ESA Earth Observation on board data processing future needs and technologies

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EOP-ΦMT

25 Feb 2019- Future Needs and Requirement on On-Board Data Processing

Content

Overview of actual and planned ESA Earth observation missions

- Meteorological & EUMETSAT
- Copernicus actual sentinels, extension and expansion
- Earth Explorers

Future

- future needs and technologies to support Earth Observation Program
- IOD from EOP

ESA Earth Observation Programmes

ESA EO is **user-driven**

EOP Users

- **Scientists**
- **Agencies**
- **Institutions** (e.g. EUMETSAT, EU/EC, space agencies)
- **EO organisations** (e.g. GCOS: Global Climate Observing System)

EOP include **end-to-end** activities, i.e. from conception to exploitation (and different types) of space missions:

- **EARTH SCIENCE MISSIONS ➔ Earth Explorers** (Core, Opportunity)
- **EARTH APPLICATIONS MISSIONS ➔ Earth Watch**, i.e. (pre-)operational missions in partnership (EUMETSAT, EU / EC, Member States, ...

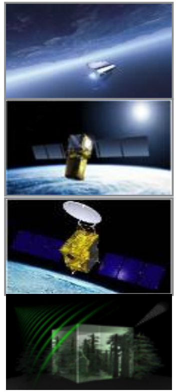
ESA Earth Observation Missions

Living Planet
(SP-1304)

Earth Explorer

Research driven

Core Missions



GOCE
2009-2013

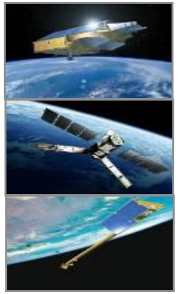
Aeolus
Aug-2018

EarthCARE
2021

Biomass
(EE7) 2022

Call EE10 –
Phase 0
STEREOID
Daedalus
G-Class:H2O

Opportunity



CryoSat-2
8 April 10

SMOS
2 Nov 09

Swarm
22 Nov 13

Initiating discussion
with NASA's
(Decadal Survey)

NGGM

Fast Track

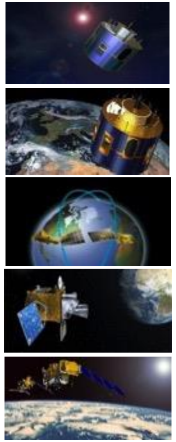
FLEX (EE8)
2022

Call EE9 –
Selected for Ph. A
FORUM
SKIM

Earth Watch

Operational Service driven
In partnership

Meteorology



Meteosat

MSG - GEO
(1 s/c x 4)

MetOp
(1 s/c x 3)

MTG - GEO
(2 s/c x 3)

MetOp SG
(2 s/c x 3)

Copernicus

Sentinel 1 A/B/C/D

Sentinel 2 A/B/C/D

Sentinel 3 A/B/C/D

Sentinel 4 (on MTG)

Sentinel 5 precursor

Sentinel 5 (on MetOp SG)

Sentinel 6 (Jason)

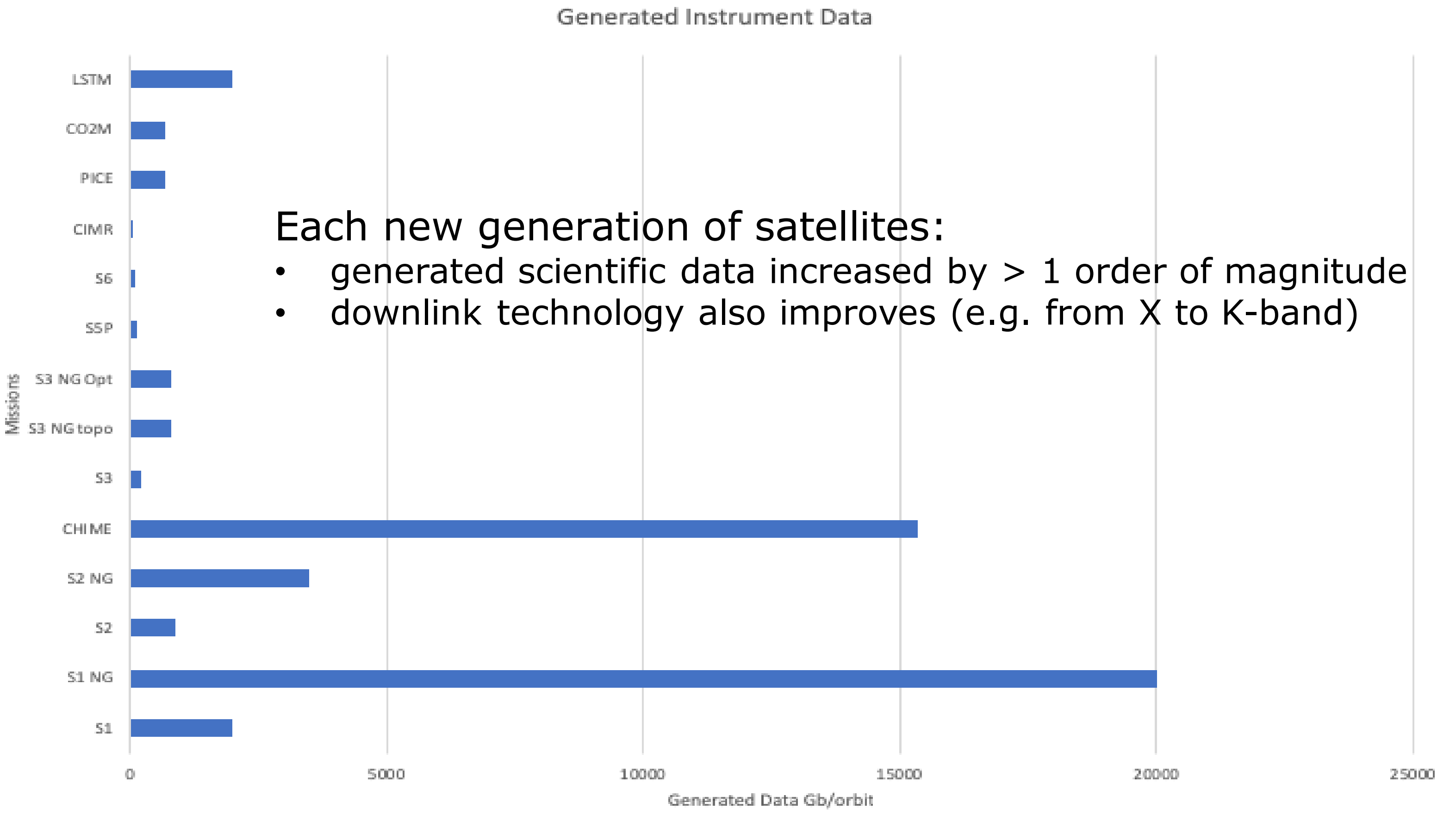
Copernicus Space Component Evolution:
Expansion: CO2M, LSTM, PICE, CIMR, CHIME, ROSE-L
Extension: Sentinel-1/2/3 NG

Colour Code:
Launched
To be launched

Copernicus Program Evolution

EO Capability	Actual Sentinels	Extended Data Availability	Sentinels Expansion	Second Generation	Instrument	Orbit
Earth Microwave (3D) Imaging	Sentinel-1 A Sentinel-1 B	Sentinel-1 C Sentinel-1 D	ROSEL	Sentinel-1 SG	C Band SAR L Band SAR + Rad HRLS SAR	LEO LEO LEO
Earth Optical Imaging	Sentinel-2 A Sentinel-2 B	Sentinel-2 C Sentinel-2 D	CIMR LSTM CHIME	Sentinel-2 SG Sentinel-3 SG OPT	Passive Microvawe Imager Multispectral TIRI Hypespectral MSI+TIRI SG Hyper-spectral SG OLCI+SLSTR SG OPT	LEO LEO LEO LEO LEO LEO LEO GEO
Earth Topography by Altimetry	Sentinel-3 A Sentinel-3 B Sentinel-6 A Sentinel-6 B	Sentinel-3 C Sentinel-3 D Sentinel-6 C Sentinel-6 D	PICE	Sentinel-3 SG TOPO	TOPO C/Ku Radar Altimeter VIS-SWIR-TIR radiometer C/Ku Altimeter GNSS Radio-Occultation Altimeter ICE/SNOW	LEO LEO LEO LEO
Earth Atmosphere by Spectroscopy	Sentinel-4 A Sentinel-4 B Sentinel-5 A Sentinel-5 B Sentinel-5 P	Sentinel-4 C Sentinel-4 D Sentinel-5 C Sentinel-5 D	CO2M		UVN Spectrometer GEO Infrared Sounder GEO UVN Spectrometer LEO Infrared Sounder LEO Spectrometer LEO CO2 Spectrometer	LEO GEO GEO LEO LEO LEO LEO

Scientific data generated



Each new generation of satellites:

- generated scientific data increased by > 1 order of magnitude
- downlink technology also improves (e.g. from X to K-band)

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On board data processing- why?

Reduce Downlink data rate

Maintain the produced Scientific data volume

➔

HW-SW O/B for processing

Compression: less bits / pixel.

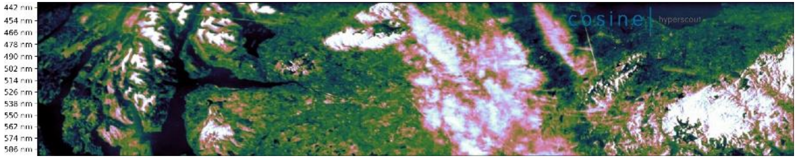
Increase scientific content of downlink data

AI: Send less pixels (those with sci- content)

OB processing Hw-SW:

- development cost

- Mass, power and volume increase must be better than the data rate reduction benefit



Data downlink rate Reduction

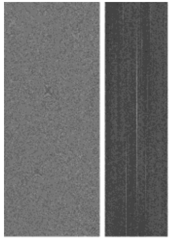
Compression Less Bit per Pixel

Lossy Compression

Lossless Compression

Increase of dynamics
Harder to compress 16 → 4 bits / pixel
(SAR is hard due to speckle – pixels are decorrelated)

Raw data :
8 → 4 bits / pixel



8 bit → compression → 4 bit

8 bit → Image Generation (90% of processing) → 16 bit → compression (10% of processing) → 4 bit

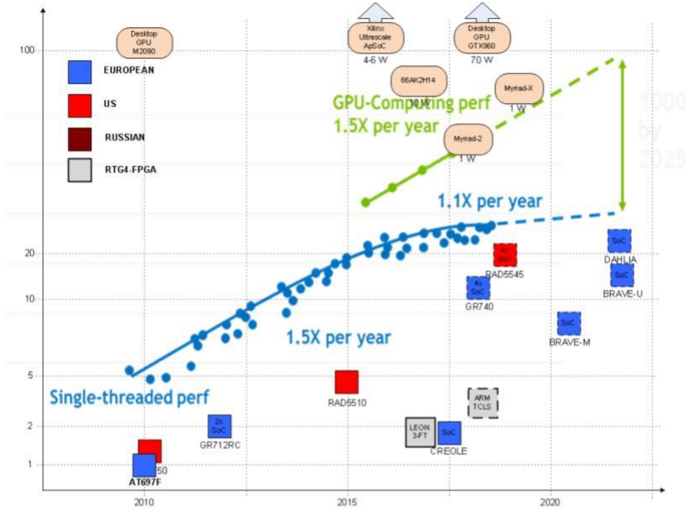
Increase the scientific content of downloaded data

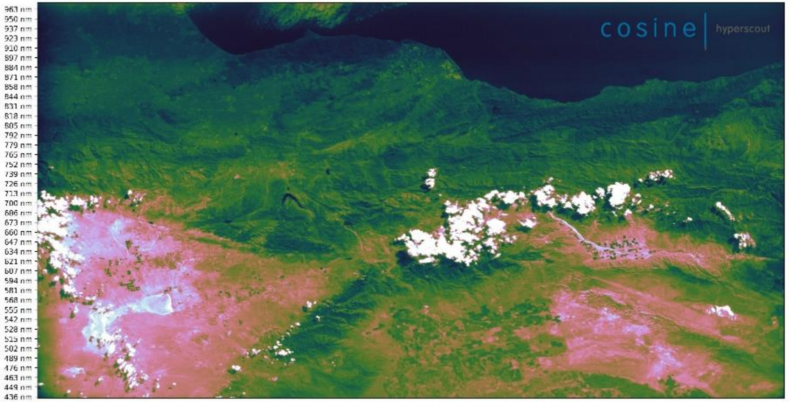
Selection Less Pixels per image

Remove not useful information

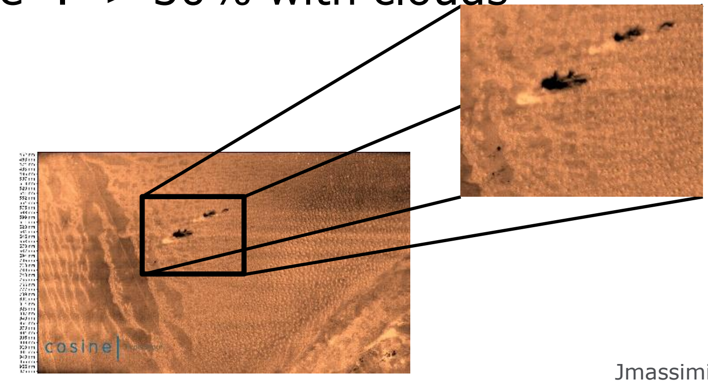
e.g. cloud detection

Select the data to download





S2 experience : > 30% with clouds



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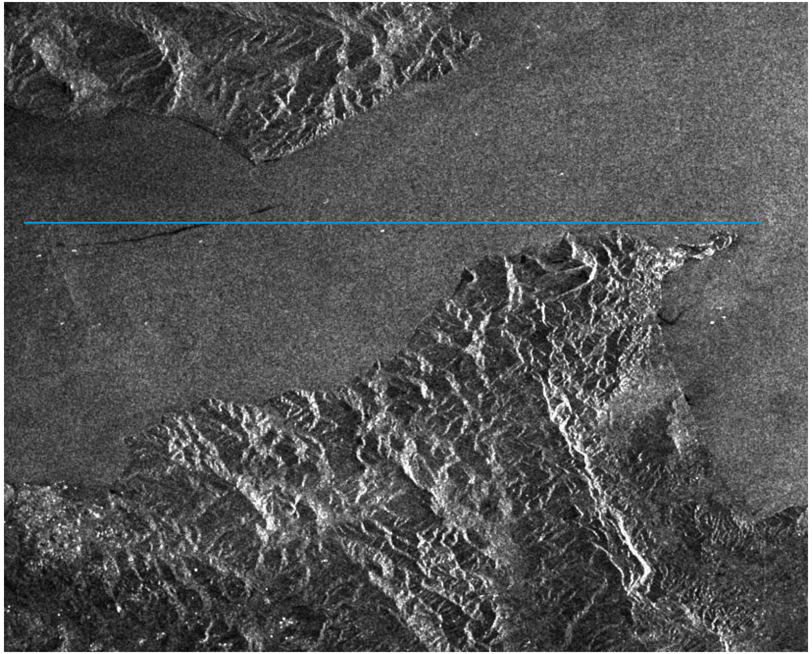
Feature Selection

Classic Algorithm



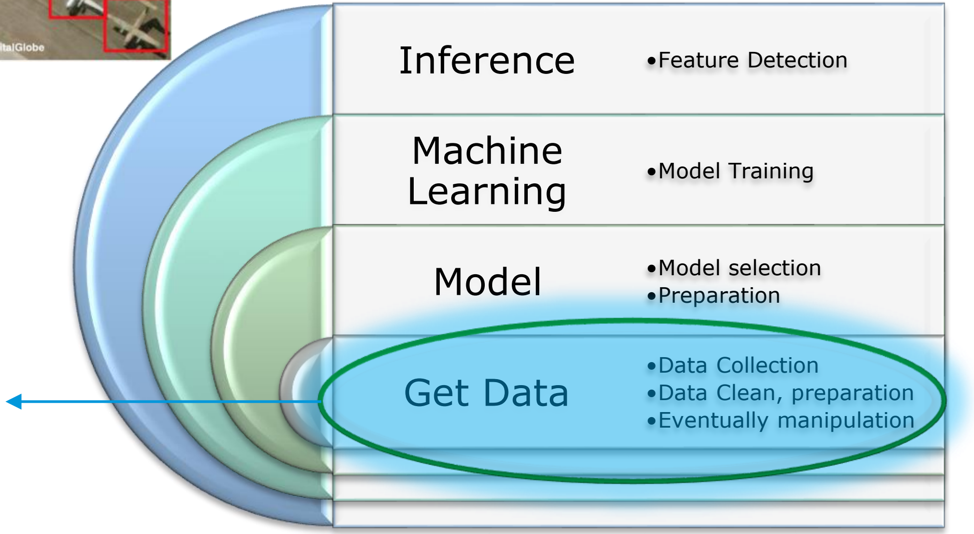
Efficiency and reliability of the feature selection with classic algorithm strongly depends on the application

High computational power needed

Feature Selection

AI

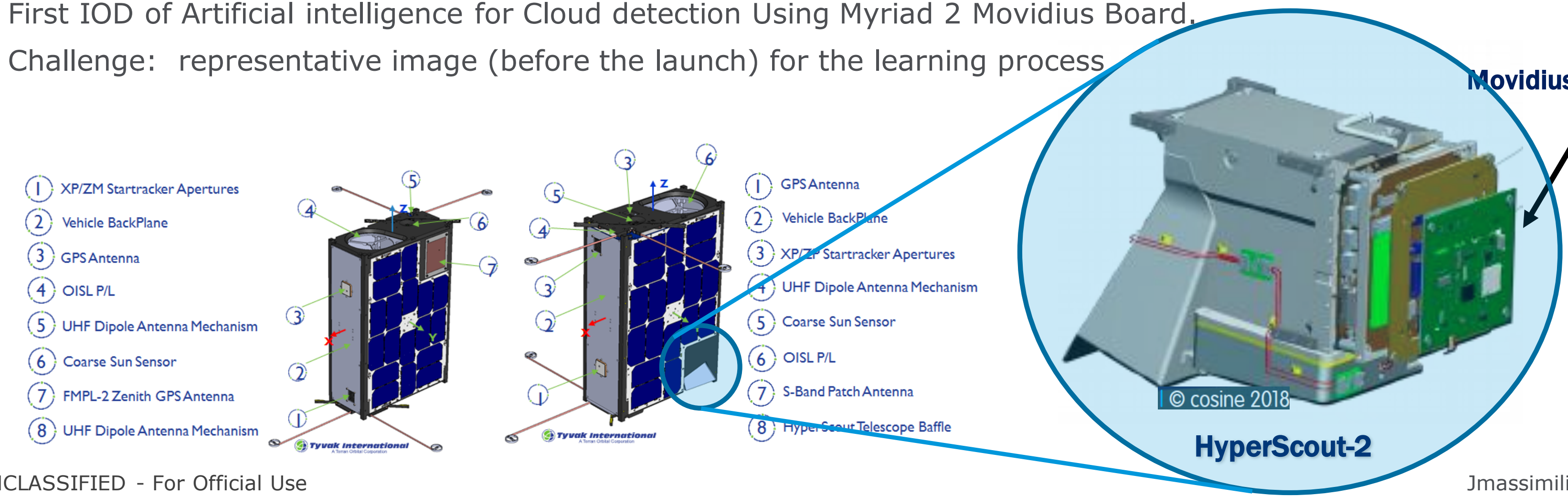
The success of the machine learning process depends on the training data.
Challenges :
- collection of representative data
- reliability of learning process using non fully representative data.



Phi-Sat

- PhiSAT : 1st EOP innovation mission based on CubeSats - from the Sentinel Small Sat (S3) challenge
- KO March 2017, launch On SSMS POC Flight Aug 2018.
- Main applications are:
  - ICE mapping and thickness measure through GNSS reflectometry (L band)
  - Soil Moisture (L band radiometer) in combination with hypespectral (VNIR-TIR) measure for pixel decomposition
  - Agriculture and water management with VNIR-TIR

- First IOD of Artificial intelligence for Cloud detection Using Myriad 2 Movidius Board.
- Challenge: representative image (before the launch) for the learning process



Conclusion

- The trend : increase of > 1 order of magnitude the generated data for a given instrument;

- Two prospective for the OB processing technology needs (assuming a given downlink data rate):
    1. Reduce the Data to download (same scientific data, but with less bits/pixel);
    2. Select the data to increase the scientific content to downlink (relevant pixels or information)

- Enablers:
    - availability of improved HW performance (GPU, VPU etc.) using COTS
    - new algorithms based on AI improving the scientific content to downlink.