Emerging EO Technology in ESA and fostering European non-dependency

(Agora)

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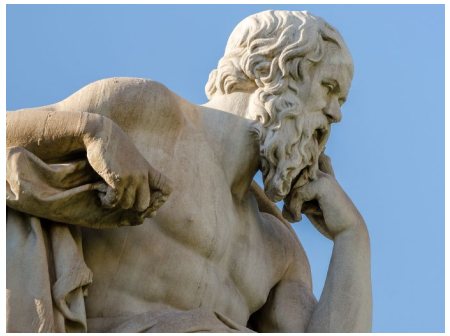
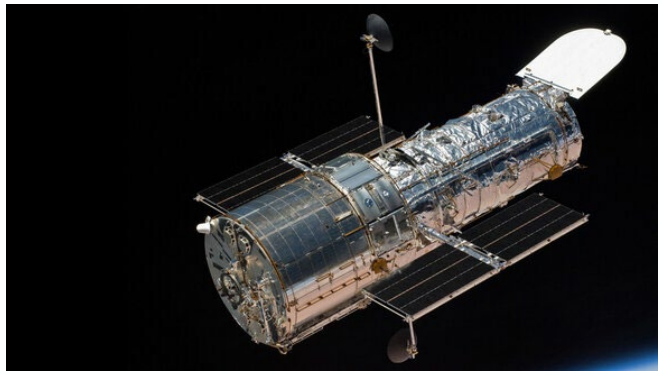
- Knowledge & EO User driven
- ESA EO Technology – key enabler
  - programmatics, examples
- Beyond technology

Human hunger for KNOWLEDGE



Socrates – *I only know that I **know nothing***

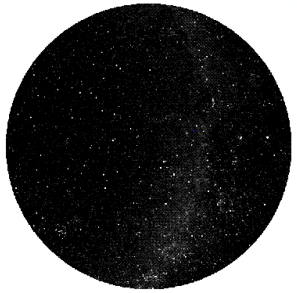
Galileo & enabling **technology**



Hubble - Space Telescope

Skies
with bare eye

Leap
in 17th century



KNOWLEDGE – same coin, two faces

1) **Science** – **the driver** - the "what" to know

2) **Technology** – **the enabler** - the "savoir-faire" to answer

Our focus : our unique Planet

→ more **technology** needed

More knowledge

21st century techniques

Have we progressed ?

1977 1991 1995 1997 1998 2022

Earthnet: European access to non-ESA missions

User

Meteosat
M-1, 2, 3

Operational
M-4, 5, 6

Transition
M-7

Meteosat(s)

Metop(s)

Meteo

Research Missions
Earth Explorer(s)
Scout(s)

Science

1991
ERS 1, 2

1995

Envisat

Earth Watch

GMES / Copernicus
(in cooperation)

Applications Services

GSTP

NewSpace
Private initiatives

Cassini

ESA EO Satellites

Science + Copernicus + Meteo
15 in operation
39 under development
12 under preparation

Small Sats

esa

Living Planet Programme (user driven)

Research Missions
EE, Scouts

Earth Watch Missions
Copernicus, Meteo, CustomisedEO (InCubed, National-driven)

2010 2015 2020 2025 2030

ERS-1, ERS-2, Envisat, MetOp-A, Proba-1, SMOS, GOCE, CryoSat, Swarm, Proba-V, Meteosat 10 (MSG), MetOp-B, Sentinel-1A, Sentinel-2A, Sentinel-3A, Sentinel-5P, Meteosat 11 (MSG), Sentinel-1B, Sentinel-2B, Sentinel-3B, Sentinel-6 Michael Freilich, MetOp-C, Sentinel-1C, Sentinel-2C, Sentinel-3C, Aeolus, ALTIUS, Sentinel-1D, EarthCARE, Biomass, FLEX, CubeMAP, HydroGNSS, TRUTHS, FORUM, Harmony, Earth Explorer-11, MTG-I1, Sentinel-5A MetOp-SG-A1, Arctic Weather Satellite, MetOp-SG-B1, CO2M-A, Sentinel-4A MTG-S1, MTG-I2, CO2M-B, CO2M-C, Sentinel-2D, Sentinel-3D, Sentinel-6B, CRISTAL-A, CIMR-A, ROSE-L-A, LSTM-A, CHIME-A, LSTM-B, CHIME-B, CRISTAL-B, CIMR-B, ROSE-L-B, MTG-I3, Sentinel-4B MTG-S2, Sentinel-5B MetOp-SG-A2, MetOp-SG-B2

Sentinel-1 Sentinel-2 Sentinel-3 Sentinel-6

Continuation of Sentinel Next Generation Missions

Many in GSTP Fly

FSScat – Φ-sat-1 UPC

Mantis OpenCosmos -+Satlantis

HyperField Kuva + VTT

Φ-sat-2 OpenCosmos

MSCM AerospaceLab

Hive ConstellR

OroraFire Ororatech

InCubed Commercial

IOD

Science esa | Copernicus | Meteorology EUMETSAT

→ THE EUROPEAN SPACE AGENCY

FutureEO Block-1 view

(Foundations and Concepts)

- strategic entry-point
- synergetic effect

Research Missions
(FutureEO Block-2)

Scouts

Earth Explorers

Operational EO

Meteorology

Copernicus

Customised EO

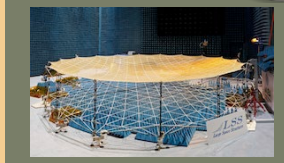
Commercialisation

Mission Implementation
CMIN_n + (1 or 2)

FutureEO - Blk.1

Mission Definition
&
Technology + Science / App

(incl. Campaigns + simulators)



CMIN_n

Competitiveness (beyond ESA missions)

BASIC ACTIVITIES

Earthnet Heritage Space

DPTDE

GSTP

H2020 techno

National techno

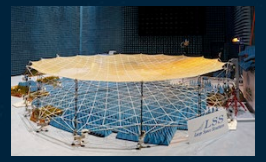
7

FutureEO CMIN-22 – Block-1 (Foundations and Concepts)

Mission Definition and Feasibility

→ Target TRL 5 / SRL 5

- Earth Explorer-12 : ≤ 5 mission concepts in Ph.0 ; ≤ 2 in Ph.A ; Implem. after CM25
- Scout-2 : ≤ 4 mission concepts in Consolidation Phase; ≤ 2 for Implem. in Blk.2
- Sent-2 NG : Phase A/B1
- Sent-3 Optical NG: Phase A/B1



Technology Maturation

- Instrument maturation
  - as part of Mission Feasibility (above)
  - support to commended EE-11, Meteosat-4G, MetOp-3G
  - enable new EO concepts (low TRL)
  - miniaturisation
- Standard Platform + Communications
  - Enablers + reducing recurring costs / operations
- Other Preparatory : e.g. architectural / system studies

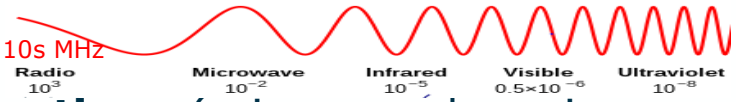
Science & Applications

- **BoostFutureEO**
  - Step-1: Living Planet Challenges (incl. ECV)
  - Step-2: New EO Mission Ideas (NEOMI)
  - Step-3/4 : Maturation - as part of Mission Feasibility
- End-to-End Simulation :
  - as part of Mission Feasibility
  - also enable new EO concepts (low SRL)
- Campaigns (in-situ, airborne)

EO Technologies and Techniques are complex / diverse

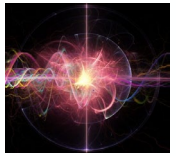
New + Higher performance Instruments - (hungry for more knowledge)

- **Higher** spatial, temporal, radiometric **resolution**
- **Full EM spectrum**



- Very **diverse observations** (science – observing geometry)

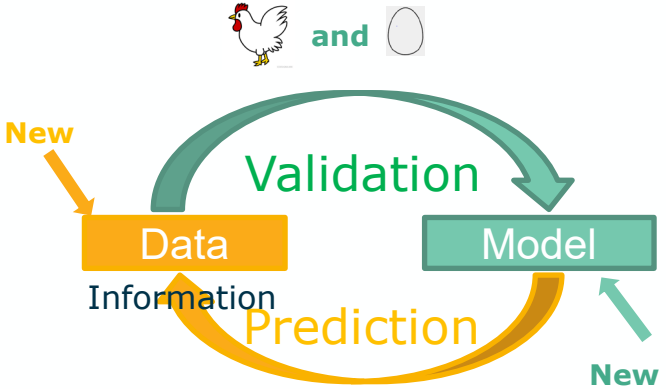
- Adopt **disruptive** : e.g. quantum sensing



EO Science & applications (EO Techniques) are complex

- data from >1 instrument → more models + data fusion
- well calibrated (incl. in-situ measurements)

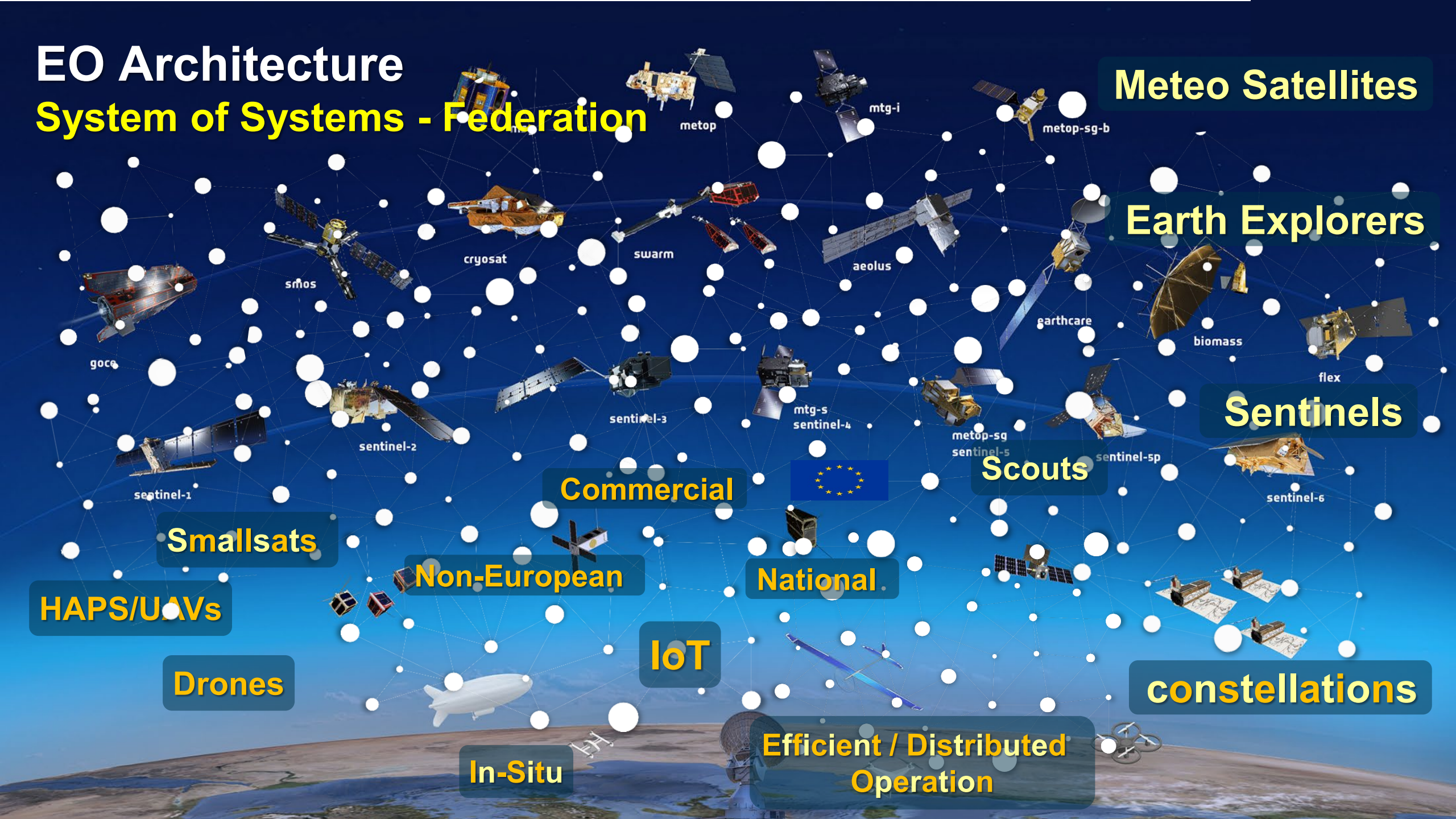
➔ Big Data **Analytics**



There is much more: Systems / Architecture

including Commercial / NewSpace , …

➔ need to focus


EO Architecture
System of Systems - Federation
Meteo Satellites
metop
mtg-i
metop-sg-b
Earth Explorers
cryosat
swarm
aeolus
smos
goce
earthcare
biomass
flex
Sentinels
sentinel-3
mtg-s
sentinel-4
metop-sg
sentinel-5
sentinel-5p
sentinel-2
sentinel-1
sentinel-6
Scouts
Commercial
Smallsats
Non-European
National
HAPS/UAVs
IoT
Drones
constellations
In-Situ
Efficient / Distributed
Operation

Example: Earth Explorer 11 – Mission Concepts

many more ideas than resources!

		Previous Calls	Title	RF - Optical	Instrument	Freq.	Preliminary Techno needs	Application
Recommended Ph.0/A/B1	WIVERN	EE-10	A 'WInd VElocity Radar Nephoscope'	RF	Conical scanning radar (3 m diam., 12 rpm)	94 GHz	- Rotating Antenna and free space Rotary joint - HPA: isolator, ferrite switch	Atmos Phys
	CAIRT	EE7 Premier EE10 CAIROS	The Changing-Atmosphere IR Tomography Explorer	Optical	Limb sounder FT	IR (4.5 to 14 um)	- Detector - ROIC - Fast FE Electronic - Dichroic optics - Back optics	Atmos comp
	SEASTAR	EE-8, EE-9, EE-10	Submesoscale dynamics and small-scale atmosphere-ocean processes in coastal, shelf and polar seas.	RF	InSAR	Ku band (13.5 GHz)	- Antenna radiators - Klystron HPA - COATS metrology sys	Ocean
	Nitrosat	EE-8, EE-9, EE-10	Mapping reactive nitrogen at the landscape scale	Optical	- Imaging FT (Hyper) Spectrometer (IFTS) - Imaging pushbroom spectrometer	- 900 - 1000 cm-1 for NH3 - 350 to 700 nm for NO2	- Imaging Motion compensation mirror - LWIR Detector	Atmos comp
Commended Maturation only	KEYSTONE	EE-9, EE-10 (as LOCUS)	Chemical and thermal structure of the upper atmosphere (50-250 km).	Optical	- THz heterodyne radiom. - IR radiometer - UV/VIS spectrometer (limb sounding)	0.8, …, 4.7 THz, 4.27 -15.2 um, UV/VIS (new)	- Quantum Cascade Laser - THz Schottky mixers	Atmos comp
	STREAM	Extended SKIM (EE-9)	Surface TRansport, ocean Energy, Air-sea fluxes and Mixing	RF /Optical	- STREAM-R: connical scan Ka radar (3 m diam., >25 rpm) -STREAM-O hi-res Optical	-Ka band (37.75 GHz) ~ as S2	- OB processing - Rotating antenna - LNA - STREAM-O: µ-vibrations, pointing knowled	Ocean
	CRYORAD	EE-10	Low freq. wideband radiometer - study of the cryosphere	RF	nadir Ultra Wideband spectro-radiometer (12 m antenna)	- 0.4 to 2 GHz (RFI critical)	- Digital Beamforming - RFI detection & mitigation - LNA - Large Deployable Reflector - Ultra Wideband feed	Cryosphere
	STRATUS	EE9, EE-10	SaTellite RAdar sounder for earTh sUbsurface Sensing (1 sat Tx + 4 sats Rx)	RF	Sounder	- VHF (40-50 MHz)	- High Power Amplifier - Matching network & antenna - Formation Ctrl techno	Cryosphere

Also positive feedback by ACEO for others: e.g. SnowCube, 2 Lidars (QSAT, ATLAS), N8, Scadi, Min2OS

ESA TECHNOLOGY AND ENGINEERING TARGETS

30%

IMPROVEMENT OF SPACECRAFT **DEVELOPMENT TIME** BY 2023

10X

ONE ORDER OF MAGNITUDE BETTER **COST EFFICIENCY** WITH EVERY GENERATION

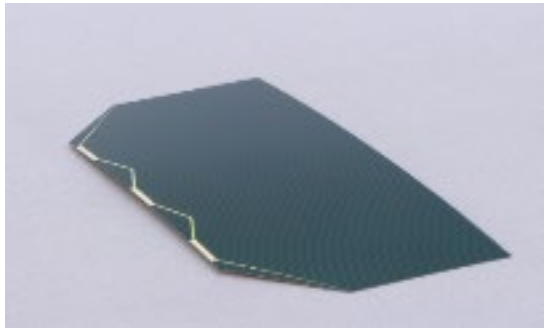
30%

FASTER DEVELOPMENT & **ADOPTION** OF INNOVATIVE TECHNOLOGY

2030

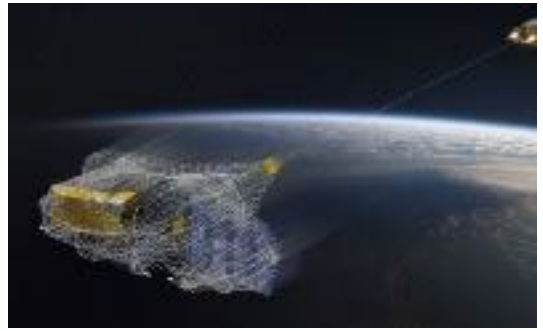
TARGET FOR INVERTING EUROPE'S CONTRIBUTION TO **SPACE DEBRIS**

3D visualisation system at ESA's Concurrent Design Facility (©ESA)



Unprecedented 30% more-efficient spacecraft solar cell (©Azur Space)

Martian meteorite on Earth calibrates camera bound for Mars (©ESA)

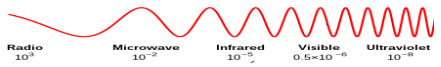


ESA's e.Deorbit mission is developing robotic arms and nets to capture Envisat (©ESA)

EO Technology needs – aligned with ESA Technology strategy

Higher performance / cost ratio

Largest part

- **New Measurements/ EO instruments** (enabler)
  - **Higher spatial, temporal, radiometric** resolution
  - **Full spectrum** – RF - Optical 

  - Disruptive: e.g. from the "2nd Quantum Revolution" 

Generic

- Lower recurring **development cost / faster adoption**
  - **Platform Standardisation**
  - **Spin-in** techno: e.g. COTS
  - Lifetime & flexibility (FPGAs)
  - Digitalisation (e.g. MBSE)
- **CleanSpace (e.g. demisable)**
- **Big Data & Analytics** (AI enabler) & Data continuity

Miniaturisation and constellations

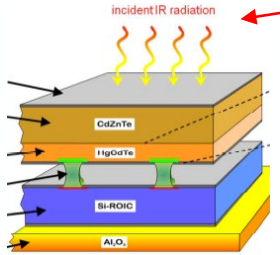
- More **autonomous** platform & operations & synchronisation
- **Distributed** Ground Segment

Not limited to LEO: also HEO & GEO orbits relevant for EO

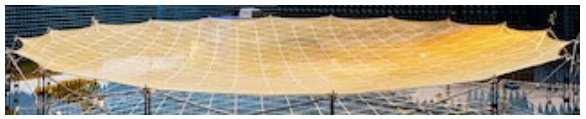
EOP technology (across and beyond ESA missions)

Instruments (Optical + RF) from components to full models) - the largest investment

Detectors
→ SWIR for CO2M
→ TIR for LSTM
→ Hyperspectral for CHIME
→ Others



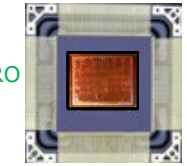
Large Deployable Antenna
→ Designed for CIMR, ROSE-L, Hydroterra, S1NG
→ Candidate for National/Commercial



FULAS (Laser source)
→ Candidate for Aeolus-FO
→ Baseline for **Merlin (CNES, DLR)**

Platform & Space-Ground Communications

AGGA ASIC
GPS/Galileo receiv.
all Sentinels, MetOp-SG RO
Earth Expl.,
many commercial



MiniRIT e-propulsion
→ **candidate for NGGM commercial**

ADHA & Std P/F
→ Increased modularity & interchangeability
→ **All future EO missions**

K-band downlink
MetOp-SG, HPCM,
→ commercial

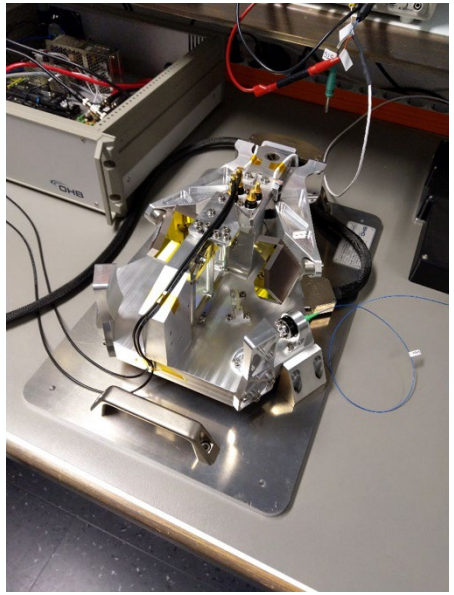
DataFlow–Ground I/F
Sentinel-NG, Constellations

Also Airborne Campaigns
- Aeolus collocations
- ACADIA for CO2M
- OSCAR – Ku-band (SEASTAR)

and Big Data Analytics
- Acquisition / Organization / Analysis / Infor.
- Φ-lab

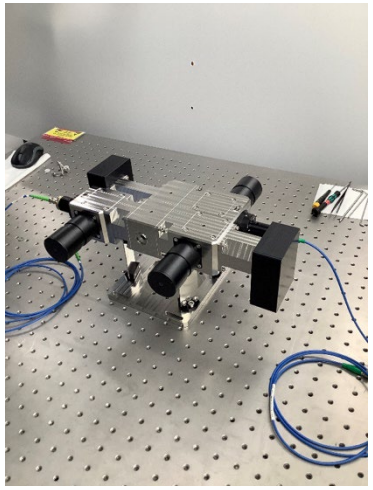
Some achievements: Optical Instrument Maturation

- Examples of key enabling activities:

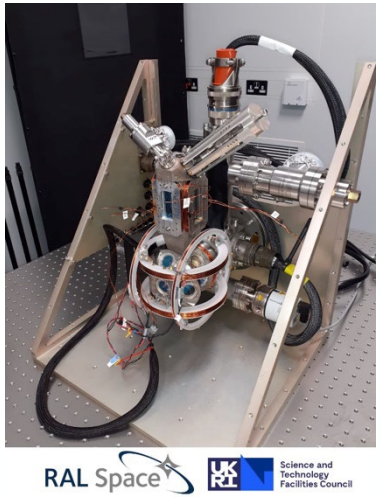


FORUM Interferometer breadboard (courtesy OHB-DE)

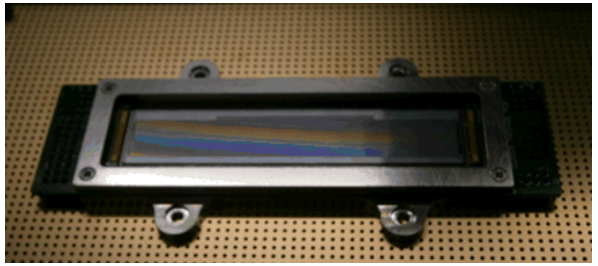
FORUM Blackbody sample (courtesy MICOS-CH)



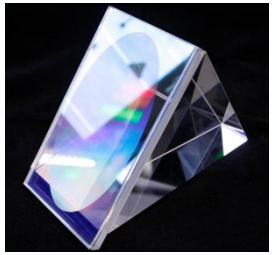
NGGM off-axis retroreflector concept optical bench breadboard (courtesy STI-DE)



Compact vacuum Chamber for CAI Gravity gradiometer



FLEX back-illuminated CCD (courtesy T-e2v-UK)



Carbonsat EE-7 grating (backup for **CO2M**) (courtesy IOF-DE)

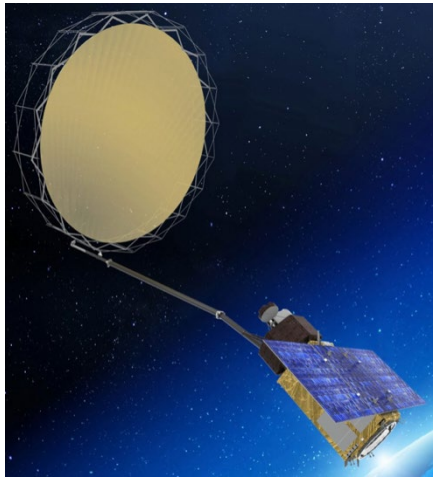
Some achievements: Microwave Instrument Maturation

- Key enabler for CIMR mission, relying on technology from H2020 actions
- Maturation of 7.4 m diam. Copernicus CIMR EM Large Deployable Reflector

(Biomass had to rely on a non-European solution)

LDR deployment (courtesy HPS-DE)

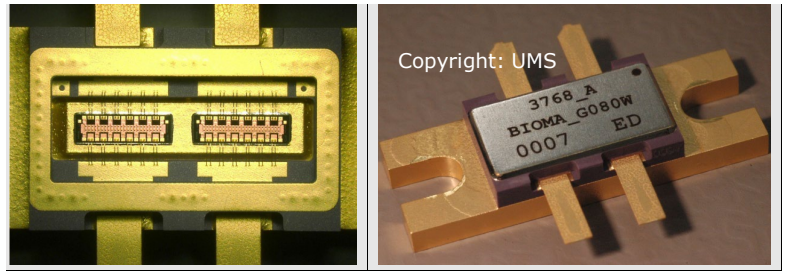
Antenna boom deployed (courtesy HPS-DE)



Artist view CIMR

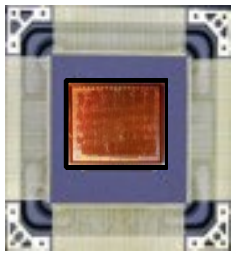
Videos at https://phi.esa.int/automatic-unfurling-of-european-large-deployable-reflector-successfully-demonstrated/

GNSS-RO MetOp-SG & going Commercial
(courtesy Beyond Gravity- SE)



GaN 80 W power transistor for BIOMASS
(P-band) (courtesy UMS-DE)

Some achievements:
Platform and space-to-ground communication technologies



AGGA-4 ASIC

GPS/Galileo receiver
all Sentinels, MetOp-SG RO
most Earth Explorers,
also **Commercial** applications
(courtesy ADS and Microchip-FR)

Next Gen: O/B reprogrammable FPGAs

MiniRIT e-propulsion enabler

→candidate for **NGGM-MAGIC**
(courtesy Mars Space-UK)
→ **commercial**

ADHA & Standard P/F

→ Adv. Data Handling Archit (ADHA)
→ Increased modularity &
interchangeability
(for **Sent.-NG & commercial**)

K-band downlink

~ up to **12 Gbit/s**
MetOp-SG, 4 HPCMs,
→ Also **commercial** application
(courtesy Kongsberg-NO)

Data Flow & Ground I/F

→ scaling to constellations
→ Ground I/F and protocols
→ **Sent.-HPCM, Sent-NG**, + **commercial**

(new CleanSpace regulations coming)

- Multi-mission purpose (also beyond ESA missions) - synergetic
  - Funded under **TDE** + **GSTP** + **FutureEO** (only **Optional Programs** can **compensate** the TDE effective-budget decrease – while ESA-wide Projects doubled these years)
  - **FutureEO** Programme **flexibility** – brings EO focus (also when co-funded with GSTP)

LEGEND
TDE = Technology Development Program , part of Mandatory Budgets
(former name was TRP) – up to TRL=4

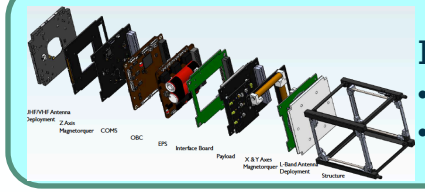
ADHA: Advanced Data Handling Architecture

Objectives:

- Reduce cost in recurring platform
- Reduce development & adoption time

Status :

- 2021-2024: Develop + integrate (multi-source) modules – EM (TRL=6)
- **Co-funded FutureEO + DPTDE (Corporate) – 2 parallel studies running**

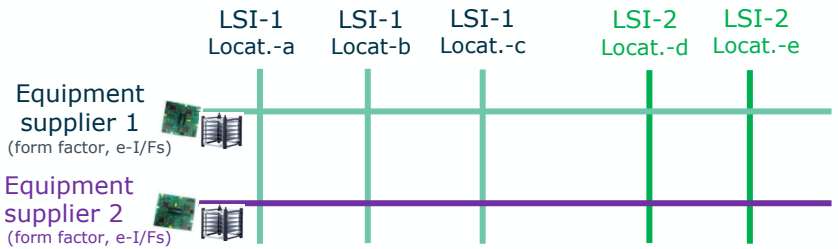


Inspirational **Cubesats**

- Standard Interfaces
- COTS enabler

STEPS TO ENABLE IT :

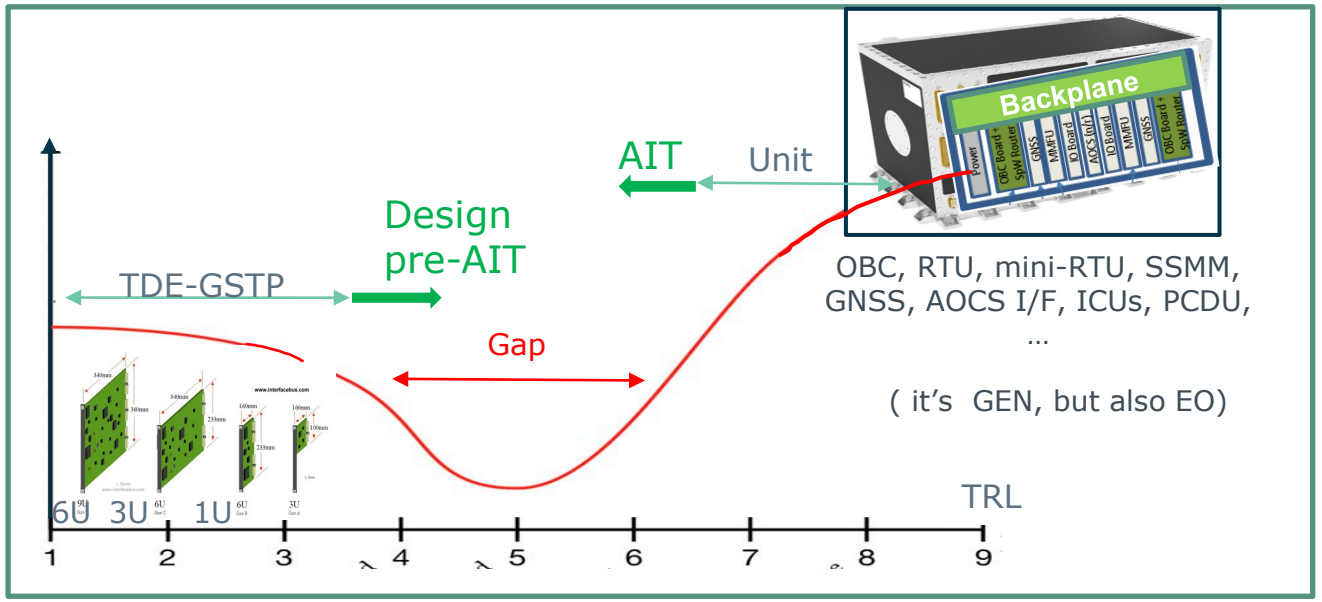
- Common Requirements – by LSIs and ESA
- Standardisation - by ESA and Industry
- Development of Units with interchangeable modules



What to standardize ?

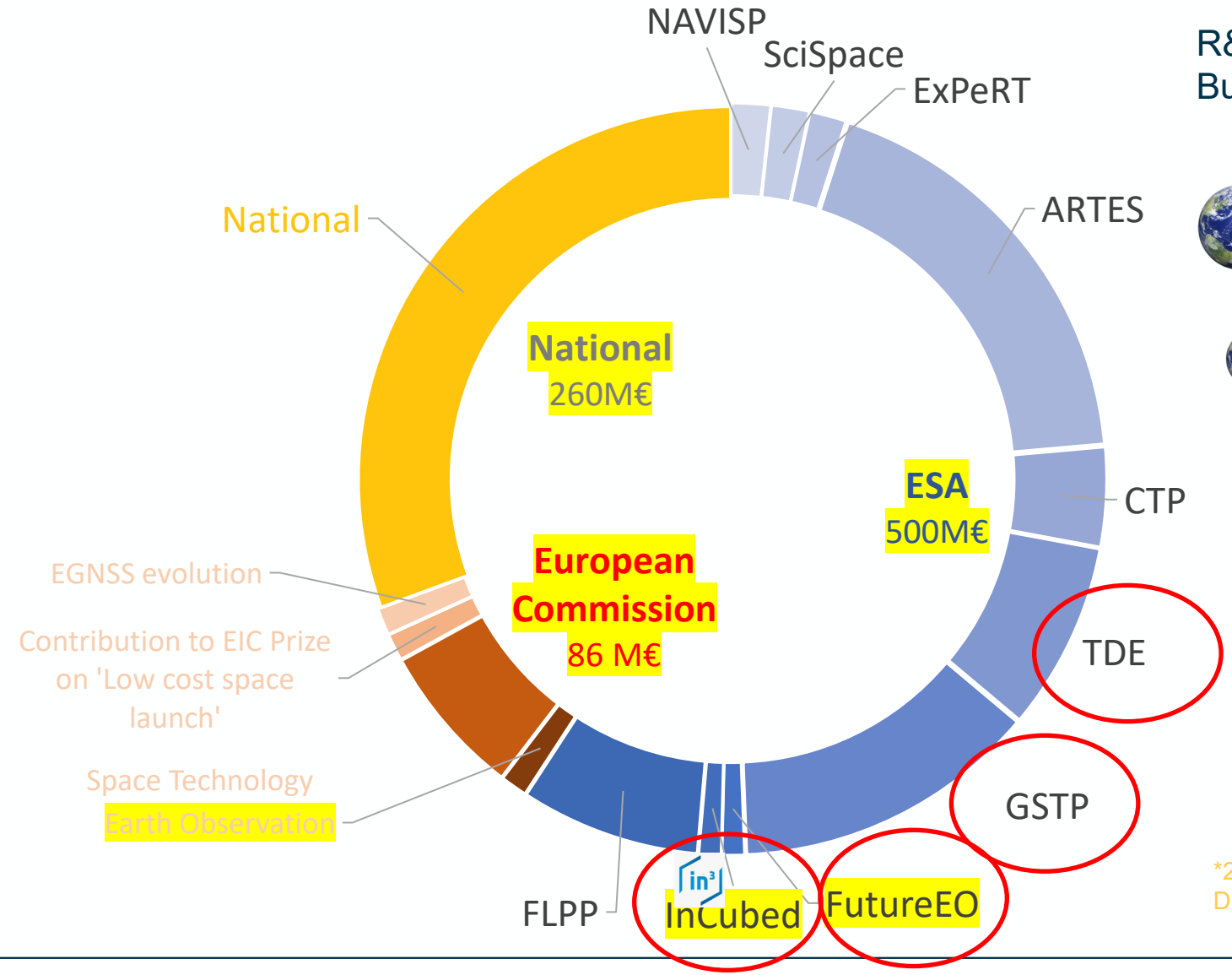
- **Interfaces: Electrical, mechanical**, thermal, … incl. backplane
- **AIT approach (modules** & **units**)

➔ Minimise the Death Valley gap



EUROPEAN SPACE TECHNOLOGY BUDGETS (2020)

(ref. ESTMP 2021)



R&D activities for space technologies in Europe
Budget nearly **850 M€** in 2020

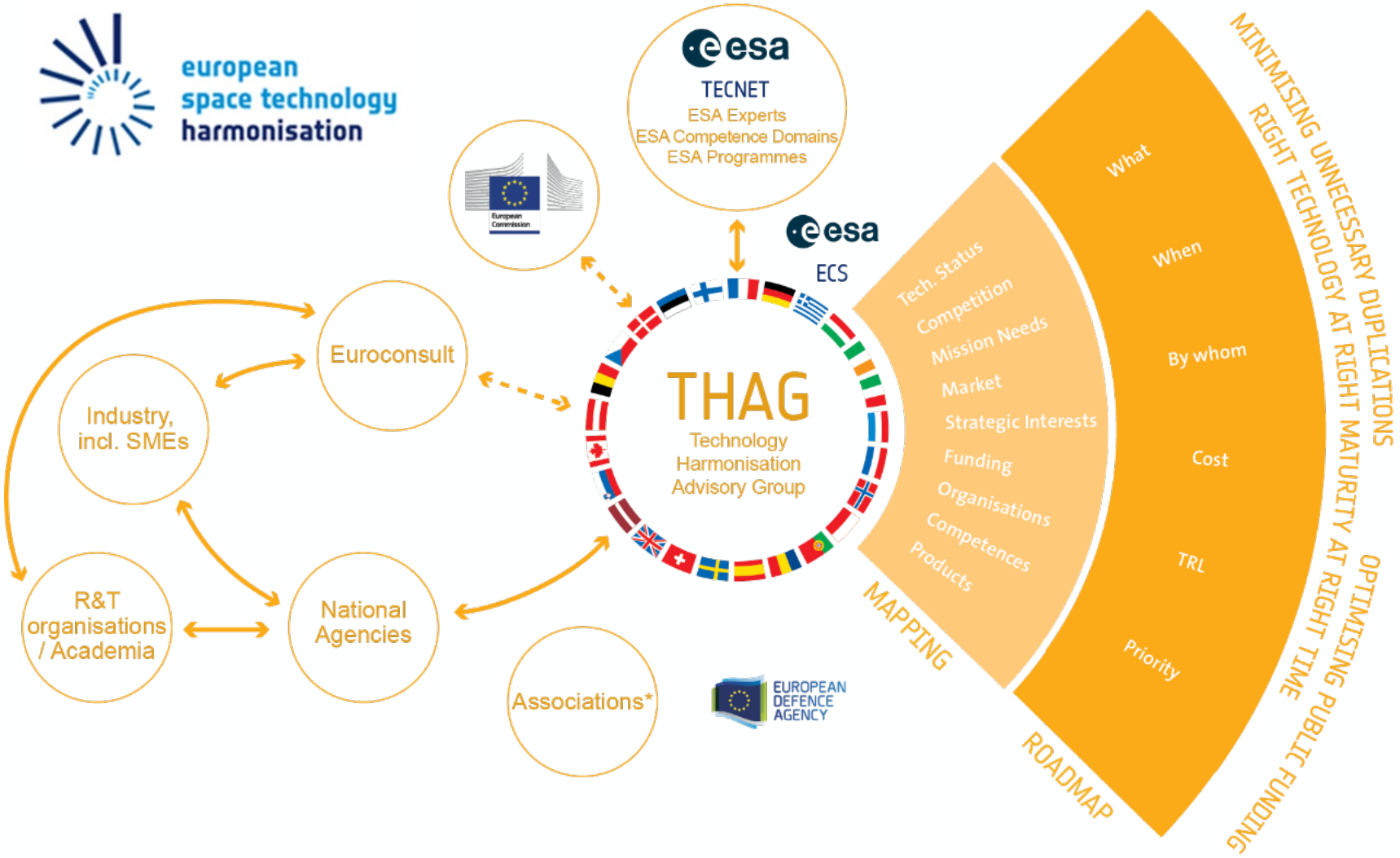
- **FutureEO** – Future EO Programme, Development and Exploitation Components
- **InCubed** – Investing in Industrial Innovation

- **TDE** - Technology Development Element
- **GSTP** - General Support Technology Programme

- **CTP** - Science
- **ARTES** – Telecom
- **SciSpacE** – Space Environment
- **ExPeRT** – Exploration
- **NAVISP** – Navigation
- **FLPP** - Launchers

*2020 budget estimation provided by the following countries: CA, CZ, FI, FR, DE, HU, IT, NL, NO, PT, SI, ES, SE, CH

HARMONISATION: ESA (not just EO) level



→ Over 2 decades of operation

→ 52 active roadmaps

→ 10 technology topics / year

→ Extensive consultation process (31 countries, ESA-EC-EDA)

Contact for copies: **ESTMP@esa.int**

*Eurospace, SME4Space, ESRE, EARTO, etc..

Technology Sessions in LPS – for the 1st time

ID	Session Title	Theme	Nb. Sessions	Day	Time	Room
B9.07	Technologies in National Agencies for EO	Space Techno	1	Mon	13:30	H1.01
B9.04	Platform and Communications technology for future EO	Space Techno	1	Mon	15:40	H1-01
B9.02	New Mission Concepts	Not selected missions	2	Tue	08:30	H1-01
B9.06	AI@edge and Emerging Computing Paradigms for the Future of EO	Space Techno	1	Tue	10:40	Garden Room
B9.05	Microwave Instrument Technology for EO	Space Techno	1	Tue	13:30	H1-01
B9.03	Optical Instrument Technology for EO	Space Techno	1	Tue	15:40	H1-01
B7.04	CubeSats at NASA	NewSpace	1	3-Wed.	10:40	H2-02
B7.03	New Space missions with small and nanosatellites	NewSpace	2	4-Thu	13:30	H2-02
B7.05	GNSS RO – GNSS-R	NewSpace	1	5-Fri	08:30	Berlin
E1.05	New Space missions in InCubed	NewSpace	1	5-Fri	10:40	Berlin

C3	Emerging EO Technology in ESA and fostering European non-dependency		Agora	Wed.	12:30

Takes away

EOP Technology needs (incl. sovereignty)

- New + higher performance (EO instruments)
- Higher efficiency (incl. platform / operations)

Market pull (User driven: EE, Copernicus, Meteo) **+** **Techno push** (enabler for new **Mission Calls**)

- **focus** on the best : **competitive** processes **+ keep innovating**

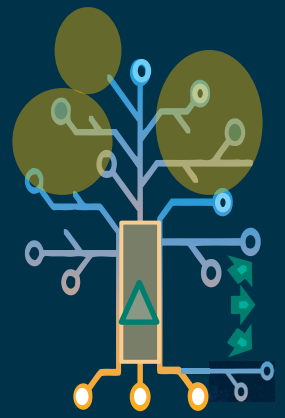
Driven by **institutional** (**Large Satellites**),
but opening to **constellations** (incl. **small sats**)  → **EO Architecture**

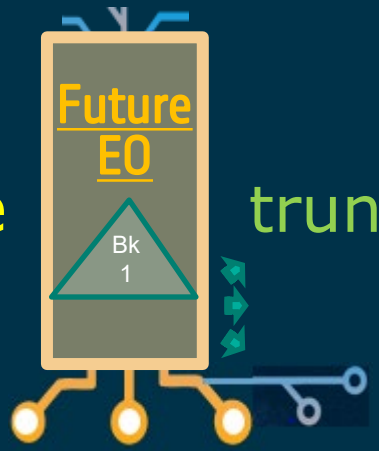
FutureEO Programme

- Unique **synergizer** to build the EO ecosystem
- **Enabler** / entry to the **whole range of ESA EO missions**
- Knowledge hunger → more ideas than resources

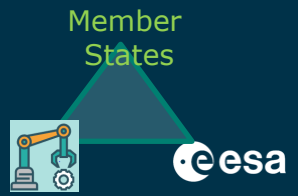
→ competitiveness and beyond

GSTP
National
Cassini
EUMETSAT
Private initiatives

The EO  tree is strong (and sustainable)

if the 

trunk +roots are strong (in CMIN22 subscription)



Agora Discussion

- Technology R&D : what is more challenging (time or resources) ?
  - What can we do to reduce development time – adoption **time** ?

- More ideas than **funding** (EO technology is complex)
  - How can we **focus** regarding technology ?
  - Non-dependency & and multiple players (ESA, EC, EDA, MS, …)

  → views on technology coordination ?

- When to be market pull (user driven) - when to be technology-push ?
  - Consider low and high TRLs

- EO-NewSpace : what technology / processes do you need from institutional (ESA) ?
  - just opportunistic, or more ?