Trends and future developments in Earth Observation

8 October 2019

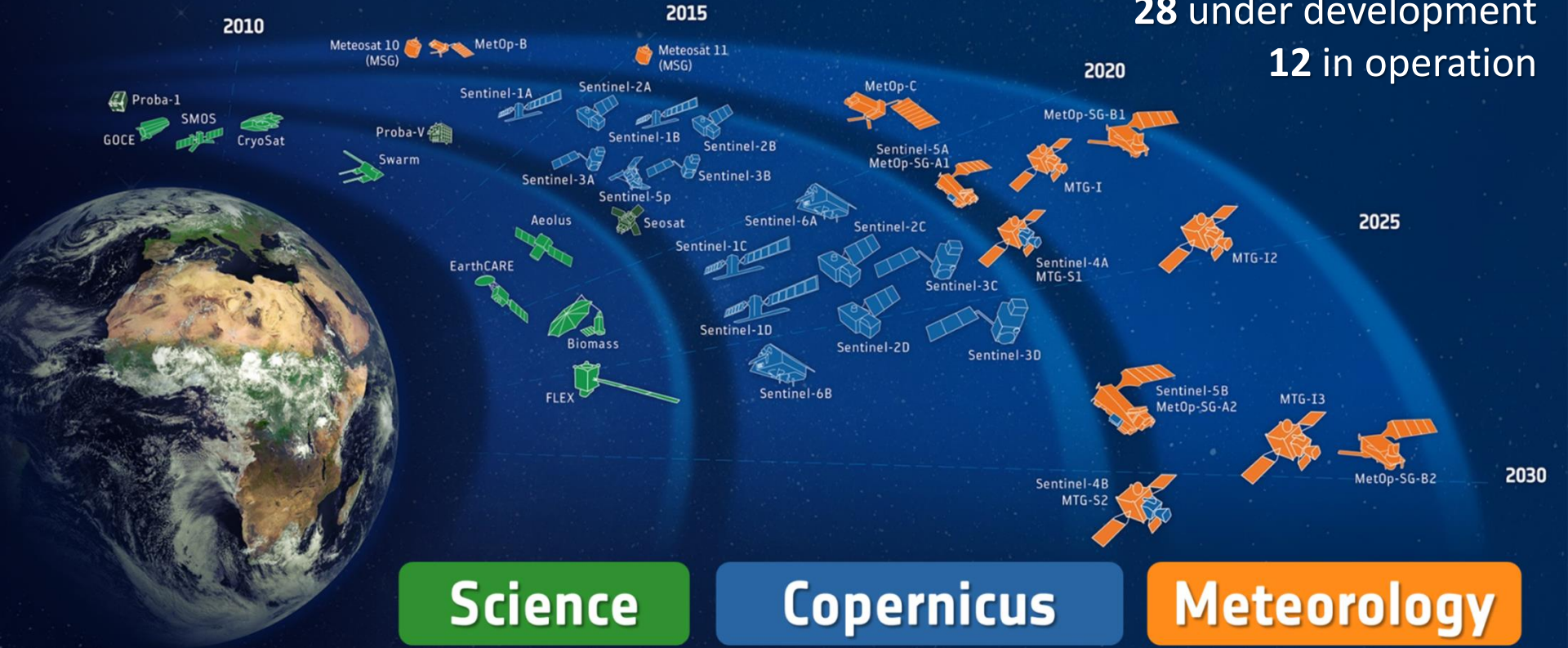
Gordon Campbell
European Space Agency

Overview

- What can you have from space
- What can we give you on the ground
- Emerging domains, issues and opportunities

ESA-DEVELOPED EARTH OBSERVATION MISSIONS

Satellites
28 under development
12 in operation



Sentinel Launches

S-1

Radar

A 3 Apr. 2014

B 25 Apr. 2016

S-2

High Resolution Optical

A 23 Jun. 2015

B 6 Mar. 2017

S-3

Medium Resolution Optical & Altimetry

A 16 Feb. 2016

B 2018

S-4

Atmospheric Chemistry (GEO)

A 2021

B 2027

S-5P

Atmospheric Chemistry (LEO)

A 13 Oct. 2017

S-5

Atmospheric Chemistry (LEO)

A 2021

B 2027

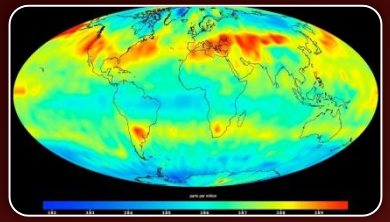
S-6

Altimetry

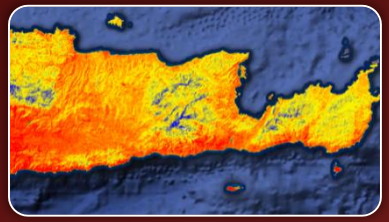
A 2020

B 2025

Copernicus 2.0 – 6 High Priority Candidate Missions

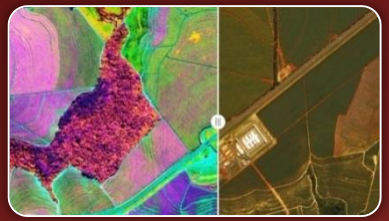


Monitor causes of Climate Change
➔ CO_2 Imaging Spectrometer

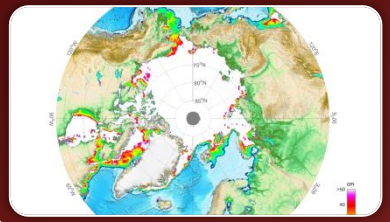


Agriculture & Water Productivity
➔ High Res. Surface Temperature

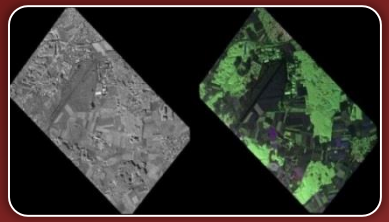
Monitor effects of Climate Change
➔ Polar Ice & Snow Topography



Food Security, Soil & Minerals, Biodiversity
➔ Hyperspectral Imaging



Sea Ice Conc. & SST
➔ Passive Microwave Imaging



Vegetation & Ground Motion & Moisture
➔ L-band SAR

Science: Earth Explorers

flex
→ ESA'S FLUORESCENCE MISSION

2022

biomass
→ ESA'S FOREST MISSION

2022

earthcare
→ ESA'S CLOUD, AEROSOL & RADIATION MISSION

2021

aeolus
→ ESA'S WIND MISSION

2018

goce
→ ESA'S GRAVITY MISSION

2009 – 2013

smos
→ ESA'S WATER MISSION

2009 – Present

cryosat
→ ESA'S ICE MISSION

2010 – Present

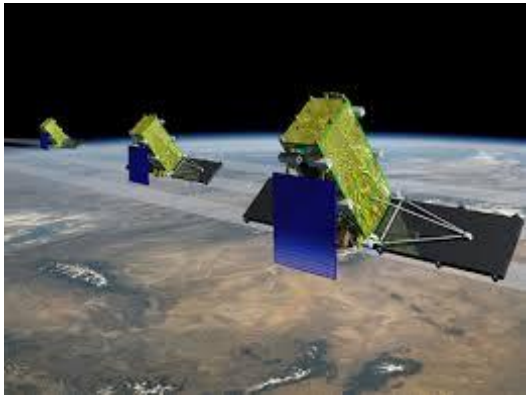
swarm
→ ESA'S MAGNETIC FIELD MISSION

2013 – Present

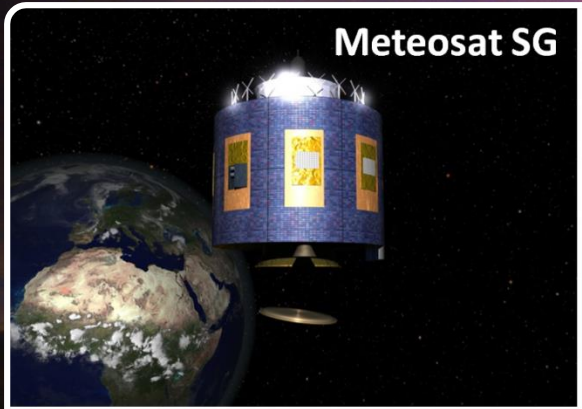
GOCE, SMOS, CRYOSAT, SWARM, AEOLUS, EARTHCARE | Credit: ESA/AOES Medialab | BIOMASS Credits: Airbus | FLEX Credits: Thales Alenia

National Missions

EnMAP
Hyperspectral Imager



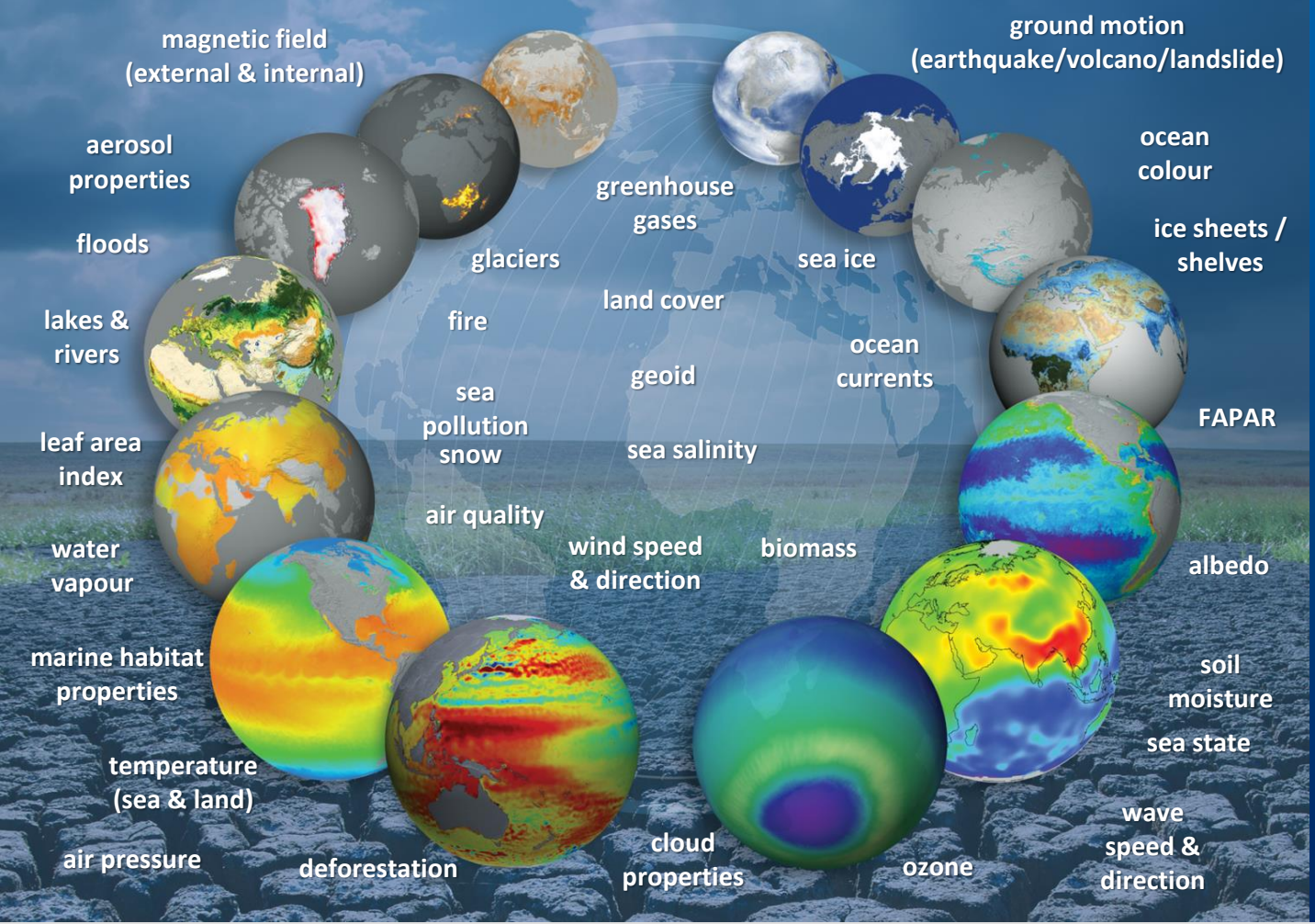
Meteorology



< Current Systems

< Post-2020 Systems

Early 2020s begin preparation for MFG and MetOpTG

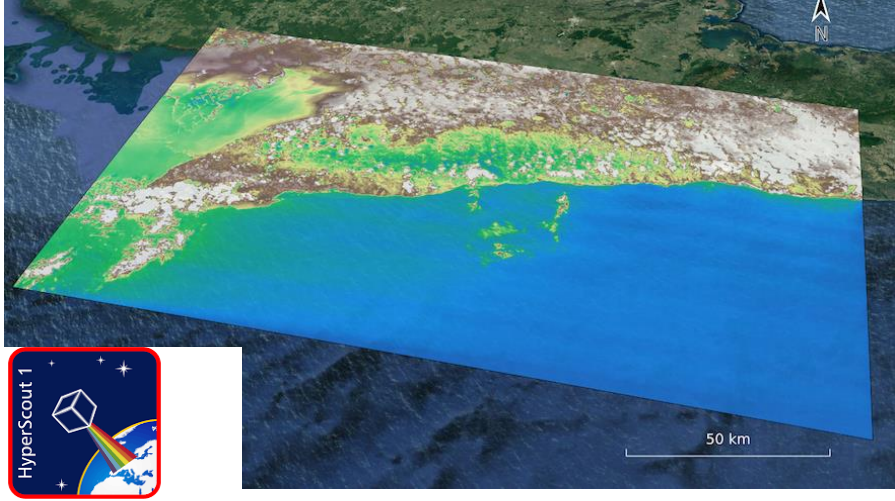


esa

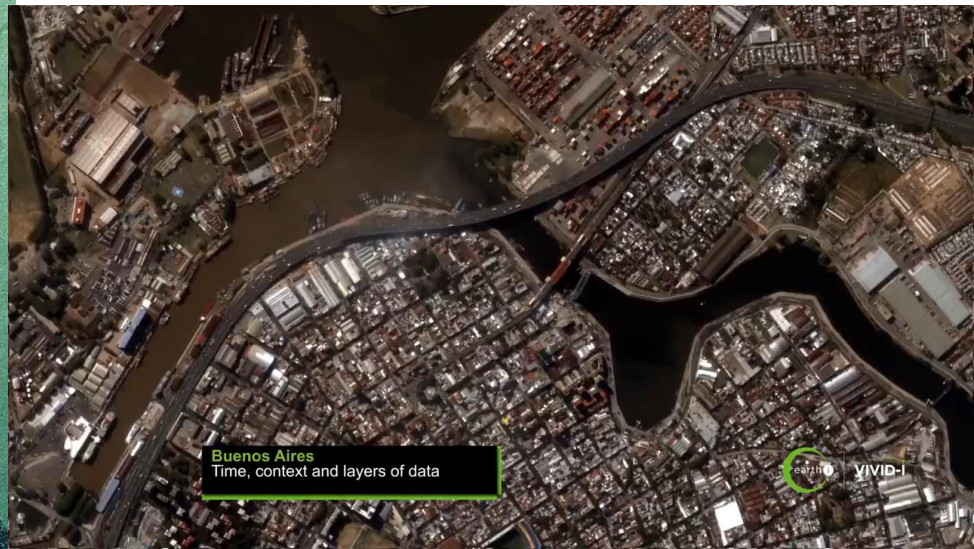
ESA provides EO mission data addressing almost **all** parameters retrievable by EO satellites

➔ **Extreme user diversity**

NewSpace – Small Satellites



HyperScout 1



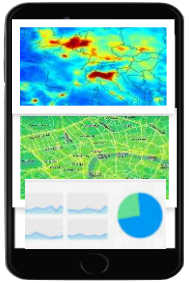
Small Satellites data collection capabilities claims

- Multiple revisits per day for
  - Optical/NIR
  - X-Band SAR
  - Satellite Video
  - Atmospheric chemistry
- Regular revisit for:
  - SWIR
  - HyperSpectral
  - TIR
  - SDR
  - S-band SAR
  - X-band SAR

- On-board processing for
  - Automated channel selection
  - Automated feature detection
  - Automated parameter calculation
  - Automated tipping & cueing
  - Automated cloud cover assessment
- Risk elements remaining:
  - Radiation
  - Attitude control/stabilization
  - Orbit maintenance

Complementary data collection platforms

UAVs



citizen science

aquaal
INTELLIGENCE BELOW THE SURFACE

HAPS

Other IOT

Robotic data collection platforms

New EO Challenges and Trends

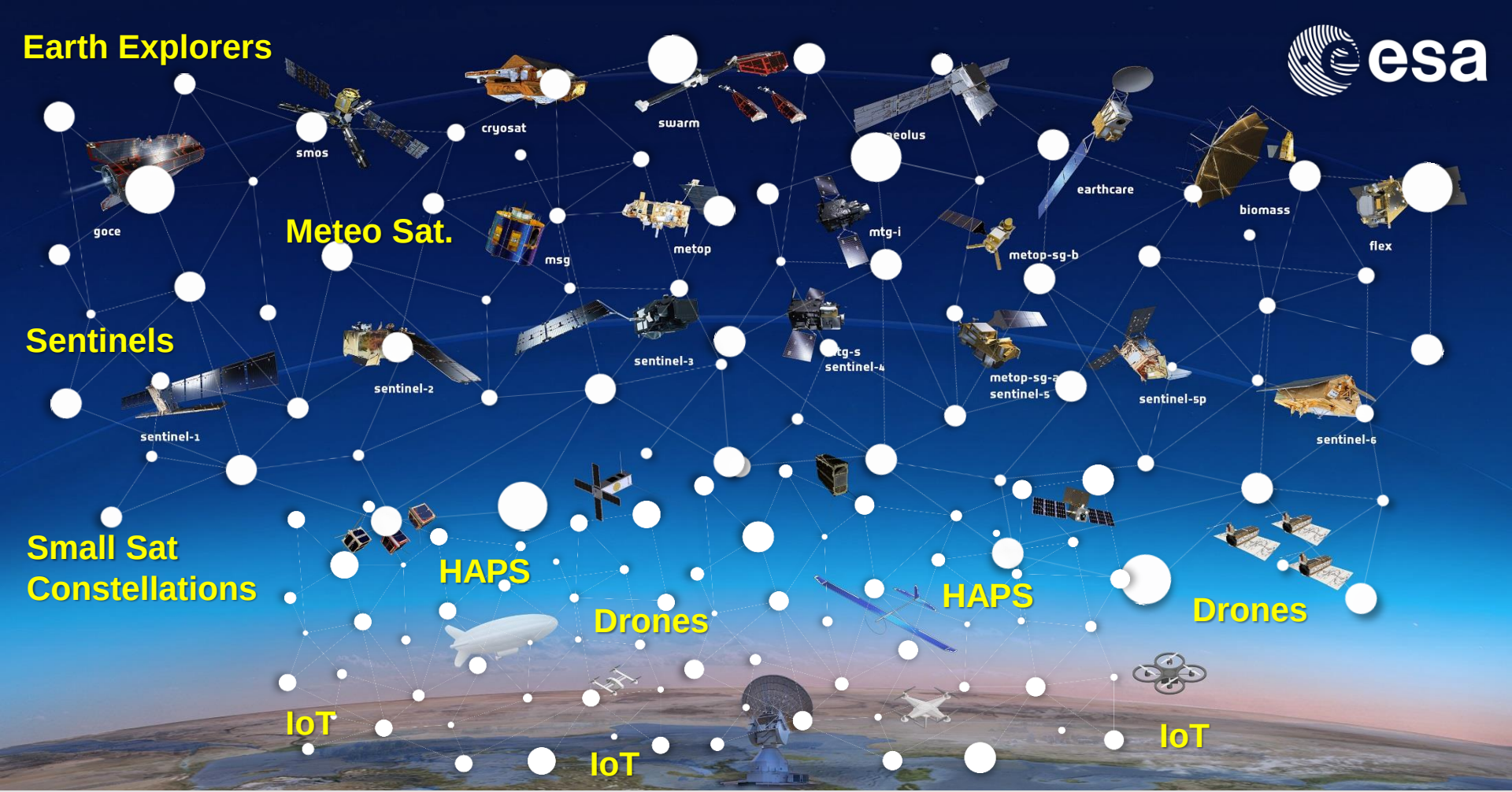
From 20 to 80 EO satellite Launches per Year worldwide

Copernicus revolutionizes EO

Daily EO dataflow in TB Archives entering PB era

New Players and Innovation Approaches in EO

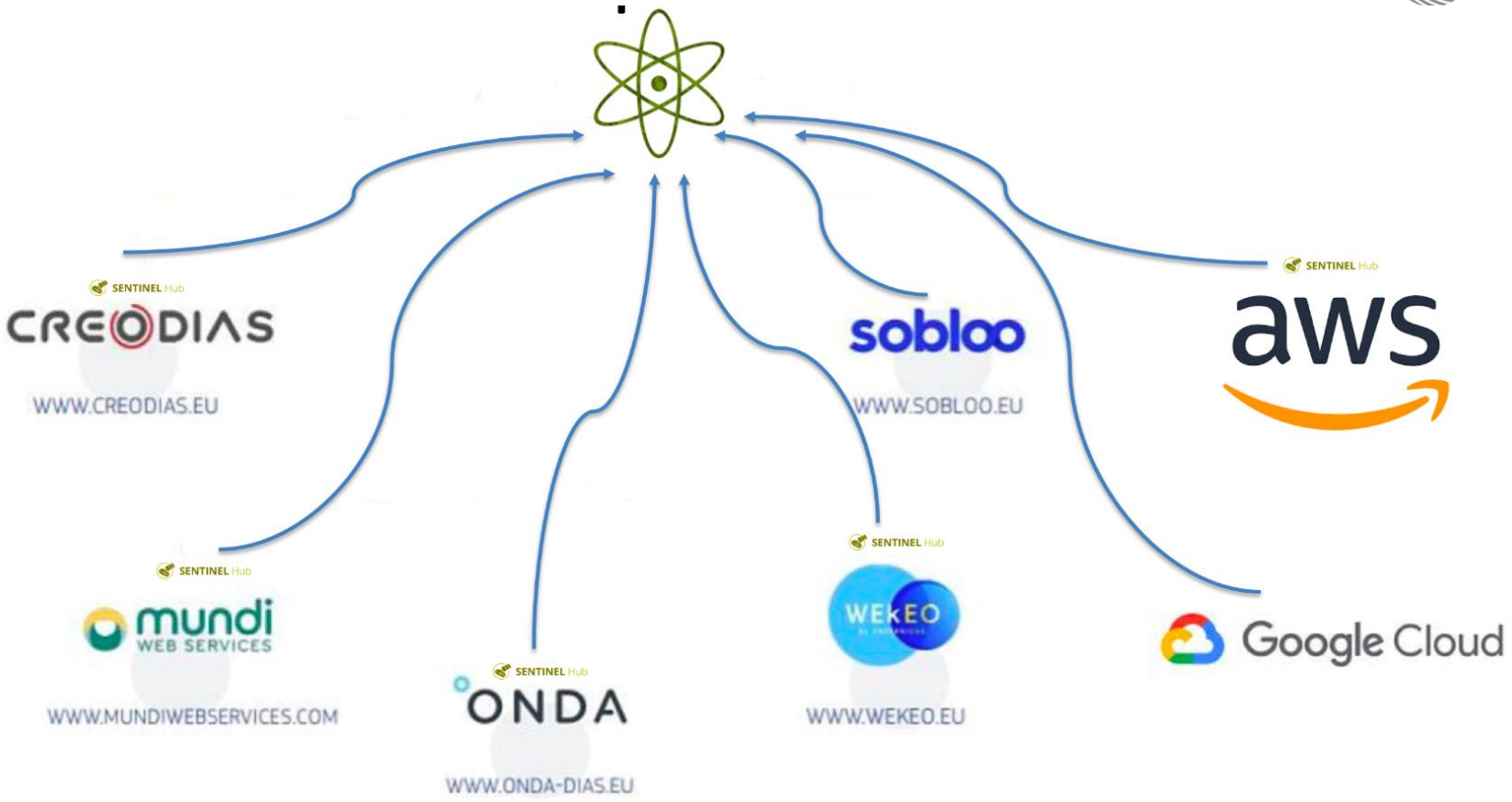
- Non-space players
- AI, IoT, HAPS, nanosat etc.


Earth Explorers
esa
goce
smos
cryosat
swarm
aeolus
earthcare
biomass
flex
Meteo Sat.
msg
metop
mtg-i
metop-sg-b
Sentinels
sentinel-1
sentinel-2
sentinel-3
mtg-s
sentinel-4
metop-sg-a
sentinel-5
sentinel-5p
sentinel-6
Small Sat
Constellations
HAPS
Drones
HAPS
Drones
IoT
IoT
IoT

How to ensure these developments maximize opportunity?

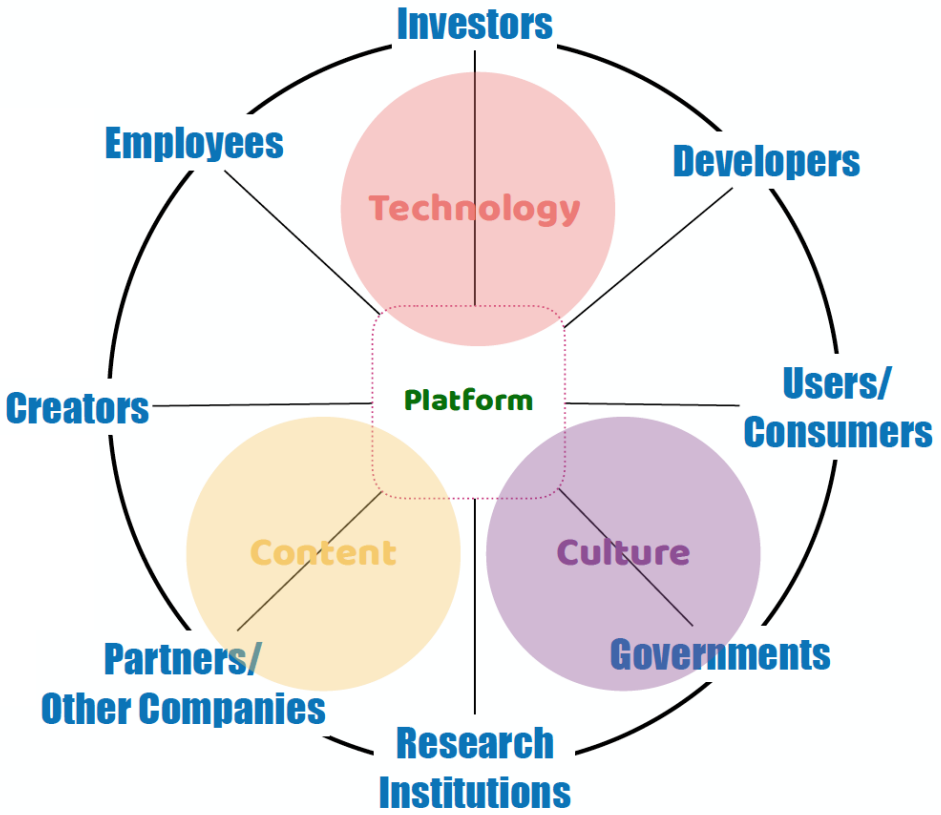
- Platform based processing and service access enabling multi-sided markets
- Orchestrate access to distributed resources
- Ensure interoperability and efficiency of data discovery and access mechanisms (in particular on-the fly processing)
- Build on state of the art rapid access/query database technologies

Scalable Access to High Performance Processing

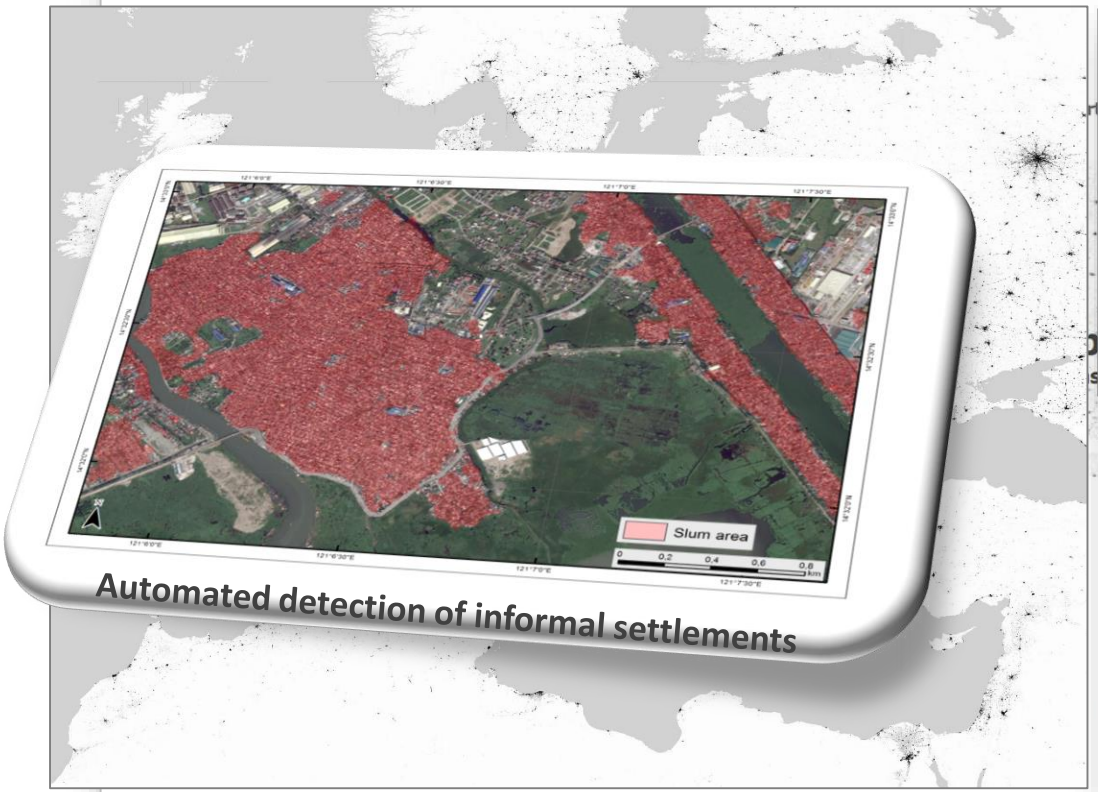


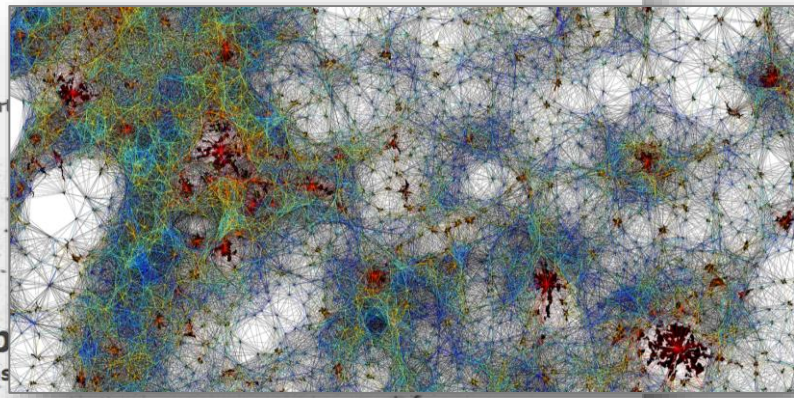
Thematic Exploitation Platforms

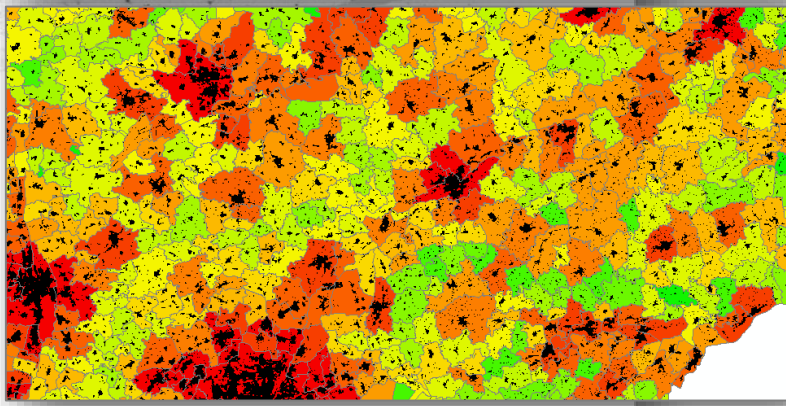
- Optimized access to multiple datasets and processing resources
- Rapid scalability from initial small scale testing to large scale execution
- Structured access to customized analytics capabilities
- Collaborative tools and support environments
- Inter-operable with complementary capabilities



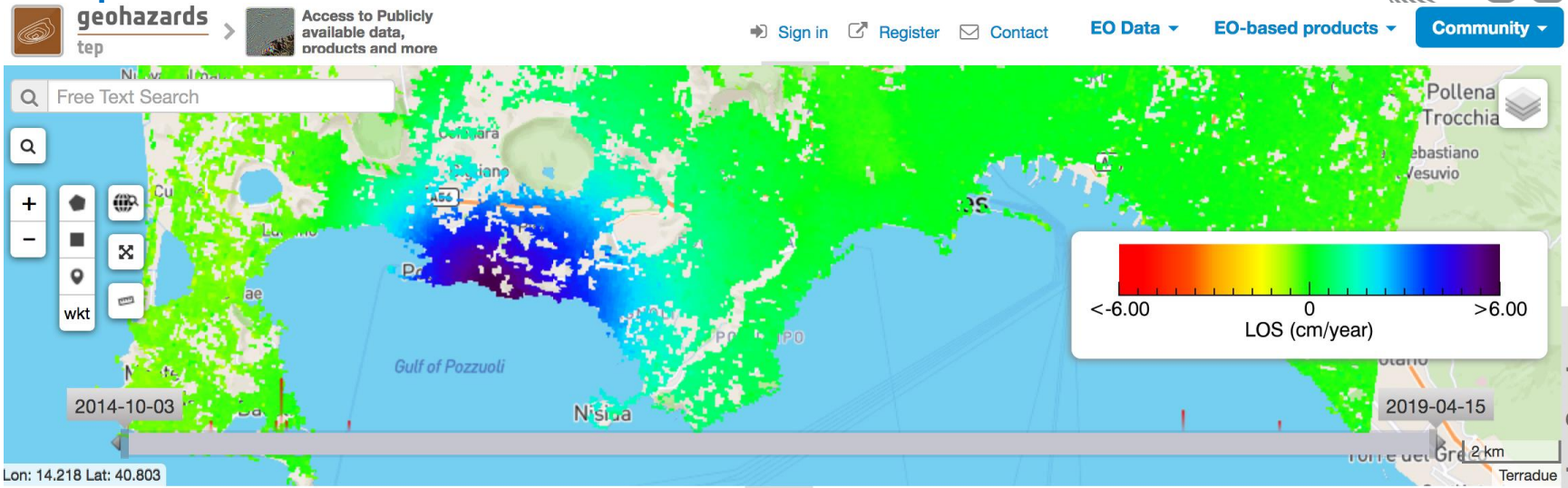
Example 1 – the Urban TEP







Example 2 – the Geohazard TEP



Processing Services

Current search result

Result for OpenSearch query over type ... Total results 38

- Sulawesi Earthquake 2018 - MPIC-OPT - Sentinel-2 - E-W displacement (Tile 50MRD)
- Sulawesi Earthquake 2018 - MPIC-OPT - Sentinel-2 - N-S displacement (Tile 50MRE)
- Italy, Alpi Retiche, landslides - TRE ALTAMIRA SqueeSAR - PS Velocity map
- Pusan urban are deformation - FASTVEL - Sentinel-1 - Velocity map
- Urban Subsidence in the Rome Metropolitan Area - SNAP-StaMPS - DESC PSI
- Urban Subsidence in the Rome Metropolitan Area - SNAP-StaMPS - ASC PSI

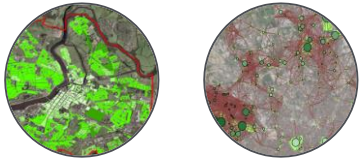
Data Packages

225 data packages found. Filter data packa

- **InSAR SBAS Hawai tutorial** — Set as current search
- **PF-ERS Tutorial** — Set as current search
- **London Desc ASAR** — Set as current search
- **Bhutan_2_tr176_desc**

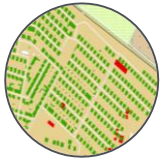
EO Products for Urban Development

Green Areas/Networks

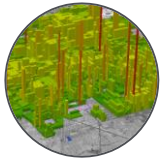


Extent, Imperviousness and Change

Building Footprint



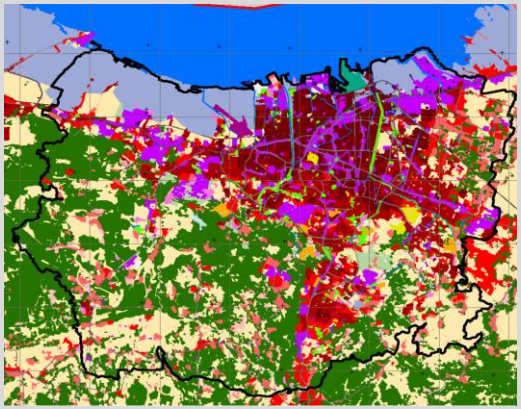
Population Density



Waste Sites

Baseline Products

Urban and Peri-Urban Land Use / Land Cover



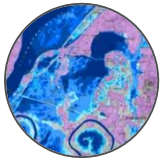
Detailed

Change

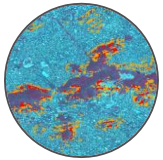
Transport Infrastructure

Informal Settlements

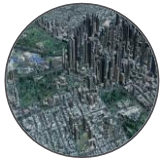
Flood Risk



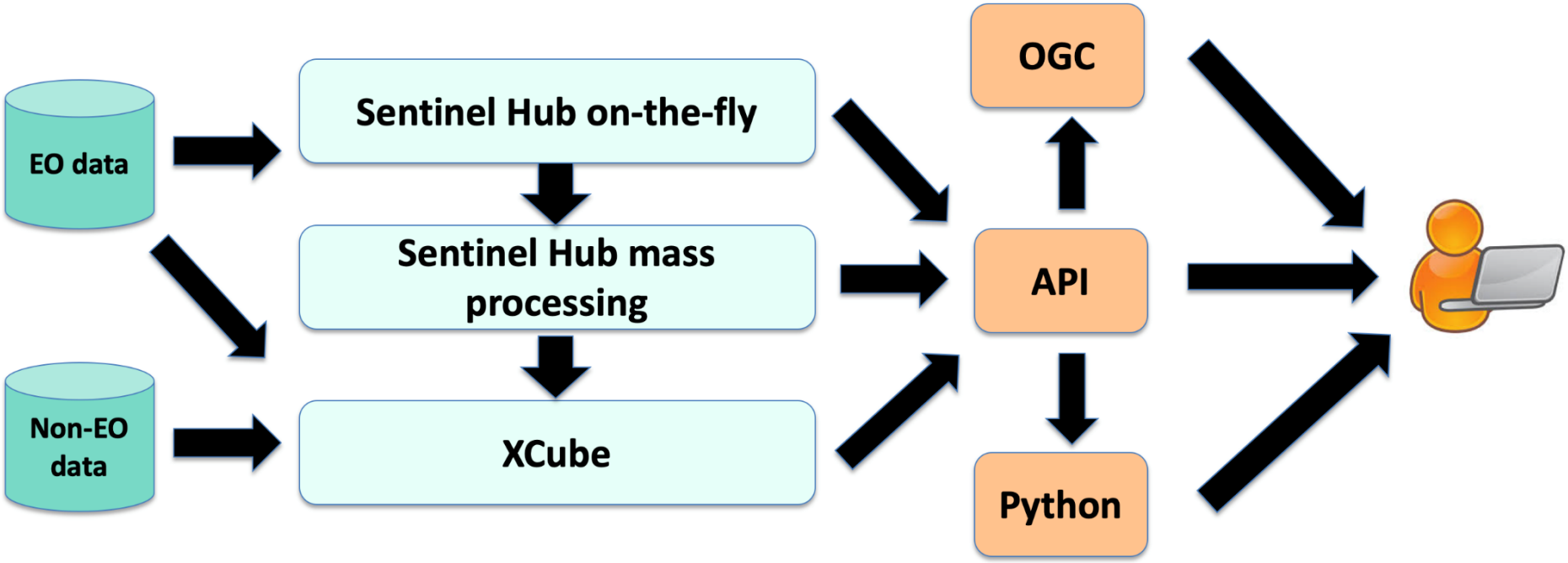
Landslide Risk



Terrain Motion



Analysis Ready Data/Data Cubes

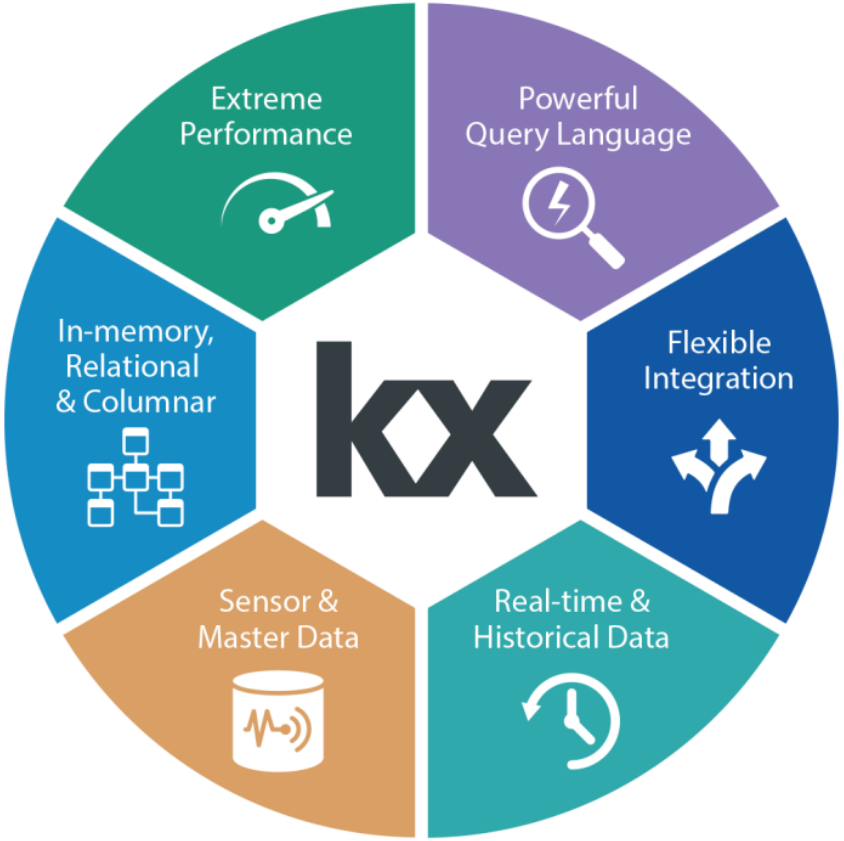


XCube

- Request data at large scale – either spatial or temporal eg:
  - Run your algorithm for a whole continent
  - Pre-process vast amount of data
- Execute, go for a coffee and have results ready.
- Build yourself a pre-processed data cube
- Additional data sets (including feature data), ESA CCI, Copernicus Services, etc.
- Additional algorithms
- Fully customizable
- Python ecosystem

Rapid access/queryable database capabilities

- World's fastest time series database
- Streaming, real-time and historical data in one platform
- Map Reduce, Lambda and Time-Series functions built-in
- In-memory compute engine for Complex Event Processing
- Extreme Compression – Proprietary, gZip, Snappy Etc
- Multi-core / Multi-processor / Multi-thread / Multi-server



External developments to build on

New Computing

AI / ML

New Data

IoT Sensors/ processing

Blockchain

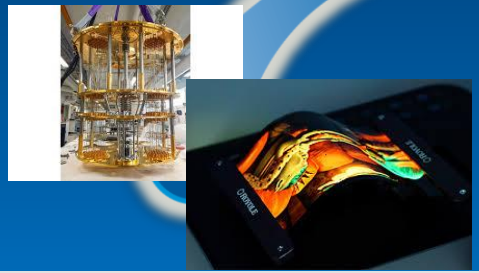
Battery technology

Re-usable Launchers

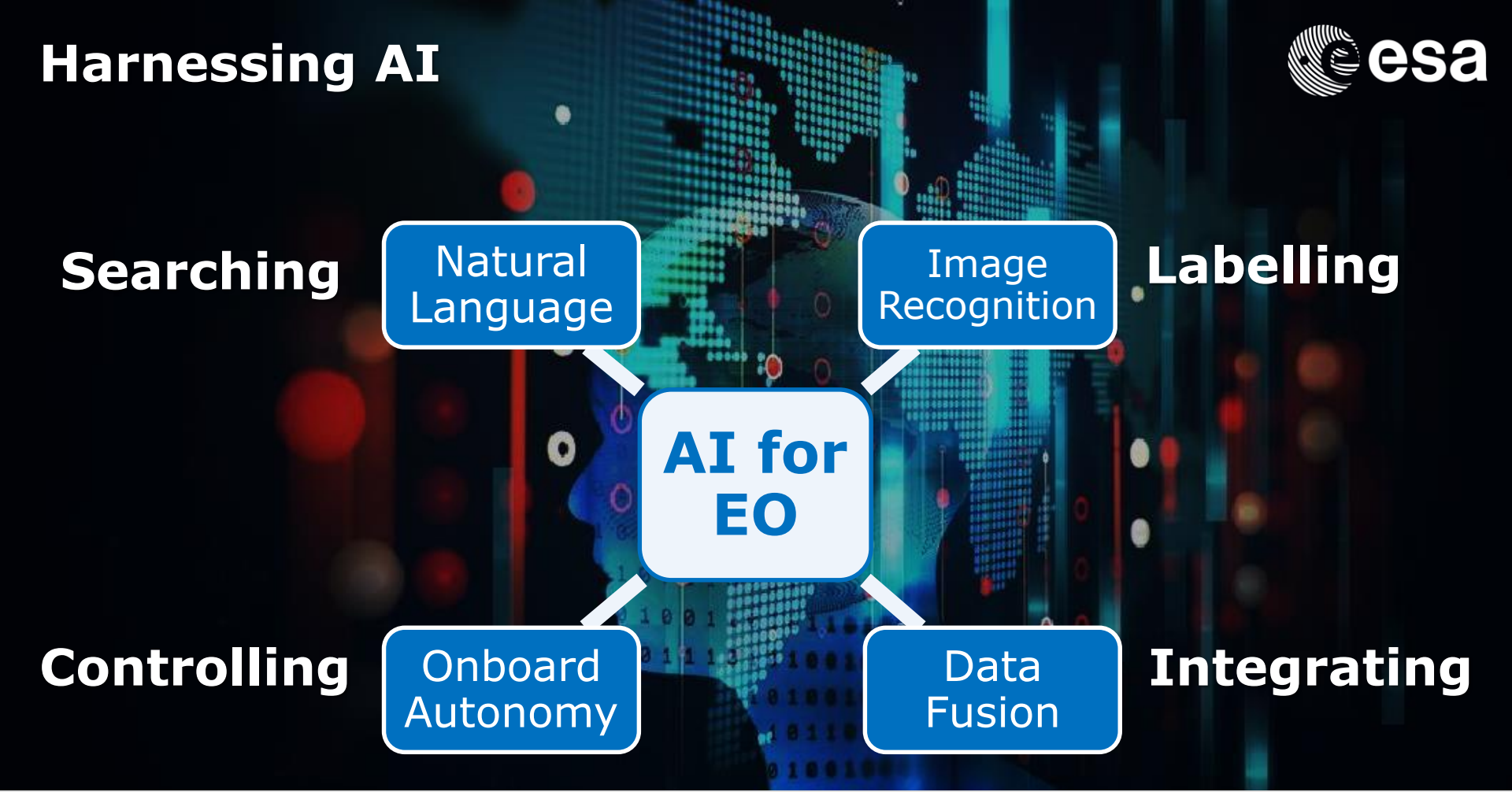
New Investors

Visualization technologies

leading capabilities in Europe



Harnessing AI



AI developments we are investigating

Application domains:

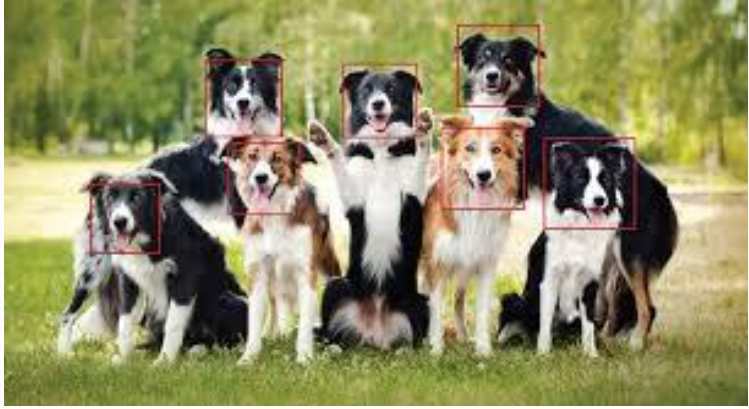
- Feature detection/identification/characterization
- Process/Pattern detection/recognition/characterization (direct and hybrid)
- Super-resolution processing
- Statistical downscaling and blending (direct and integrating physical models)
- Dynamic time series modelling
- Automated data quality anomaly detection/recognition/characterization

Technical domains:

- Improving parameterizations
- Replacing physical sub-models with ML data driven model
- Analysis of model-observation mismatch
- Constraining sub-models
- Emulation

AI ≠ magic happens

- Step change in feature detection was based on dogs and cats – EO is multi-scale, multi-channel image with highly variable signature visibility
- AI based approaches absolutely critical:
  - Data volume so large, AI is the only viable analysis approach
  - Significant emerging capabilities in feature recognition, super-resolution, correlation extraction etc
  - AI only as good as the training data
  - Algorithms for more complex analyses remain under-developed



Examples

HOME
PROFILE
EXPLORE
AIRPLANE
Total annotations: 93

20170103 S2

Opening up opportunity for European SMEs?

Global Geospatial Analytics Market

US$ 72.21 Bn by 2020

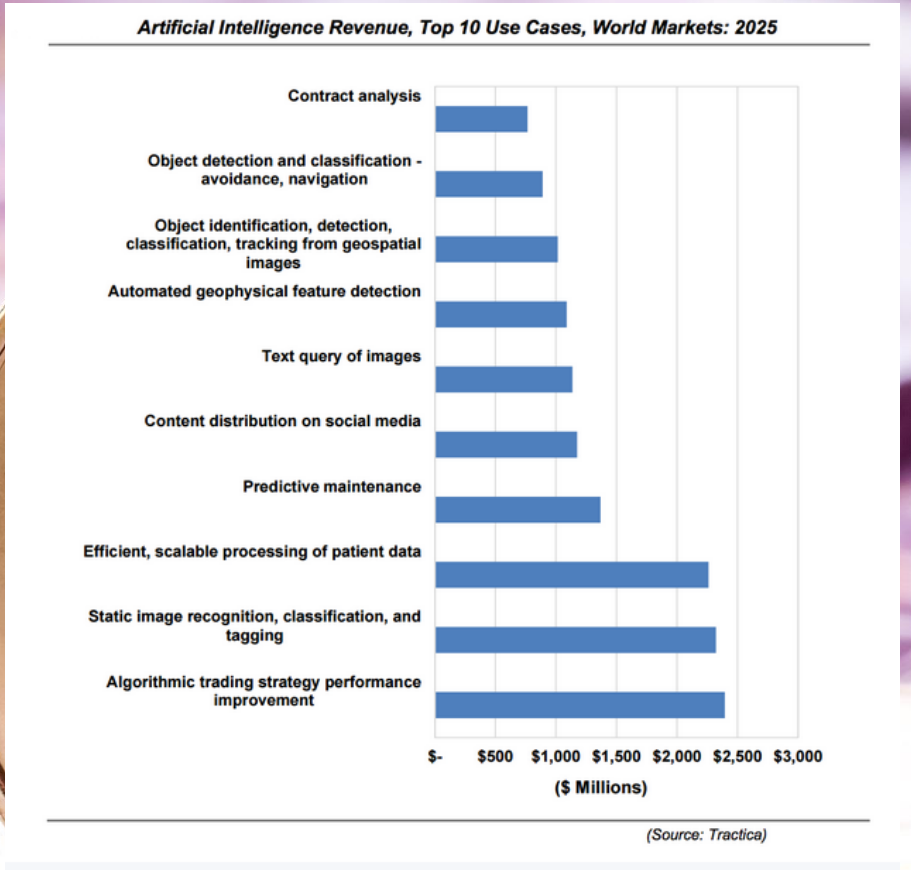
→ 3x increase in 5 years
Research and Markets, 2016

Global revenue from direct & indirect application of AI

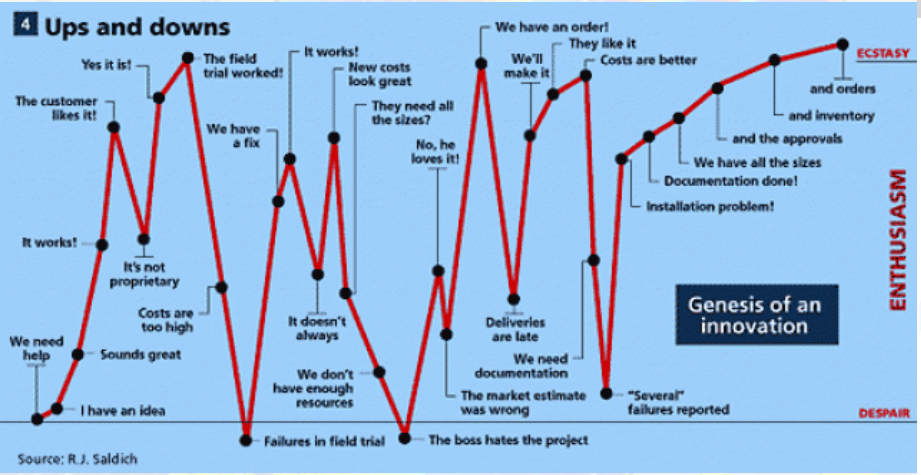
US$36.8Bn by 2025

CAGR of 56.8%.
(Tractica)

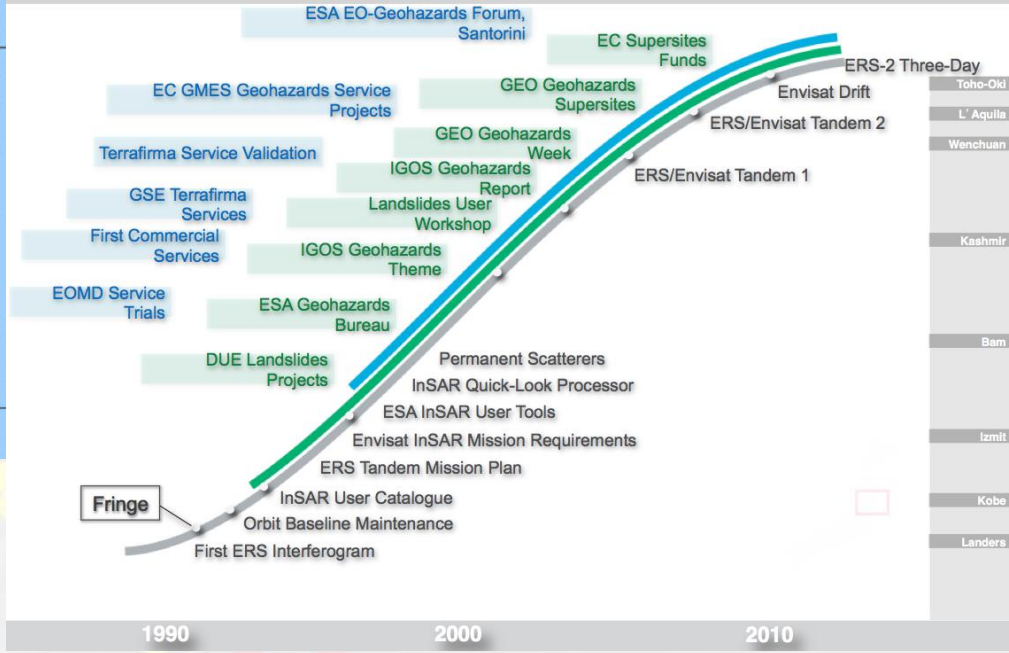
"Over 2000 EO smallsats expected by 2026"



No easy answers, no magic solutions



Science ➔ Applications ➔ Services

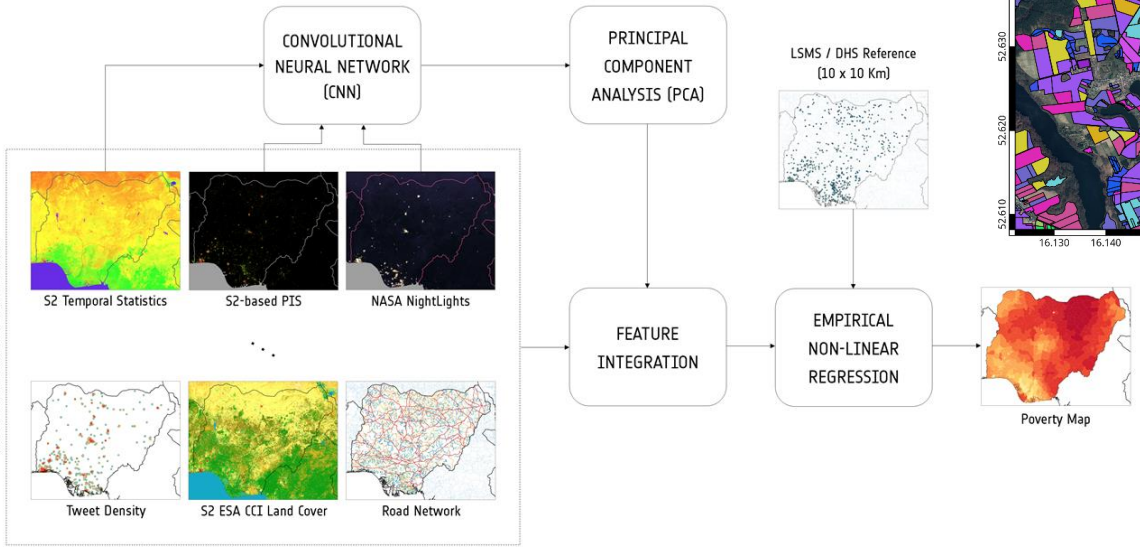


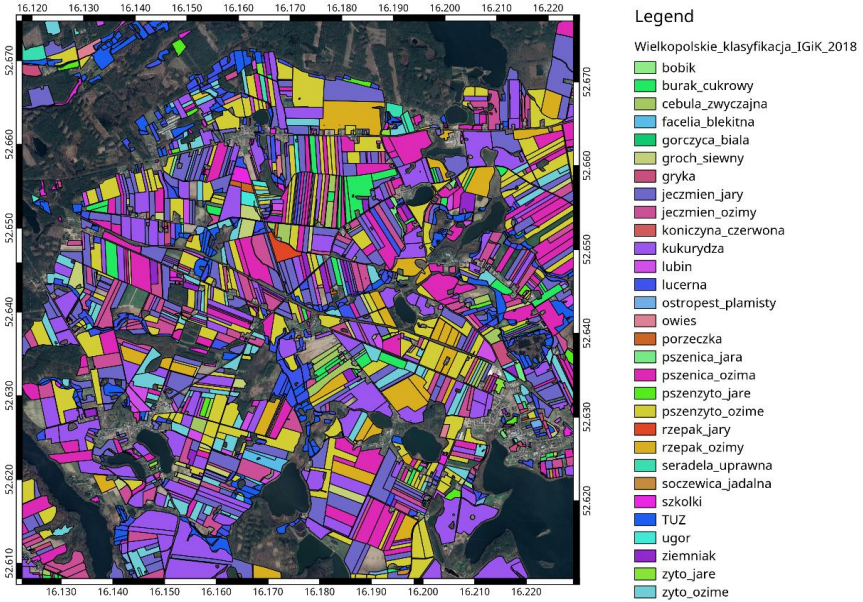
Emerging Opportunity

						1.4	1.5	1.4.2							
					2.3	2.4	2.c	2.4.1							
				3.3	3.4	3.9	3.d	3.9.1							
							5.a	5.a.1							
	6.1	6.3	6.4	6.5	6.6	6.a	6.b	6.3.1	6.3.2	6.4.2	6.5.1	6.6.1			
				7.2	7.3	7.a	7.b	7.1.1							
							8.4								
				9.1	9.4	9.5	9.a	9.1.1	9.4.1						
					10.6	10.7	10.a								
11.1	11.3	11.4	11.5	11.6	11.7	11.b	11.c	11.1.1	11.2.1	11.3.1	11.6.2	11.7.1			
			12.2	12.4	12.8	12.a	12.b	12.a.1							
				13.1	13.2	13.3	13.b	13.1.1							
	14.1	14.2	14.3	14.4	14.6	14.7	14.a	14.3.1	14.4.1	14.5.1					
15.1	15.2	15.3	15.4	15.5	15.7	15.8	15.9	15.1.1	15.2.1	15.3.1	15.4.1	15.4.2			
							16.8								
17.2	17.3	17.6	17.7	17.8	17.9	17.16	17.17	17.18	17.6.1	17.18.1					

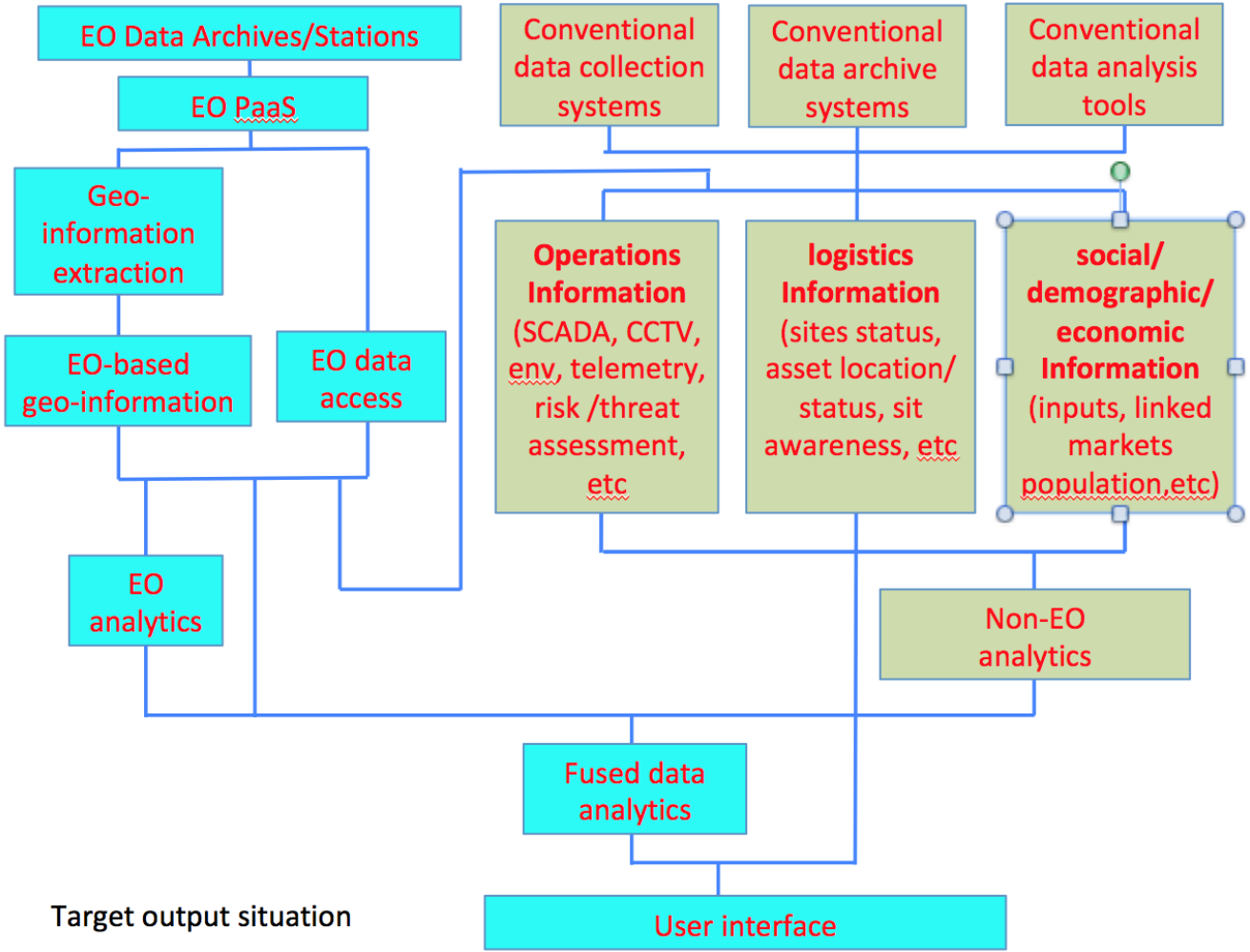
Example responses – changing attitudes to statistics

Below: CNN based methodology for poverty mapping
Right: expansion of EO based agri-statistics for Polish national statistical office



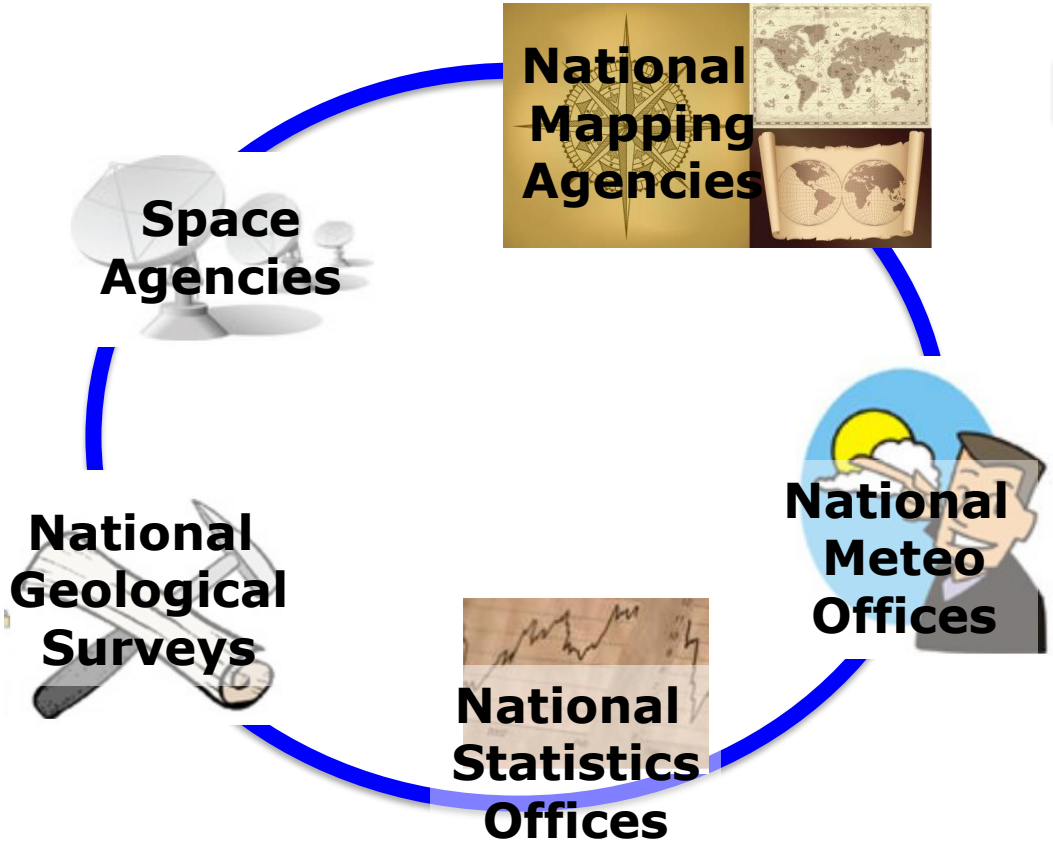


Embedding EO/geodata



Target output situation

Putting it all together



World leading industrial competence in Europe

Dynamic University/ Innovation Cluster Interactions

Sustainable low-carbon economies

Collaboration Opportunities with ESA

- Proposal to ESA Ministerial Council in November 2019 covering:
  - AI4EO (dedicated developments)
  - Resilient Societies and SDGs
  - Enhanced Regional Collaboration (Baltic, Atlantic , Black Sea/Danube etc)
  - Prototype HAP/EO methodologies
  - Permanently Open Call for Proposals – try out new ideas quickly
- Additional domains of potential relevance:
  - Close cooperation with EC DG Research on Grand Challenges
  - Close cooperation with International Development Banks
  - Structured cooperation with AI bodies
- And finally – we come to your meetings, please come to ours:
  - Phi-week
  - Big Data from Space
  - Monitoring Urban Areas from Space
  - Living Planet Symposium

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Thank you!
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