Constellation Design for High Responsiveness SAR
SPOKE 3 - WP3.4

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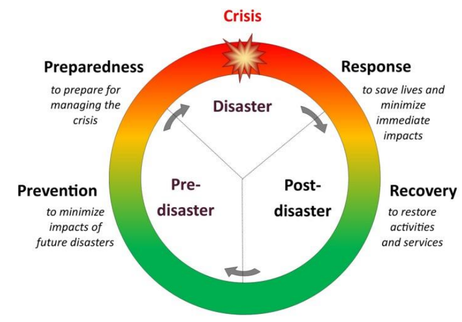
Context

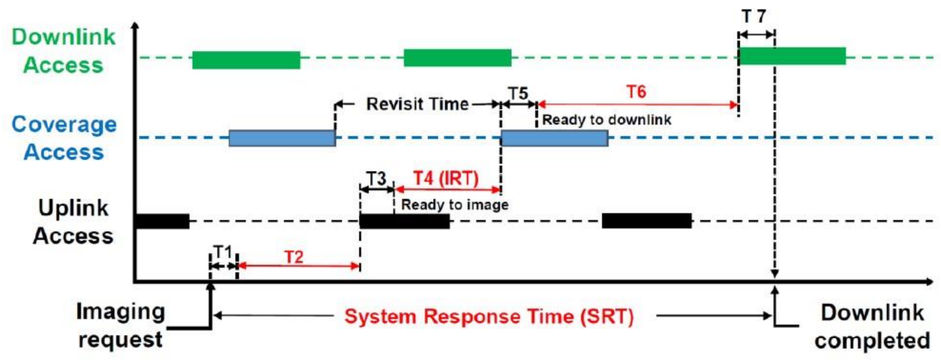
- It universally recognized that, the prevention phase or the management of post-emergency phase of a **crisis event** cannot ignore the possibility of **observing from space**. These new solutions have to provide **high spatial resolution** measurements as well as **fast access to this data.**
- To this end, **use cases** has been identified, in order to select **key parameters** from the literature that can lead to an effective and **innovative constellation design** together with **innovative payload and platform characteristics.**
- The analysis has been performed starting from the identification of **thematic areas** that can benefit from **high responsiveness Synthetic Aperture Radar (SAR).** The main individuated thematic areas are:
  - Maritime monitoring
  - Marine plastic debris measuring
  - Natural hazards forecasting and disaster management
  - Resilience of critical infrastructures



Disaster Risk Management.

System Response Time

- The space system performance of **revisit time** and **responsiveness** are crucial for all disaster risk management phases.
- Most **traditional** constellation design methods for remote sensing satellite constellations focus on minimizing the **revisit time**, even though it **does not directly describe the actual acquisitions' frequency.**
- **System Response Time (SRT)** accounts for times in getting collection requests to the imaging satellites, times in transmitting collected data to a receive ground station (GS).



T1 Command preparation Time. T2 Command uplink delay Time. T3 Command time and pre-collect Time. T4 Intrinsic Response Time (IRT). T5 Imaging and post processing Time. T6 Data downlink delay Time. T7 Downlink Time

SRT time components.

Constellation Definition

	ICEYE	StriX	Capella	Umbra	IRIDE NIMBUS	SIU
Bistatic	➪	✗	✗	➪	✗	✓
Single-Pass InSAR	✓	✗	✗	✗	✗	✓
SSO and MIO planes	➪	✓	✓	✗	✓	✓
ATI	✗	✗	✗	✗	✗	✓
Repeat-Pass InSAR (e.g. DInSAR)	✓	✓	✓	✗	✓	✓

State-of-the-art constellations product capabilities.

Spatial Resolution	Interferometric Revisit Time	Latency	Measurement description	Swath
1 m	3 hours	1 hour	- At least 2 LOS components - DInSAR - ATI	2 km up to 100 km

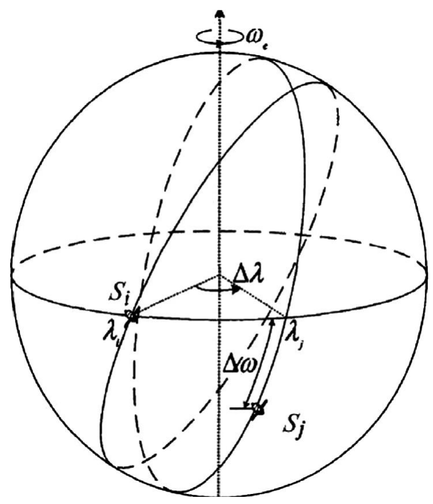
Constellation key parameters and properties driven by users.

Technical Solutions

- **Interferometric** Capabilities → **RGT** Orbits.
- Minimum Interferometric Revisit Time (IRT) achievable with **One-Plane** RGT Constellation: **1 day** → **Not enough**.
- **Very Low** IRT → **Multi-Plane** RGT.
- **Steps:**
  1. Swath definition → R_{min} definition.
  2. Optimization of Q=R/N, by selecting the solution with minimum N.
  3. Orbital plane longitude separation → **Number of Planes.**

$$\Delta\lambda = \left(\Omega_{\oplus} - \dot{\Omega}\right) \cdot \frac{\Delta M}{\dot{M} + \dot{\omega}} == \left(\Omega_{\oplus} - \dot{\Omega}\right) \cdot IRT$$

  4. Computation of anomaly shift of successive satellites of adjacent orbits.
  5. Orbits are filled until the first satellites does not repeat its GT → **N satellites per plane**.



$$\frac{\Delta\lambda}{\Omega_{\oplus} - \dot{\Omega}} = \frac{\Delta M}{\dot{M} + \dot{\omega}}$$

$$\Delta M = \Delta\lambda \cdot Q$$

Condition for GT repeatability in different planes.

	SSO	MIO
Q (R/N)	107/7	89/6
H/i	474 km / 97.99°	548 km / 49°
Planes	8	8
Total Satellites	56	48

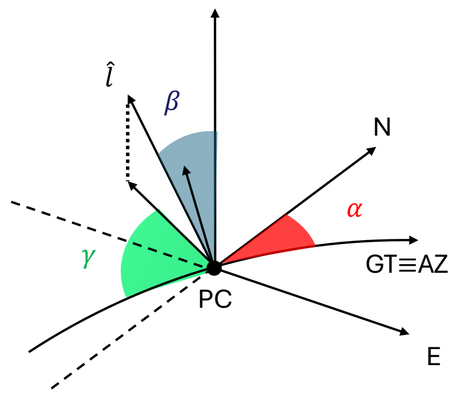
Multi-Plane RGT Constellation Design Results.

Future Works

Final Constellation Design

Bistatic Capabilities

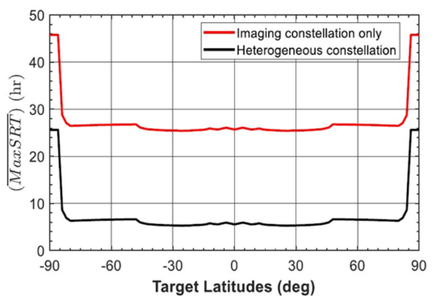
- Additional Line of Sights (LOSs) for **additional Interferometric Capabilities.**
- **Further scene information** related to the different scattering process.
- **Design:** Optimization of bistatic companions based on LOS diversity.



LOS representation for a bistatic forward-looking SAR in right-looking scenario.

SRT Performance Analysis

- **GSs selection**.
  - Matera/Fucino (Lat 40°/42°).
  - Kiruna (Lat 68°).
  - Santa Maria (Lat 37°).
  - Malindi (Lat -3°).
- **Relay constellation** definition, based on literature review.
  - Walker 4/2/1, h=8000 km, i=25°.
  - Walker 3/3/0, h=14000 km, i=25°.
- **Orbital analysis** to verify constellation performance.



Average of maximum SRT as a function of ground target latitudes for both the imaging constellation only and the heterogeneous constellation.

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