CEOI
2nd May 2019

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Prepared by EOP-ΦMT
Technology Coordination & Frequency Management Section

Table of Content for ”Status Update on EO”

EO Technology : Enabler of a User Driven approach
Science & Services (land, ocean, ice, atmosphere, …)

Higher performance / cost ratio

- **New Measurements** (enabler)
- **Higher spatial, temporal, radiometric** resolution
- Instruments in the **whole spectrum** (RF, Optical) – active & passive
- 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** : specific EO needs (AOCS, storage, comms speed, more autonomy) + Standardisation
- Lower recurring **cost** (**spin-in** techno: e.g. COTS , multi-source providers)

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 HEO & GSO (e.g. G-Class EE-10).

2a) EO missions overview (user driven)

Colour Code:
Launched
To be launched

Living Planet
(SP-1304)

Earth Explorer
Research driven

Core Missions


GOCE
2009-2013


Aeolus
Aug-2018


EarthCARE
2021

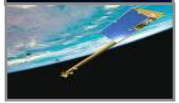

Biomass
(EE7) 2022

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

Opportunity


CryoSat-2
8 April 10

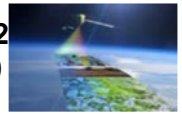

SMOS
2 Nov 09


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

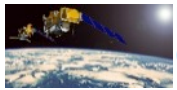
Meteorology


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)

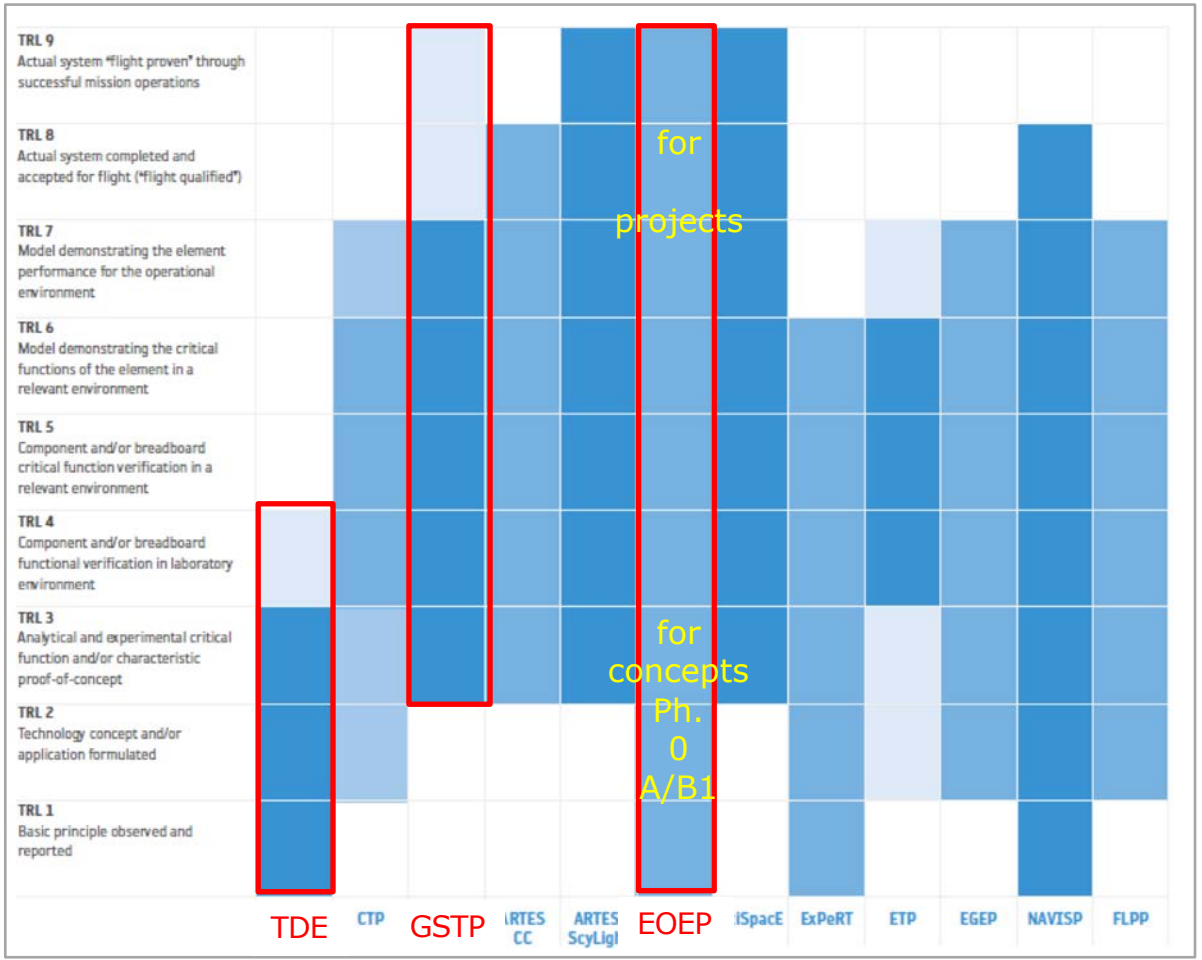
Copernicus Space Component Evolution:
Expansion: CO2M, LSTM, PICE, CIMR, CHIME, ROSE-L
Continuation: Sentinel-1/2/3 NG

ESA Technology Programmes

EOP Technology under 3 programmes:

- **TDE** (former TRP): up to TRL 3-4
- **GSTP** : higher TRLs

- **EOEP** : all TRLs

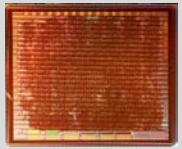


EOEP : EO Envelope Programme

Large scope for EOEP technologies

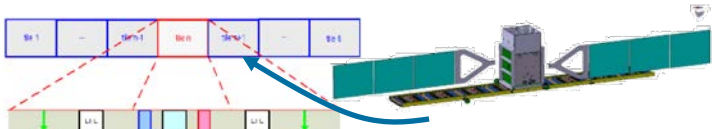
New **instruments** and observation techniques
- RF & Optical
- from concept to Components & full HW demonstrators
- for satellites (and airborne campaigns)

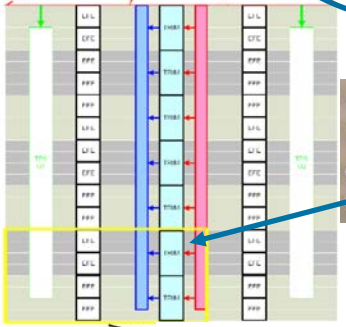
Standardisation of **Platform**
Big data challenges



AGGA-4
GNSS ASIC

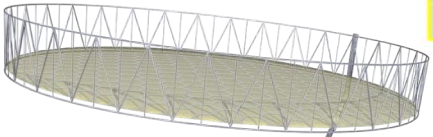
Horn antenna

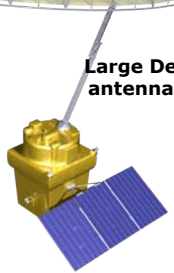




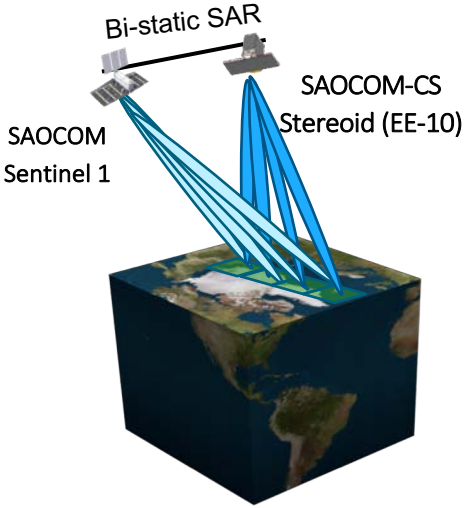
Digital Beamforming Unit (TRIM)
by Airbus

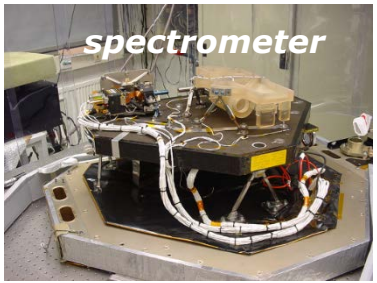
Integrated Tile Demonstrator



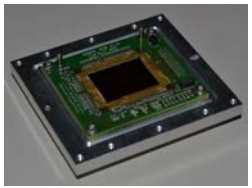


Large Deployable
antennas (CIMR)





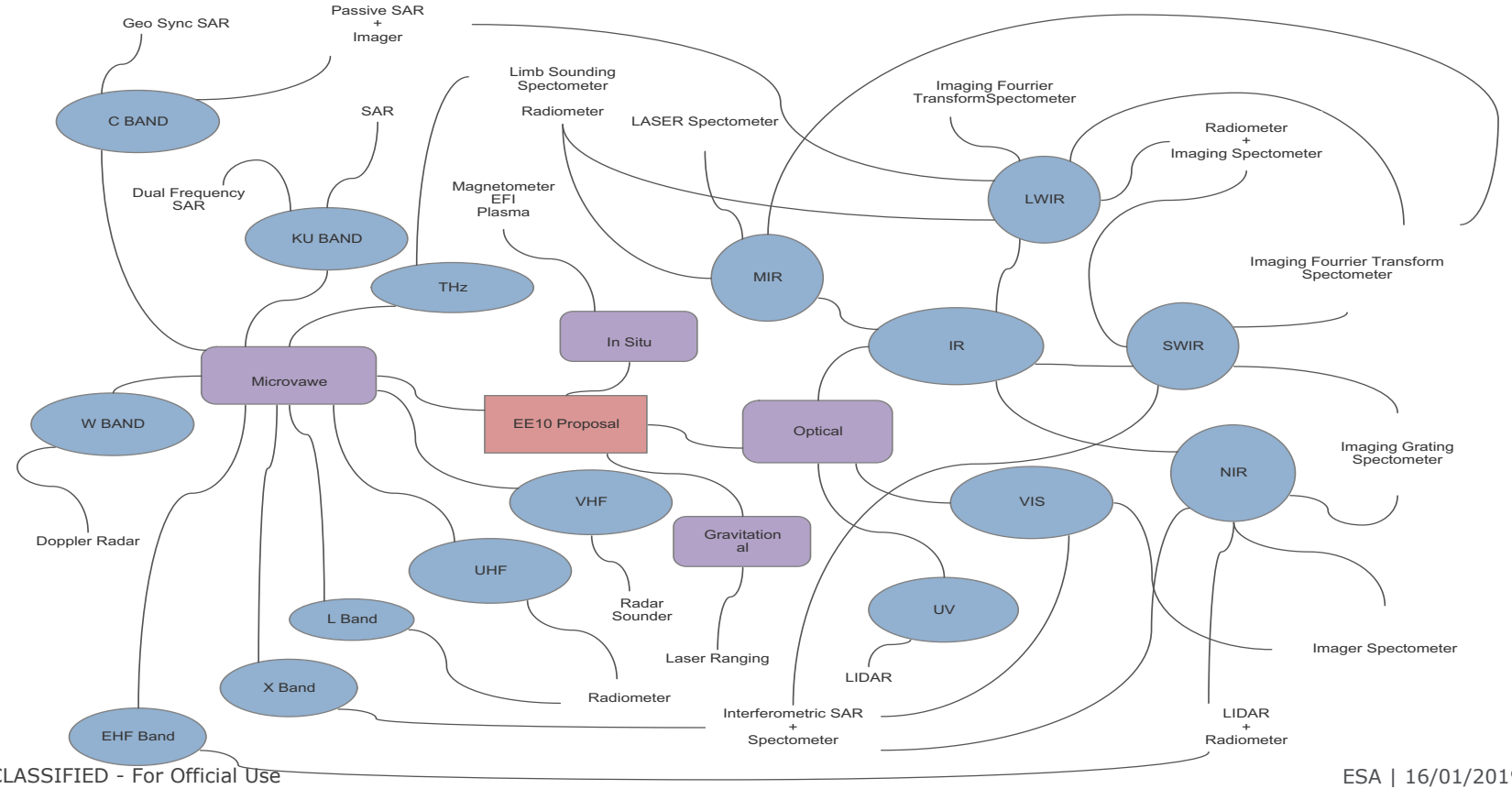
Airborne campaigns
(ACADIA, A2D)



TIR detector
Array

EE-10 candidate missions (21 concepts)

➔ instrument technology driven by frequency / wavelength



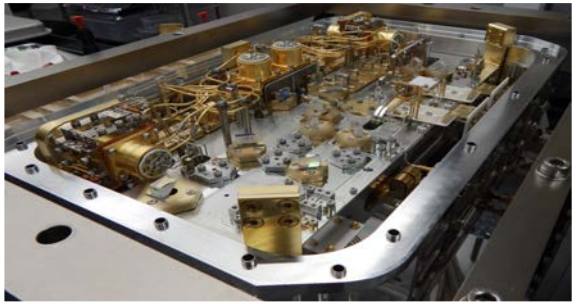
Instrument Pre-Development

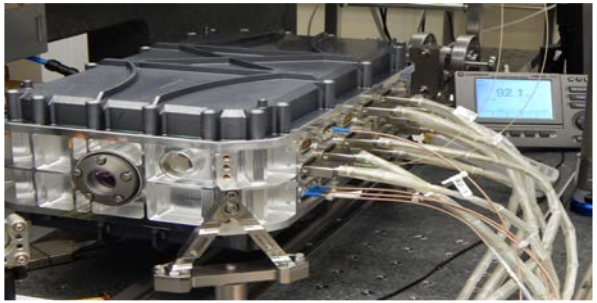
- and **Complete Sub-Systems / Optical Models**

FULAS
FUture LidAr System

(by EADS, D)

Pressurised laser source





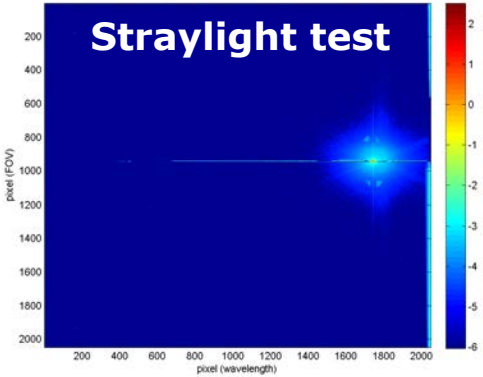
➔ baseline for MERLIN mission

FLEX

(by LEONARDO, I)

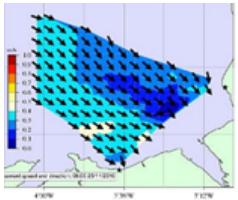
Telescope

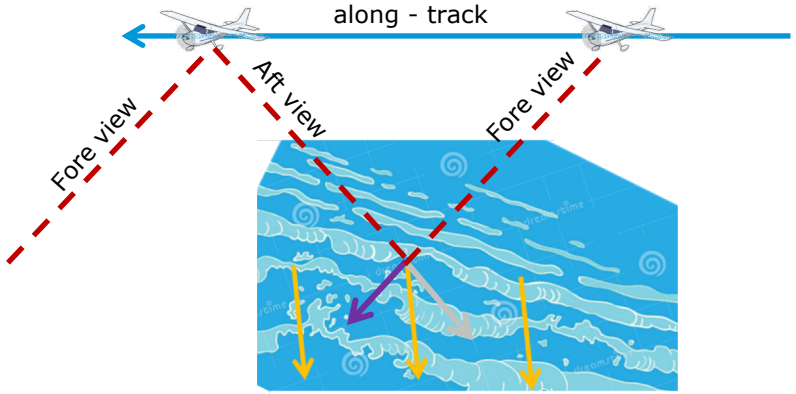
HR Spectrometer



Ocean Surface Currents Airborne Radar Demonstrator

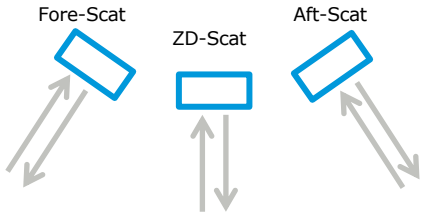
Airborne Ku-band (13.5 GHz) radar instrument for ocean surface motion and wind retrieval





Surface current retrieval using along track interferometry

OSCAR installed in a Pod under a Piper PA-31

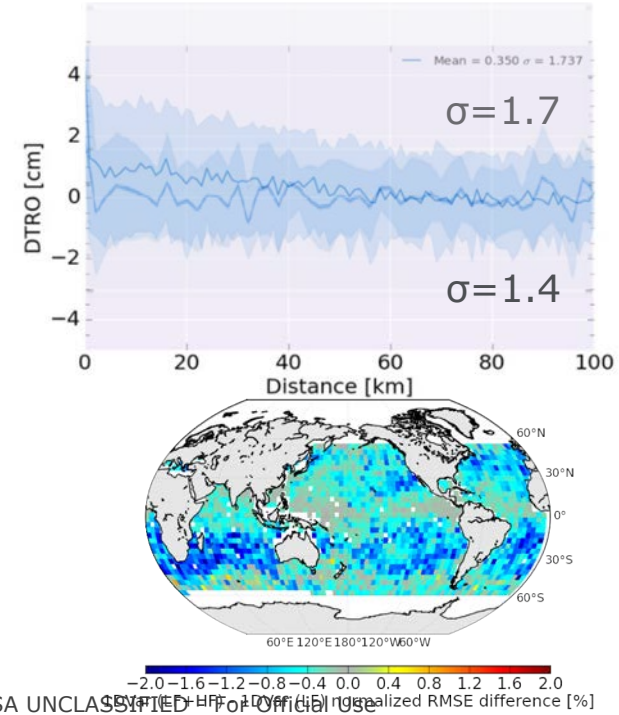


Surface wind retrieval using scatterometer measurements

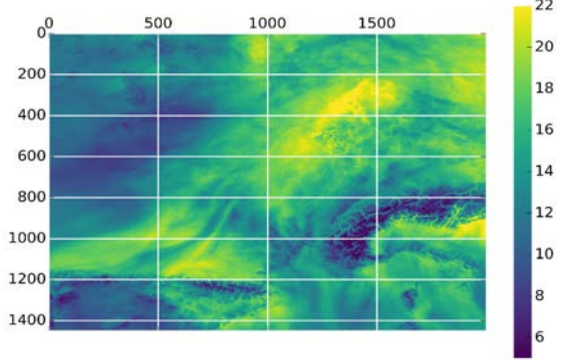
Coastal Radiometers - under Instrument pre-Development

Provide **European sourced solution** for high resolution radiometer, including:

- high reliability and full sensor chain characterisation for best data products
- high frequency channels to improve coastal & global performance.



S6 using non-European radiometers:
- black box for European users
- Single Point Failure issues



Frontal system SW France, Iberian peninsula
AROME analysis at 0.01°,

Technology developments in System Studies

On-going System Studies for Earth Explorers & CSC Evolution HPCM :

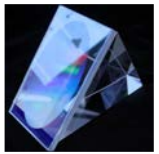
- Two parallel system studies per Candidate Mission
- **Technology pre-development part** : (33% to 43% allocation)

	Phase	Amount / study M€	Technology part M€	%	TRL target
EE-9 (Skim, Forum)	A	3.5	1.5	43%	4
	B1	4.5	1.5	33%	5/6
EE-10 (Stereoid, G:Class, Daedalus)	0	1	0.4	40%	
	A	3.5	1.5	43%	3/4
CO2M, PICE, CMIR, ROSE-L	A/B1	5	1.8	36%	3-4 / 6
LSTM, CHIME	A/B1	6	2	33%	3-4 / 6

Details at QSR :
ESA/PB-EO/DOSTAG(2019)1

Block-1 is fundamental , also for low TRLs

- It enabled the above studies (e.g. CO2M benefits from EE-8 predevelopments)
- Needed to mature new ones : e.g. EE-11 (Fast Track) will need TRL-4 technology



SWIR grating for CarbonSat

2.c) Copernicus Space Component (CSC) in Block-1
Phases A/B1 System Studies of Potential Expansion Sentinels

Six **Phase A/B1 missions initiated in 2018**

(HPCM : High Priority Candidate Missions)

- Antropogenic CO2 Monitoring
- High Spatio-Temporal Res. Land Surface Temperature Monitoring
- Polar Ice and Snow Topographic (PICE)
- HyperSpectral Imaging (CHIME)
- Passive Microwave Imaging (CMIR)
- L-band SAR

HPCM	System study	Technology	Total	
CO2	3.2	1.8	5	M€
LSTM	4	2	6	M€
P-ICE	3.2	1.8	5	M€
CHIME	4	2	6	M€
CMIR	3.2	1.8	5	M€
L-band SAR	3.2	1.8	5	M€
TOTAL	20.8	11.2	32	M€
x2 (parallel studies)	41.6	22.4	64	M€
	65%	35%	100%	

For each mission, parallel studies and with two technical contributions (under EOEP):

➔ Block-1 funds (~65%): Mission studies

➔ Block-2 funds (~35%): Technology Part (related to pre-development of Critical Elem. to reach **TRL 3-6**)

Ref. ESTEC/AC/496-11
& ESTEC/AC/497-17 ROSE-L

2c) Additional Technology Activities for Copernicus CSC Evolution missions

In addition to the technologies in the Phase A/B1 studies, there are more more pre-development activities on-going:

- SWIR detector for the Anthropogenic CO2 Monitoring Mission
- TIR cooled detector for the High Spatio-Temporal Resolution Land Surface Temperature (LST) Monit. Mission
- Detector for HyperSpectral Imaging Mission

- Common Platform technology developments (see example in two slides)

- Large Reflector Antenna for low frequency SAR and imaging microwave radiometer

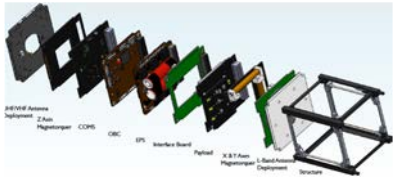
- CO2 spectrometer elegant breadboard
- CO2 clouds and aerosol instrument elegant breadboard

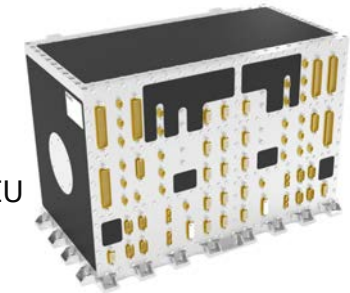
Standard Platform → more resources for the Paylaod

Platform Needs:

- **Architecture changes**
  - Miniaturisation & more Integration (units → boards → components)
  - Digital Interfaces : shifting intelligence & less cables
- **Standardisation**:
  - Common interfaces (electrical & mechanical form-factor)
  - Interchangeable Modules ➔ multi-suppliers
- Increased **functionality / reliability**: e.g. CFDP (file transfer), …

Standardisation done for Cubesats ➔ big success





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

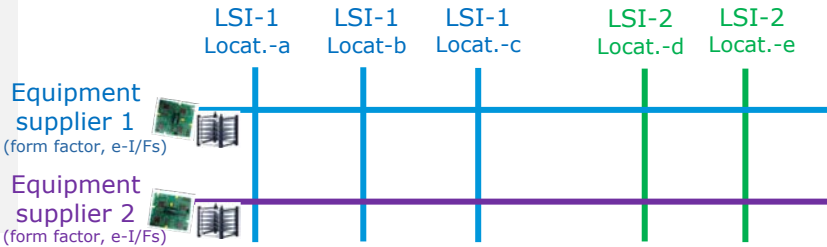
EOEP-5 funding **System studies** → **Roadmap for standardisation:**

- 3 x 2 M€ studies: EO Standard Platform for Copernicus (EOP-P)
- 2 x 400 k€ studies : Data Handling Roadmap (EOP-ΦM)

but

- **GSTP/Incubed** should (co-)fund **future Module Developments**

(e.g. GNSS Rx board in O/B Computer)

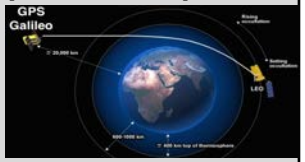


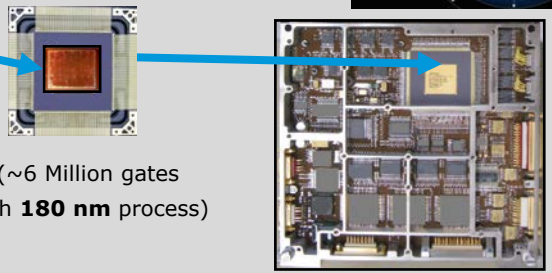
Examples of developments (from EOP/TDE to GSTP)

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:

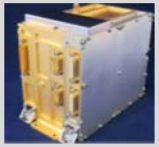
- **COTS FPGAs –** reprogrammable on-board **(7 nm)**
  L1 freq. & multi-GNSS (GPS, Galileo)

- **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, TDE, ARTES,**
  for **OB / OG** Antennas, OB Tx / OG Rx), Propagation, …



Tesat

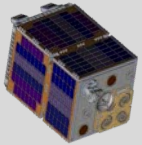
Adaptable speed (**Gbit**/s)
Transmitter

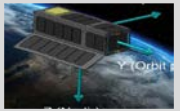
Konsberg

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

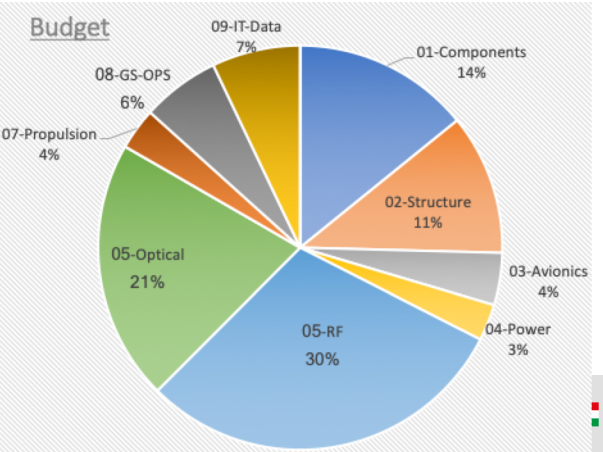
- GaN SSPA – power amplification
- Smaller antenna (steerable or agile satellite)

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

Selected activities for TDE 2019-2020

All details at ecpb: ESA/IPC(2018)103

	Activities	Budget
Competence Dom. (CD)	**Nb**	**k€**
01-Components	2	1700
02-Structure	3	1350
03-Avionics	2	500
04-Power	1	350
05-RF	9	3600
05-Optical	5	2500
06-Life, Robotics		
07-Propulsion	1	400
08-GS-OPS	2	750
09-IT-Data	3	850
10-Environment	0	0
Grand Total	**28**	**12000**



Relevant to EE-10

Compet. Domain	TDE. Ref.	Title	Budget	EE-10	2019 / 2020
5- RF	T107-602EF	Geometry- and wavelength-agnostic highly-efficient forward and reverse SAR processor	450	STEREOID, + G-CLASS	2019
5- RF	T107-607EF	Antenna Verification Methodologies for Large Antennas	400	G-CLASS	2019
2 - Struct	T120-601MS	In-Orbit Surface Metrology for Large Deployable Reflectors	450	G-CLASS	2019
7 - Propul	T119-601MP	Ram-EP VLEO satellite mission design and integrated ram-EP ground testing	400	Daedalus	2020
5- RF	T106-604EF	Development of 4.7 THz Schottky device	500	LOCUS	2019
2 - Struct	T121-601MT	Low Noise Miniaturized very high frequency Pulse Tube cooler	600	LOCUS	2019
5- RF	T106-605EF	A low-frequency and wide-band reflector antenna feed for future earth observation radiometers	350	CryoRad	2019
3 - Avioni	T101-601ED	Future On-Board Processing and Information Extraction Algorithms Study	250	Nitrosat	2019
5- OPTICAL	T116-601MM	Low straylight diffraction grating	600	Nitrosat	2020
		TOTAL	4,000	9	

Notes:

- TDE Call closed on 14-Sept., and EE-10 was announced on 21-Sept.
  (not all details from Proposals could be shared in enough detail)
- SEASTAR (former Wavemill) already had many pre-developments
- Daedalus requirements: need clarification from a Technology view

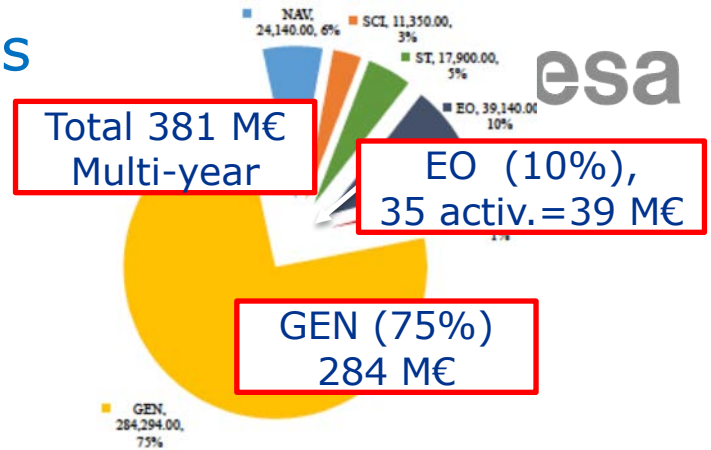
GSTP-6 (Elem. 1 & 2) activities

GSTP-1 Elem. 1- Develop

ESA/IPC(2018)105 - May 2018

EO part (with **G611 ID**) - often co-funded with Block-1 :

- **upstream** (components & modules)
- **downstream** (with ESRIN)



http://emits.sso.esa.int/emits-doc/ESTEC/News/GSTPE1-DevelopCompendium2017.pdf

GSTP-1 Compendium

	Jun-17		in GSTP Elem.1 WP (Jan.2019)	
	Nb. Activ.	M€	Nb. Activ.	%
Total	143	144	32	22%
EO only	14	11.6	2	14%

➔ Potential for transferring many more to GSTP Elem. 1 WorkPlan

GSTP- Elem. 2 - MAKE

ESA/IPC(2018)110 - Sep 18

- 10 activities / 11.6 M€ in EO (i.e. 17% of 70 M€ total)
- not necessarily aligned with ESA EOP (partly driven by National interests) ➔ **Consider InCubed in the future**

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

Other Technology Innovations
High Altitude Platforms (HAPS) –

Workshop on 9-10 Oct. 2017

Two system studies initiated in 2018,

- HAPS in support of ESA EO missions
- Identification of HAPS in support of satellite air quality activities

No Technology development planned at present

Workshop on 12-14 Feb. 2019 in Leiden (NL)

https://atpi.eventsair.com/QuickEventWebsitePortal/haps4esa/website

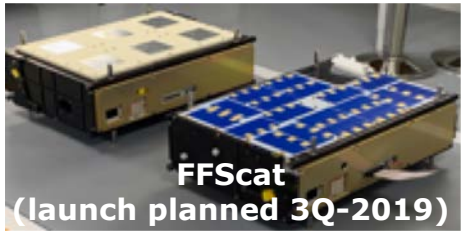
EOP-ΦM Small Sats

(EOEP funded activities)

Sentinel Small Sat. (S^3)- Challenge

- FFScat (UPC Barcelona) selected in 4Q-2017 : with two 6U Cubesats
  - Sat-1: GNSS-R + radiometer
  - Sat-2: Hyperspectral, including TIR + Art.Intelligence (Φ-Sat)
  + InterSat Links (RF + Optical)

LAUNCH planned in August 2019 on Vega-SSMS PoC



New challenge for SmallSat concepts– current plan

- up to 4 Sys. Consolidation studies – 400 k€ each
  - ➔ tendering planned for May-2019
  - ➔ strong EO scientific case required
- Mission industrial cost (Space + Ground + Launch+IOC) ≤ 30 M€
  - ➔ development depending on resources allocation in Future EO-1

ideas

Defining EOP landscape for Small EO Instruments

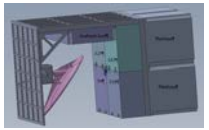
- For Microwave Instruments : 2 studies: (Omnisys, HARP) – ending in 2Q-2019
- For Optical Instruments : 2 studies initiated in Q1-2019 (SSTL, Cosine)

ideas

GSTP Elem.3 (Fly)

3 EO-related studies in 2019

ESA/IPC(2018)107
in Sep-2018



WeatherCube
(12U by Omnisys, SE)

Conclusion

EARTH OBSERVATION : USER DRIVEN with wide range of innovation

- Technology is the ENABLER

EOP Technology NEEDS:

- Higher performance / cost ratio (also faster design & deployment)
- Driven by institutional, but opening to Constellations (Space 4.0)

Acknowledging trends:

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

Space19+ and **Future EO Block-1** are key

- to continue the EO success (many achievements, lessons learnt)
- to foster/focus innovation (within the EO user driver approach)