IOT4EO WORKSHOP 1

Executive Summary

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i. Introduction

The workshop, organized by ESA and held on 16-17 February 2023, aimed to investigate the feasibility and potential benefits of seamless integrated networks with near-permanent connectivity to Earth Observation (EO) satellites in Low Earth Orbit (LEO). The workshop was conducted in a hybrid format, with physical attendance at ESA-ESTEC and remote participation via Webex.

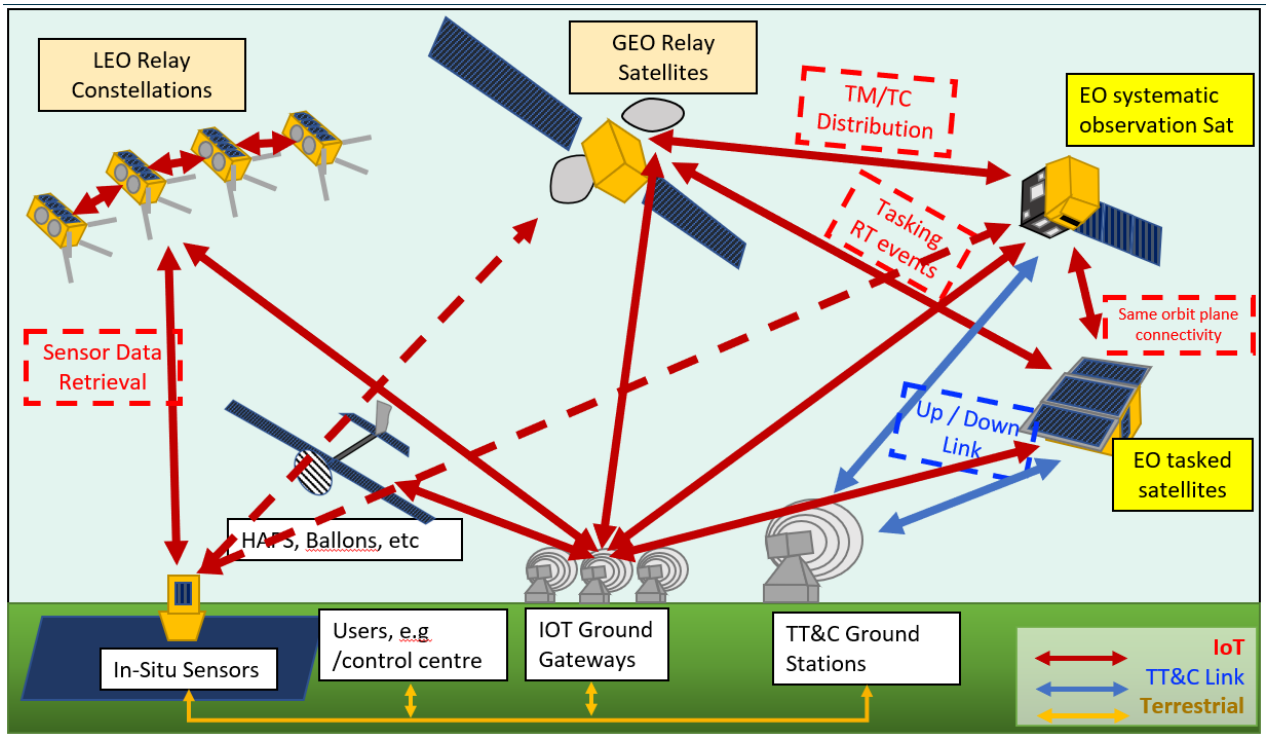

Figure 1 IoT4EO Preliminary Connectivity architecture

The workshop was split into three sets of sessions, spanning two half days, which covered:

- EO user needs, which included presentations from various organizations such as EU EMSA, ESA, and NASA Earth Observation, as well as two LSIs (Airbus and OHB) that conducted ESA studies on the topic. Additionally, there were presentations from ESA-ESOC and EUMETSAT, which provided an operational perspective on the topic.
- EO upstream users for IoT, including presentations from e-GEOS and RHEA, who conducted ESA Rapid and Resilient crisis Response studies. There were also presentations from various EO constellation providers such as Iceye, PlanetLabs, Spire, AerospaceLab, Capella, and its experience with Inmarsat, Orotatech, and UnseenLabs, as well as the prospects of collection of in-situ sensor data by ESA-ESRIN.
- IoT connectivity provided by GEO and LEO satellites. The session included presentations from various organizations, such as ESA, Viasat, AddValue, SES, NeoSat, Lacuna Space, SatelioT, Astrocast, and Kineis.

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The workshop concluded with a round table & open discussion, addressing the following questions:

Benefits	What advantages does near-permanent connectivity provide for various EO applications?
	Does near-permanent connectivity complement higher speed (Gb/s) connections, or would an all-in-one solution be preferable?
	How attractive is the EO market for connectivity service providers?
Priority	Moving forward, the priorities are to determine whether simplicity, with assumptions such as low data rate and no steering, is reasonable or if performance, including data rate (measured in kb/s), availability, and service cost, should take precedence?
Feasibility	Do the current services meet the requirements, and if not, what improvements are necessary?
	Should standardization be implemented for frequency, bandwidth, ITU service, and other factors?
	What is the required capacity and availability, such as the number of satellites in orbit?
	Should flexibility be provided, such as the possibility of multiple providers, like phone services?

A total of 127 registered attendees, with 53 on-site and 74 via Webex. Out of these, 19 ESA and 108 not ESA

ii. Key takeaways

Topic	Description
EO Use Cases	There is a clear demand for improved **timeliness** in Earth Observation (EO) satellite, for monitoring human activity, and as well but to a less extent for observing natural phenomena. This affects use cases such as: • Tasking the satellites • Bringing actionable information to Earth and complementing other more-complex means capable to connect at higher data rates. • Higher interaction from the mission control centre with the satellite to gain autonomy in operations. Collecting **in-situ measurements**, • Via terrestrial IoT networks • Complemented with satellites, when necessary, is very important for EO missions to support calibration purposes or to acquire complementary observations. IoT can facilitate automation and efficiency in data fusion.
Cost-effectiveness	IoT can enable very rapid response systems and open new market opportunities with the timeliness added value, but in a context of near-permanent connectivity for multi-satellite constellation, it is confirmed that: • Simplicity (e.g., SWaP of terminals) • Cost-effectiveness in operations is of paramount importance.
Provider-Agnostic	To facilitate worldwide and near-permanent connectivity to EO satellites both over land and ocean, as well as scalability, long-term availability and longevity, the implementation of seamless integrated network services should be provider-agnostic. In the event of any downtime or failures, contingency plans for replacement solutions must be readily available. In this respect, it will be important: • To standardise and enable inter-operability. • To establish technology roadmaps to support a solid standardisation based on hands-on prototyping, testbeds and even in-orbit validation to demonstrate feasibility and facilitate the adoption of the standards. • Address security aspects with an end-to-end perspective
GEO/MEO IoT Providers	The session demonstrated that there are already solutions being used, both from GEO and LEO, and planned from MEO. These cases benefit from good time visibility between satellites and therefore with not too frequent switching needs to connect to other GEO/MEO satellites. Multiple frequency bands and services are being used. It is therefore recommended to give a high priority to standardise enabling elements of this GEO/MEO to LEO connectivity. Several key questions will have to be addressed for the mid/long term scenarios to facilitate growth and adoption: • For inter-operability, should we privilege one or a few of the frequencies (and even request specific allocation or protection criteria at a next ITU WRC), or should EO terminals have the intelligence and capability to choose among a large number of possible frequencies and services. • what synergies can be taken from commercial on-ground IoT and standards like 3GPP, what adaptations (e.g., Doppler in LEO, optimal waveforms, would a simple SIM card be sufficient? etc…) should be considered.

	• What technology roadmaps should be envisaged to support a solid standardisation based on hands-on prototyping, testbeds and even in-orbit validation to demonstrate feasibility of the proposed solutions to answer the other key questions above. One suggestion was made to try to embark IoT into future GNSS constellations in MEO. It will be important that it is based on an open standard.
LEO IoT Connectivity	The session also demonstrated the feasibility of connecting in-situ sensors to the LEO IoT constellations under development. These solutions might be proprietary but constitute a solid technical base for evolution. Developing connections between LEO IoT constellations and EO Satellites in LEO presents a challenge, as some IoT constellations are in similar altitudes. Also, IoT constellations flying in lower orbits will have difficulties in serving EO constellations in higher orbits, unless they are equipped with zenith pointed antennas. However, the IoT connectivity between EO satellites flying in formation (e.g. in the same plane) can be simple and is attractive. Several key questions will have to be addressed for the mid/long term scenarios to facilitate growth and adoption, such as: • How to ensure inter-operability of in-situ sensors with both IoT LEO constellations and directly to EO satellites to build up the connectivity scale required and take advantage of enabling building block interfacing technology based on common standards. • Synergies with the connectivity to GEO/MEO (e.g., frequencies, services), including related intelligence and capability to choose the optimal connection, need to be identified. • Synergies from commercial on-ground IoT and standards like 3GPP, and adaptations needed. • Relevant technology roadmaps
Role of the public Agencies	Brief discussion on the reasons for standardisation and the need to complement it with technology developments as mentioned above. The objective is to pave the way for more cost-effective communications with the EO LEO satellites and to develop growing and sustainable services by IoT providers.
Mechanisms for ensuring ongoing productivity.	From the ESA side, the intention is to keep working on the topic: • Via the two industrial studies (Airbus, OHB) • Via IOAG with other Agencies (currently DLR, NASA, CNES) It was discussed if the planned workshop in 1 year would be sufficient. Seeing the positive reaction, another Workshop, possibly just after the summer period, will be considered to keep this community active. The objective is to also propose technology roadmaps, including prototyping, testbeds, IoD/IOV will be elaborated to support the envisaged future standardisation.

iv. Conclusion and Next Steps

The attendance to the workshop (127 registrations) has exceeded the initial expectations. The quality of the presentations was very high, and many questions could be answered, such as:

- The benefits of a simple and cost-effective IoT near-permanent connectivity solution have been confirmed with the presented use-cases. This will improve timeliness, improve operations, and facilitate the acquisition of in-situ measurements for EO missions.
- The concept is feasible: there are already existing solution regarding IoT connectivity to LEO/MEO, and in-situ sensors can connect to LEO IoT constellations.
- Priorities will need to be addressed in the preparation of standards and technology roadmaps.
- New workshops (after the summer and in 1 year) will be planned.

Presentations will be distributed (subject to permission) to all attendees who registered for the event.

Thank you all for your contributions, **AND DO NOT HESITATE TO PROVIDE US ADDITIONAL FEEDBACK, IF ANY**.