EO Technology at ESA:
Processes, achievements and future trends

Φ-week - Future EO (part 5) session

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Why Technology ?

Application 1.0

Sony Walkman

Technology

- Components
- Processing algorithms (mp3)

Any parallel for Φ-space ?

Vision (e.g. miniaturisation) **with a purpose** (better)

Application 2.0

- In the pocket
- Multi-CDs

Vision: integration

Application 3.0

Application / Science is the driver, **Technology** is the **ENABLER** !!

Why Technology? Why early ?

ADM-Aeolus – launched 10+ years later (2018) than initially planned

- Aladin's laser **technology**: **not ready** when mission selected

Ariane-5 first launch: failure

- thought that space it was a commodity
- Software not verified under the new conditions

Lessons learnt:

- consequences of having technology not ready are very costly
- start technology development asap

ESA EO: large range

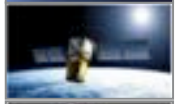
Colour Code:
Launched
To be launched

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

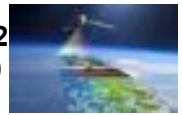

SMOS
2 Nov 09


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

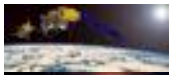

Sentinel 1 A/B/C/D


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:
CO2M, LSTM, PICE, CIMR, CHIME, ROSE-L
Sentinel-1/2/3 NG

EO Technology needs

Higher performance / cost ratio

- **New Measurements** (enabler)
- **Higher spatial** and **temporal** resolution
- Higher **lifetime** (7 yrs → 10 yrs or more)
- Increased **flexibility** (advanced manufacturing, re-programmable FPGA onboard, COTS)
- **Faster** to design/develop and deploy
- Long-term data **continuity** → BIG DATA + AI
- Platform : Lower recurring **cost** (COTS),
  with specific EO needs (AOCS, storage, comms speed, more autonomy)

Miniaturisation and constellations (incl. convoys and formations)

- More autonomous platform & operations
- Distributed Ground Segment
- Synchronisation (with ISL beacon and/or with GNSS)
- Launcher techno for efficient access to space
- lower cost, fast-to-market ability, adaptability and flexibility.

Mainly, but NOT LIMITED to LEO: also High-Elliptic (HEO) and GSO (e.g. G-Class EE-10).

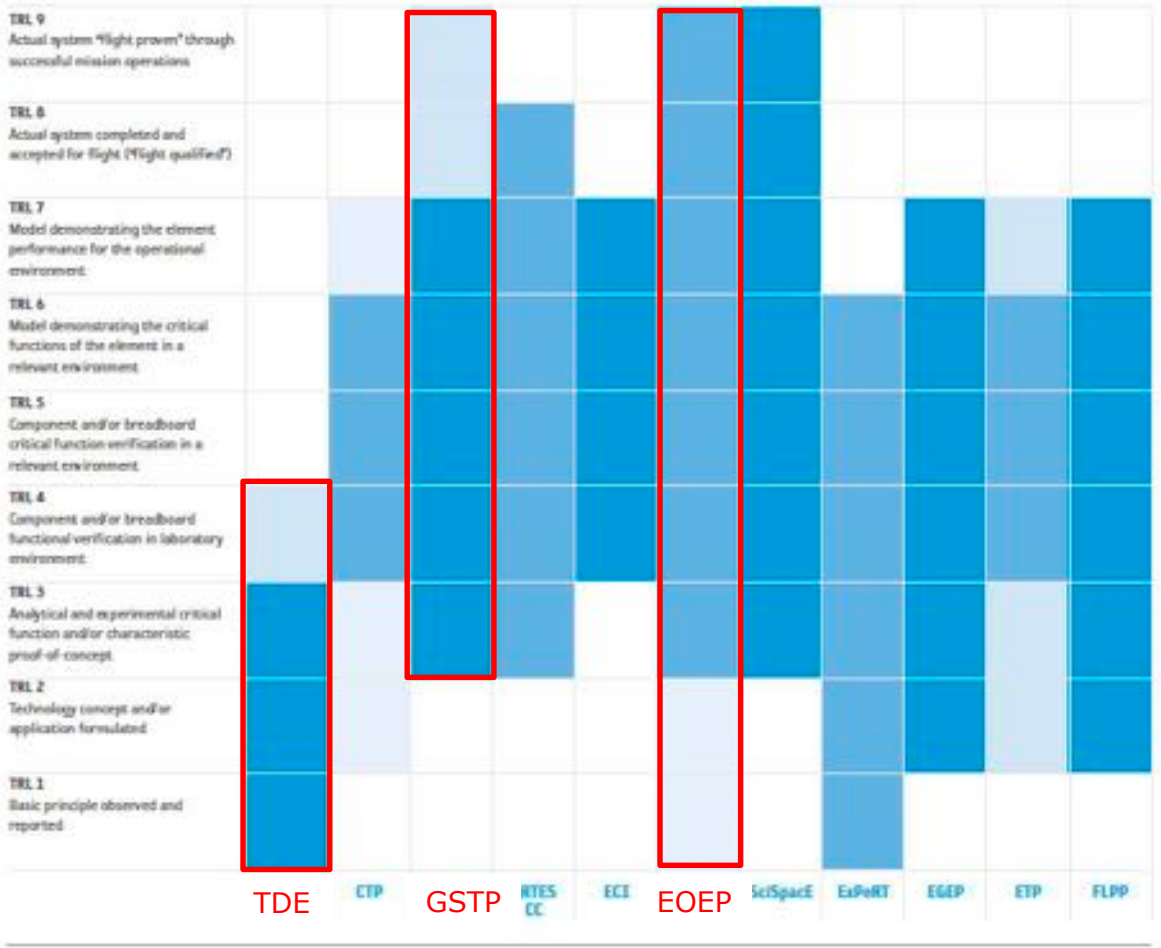
ESA Technology Programmes

EOP Technology under 3 programmes:

- TDE (former TRP): up to TRL 3-4
- GSTP : higher TRLs
- EOEP : all TRLs (from concept to flying products)

ESA Matrix: Collaboration between Application (**D/EOP**) and Support Directorates (**D/TEC** & **D/OPS**)

- **Multi-year** (TDE-GSTP) **Workplan** preparation via **TECNET** WGs
- **Executing** individual activities: ITT prepar., Evaluations, Tech. Officer assignment
- **Harmonisation** (also with EU)



TDE 2019-2029 - Priorities for EO

In green : top EO priorities for TDE.

Earth Expl. 10 (3 concepts for Ph.0) + 6 more for Technology	**Science** driven	**Instrument** (Optical/RF/Digital)	**System** (Platform + GS)	**Constellation enabler** (autonomy, GS, …)	**TDE** + EOEP + GSTP
Copernicus & Meteo Evolution	**User** driven	**System** of Systems (architecture, formation)	**Std/ Common Platforms / GS**: e.g. high speed techno, autonomy,..	Constellation management	EOEP + Copernicus
Space 4.0 (incl. Φ work)	**Innovation** driven	**Full Instrument** Miniaturisation + OB processing	**Mission** - SmallSats /CheapSats - Hosted P/L	**Big Data**: AI (Deep/Machine Learning)	**TDE** + EOEP + InCubed + GSTP

Basic Activities, including TDE

Changes in 2017 led to the creation of the **DPTDE** programme within ESA's Basic Activities:

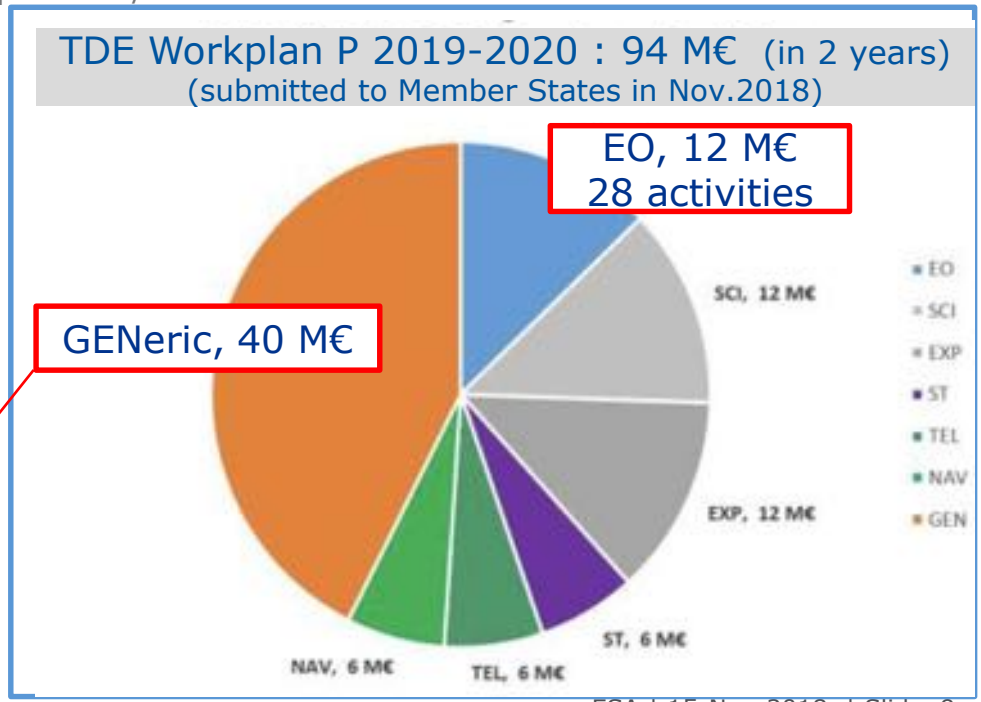
- **D**iscovery: former SysNova, ITI, NPI, Ariadna,… and other TEC-run activities (e.g. ACT) – in principle supporting also optional programs (**e.g. Φ-Lab**), TBC
- **P**reparation: former **GSP** - often used to support Ph.0/A studies
- **T**echnology **D**evelopment **E**lement : former **TRP**

TDE specifics :

- *Low TRLs*
- mostly competitive tendering
- Open to companies from all Member States
- average budget : 400 k€

GEN: FPGAs, Memories, AOCS, other building blocks…

TDE Workplan P 2019-2020 : 94 M€ (in 2 years)
(submitted to Member States in Nov.2018)



GSTP (General Support Technology Programme)

GSTP specifcs :

- *High TRLs* ➔ Budgets larger than for TDE
- It is an OPTIONAL programme

  ➔ Tendering limited to companies from countries supporting the specific activity
- Our interest: EO and also GEN Serv.Domains

Three Elements :

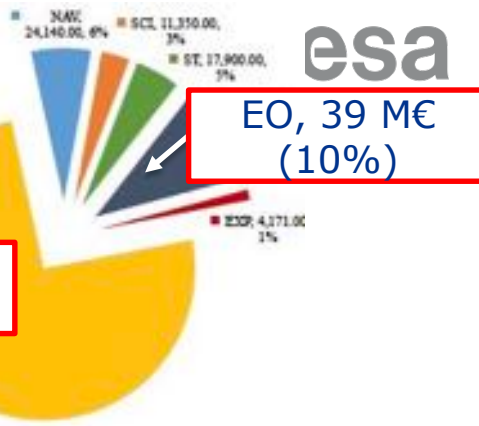
- Elem. 1: Develop
- Elem. 2: Make
- Elem. 3: Fly

GSTP-6 activities - Develop

GSTP Elem. 1 "Develop" - ESA/IPC(2018)105 on 18-April-2017

G611 ID is for EO

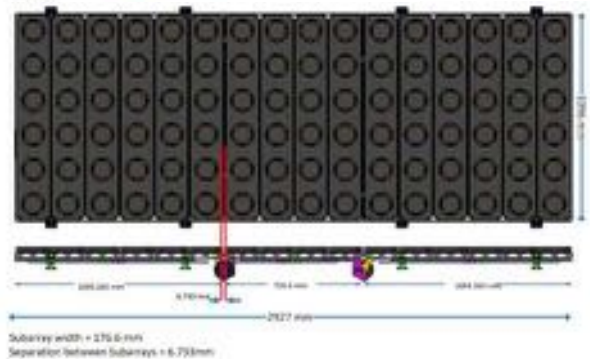
- 35 activit. in **EO Domain (39 M€ - i.e. 10%**)
- Total is 381 M€ - multi-year envelope .



Examples of SD-EO (many co-funded with EOEP):

Many Activities for upstream (components & modules)

- G611-039EE : Passive bi-static L-band SAR Antenna) – (EADS, ES)
- G611-038ET : EQM Radar Electronics bi-static SAR – (TAS-IT)
- G611-002T : IASI-NG Laser Source electronics (Konsberg, No)
- G611-008ET : High Power GaN C-band Tx/Rx (TAS-I)
- G611-017MM : High Stability Laser for NGGM – Many (DE, GB)
- G611-031EP : Solar Cell Interconnector … (Leonardo, IT)
- G611-037SY : EQM of a Compact Spectrometer & Free Form Gratings (AMOS,BE)
- G611-041SY : Continuation VEGETATION (VITO , BE)
- G611-045EO : Pre-development ALTIUS instrument (OIP, BE)
- G611-048EO - GNSS ADC ASIC (Saphyrion, CH)
- G612-001QT - White thermal coating process optimisation (ENBIO, IE)



Many Activities for downstream (with ESRIN, see next slide**)**

Main reference for implementation of projects in ESRIN (EOP-G/-S/-Φ) is the **data lifecycle**.

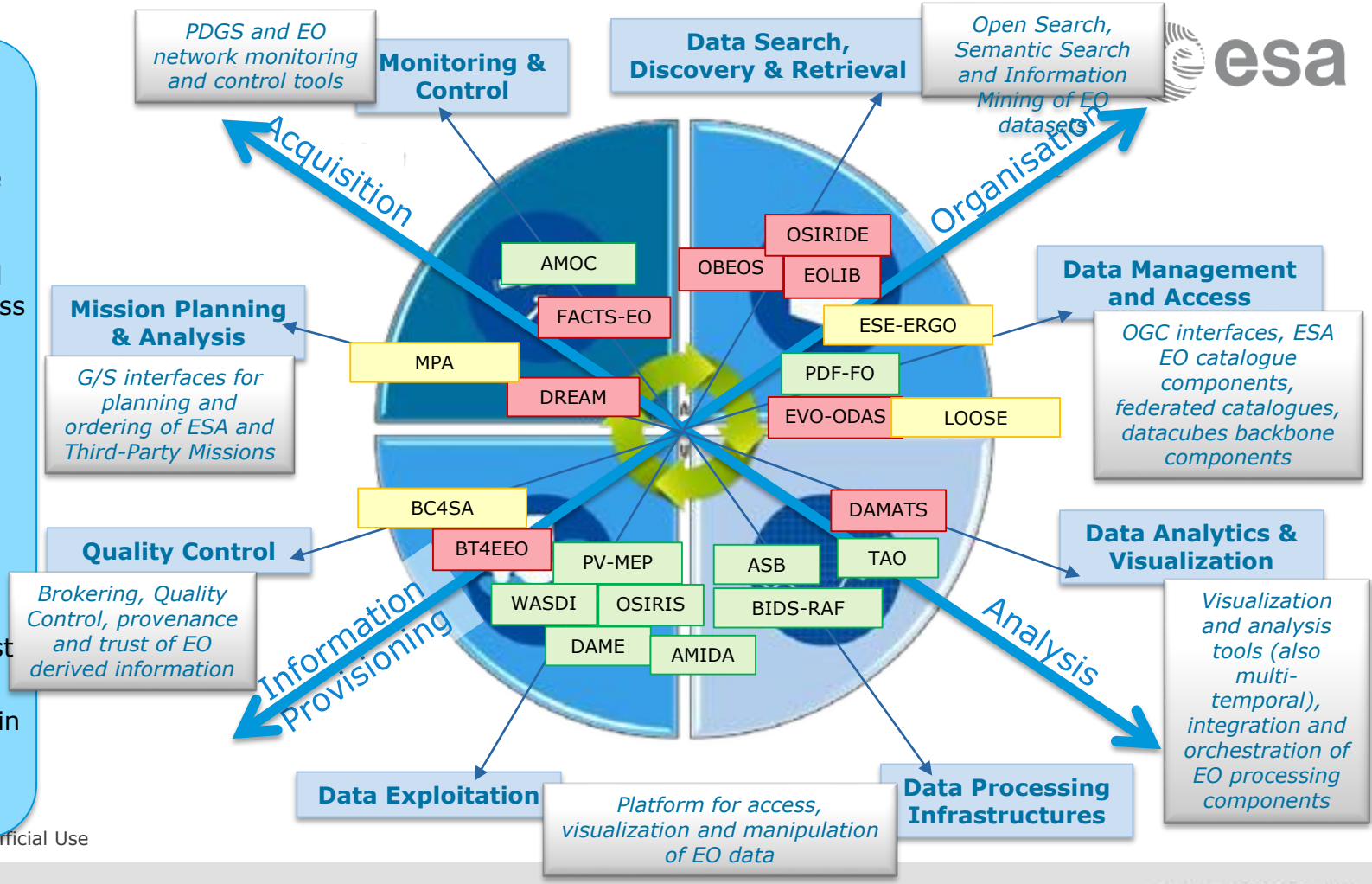
Four Action lines and sub-action lines across →

A whole series of projects: -

COMPLETED
ON-GOING
PLANNED

implemented along these lines in the last 6 years.

Leading to progress in technological developments.



GSTP-6 Elem.2 "Make" EO activities 2013- 2018

ESA/IPC(2017)110

Product oriented - with co-funding scheme (typically 50% by company)

Stepped approach: 1st outline proposal + 2nd full proposal

- 10 activities in Domain EO (11.6 M€ - i.e. 17% of 70 M€ total)
- not necessarily aligned with ESA EOP (partly driven by National interests)

Activity ID	Title	Class
G621-001MM	Optimisation and valorisation of long, modular linear InGaAs imagers	Upstream Techno
G621-008EP	PCDU Product Line Building Blocks	Upstream Techno
G621-011MM	STREEGO – Innovative Solutions for High Resolution Small Satellites	System / Upstream
G621-014SE	EO driven Landscape Infrastructure Modelling	Downstream
G621-031MM	High performance SWIR detector for high resolution land observation payload	Upstream Techno
G621-033MM	Development for future high resolution land observation payload	Upstream Techno
G621-053SY	sat4EO	System / Upstream
G621-076ET	Multimission Direct Access Terminal for PAZ, TerraSAR and Other Satellites	Upstream Techno
G621-079ET	Land analytics EO Platform	Downstream
G621-064ED	Image Compression Module	Upstream Techno

EO also interested in the **GENERIC-part**. e.g.
- GNSS Receivers G627-003ET
- Mass Memories G627-089ED

EO InCubed (also co-funded + stepped Program)
- Part of Φ-Lab
- NEW (since 2017)

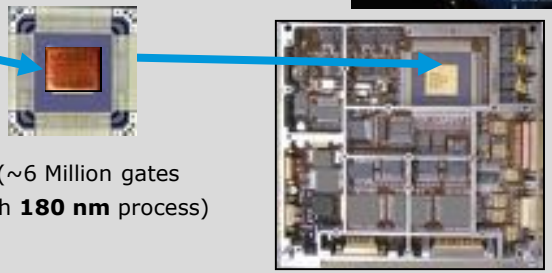
➔ More co-ordination with GSTP in the future

Examples of developments

Advanced GPS-Galileo ASIC (AGGA-4)

EOEP funding → **ASIC** (**enabler**)

GSTP funding → **GNSS Receivers**



By Airbus, ATMEL, RUAG

(~6 Million gates with **180 nm** process)

Programs adopting AGGA-4:

- MetOp-SG (P/F & RO inst.), S1c/d, S2c/d, S3c/d, S6, Proba-3, Neosat, others TBC (e.g. Biomass, Flex)
- CSO, SARah, + Comp.Adv Sat. 500 (S Korea), **Mohammed VI**
- Vega-C

Future:

- **COTS FPGAs –** reprogrammable on-board **(7 nm)**
  L1 freq. & multi-GNSS (GPS, Galileo)

- **A niche for ASICs (28 nm): multi-GNSS freq. → top accuracy**

26 GHz (K-band)data **downlink** (up to 10 Gb/s)

EOEP funding for **System studies** → **enabler**

- **EOEP, GSTP, TRP, ARTES,**
  for **OB / OG** Antennas, OB Tx / OG Rx), Propagation, …

20 cm

Konsberg

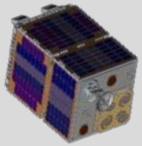
Tesat

Adaptable speed (**Gbit**/s) Transmitter

Joint report (NASA, JAXA, CNES, DLR, …) available

Programs adopting the 26 GHz band:

- MetOp-SG, MTG, EDRS, Euclid → next Generation Sentinels (TBC)
- NASA (JPSS-1, NISAR, PACE, …), … JAXA, SARah, …
- **feasible for small sats : two ESA studies**
  - **150 kg. P/F** (with SSTL)
  - **CubeSats** (with Calisto-SSBV)



Technology enablers for small sats

- GaN SSPA – power amplification
- Smaller antenna (steerable or agile satellite)

Time to start Q/V band comms (more Bw)

Optimise Standard Platform → more resources for the Payload

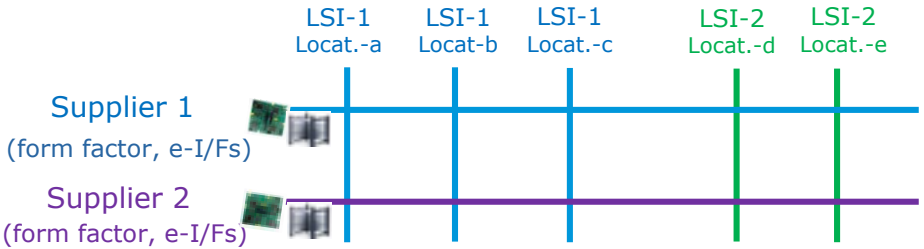
Lower Cost + Faster to adopt

- Mind EOP specific requirements: AOCS, Storage, downlink

Platform Needs:

- Architecture evolution
  - Miniaturisation (units→ boards → components)
  - more Integration (AIT) → potential savings
  - Higher performance (speed) + functionality (protocols)

- Standardisation:
  - Common interfaces (electrical & mechanical form-factor)
  - Multi-source suppliers :
    - ✓ interchangeable modules
    - ✓ newcomers (incl. COTS)



Standardisation done for Cubesats → big success

Learning from NewSpace
Industrial challenge: collaboration (big & SMEs)

Multi-board SMU:
OBC, GNSS, SSMM, mini-RIU

GSTP Elem. 3 - Fly

ESA Roadmap & Workplan for IOD CubeSat missions and Technologies - ESA/IPC(2018)79

➔ several smallsats are relevant for EO..

➔ Three Phase A planned for 2019 (inspired from SYSNOVA studies, GSP funded, with EOP participation)

- EOP running studies to define Small RF instruments

<u>Good D/EOP & D/TEC co-ordination</u> :

- EOP uniqueness: <u>USER DRIVEN</u> approach + need for <u>highly calibrated P/L</u>
- EOP is benefitting from GSTP Fly Technology

EOP Small Sats

(EOEP funded activities)

Sentinel Small Sat. (S3)- Challenge

- FSScat (UPC Barcelona) selected in 4Q-2017 : with two 6U Cubesats
- Sat-1: GNSS-R + radiometer & Sat-2: HyperScout + InterSat Links

New challenge for SmallSat concepts– current plan:

- 4 phase-A studies (ITT planned for 1Q-2019)
- development depending on resources allocation in CMIN-19

Defining EOP landscape for small sats

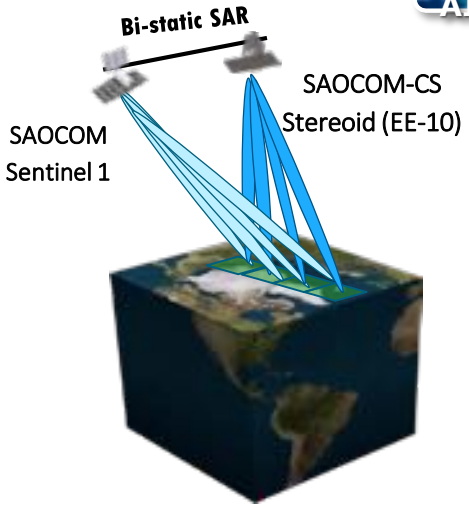
- For Microwave Instruments (2 studies: Omnisys, HARP) – ending in 2Q-2019
- For optical instruments (being initiated)

Inspiring looking outside: e.g. NASA's "ESTO Invest" good results

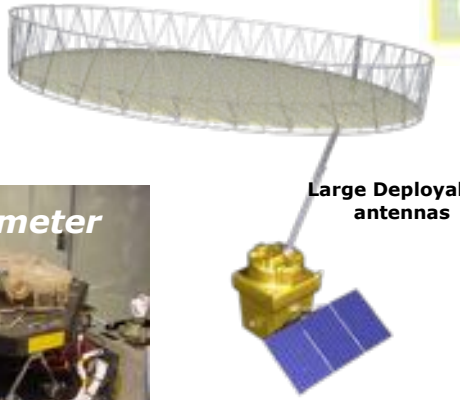
Core business not to be forgotten

Preparing new instruments and observation techniques
- RF & Optical
- from concept, Components & HW demonstrators, up to qualified models
- for satellites (and airborne campaigns)

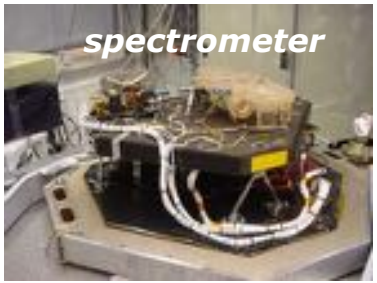
Big data challenges

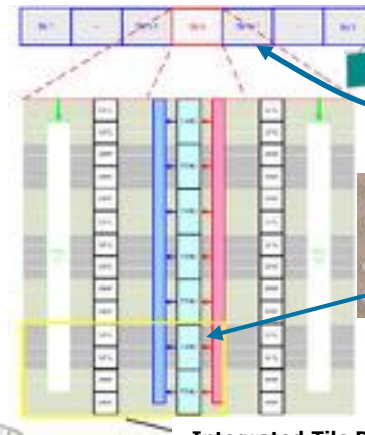


Horn antenna



Large Deployable antennas





Integrated Tile Demonstrator

Digital Beamforming Unit (TRIM)

Airborne campaigns

IR detector Array

Future EO: leveraging the digital revolution (Technology as enabler)

10x More Data

Expanding EO Landscape: Copernicus 2.0 + Meteo SG + Science + Commercial / SmallSat Constellations..

HAPS, UAV,..

IoT, Open Data

Rapid Innovation

Cloud Computing
Big Data Analytics

AI, esp.
Deep Learning,
Autonomous Syst.

Miniaturisation
& Integration

New Solutions / Partnerships

Demo end-to-end distributed smart sensing systems (AI+EO+HAPS … +IoT)

Environment for Rapid Innovation / Prototyping, to test ideas via Proof of Concept, Challenges, Hack, Research/Sprint

Foster New Partnerships (e.g. ICT, startup, investors, non-space users), New start-up

CHALLENGES → **OPPORTUNITIES** → **SOLUTIONS**

Conclusion

EARTH OBSERVATION : USER DRIVEN with wide range of innovation

- **Technology** is the **ENABLER ➔ start early**

- EOP Technology NEEDS:
  - Higher performance / cost ratio (also faster design & deployment)
  - Opening to Constellations (Space 4.0)

Large range of Technology under EOEP & (TDE + GSTP) Program (in collaboration with D/TEC- D/OPS):

- from concept to qualified equipment
- from micro (component) to macro (equipment, system)
- focus on instruments (RF, Optical) & Platform and downstream too

Harmonisation (also with EU) on-going - not discussed today

Trends:

- **Spin-in** : COTS + digitisation (FPGA re-programmable on-board) + smart manufacturing + Artif. Intelligence
- **Miniaturisation** opening new applications: for Institutional & Space 4.0
- **Standardisation** required - to foster industrial collaboration