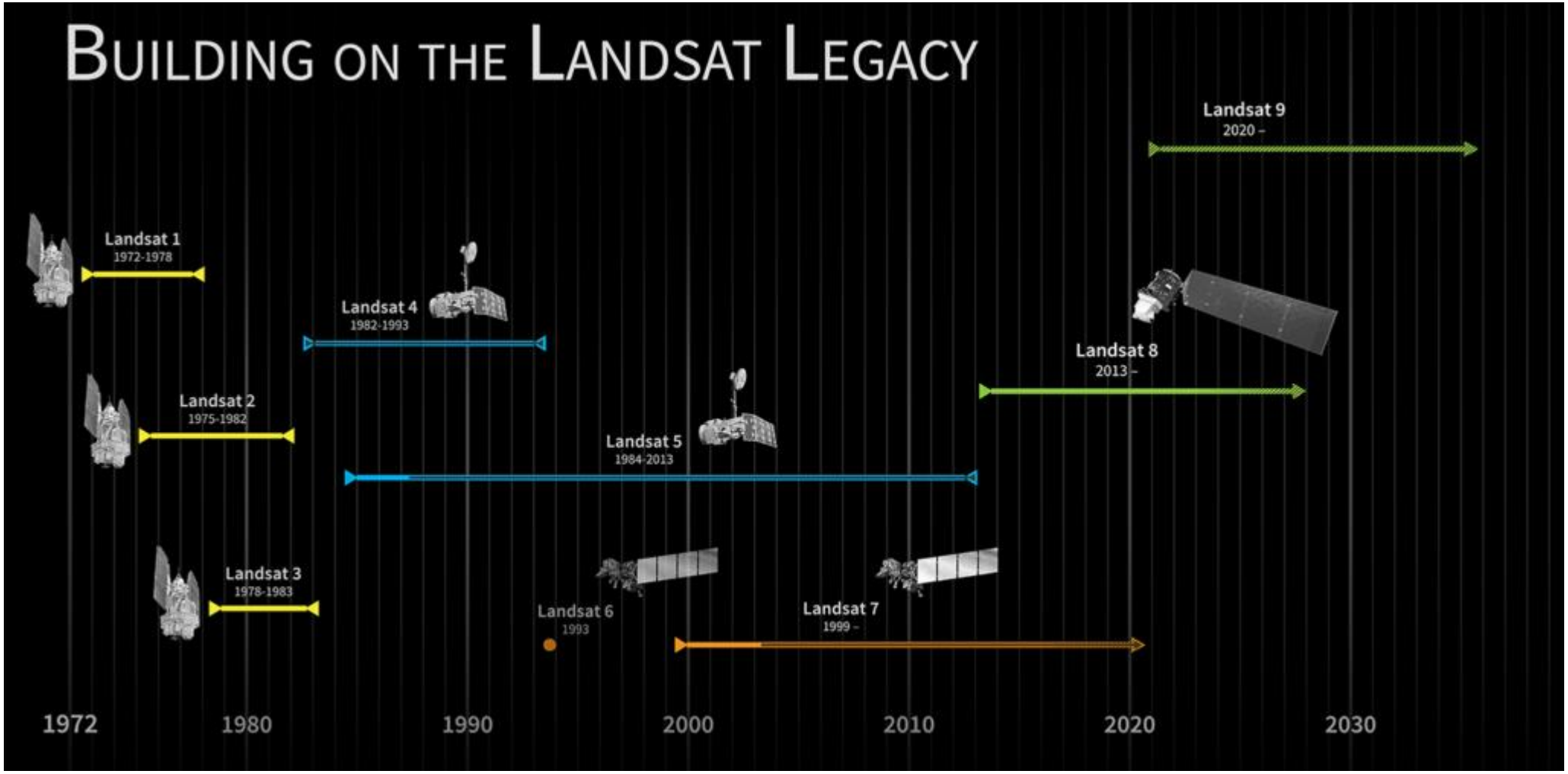
The Future of
Observing the Earth from Space

Learning Objectives

- In this lecture you will learn about…
  - New/future satellite missions
  - Satellite constellations
  - Democratization of space/open skies
  - Observing other planet using satellites
  - Drones

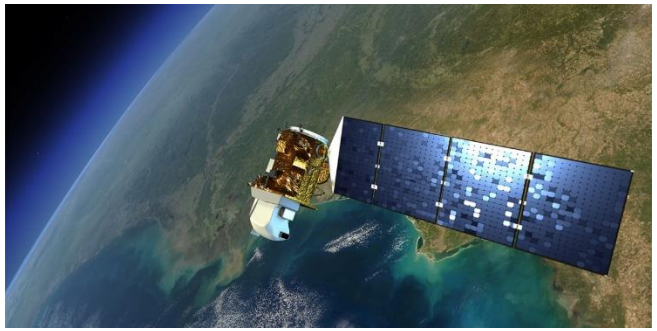
Refresher of Landsat Program

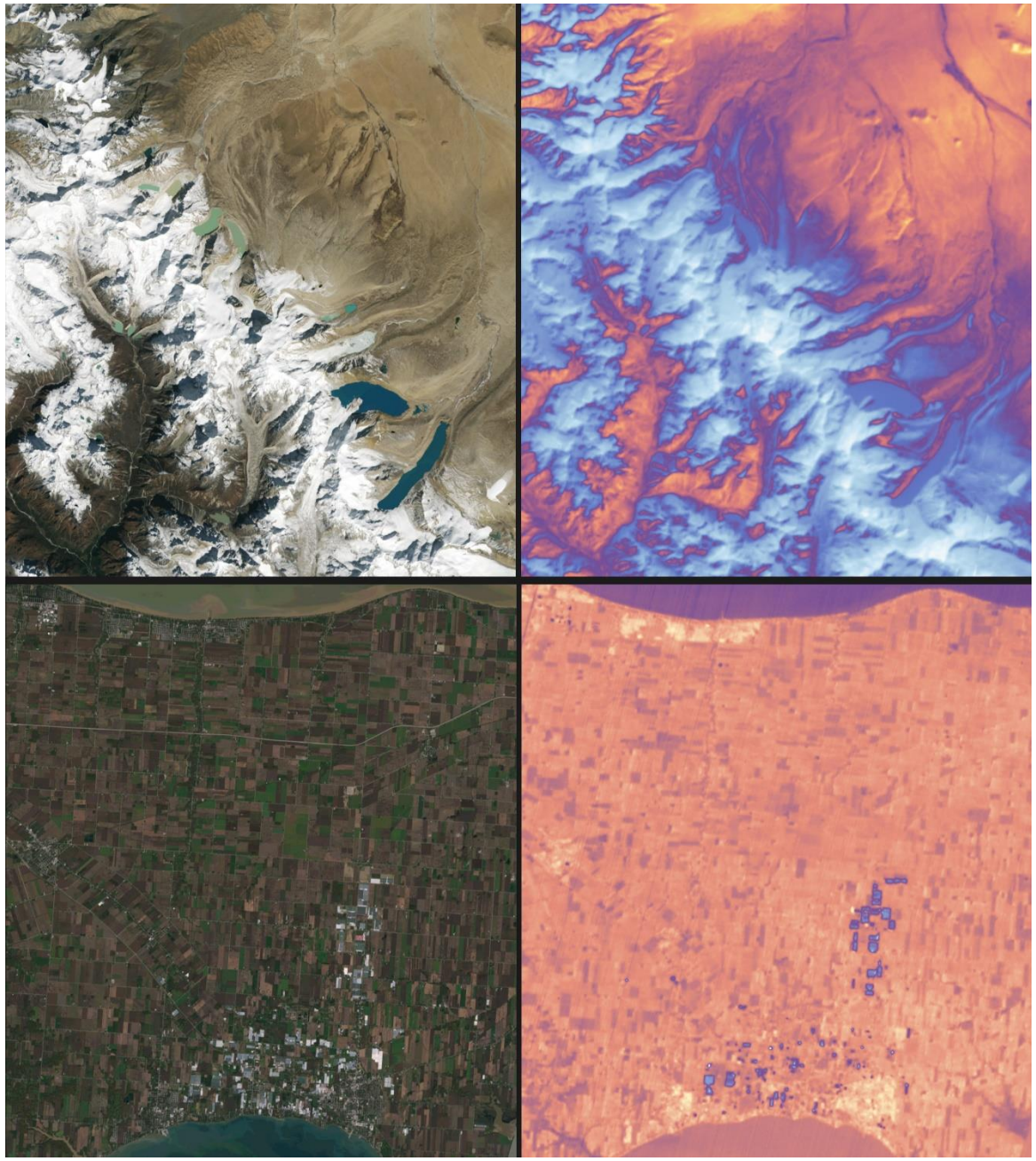


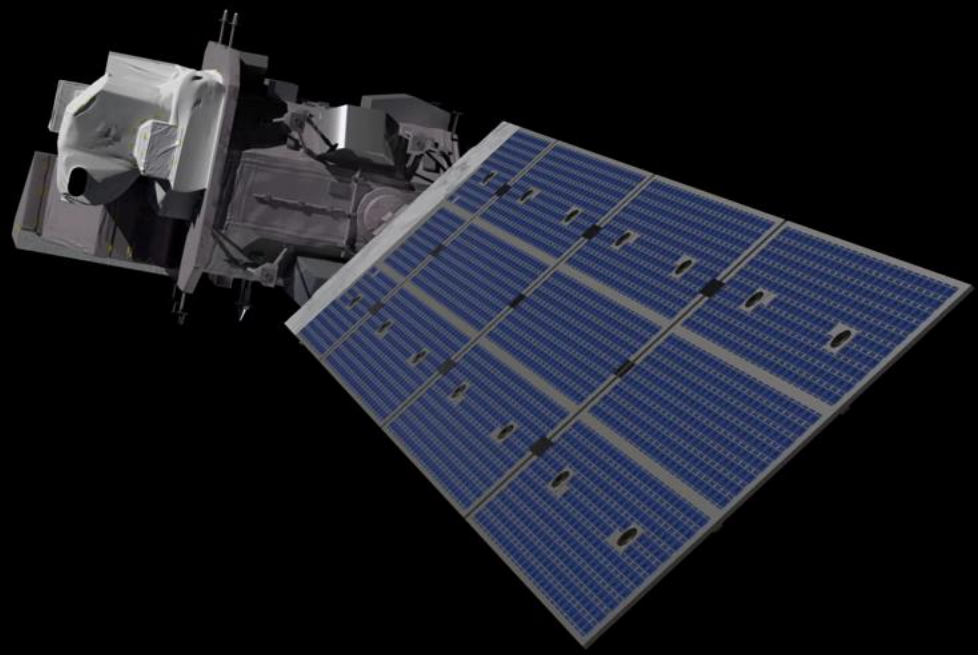
The past and future of Landsat (Source: NASA)

The Future of Landsat

- Landsat 9 was just launched in September 2021
  - It has the OLI-2 and TIRS-2 on board
  - Which are copies of the OLI and TIRS on Landsat 8
  - But improved radiometric resolution (14-bit)

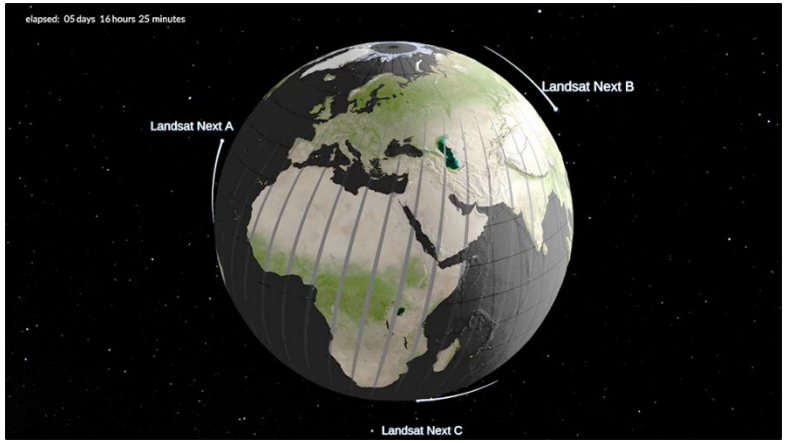


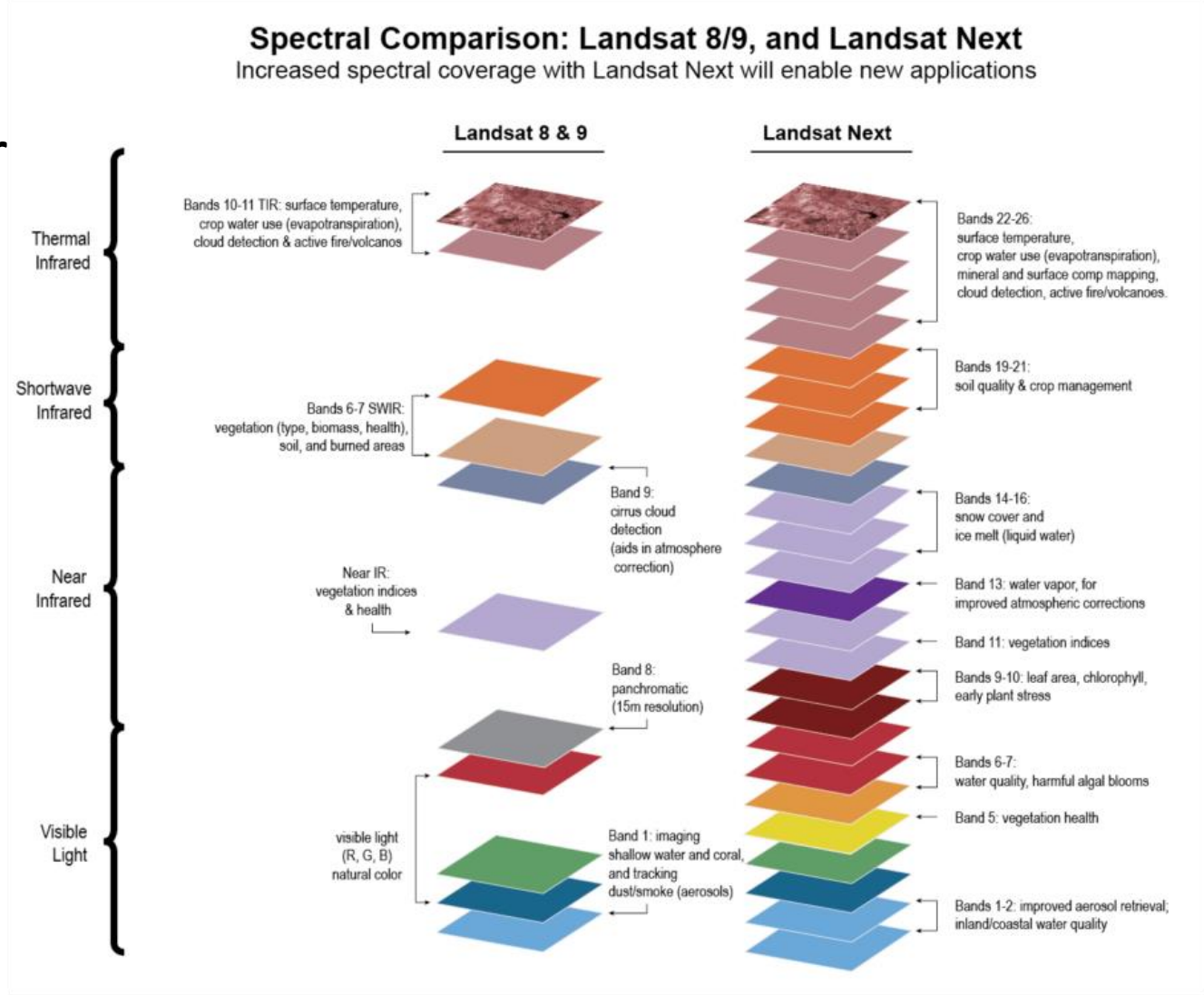




The Future of Landsat

- Landsat Next (launch planned for 2030)
  - Will be a constellation of 3 satellites
    - Improving temporal resolution
  - Will have 26 bands





ESA Sentinel Series of Satellites

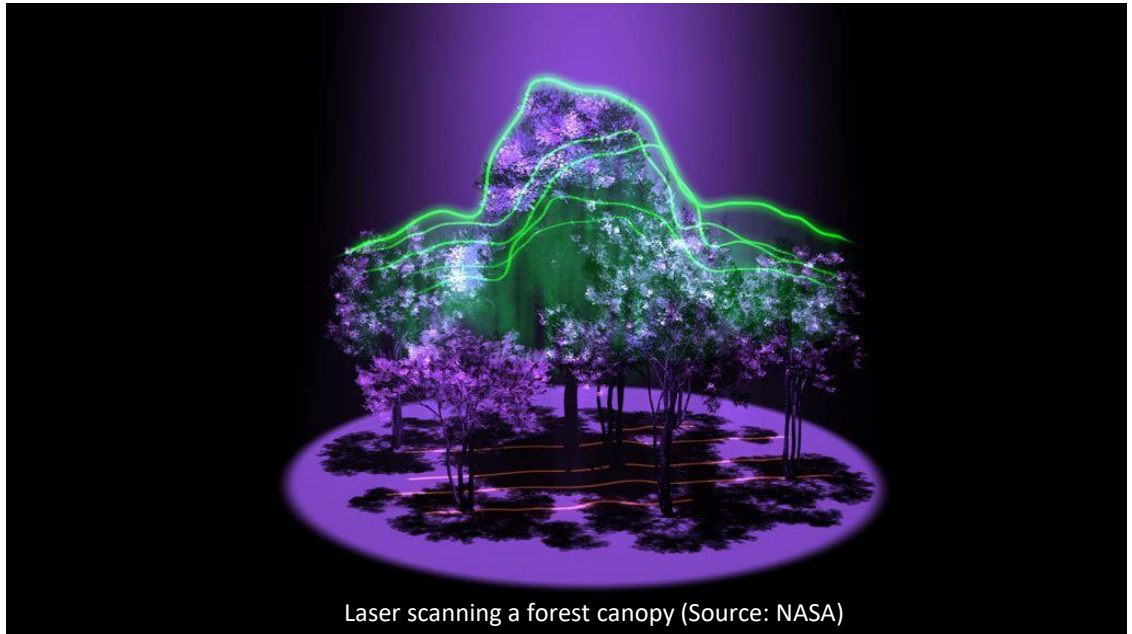
- European Space Agency
- 6 satellites types in the mission

Sentinel 2 (Source: Wikimedia Commons)

1. Weather (launched) – RADAR
2. “Land services” (launched) - Multispectral
3. Ocean and land monitoring (launched) – Multiple instruments
4. Atmospheric composition monitoring
5. Atmospheric composition monitoring (launched)
6. Global sea surface height for climate studies (launched) - RADAR

LiDAR Satellites

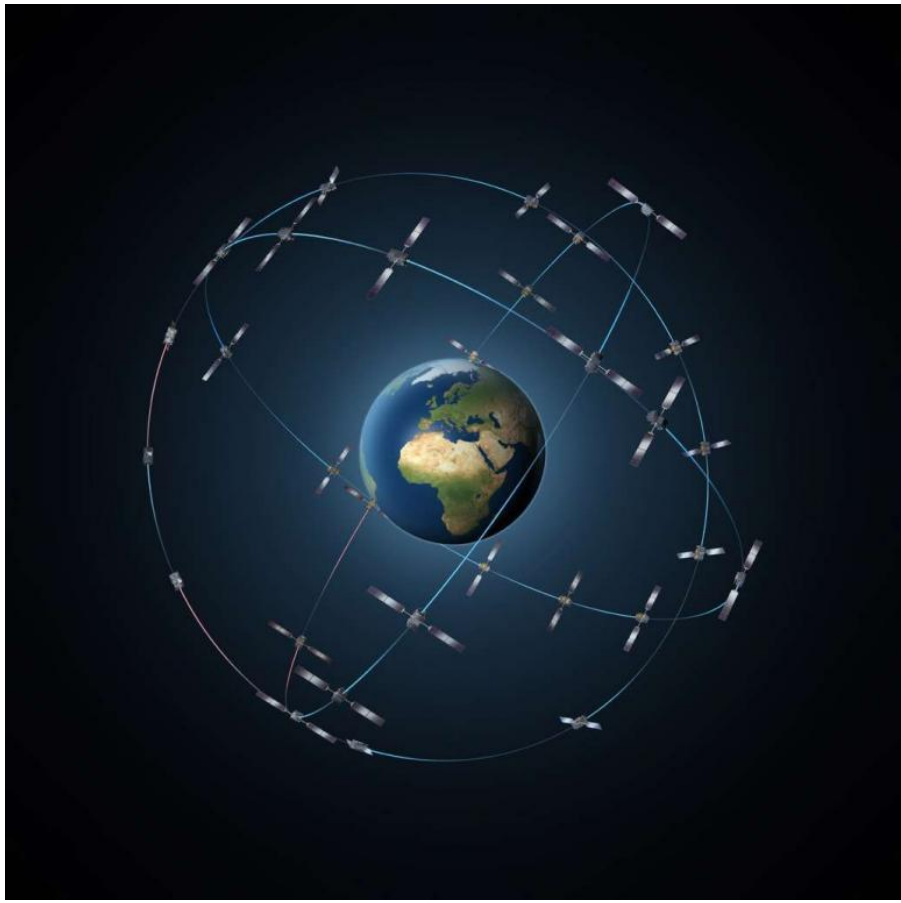
- We've already talked about ICESat
- Global Ecosystem Dynamics Investigation Lidar (GEDI)
  - GEDI is on the International Space Station
  - It provides global, high-resolution LiDAR data



Laser scanning a forest canopy (Source: NASA)

Constellation Satellites

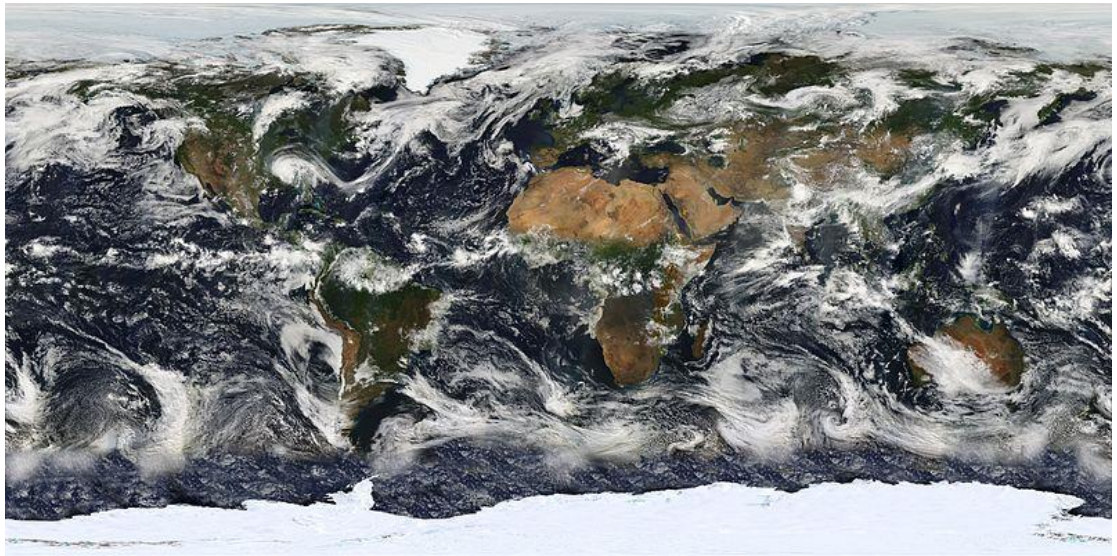
- Group of satellites working together
  - Improves temporal resolution
    - Earth observation satellites in constellations are often offset in the same orbit
- For the future:
  - Continuing to develop the GNSS & earth observation constellations
  - Small Earth-observing satellites in constellations (CubeSats - more on this later in the lecture)



Constellation of satellites (Source: ESA)

Open Skies

- Historically, high costs of operating large earth-observing satellites make it difficult for a single nation or company to collect all relevant data
  - As a result, many satellites observe the entire earth and share data with other countries (e.g. Landsat, Sentinel)
  - This allows research from many countries
  - Additionally, satellites can legally observe the entire Earth

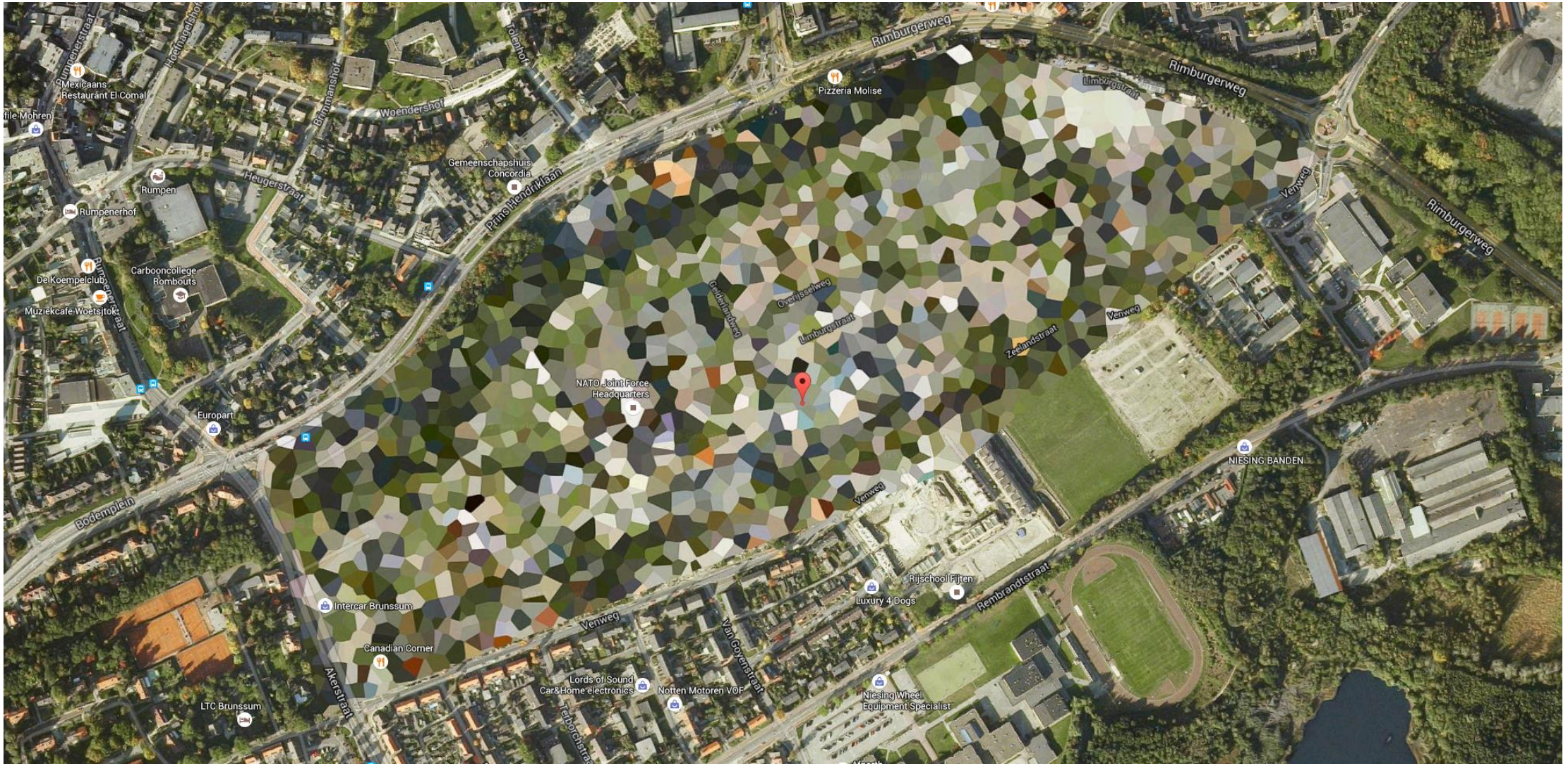


Open Skies

- This poses issues for finer spatial resolution images (that go as detailed as 30 cm) as some areas are sensitive and countries would not want them to be publicly available

Quickbird image (Source: Flickr; Irish Typepad)

- These satellites are commercial and the imagery is not publicly available
- On websites where satellite and aerial images can be freely viewed (such as Google maps), many areas are blurred out



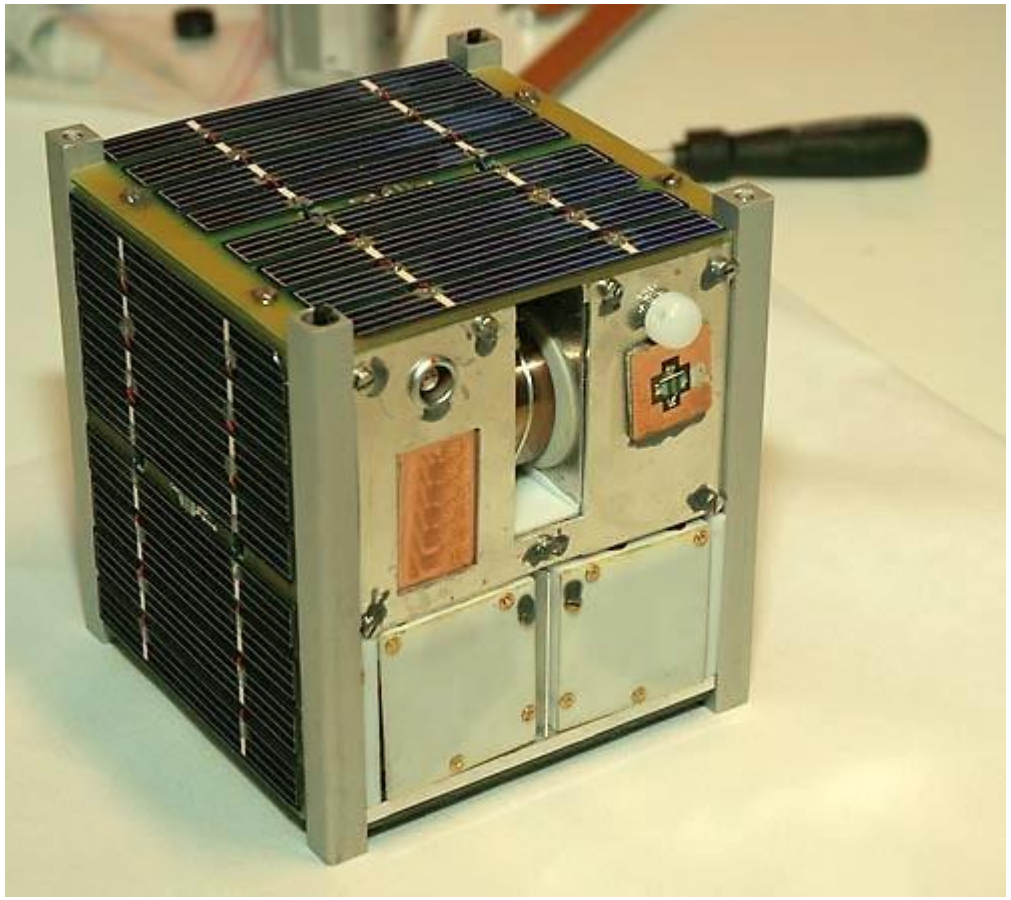
NATO headquarters in the Netherlands (Source: Google Maps)

More about open skies

- It no longer takes a nation to build satellite
- Private enterprises can enter into Earth observation
  - Due to technological advancements and lower costs
  - For example: miniature satellites (CubeSats)
    - Such as Planet Labs
- Leading to democratization of space

The Revolution of CubeSats

- Developed over the past 5-10 years
- Miniaturized satellites that are usually 10 cm cubes and a mass of less than 1 kg
- Hundreds of CubeSat launches from governments, NASA, private companies



CubeSat (Source: Wikimedia Commons)

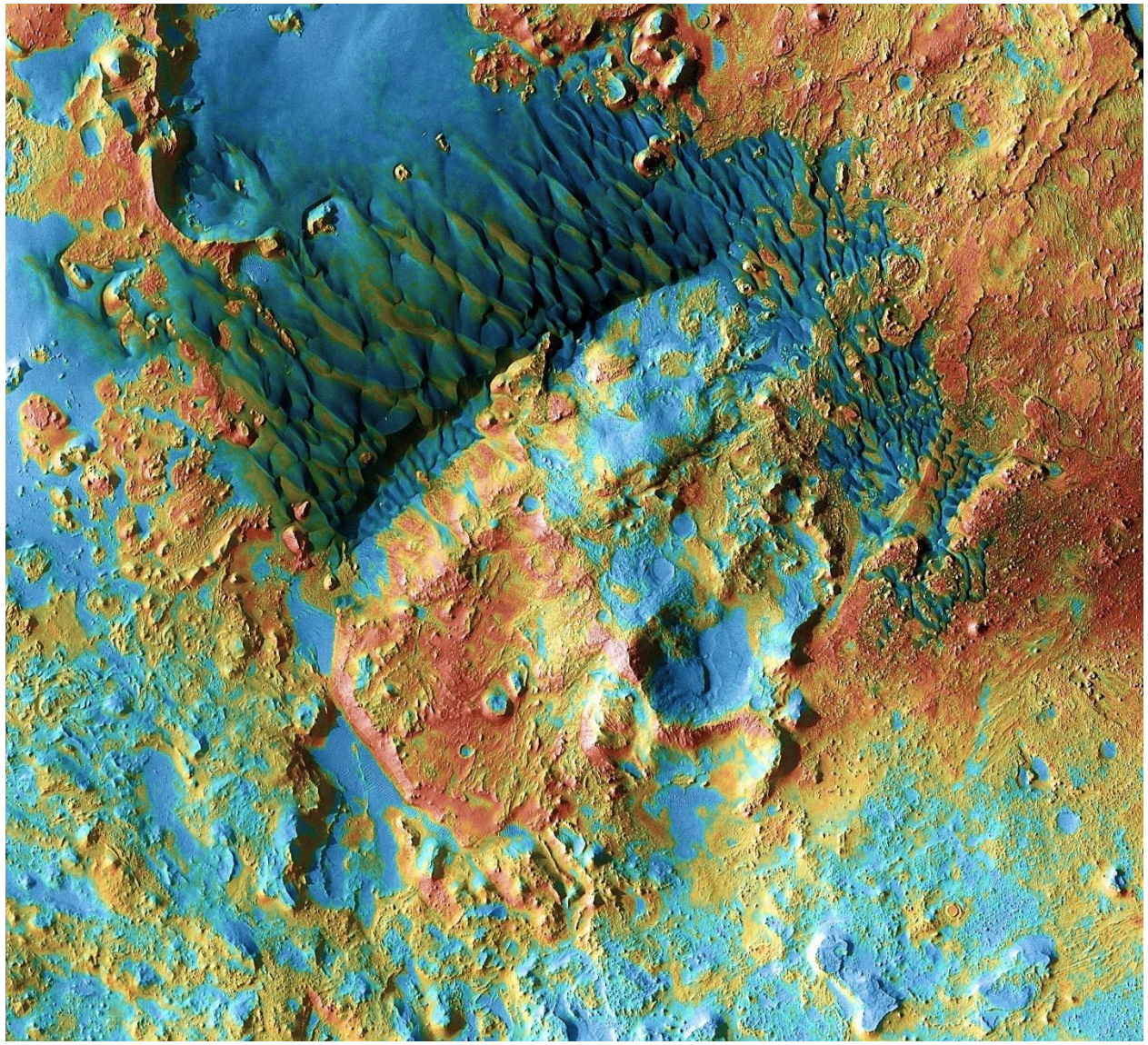
Advantages of CubeSats

- Very inexpensive
  - Standard, off the shelf technologies
  - Can be built very quickly
  - Simple design
- You can efficiently build up very large constellations
  - Allowing for very high temporal resolution
  - Potential for high/moderate resolution imagery with daily global coverage

Other emerging technologies and interplanetary remote sensing

Beyond Earth

- Satellites currently observe, have observed, or are planned to observe the following planets:
  - Mars
  - Saturn
  - Venus
  - Mercury
  - Jupiter
- Other satellites are also observing moons and asteroids
- These satellites mainly observe:
  - Atmospheric composition
  - Geological composition

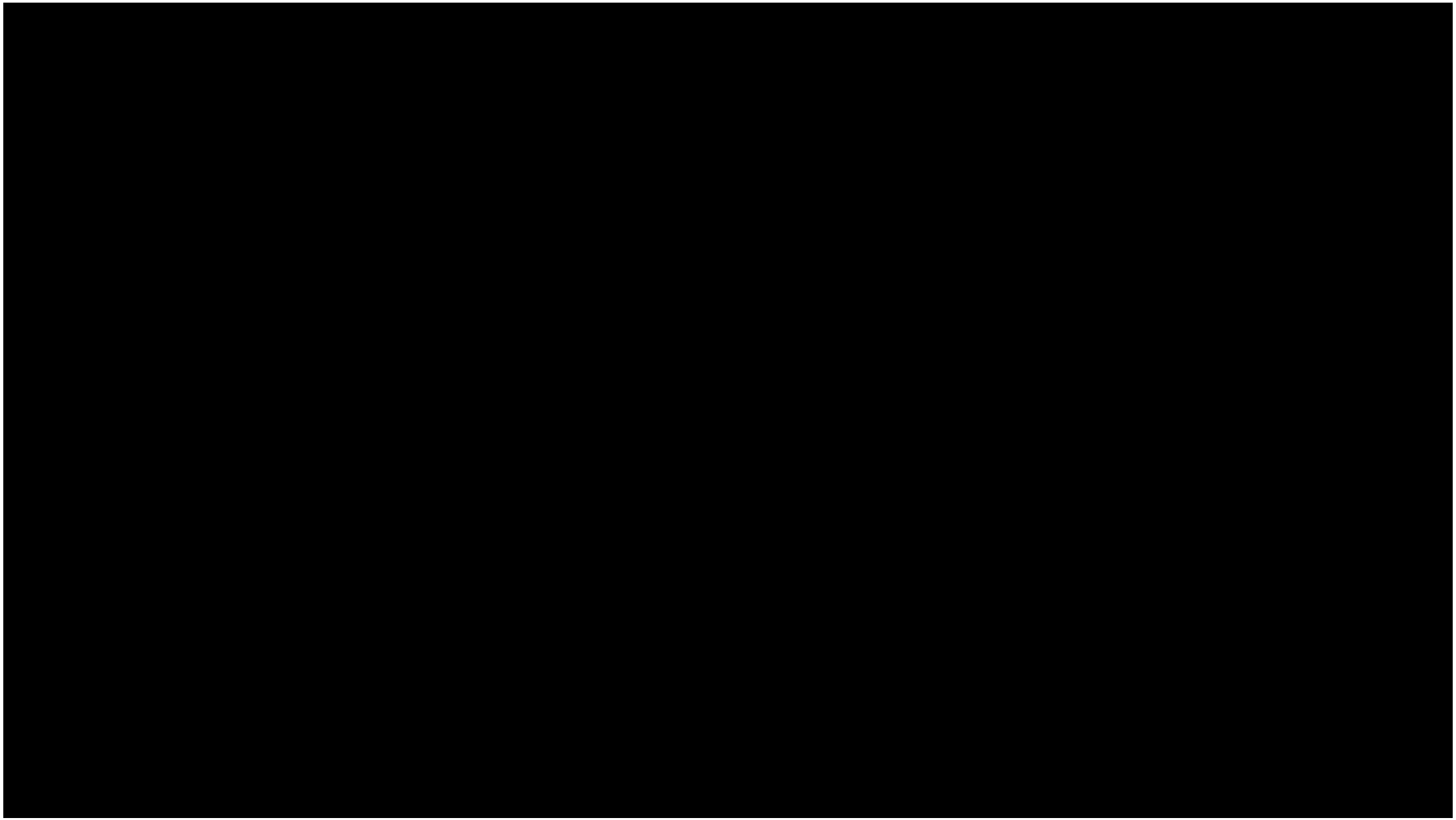


Sand dunes on Mars. Photo credit: Defense video and imagery distribution system

Beyond Earth

- Pluto was observed using the New Horizons spacecraft in 2015
- (Hubble telescope on the left)

Images of Pluto before and after New Horizons. Photo credit: Slate



Unmanned aerial vehicles (UAVs) / Drones

- Although drones do not observe the Earth from space, they are still important for the future of remote sensing
- Carry imagers on a pre-programmed path that can help
  - Determine plant health and cover,
  - Determine mineral locations,
  - Create 3D models of an area,
  - Map wildlife migrations,
  - Emergency responses,
  - Track storms,
  - And more

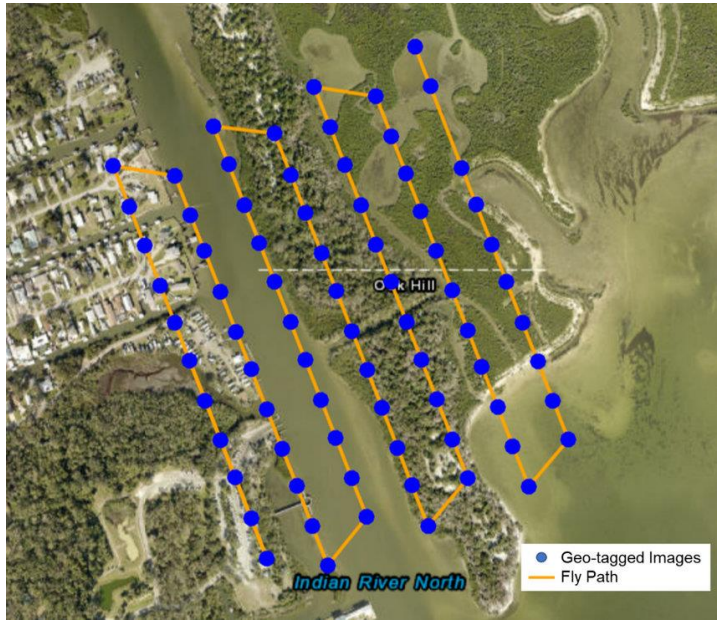
Photos: Arko Lucieer, Keeyen Pang

Technologies Allowing Advancement

- Price
  - Electronics much cheaper
- GIS/GPS
  - More accurate control
- Battery
  - Lighter and longer lasting

Advantages of Drones

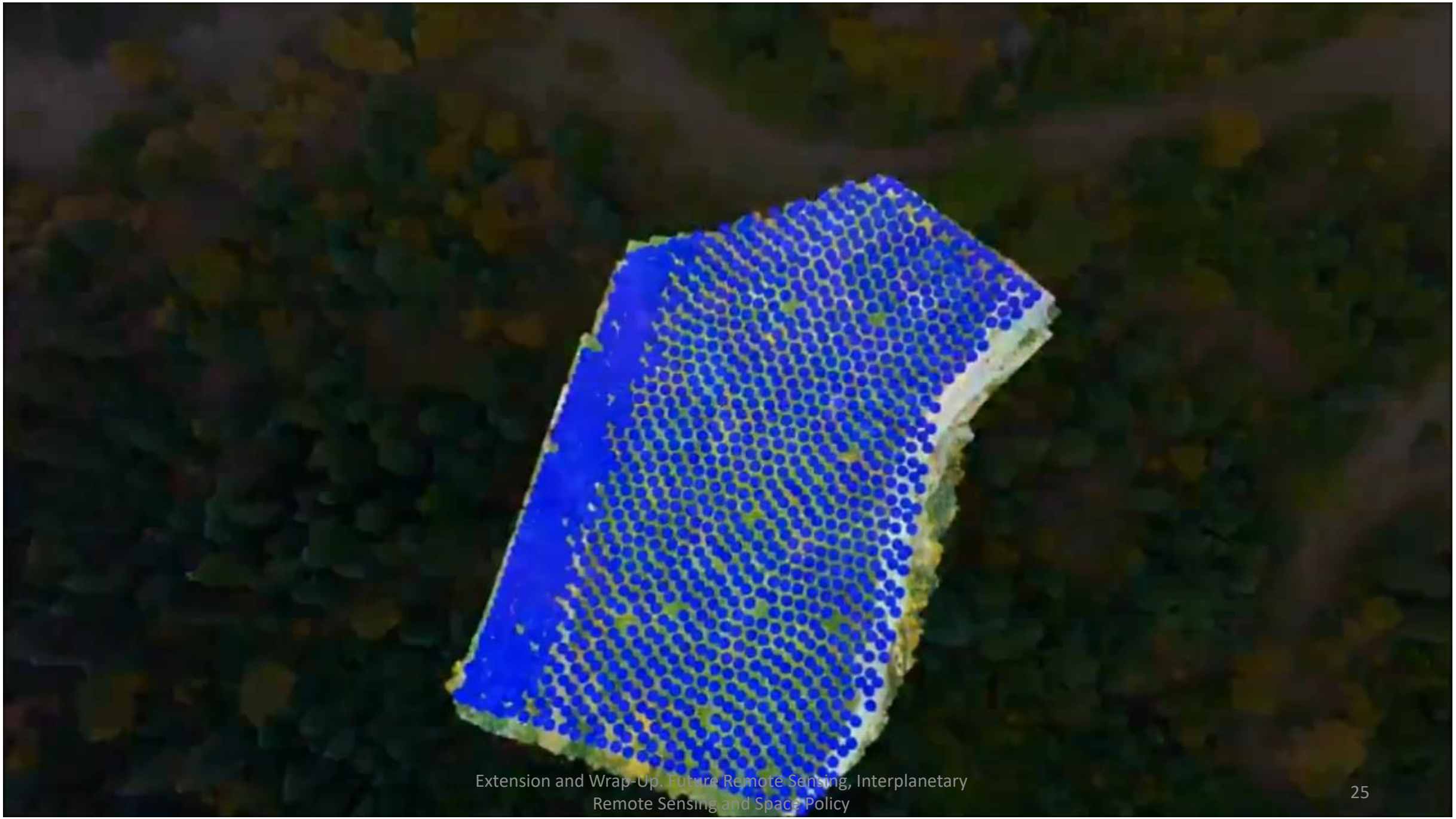
- Very high resolution imagery
  - Sub-centimetre
- Custom spectral resolution
  - NIR common
  - RGB common
  - Lidar
- Custom temporal resolution
  - Fly every day
  - Every week
  - Every month
  - Every year



Yang et al. 2019

Disadvantages of Drones/Future Advancements

- Flight time
  - Typically batteries last 30-45mins
  - Reduces ability to get larger coverage
  - Battery life continuing to improve
- Licensing and flight zones
  - You need a license to fly certain drones
  - Can only be flown in certain areas



Drones and forestry

- Current technology can produce 3D models of forests using aerial imagery and LiDAR
- Valuable for predicting timber volume, forest structure, and fire regimes
- May be less expensive than airplane-based aerial imagery and LiDAR

Photos: Tristan Goodbody

Important Topics

- What technologies are allowing the advancement of drones?
- What are cubesats?
- What is a satellite constellation?
- What has led to the democratization of space?

Images and Videos Cited

The past and future of Landsat (Source: NASA). Image retrieved from https://landsat.gsfc.nasa.gov/landsat-9/

Landsat 9 (Source NASA; Northrop Grumman). Image retrieved from https://landsat.gsfc.nasa.gov/landsat-9/landsat-9-overview/

Image of the Week – RBV and Alaska Glaciers (Source USGS). Video retrieved from https://www.usgs.gov/media/videos/image-week-rbv-and-alaska-glaciers

Sentinel 2 (Source: Wikimedia Commons). This file is licensed under the Creative Commons Attribution-Share Alike 2.0 France license. Image retrieved from https://commons.wikimedia.org/wiki/File:Sentinel_2-IMG_5873-white_(crop).jpg

Sentinel 2 Liftoff (Source: ESA). Video retrieved from https://www.youtube.com/watch?v=mquIMpilG34

Laser scanning a forest canopy (Source: NASA). Image retrieved from https://www.space.com/27795-space-lasers-3d-forest-map.html

Quickbird image (Source: Flickr; **Irish Typepad**). Image retrieved from https://www.flickr.com/photos/irisheyes/2650367

CubeSat (Source: Wikimedia Commons). This file is licensed under the Creative Commons Attribution 1.0 Generic license. Image retrieved from https://commons.wikimedia.org/wiki/File:Ncube2.jpg

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Sentinel image (Source: Wikimedia Commons). This file is licensed under the Creative Commons Attribution-ShareAlike 3.0 IGO license. Image retrieved from https://ia.wikipedia.org/wiki/File:North_Holland_by_Sentinel-2.jpg

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Thank you!