Compact Geophysical Instrumentation for Asteroid Exploration

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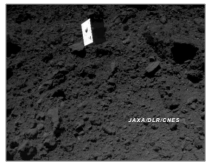
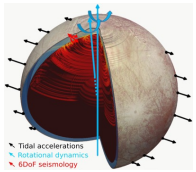
CONTEXT

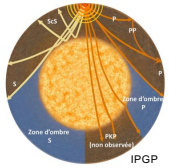
- Understanding the physical properties and internal structure of asteroids is key for science, planetary defense and future in-situ resource utilisation.
- Ground rotation and translation sensors are complementary instruments that can be used in-situ (on the surface) to infer the mechanical properties and internal structure of planetary bodies at different scales.



Accelerometer measurements during landing and rebounds can be used to constrain the surface mechanical properties



Rotational measurements can provide information on physical properties and mass distribution, as well as the physical processes that govern the rotation.



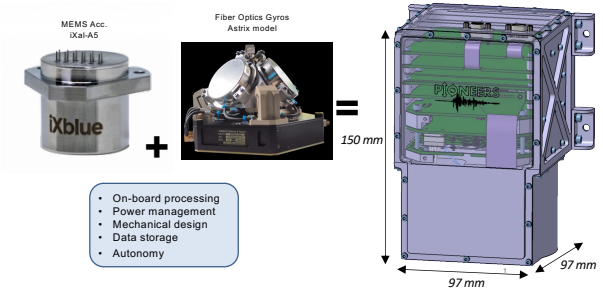
Seismology 'images' the internal structure using either natural or artificial seismic sources

- In the framework of two European Commission Horizon 2020 projects (PIONEERS and NEO-MAPP), we are developing **two in-situ geophysical instruments**, designed specifically to fit inside a small lander and function in the challenging environment of the asteroid surface.

6 DEGREES OF FREEDOM INSTRUMENT

- **What is a 6 degrees of freedom (DoF) instrument?**
  - The 6 DoF instrument combines MEMS accelerometers, small fiber optic gyroscopes (and electronics and mechanical interface) in order to be sensitive to motion in three translational and three rotational axes.
  - The instrument re-uses and space qualifies Exail (previous iXblue) technology.
- **What does the 6 DoF instrument measure?**
  - The 6 DoF instrument makes precise measurements of the landing dynamics (acceleration profile, rotataion), the in-situ rotational dynamics, and the ground acceleration during active seismic experiments.
- **Who is building the 6 DoF instrument?**
  - The consortium, led by ISAE-SUPAERO, have a strong expertise in state of art instrument development (SEIS/INSIGHT, BlueSeis).
- **What is the development status of the 6 DoF instrument?**

✓Breadboard of sensors acquisition electronics (TRL 3): mid 2021.
✓Instrument EM (TRL 4/5): early 2023.
•Instrument PFM (TRL 6): late 2023.



- On-board processing
- Power management
- Mechanical design
- Data storage
- Autonomy

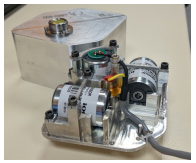
Expected 6 DoF instrument Performance	
Rotation sensor	
Range	+/- 50 rad/s
Bias	< 5 µrad/s (1 °/hour)
Noise	< 5 µrad/s/sqrt(Hz) over 1-200 Hz
BW max	DC-800 Hz
Accelerometer	
Range	+/-30 g
Bias	< 1 mm/s²
Noise	< 100 µm/s³/sqrt(Hz) over 1-200 Hz
BW max	DC-800 Hz

Expected 6 DoF instrument System Budgets	
Power	<15W
Mass	<1.5 kg
Volume	97x97x150 mm
Storage temperature	-40/+85 °C
Operating temperature	-30/+45°C
Radiation	10 krad(Si)

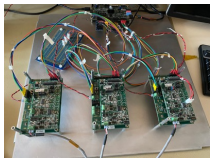
COMPACT SEISMOMETER

- **What is a compact seismometer?**
  - The compact seismometer consists of 3 small geophone sensors + analog and digital electronics and the mechanical interface
- **What does the compact seismometer measure?**
  - Each of the geophones measure the ground motion along one axis. The compact seismometer measures, therefore, measures the ground motion along 3 axes generated by natural of artificial seismic activity.
- **Who is building the compact seismometer instrument?**
  - The sensors are commercial sensors specifically designed for borehole extreme environment, the dedicated acquisition electronics are being developped at ISAE-SUPAERO.
- **What is the development status of the compact seismometer?**

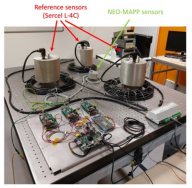
✓Breadboard of sensors acquisition electronics (TRL 3): mid 2021.
✓Instrument EM (TRL 4/5): early 2023.



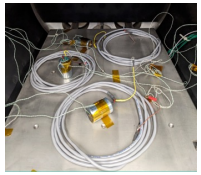
Integrated seismic sensors



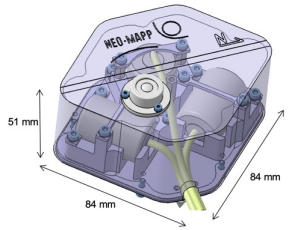
Breadboard of the 3 axis electronics

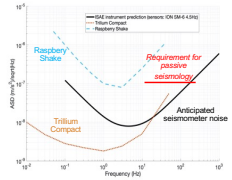


Integrated seismometer performance testbed @ ISAE-SUPAERO



Environment testing of the seismic sensors @ ISAE-SUPAERO





Expected Seismometer Performance	
Bandwidth	5-200 Hz
Noise level	<0.1 µm/s²/sqrt(Hz)
Measurement range	40 microns/s

Expected Seismometer System Budgets	
Power	~2 W
Mass	~1 kg
Volume	Max 2U (2L)
Sensor storage temperature	-55/+125°C
Sensor operating temperature	-40/+100°C

PERSPECTIVES

- The two in-situ geophysical payloads being developed at ISAE-SUPAERO have been designed specifically to fit inside a small lander and function in the challenging environment of the asteroid surface.
- The instruments are complementary and can be flown together or separately.
- The concept of operations can be adapted depending on the mission profile.

Science objective	Measurements	6 Degree of Freedom instrument	Compact Seismometer
Surface mechanical properties	Landing dynamics	✓	
Density distribution and internal structure	Precise measurements of rotational dynamics	✓	
Subsurface and internal structure	Active seismic experiment	✓	✓
	Natural seismic experiment		✓
Impact physics	Active seismic experiment	✓	✓
Seismic background noise estimates	Monitoring of natural seismic sources		✓
Diurnal and orbital activity	Monitoring of natural seismic sources		✓

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