Passive EEE parts in the Biomass Payload: challenges and lessons learned

Adriano Carbone, Léo Farhat, Paloma Villar

A. Carbone,

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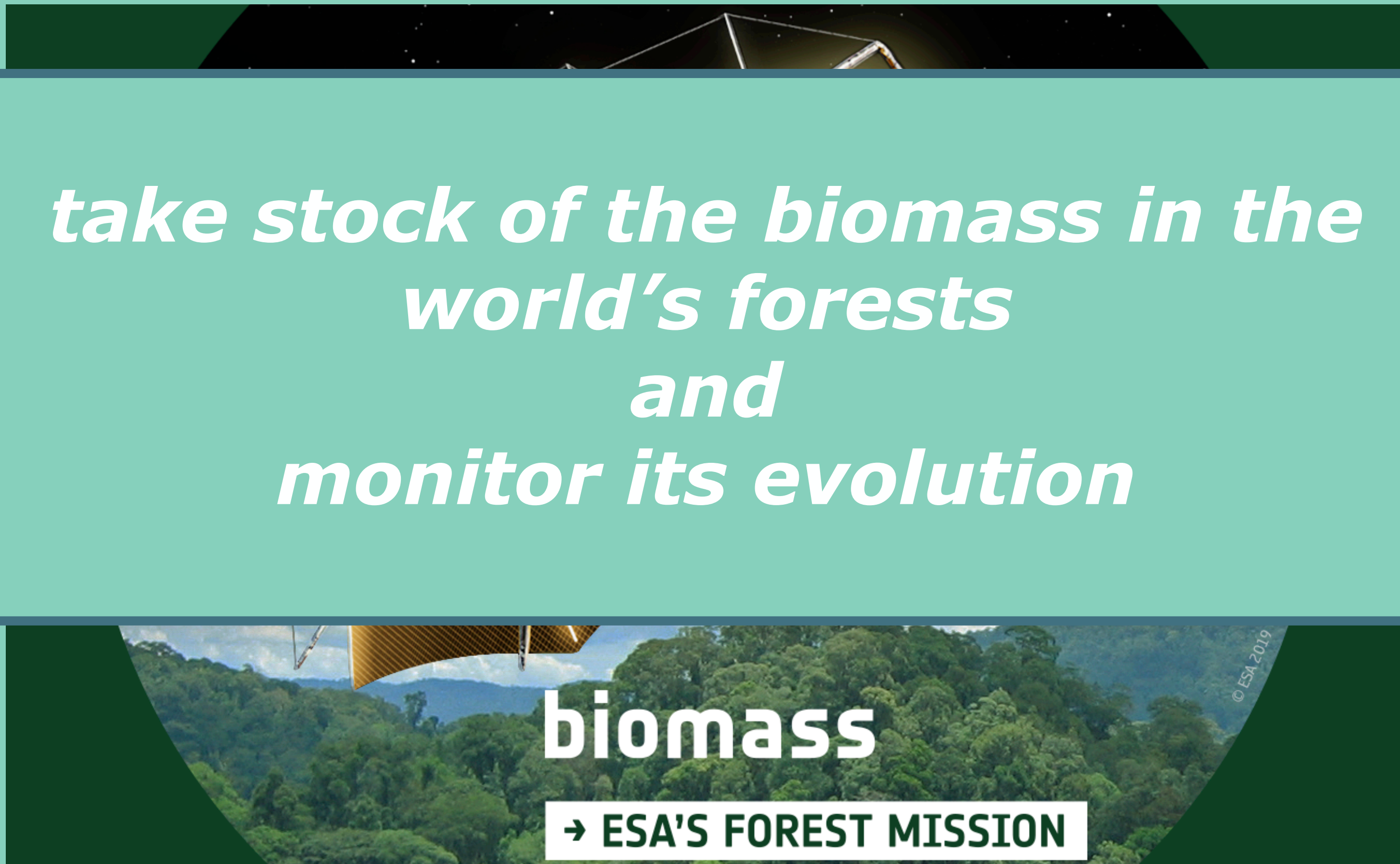
Outline

- Biomass mission, its objectives and its satellite
- Biomass Payload
- Payload calibration and the importance of the passive elements

- Multipaction: a special topic
- Some other passive EEE topics
- Mission status

Biomass: Mission

take stock of the biomass in the world’s forests
and
monitor its evolution



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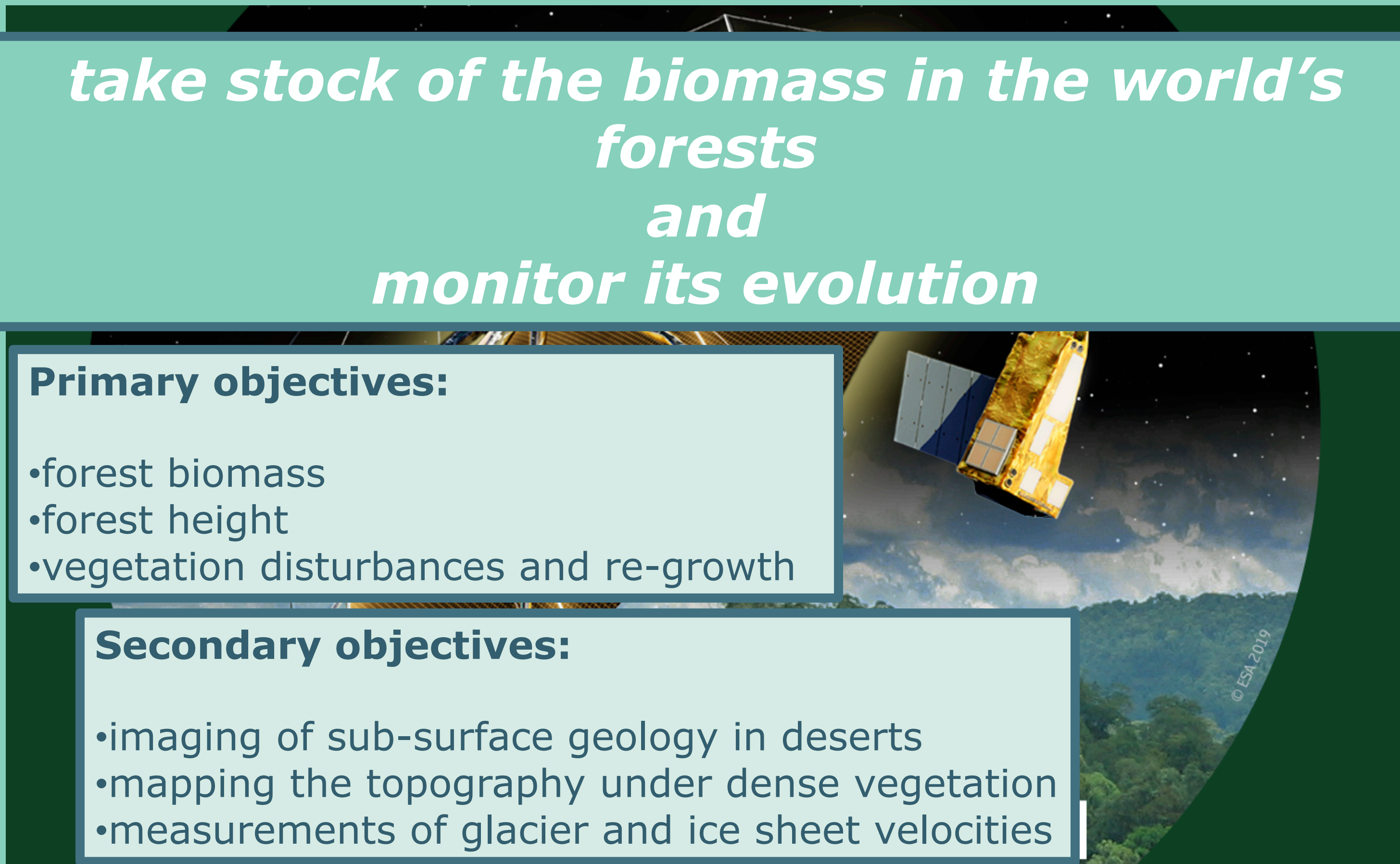

Primary objectives:

- forest biomass
- forest height
- vegetation disturbances and re-growth

Secondary objectives:

- imaging of sub-surface geology in deserts
- mapping the topography under dense vegetation
- measurements of glacier and ice sheet velocities

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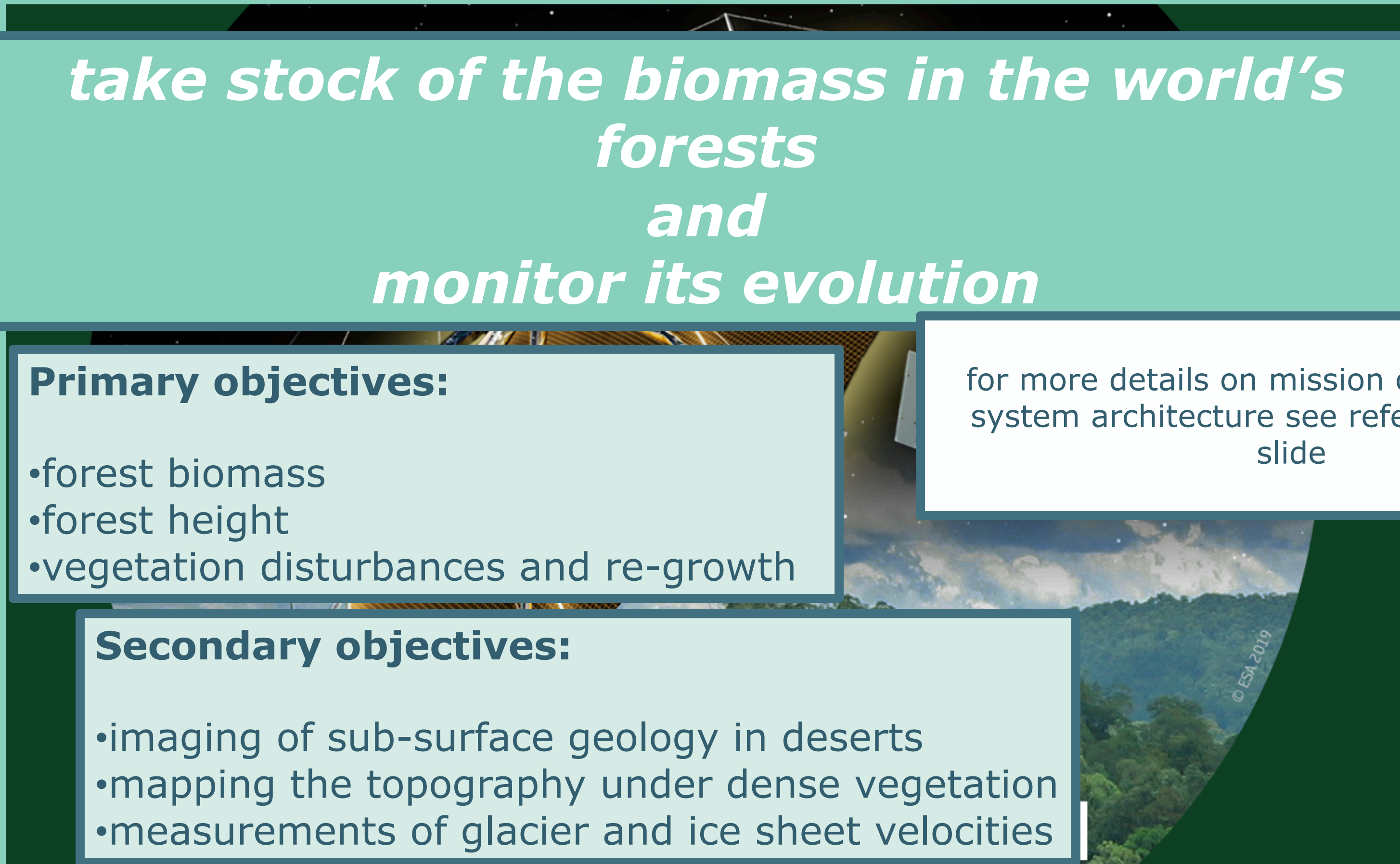

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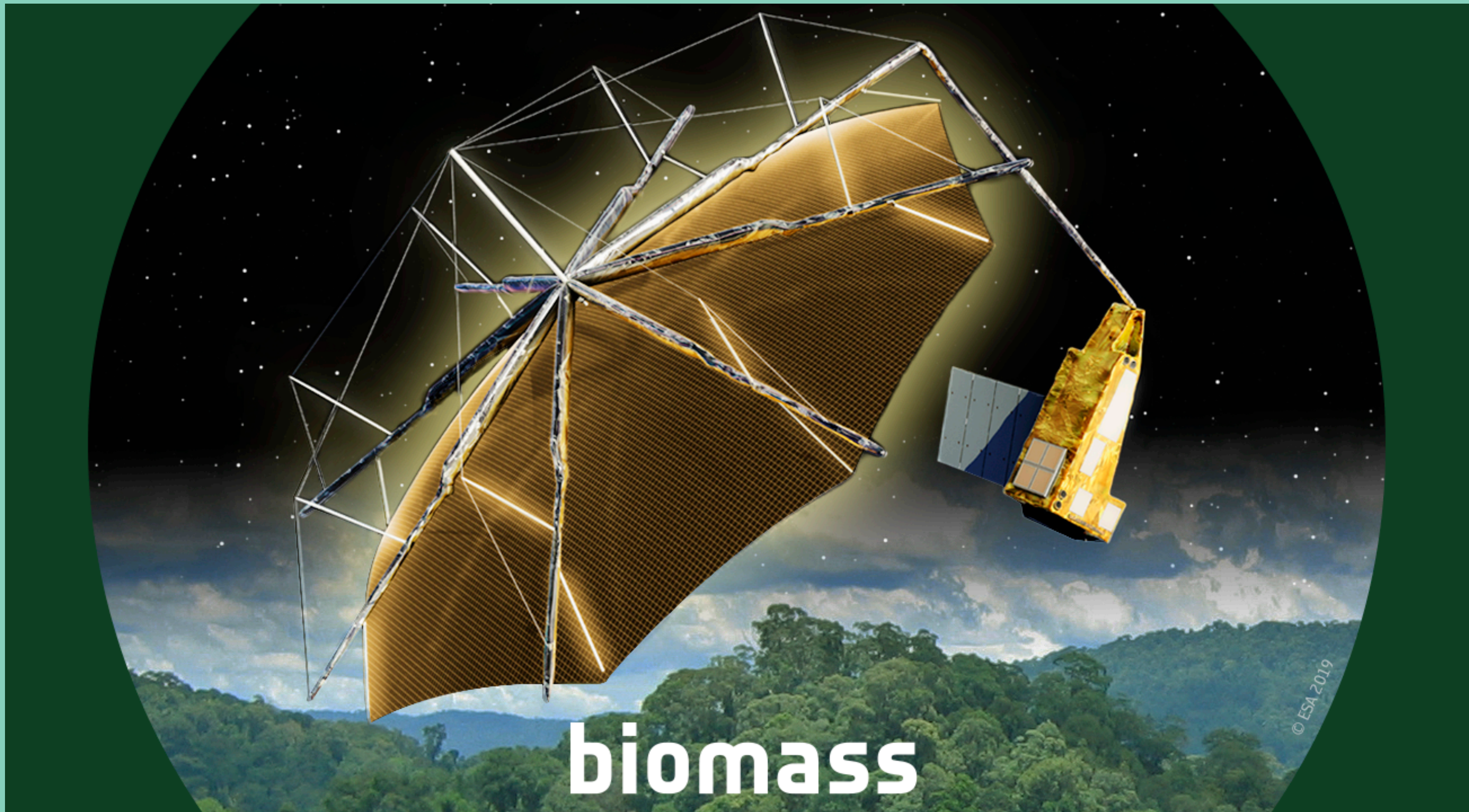
for more details on mission objectives and system architecture see references in last slide

Biomass: Space segment

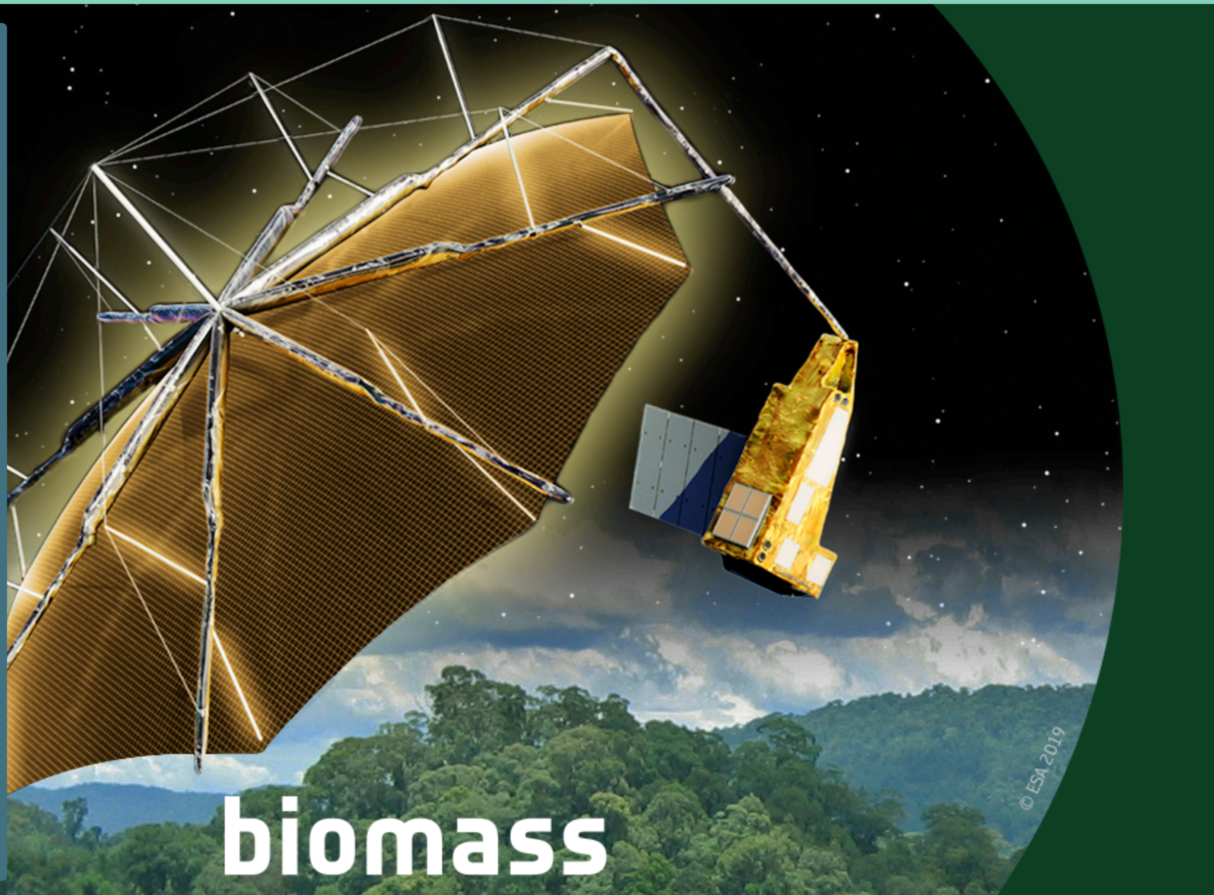


Biomass: Space segment

orbit
dawn-dusk, Sun-synchronous orbit:
- mean altitude of 666 km,
- inclination ~98°,
- 3 day repeat cycle orbit (drifting)

spacecraft
single satellite
based on AirbusDS AS250
~1250 kg
large deployable reflector

payload
P-band (435±3MHz),
full-polarimetric,
Synthetic Aperture Radar



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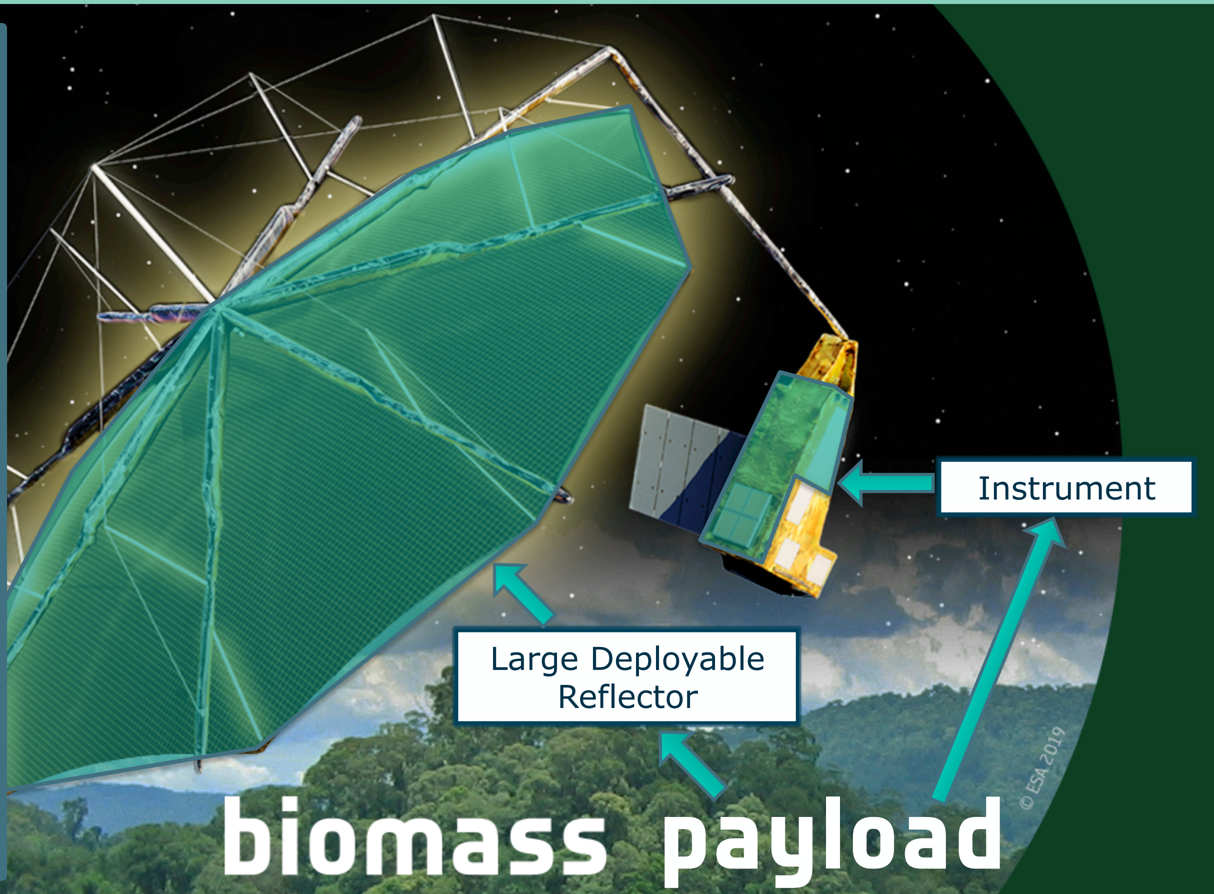
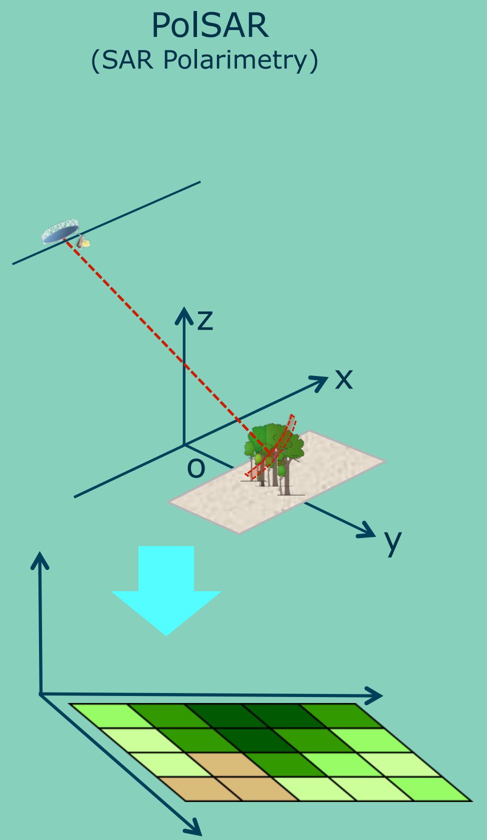
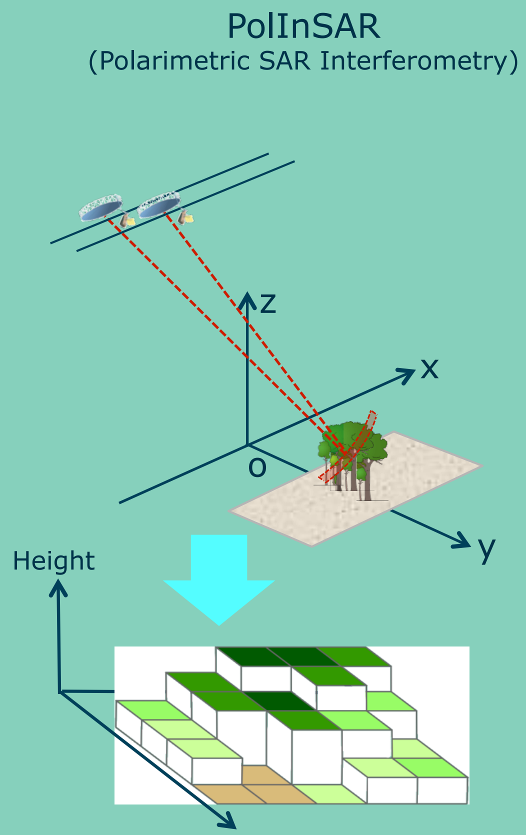
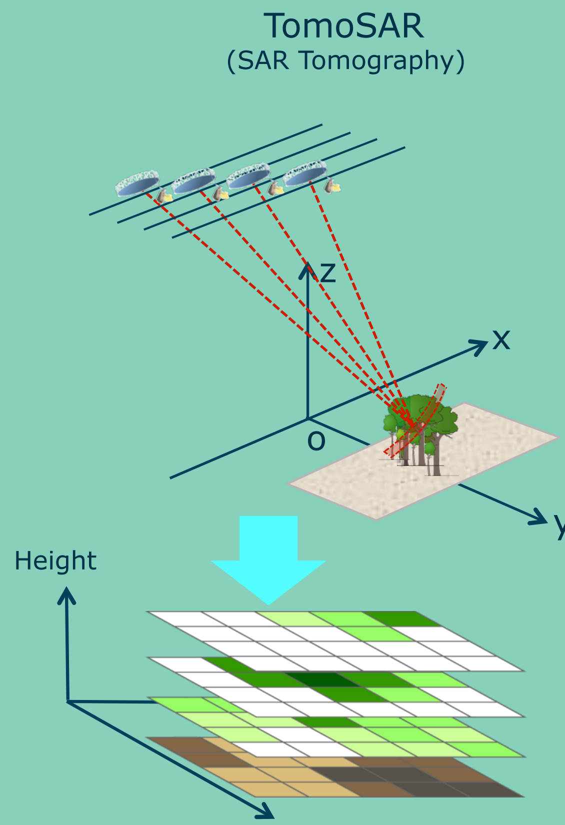


Biomass: observation techniques







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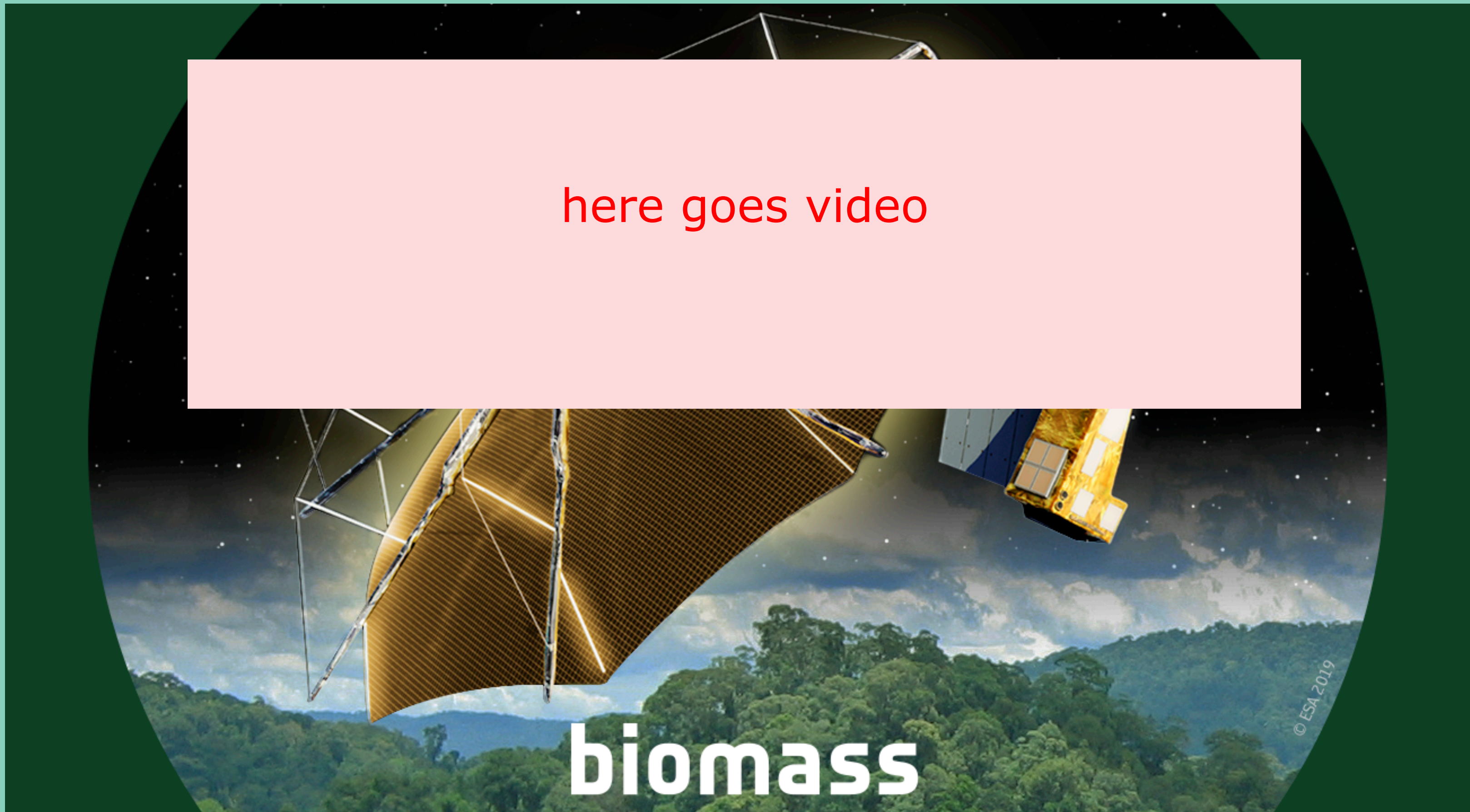

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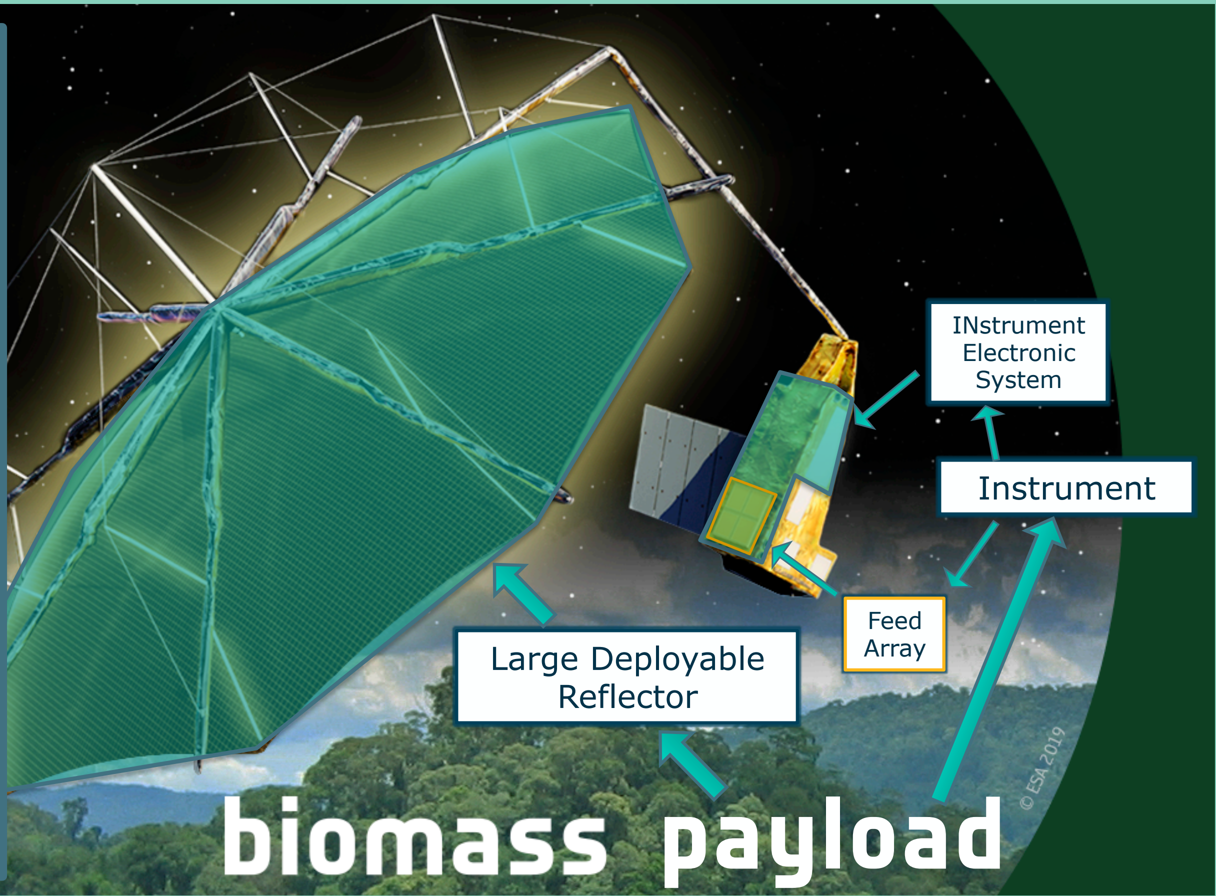
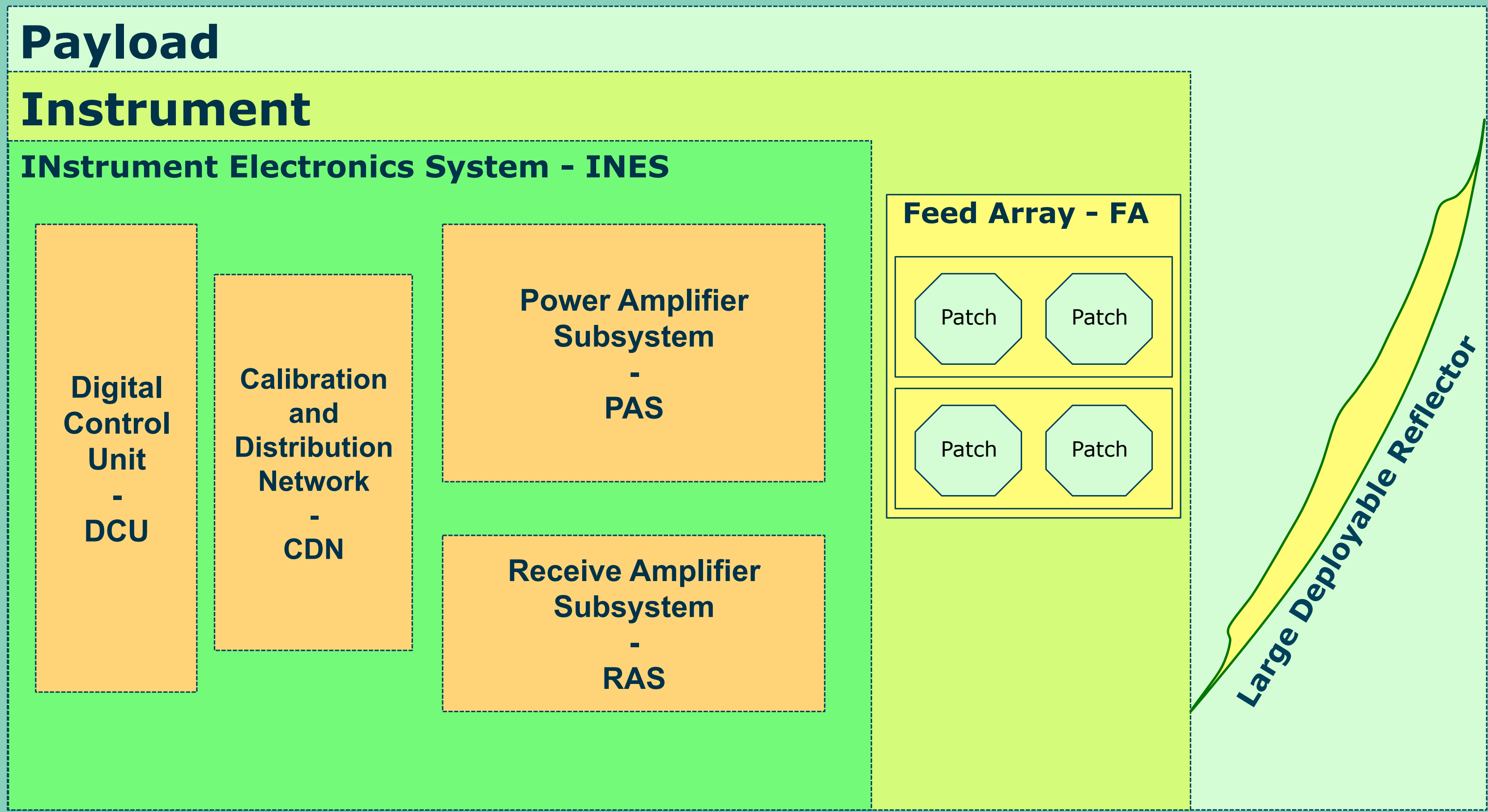
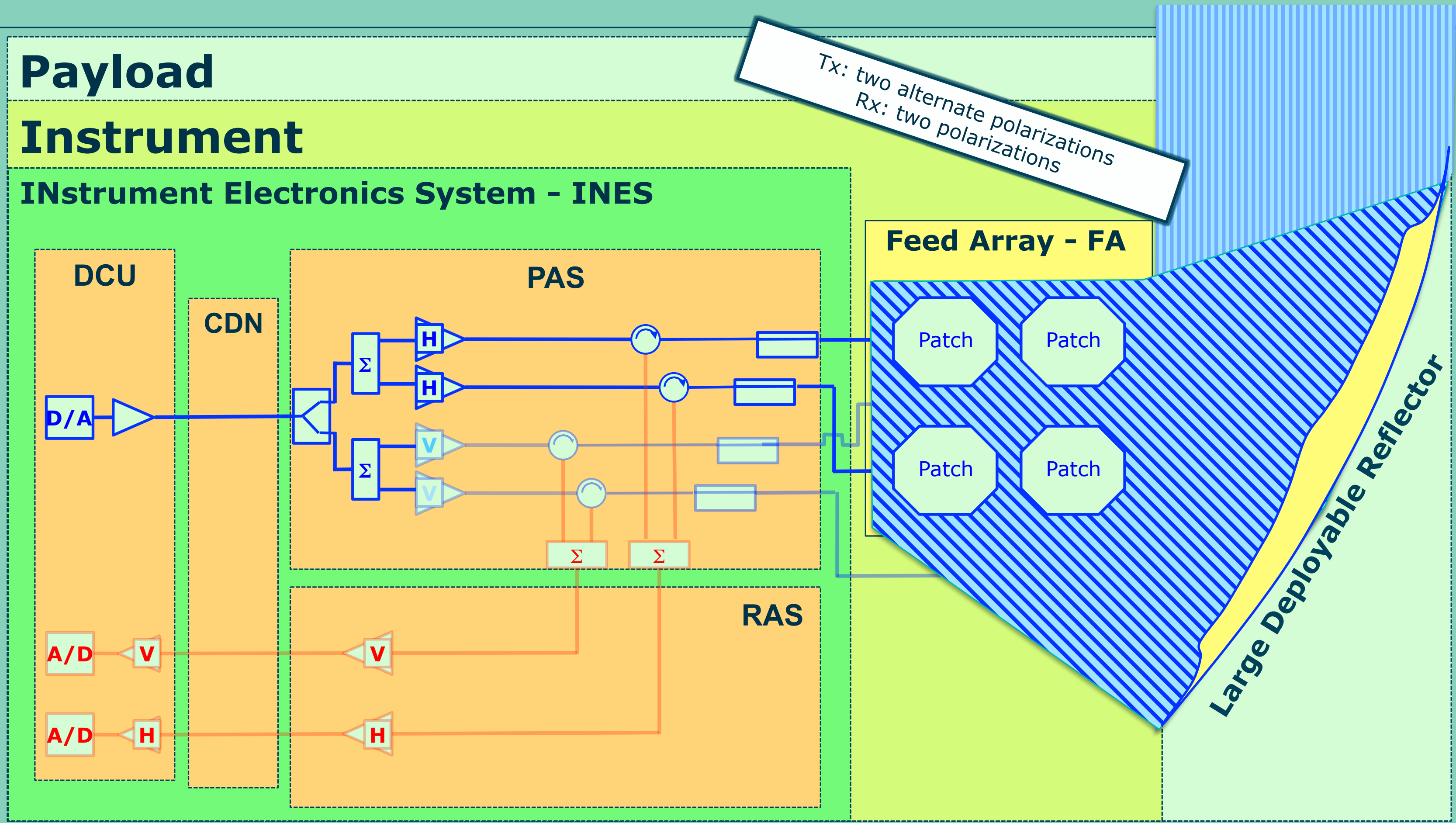


Biomass SAR Instrument: Nomenclature and breakdown



Biomass SAR Instrument: Full polarization



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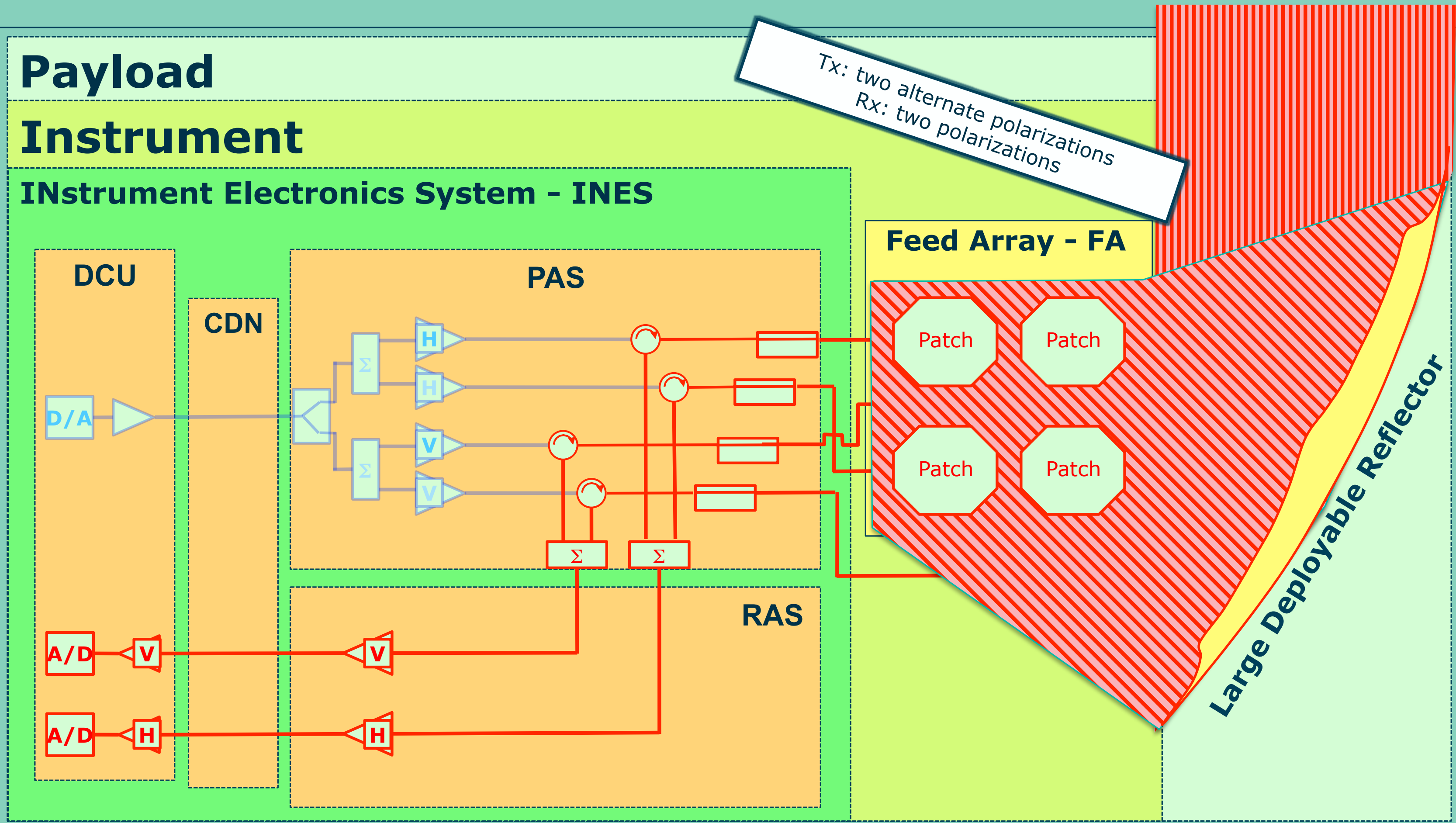

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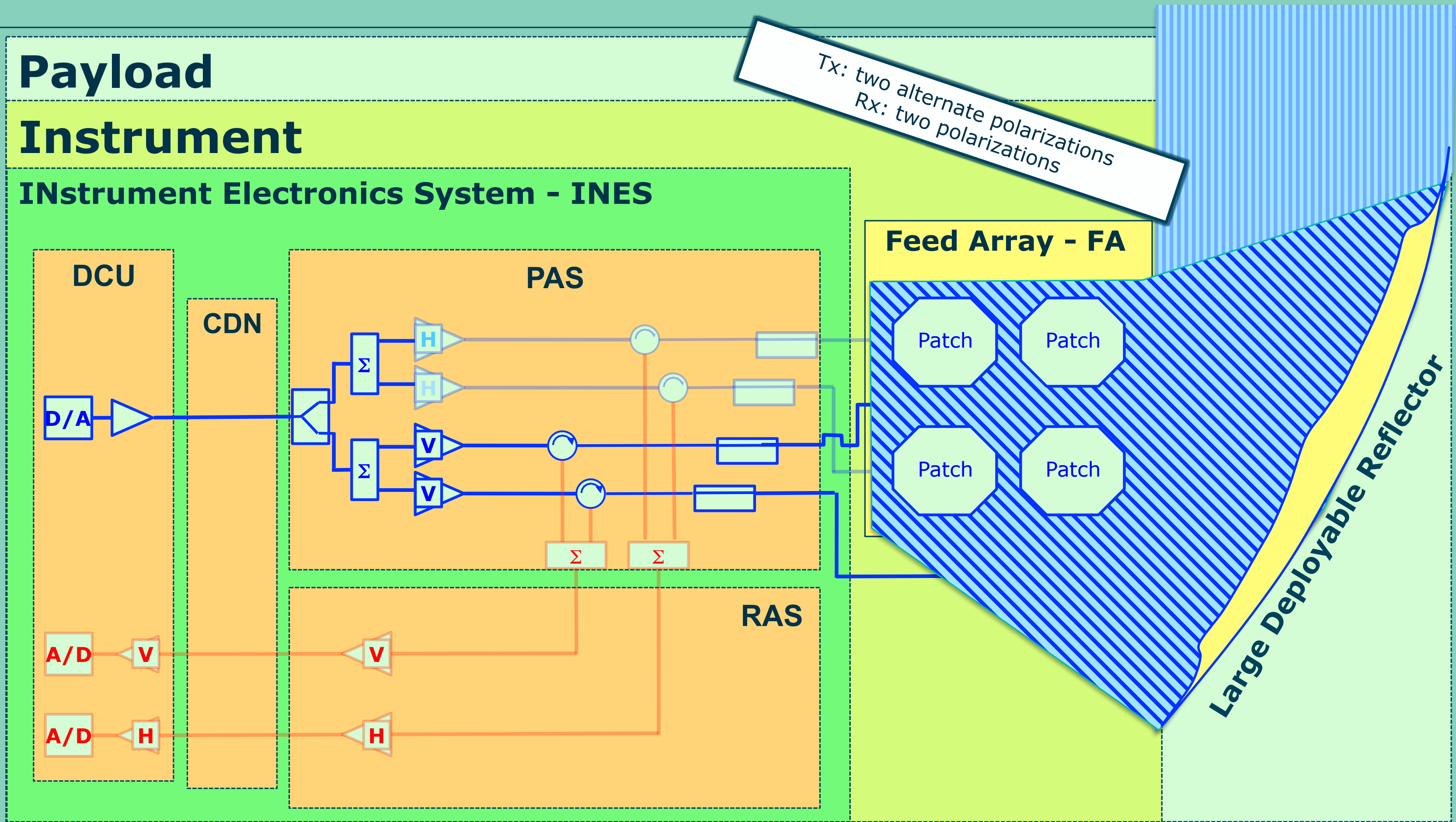

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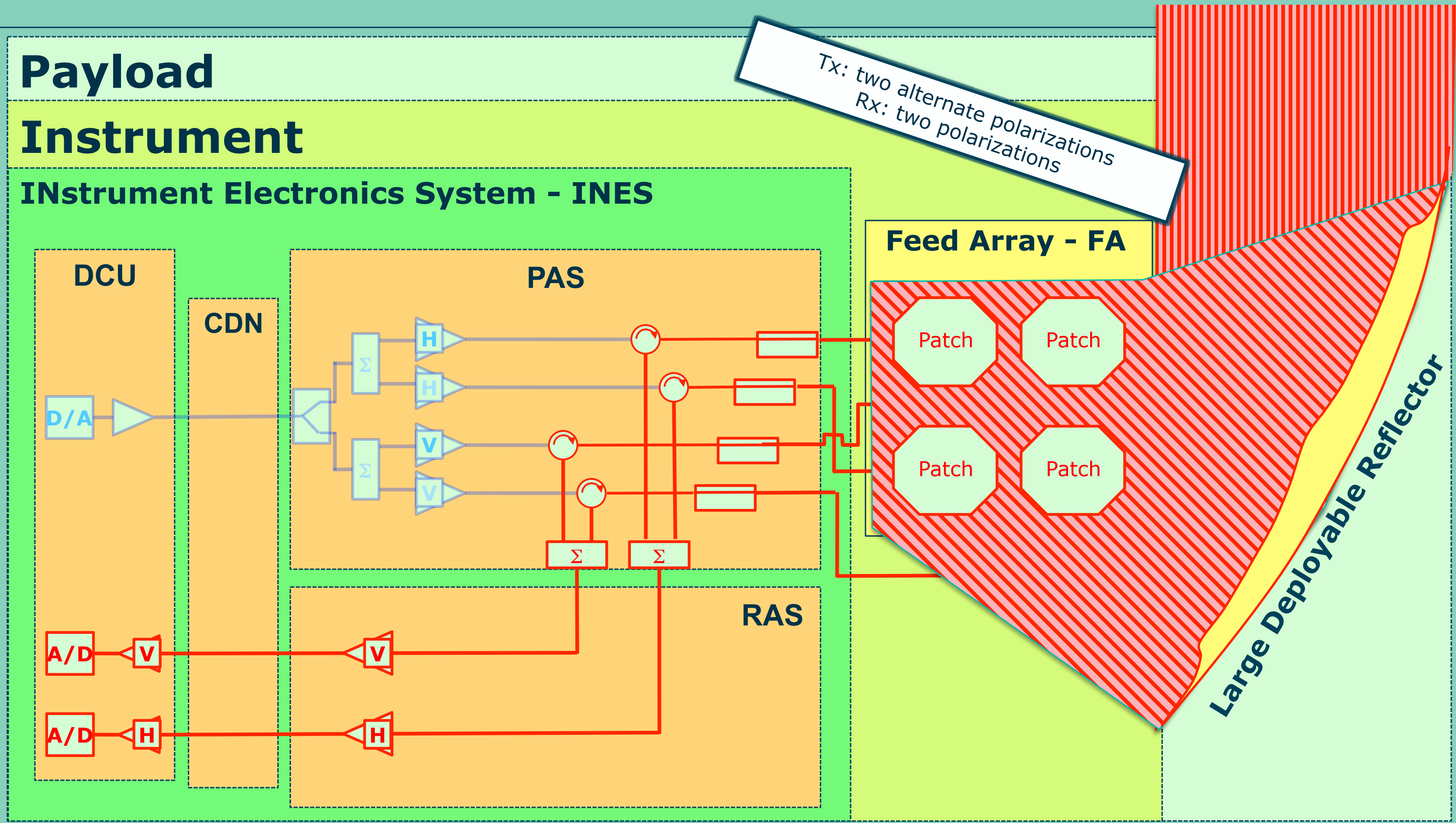
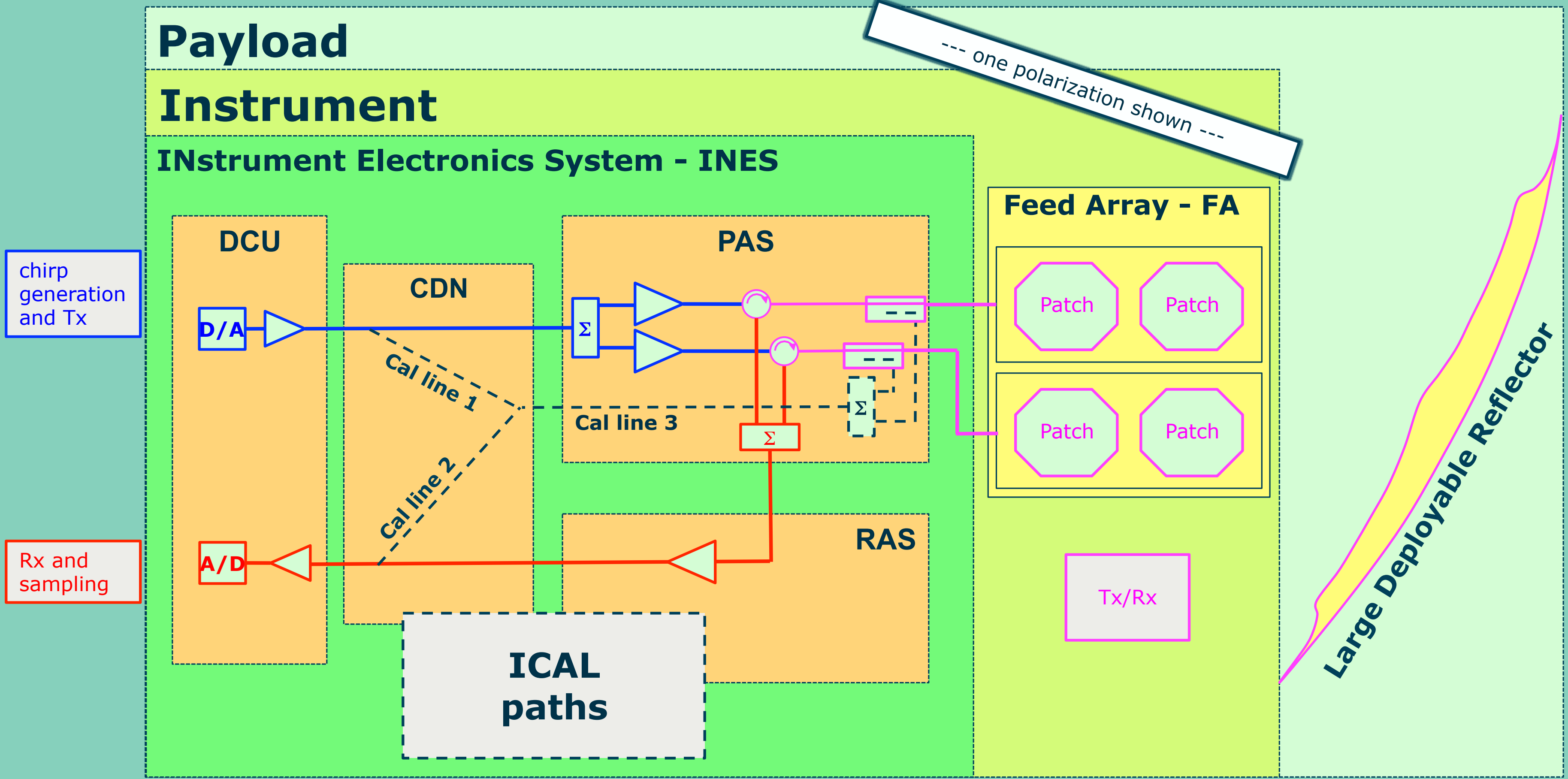
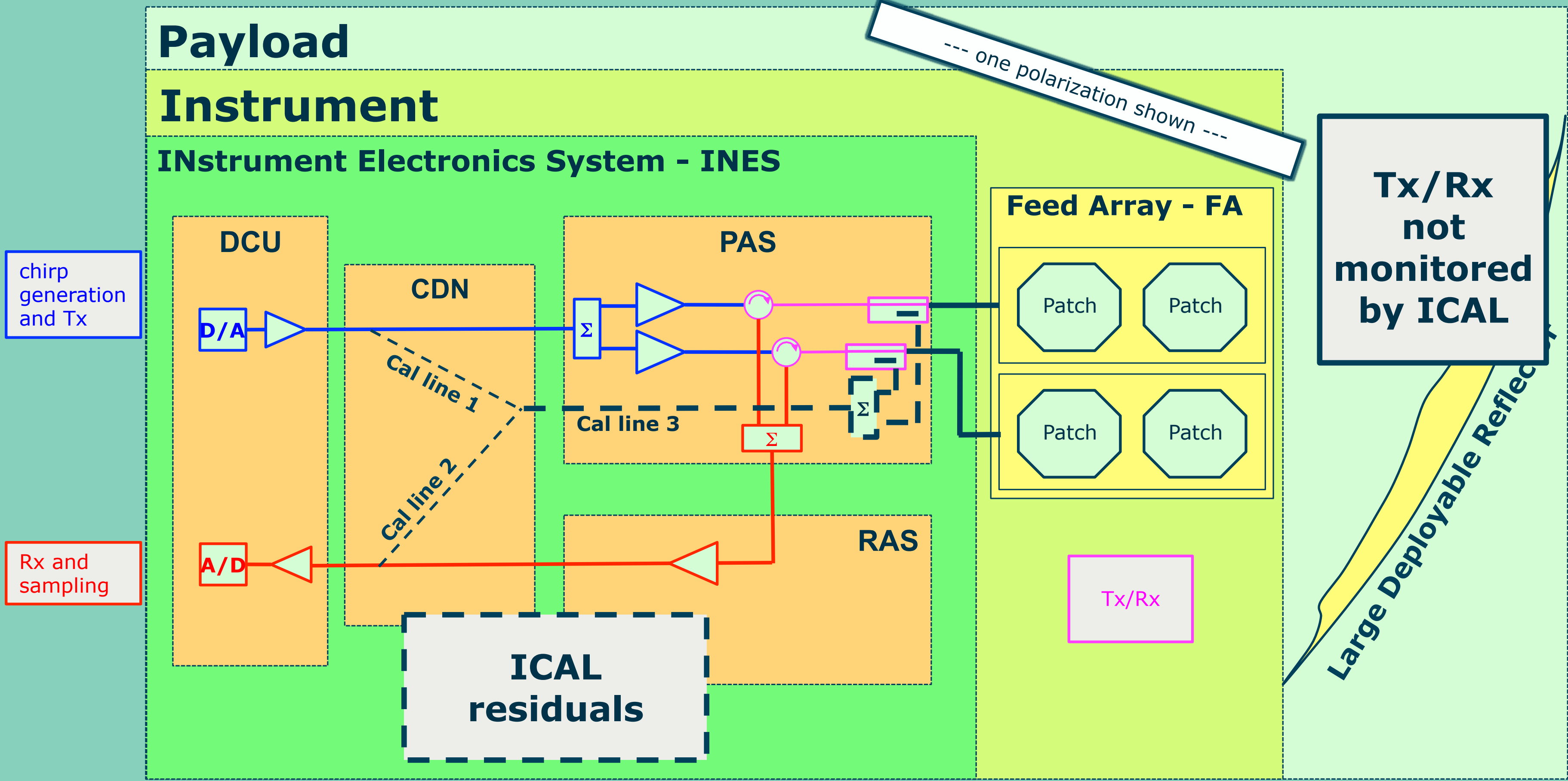


Biomass SAR Instrument: Internal calibration (ICAL)



Biomass SAR Instrument: ICAL residual/Charact./Ext. calibration



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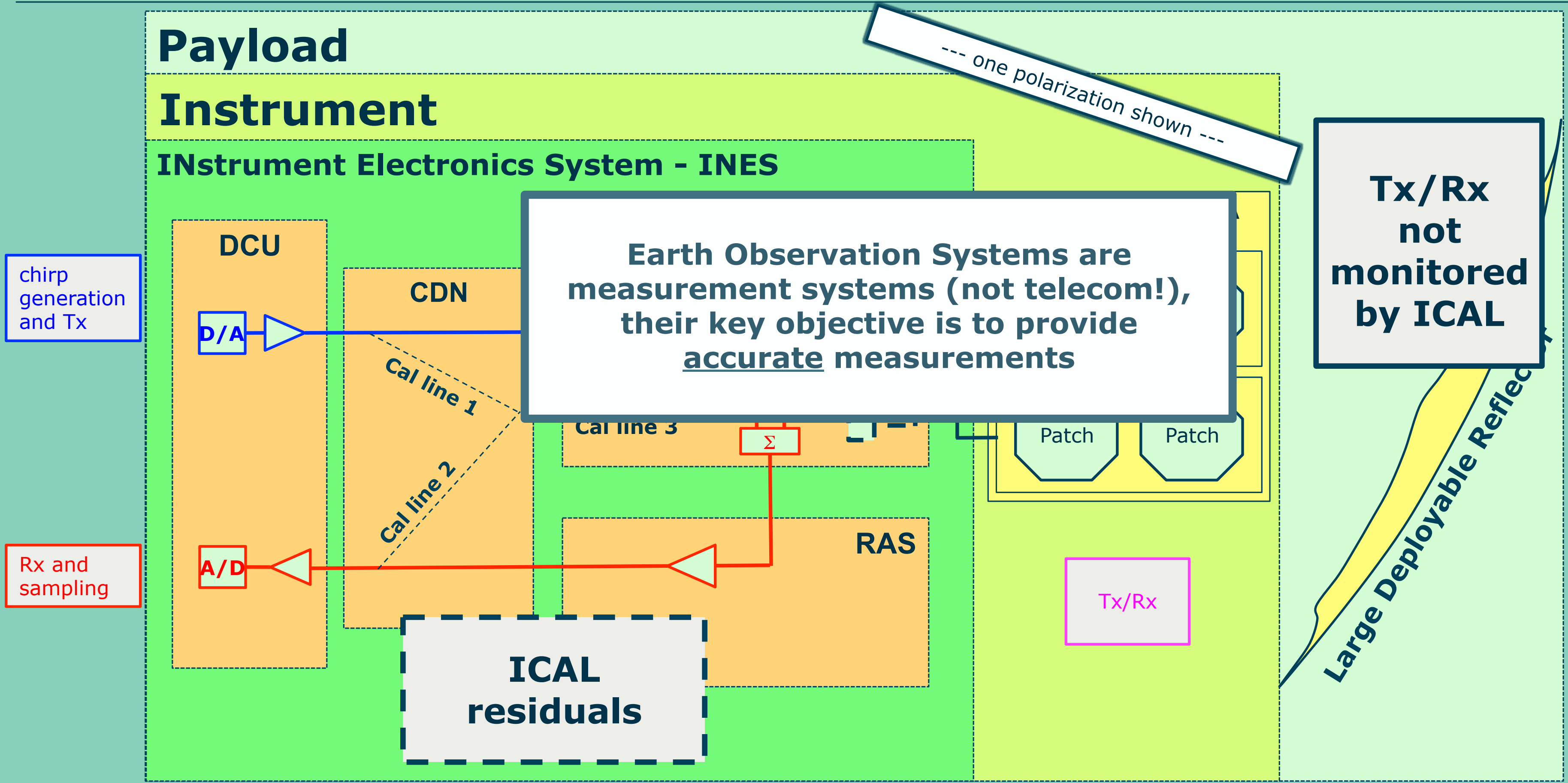

Earth Observation Systems are measurement systems (not telecom!), their key objective is to provide <u>accurate</u> measurements

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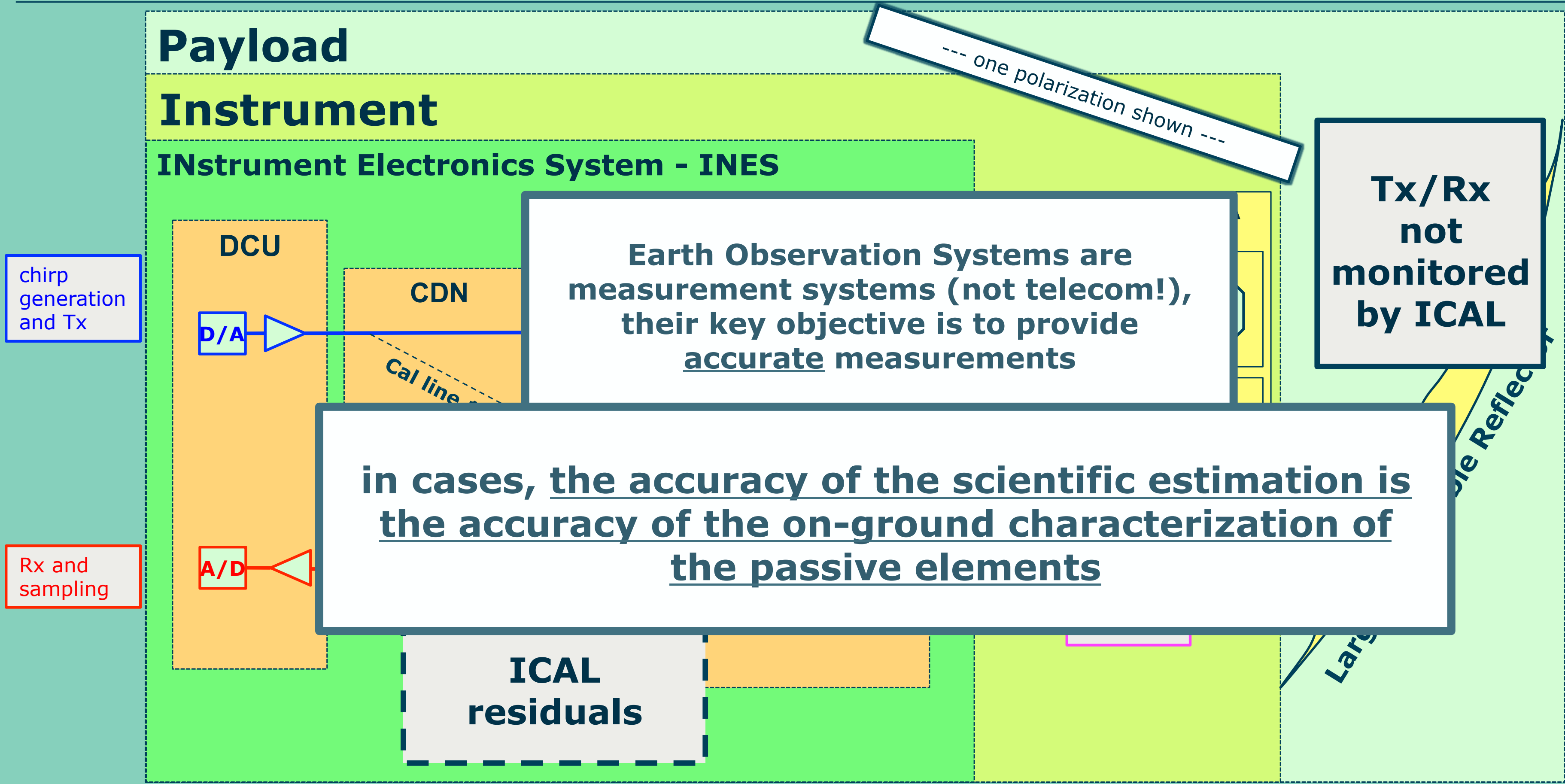

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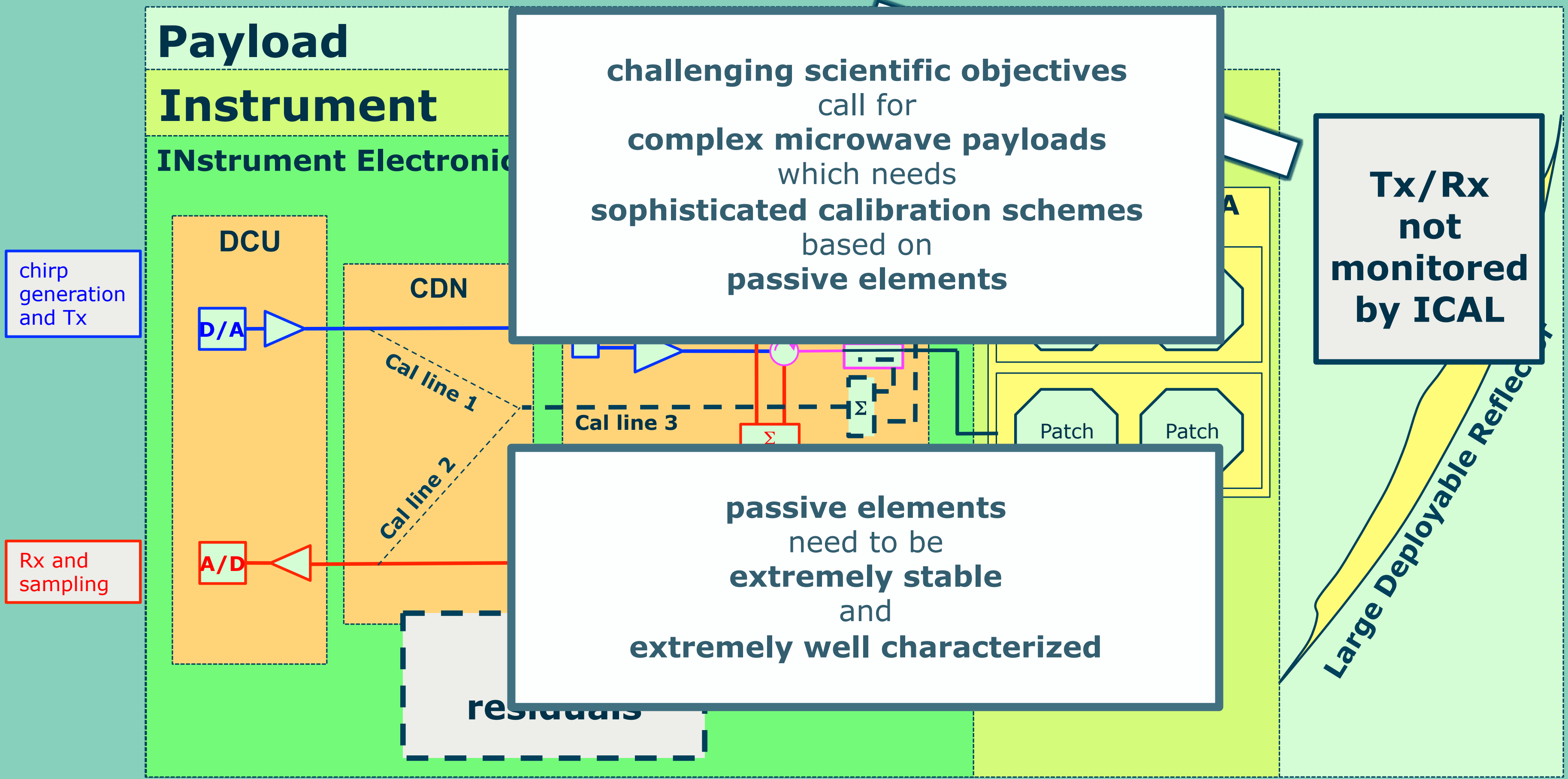
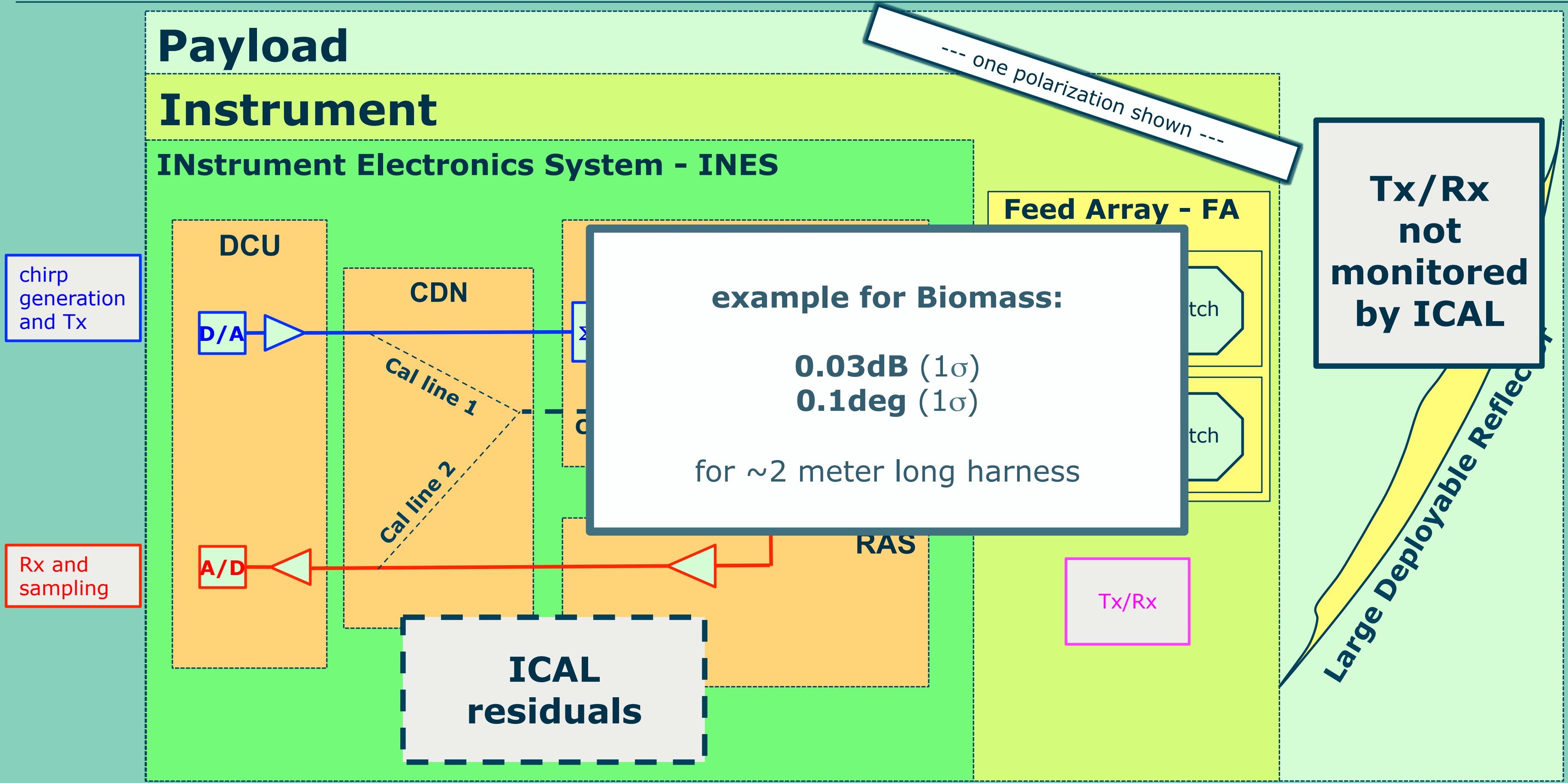


challenging scientific objectives
call for
complex microwave payloads
which needs
sophisticated calibration schemes
based on
passive elements

passive elements
need to be
extremely stable
and
extremely well characterized

Biomass SAR Instrument: ICAL residual/Charact./Ext. calibration



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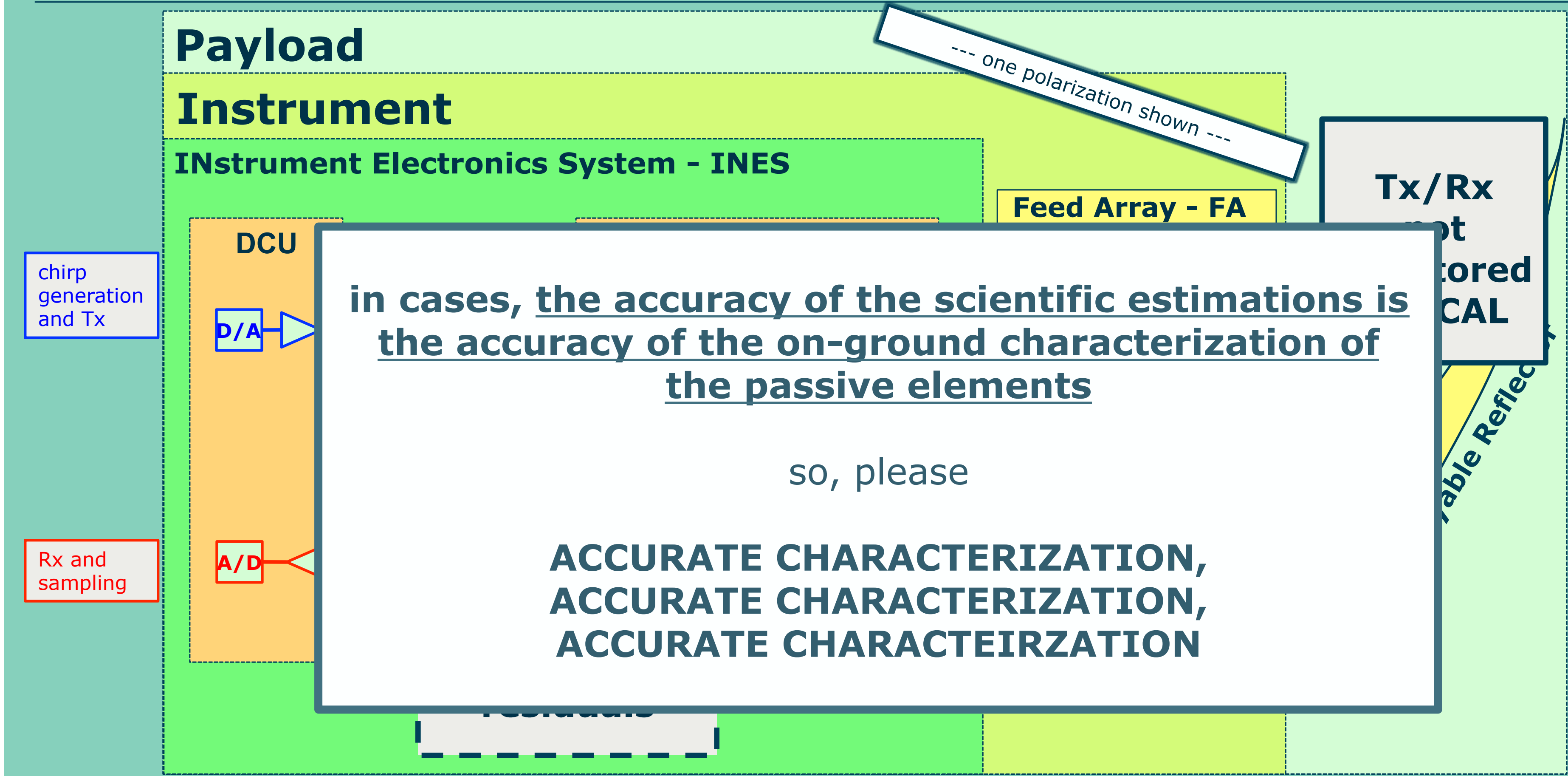

in cases, the accuracy of the scientific estimations is the accuracy of the on-ground characterization of the passive elements

so, please

ACCURATE CHARACTERIZATION,
ACCURATE CHARACTERIZATION,
ACCURATE CHARACTEIRZATION

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- **Multipaction: a special topic**
- **Some other passive EEE topics**
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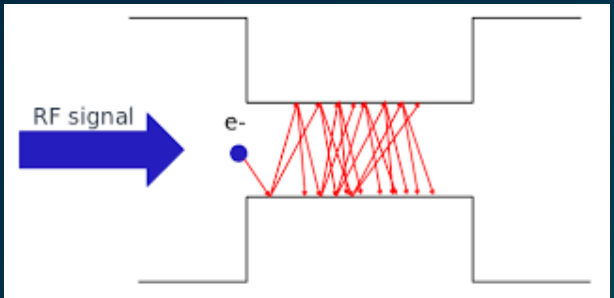
Multipactor Challenges

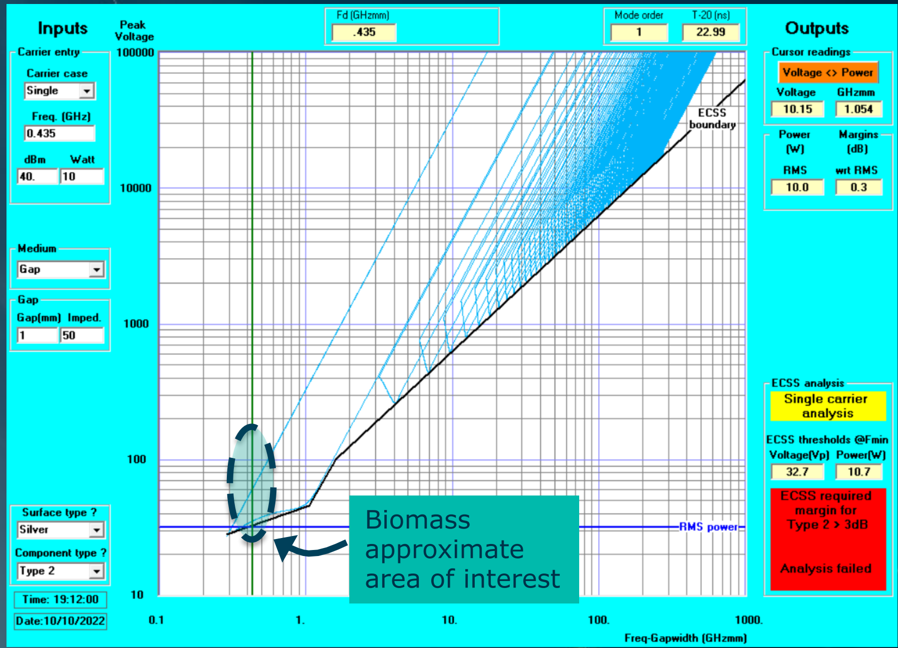
Multipactor effect is a RF breakdown in vacuum phenomenon, where, under certain conditions, secondary electron emission in resonance with an alternating electric field leads to exponential electron multiplication (electron avalanche), possibly damaging and even destroying the RF device.



The following parameters:

- Frequency = 435MHz
- Power =10W
- Gap > 1mm

can theoretically trigger a multipaction discharge!



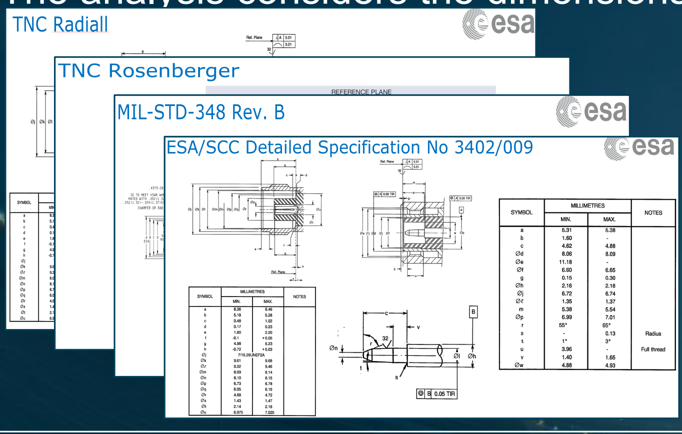
Multipactor Challenges: TNC Connectors

Each Payload subsystem is composed of a number of stand-alone RF modules equipped with coaxial connectors, then interconnected by RF coaxial cables.

There is a different supplier for each module/equipment. This implies a compatibility issue between the interface of the RF harness and the equipment/components.

A detailed verification by analysis of the compatibility with respect to multipactor discharge between the TNC connectors of the equipments/components and those of the RF coaxial cables has been carried out.

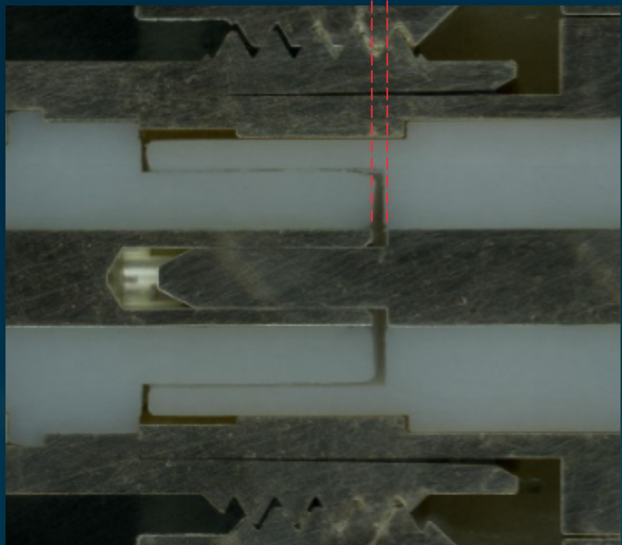
The analysis considers the dimensions and tolerances of the interfaces between different connectors' .

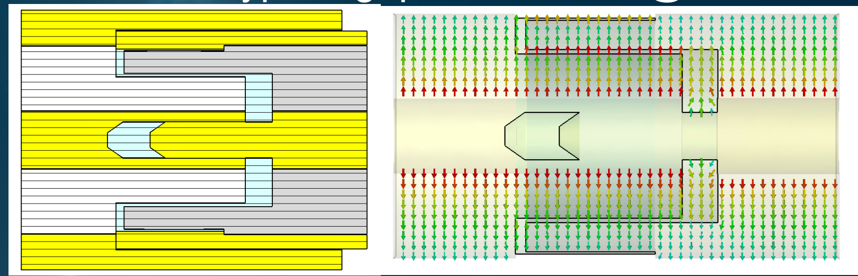


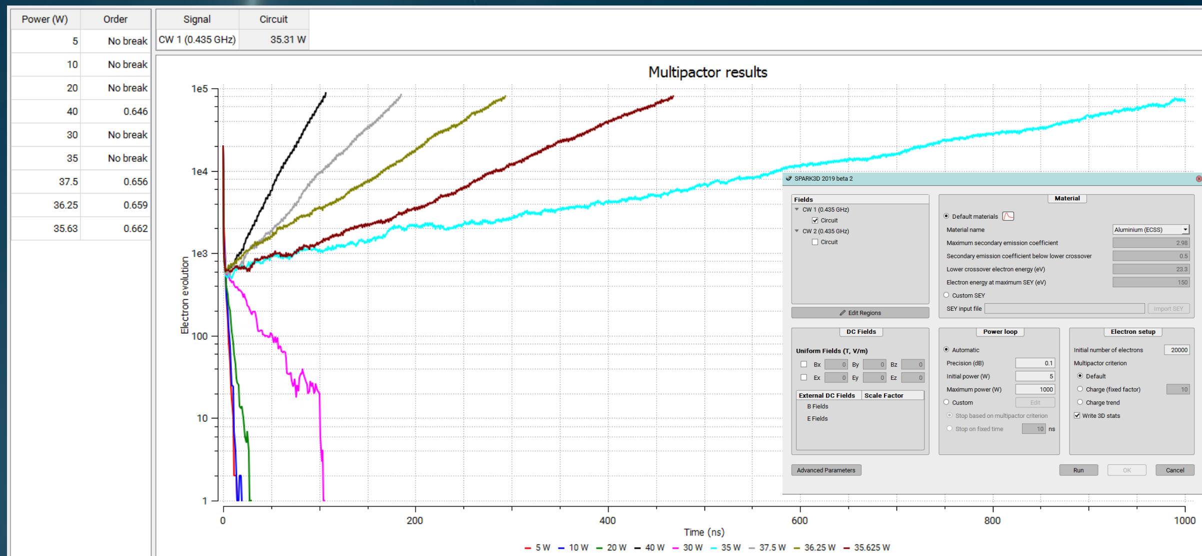
			ROSENBERGER		RADIALL		No 3402/009		MIL-STD-348	
			Min	*Max*	*Min*	*Max*	*Min*	*Max*	*Min*	*Max*
Dimensions in Cross-section	Male	Φ Inner Connector	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Φ Internal PTFE	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
		Φ External PTFE			[illegible]	[illegible]	[illegible]	[illegible]		
		Φ Internal Housing			[illegible]	[illegible]	[illegible]	[illegible]		
	Female	Φ External PTFE		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
		Φ Internal Housing	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Longitudinal Dimensions	Male	Depth PTFE wrt Ref	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Depth Ref to PTFE			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
	Female	Length PTFE wrt Ref	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Multipactor Challenges: TNC Connectors

SPARK 3D simulations show breakdown starting from 35W for a typical gap of ~0.7 mm @435MHz:





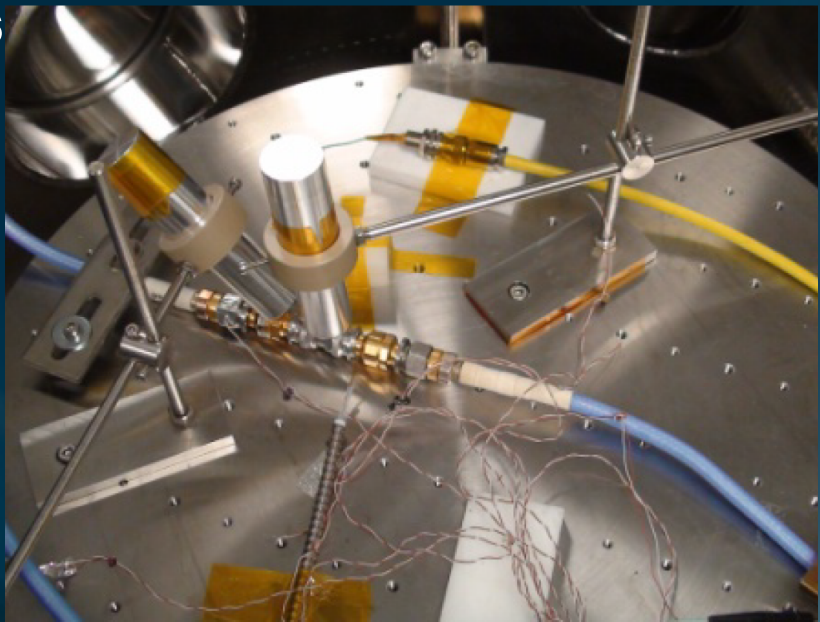


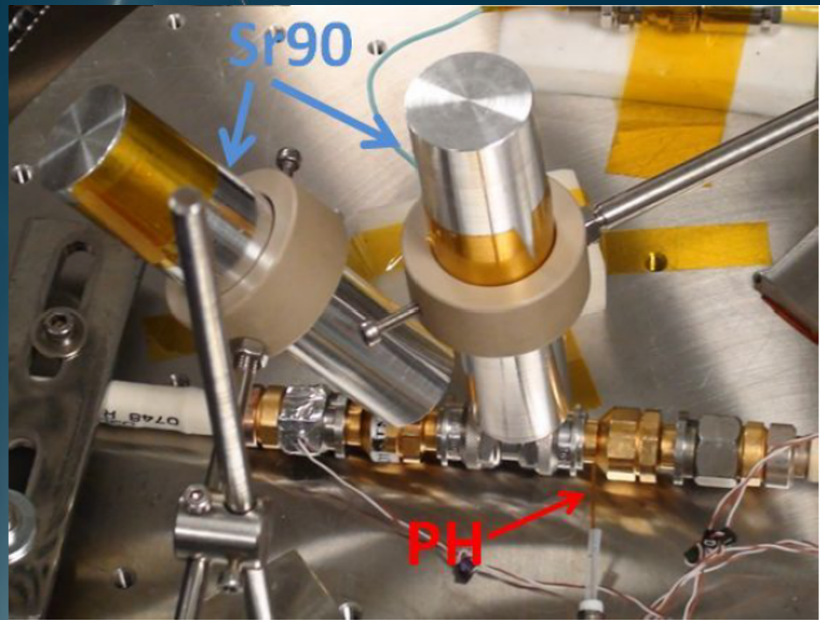
Power (W)	Order
5	No break
10	No break
20	No break
40	0.646
30	No break
35	No break
37.5	0.656
36.25	0.659
35.63	0.662

Multipactor Challenges: TNC Connectors

First tests show multipaction at 25W.

After shimming between connectors from different manufacturers: no threshold crossings were seen up to 6

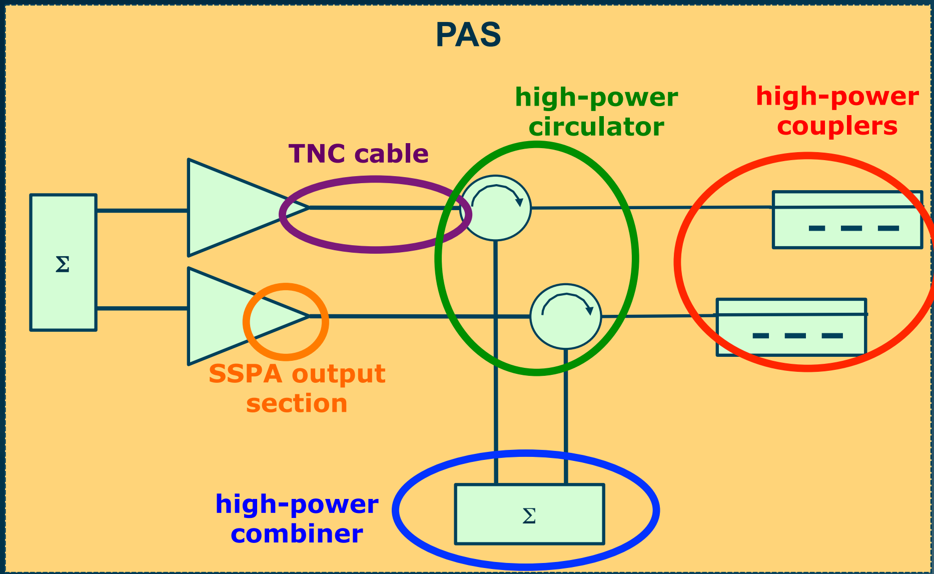




435 MHz	no Discharges up to at least 600 W

Multipactor Challenges: PAS RF Passive Components

The PAS subsystem is the subsystem that handles and transmit the RF high power to the **antenna**



Note: RF switch was treated as a self-standing equipment so multipaction was treated at that level (within the qualification of the equipment)

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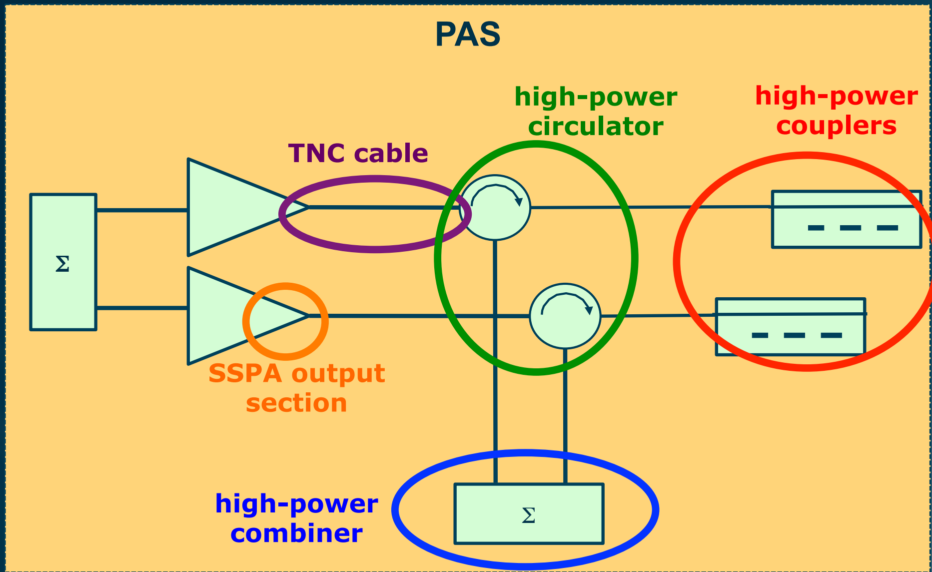

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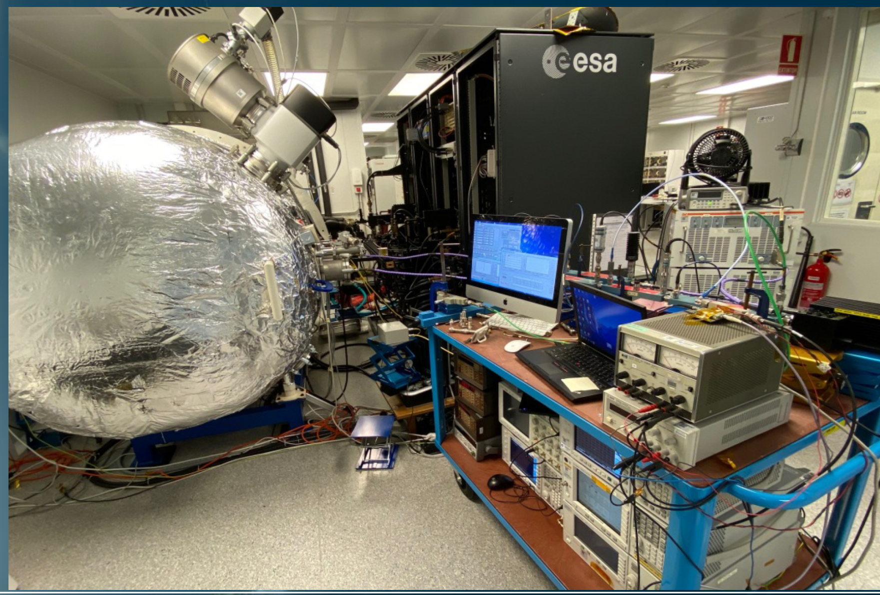


Multipaction tests were conducted at the European High Power Laboratory in Valencia (Spain) on the following critical RF Passive parts:
(see next slide)

Multipactor Challenges: PAS RF Passive Components

High Power Combiner (Cobham)

High Power Coupler (Cobham)

High Power Coaxial Circulator (Cobham)

RF TNC Cable Assemblies (Times Microwave)

SSPA Output section (LND & Cobham)

Frequency = 435 MHz – RF Power up to ~800Wp

Temperature = -30C +60C

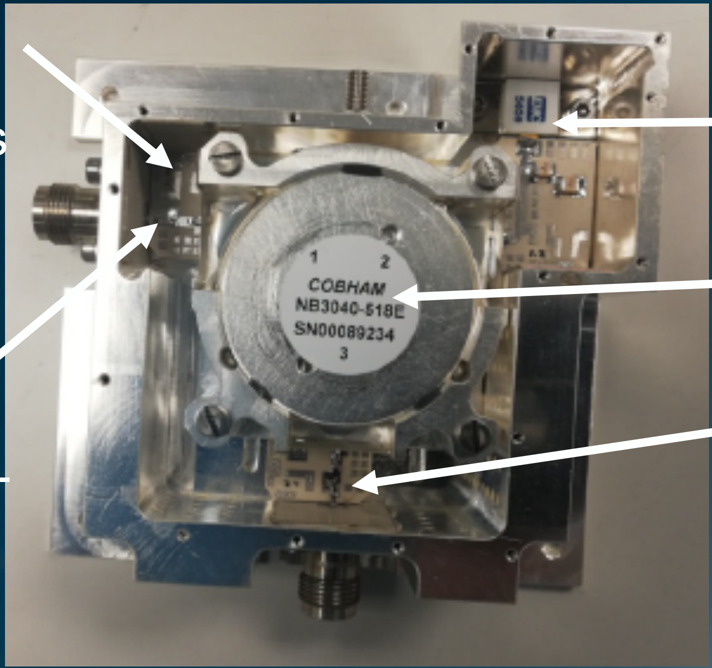
Different conditions:

- Full reflection and Matched output with maximum level for the Coupler
- Forward configuration for the Combiner
- Forward and Full reflection for the Circulator
- Forward for the RF Cable Assemblies
- Forward and Full reflection for the SSPA Output section

Multipactor Tests: a specific example

SSPA Output power section (LND & Cobham)

Chip Capacitors

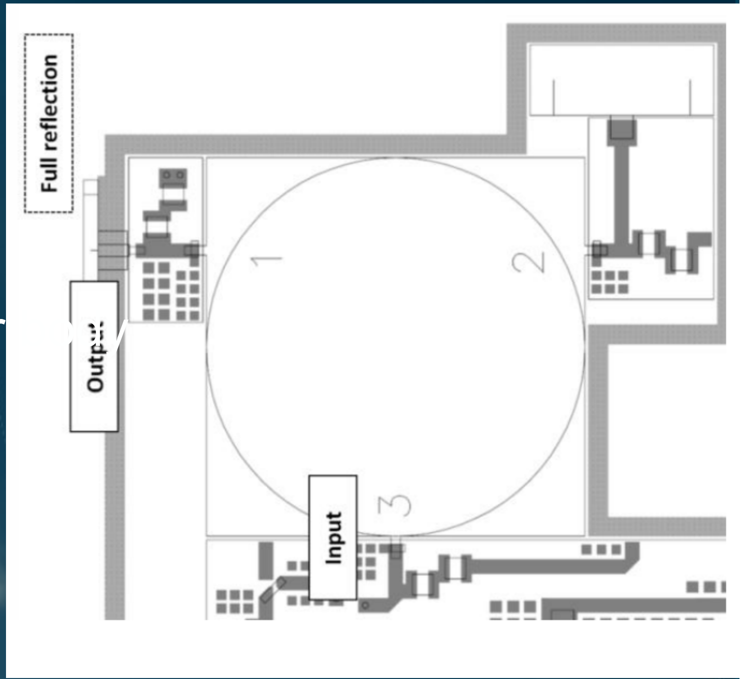


Loaded port section: **resistors**

RF Circulator

Output Microstrip-to-TNC transition

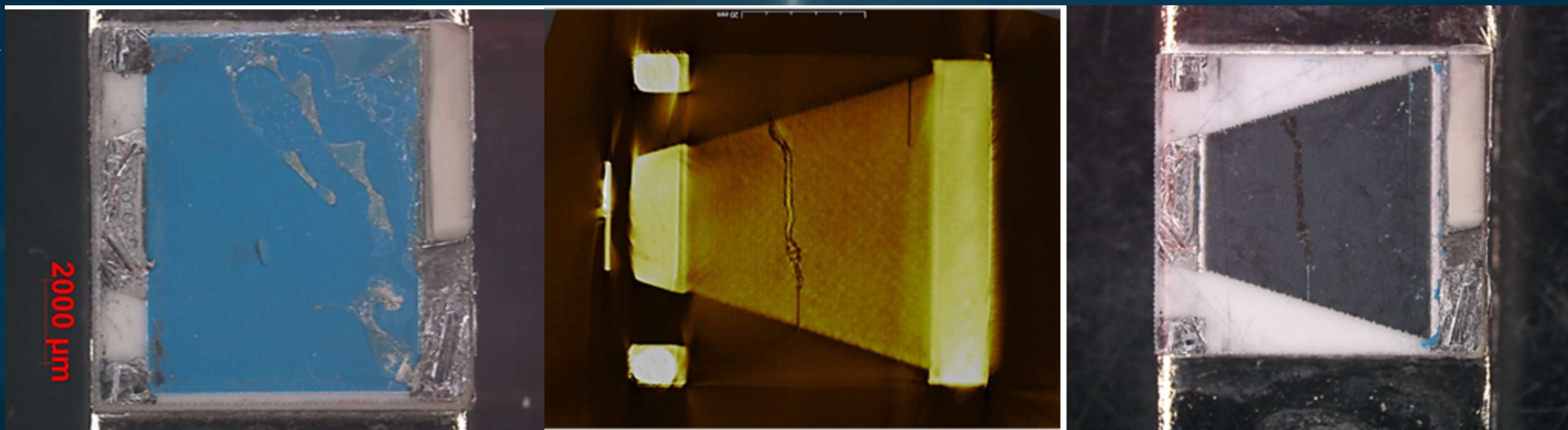
Input Microstrip-to-TNC transition



It was detected one discharge after 15 minutes at 630 W peak. Both local and global methods were triggered. After this anomaly, the return losses suffered degradation to around 3dB. Measurement of the commercial load shows an open circuit (9K Ohm!).

Multipactor Challenges: a resistor multipaction

- The electrical arcing has been produced at the end of the trimming line of the internal impedance transformer adaptation of the commercial load.
- The resistance has dropped locally at this end point due to an increase in temperature, this implied an electrical arcing, with a concentration of the arc fault current and voltage at one place (the end of the trimming line). The arc has then propagated to the nearest ground and crossed and damaged the resistive layer.
- The ca



plied power.

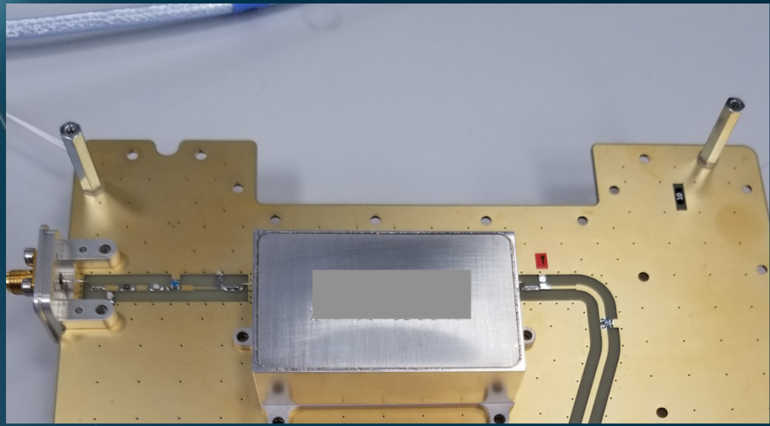
- MP were performed again on the output power section with a proper space quality level of the RF chip

Multipaction: Conclusions & Lessons Learned

- The “claimed” heritage was not valid, mainly due to the specific requirements of BIOMASS, mainly low frequency (P-band) and High Power (~200W).
- Multipaction Analysis were giving a certain confidence on some parts. However, proper and representative (including flight model quality) Multipactor tests were performed as per BIOMASS’s requirements and including assembly/mounting conditions (e.g. SMT/microstrip parts, torque of connectors, etc.)
- Adding Teflon shim (suitable gasket) sheets between connectors helps to fill the gaps and reduce risk of multipaction discharges.
- Internal filling with a proper potting in the internal designs of RF parts helps fills the gaps, as well as adding proper coating on SMT/microstrip interfaces.
- Qualification tests of the payload instrument equipment show good results!

RF filters

Challenging activity: difficult qualification/ acceptance



Several actions were taken and lesson learned:

- Improve the internal design and to procure such filters as RF filters (or, even as equipment!) instead of hybrids.
- Adapt the LAT (Group C) testing to the project requirements, flight representative test flow with margin (i.e. thermal range, constant acceleration down to e.g. 250g).
- Add CSAM inspections (in-process control, screening and LAT) to be able to properly screen the parts and check the evolution of internal soldering/attachment and voids.

RF filters

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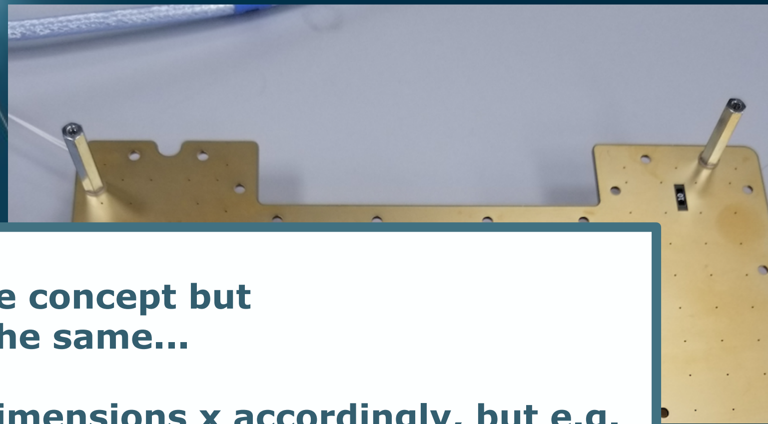

Note: scaling is a valuable concept but not everything scale the same...

adapting for longer wavelength -->> scale dimensions x accordingly, but e.g.

surface areas scale with the square: x^2
weight scale with the cube: x^3 !

Several actions

- Improve the ... stead of hybrids.
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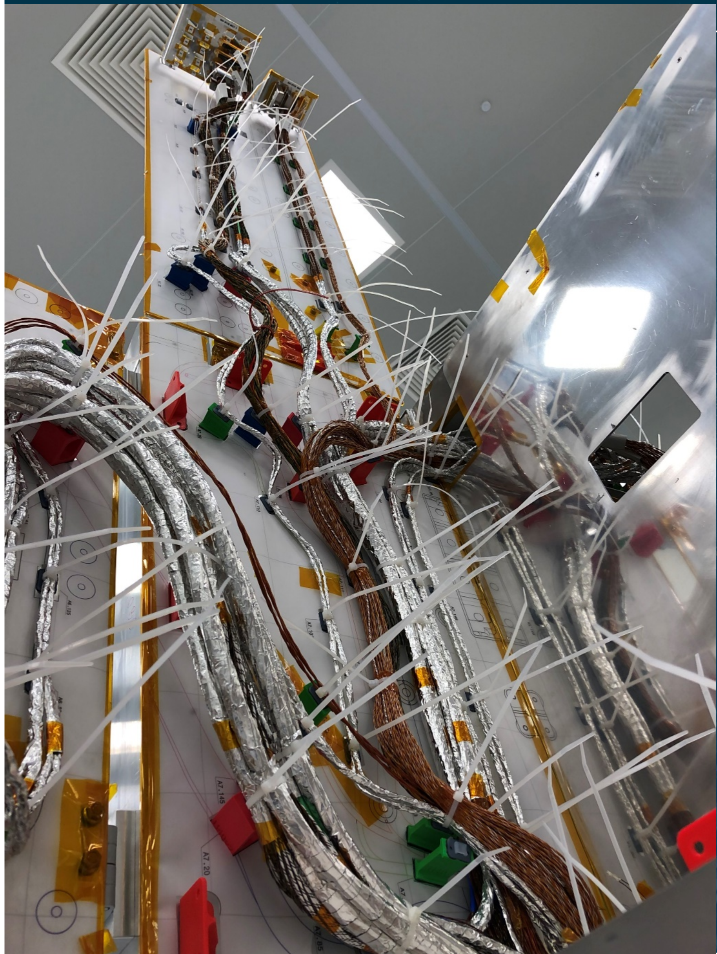
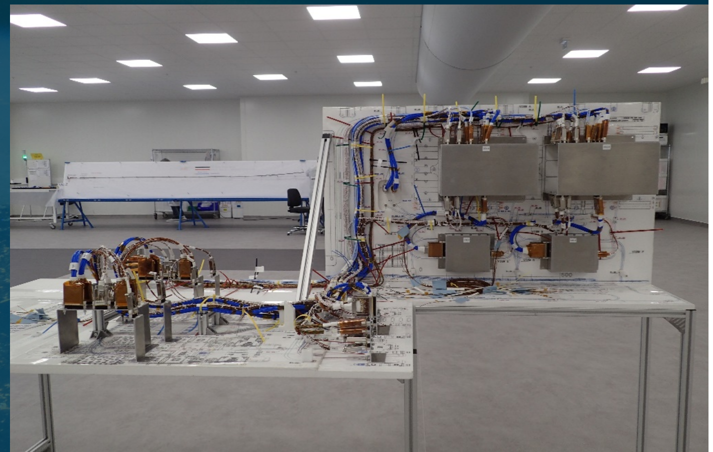
S/C Flight Harness + Payload Instrument Harness

esa



DC, Power, RF and Wizardlink Harness



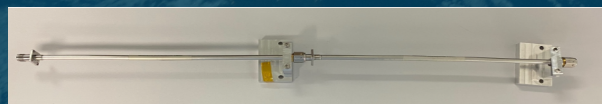
Procurement of ESCC QPL components (or according to) :

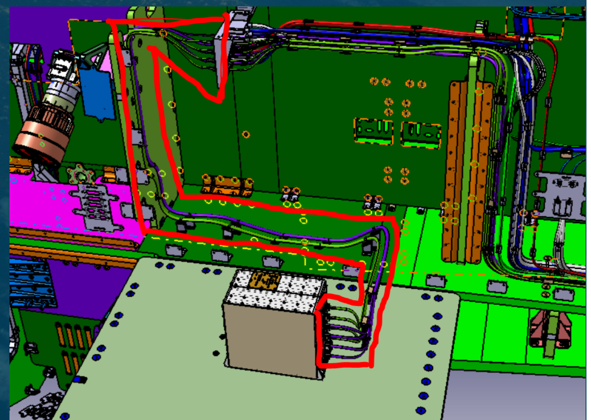
ESCC 3401, ESCC3402, ESCC3901, ESCC3902, ESCC3408

Project qualification:

Axowave (AXON, FR) for Wizardlink (high data transfer).

+ SiO2 RF phase-stable semi-rigid (Times Microwave)



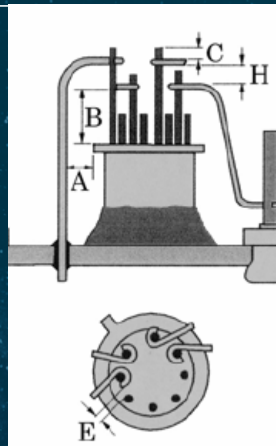


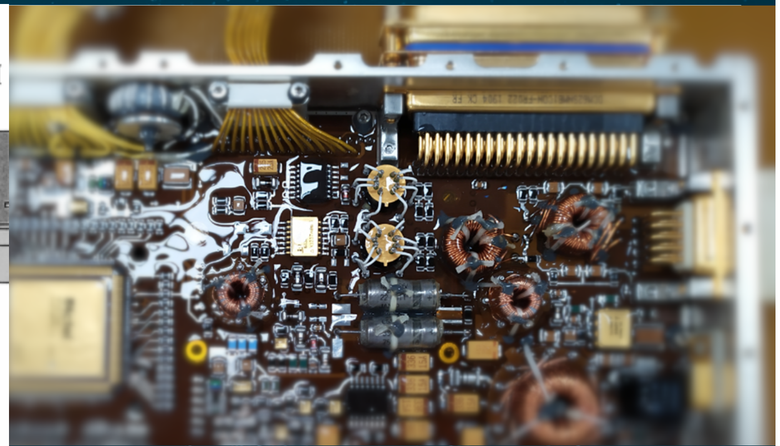
SMT related issues: Relays upside/down

- Relays (as well as oscillators, switches, crystals) are considered as sensitive parts to mechanical loads.

- TO-5 relay has been mounted upside/down!

- This Relay is QPL but has not been tested in this specific mounting conditions.





- At the time of the procurement, ECSS-Q-ST-70-08 allowed this specific mounting for TO-5 package, **without** any verification assembly (i.e. 500 thermal cycling, vibration and DPA).

- ESA Recommendation was to :

1. Verify that the relay has been procured properly, i.e. QPL or with LAT testing including vibration and shock on the three axes,

2. Ensure QM have been mechanically tested and relays have successfully switched afterwards,

3. Use a less rigid adhesive, i.e. flexible adhesive based on Silicone instead of rigid adhesive.

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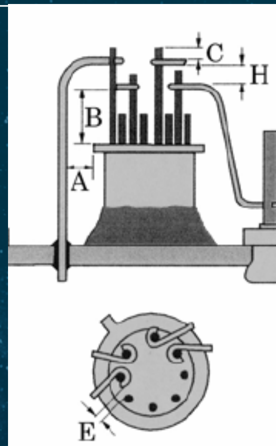
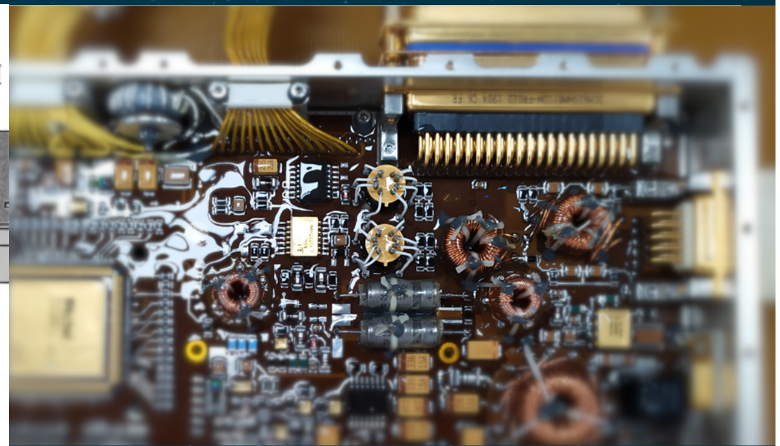
- TO-5 relay has been mounted upside/down!
- This Relay is QPL but has not been tested in this specific mounting conditions.





- ECSS-Q-ST-70-08C Standard has been cancelled and superseded **by ECSS-Q-ST-70-61C,** since April 2022. This new standard do NOT allow this specific mounting configuration for components sensitive to mechanical loads, unless a proper verification assembly campaign has been conducted.

ECSS-Q-ST-70-61_1510331

Components sensitive to vibrations and shock tests shall not be assembled as described in requirement 8.2.6a.

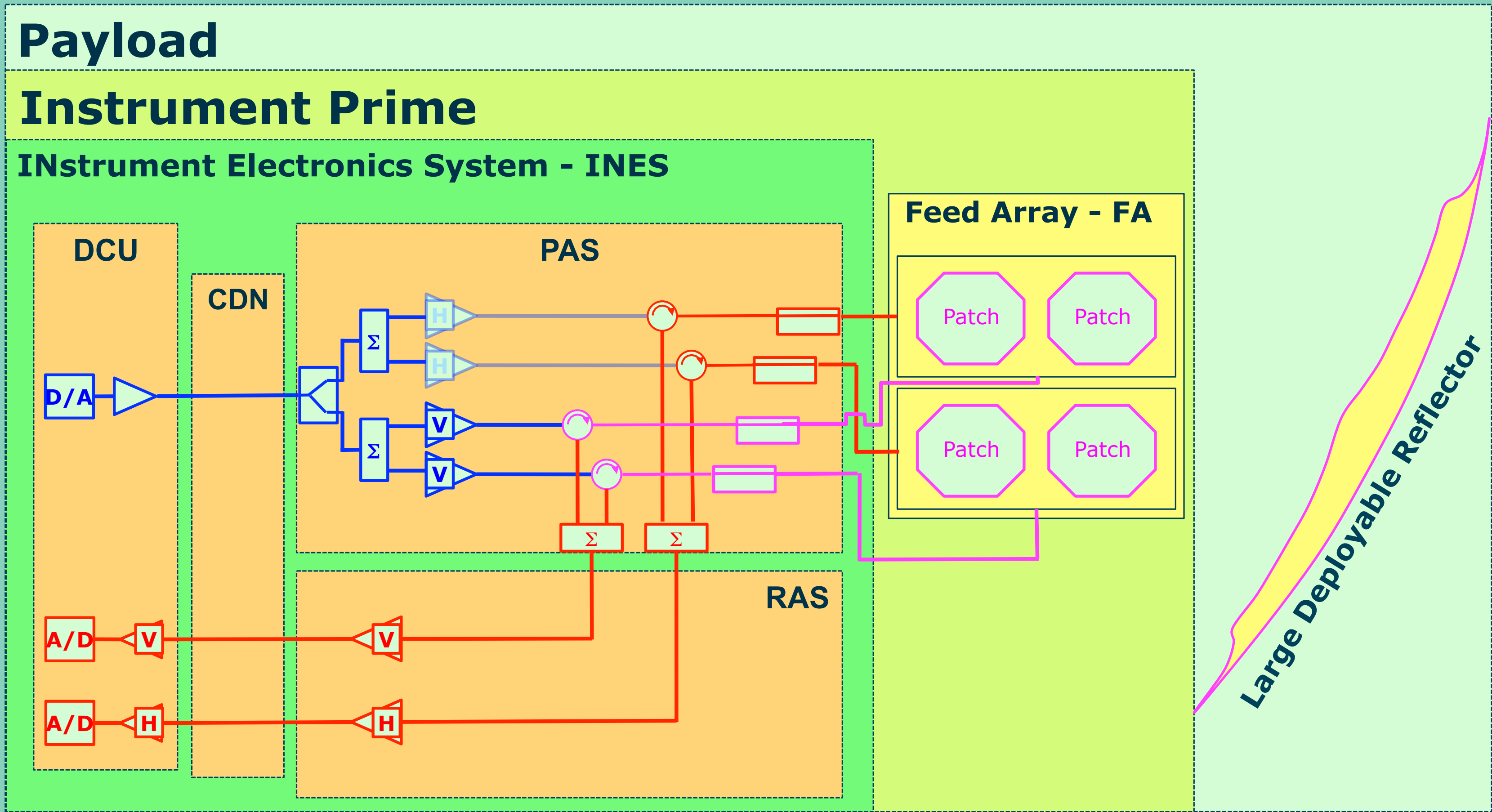
NOTE Examples of such sensitive components are: relays, oscillators, crystals. ECSS-E-HB-32-25A is providing a list of components known as sensitive to vibration and shock.

Outline

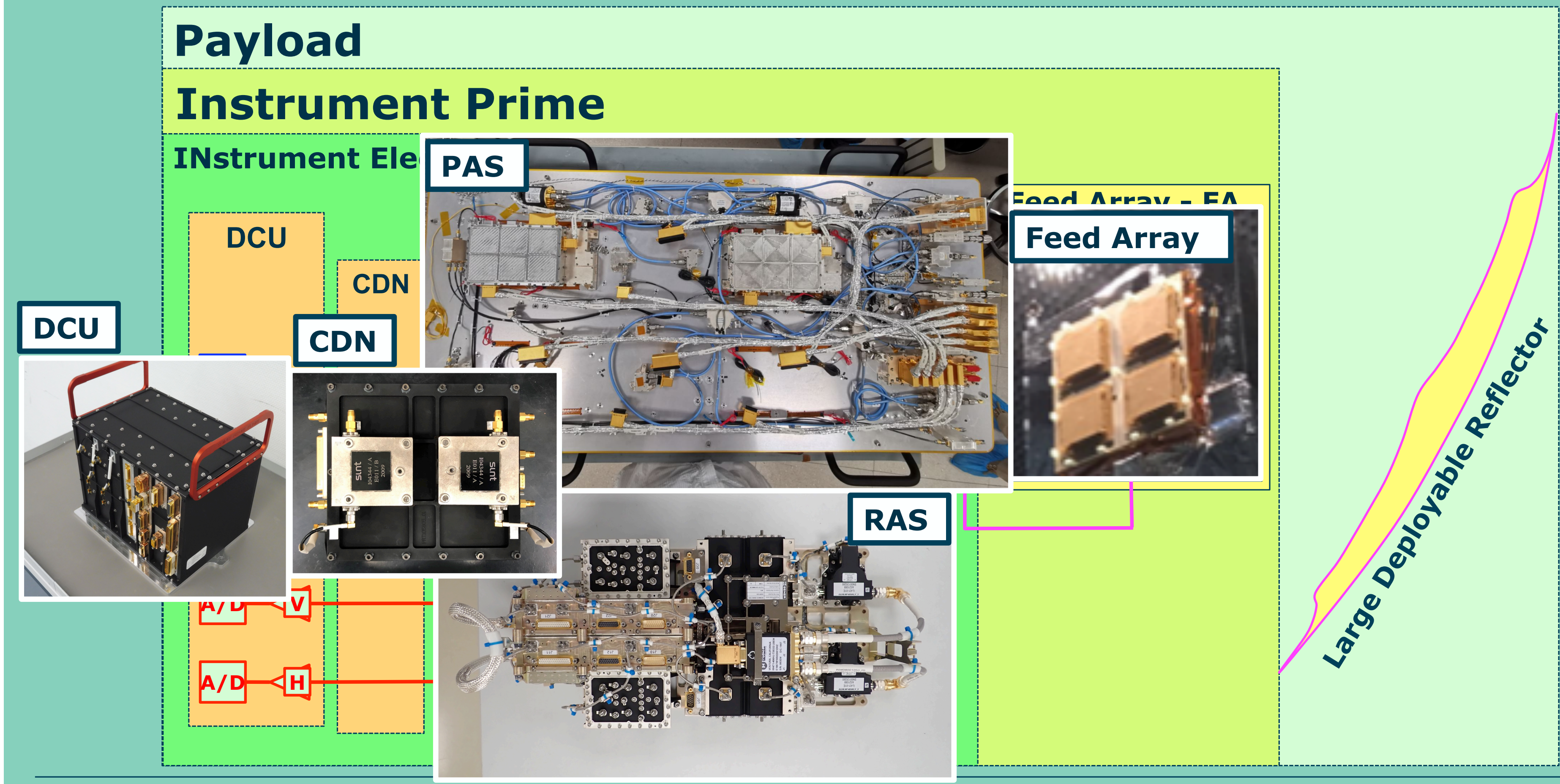
- Biomass mission, its objectives and its satellite ✓
- Biomass Payload ✓
- Payload calibration and the importance of the passive elements ✓

- Multipaction: a special topic ✓
- Some other passive EEE topics ✓
- **Mission status**

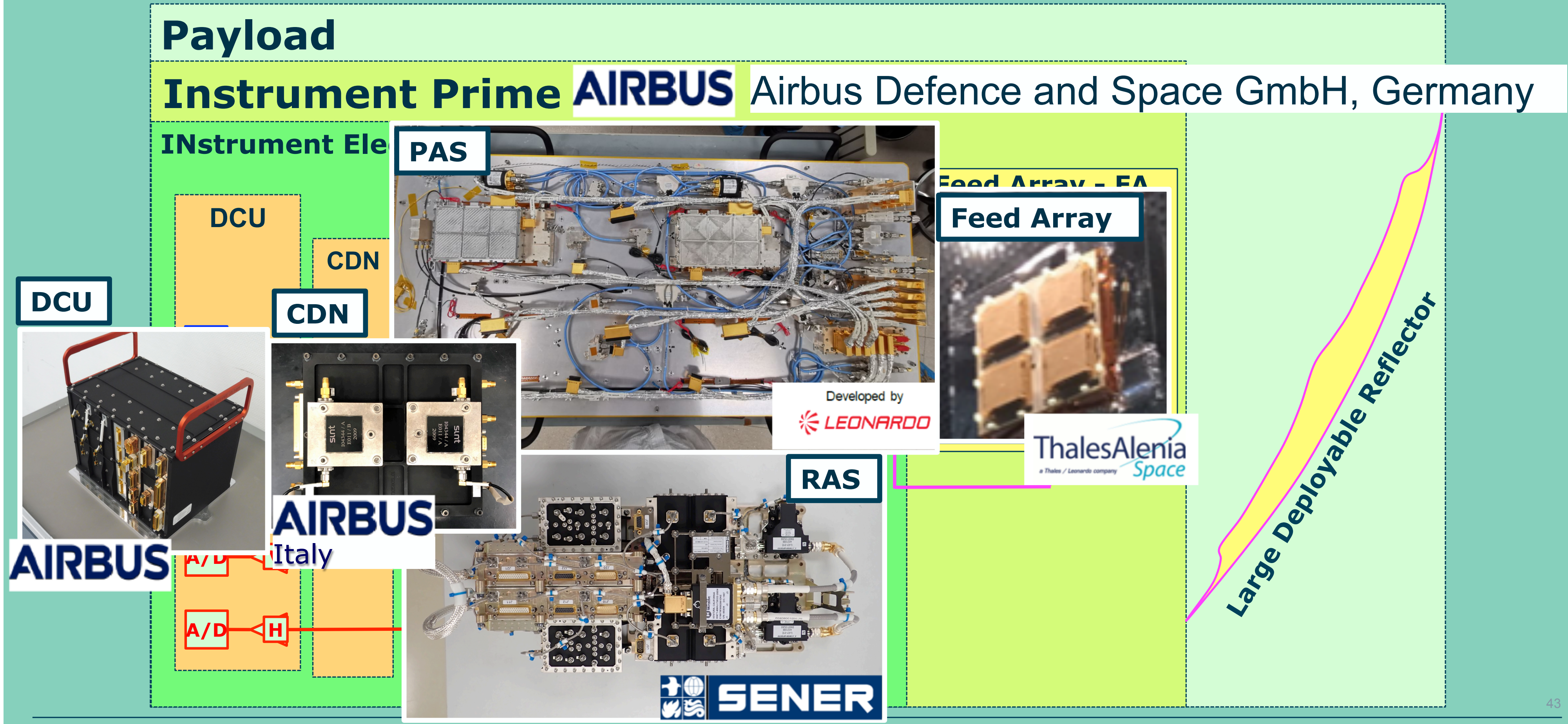
Biomass SAR Instrument: flight HW being delivered



Biomass SAR Instrument: flight HW being delivered



Biomass SAR Instrument: European consortium led by Airbus Germany



Biomass: Space segment

AIRBUS Airbus Defence and Space Ltd, UK

courtesy of Airbus Defence and Space Ltd.

Biomass: Mission Status

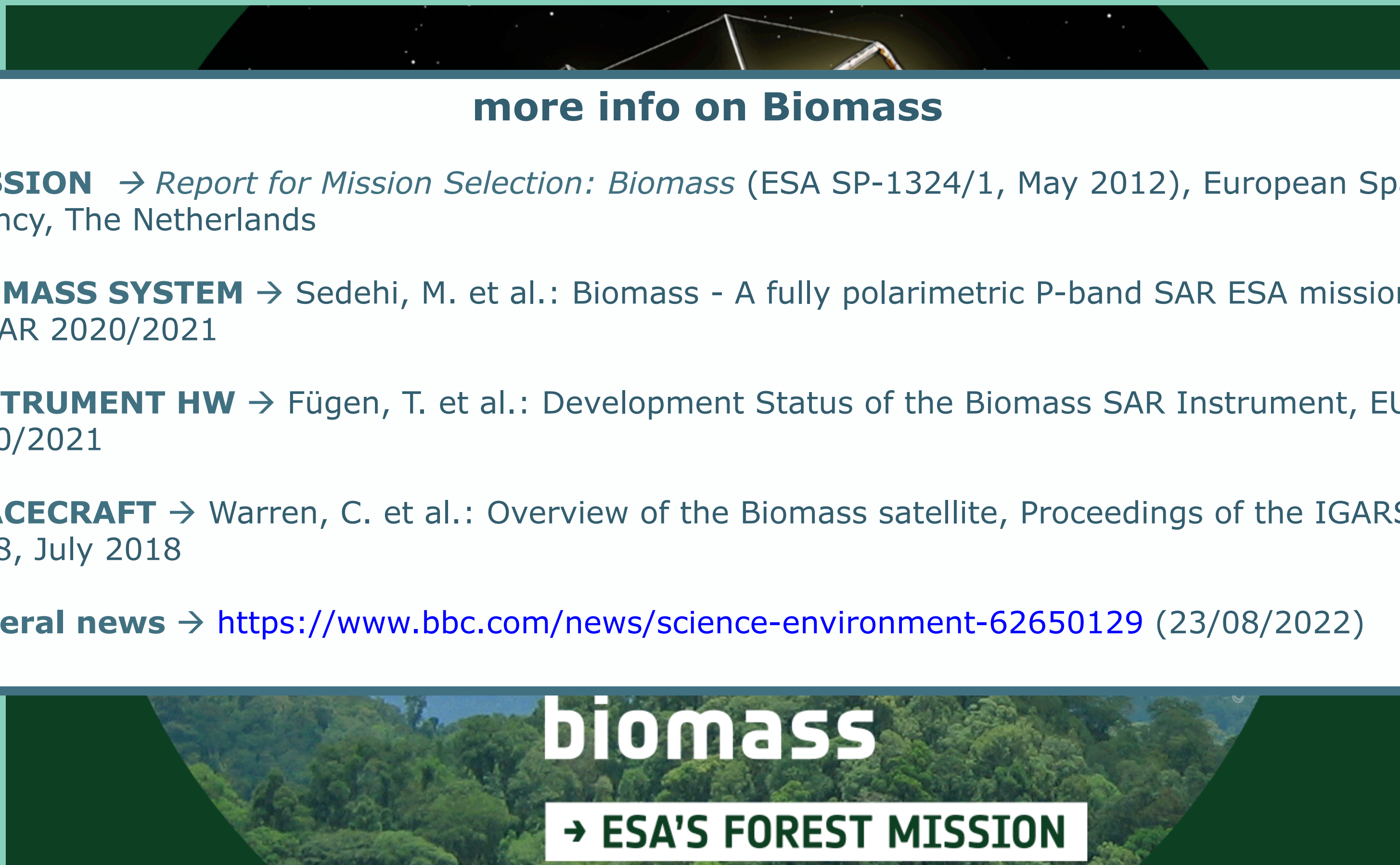
AIRBUS Airbus Defence and Space Ltd, UK

courtesy of Airbus Defence and Space Ltd.

- **Q3/4 2022**: satellite integrated with reflector and Instrument Hybrid → Satellite to mechanical testing
- **2023**: completion of Payload PFM → finalization of satellite tests

Q2 2024: launch!

Biomass: references



more info on Biomass

- **MISSION** → *Report for Mission Selection: Biomass* (ESA SP-1324/1, May 2012), European Space Agency, The Netherlands
- **BIOMASS SYSTEM** → Sedehi, M. et al.: Biomass - A fully polarimetric P-band SAR ESA mission, EUSAR 2020/2021
- **INSTRUMENT HW** → Fügen, T. et al.: Development Status of the Biomass SAR Instrument, EUSAR 2020/2021
- **SPACECRAFT** → Warren, C. et al.: Overview of the Biomass satellite, Proceedings of the IGARSS 2018, July 2018
- **general news** → https://www.bbc.com/news/science-environment-62650129 (23/08/2022)

Biomass: references

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here goes video

biomass thanks you very much!