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SAILS

Spaceborne Autonomous Identification and Localization System (SAILS) for a single 12U Cubesat platform in LEO Orbit

L'Impegno Italiano nel Settore dei CubeSat: Tecnologie e Missioni Future – Seconda Edizione

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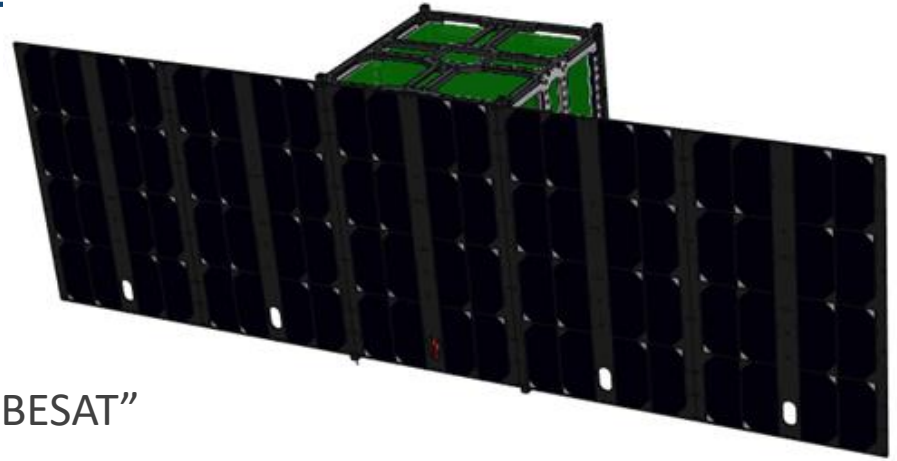
Introduction



- Spaceborne Autonomous Identification and Localization System (SAILS)

- SAILS has been proposed as a mission in response to the call “FUTURE MISSIONI PER CUBESAT”

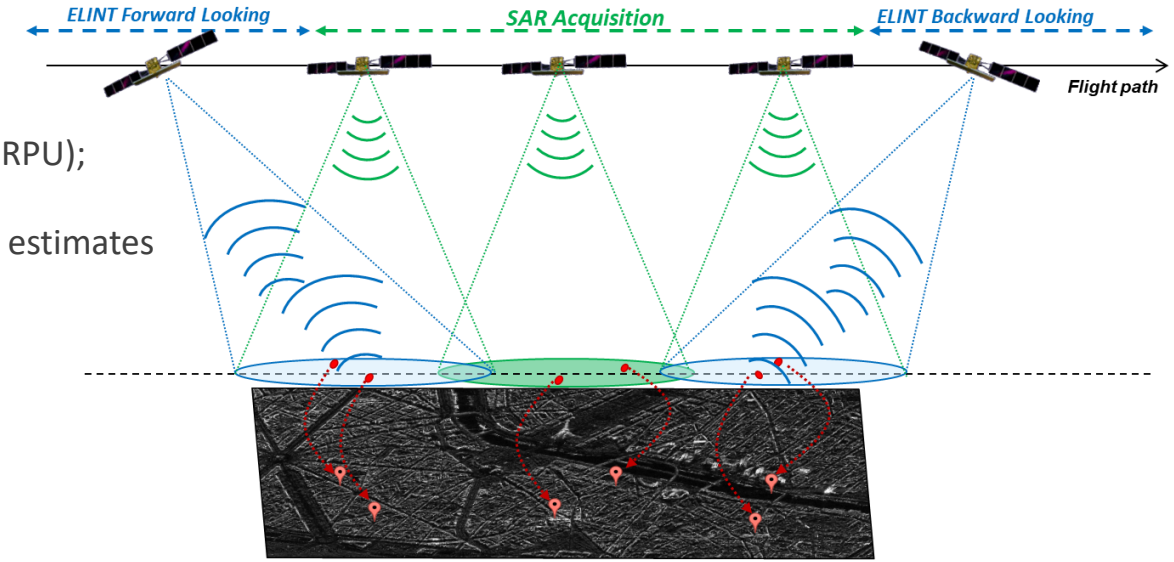
- It is a multichannel passive X band received with on board digital beamformer and steering for the geolocalization of RF transmitter on Earth
- The platform is a 12U Cubesat bus
- The mission include a ground processing station for the further improvement of the onboard geolocation

Introduction

The SAILS Instrument is a passive sensor operating in X-Band and conceived to meet small platform constraints.

Its main elements are:

- X-band Antenna Array;
- IF Conversion Unit (IFCU);
- Digital Receiver & Processor Unit (DRPU);
- Power and Control Unit (PCU);
- Real-time algorithms for initial DOA estimates



Partners

- METASENSING SRL

  Payload and Ground Facility design, manufacturing and integration. Responsible of the End to End Demonstration Results.

- NPC SPACEMIND

  Platform design, manufacturing and integration

- POLITECNICO DI BARI

  The University will support the ADCS manufacturing and testing.

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SAILS : Mission

Objectives

- To design and manufacture a small payload for passive surveillance of non-cooperative emitters working at X-band and located on ground.
- Applications are both civilians and military:
  - rescue of boats and ships
  - Detection of unwanted emissions (disturbing other signals)
  - Additional payload for other radar or communication satellites (anti-jamming)
  - At different bandwidth can be used to receive ADS-B or AIS
  - Gather information about radar

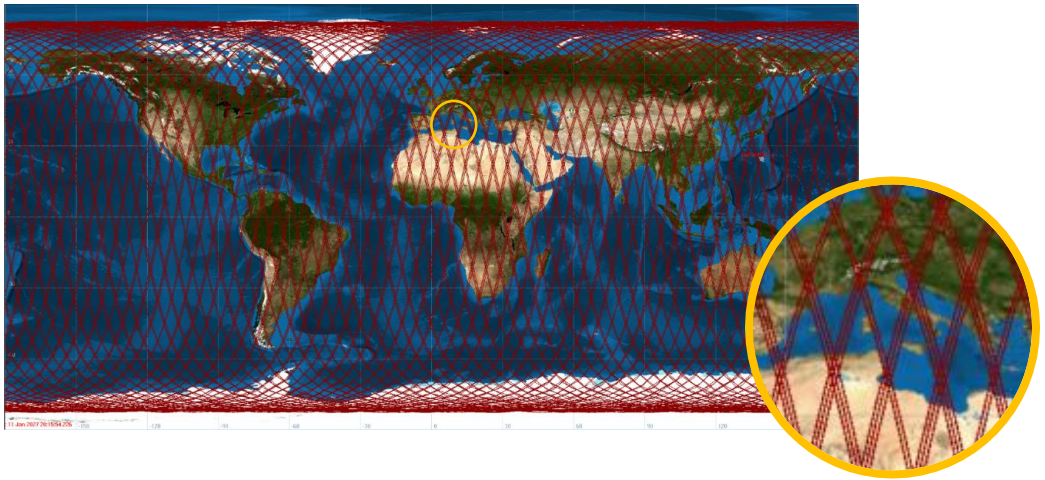
Pros & Cons

Pros:

- Compact and lightweight
- Spaceborne systems can observe all the earth
- Geometry allows to discriminate the emitters in both azimuth and elevation

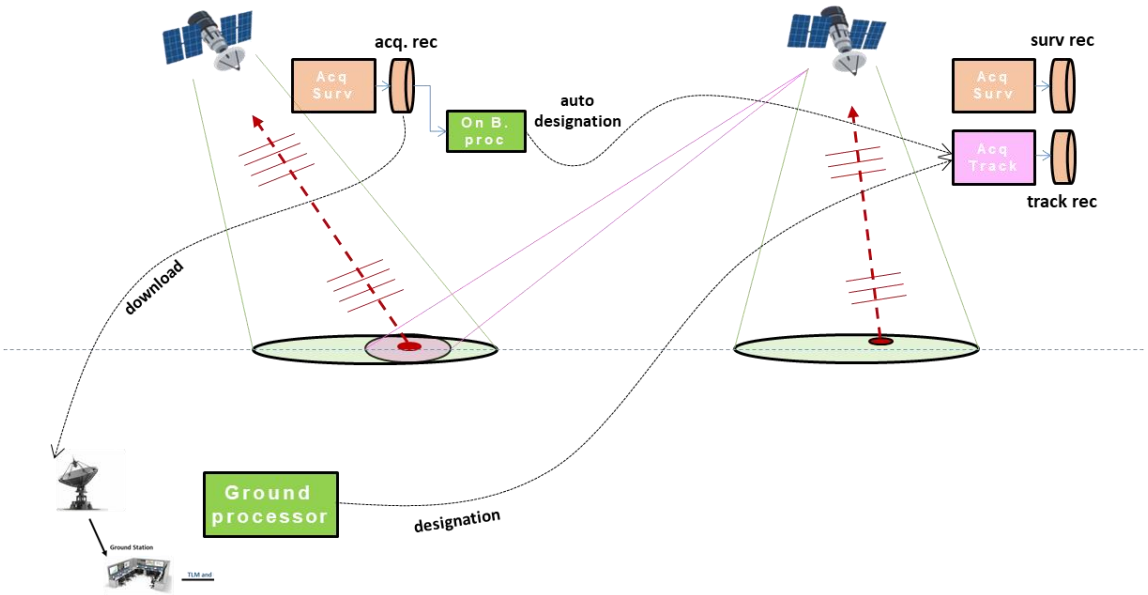
Cons:

- Limited processing power
- Limited antenna & payload size
  - A swarm of cubesat each specialized in its band could resolve this aspect
- Limited persistence



Concepts of Operations (CONOPs)

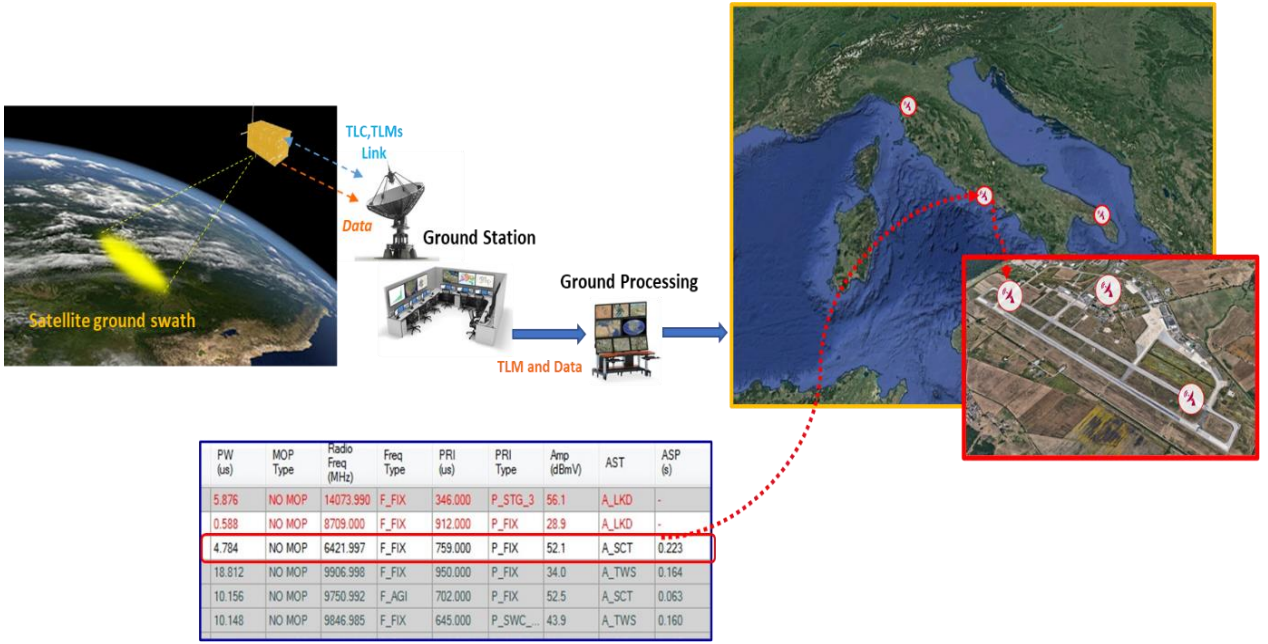
- Detection
  - Data Reduction
  - Data Transfers
  - Auto-designation
  - Ground Processing
    - geolocation
- Acquisition & Tracking
  - Measurement of
  - designated from ground or auto-designated
  - Interference suppression
  - Specific Emitter parameters



When measuring one emitters the other must be cancelled

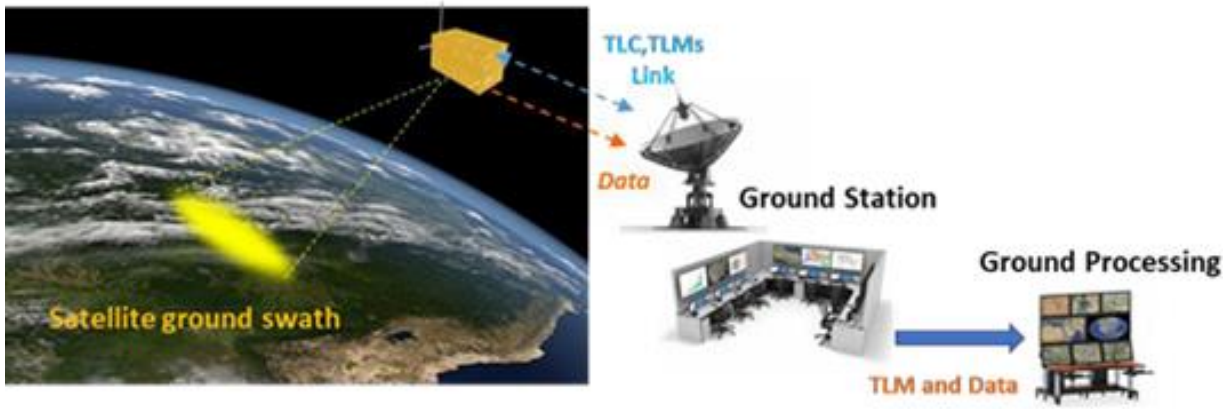
SAILS mission concept

- At the end of each acquisition, the dataset containing a list of all the generated emitter track files will be formatted & made available for other purposes.



PW (us)	MOP Type	Radio Freq (MHz)	Freq Type	PRI (us)	PRI Type	Amp (dBmV)	AST	ASP (s)
5.876	NO MOP	14073.990	F_FIX	346.000	P_STG_3	56.1	A_LKD	-
0.588	NO MOP	8709.000	F_FIX	912.000	P_FIX	28.9	A_LKD	-
4.784	NO MOP	6421.997	F_FIX	759.000	P_FIX	52.1	A_SCT	0.223
18.812	NO MOP	9906.998	F_FIX	950.000	P_FIX	34.0	A_TWS	0.164
10.156	NO MOP	9750.992	F_AGI	702.000	P_FIX	52.5	A_SCT	0.063
10.148	NO MOP	9846.985	F_FIX	645.000	P_SWC_...	43.9	A_TWS	0.160

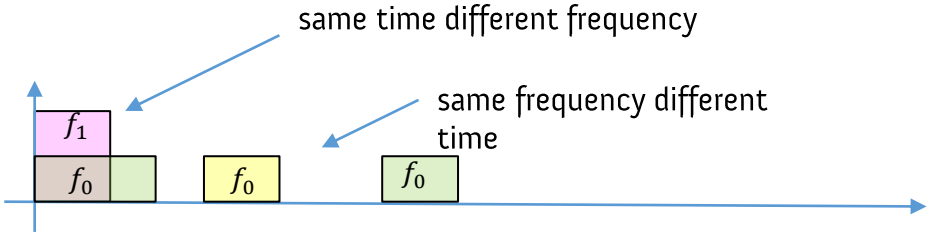
Basic mission parameters



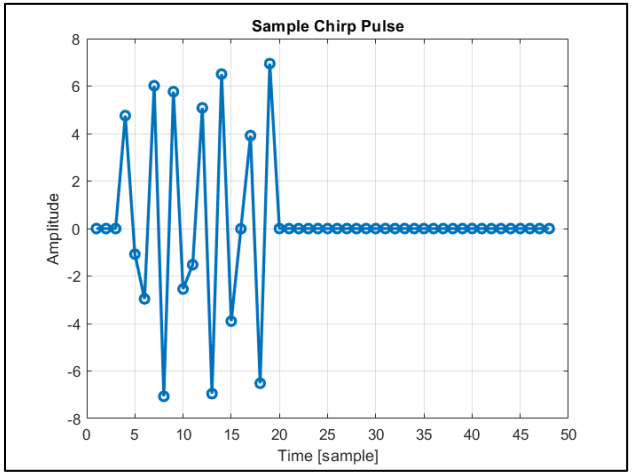
Mission Element	Description
Mission lifetime	6 months
Orbit parameter	i=97.38° (SSO), e=0, RAAN=0°, w=0°, θ=0°;
Altitude	500 km
Ground Station	Rome: average visibility 400 s, 4 times a day

Specification of an Emitter

Name	Description	Note
ERP	Effective Radiated Power	Radiated towards satellite $P_t \cdot G_{Tx}(\phi_s, \theta_s)$
PRI	Pulse Repetition Interval/Width	Persistence: pulsed or continuous
	Position on Ground	
f_c	Central Frequency	
B_w	Signal Modulation Bandwidth	Chirp/PAM/PSK,FSK
PW	Pulse Width	If pulsed



Deinterleaving: emitters can be discriminated in **time**, **frequency** and **position (angle)**



The system must be designed to work even with a single pulse

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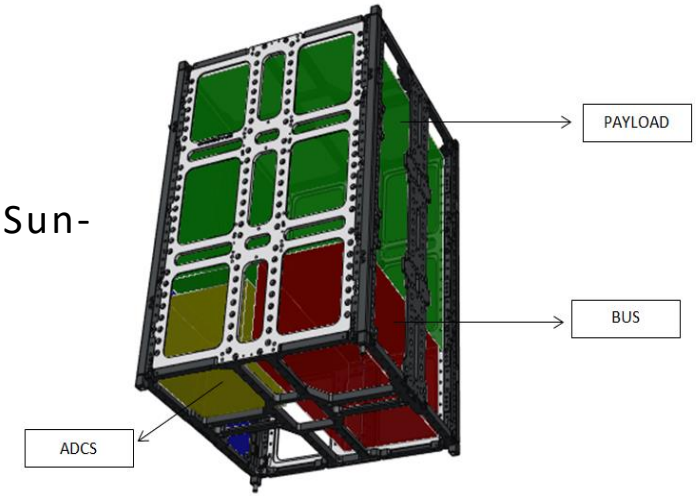
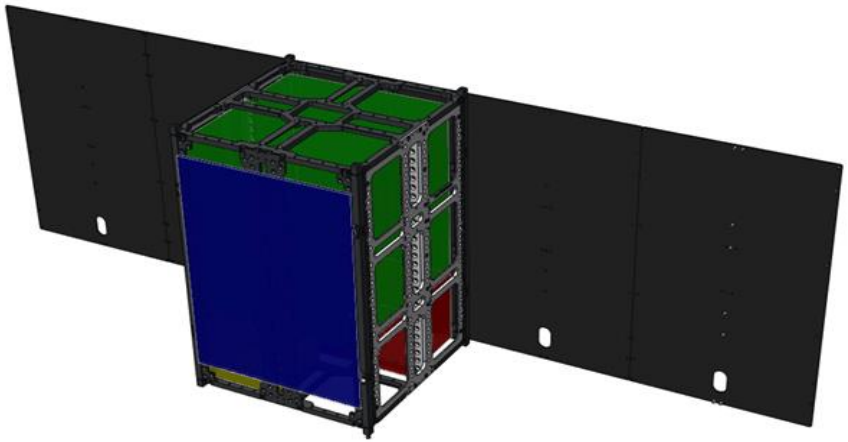
SAILS : System

SAILS bus

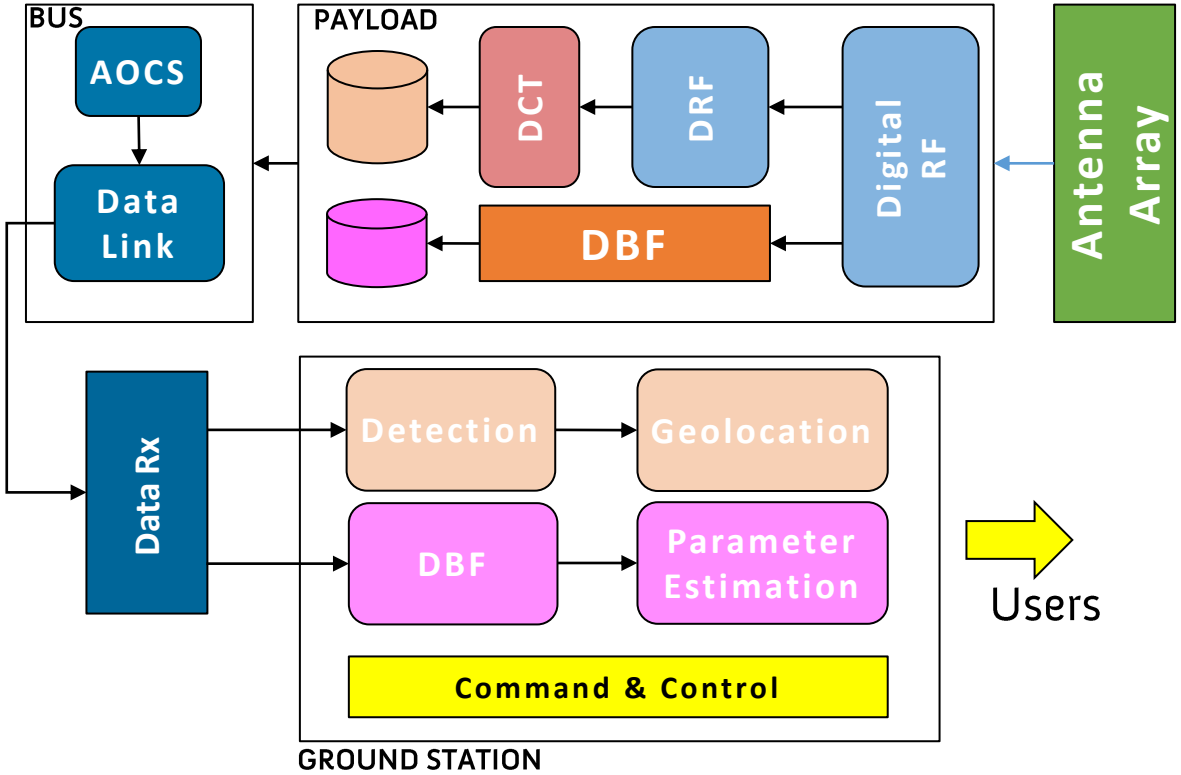
The SAILS Cubesat ia 12U/16U platform for a LEO Sun-synchronous Orbit and includes:

- Attitude Determination and Control System (ADCS)
- Power supply
- Data link subsystems
- RF Payload





System Functional View



Space Segment

- Antenna Array
- RF & Digitizing unit (merged?)
- Data Reduction Filter
  - Based on detection threshold
- Data Records (w/Attitude)
- Data Link

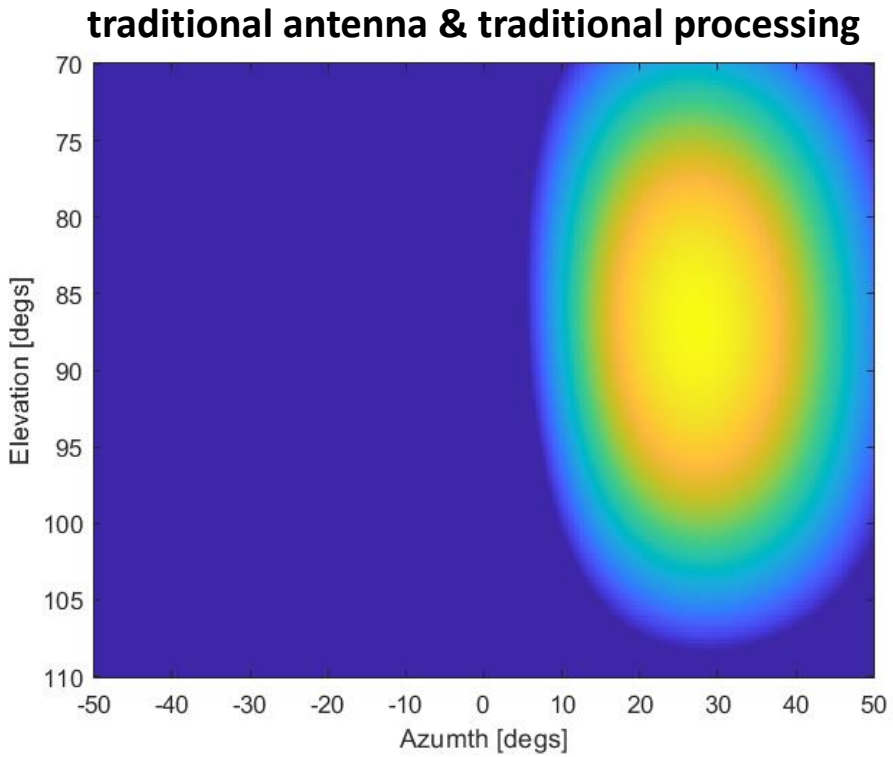
Ground Segment

- Detection & Surveillance
- Geolocation
- Interference Suppression
  - Digital Beamforming
- Parameter Extraction
- Command & Controls

Critical Items: Antenna Array

Antenna

- Coverage on ground
- Angular accuracy
- Angular discrimination (resolution)
- Sensitivity (array gain)
- Size and Weight
- Number of emitters on ground
- Number of Rf – Channels
- System Bandwidth

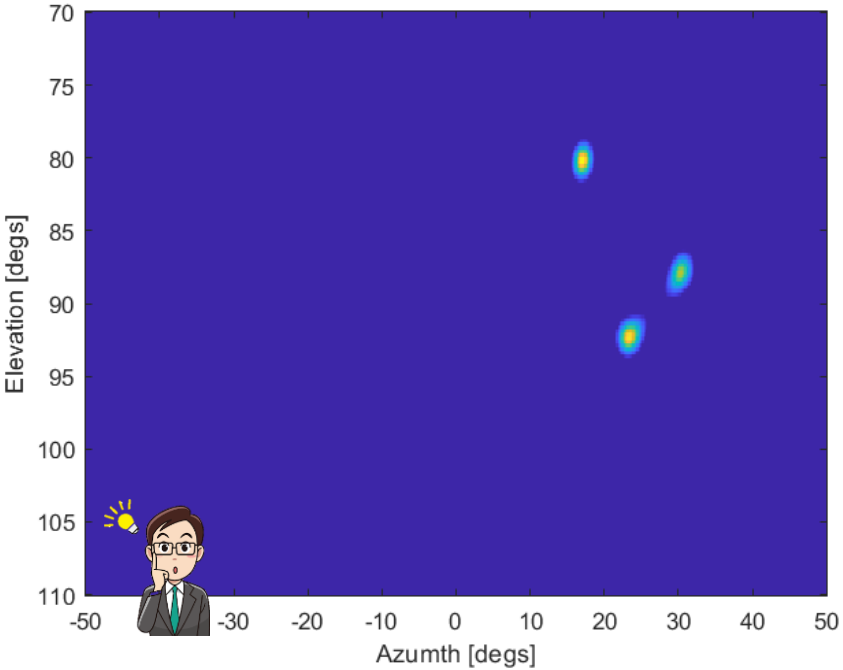


How to maximize swath area while keeping high resolution ?

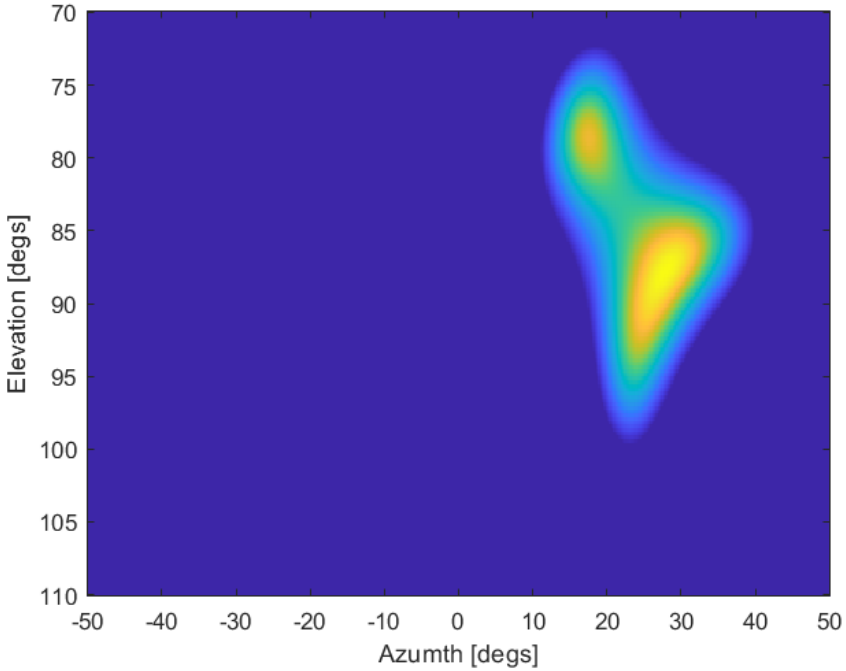
Advanced Antenna & Processing

… by working on the antenna array and on signal processing …

Advanced Processing & Advanced Antenna

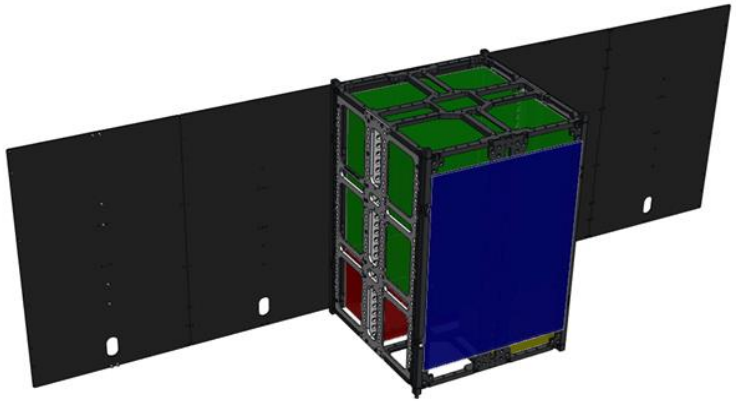


Advanced Processing & Traditional Antenna



Implement the detection as an image processing problem & consider using AI

Performance overview



Parameter	Estimated Performance
Frequency Coverage	8 ÷ 12 GHz
Instantaneous Dynamic	65 dB
Frequency Band	Selectable
Digital IBW	600÷700 MHz
Antenna Array Gain	> 12 dBi
Nr of Array Elements	16
Array Size	< 20 cm x 20 cm
Antenna Array FOV	> 30 degs
DOA Accuracy	0.1 ÷ 0.5 deg rms
Swath	> 300 x 300 Km
Emitter ERP	80 dBm
Single-Pulse Localization Accuracy	Better than 3 Km rms
On-Ground Tracking Localization	Better than 300 m rms
Uplink bit rate [Mbps]	TBD
Downlink bit rate [Mbps]	TBD
AOCS Pointing Accuray	<0.2 [degs]
Pointing knowledge Accuracy	<0.1 [degs]

Incremental approach

- The lack of a reference scenario makes the maturity of algorithm at the time of launch to be necessarily low
- Exploit commissioning phase to gather information about real scenario and trim algorithms and strategies for both on-board (mostly) and on-ground processor.

- Need of a mechanism for fast reconfiguration of on-board FPGA & SW

REQ: Uplink must support one reconfiguration per pass

Conclusion

- The SAILS mission concept and partner has been introduced

- The mission is a selected project for the ASI Future Cubesat Missions and it features an RF passive payload with an X band phased array antenna and the digital beam forming processing unit

- The main focus of the mission is to demonstrated **the real time in-orbit detection and tracking capability**

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