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MINS Lander

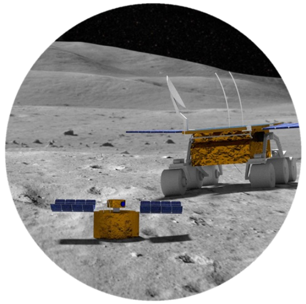
MiniPINS - Miniature Planetary In-situ Sensors

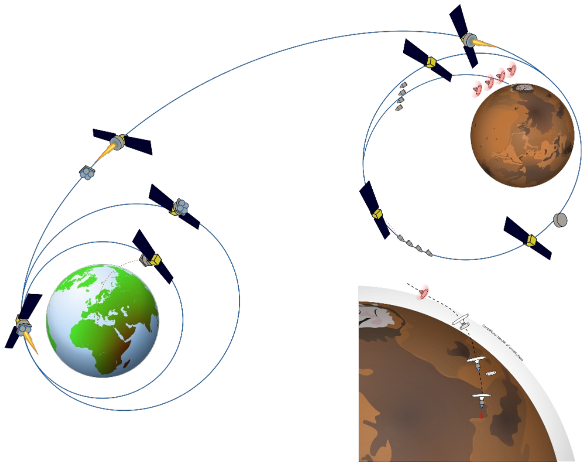
Moving to Mars, Nov 17-18, 2022, Montreal, Canada

Maria Genzer & the MiniPINS team

MiniPINS study

- The study focused on concepts, requirements and specifications of miniaturized Surface Sensor Packages and their successful delivery systems for Mars (MINS) and Moon (LINS) missions with as much synergy between Mars and Moon cases as possible.





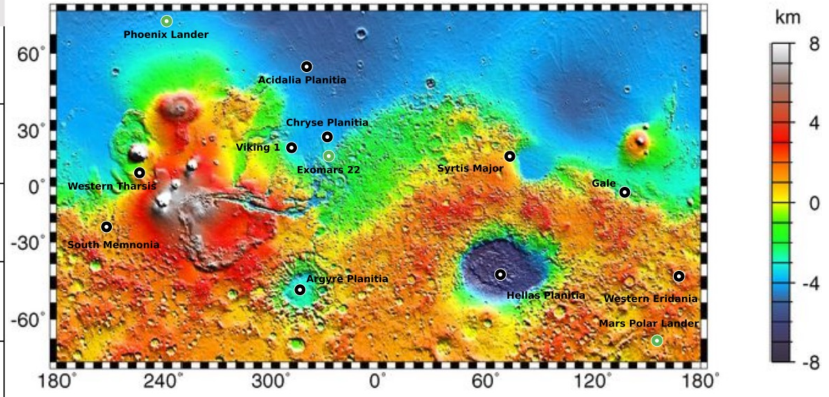
MINS mission overview

- MINS: 4 Surface Sensor Packages (SSP) in different Martian locations
- Characterize the local environment from an environmental, geophysical, and chemistry perspective, above, at, and below Martian surface
- Designed for 1 MY nominal mission, with 2nd MY as an option
- 25 kg total mass, 15 kg penetrator with 4.5 kg payload
- Based on inflatable technology for Entry, Descent and Landing (EDL), with significant heritage from FMI's MetNet mission
- 10 different candidate landing locations considered. 5 pre-selected based on most suitable impact velocity, local latitude, solar illumination profile, elevation and local geographic conditions.
- Penetration Depth ➔ approximately 0.5 m (maximum), impact speed 60-80 m/s
- PROX-1 UHF link.

Suggested landing sites

Name	Location	Elevation	Crustal magnetic field	Soil penetrability
Gale Crater	5S, 140E	-4 km	Not active	Sand and duricrust (cemented regolith), not much dust
Western Tharsis, South of Olympus Mons	10N, 135W	-1 – 0 km	Not active	Thick covering of dust (2-6 m)
Syrtis Major	15N, 70E	0 – 1 km	Slightly active	Coarse sand and duricrust, little dust
Western Eridania (Crater)	45.5S, 169.5E	0 – 1 km	Active	Sand and duricrust, not much dust, possibly subsurface ice
South Memnonia (Bernand Crater)	23S, 154W	0 km	Active	Mixture of dust and sand
*Mars Polar Lander area (near South Pole)**	*73S, 150 W*	*1 – 2 km*	*Active*	*Several centimetres of cemented dust or lag material overlying volatile rich deposits*

** Requires design modification to include RHU or RTG*



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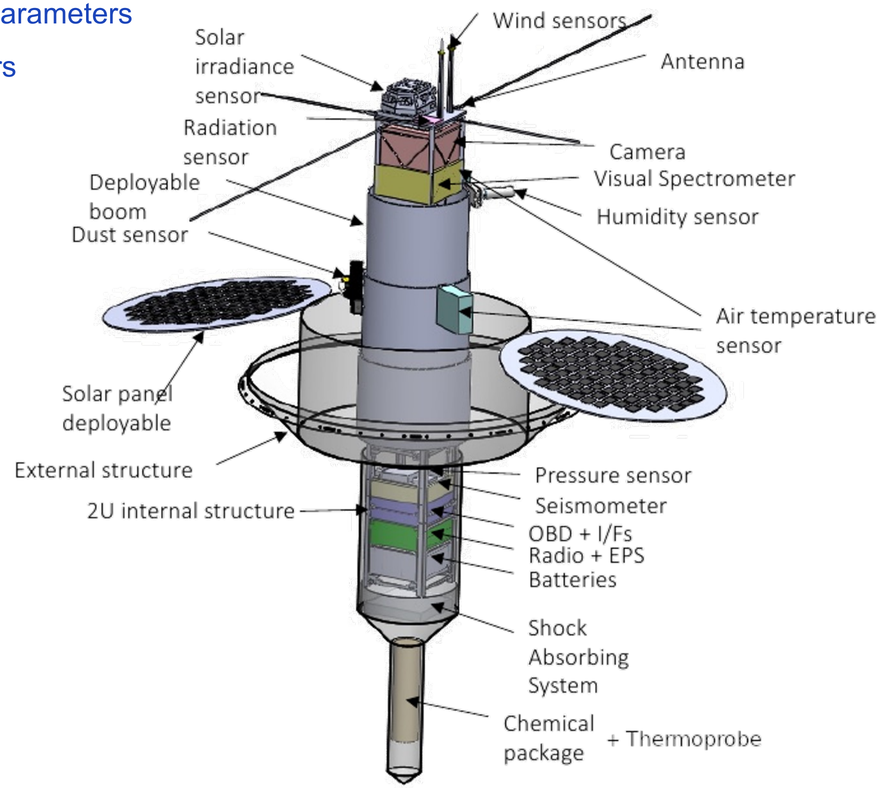
MINS penetrator and payload

- Observing Mars Environment
  - Measure atmospheric parameters
  - Measure soil parameters
  - Measure radiation
  - Take context pictures

The MINS Sensors :

- Impact Accelerometer
- Panoramic Camera
- Air Temperature Sensors
- Pressure sensor
- Humidity sensor
- Wind sensors
- Dust sensor
- Solar irradiance sensor
- Chemistry Package
- Soil thermoprobe
- Visual Spectrometer
- Dosimeter
- Seismometer

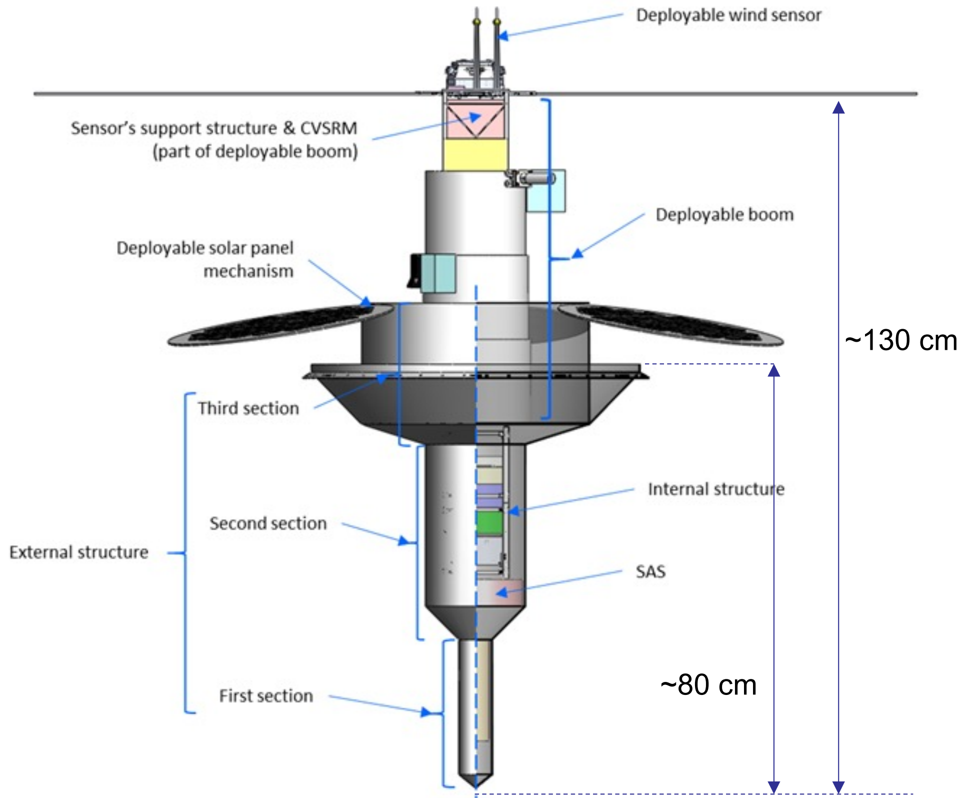


Penetrator mechanical system

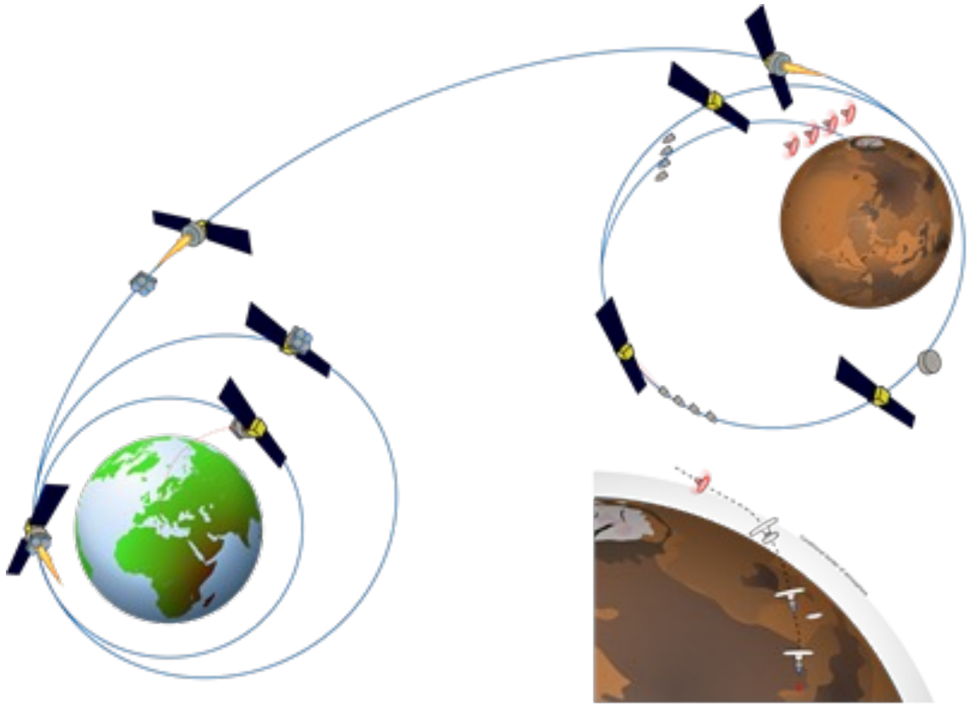
- **External structure**
  - 3-section geometry
  - 2.5 mm thick Aluminum, reinforced in conic sections

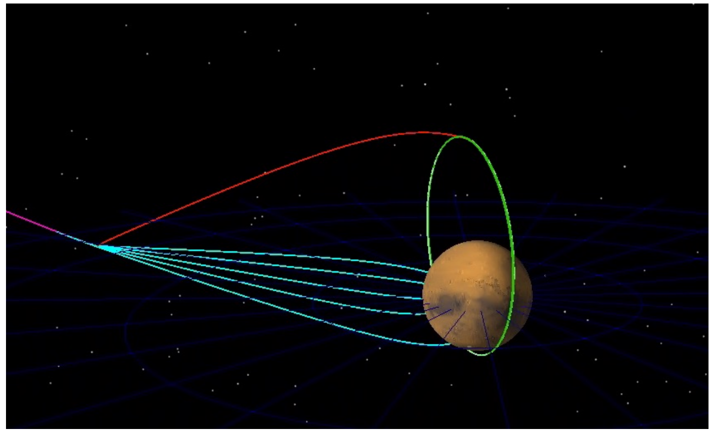
- **Internal structure or electronics holder.**
  - Based on 2U CubeSat structure (150 mm diameter)
  - Holds the EPS, the battery box, the radio, the OBC, the control accelerometer, the seismometer and the pressure sensor.

- **Telescopic deployable boom, including camera and visual spectrometer rotation mechanism (CVSRM).**



Delivery to Mars





Release from a hyperbolic orbit preferred (parabolic as an option).

The approach phase after release from the carrier S/C lasts up to 80 days.

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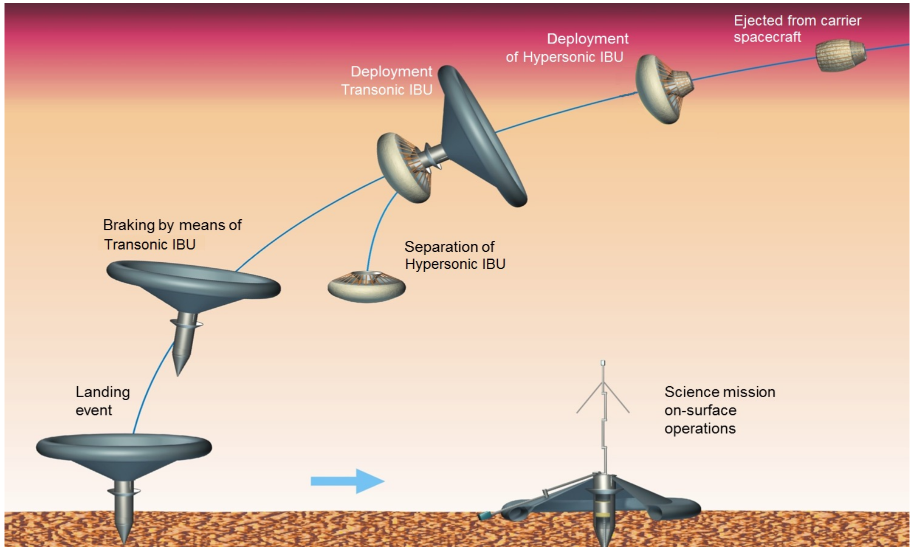
MINS entry, descent and landing sequence in nominal case

1. The complete lander in stowed configuration during cruise and coast phase prior to atmospheric entry;
2. Hypersonic inflatable braking unit (H-IBU) with thermal protection system (TPS) deployed for atmospheric entry (T_0 - 30 min);
3. Transonic inflatable braking unit (T-IBU) deployed, H-IBU and rigid aerodynamic shielding (RAS) not yet jettisoned (T_0 + 170 … 290 s, based on g loads);
4. Ejection of the H-IBU (T_0 + 180 … 300 s);
5. Surface module in landing configuration (T_0 + 215 … 490 s, depending on ground elevation)



The landing sequence is executed autonomously.

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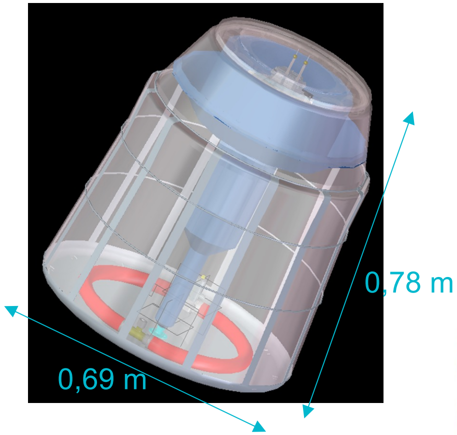

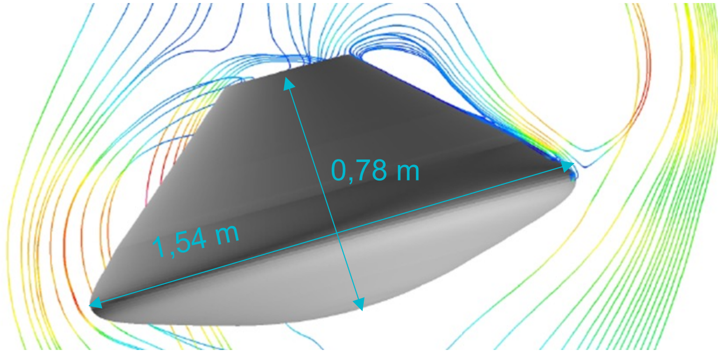

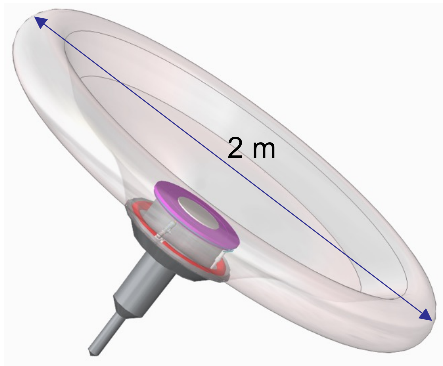

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Development steps for the future

- Development of penetrator subsystems is planned with 2 different approaches:
  1. In-house development according to ECSS guidelines
  2. Delta-qualification of COTS systems with flight heritage (e.g. CubeSat)
- Most payloads planned for MINS are already at high TRL (6…9), but need delta-qualification for landing shock
  - Some, like panoramic camera or dust sensor need also thermal qualification, the camera needs also optics validation
- Penetrator mechanical subystems need
  - Impact tests at representative conditions of mass and speed to verify the concept
  - Analysis of the soil and structure interaction during the impact
- The biggest effort is needed in development of European solution for inflatable Entry, Descent and Landing system

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Backup slides

System Technical Budgets

Mass Budget

Total Mass Budget			
System/part	Mass [g]	Margin [g, 5-20 %]	Mass with margin [g]
EDL system	10850	2170	13020
Mechanical system	5450	1090	6540
Thermal system	1100	20	1120
Power system	1102	73.1	1175.1
Communications system	670	86.0	756.0
Command & Data Handling System	316	63.2	379.2
Payload system	1861	186.1	2047.1
Total Mass Budget	21349	3688.4	**25037.4**
System margin (20%)			(20% → 25037.4) 5007.48
Total with system margin			**30044.88**

Power and energy

- Total energy needed before the first re-charge on Mars: 32 W·h (with margin)
- Battery capacity (Li-ion cell): 40.8 W·h @ 25ºC, 36.4W·h @ 0ºC, charged full before the release from the S/C
- Solar panel area: 1500 cm^2
- After landing:
  - Battery heater consumes 14 W·h/sol in WCC
  - 2W-equivalent payload can be operated with at least 16% duty cycle in all planned landing areas

Thermal system

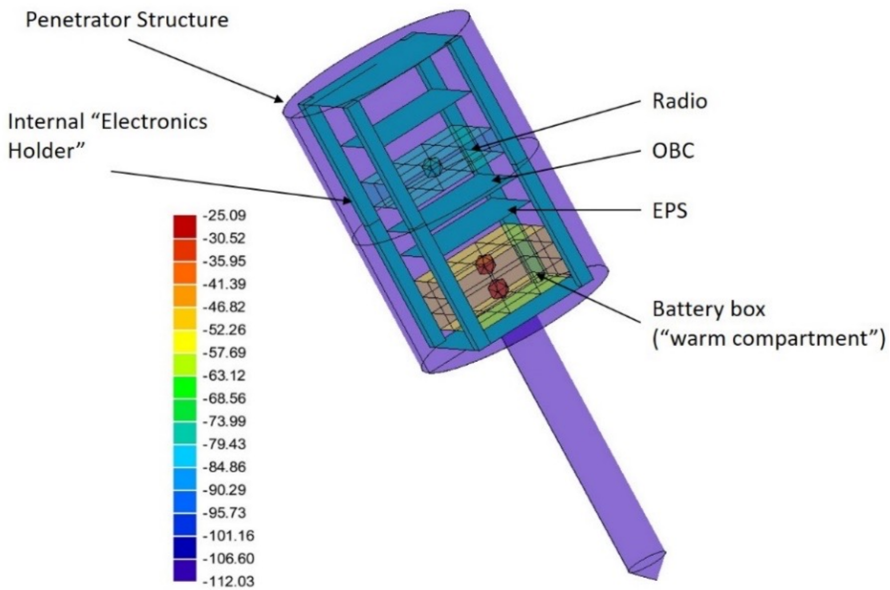
TCS goal: Maintain the probe's parts within their required temperature limits at any foreseen scenario.

➔ Restricted to landing **latitudes below 40°.**

➔ No RTG.

Key aspects:

- Electronic equipment will not be heated → large **heritage** from previous Martian missions with instruments working from -130ºC.
- Only an insulated **warm compartment** for the batteries.
- **Delta qualification** for temperature down to -70ºC, e.g., EPS (COTS from Cubesat).
- Avoid **overheating** during Hot parts of the Sol.



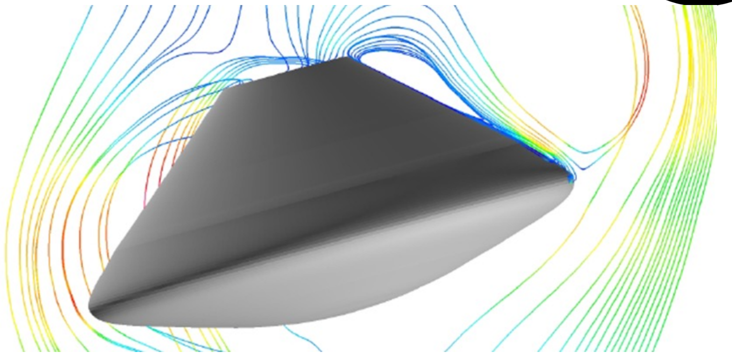
MINS penetrator thermal model with internal equipment. Probe Temperature field [°C] at WCC.

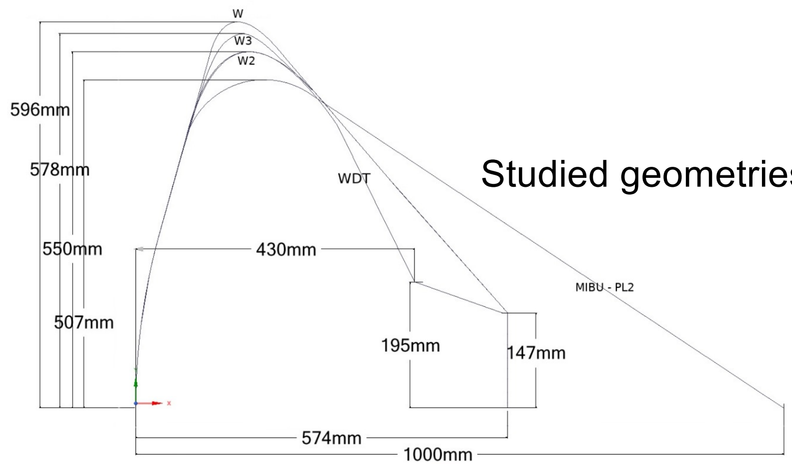
EDLS current system technology readiness levels

Element	TRL	Comments and justification of TRL	Possible supplier	Risk
H-IBU + Inflation system	4 1 4 4	Wind tunnel tests and computer modelling performed.	FMI/Lavochkin Association ESA NASA EFESTO consortium	Medium/High High Medium/High Medium
Flexible heat protection (TPS)	6 6 4 5-6	Arc jet tests have been made for the MetNet TPS LOFTID tests FTPS by Vorticity	FMI/Lavochkin Association NASA EFESTO consortium ESA	Medium Medium Medium Medium
H-IBU separation mechanism	9 6 6	 Separation tested during drop testing	NASA ESA FMI/Lavochkin Association	Low Medium Medium
Three-axis accelerometer and gyroscope	4	COTS sensors available, to be qualified for Mars. ADIS16365 flown with Cubesat Prox-1.	Analog Devices	Low
EDL beacon antennas	9	ExoMars Schiaparelli		Low
T-IBU + inflation system	9 6 4	IRVE-3, HIAD Drop tested from an aeroplane 2500-3000m: T-IBU deployment, T-IBU inflation by means of high-pressure cylinder, front shield separation EFESTO H2020 project	NASA FMI/Lavochkin Association EFESTO consortium	Low Medium Medium

MINS H-IBU stabilization analysis

- H-IBU geometry stable with the MINS entry and landing parameters.
- H-IBU geometry confronted most modifications from the previous studies (MetNet).
- Several geometry options simulated and studied.
- Depends on Center of Mass





Studied geometries

MINS H-IBU stabilization analysis