IOT FOR EARTH OBSERVATION USES CASES

INCL. ZOOM INTO VHR CONSTELLATION

IOT4EO STUDY TEAM

16/17 FEBRUARY 2023

IOT4EO STUDY

GOALS AND PARTNERS

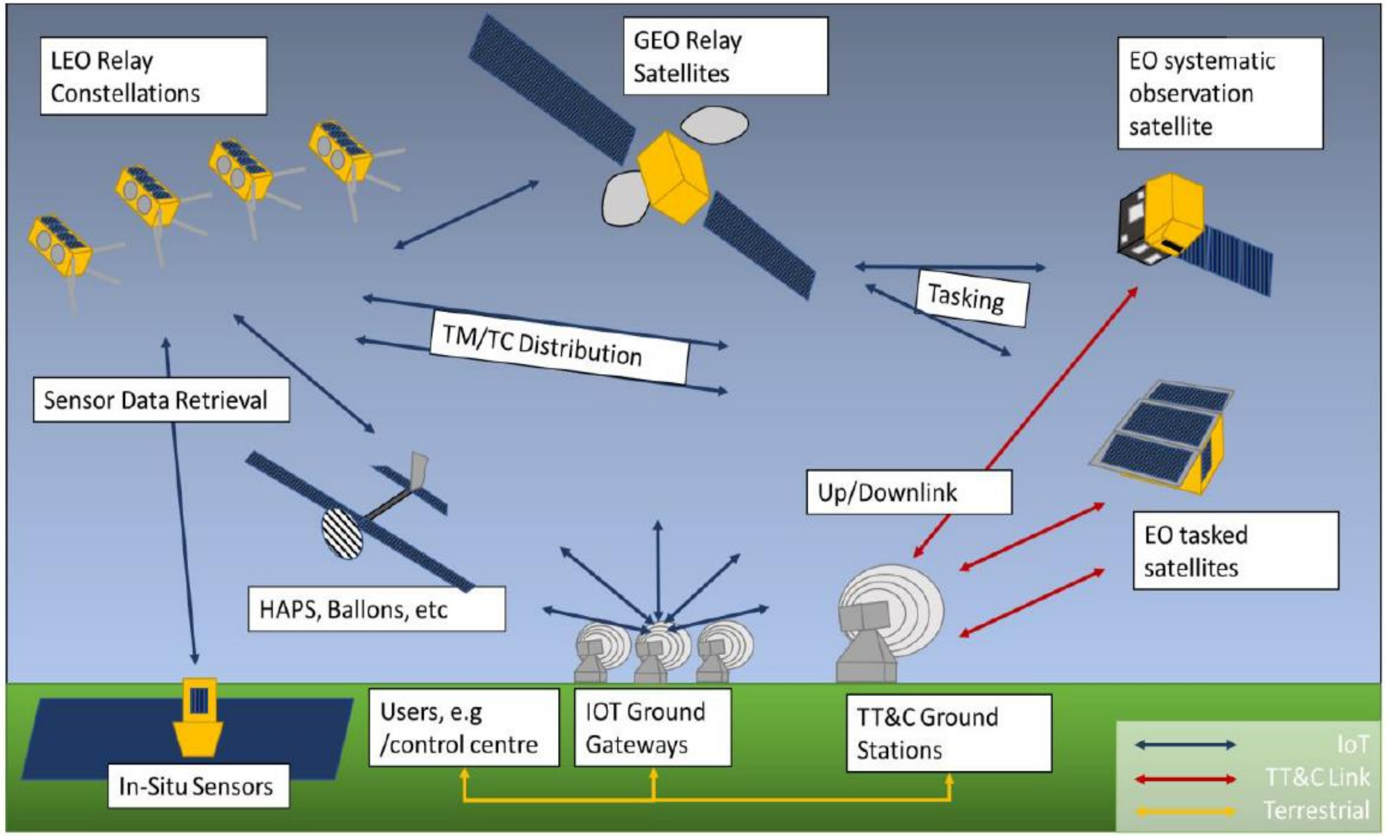
- To exploit the IoT seamless integrated networks with **near instant connectivity** to derive new and promising applications for Earth Observation (EO) satellite systems
- IoT nodes on-ground can be **in-situ sensors**, EO sensors on buoys, aboard aircrafts or HAPS and IoT Gateways
- IoT nodes in space are EO satellites, limited to LEO orbit in this study, and relay satellites in LEO, MEO and GEO
- IoT seamless communication entails simplified and low power communications systems and hence, **low data rates**
- EO systems can thus exploit the IoT network to send and receive urgent information, rather than as means for science data downlink and reduced latency
- IoT for Earth Observation can exploit the following four **AI** on-board autonomy enablers:
  - Data processing
  - Decision making
  - Satellite cooperation
  - RF spectrum management

Industrial Team

STUDY INTRODUCTION AND UNDERSTANDING

IOT SEAMLESS NETWORK

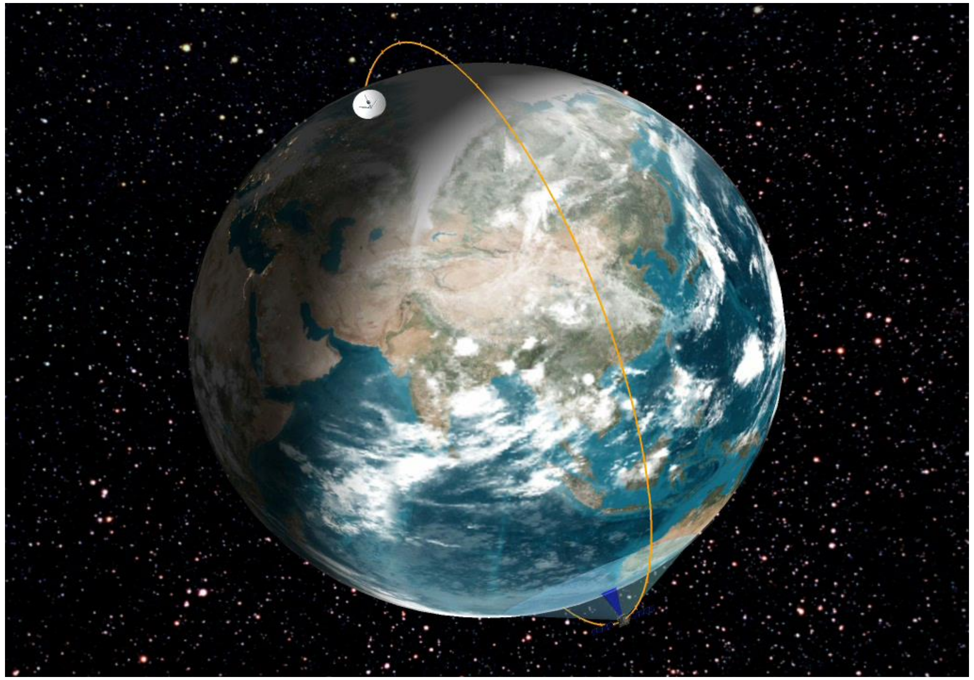
- The first examples that arise are the fast delivery of **telemetry and telecommands** in case of anomalies, but also, a wide range of new end-user applications
- With on-board processing and **events detection** aboard the EO satellites, the IoT network could be exploited for providing end-users with key extracted information such as warnings and alarms, the location and velocity of a target, or even the **triggering of an IoT actuator.**
- In the definition of the EO use cases, two scenarios shall be considered:
  - <u>**3 years scenario**</u>: EO use cases that can be implemented with commercial IoT services that will be available in the next 3 years, with **minor changes** on technologies, standards and international radio regulation
  - <u>**7 years scenario**</u>: a more advanced and ideal case with technologies, services and **standards** that will be deployed in 7 years.



EO SATELLITE – PRESENT AND FUTURE

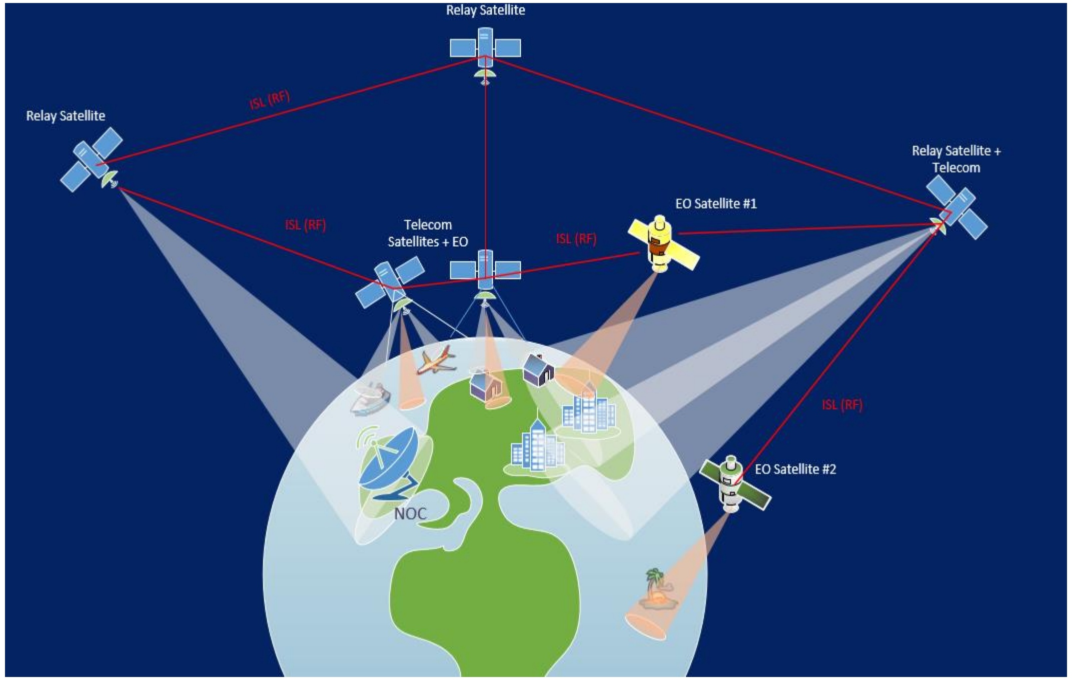
MOTIVATION FOR NEW SOLUTIONS

Current Configuration – EO satellite links



- Limited contact time
- EO Satellite working standalone
- Ad-hoc communication protocols
- High latency in transferring data
- Fixed time slots for acquisition

Future EO Satellite - Integrated Network

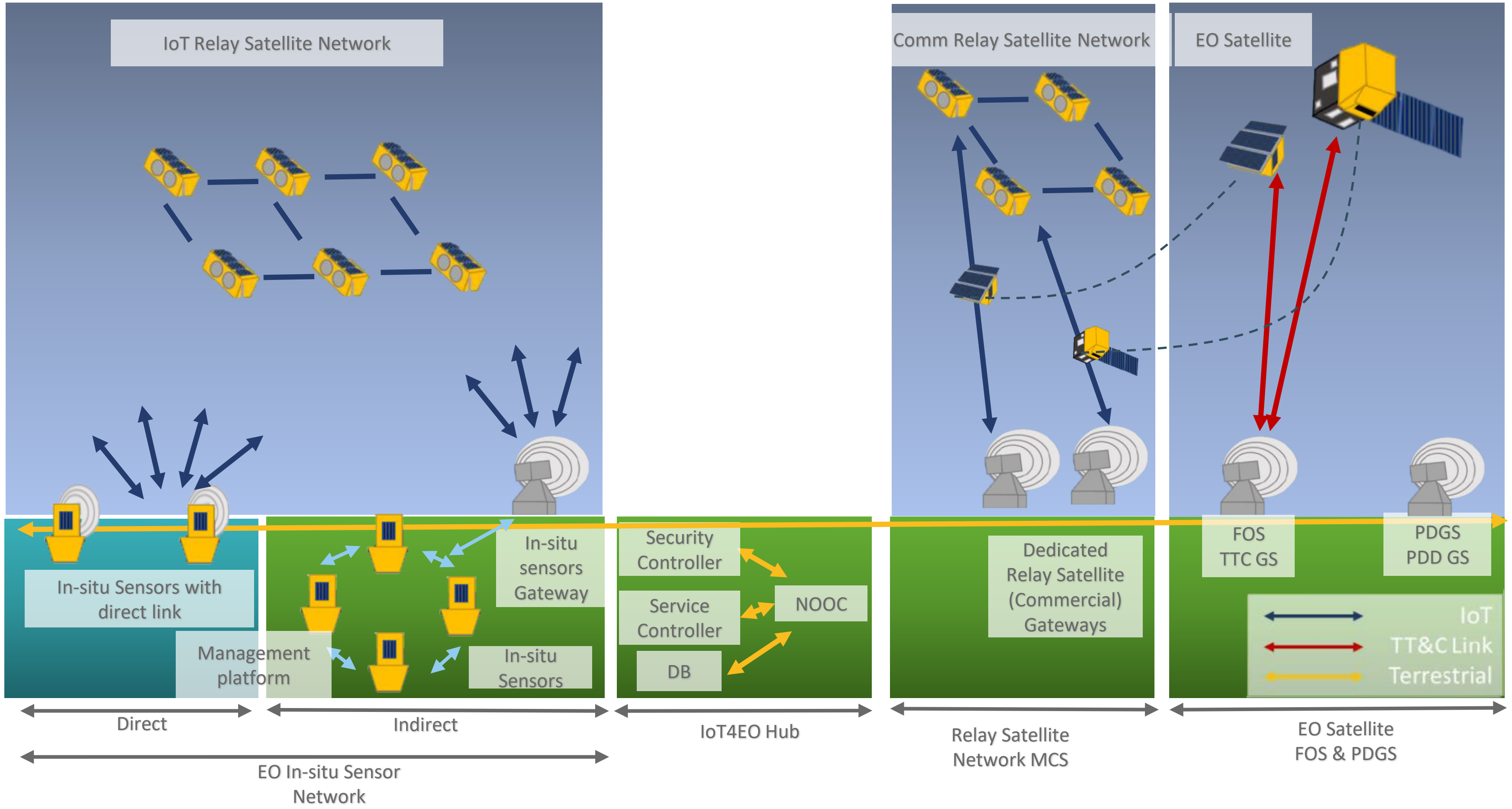


- EO satellite interconnected with other satellites
- Protocol /Frequencies/ to be standardized
- Low latency in transferring data
- „Near real-time" acquisition time
- Seamless network connectivity

IOT4EO NETWORK ARCHITECTURE

STANDARDIZATION AND INTERCONNECTION (NETWORK OF SYSTEM)

- **3 years scenario**
  - **Specific** ISL transponder to be installed in new EO Satellites
  - IoT Provider connected to Service Manager (NOOC) (on ground)
  - NOOC as proxy between IoT provider and EO control center
  - Relying on specific IoT service provider(s) (waveform and frequency)
  - Limited availability of connectivity with other satellites



NOOC = Network Orchestration Center
FOS = Flight Operations Segment
PDGS = Payload Data Ground Segment
GS = Ground Segment

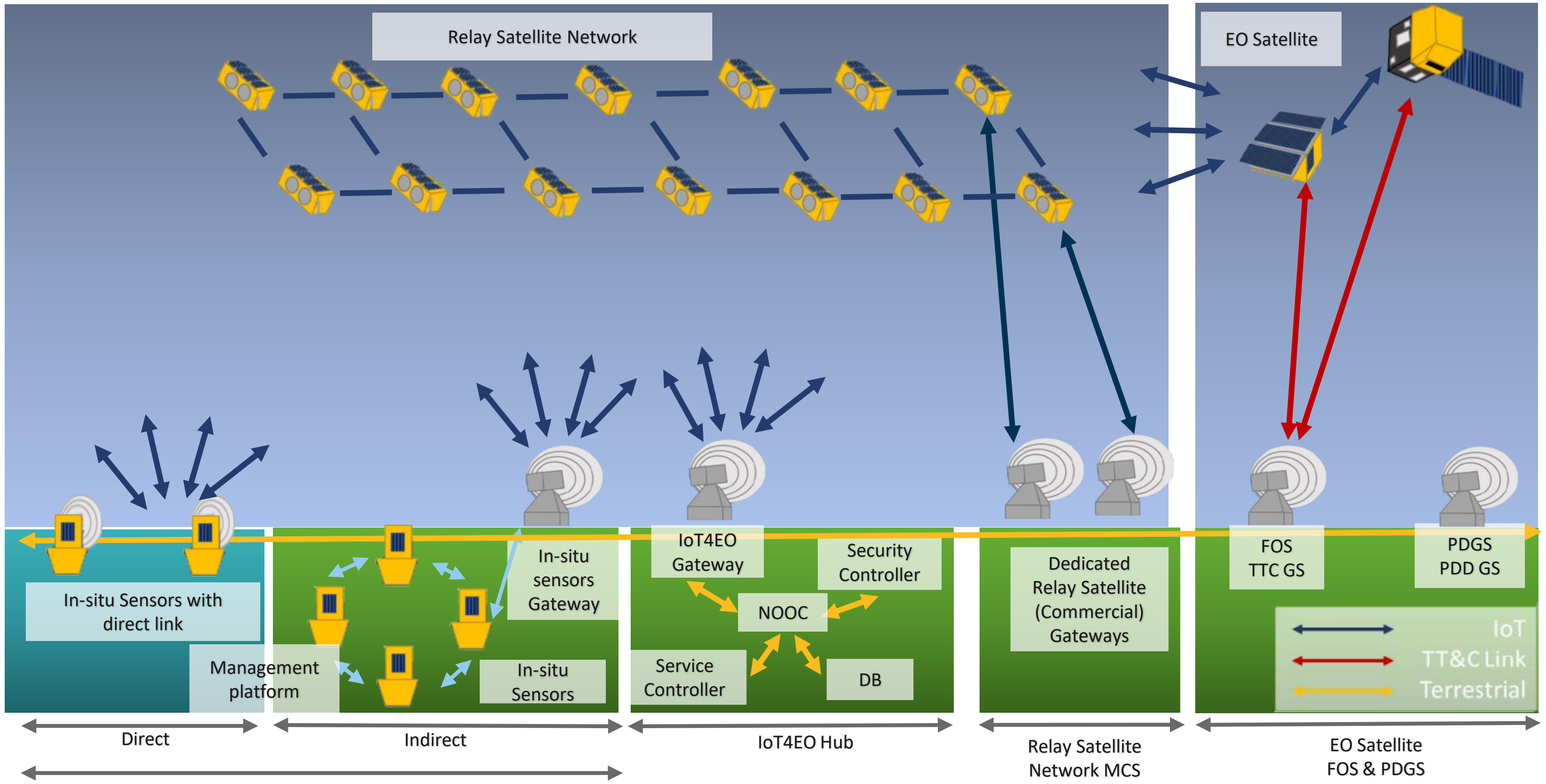
TTC = Telemetry and Telecommand
PDD = Payload Data

IOT4EO NETWORK ARCHITECTURE

STANDARDIZATION AND INTERCONNECTION (NETWORK OF SYSTEM)

- **7 years scenario**
  - a standardization is expected to be finalized, agreement about a standardized waveform and frequency selection
  - Connectivity to all future standardized satellites allowing EO – ISL
  - Service Manager directly interfacing either any standardized satellite or directly to the EO satellites

- **Development of dedicated standard transponders with low SWaP to be embarked in each EO satellite**
- **Standardization of IoT and data transfer protocols (Ground to Space and Space to Space)**
- **Definition of available spectrum and frequency selection**



NOOC = Network Orchestration Center
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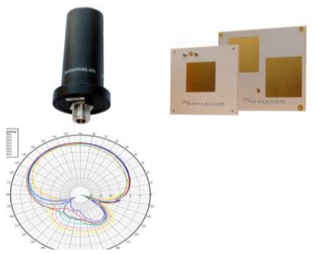
USE CASES – FIRST ITERATION

CURRENT TRADES

- Development of dedicated standard transponders with low SWaP to be embarked in each EO satellite



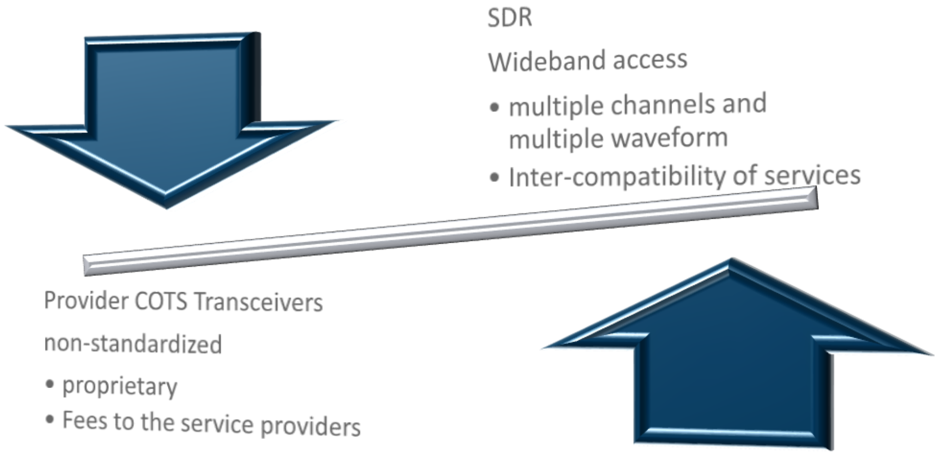
Iridium and Globalstar transceivers / Iridium and IQ Spacecom S-Band Antennas

- Definition of available spectrum and frequency selection (First iteration)

Use case #1 (3 years)	Use case #1 (7 years)	Use case #2 (3 years)	Use case #2 (7 years)
• 137-138 MHz • 1610-1675 MHz • 1980-2025 MHz • ISL: 22-24 GHz (TBC)	• UHF (400 MHz), • S-Band (2 GHz) • ISL: S-band, Ka band	• As per UC#1 • ISM bands at 2.4 GHz	• As per UC#1 • ISM bands at 2.4 GHz

- Standardization of IoT and Data Transfer protocols (GND↔Space and Space↔ Space)
- Definition of Link Budgets and Simulations

- **For the 3 years scenario**



- **For the 7 years scenario**
  - SDR solution
  - Standardized waveform and frequency
  - Dual pointing antenna (also to ground)

USE CASES – TRADE OFF

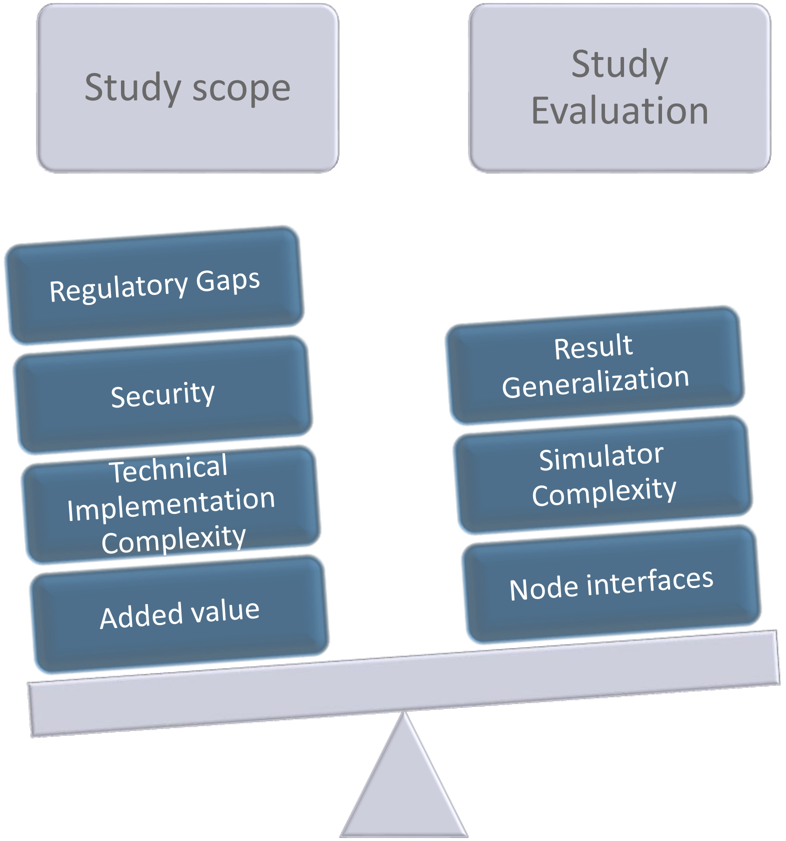
DOWN-SELECTION BASED ON CRITERIA

11 Use Cases considered

Down-selection of two uses cases together with ESA

- #1: Distribution of telecommands to EO sat (including reception of telemetry for acknowledgement)
- #2: Collecting data from in-situ EO ground sensor or beacon

- **Trade-off criteria**



SHOWCASE SETUP OF USE CASE #1

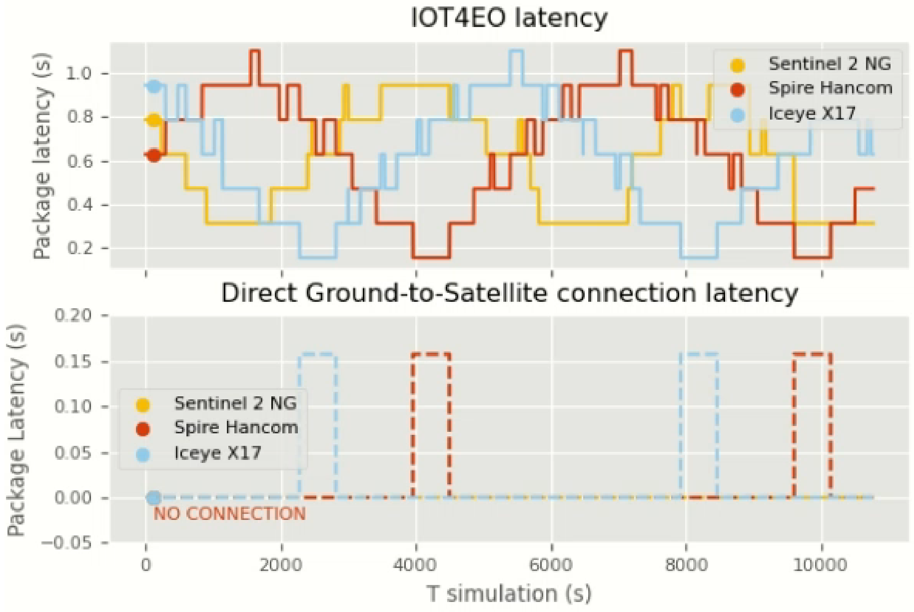
KEY ASSUMPTIONS

- 7 years scenario
  - Standardized IoT4EO network where EO Satellites, Relay Satellites and Ground nodes can all communicate between them
- Iot4EO use case
  - FOS sends 6 KBytes TC to EO Satellite via IoT4EO network
    - Sentinel-2 NG
    - Iceye
    - Spire
  - IoT4EO network with
    - LEO relay satellites (Iridium constellation)
    - GEO relay satellites (Inmarsat)
- NBIoT Protocol, with 105 kpbs data rate capability
  - LEO – LEO
  - LEO – GEO
  - LEO – Ground

Object	Properties in simulation
FOS Ground Station	Kiruna Ground Station
GEO Relay Constellation	Inmarsat 4-F1, 4-F2 and 4-F3
LEO Relay Constellation	66 Satellites Delta constellation 6 orbit planes 785km at 90° inclination Inter and intra plane ISL
EO Sentinel 2 NG	SSO 631km at 10:30 LTDN
EO Spire	SSO 500km
EO Iceye	SSO 500km

SEND TELECOMMANDS VIA IOT4EO NETWORK

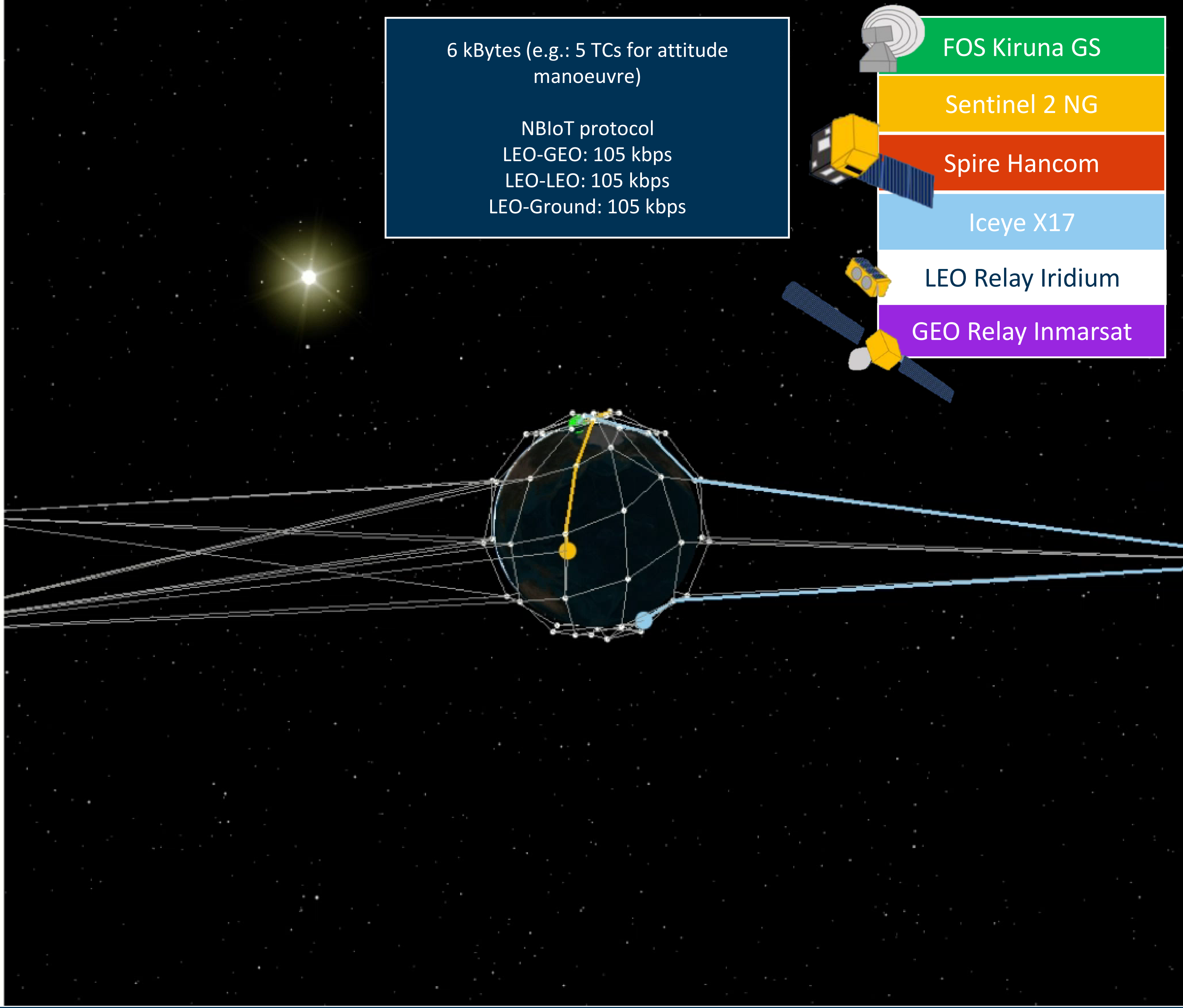
7 YEARS SCENARIO



- **Communication availability with EO satellite >99%**
- **Intersatellite Link (ISL) between different satellites/constellations**

6 kBytes (e.g.: 5 TCs for attitude manoeuvre)

NBIoT protocol
LEO-GEO: 105 kbps
LEO-LEO: 105 kbps
LEO-Ground: 105 kbps



VHR CONSTELLATION STUDY

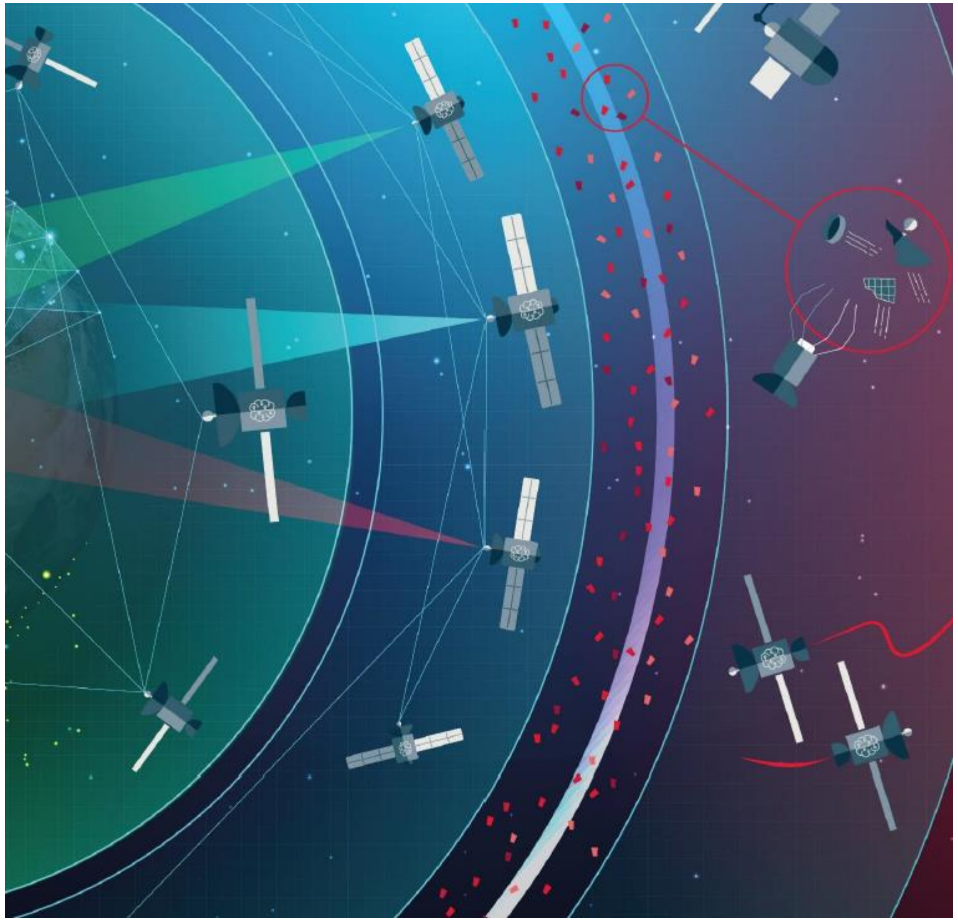
VHR CONSTELLATION STUDY

GOALS AND PARTNERS

HiREMS
HIGH RESOLUTION
EARTH MONITORING SYSTEM

OHB

- Define potential VHR constellation system architecture concepts meeting the observation needs
  - For the global mapping component
  - For the on demand and rapid response component
- The system should complement the current and evolving Copernicus data set and support downstream services
- The system should complement Sentinel-2 NG
- The system should provide non-systematic sub-metric image acquisitions in a rapid response and agile manner
- The activity is not only covering technical aspects but also programmatic, business and legal related aspects (e.g. PPP schemes)
- Maximum reuse of European technologies and heritage



MAIN MISSION REQUIREMENTS

TWO MISSION TYPES

- **Constellation A** – Systematic Carpet Mapping
  - RGB + PAN
  - GSD (Goal): 2 m; PAN: 1 m
  - Effective coverage: cloud free acquisitions
    - Images with max. 10% cloud coverage
  - Map of global landmasses + coastlines: 60 days
  - Co-registration with S2-NG
  - Coverage Europe: tbd

Large constellation of High Resolution microsatellites

- **Constellation B** – Agile Targeted VHR Image Acquisition
  - RGB + PAN + Video
  - GSD (Goal): 0.6 m; PAN 0.3 m; Video 0.5 m
  - Video duration: 1,5 – 2 min
  - Maximum access time: < 3 hrs (Goal) - 24 hrs (Threshold)
  - Coverage requirement: 100.000 km² per day
  - Geolocation accuracy < 1 SSD with GCP

Small constellation of Very High Resolution satellites

MAIN MISSION REQUIREMENTS

VIDEO REQUIREMENTS FROM EC/SECURITY DOMAIN

HiREMS
HIGH RESOLUTION
EARTH MONITORING SYSTEM

OHB

- **EMSA** use cases
  - Support to search and rescue
  - Monitor ship transfer
  - Monitor dark/suspicious vessels
  - Monitor sensitive areas of interest, where there shouldn't be vessels
  - Monitor small vessels that don't reflect on SAR and that are fast

EMSA European Maritime Safety Agency

- **SATCEN**, use cases
  - Evacuation plans
  - Critical infrastructure (e.g. analyse if an activity is ongoing on a critical infrastructure)
  - Smuggling
  - Monitor migration
  - Moving vehicles, people, ships

EUROPEAN UNION SATELLITE CENTRE SatCen Analysis for decision making

- **FRONTEX**, use cases
  - Maritime: Detection of moving vessels, small speed boats
  - Terrestrial: trans-border movements; movements close to borders

FRONTEX

VIDEO REQUIREMENTS FROM EC:

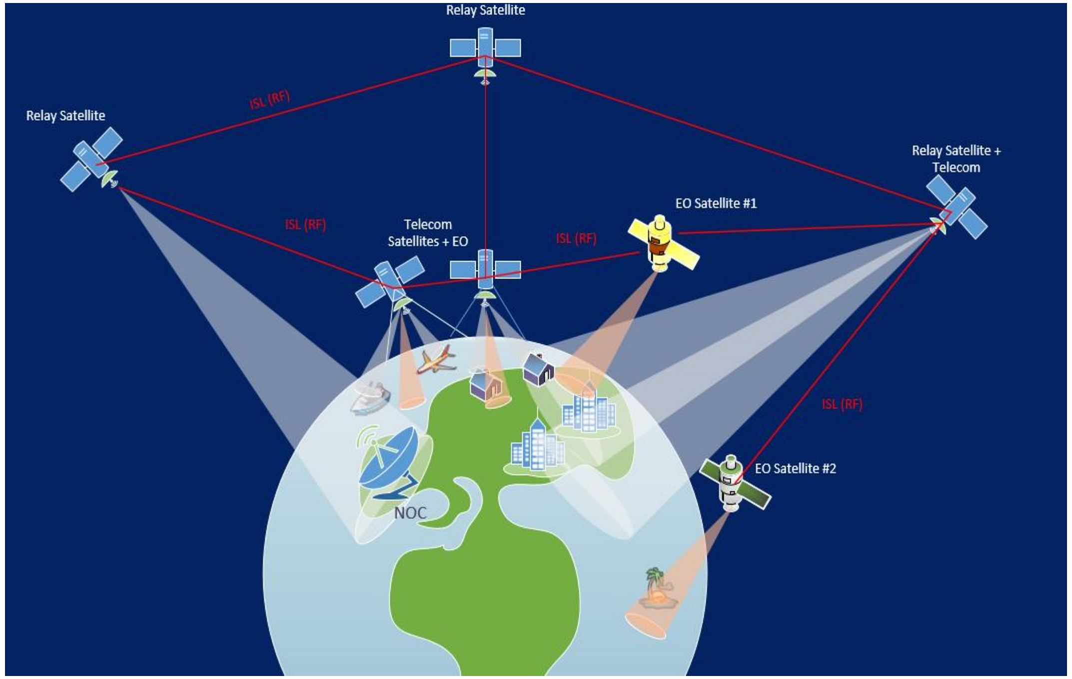
- **Video duration:** from 20 seconds to 2 minutes
- **Required resolution:** less than 1 meter (ideally less than or equal to 0.5 m)
- **Frame rate:** larger than 5 (ideally in the range 15-30 fps)
- **Frequency:** on-demand, with the possibility of more than 1 capture per day
- **Latency (from sensing to product availability):** < 15 minutes
- **Tasking Lead Time (from User request to sensing):** < 2 hours
- **Revisit time:** < 2 hours

ADVANTAGES IN THE AVAILABILITY OF AN IOT4EO SYSTEM

SOME EXAMPLES

- Achieving low system latency by faster distribution of tasking commands
- IoT sensors on ground automatically trigger imaging modes (e.g. calibration)
- Triggering of other satellites to acquire new observations in specific areas (-> interoperability)
- Support to on-board autonomy in constellations
- Download of on-board processed data (-> actionable information) directly to the ground

→ **Vision: (Near) Real-time EO satellite Data-as-a-Service**



- **EO satellite interconnected with other satellites**
- **Protocol /Frequencies/ to be standardized**
- **Low latency in transferring data**
- **„Near real-time“ acquisition time**
- **Seamless network connectivity**

THANK YOU!

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