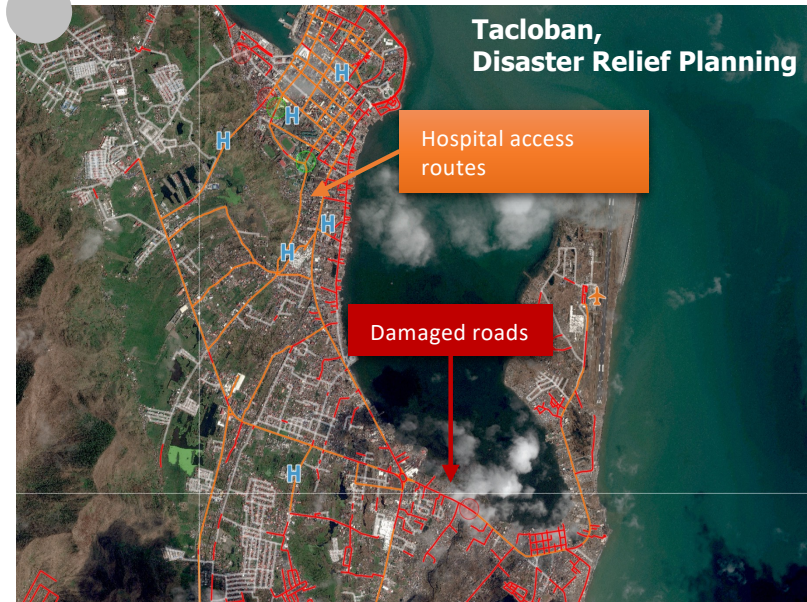
Tacloban airport damaged by Yolanda (Photo credits: sunstar.com.ph)



From a physical event



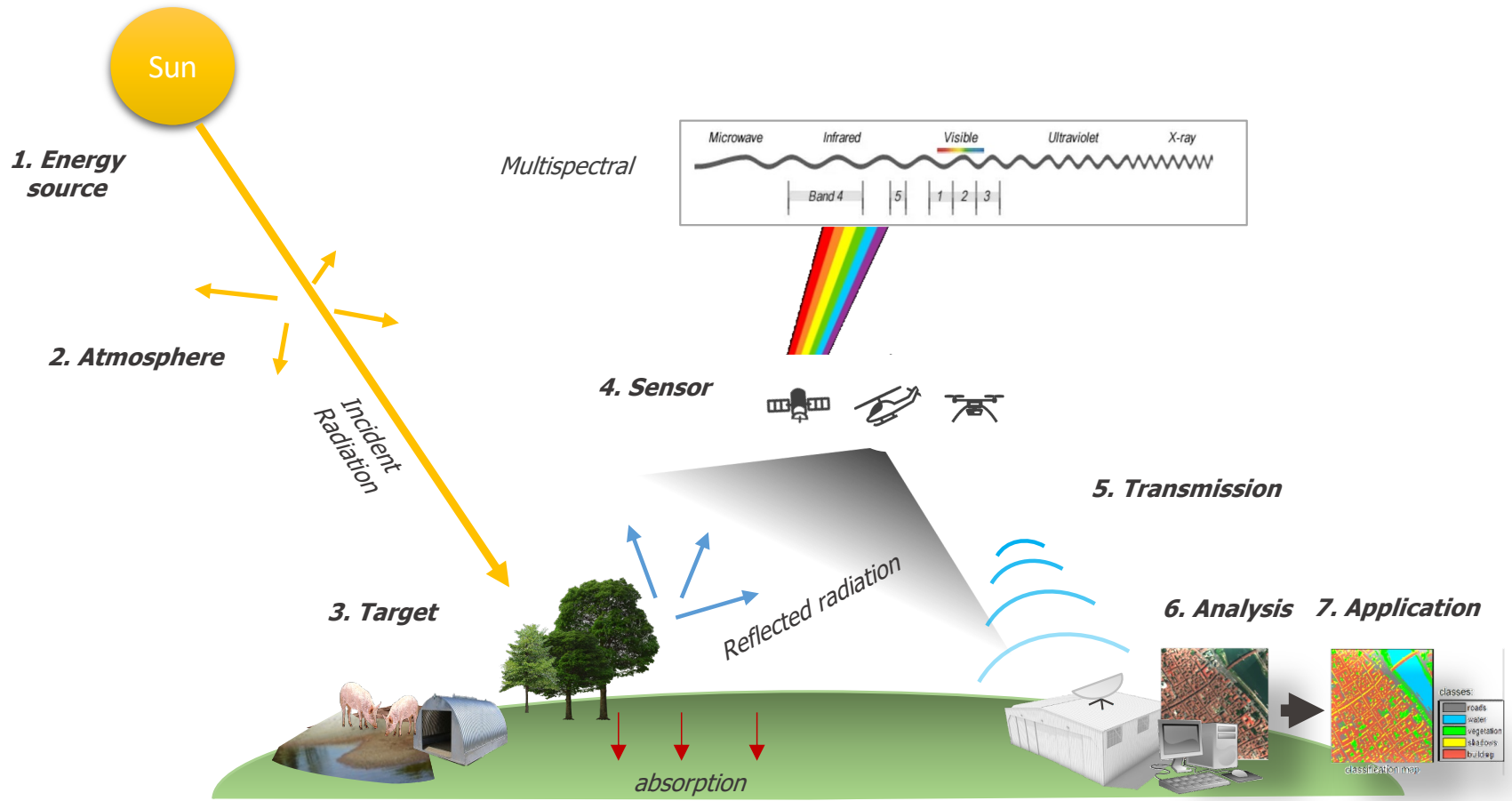
to a map of the situation



Source: Worldview3, Digital Globe



A series of steps



In this course we focus on (4.), 6. and 7.

4. Sensors.

- The different sensors: next course.

6. Analysis.

- Feature extraction: indices and spatial context, next two weeks.
- Classification/segmentation with machine and deep learning (weeks 4-9).

7. Applications.

- You personal projects, for the rest of the semester.

Rough timetable.

W	date	Class	h	Exercises	h	Project	h	Tot
1	12.09.2025	Welcome, What is remote sensing Sensors	2	Group work on sensors	2			4
2	19.09.2025	How to access images (sentinelHub, GEE, ...) Vegetation indices (1h)	2	Intro python, Vegetatio n indices on time series	2			4
3	26.09.2025	Spatial support Descriptors	2	Exercise feature extraction	2			4
4	03.10.2025	Classification 1: basics, accuracy	2	Exercise classification	2	Intro projects	0	4
5	10.10.2025	Classification 2: RF and SVMs	2	Exercise classification	1	discuss projects ideas	1	4
6	17.10.2025	MLP optimizers backprop	2	Intro PyTorch	2			4
	24.10.2025	VACANCES SEMESTRE						
7	31.10.2025	CNNs for classification	2	Exercise CNN	2			4
8	07.11.2025	Semantic segmentation	2	CNN Model Training	2	give DL project datasets		4
9	14.11.2025	Sequence modelling + change detection	2	Semantic segmentation	2			4
10	21.11.2025	Q&A	1			Project	3	4
11	28.11.2025	Exam	3			Project	1	4
12	05.12.2025					Project	4	4
13	12.12.2025					Project time	4	4
14	19.12.2025					Project time	4	4
			22		17		17	56
15	15.01.2026					Hand in projects		