GV2300

Lecture 11: Future of remote sensing

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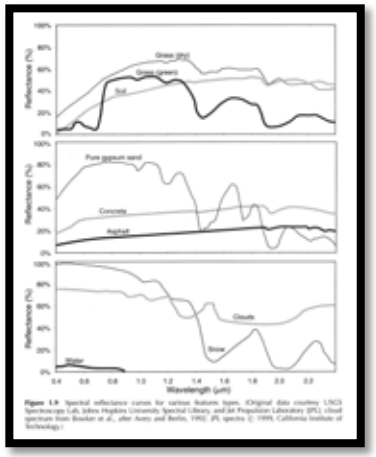
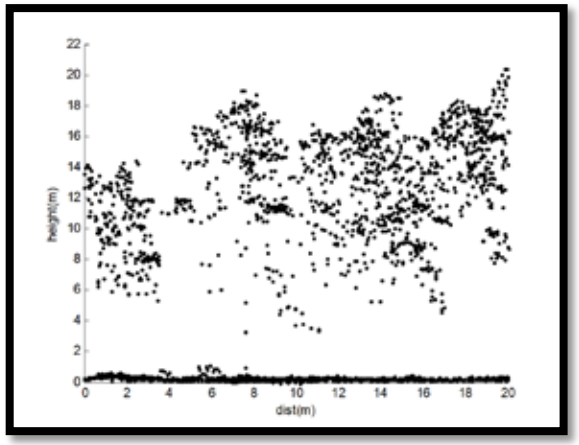
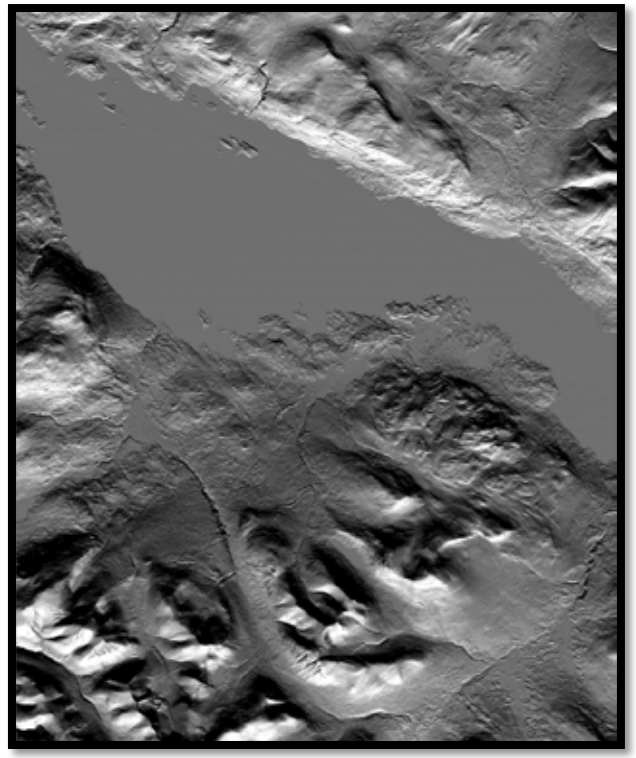
Department of Earth Sciences

January 2023







Current trends in remote sensing

Data

- High temporal resolution satellite data (for free)
- Private actors launching micro-satellites
- 3D data from LiDAR, radar, photogrammetry
- Hyperspectral data
- Personal remote sensing (drones, etc)

Current trends in remote sensing

Data

- High temporal resolution satellite data (for free)
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Combining multi-source data

Methods

- Artificial intelligence/deep learning algorithms

Current trends in remote sensing

Centralization

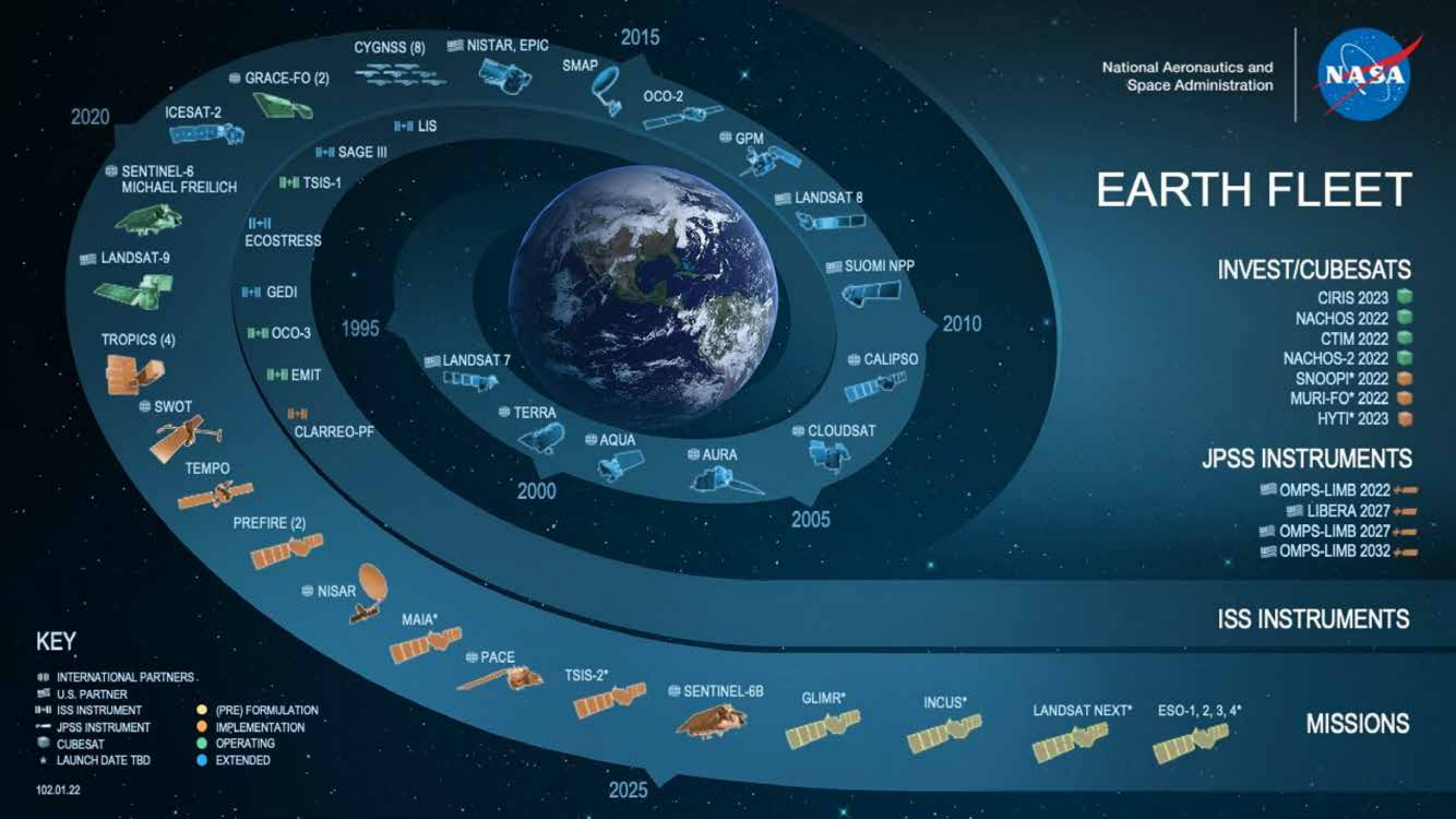
- Cloud computing
- Provision of ”analysis-ready-data” and ”already-analyzed-data”

Decentralization

- Citizen science & increased awareness of remote sensing
- Drones

Future satellites planned

- Focus is on Earth Observation sensors
- Focus on NASA and ESA (or other European)
- India and China are also big space nations, but I have not focused on their satellite programs here, as the data can be difficult to access.

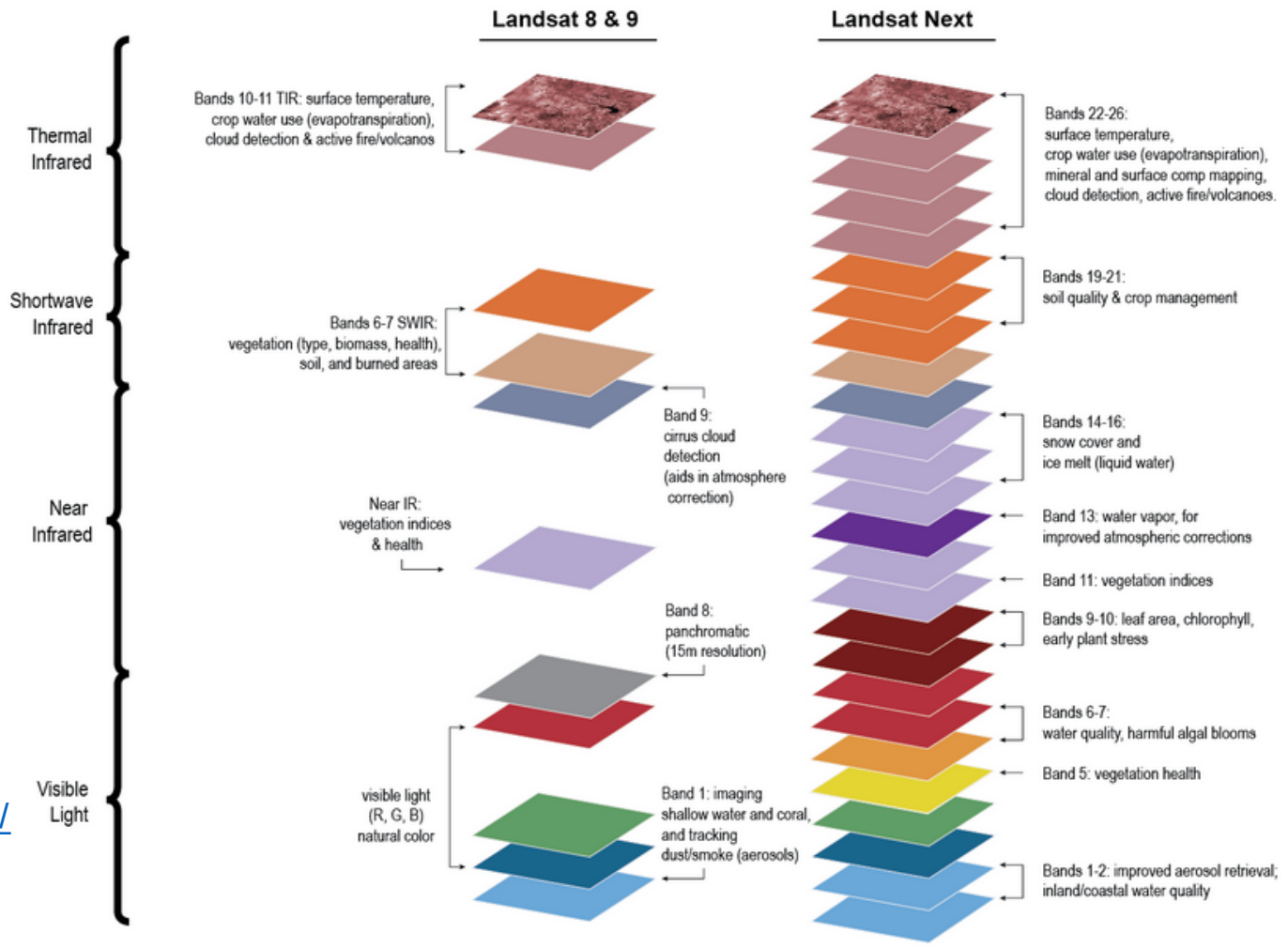

National Aeronautics and Space Administration
NASA
EARTH FLEET
2015
CYGNSS (8)
NISTAR, EPIC
SMAP
OCO-2
GPM
LANDSAT 8
SUOMI NPP
2010
CALIPSO
CLOUDSAT
AURA
AQUA
TERRA
LANDSAT 7
2005
2000
1995
2020
GRACE-FO (2)
ICESAT-2
LIS
SAGE III
TSIS-1
SENTINEL-6 MICHAEL FREILICH
ECOSTRESS
LANDSAT-9
GEDI
OCO-3
TROPICS (4)
EMIT
SWOT
CLARREO-PF
TEMPO
PREFIRE (2)
NISAR
MAIA*
PACE
TSIS-2*
SENTINEL-6B
GLIMR*
INCUS*
LANDSAT NEXT*
ESO-1, 2, 3, 4*
2025
INVEST/CUBESATS
CIRIS 2023
NACHOS 2022
CTIM 2022
NACHOS-2 2022
SNOOPI* 2022
MURI-FO* 2022
HYTI* 2023
JPSS INSTRUMENTS
OMPS-LIMB 2022
LIBERA 2027
OMPS-LIMB 2027
OMPS-LIMB 2032
ISS INSTRUMENTS
MISSIONS
KEY
INTERNATIONAL PARTNERS
U.S. PARTNER
ISS INSTRUMENT
JPSS INSTRUMENT
CUBESAT
LAUNCH DATE TBD
(PRE) FORMULATION
IMPLEMENTATION
OPERATING
EXTENDED
102.01.22

Landsat “Next”

Landsat “Next” (or Landsat-10)

- Constellation of 3 satellites (A, B and C)
- 11 wavelength bands used by Landsat 8 & 9
- 6 new bands in Red Edge and NIR region matching Sentinel-2 bands
- 10 other new bands
- A total of 26 bands
- Changing to 10 and 20 m pixel sizes!
- One image every 6 days at equator
- Launch “late 2030”

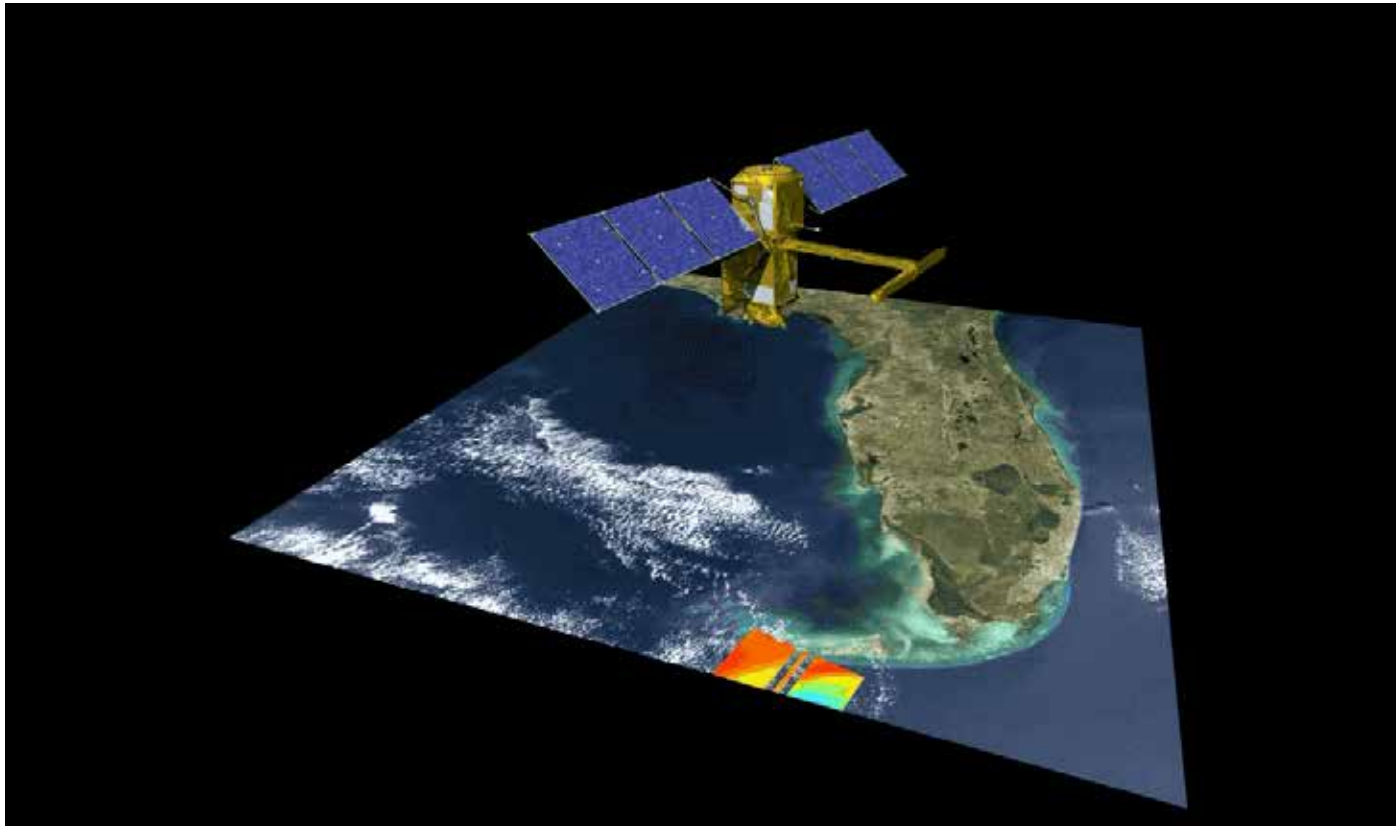
See all bands here: https://landsat.gsfc.nasa.gov/satellites/landsat-next/



NASA

SWOT (Surface Water and Ocean Topography)

- Radar altimeter and KA-band radar interferometer
- Global sea surface levels, surface water
- Two images every 21 days
- Just launched 17 Dec 2022



NASA - ISRO

NISAR (NASA-ISRO Synthetic Aperture Radar)

- Two radar frequencies (L-band and S-band)
- Surface topography at < 1 cm resolution
- Biomass, sea-level, ice masses, ground-water, …
- 3 – 10 m resolution
- Launch 2023 or 2024

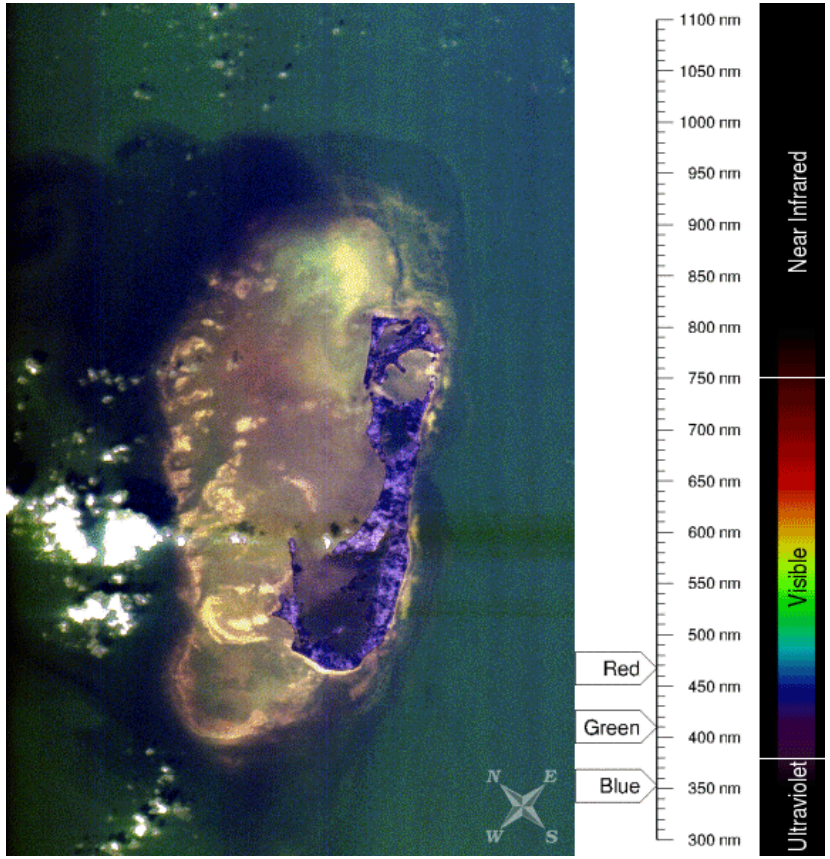
NASA

PACE (Plankton, Aerosol, Cloud and ocean Ecosystem)

- For distribution of phytoplankton, tiny plants and algae. Also key atmospheric variables on air quality.
- Ocean Color Instrument (OCI)
  - Hyperspectral (UV-NIR) with 5nm spacing + 7 SWIR bands
  - 1 km spatial resolution
  - Daily data
  - 20° look angle to avoid sun-glint
- Launch Jan. 9, 2024

GeoCarb (Geostationary Carbon Cycle Observatory)

- Daily observations of CO_2, CH_4, CO and solar-induced fluorescence (SIF) at a spatial resolution of 5 to 10 km, planned for 2024
- **Cancelled** due to cost overruns and similarity to EMIT (https://www.nasa.gov/press-release/nasa-to-cancel-geocarb-mission-expands-greenhouse-gas-portfolio - Nov 2022)

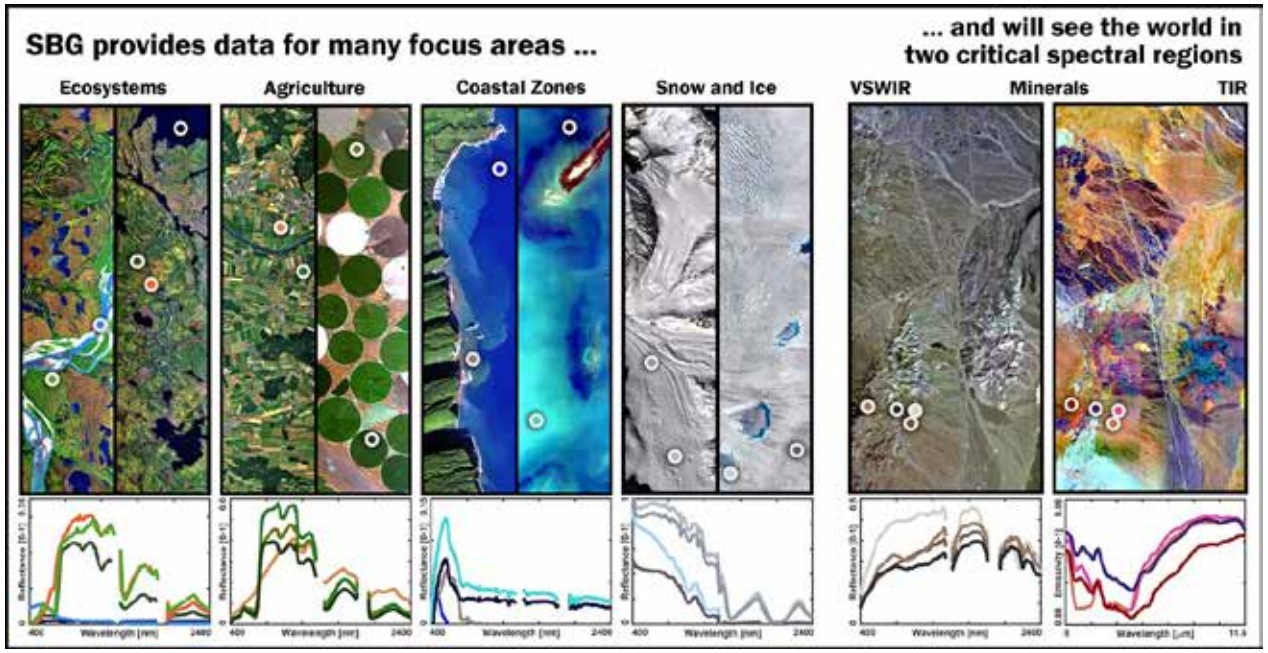


Plankton over Bahamas
Credit: Norman Kuring (NASA)

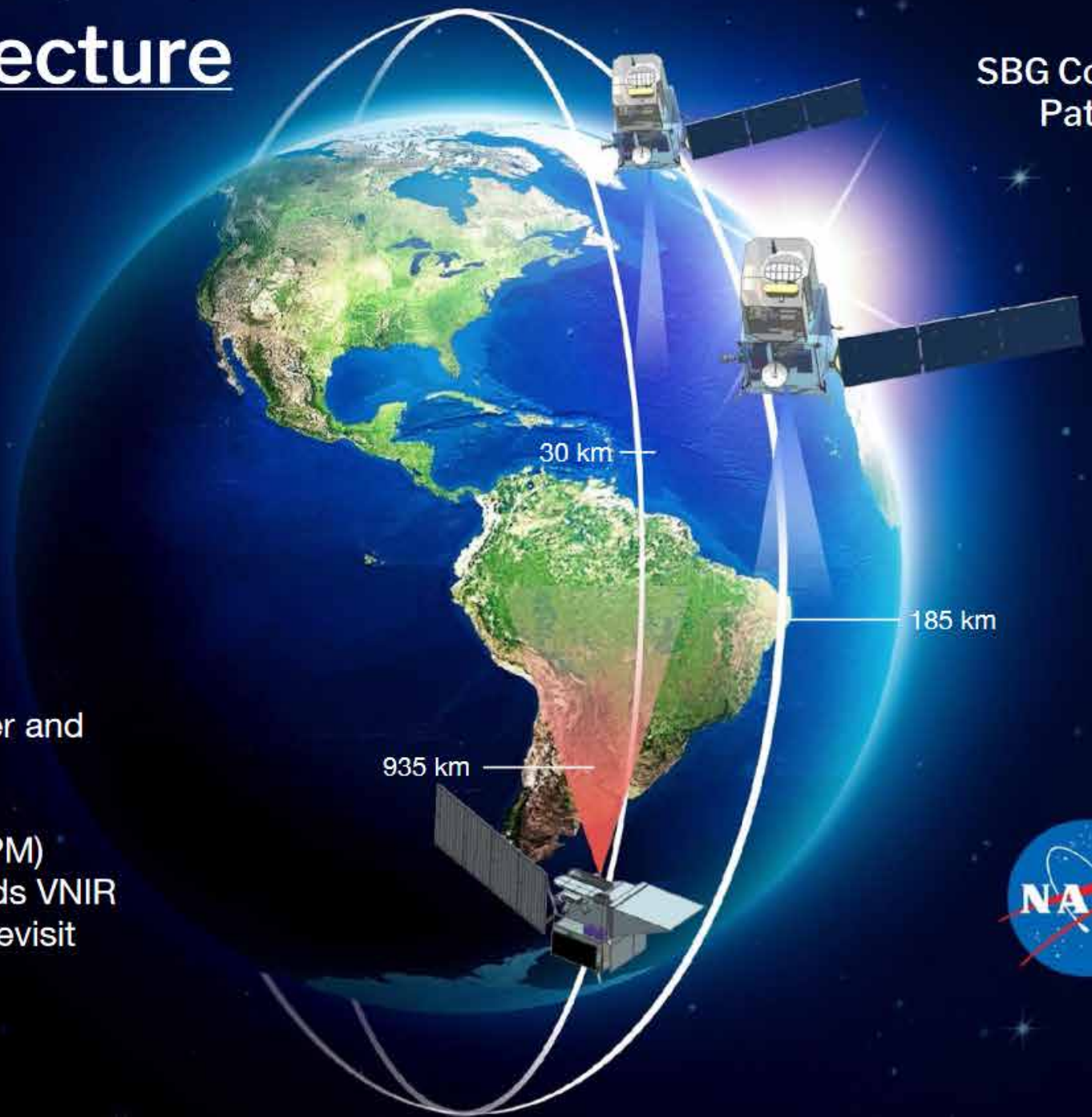
NASA

Surface Biology and Geology mission (SBG)

- Hyperspectral sensor with 30-45 m pixels (VNIR) and revisit time 6-17 days
- TIR (> 5 bands) 40-60 m pixels and revisit 1-7 days
- Focus on Earth surface geology and biology, ground/water temperature, snow reflectivity, active geologic processes, vegetation traits, and algal biomass
- Launch 2027/28 (??)



SBG Architecture



SBG Constellation Pathfinder

agenzia spaziale italiana

SBG Light

Wide-swath VSWIR spectrometer

Sun-sync orbit (late AM)
185 km swath
16 day revisit
10 nm, 200+ bands
30 meter GSD
High SNR and radiometri performance
~5 deg off-nadir tilt

SBG Heat

Wide-swath TIR imager and ASI VNIR camera

Sun-sync orbit (early PM)
5+ bands TIR, 2+ bands VNIR
935 km swath, 3 day revisit
60 meter GSD
0.2K NeDT

NASA

NASA

PREFIRE (Polar Radiant Energy in the Far InfraRed Experiment)

- Two cubesats
- Measuring 0-54 цm at 0.84 цm intervals
- Monitoring the radiant energy of the Arctic
- Launch 2023

Small Satellite Missions

Small Spacecraft Technology Program
Earth Science Technology Office
CubeSat Launch Initiative
CubeSats on Exploration Mission-1
Ames Small Satellite Portal
JPL Small Satellite Portal

Related Topics

Commercial Space
CubeSats
CYGNSS Hurricane Mission
Space Station
Space Tech
All Topics A-Z

NASA Kennedy

NASA CubeSat Launch Initiative Deploys 150th from Space Station

Media Contacts

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About

Small spacecraft and satellites help NASA advance scientific and human exploration, reduce the cost of new space missions, and expand access to space. Through technological innovation, small satellites enable entirely new architectures for a wide range of activities in space with the potential for exponential jumps in transformative science.

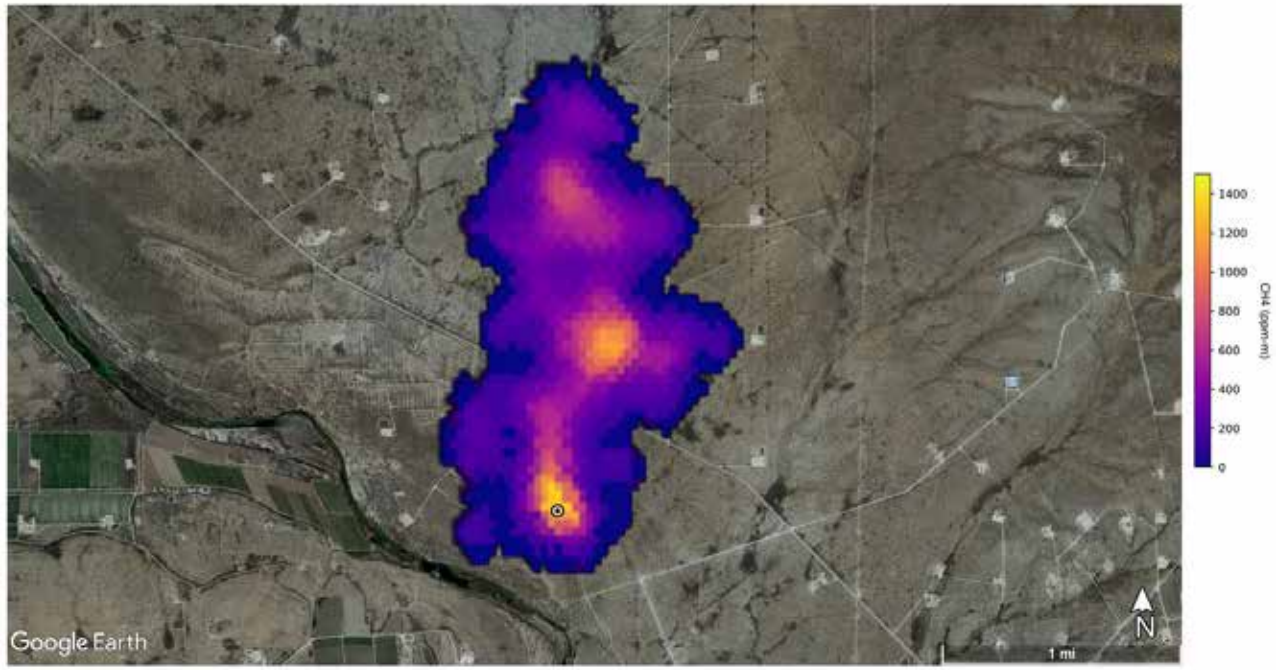
NASA Ames

CAPSTONE Will Soon Meet the Crux of Its Deep Space Route to the Moon

NASA

Relatively new sensors placed on the ISS

- **Earth Surface Mineral Dust Source Investigator (EMIT)** – Hyperspectral imaging spectrometer (380 – 2500 nm) - Sent 2022. Also useful for CH_4
- **GEDI** – Campaign to keep this lidar past 2022



This image shows a methane plume 2 miles (3 kilometers) long that NASA's Earth Surface Mineral Dust Source Investigation mission detected southeast of Carlsbad, New Mexico. Methane is a potent greenhouse gas that is much more effective at trapping hea... Credit: NASA/JPL-Caltech

A few recommendations - NAS 2017 Decadal plan

(still in an early phase)

Can be missions or target variables

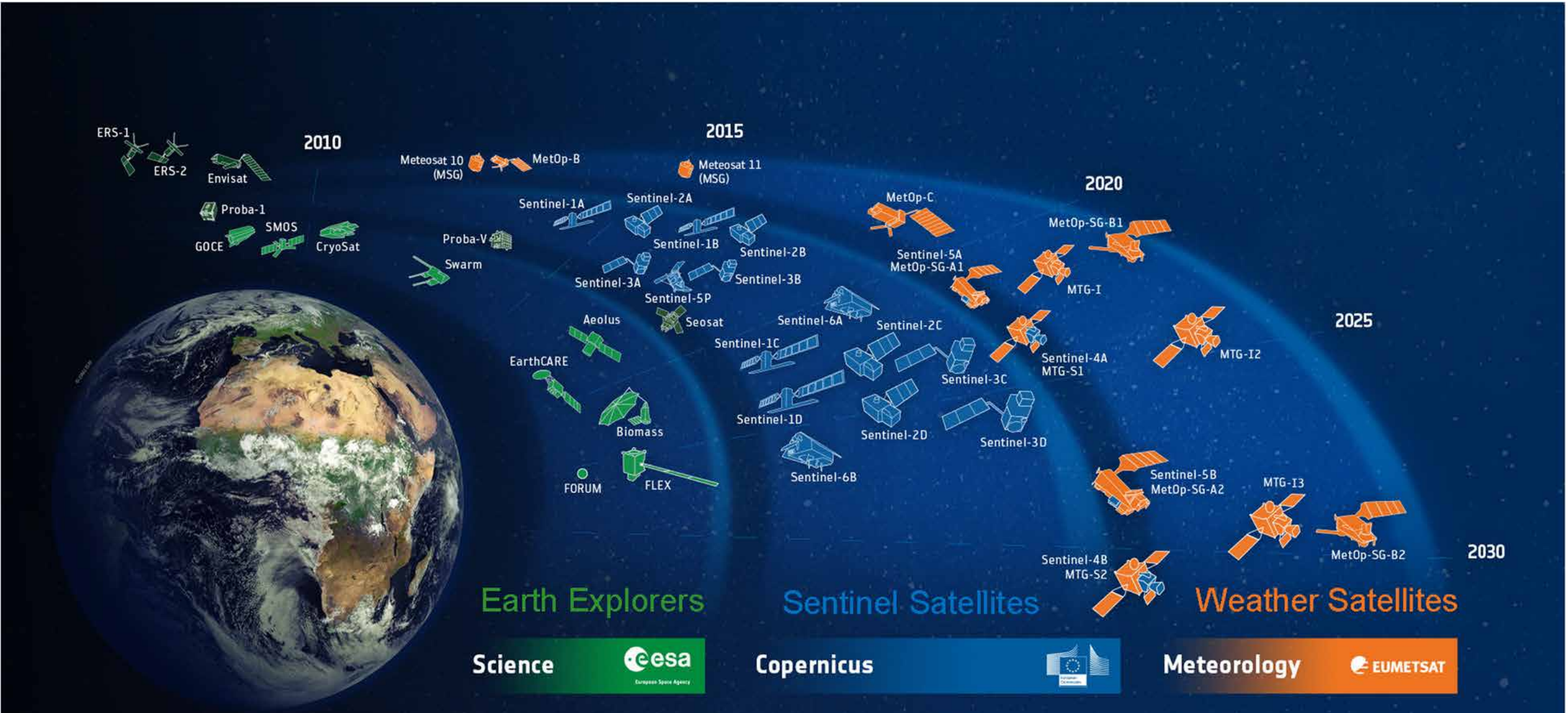
- LIST – Surface Topography and Vegetation
- GRACE-II – Gravitational changes in Earth surface
- SDC – Surface Deformation and Change (InSAR at high resolution)
- SCLP (Snow and Cold Land Processes, part of the Earth System Explorer program)- Snow Depth and Snow Water Equivalent

Read more at https://science.nasa.gov/earth-science/decadal-surveys/

Websites used for NASA+

- https://science.nasa.gov/earth-science/earth-missions-future
- https://eospso.nasa.gov/future-missions
- https://landsat.gsfc.nasa.gov/satellites/landsat-next/
- https://sbg.jpl.nasa.gov/
- https://earth.jpl.nasa.gov/emit/resources/99/emit-fact-sheet/
- https://science.nasa.gov/about-us/science-strategy
- https://nap.nationalacademies.org/catalog/24938/thriving-on-our-changing-planet-a-decadal-strategy-for-earth
- https://science.nasa.gov/earth-science/decadal-stv
- https://eospso.nasa.gov/earthobserver/
- https://eol.jsc.nasa.gov/ESRS/ISS_Remote_Sensing_Systems/

ESA – European Space Agency



ESA – Sentinel continuation

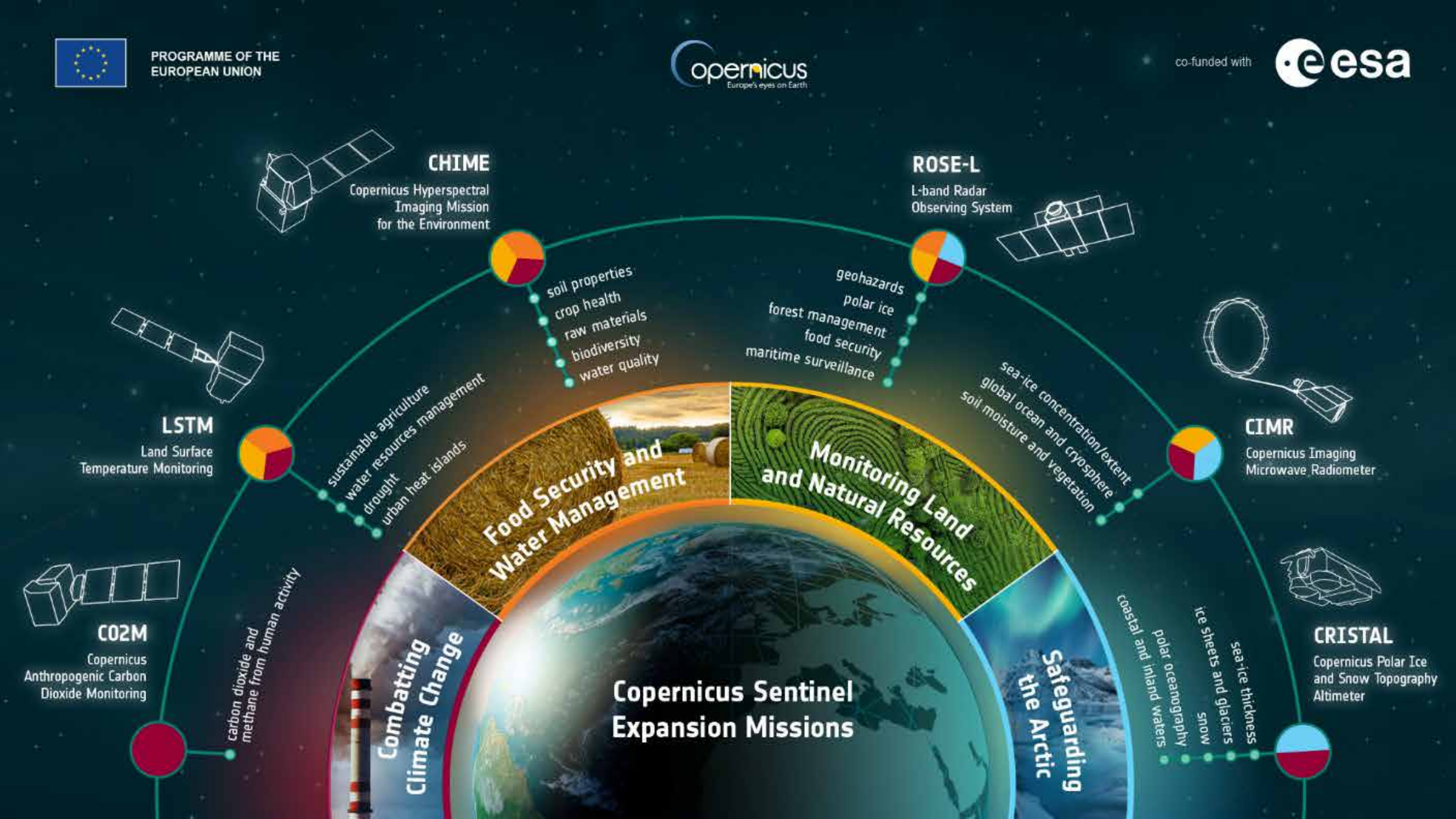
Continuation and complements to the current Sentinel satellites (1-6)

Sentinel-1C & 1D – 1C launch Q2 of 2023 (due to 1B failure Dec 2021)

Sentinel-2C & 2D – 2024 and 2025, resp.

Sentinel-6B “Michael Freilich” (6A already launched 2020) – with NASA

- Sea-level altimetry
- Launch 2025


PROGRAMME OF THE EUROPEAN UNION
Copernicus
Europe's eyes on Earth
co-funded with
esa
CHIME
Copernicus Hyperspectral Imaging Mission for the Environment
soil properties
crop health
raw materials
biodiversity
water quality
ROSE-L
L-band Radar Observing System
geohazards
polar ice
forest management
food security
maritime surveillance
LSTM
Land Surface Temperature Monitoring
sustainable agriculture
water resources management
drought
urban heat islands
CIMR
Copernicus Imaging Microwave Radiometer
sea-ice concentration/extent
global ocean and cryosphere
soil moisture and vegetation
Food Security and Water Management
Monitoring Land and Natural Resources
CO2M
Copernicus Anthropogenic Carbon Dioxide Monitoring
carbon dioxide and methane from human activity
Combatting Climate Change
Copernicus Sentinel Expansion Missions
Safeguarding the Arctic
CRISTAL
Copernicus Polar Ice and Snow Topography Altimeter
coastal and inland waters
polar oceanography
ice sheets and glaciers
snow
sea-ice thickness

ESA – Copernicus Expansion

CO2M (Copernicus Anthropogenic Carbon Dioxide Monitoring) will track individual sources of anthropogenic emissions of CO2 with a relatively high spatial-resolution imaging spectrometer

- Global weekly coverage
- Two satellites
- Launch 2026

LSTM (Land Surface Temperature Monitor)

- 3 satellites
- 1 to 3 day global coverage
- Thermal IR bands, 50 m pixel size
- Synchronous orbit with Sentinel-2
- a wide temperature range, from approx. -20°C to +30°C, with high precision (0.3°C)
- Launch 2029

ESA – Copernicus Expansion

ROSE-L (Radar Observing System for Europe – L-Band) Sentinel 12

- Surface deformation, forest biomass, soil moisture, sea and land ice
- Dual satellites, with global coverage every 6 days, and over Europe every 3 days
- < 50 m^2 pixels (e.g., 5 x 10 m?)
- Launch 2028

ESA – Copernicus Expansion

CRISTAL (Copernicus PolaR Ice and Snow Topography Altimeter)

- For sea-ice thickness & snow depth, as well as ice elevation on land
- Launch 2027

CIMR (Copernicus Imaging Microwave Radiometer)

- A marine-focused mission providing observations of sea-ice concentration, sea-surface temperature and salinity via passive microwave sensing
- L-Band radar
- Launch 2028

CHIME (Copernicus Hyperspectral Imaging Mission for the Environment)

- Hyperspectral with 225 bands from Blue to SWIR
- 20-30 m pixels
- 2 satellites
- Launch 2029

ESA – “Earth Explorers”

EarthCARE (EE-6)

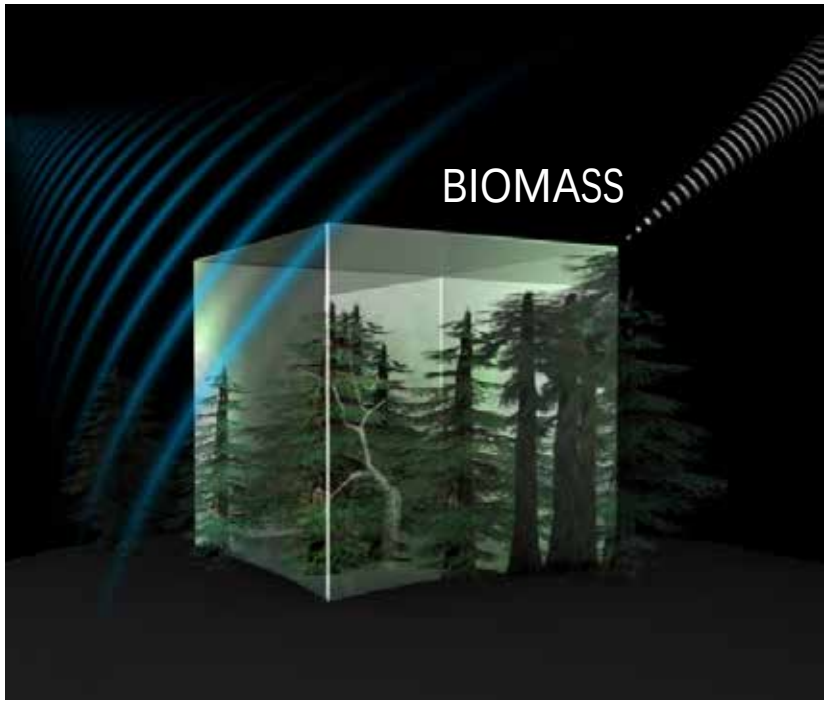
- Clouds, Aerosols, and Radiation Explorer
- 2 NIR, 2 SWIR, 2 TIR bands at 500 m pixel size
- Launch Q4, 2023

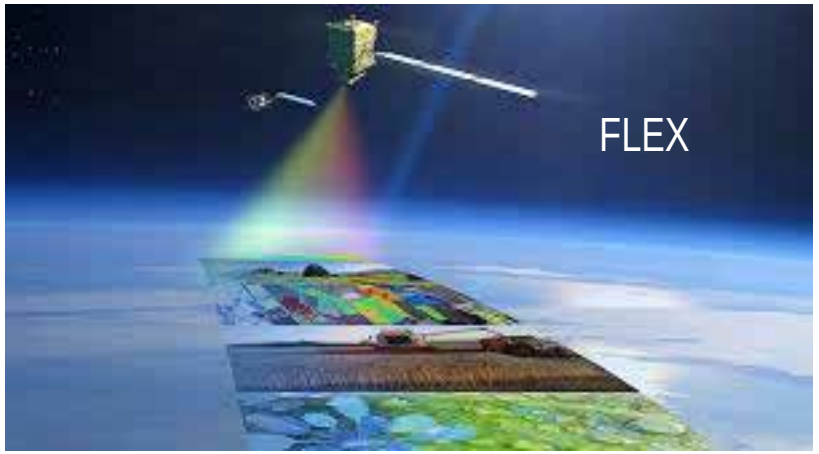
BIOMASS (EE-7)

- First spaceborne P-band radar satellite
- Launch 2024

FLEX (EE-8)

- Flouresence in 434 spectral bands
- Fluorescence shows vegetation photosynthetic activity and plant health and stress.
- Visible to NIR at 300 m pixels
- Launch mid-2025





More websites used

ESA EO news

- https://sentinels.copernicus.eu/web/sentinel/missions/copernicus-expansion-missions
- https://www.esa.int/Applications/Observing_the_Earth/Copernicus/Copernicus_Sentinel_Expansion_missions

General

- https://www.eoportal.org/satellite-missions
- http://www.eohandbook.com/eohb05/ceos/part3_3.html
- https://www.eoportal.org/
- https://space.oscar.wmo.int/satellitefrequencies

Other

Pléiades Neo (France - CNES)

- Visible to NIR
- 30 cm (pan) and 1.2 m (multispectral) pixels
- 14 km swath width
- Launch 2021 (2 satellites)
- Two satellites were to be launched Dec 20, 2022, Pléiades Neo 5 & 6, but were lost after a failure in the Vega C launcher.

https://www.eoportal.org/satellite-missions/pleiades-neo#performance-specifications

WildFireSat (Canada) https://www.asc-csa.gc.ca/eng/satellites/wildfiresat/

- Will monitor all active wildfires in Canada from space on a daily basis
- Red, NIR, & MWIR & LWIR, 200-400 m pixels
- Launch 2029

TerraSAR (Germany)

- L-band SAR, Launch 2026

SPACENEWS

Vega C fails on second launch

by **Jeff Foust** — December 20, 2022

A Vega C lifted off Dec. 20, only to suffer a failure with its second stage about two and half minutes later. Credit: Arianespace webcast

Commercial

Planet SuperDoves

PlanetScope
Always-on Monitoring

~200
Satellites

3.7 m (3.0 NIIRS)
GSD

8
Spectral Bands

Not required
Tasking

SkySat
High-Resolution Tasking

21
Satellites

0.5 m (4.0-5.0 NIIRS)
GSD

RGB, Pan and NIR
Spectral Bands

Sub-daily
Tasking

Pelican
Very High Resolution

~32
Satellites

0.3 m (>5.5 NIIRs at-nadir)
GSD

7
Spectral Bands

Up to 12 revisits/day
Tasking

Hyperspectral
Broad Spectral Range

2
Satellites

30 m
GSD

400-2500nm
(5nm spacing)
Spectral Bands

Tasking Required
Tasking

Planet Tanager

- Launch 2023
- 400 bands
- In cooperation with Carbon Mapper Initiative

https://www.planet.com/products/hyperspectral/

Commercial

Planet Pelican

- Will replace SkySat
- 30 cm pixel size
- 32 satellites will allow tasking 12 to 30 images over one site per day
- Starting launches in 2023

Commercial

Planet will be spectrally calibrated with Landsat in the future to produce high-spatial resolution (ca 5 m pixels) daily data

Planet is currently spectrally calibrated with Sentinel-2 data and MODIS data

Their data will also be fused with Sentinel-1 SAR data

Note: Dec 2022, Planet Labs merged with dMY Technology Group, and the combined company is renamed Planet Labs PBC.

https://www.eoportal.org/satellite-missions/planet-pelican#development-status

Commercial

Launch of 36 “SuperDoves”

3 January, 2023, 14:56 UTC (13:56 Swedish time)

Space-X launcher

Some are decorated art to honor Gene Roddenberry (Star Trek creator)

You can watch the launch here:
https://www.spacex.com/launches/

Credit: Planet Labs PBC

Commercial

MAXAR

WorldView Legion

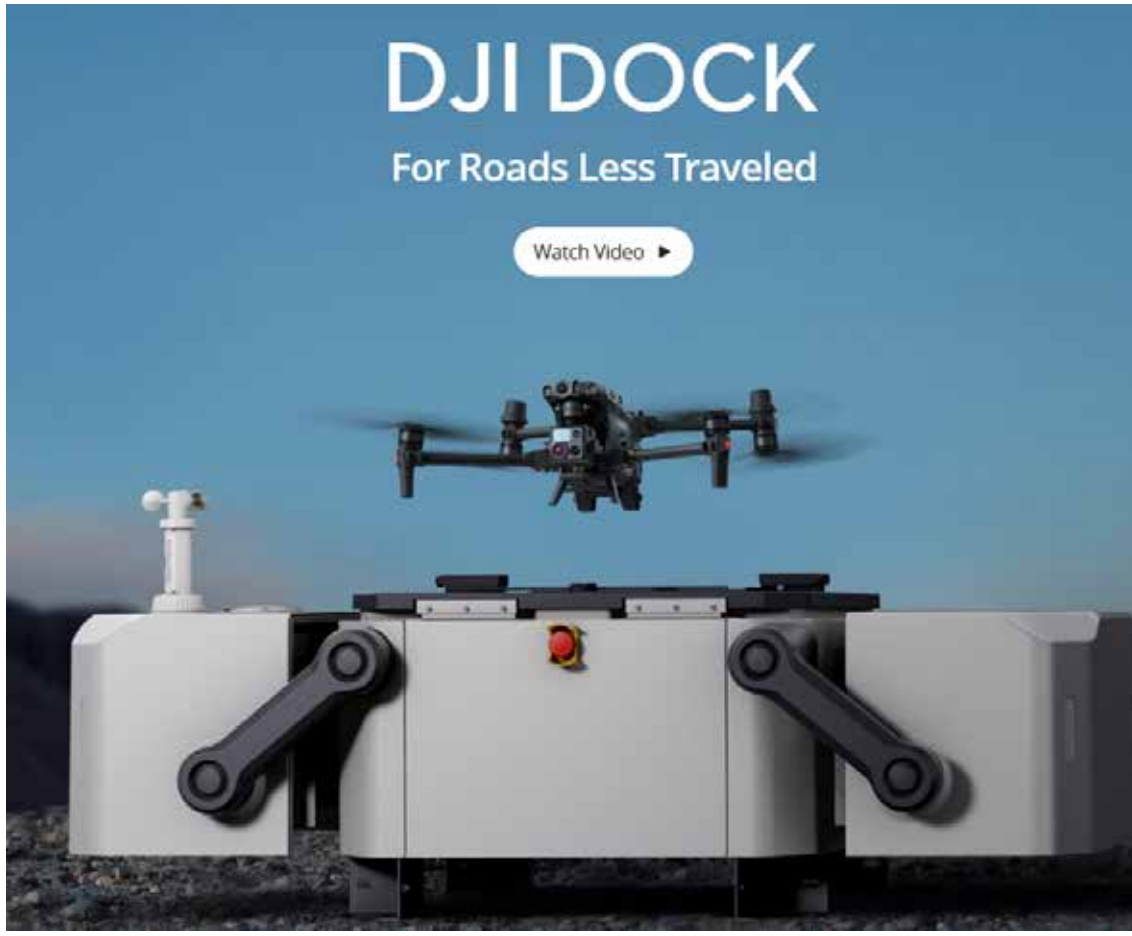
- > 20 satellites (WorldView + GeoEye + Legion)
- 15 revisits / day
- 30 cm pixels

https://www.maxar.com/splash/it-takes-a-legion

Note: Maxar has been bought (Dec 16, 2022)
https://www.maxar.com/press-releases/maxar-technologies-to-be-acquired-by-advent-international-for-6-4-billion

Future of drones for environmental remote sensing

- Automated re-charging and take-off
- Longer-life batteries
- Self-navigating drones (eg, through forests)
- Hyperspectral sensors hopefully coming down in price
- Radar sensors may become available
- Integrated AI data processing on-sensor



https://www.dji.com/newsroom/news/dji-shows-the-future-of-working-drones-at-airworks-2022

SAFETY & SECURITY

ESA commissions world's first space debris removal

I hope you enjoyed the course GV2300 and learned about some of the different remote sensing techniques and data sources

- Optical data
- Data access
- Lidar data
- Radar data
- Drone-based data
- Photogrammetry
- Classification
- Change detection
- NDVI

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