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NEO-MAPP

Near Earth Object Modelling And Payloads for Protection

A Compact Seismometer for the Geophysical Exploration of Small Bodies

Planetary Defence Conference 2021

Naomi Murdoch, R.F. Garcia, A. Sournac, M. Bassas-Portus, A. Cadu, A. Wilhelm, M. Drilleau, A. Stott and D. Mimoun

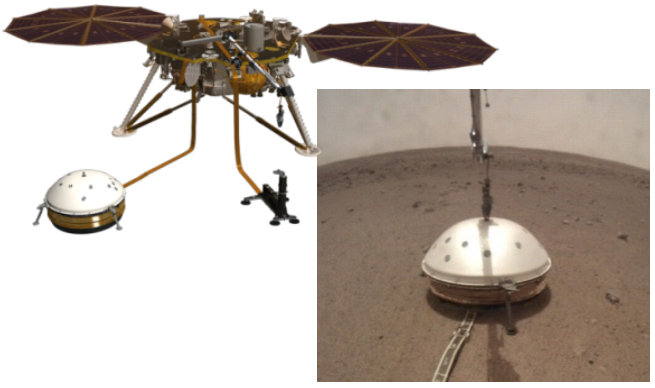
ISAE-SUPAERO, Toulouse, FRANCE

NEO-MAPP instrument development

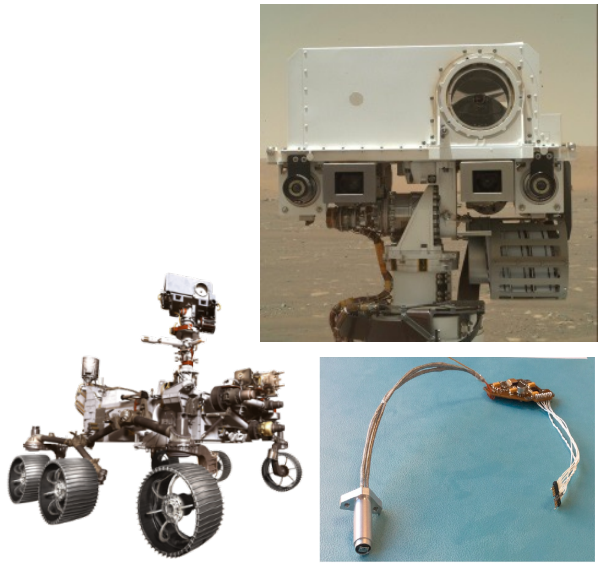
Part of the NEO-MAPP project (see talk by Patrick Michel) focusses on increasing the maturity of key spaceborn and landed instruments that will measure the surface, shallow sub-surface and internal properties of a NEO.

At ISAE-SUPAERO we are combining our expertise in seismology with our experience in space instrumentation in order to develop **a compact seismometer (geophone) for the geophysical exploration of small bodies**

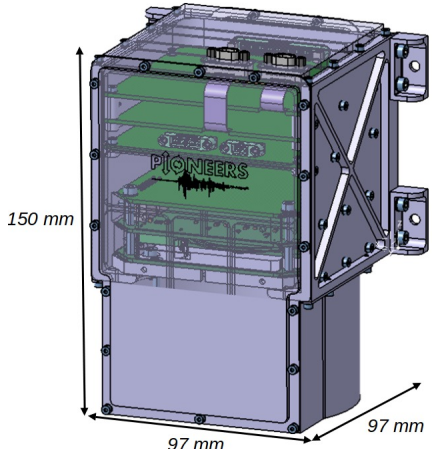
This **low mass, low power three axis seismometer** is being designed specifically to function in the challenging environment of the asteroid surface.



InSight SEIS (NASA/JPL)



Mars 2020 Microphone (NASA/JPL)



6 DoF instrument for asteroid exploration (Garcia et al. this conference)

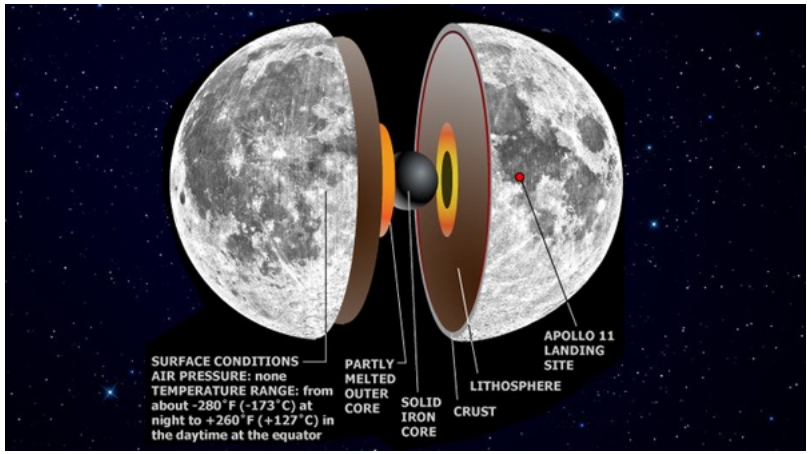
EntrySat 3U CubeSat, deployed from the ISS in 2019 (ISAE-SUPAERO)

Why a seismometer for asteroid exploration?

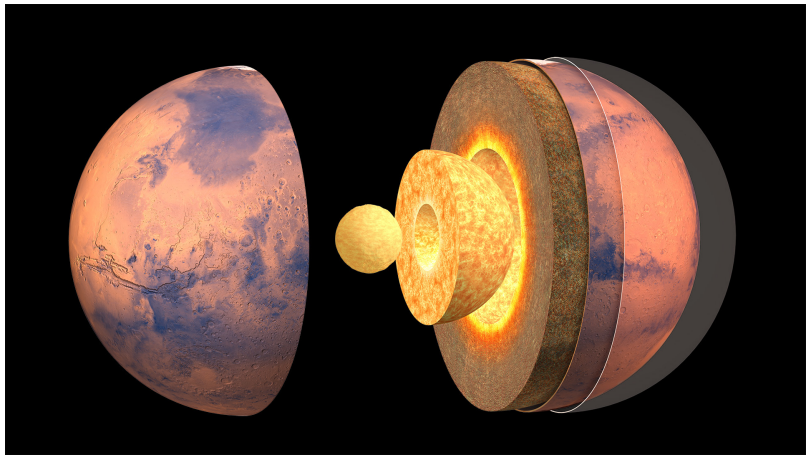
Over the last century seismology has revolutionised our understanding of our planet, of the Moon, and of Mars.

The power of seismology for geophysical exploration has been clearly demonstrated, but seismic measurements have never been made on the surface of an asteroid.

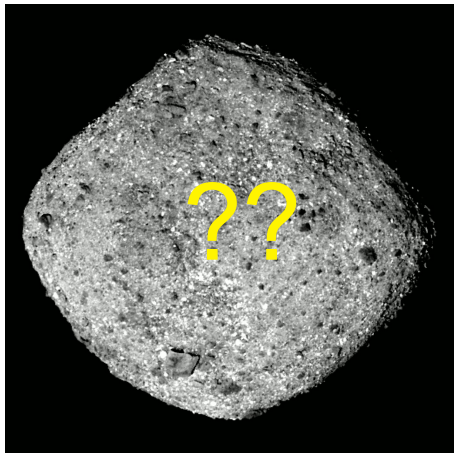
By measuring the ground displacement due to seismic activity (natural or active) on the surface of asteroids, we could vastly **improve our knowledge about the asteroid seismic environment and sub-surface structure**



Apollo missions to the moon (NASA)



InSight on Mars (NASA)

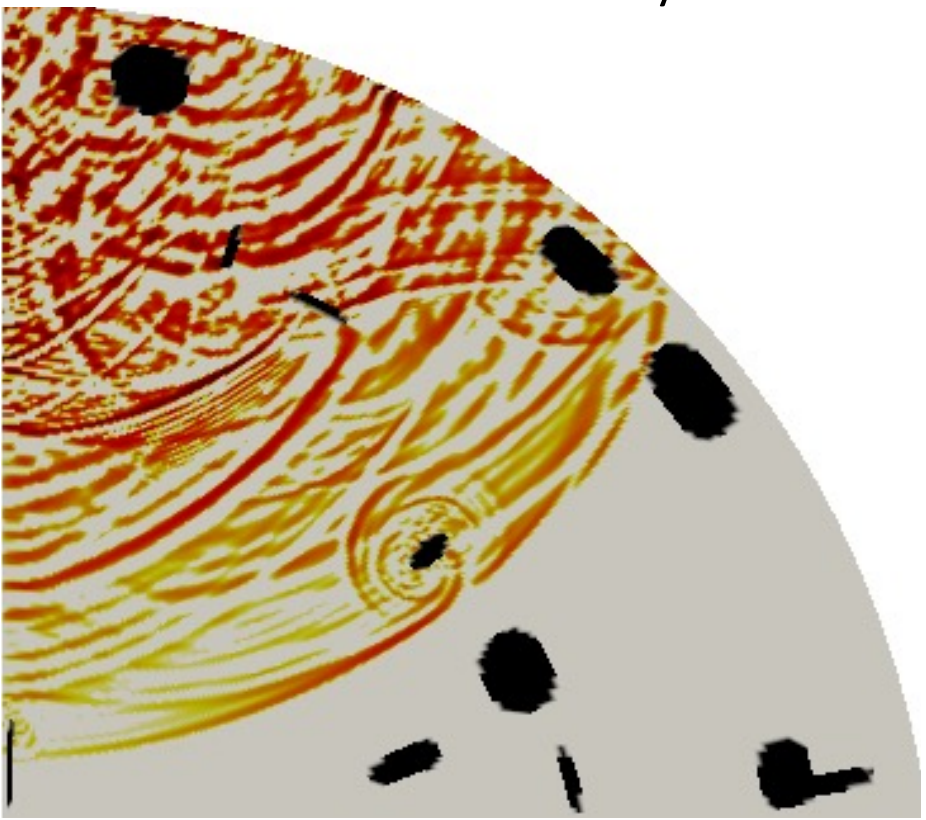


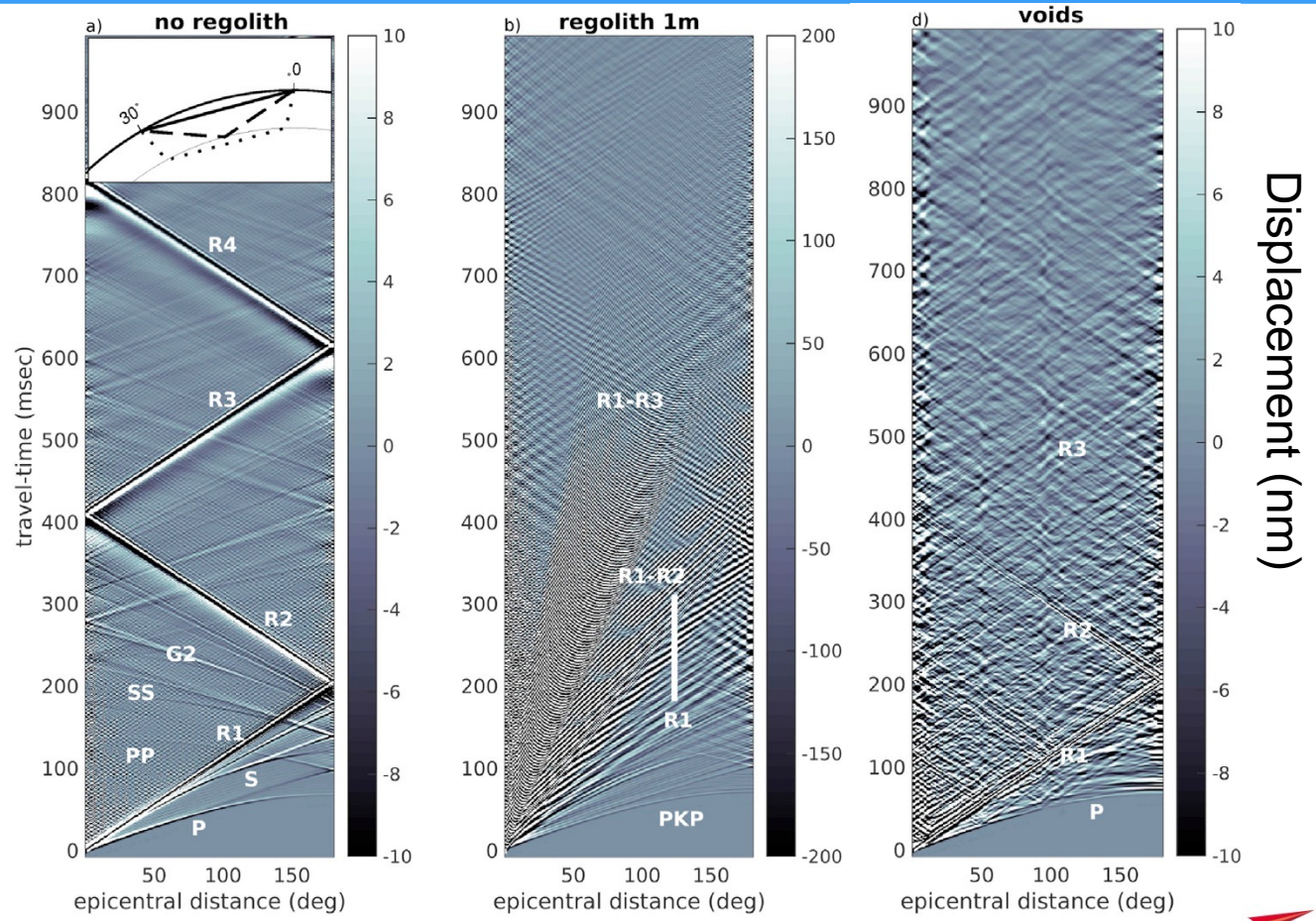
Bennu (NASA)

Studying the sub-surface with seismology

Murdoch et al., (2017)

A **regolith layer** results in seismic energy becoming trapped in the regolith due to the strong impedance contrast at the regolith-core boundary





Voids lead to the wave-field becoming more complex and the onsets of seismic waves becoming less clear due to increased scattering

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Studying the sub-surface with seismology

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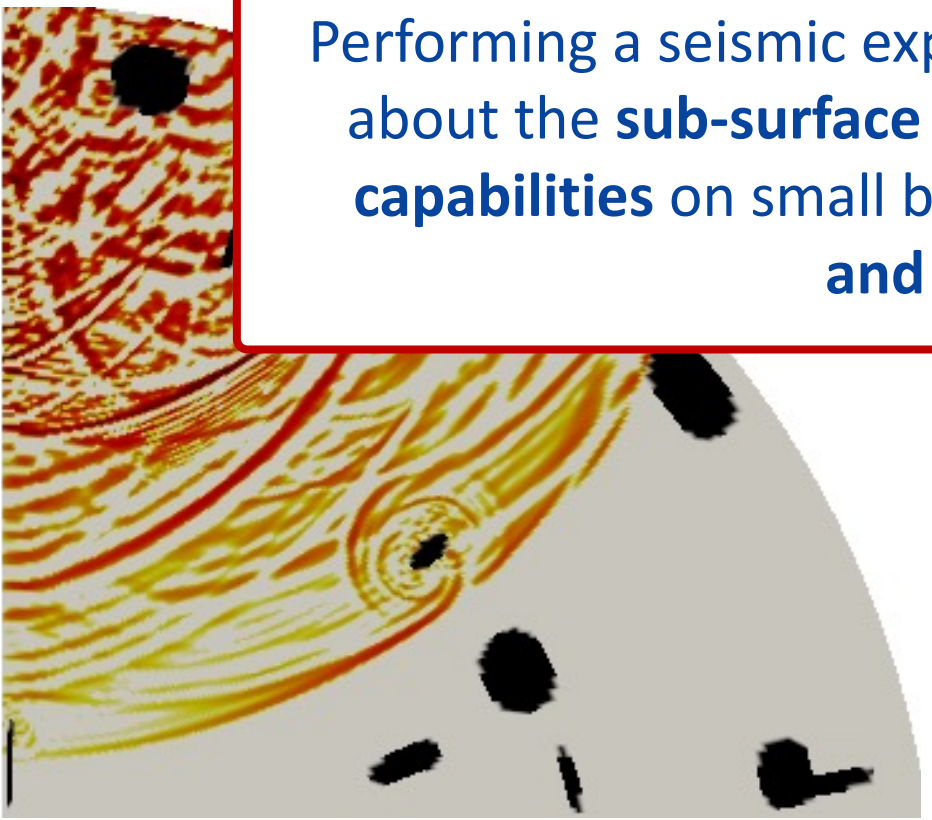

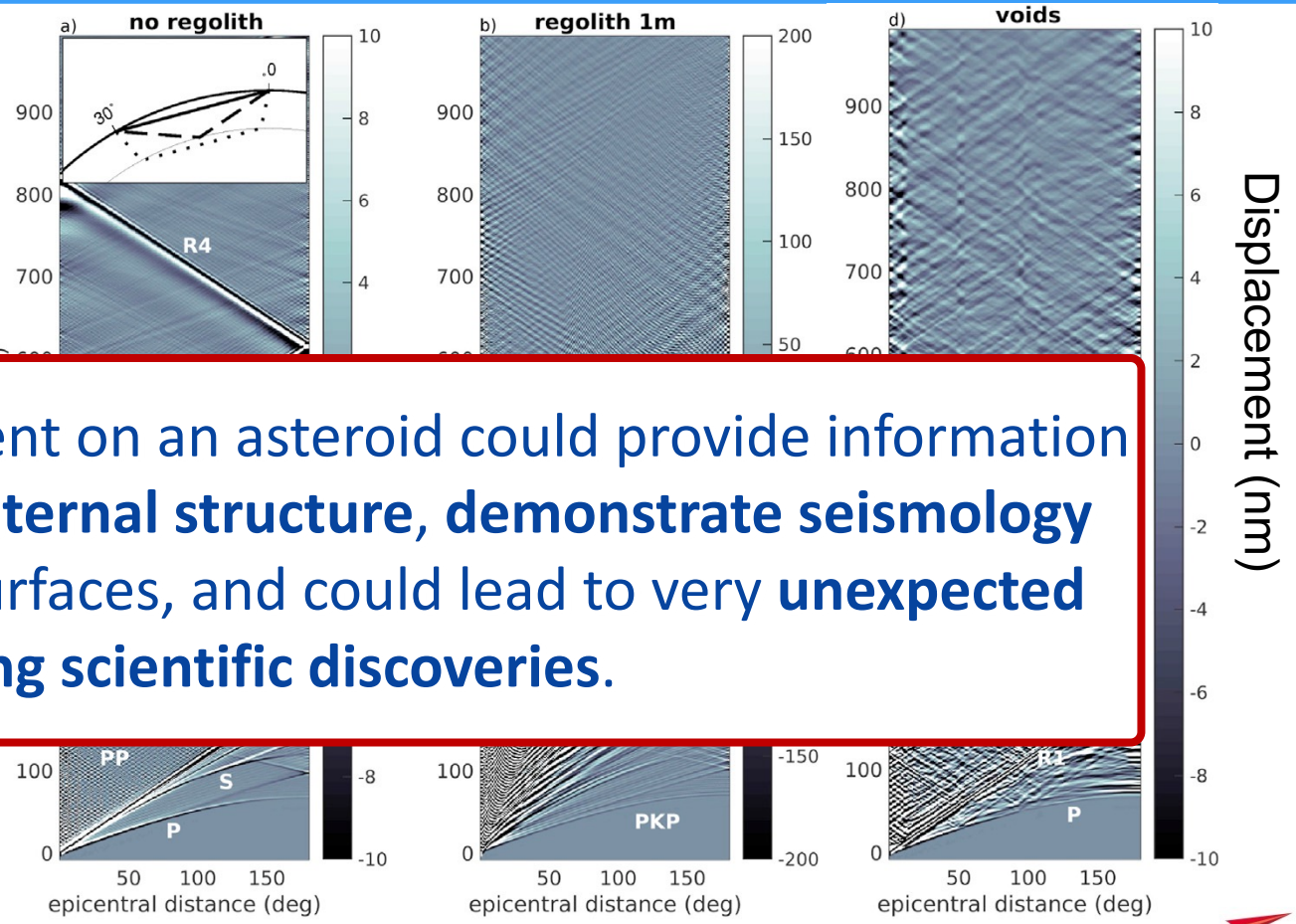

Performing a seismic experiment on an asteroid could provide information about the **sub-surface and internal structure**, **demonstrate seismology capabilities** on small body surfaces, and could lead to very **unexpected and exciting scientific discoveries**.

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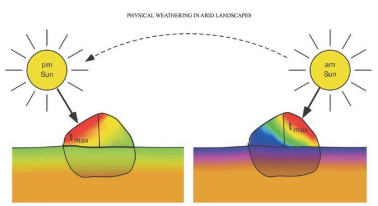
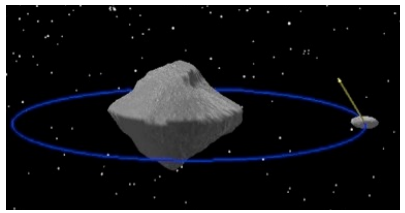
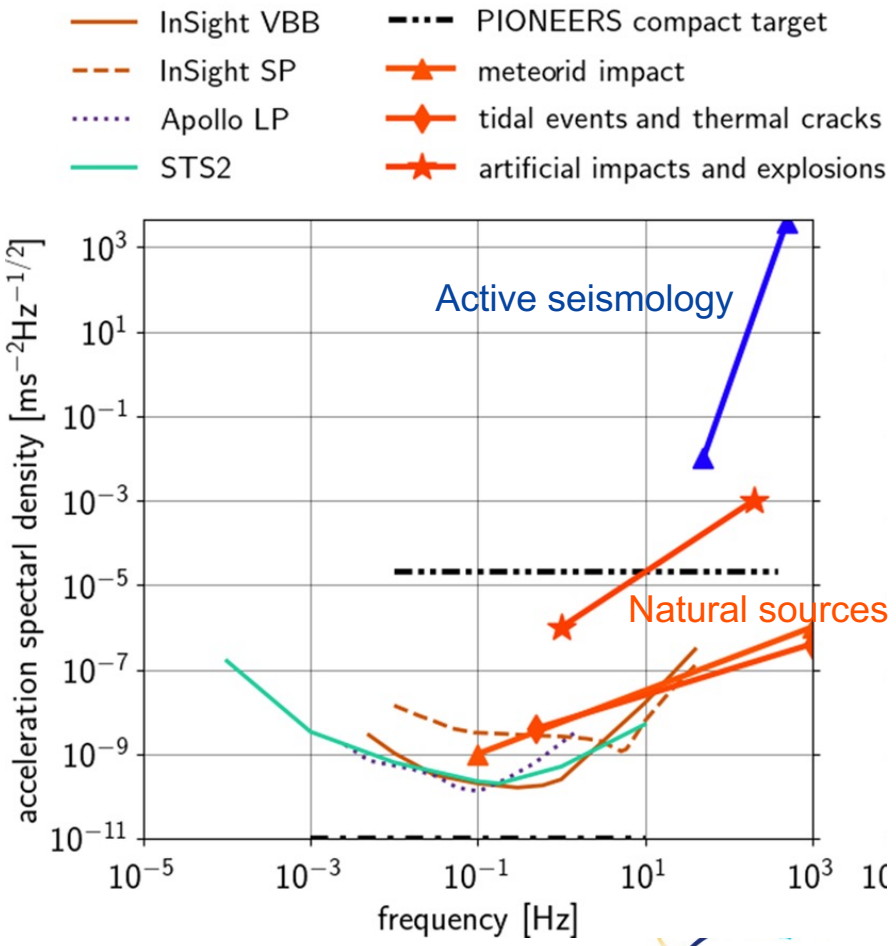
Expected seismic signals: Dimorphos example





	Meteroid Impact: 1 mg, 6 km/s	Meteroid Impact: 10 g, 6 km/s	Thermal Crack: A = 1 cm^2 D = 1 nm	Thermal Crack: A = 1 m^2 D = 10 cm	Tidal Crack: A = 1 cm^2 D = 1 nm	Tidal Crack: A = 1 m^2 D = 10 cm
Seismic moment, M_0	~5e3 N.m	~8e6 N.m	~2.5e-5 N.m	~2.4e7 N.m	~2.5e-5 N.m	~2.4e7 N.m
Frequency of occurence	10-100 /yr	< 1/yr	Local dawn and dusk, potentially a permanent source		Tidal periodicity (every 6 hrs)	
Location of source	Random		Close to the terminator		Poles	



Murdoch et al., (2017)
Bernauer et al., (2020)

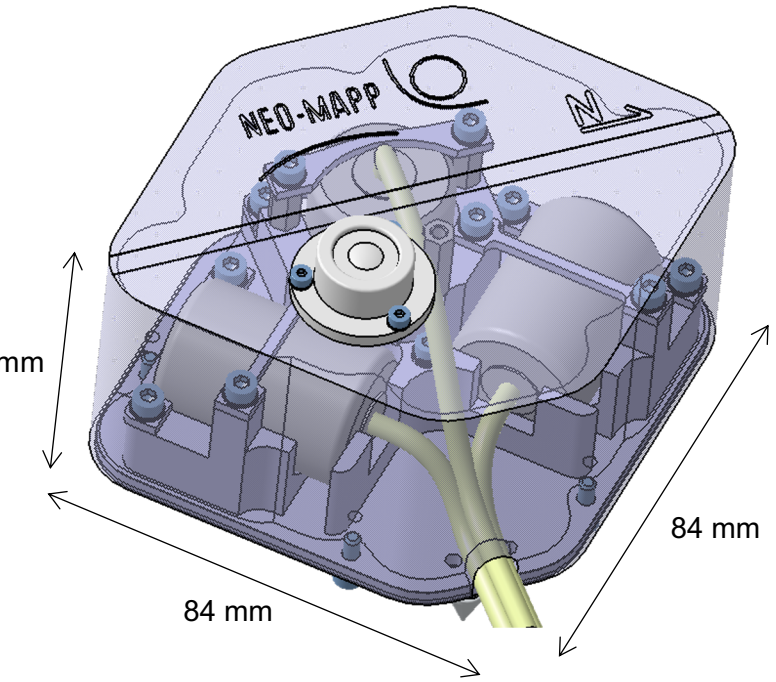
The ISAE-SUPAERO asteroid seismometer

The **seismic sensors are commercial sensors s**pecifically designed for borehole extreme environments

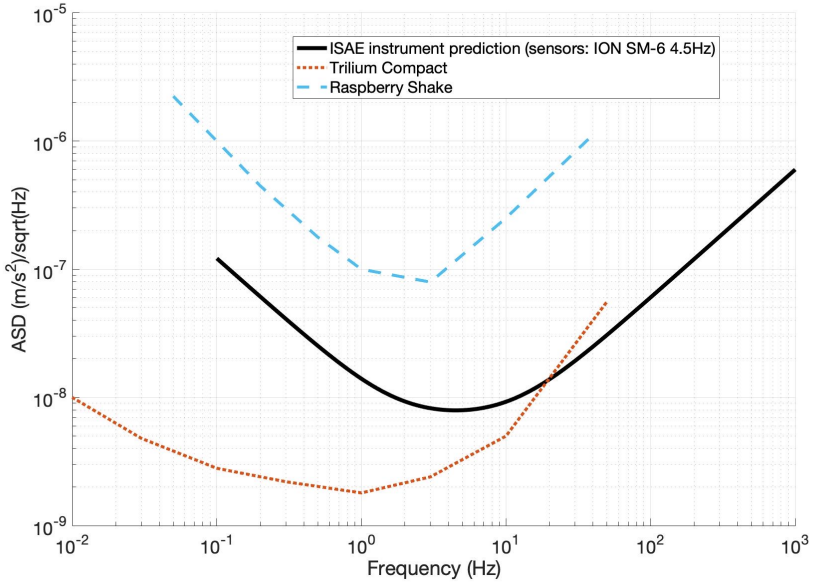
- Operating temperature range: -40 to +100 C
- No active electronics

The dedicated acquisition electronics are **under development at ISAE-SUPAERO**

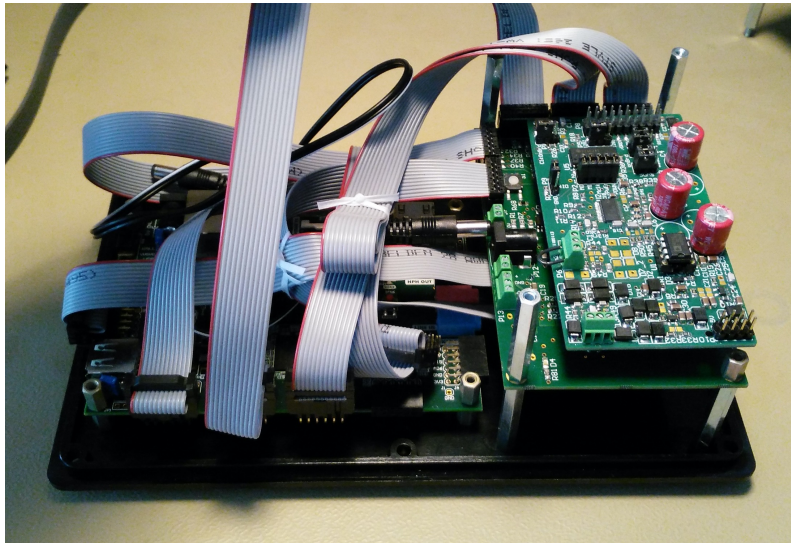
- Breadboard instrument uses COTS easily “flight upgradable” components (i.e., a space qualified version of critical components exists).



Design of the ISAE-SUPAERO seismometer

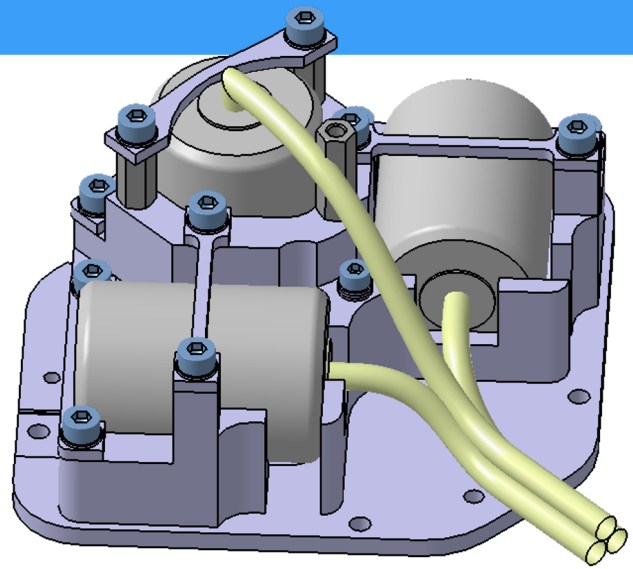


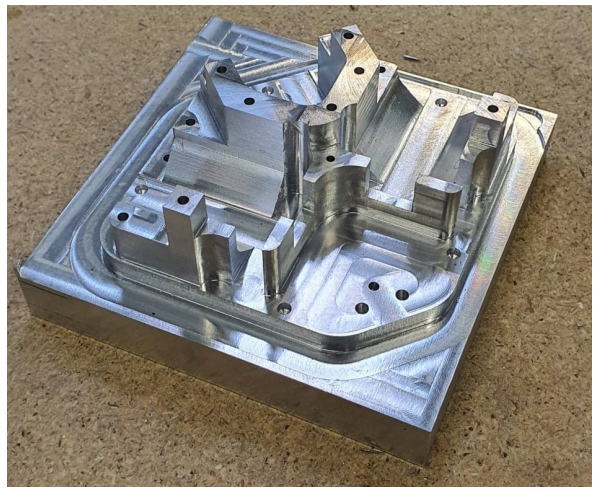
Anticipated sensor noise floor (black), compared with a Trillium compact (red) and Raspbery Shake (blue)



Breadboard of the ISAE-SUPAERO seismometer electronics

The ISAE-SUPAERO asteroid seismometer

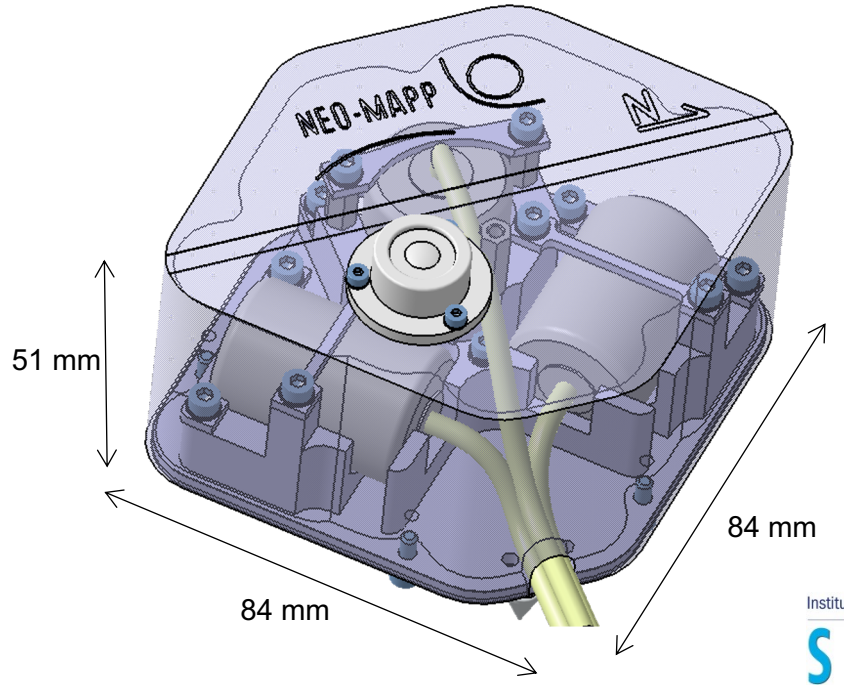




Performance (CBE):
Bandwidth: 5 to 250 Hz
Noise: < 10^-9 m/s/sqrt(Hz)
Measurement range: 40 μm/s

System budgets (CBE):
Power: ~2 W
Mass: ~1 kg
Volume, including electronics: 2U (2L)
Sensor temperature:
-55/+125°C (storage), -40/+100°C (operating range)

Development plan:
- **Breadboard of acquisition electronics** (TRL 3): end 2021
- **Instrument EM** (TRL 4/5): early 2023



Summary

- NEO-MAPP is a European Commission Horizon 2020 study (H2020-SPACE-2018-2020) involving teams from multiple European countries

- As part of the NEO-MAPP project, at ISAE-SUPAERO we are combining our expertise in seismology with our experience in space instrumentation in order to develop **a compact seismometer (geophone) for the geophysical exploration of small bodies**

- This **low mass, low power three axis seismometer** is being designed specifically to function in the challenging environment of the asteroid surface.

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- **TRL 4/5 expected early 2023.**