Ordine degli Ingegneri della Provincia di Roma

Fondazione Ordine degli Ingegneri Provincia di Roma

Seminario

Tecnologie e costellazioni satellitari emergenti

Scenario Nuovi Servizi con Costellazioni Ibride

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Indice degli argomenti:

Hybrid Satellite Constellation (HSC) - Overview (1/3)

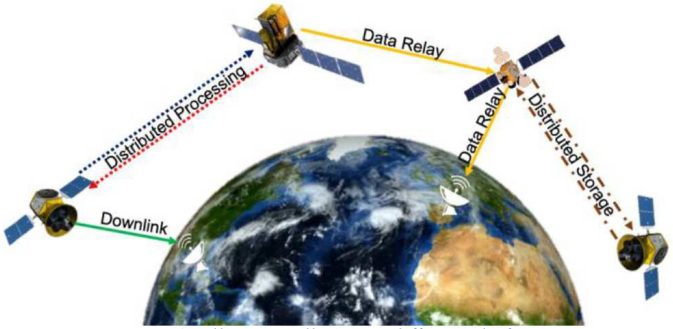
What is an Hybrid Satellite Constellation?

*A **hybrid constellation** is composed of satellites in **different types of orbit**, such as LEO/MEO/GEO satellites, incline geosynchronous orbit (IGSO) satellites, and highly elliptical orbit (HEO) satellites. They can be eventually of different dimensions and weight, host different payloads and/or be dedicated to more than one purpose.*

Source: A Global Seamless Hybrid Constellation Design Approach with Restricted Ground Supporting for Space Information Network , Wei Zhang, Tao Wu, Hong Ma and Guixin Li , August 27, 2019 , Journal of Systems Science and Information Volume 7 Issue 3

A specific case of HSC leveraging on different Service Scenarios is the Federated and Fractionated Satellite Systems (FFSS)?

Federated Fractionated Satellite Systems (FFSS) involve a **network of multiple independent** and **heterogeneous space elements** that interact, cooperate and communicate among theme using ISL, creating new emerging capabilities. The FFSS architecture can improve the **sustainability of new missions and services** by enabling use of **small satellite platforms** and distributed processing among heterogeneous satellites, allowing new missions not feasible without FFSS.



Satellite constellation on different platforms
With Intersatellite link fo data distribution

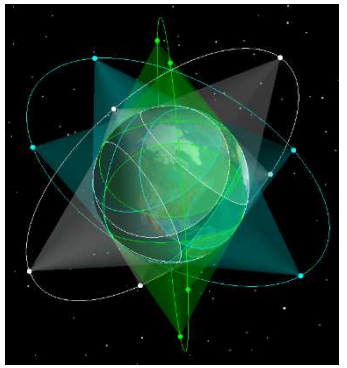
Cluster of similar satellites on different orbits

Formation flight configuration

Source: ONION - EU-funded H2020 research project "Operational Network of Individual Observation Nodes"

Hybrid Satellite Constellation (HSC) - Overview (2/3)

Hybrid onstellations composed eventually by different SpaceCrafts (S/C) typologies :



- Orbital regions: VLEO (below 450 Km) / LEO (up to 1500 Km) / MEO (1000 - ~23000 Km) / GEO (~36000 Km), HEO (~40000 Km as for Molniya satellite for Polar regions)
- Satellite configuration: with Large, Medium and Small (Mini/Micro/Nano..) Satellites
- Enabling to decouple the system functions by splitting on two or more small spacecrafts the antenna or payload sub-systems with inter-satellite-links

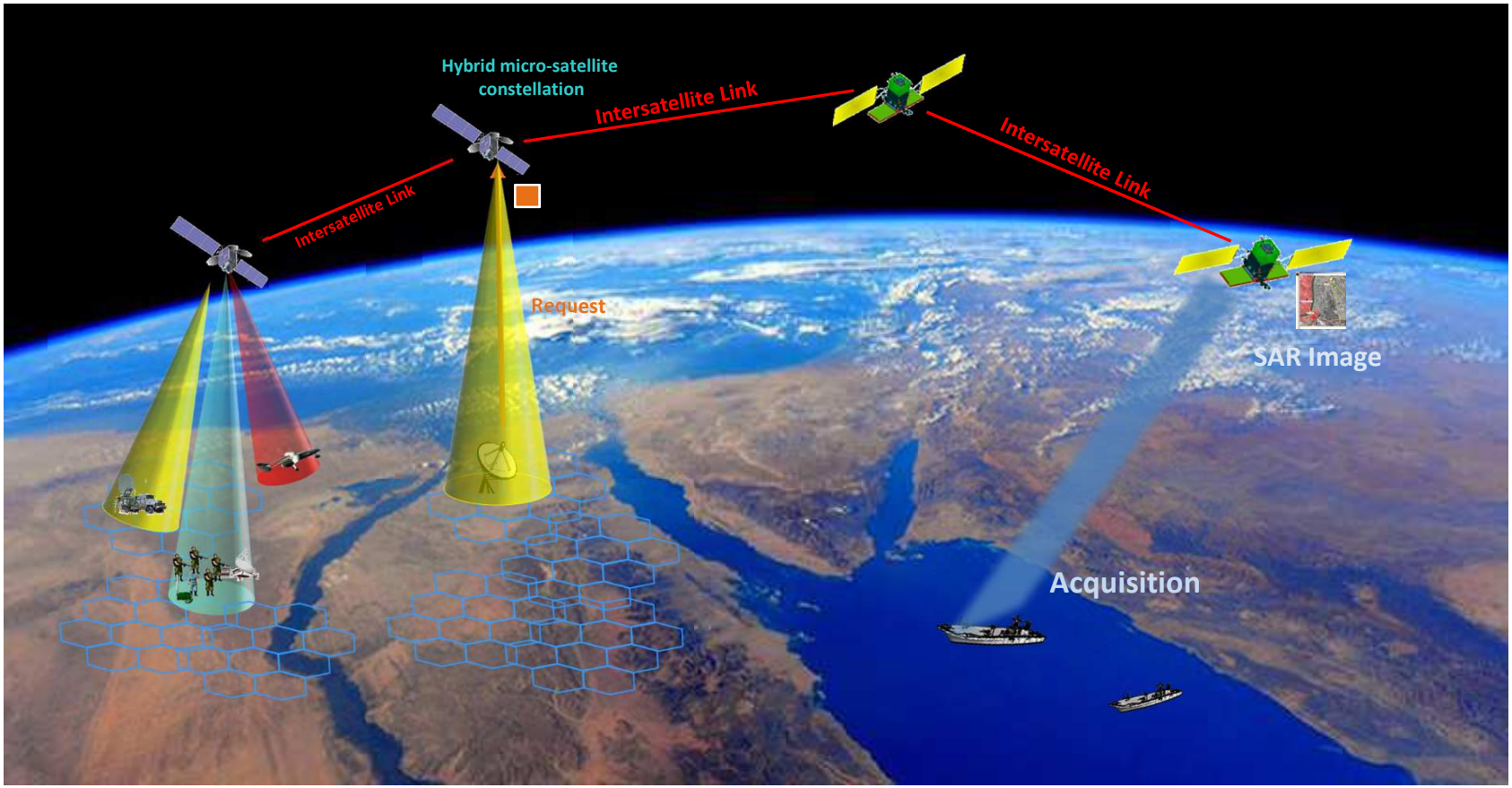
Satellite Class	Mass (Kg)
Large	>1000
Medium	500-1000
Mini	100-500
Micro	10-100
Nano	1-10
Pico	<1
Femto	0.1-0.01

Small Satellites Main Benefits

- ✓ Small platforms
- ✓ Low-cost platform
- ✓ Fast development phases
- ✓ Resilience to failure
- ✓ Resilience to Mission changes
- ✓ Delegate processing capability

Hybrid Satellite Constellation (HSC) - Overview (3/3)

Example of Hybrid Micro-satellite Constellation for On-demand dissemination of space sensing data and emergency communications

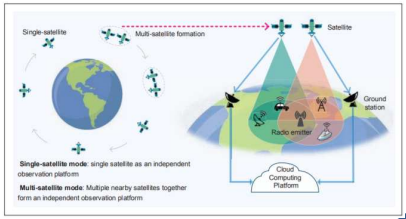


Hybrid Satellite Constellation – Services Overview

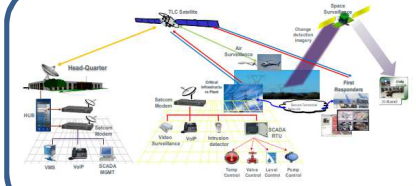
Earth Services

- Extensive low-latency broadband coverage
- Maritime: emergency & surveillance
- Critical infrastructures
- Aeronautical tracking and communication
- Remote sensing - including Earth exploration and Meteorological satellite systems
- Astronomy, Space and upper atmosphere research
- Intelligence: Space Situational Awareness (SSA), RF Spectrum Monitoring
- Internet of Things (IoT) Services

RF Spectrum Monitoring



Critical Infrastructure - IoT



SSA – NorthStar Constellation

Remote Sensing for Natural Disasters

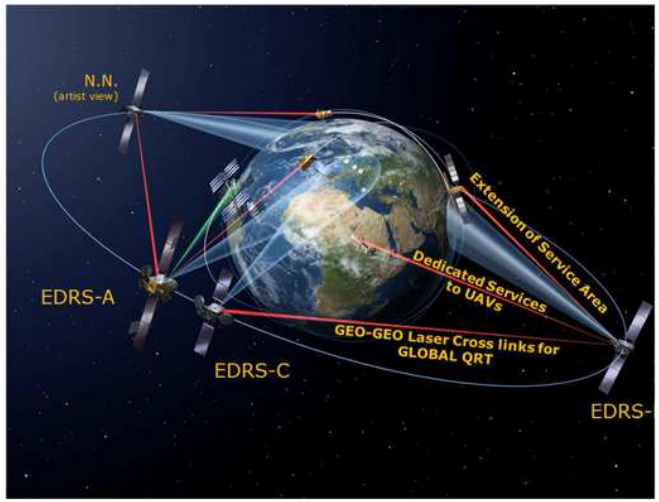
Maritime: Emergency and Surveillance

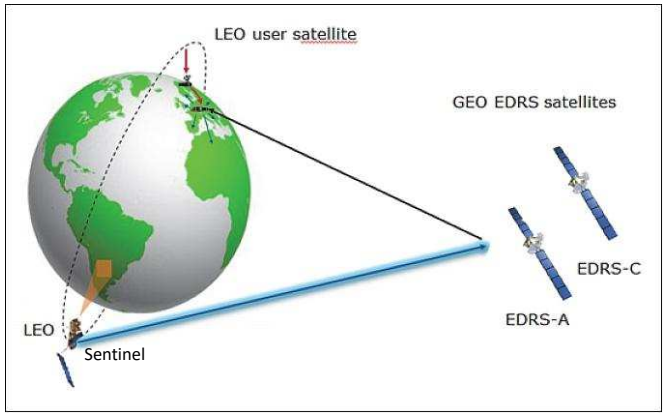
Hybrid Satellite Constellation – Earth Observation and Data Relay

- The **European Data Relay System (EDRS)** is a GEO optical Data Relay satellite communications system enabling near-realtime data relay from Low Earth Orbit (LEO) satellites to Europe and in particular also to **Sentinel** EO satellites.

- Telespazio with e-GEOS is involved for the *Matera User Ground Station (MUGS)* for EDRS. The Ground Station is designed to receive, process and distribute streams of data for the EDRS space segments, which will serve the EU's Earth Observation Programme Copernicus, supporting agricolture, urban area management, civil and nature protection.

- The new MUGS station will be installed and integrated at the Geodesy Center of ASI within the Matera Space Center, which has been providing geo-information services and solutions with e-GEOS for over twenty years.



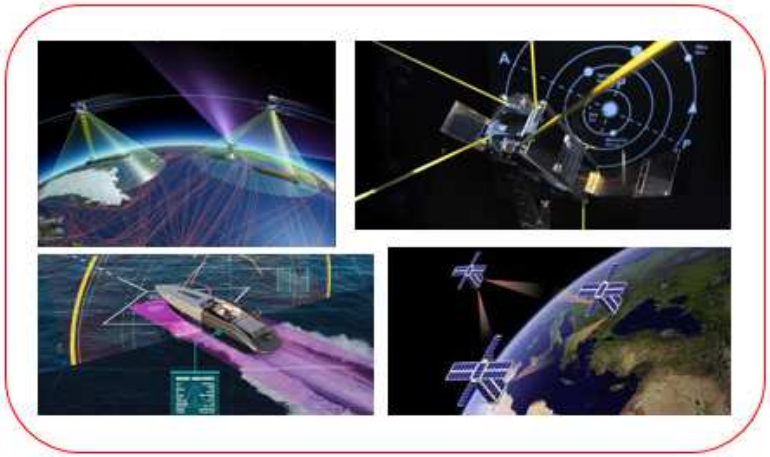


Hybrid Satellite Constellation – Maritime Surveillance

Small and Micro-satellite Constellation Systems result to be very effective and useful to respond to the strong **Maritime Security & Safety** requirements with flexible and modular Spacecraft configurations able to host new high performing space communication and sensor payload technologies, such as **SAR, VDES/AIS, COMINT/ELINT** and to sustain suitable mission performances in terms of responsiveness (**Revisit Time**), resilience and processing distributed in the space.

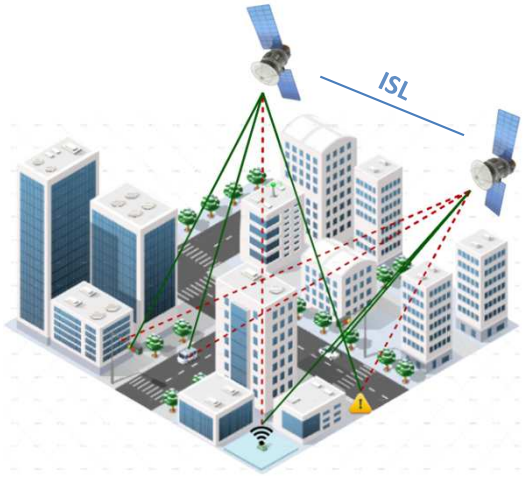
Application and Services

- Maritime accidents investigations;
- Piracy and armed robbery at sea;
- Terrorist threats in maritime environment;
- Maritime Safety (including Search and Rescue),
- Maritime Security and prevention of pollution caused by ships;
- Fisheries control;
- Marine environment monitoring and disaster prevention;
- Sea Border Control;
- Maritime Defence operations.

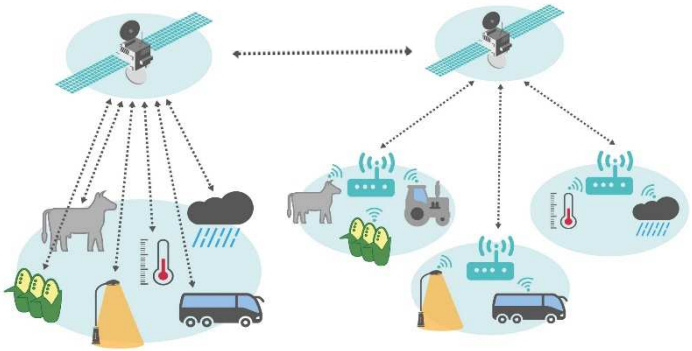


Hybrid Satellite Constellation – Internet of Things (IoT)

Satellite technology serves as a **key enabler** to transform **IoT connectivity** across industries and geographical borders. The applications range from **oil and gas**, to **mining**, **consumers** and **transportation**.



Connecting **terrestrial IoT network segments** directly to IoT service back ends via **satellite broadband** is becoming a new business focus, creating opportunities for notable use of hybrid **Low-Power Wide-Area Network (LPWAN)** to satellite gateways.



The **major advantage** is to bring connectivity to remote area, which will serve many IoT devices in local area.

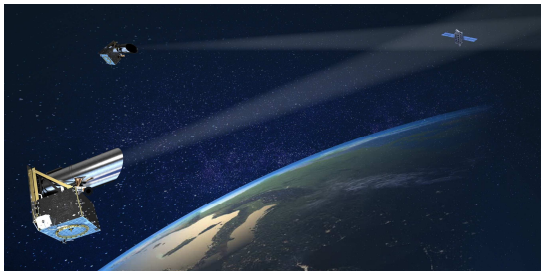
Applications

- Agriculture
- Maritime
- Emergency (Environmental monitoring, geologic disaster forecasting, etc)
- Civil Engineering
- Healthcare (post-operative treatment)
- Multi-modal logistics (smart grid, containers, etc)
- Smart City

Hybrid Satellite Constellation for IoS/SSA: NorthStar Constellation (1/3)

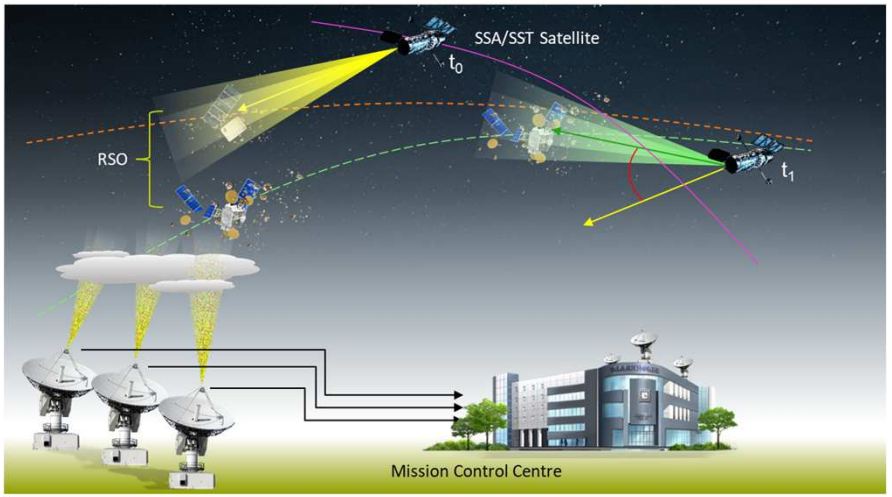
NorthStar (Montreal, Canada) is the **first commercial service** to **monitor space**, from space, via a constellation of satellites (40 satellites)with dedicated optical sensors (Hyperspectral, IR and Optical SSA).

With a secure and expanded data-driven 3D catalogue of the entire space environment powered with advanced **SSA analytics**, NorthStar's information services will enable **safe navigation** in space.

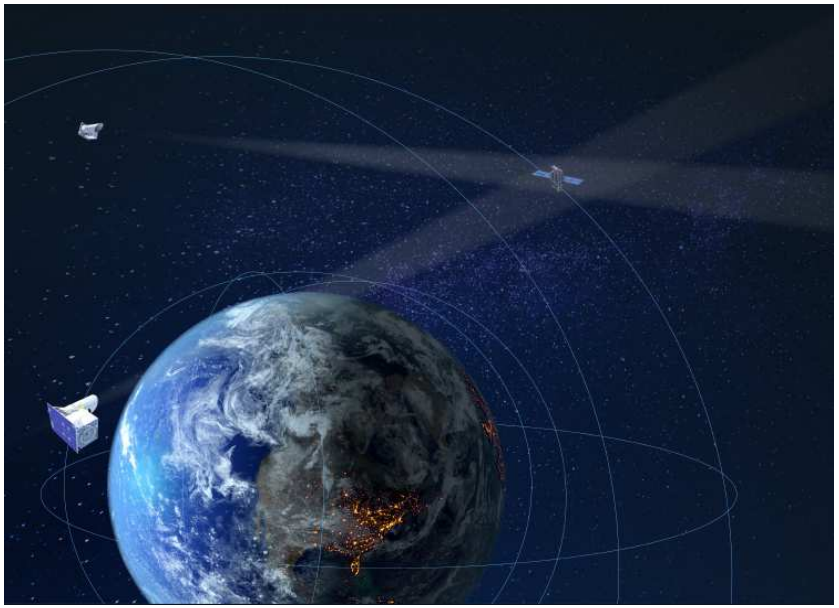


The platform will provide services for two missions:

1. Space Situational Awareness (SSA) with : a) Space Object Tracking, b) Launch and on-orbit collision avoidance services, c) Manoeuvre planning and detection, d) Space Traffic Management.
2. Earth Information and Intelligence (EI2) for the following markets: a) Pollution, b) Ocean Protection, c) Agriculture, d) Forestry, e) Oil and Gas



Hybrid Satellite Constellation for IoS/SSA: NorthStar Constellation (2/3)



Northstar Earh & Space

- Start-up established in Canada with two mission:
  - Space Information and Intelligence (**SI²**): provide space-based SSA information and services
  - Earth Information and Intelligence (**EI²**): provide hyperspectral and infrared data
- Space Alliance **invested** to support the initial de-risking phase (**Stage 1**)

1st stage constellation - Skylark

- Northstar **precursor** constellation of 12 small satellites
  - **SI²** optical sensor only (single mission) directed to near-Earth space for tracking other satellites across multipleorbits
  - **LEO** orbit
  - High Resident Space Object (RSO) **revisit** and **custody**
- First launch (3 sats) in **2023** and full constellation (12 sats) in **2025**

2nd stage constellation

- 40 satellites with Hyperspectral, InfraRed and Optical SSA sensors for Earth monitoring
  - 4 planes of 10 S/C
  - altitude = 550 km
  - SSO Inclination (97.6°).

Telespazio role

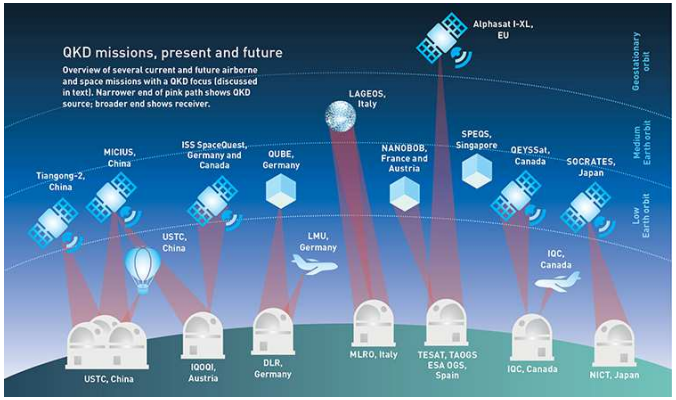
- **Value added services** provider, based on Northstar superior data and services
- **Industrial partner** for Ground Segment and Operations of Skylark constellation

Hybrid Satellite Constellation for IoS/SSA: NorthStar Constellation (3/3)

- The combination of different on-board technologies and solutions with the use of various orbital planes make
- It is possible to offer particularly relevant space operations services for run service providers such as Telespazio and currently not adequately supported
- An example of interest for Telespazio is Northstar, a constellation of satellites capable of providing advanced services in two different and complementary areas:
  - Space Situational Awareness (SSA)
  - Space Traffic Management (STM) - ability to visualize, understand and map the physical location of natural and man-made objects orbiting the Earth
  - Space Information & Intelligence (SI2) - for the study and monitoring of the Earth's orbit through optical telescopes in turn positioned in orbit
- Examples of SSA services are:
  - Space Object Tracking
  - Launch and on-orbit collision avoidance services
  - Manoeuvres planning and detection
  - Space Traffic Management
- Earth Information & Intelligence (EI2) Services : for monitoring the Earth's environment from space using hyperspectral and infrared sensors
- Markets of interest for EI2 services are: Pollution, Ocean Protection, Agriculture, Forestry, Oil and Gas

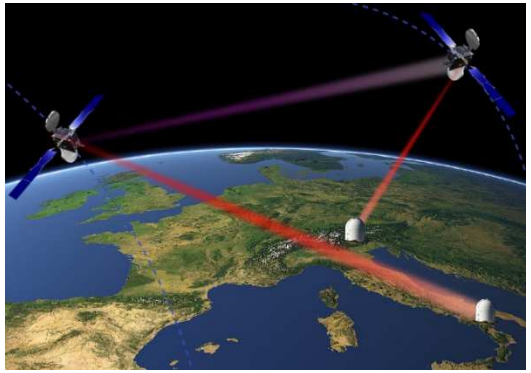
HSC for Security services based on Quantum Communications

- Potentially, cryptographic communications can be hacked by increasing the computing power
  - e.g. a quantum computer may factor a 300 digit number in minutes
- Algorithm-only based cryptography (even Post Quantum Algorithms) cannot detect if eavedropping occurred
- Quantum Key Distribution (QKD) offers a new solution to grant security in the communications. Major advantages:
  - It relies on physical laws rather than algorithms
  - It allows detectability of attackers (as quantum states are perturbed when measured)
- QKD in terrestrial optical fibers are subject to signal attenuation – Repeaters every 70-100 Km needed
- QKD Satellite solution can easily cover large distances and are recognised to possess many advantages
  - In atmosphere path: Effective thickness of always <10km
  - In outer space path: No quantum decoherence experienced
  - Effective link losses reduced by several tens of dB at same link length wrt fiber
  - Large nr of missions already accomplished or planned for next years on global scale (China, Japan, Canada, France, ESA ...)

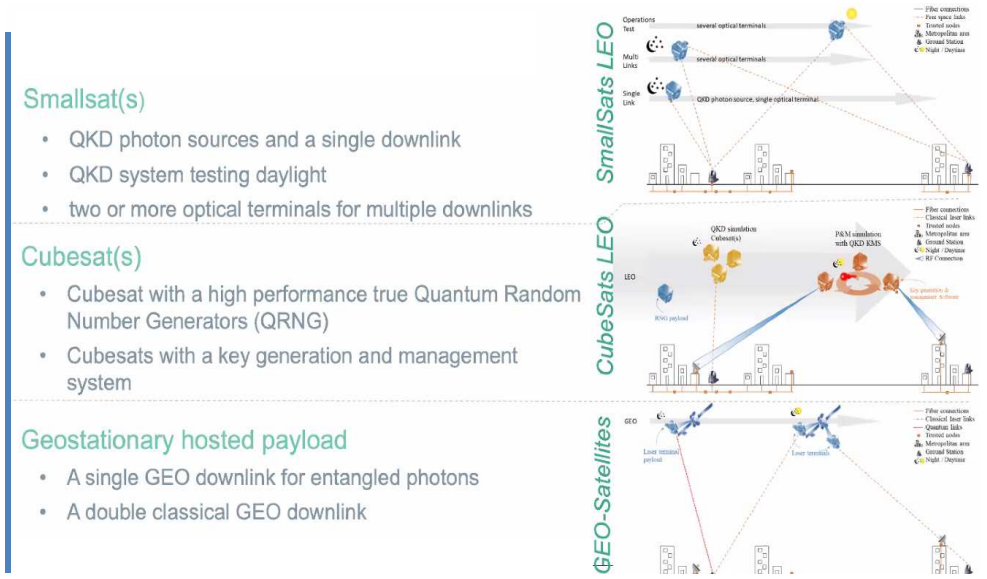


HSC - Satellite configurations for QKD services

- Various solutions can be deployed to implement a Satellite QKD networks
  - Cubesat LEO constellations
  - Smallsat LEO constellations
  - Hosted optical payloads on larger LEO satellites
  - In perspective, after further technology developments: Hosted payloads on board MEO / GEO satellites

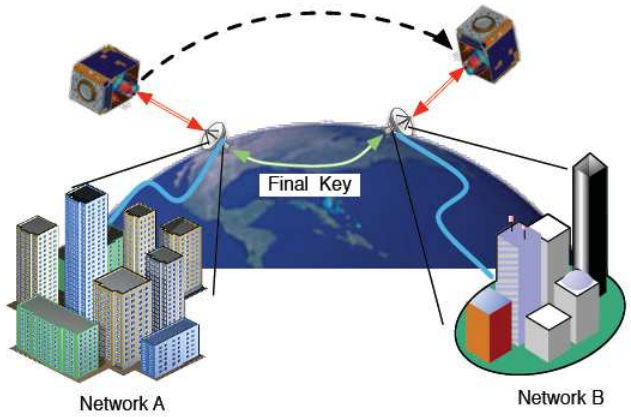


- But also:
  - Cubesat/Smallsat LEO constellations
    + +
  - Overarching GEO satellites
    + +
  - (classical) Optical GEO-LEO ISL for wider and more efficient Key Distribution



HSC for QKD-based Security services

- Sample of security services
  - Distribution of highly secure keys between remote sites (no intermediary nodes)
  - Security services between backbone network nodes
  - Protection of backup services and other business continuity processes
  - Protection of infrastructures and services in Enterprise MAN networks
  - Protection of communication in critical infrastructures (both control and data acquisition services)
  - Security services for Data Storage & Cloud services
  - Encryption of Telemetry and control data/information exchanged between Ground Control Centres and Satellites
  - Protection of data confidentiality in Ground Segment applications where same infrastructure are shared by multiple users



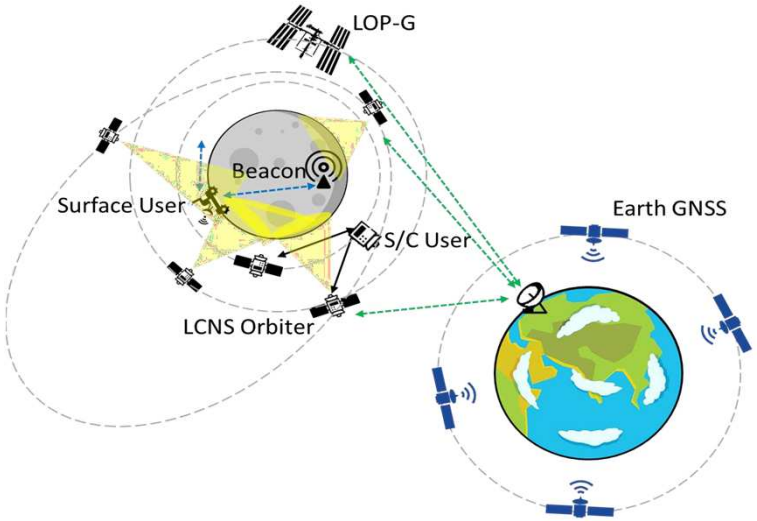
- Addressable customers (in initial deployments)
  - Governmental Institutions
  - Defense
  - Puiblic entities / Infrastructures
  - Large Enterprises
  - Financial sector
  - Health sector

Hybrid Satellite Constellation – LCNS Project

Moonlight Program

MOONLIGHT is the initiative of the European Space Agency (ESA) for the creation of lunar Communications and Navigation services (Lunar Communications and Navigation Services, **LCNS**) and the related infrastructure.

A **Lunar Hybrid Satellite Constellation** is expected to be the most promising solution.



Benefits

- ✓ Gradual Coverage (from South Pole to Global)
- ✓ More space assets (e.g., LCNS orbiters, Mother Hubs, Lop-g, etc)
- ✓ Communication & PNT Services
- ✓ Other services (Search And Rescue, Moon Observation, Space Environment Monitoring, Astronomy, etc)
- ✓ Scalability

Hybrid Satellite Constellation – Conclusions

- The Federate Fragmented Satellite System (FFSS), as an **integrated solution** at space and ground segment level **will enhance many services** by **merging**, **correlating** and **extracting** the information given by different space sensors, included the ones already operative
- Small Federated Fragmented Satellite constellations able to capture and **redistribute large amount of data** coming from a **distributed IoT network** will provide a large number of benefits in terms of costs
- FFFS allow **replacement solutions** or **addition of new subsystems** and **payloads** in case of failures, instruments upgrade or mission changes, thus increasing the overall **system resilience** and **lifetime**
- Possibility of developing different space platforms connected by ISL, in order to achieve different goal reducing time, revisit, costs and operational complexity.

Thanks for the attention