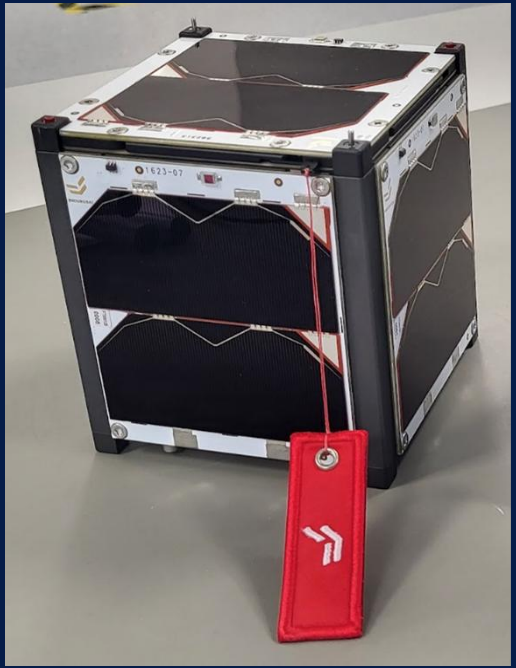
ZeDeCS: a Zero Debris CubeSat Platform

ESA CleanCube Campaign

Andrei-Gabriel Pavel
30th June 2026

RISE – company overview

- Space R&D company activating in 4 key domains: **nanosatellites, GNSS, SST, AIT**
- Established in 2017, >40 employees, located in **Bucharest, Romania**
- Contracts for ESA, national & int'l customers, incl. payload on the ISS
- EMISAR CubeSat currently in orbit



RISE – OrbFIX

- PNT device for precise LEO positioning: <10 cm accuracy
- Multi-constellation and multi-band GNSS (+ Galileo HAS)
- RadHard and high-performance, based on COTS
- Compact and low-power, but robust (hot/cold redundant)
- TRL9
- **Applications**: precise orbit determination (AI-enhanced orbital propagator), collision avoidance, close-proximity operations, formation flying, rendezvous (algorithms for CPOs/CAMs can be implemented in MCU)

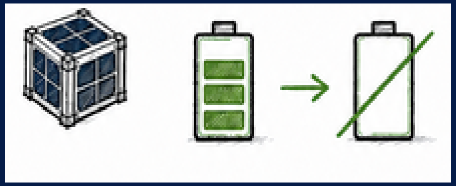
ROMANIAN INSPACE ENGINEERING
rise

ZeDeCS mission objectives

- Prepare an IOD mission demonstrating key **Zero Debris capabilities for CubeSats**:

1. Reliable disposal

- LEO deorbiting in <5 years from the EOL, with a probability of success ≥90% (≥ 95%?);



2. Reliable passivation

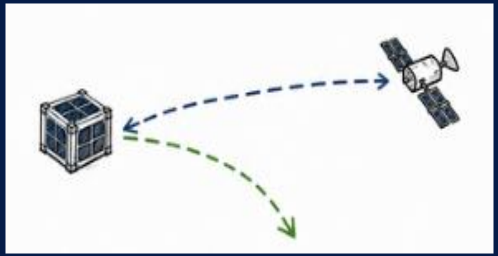
- By permanently and irreversibly depleting stored energy sources, with a probability of success ≥ 95%;

3. Systems resilience and monitoring

- Minimise in-orbit break-up risk: enhanced health monitoring, prognostic methods for failure prediction, autonomous FDIR;

ZeDeCS mission objectives

- Prepare an IOD mission demonstrating key **Zero Debris capabilities for CubeSats**:



4. Collision risk reduction

- Enhanced collision avoidance capabilities: quick (<12 h) CAM responsiveness, maintain recurrent CAM capabilities with reliability ≥90% through to EOL;
- Improved S/C trackability: unambiguous ID in <1 day of orbit injection;

5. Dark and Quiet Skies

- Assess visual brightness, mitigate impacts on visual and radio astronomy.

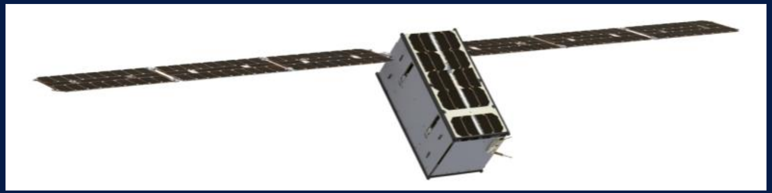
ROMANIAN INSPACE ENGINEERING
rise

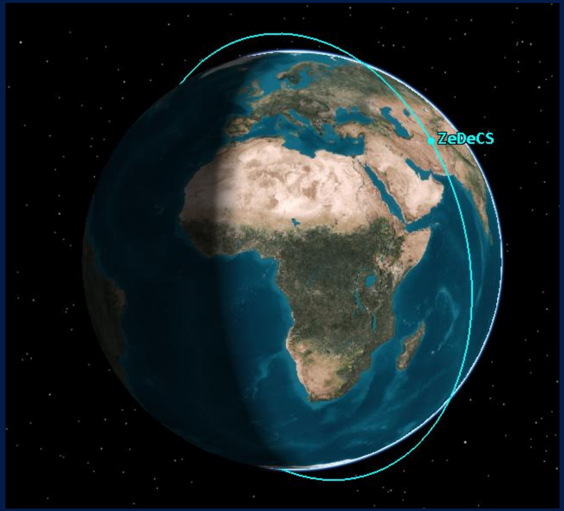
ZeDeCS mission overview

Spacecraft
16U CubeSat (based on GomSpace platform)

Launch	
Target date	Q2 **2028**
Launch vehicle	**Vega-C** (baseline); SpaceX Falcon 9 (backup)

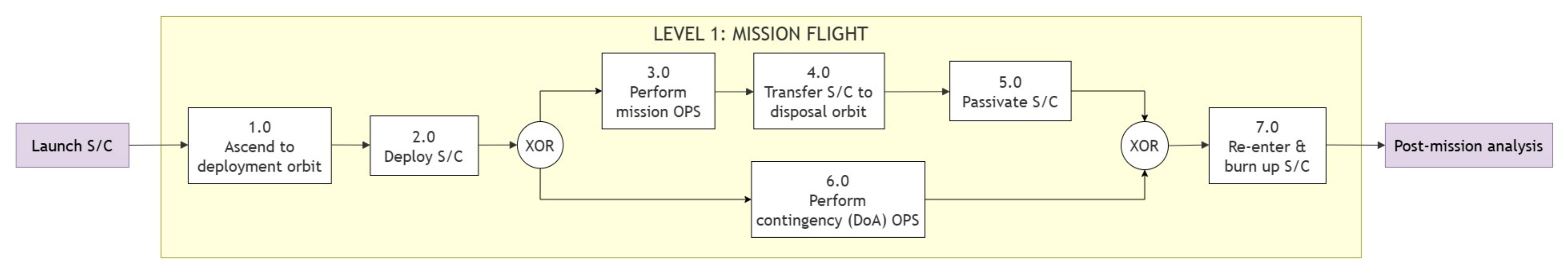
Orbit	
Type	**SSO**
Altitude	**550 km**
Inclination	97.6°
LTAN	10:30





System functions

1. Mission-level

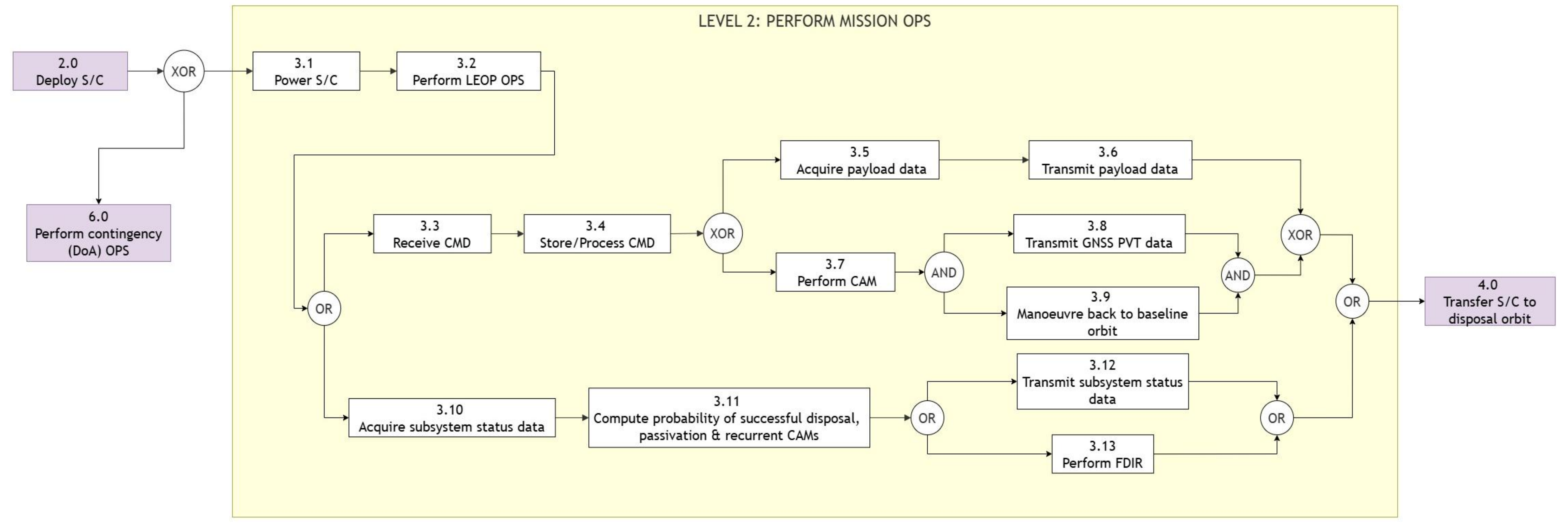


Two exclusive functional branches:

- Nominal mission operations → Transfer to disposal orbit at EOL → Passivation;
- Contingency operations (for Dead-on-Arrival scenario).

System functions

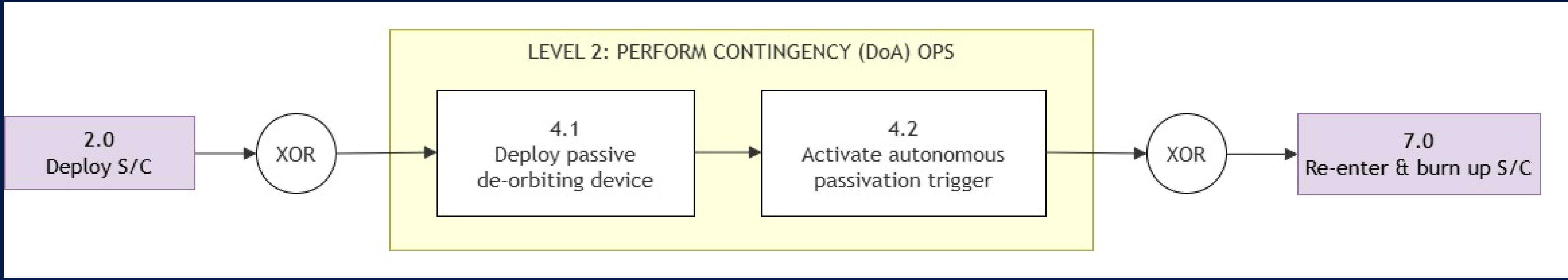
2.a) Mission operations



Two inclusive alternative branches:

- Command-based: payload operations XOR collision avoidance manoeuvres (CAMs);
- Autonomous: health monitoring, failure prognostics, FDIR.

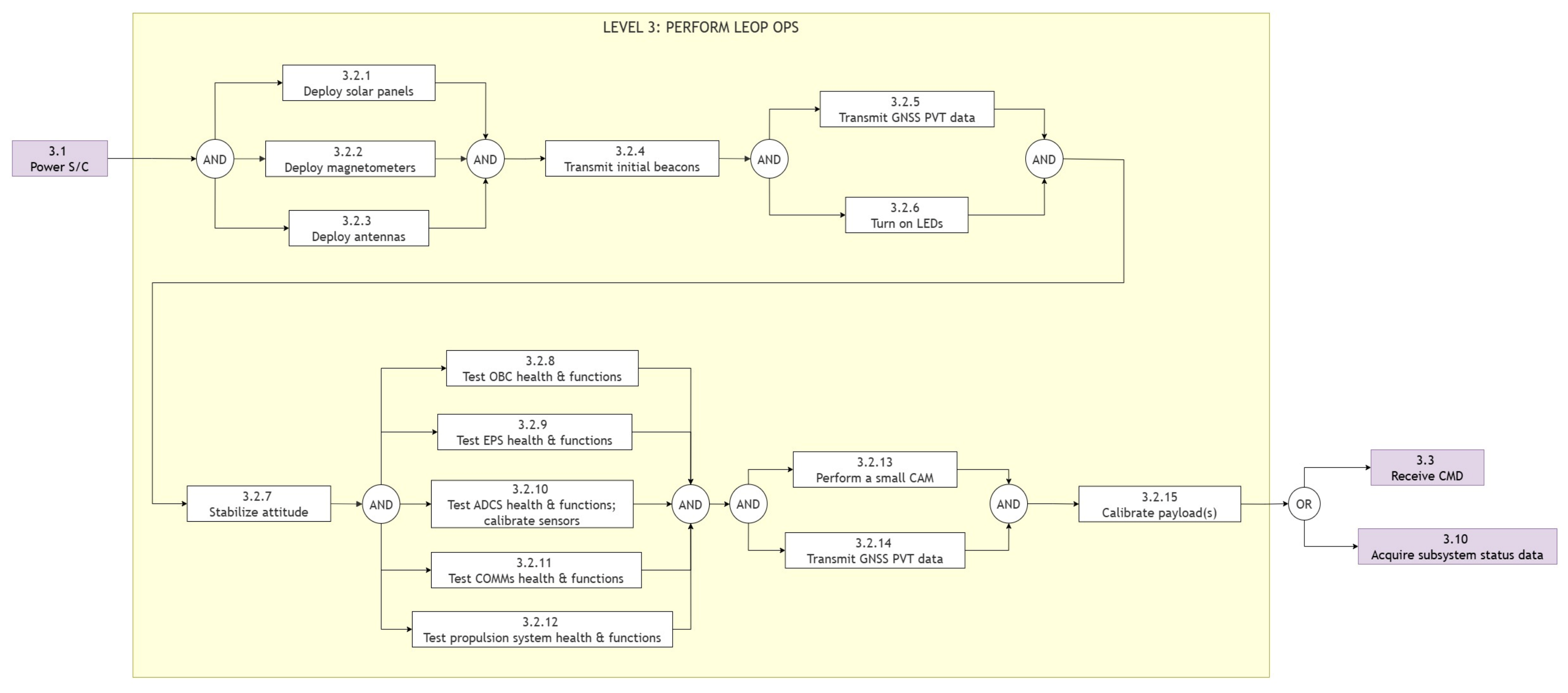
2.b) Contingency (Dead-on-Arrival) operations



- Reliable disposal by passive deorbiting device (separate from the S/C avionics).
- Autonomous passivation trigger for EPS batteries.

System functions

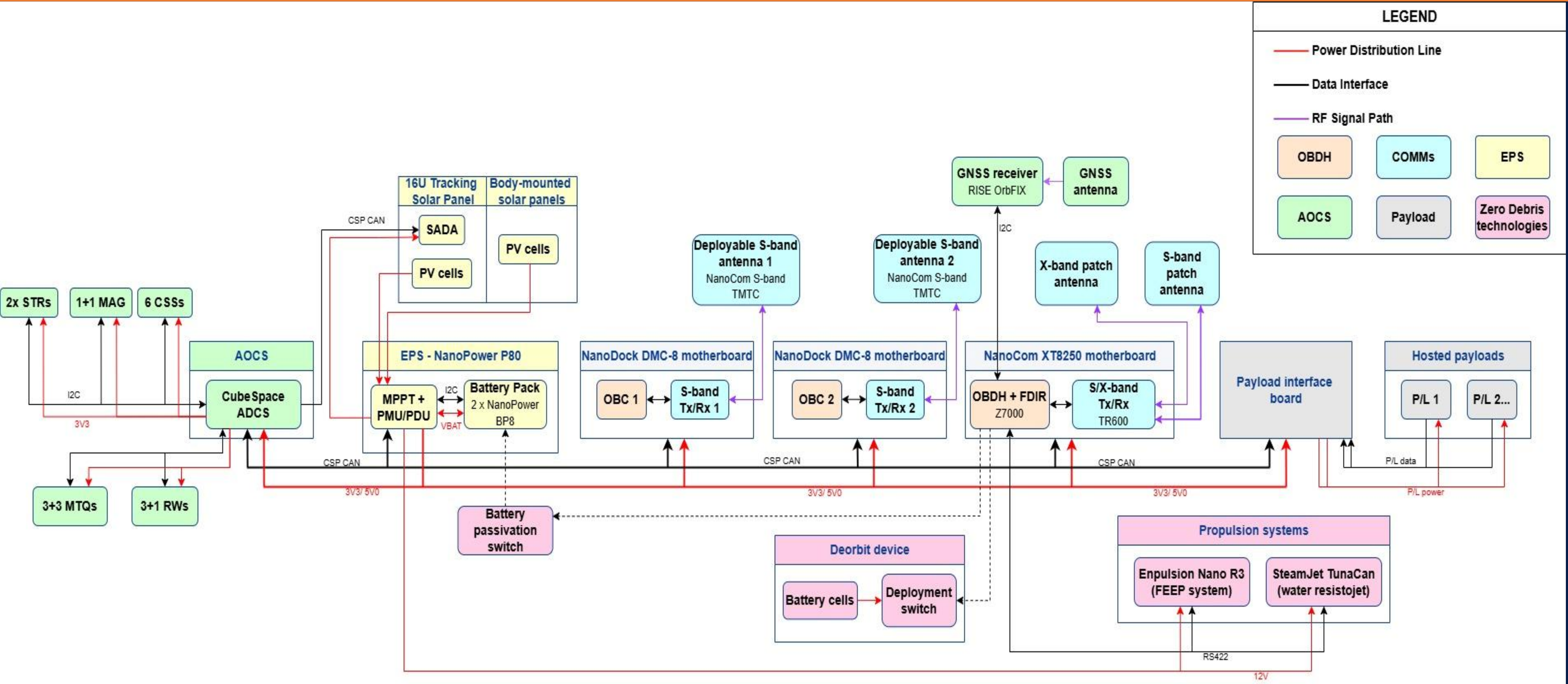
3. LEOP & commissioning



Driving SDM requirements for LEOP:

- Unambiguously ID S/C in <1 day of orbit injection;
- Demonstrate CAM capability in <2 days of orbit injection.

System architecture



rise

Disposal

Driving requirement:

- Deorbit in <5 years from the EOL, with a probability of success ≥ 95%.

Proposed approach:

- **One-fault tolerant** disposal functional chain: **electric propulsion system + drag sail**
- **Hybrid approach:** at EOL, initial EP-based transfer to lower orbit, then deploy drag sail
- Drag sail also used in case of **DoA** → separate from S/C avionics, hardware-defined, time-based trigger

Advantages:

- Mitigates challenges associated with EP thrusting down to <5 year-compliant disposal orbit (high power, full ADCS)
- Robust architecture for CubeSat missions on higher orbits, where drag sail alone may be insufficient
- One-fault tolerance increases reliability of disposal

+ IOD objectives

© Enpulsion

© HPS

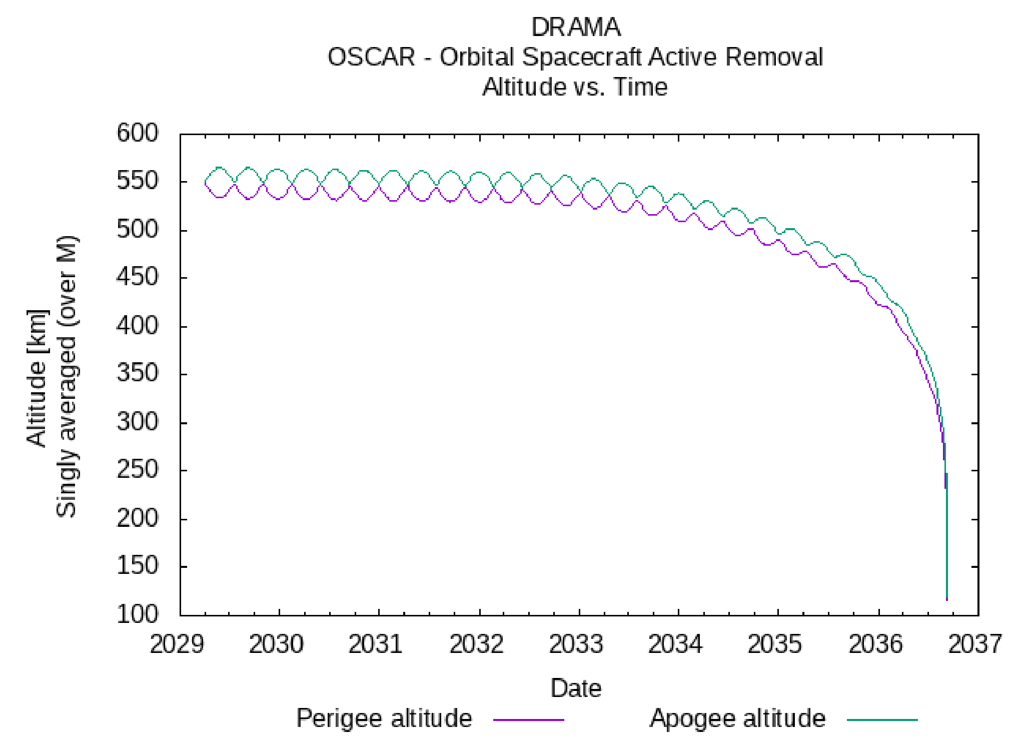
Disposal

Orbit lifetime analysis

- DRAMA; probabilistic assessment across one solar cycle (11 years)

1) Natural orbital decay

Lifetime (years)
7.81



2) Drag sail only

Drag sail area (m^2)	Lifetime (years)
1.0	4.77
2.0	3.83

3) FEEP system only

FEEP system parameters				Results				
I_{sp}	Thrust	Thruster lifetime	Propellant	Orbit lifetime	ΔV	Propellant mass	Disposal duration	Perigee altitude
2500 s	0.35 mN	4206 h	Indium	4.72 yrs	33.83 m/s	30 g	26.9 days	488.6 km

4) Hybrid approach (FEEP + drag sail)

- **First:**

FEEP system parameters				Results				
I_{sp}	Thrust	Thruster lifetime	Propellant	Remaining orbit lifetime	ΔV	Propellant mass	Disposal duration	Perigee altitude
2500 s	0.35 mN	4206 h	Indium	6.18 yrs	11.27 m/s	10 g	9.0 days	529.4 km

- **Then, starting from the transfer orbit:**

Drag sail area (m^2)	Final lifetime (years)
2.0	1.93

ROMANIAN INSPACE ENGINEERING

rise

Reliability ≥ 95%:

- EP system reliability depends on the whole bus:

OBDH	EPS	COMMs	ADCS	Propulsion	Disposal
95%	x 95%	x 95%	x 95%	x 95%	= 77.4%
99%	x 99%	x 99%	x 99%	x 99%	= 95.1%

- But prove ≥ 95% reliability by **one-fault tolerance**:
  - Disposal reliability using propulsion only: 77%
  - Disposal reliability using drag sail only: 95%

    → **P (total failure)** = (1 – 0.77) x (1 – 0.95) = 0.0115

    → **P (success)** = 1 – 0.0115 = **98.85%**

ROMANIAN INSPACE ENGINEERING

rise

Passivation

Driving requirement:

- Permanently and irreversibly deplete stored energy sources, with a probability of success ≥ 95%.

Proposed approach:

- **For EPS batteries**:

  1) Disconnect solar arrays to prevent battery recharging;

  2) Disconnect the batteries from the bus (by MOSFETs or relays);

  3) Discharge the batteries to a low SoC through a controlled resistor.

  → Exact solution and reliability to be discussed with provider.

  → Considering use of autonomous passivation trigger for batteries in case of DoA.

- **For ADCS reaction wheels:** offload RWs using MTQs, disable power to RW electronics.
- **For pressurised propellant tanks:** by venting.

  But FEEP system + water-based resistojet used → this is not required.

ROMANIAN INSPACE ENGINEERING

rise

Systems resilience and monitoring

Driving requirement:

- Reliability thresholds: ≥ 95% for disposal, ≥ 95% for passivation, ≥ 90% for maintaining recurrent CAM capabilities;
- In-orbit: periodically monitor the probability of successful disposal & passivation.

Proposed approach:

1) To assess reliability:

- Use statistical data for TRL9 components with many units flown;
- FIDES analyses for newer components/ those with fewer units in orbit.

2) To monitor reliability and implement recovery actions:

- FIT/wear-out data to be included in telemetry packets;
- Predictive models periodically compute probability of successful EOL disposal & passivation on board – dedicated OBDH
- Autonomous FDIR for entry into safe mode & resets, but re-entry into nominal mode authorized by ground
- If predictive models indicate anomalies, FDIR actions authorized by ground

Collision avoidance

Driving requirements:

- CAM readiness within 2 days of on-orbit injection;
- Perform CAM in <12 hours from conjunction warning reception;
- Maintain recurrent CAM capabilities with ≥ 90% reliability;

Proposed approach:

- **One-fault tolerant propulsion system**: water-based resistojet + FEEP system
- Perform CAMs based on true or artificial CDMs (demonstrate <2 day-compliant initial CAM even if no CDM is received)
- Commercial SSA service for initial ID, orbit determination, collision screening and CAM computation → quick, automated analysis (<30 min) of optimal CAMs
- On-call 24/7 availability of operators if CDM received → final go/no-go for collision avoidance action
- Access to commercial ground station network for quick responsiveness to CDMs & CAM uplink

© SteamJet Space Systems

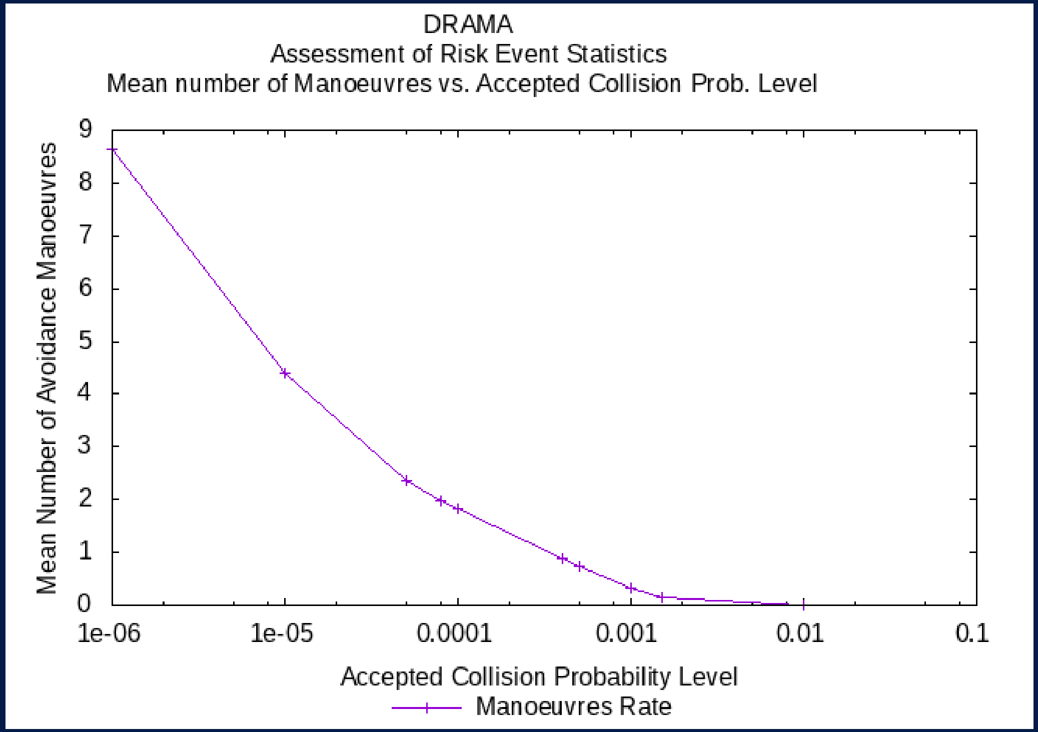
© Enpulsion

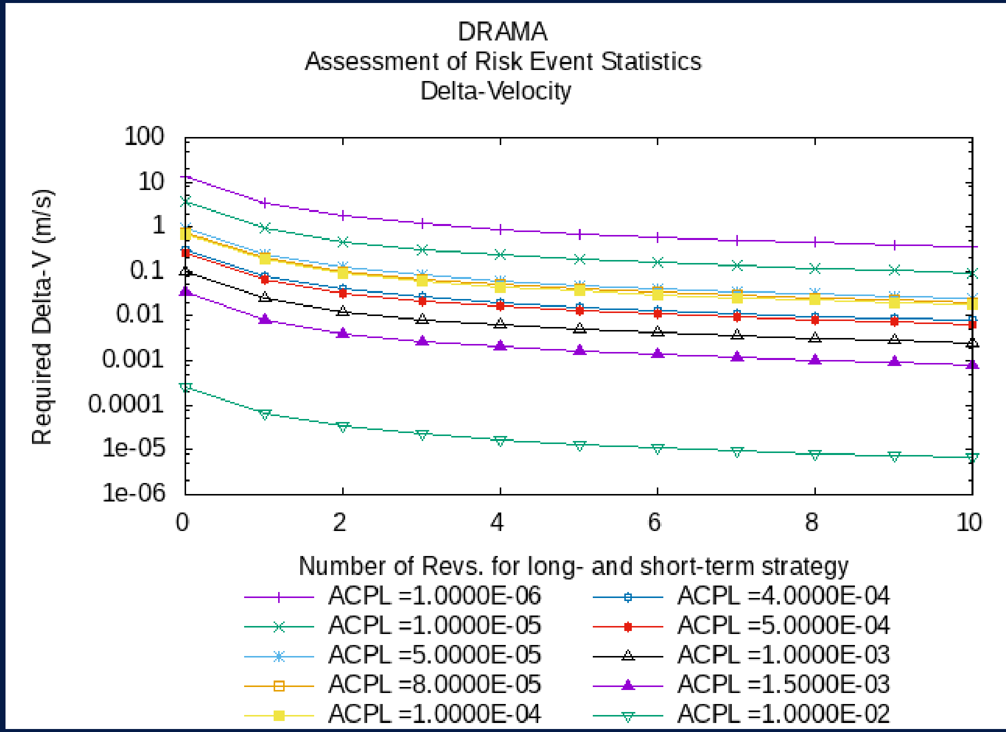
rise

Collision avoidance

ACPL	No. CAMs/year
10^{-4}	1.81

No. revs. before event	ΔV (m/s)
0	0.68
1	0.18
2	0.09





rise

Trackability

Driving requirements:

- Unambiguously ID S/C within 1 day of on-orbit injection.

Proposed approach:

- Commercial SSA service for initial ID & orbit determination;
- Leverage existing partnerships for SST with optical telescopes;

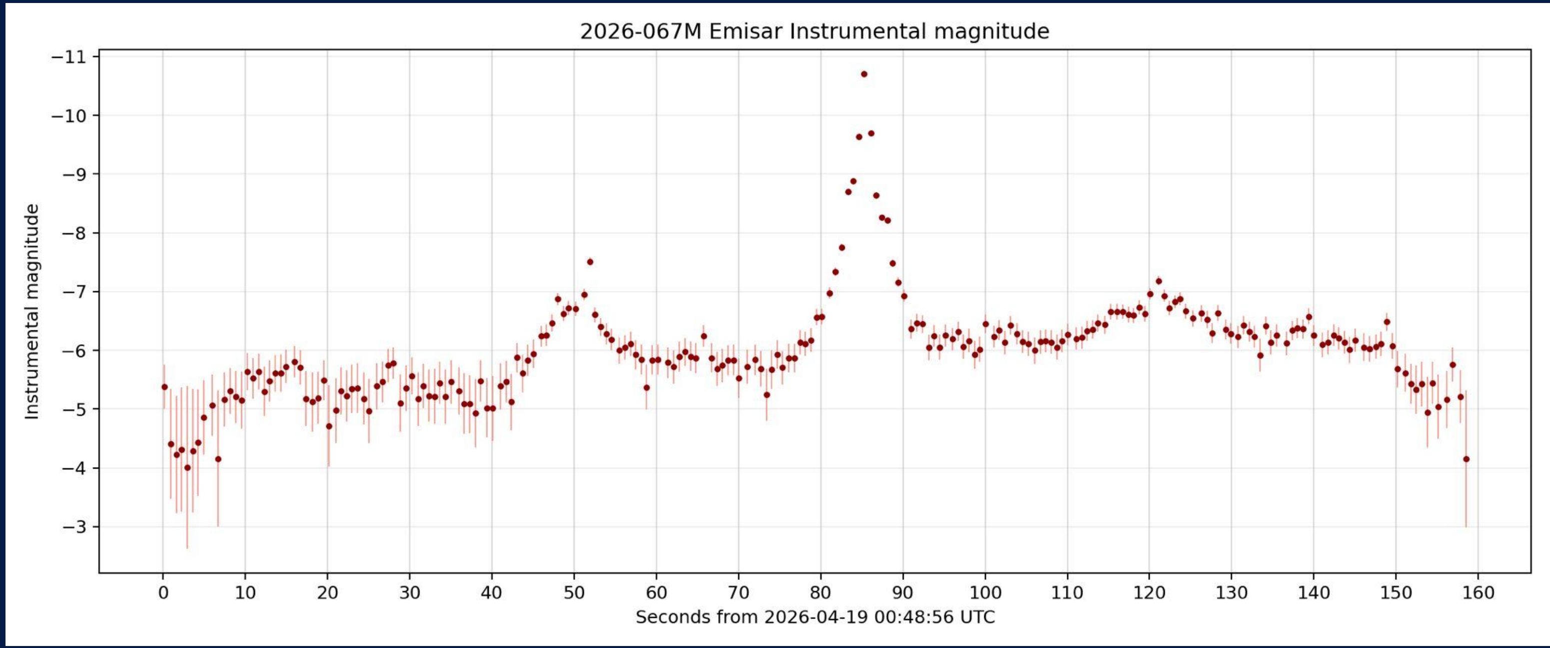
- For <1 day ID: use GNSS telemetry + Doppler freq. beacon measurements + optical tracking (+LEDs?) + CCR (would need access to SLR station).

rise
ROMANIAN INSPACE ENGINEERING

Astronomy protection

- Quantify the visual brightness of the S/C throughout main mission phases (LEOP, nominal, post-EOL).
- Test attitude changes, correlate PVT and attitude telemetry with optical observations from ground-based telescopes.

- Optional: test use of dielectric mirror films & dark coatings on selected S/C surfaces. Compare visual brightness differences, knowing attitude.
- Test real-time ephemeris data sharing with astronomers. Implement RF transmission exclusion zones.



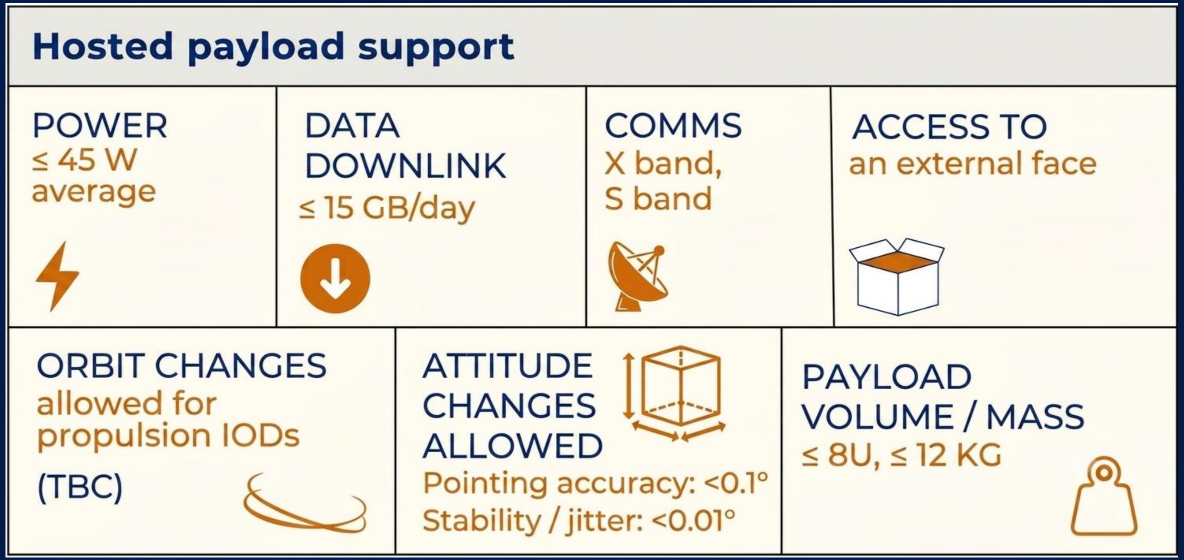
ROMANIAN INSPACE ENGINEERING
rise

Conclusions & next steps

- The ZeDeCS IOD mission sets a pathway towards Zero Debris compliance and sustainable CubeSat operations in LEO

Next steps:

- Consolidate the system design & close remaining system-level trade-offs.
- Consolidate the framework for reliability analyses of COTS components by discussion with providers.
- Identify potential co-funding **hosted payload** partners:



rise
ROMANIAN INSPACE ENGINEERING

Thank you!

www.roinspace.com

office@roinspace.com

roinspace