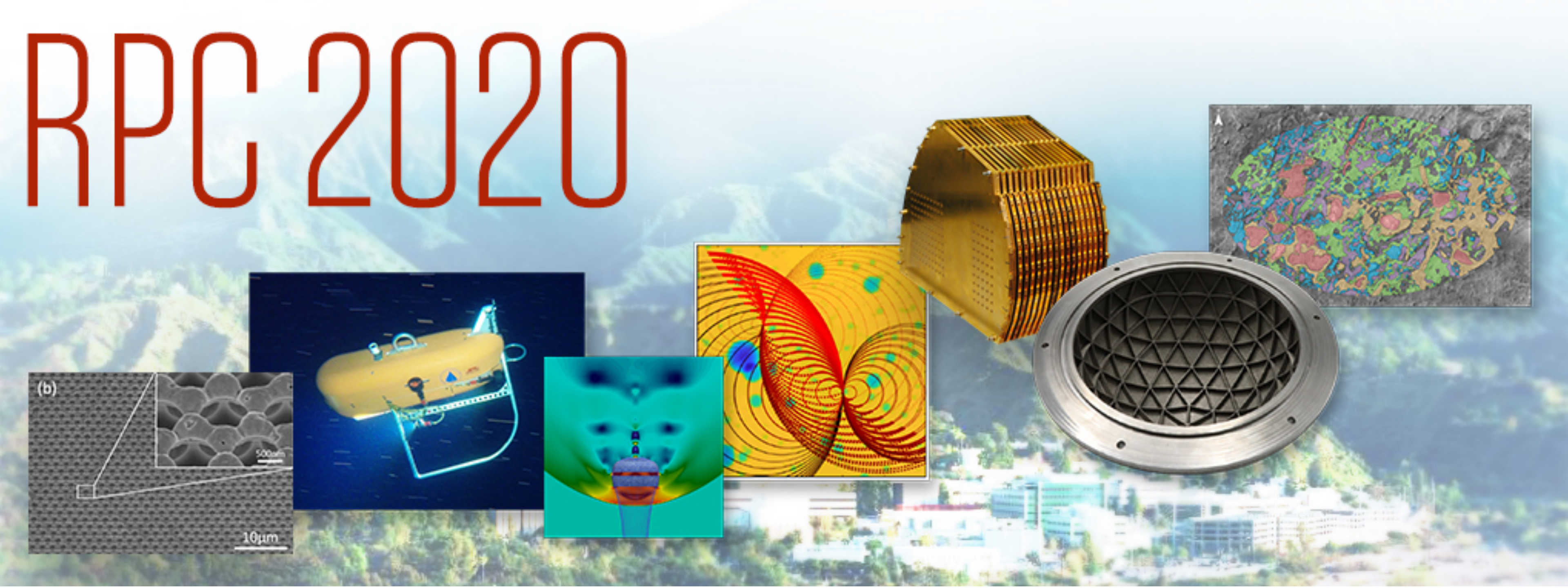

Virtual Research Presentation Conference

Planetary interior structure and dynamics: New directions for research at JPL

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Program: Strategic Initiative
Assigned Presentation #RPC-078

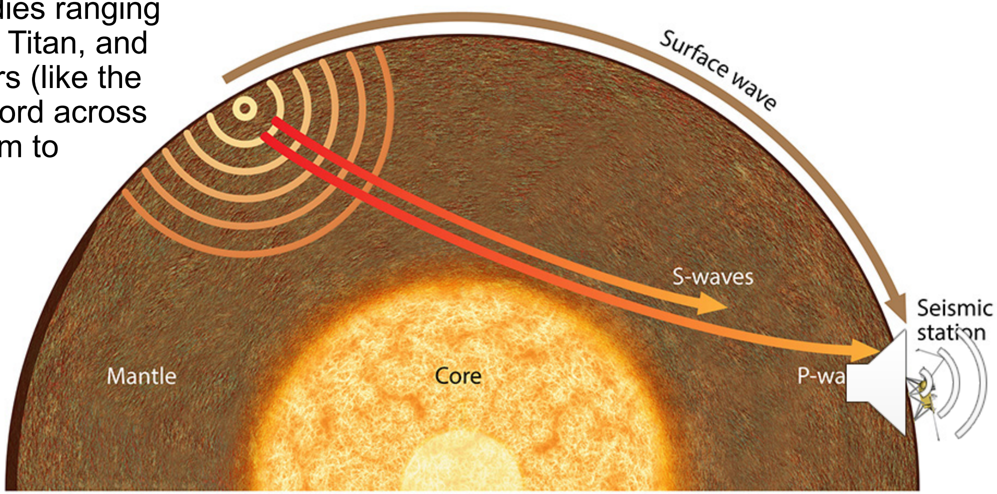
Jet Propulsion Laboratory
California Institute of Technology

Tutorial Introduction

Abstract

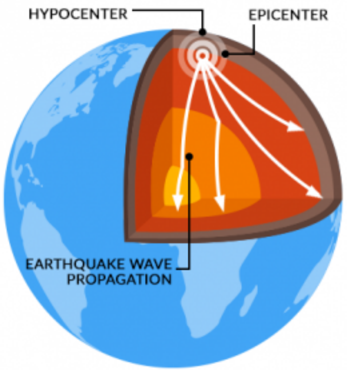
This initiative was put in place to fund a strategic hire to position JPL for the geophysical study of planetary interiors, which was completed successfully to hire Mark Panning, who focuses on using seismic energy from quakes to study planetary interiors (see below), in May 2017.

The project, which was completed in Fiscal Year 2020, focused on developing improved models of interior structure for bodies ranging from the Moon to Mars to icy ocean moons like Europa, Titan, and Enceladus, and better understanding what seismometers (like the InSight one on Mars in the picture) would be able to record across this range of planetary bodies, and how we can use them to understand the interiors of these bodies.



Problem Description

The **measurement and modeling of the interiors of solar system bodies**, including planets, satellites, and small bodies, are important to the scientific goals of NASA and JPL through *Discovery*, *New Frontiers* and flagship programs. **Geophysical approaches to determining interior structure such as gravitational measurements have been a primary objective** of *Discovery* missions for the Moon, Mercury, Vesta, and Ceres. Gravity and magnetic measurements to determine interior structure are also primary science drivers for the *New Frontiers* Juno mission and Europa Clipper.



Our most precise measurements of the interior of our own planet come from seismology. The *Discovery* InSight mission to Mars landed in November 2018, ushering in a new wave of interest in planetary seismology. The Dragonfly mission to Titan, selected as the next *New Frontiers* in summer 2019, includes seismic instruments for the surface of Titan. The Lunar Geophysical Network (LGN) remains a high priority possible *New Frontiers* mission with seismology as a primary driver. The possible Europa Lander mission would include a seismic instrument in both baseline and threshold mission requirements. Interest is growing for similar exploration of Enceladus, while either surface, orbital or airborne techniques have been proposed to enable seismology on Venus.

By defining the key science drivers and instrument requirements for future missions, as well as continuing development of instrumentation, JPL positions itself as the future of this important field of planetary science

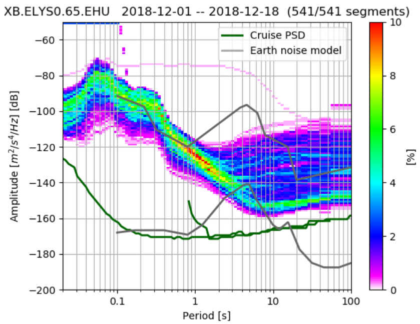
Methodology

This project proceeds along 4 objectives:

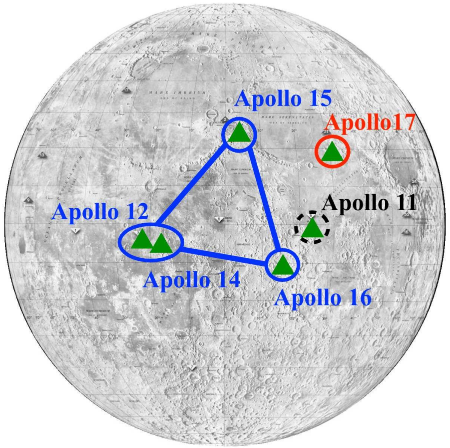
1. Development of interior models of planetary bodies – this task focuses on improvement and application of state-of-the-art seismic inversion techniques, initially focused on the Earth's moon and icy ocean worlds, to obtain interior models from modeled planetary data and analog Earth data. This work runs in parallel with NASA-supported work using InSight data from Mars.
2. Improved modeling of anticipated planetary seismic data – This involves simulation of seismic waves using a variety of methods ranging from simple approaches for low frequencies to state-of-the-art parallel numerical techniques.
3. Prediction and interpretation of seismic activity on planetary bodies –The energetics of possible seismic sources are fundamentally connected to basic science questions about the evolution of solar system bodies, while also serving practical mission design roles through the data modeling of objective 2. In this objective, we will model sources of seismic energy to predict the amplitude and frequency characteristics of expected seismic signal and noise.
4. Advance the science case for future inclusion of seismic instruments in planetary missions –Work that demonstrates science potential from low-cost, robust instruments without complicated deployment and techniques to reduce required data volumes are necessary to broaden the use of seismology in planetary settings.

Results (a few key highlights)

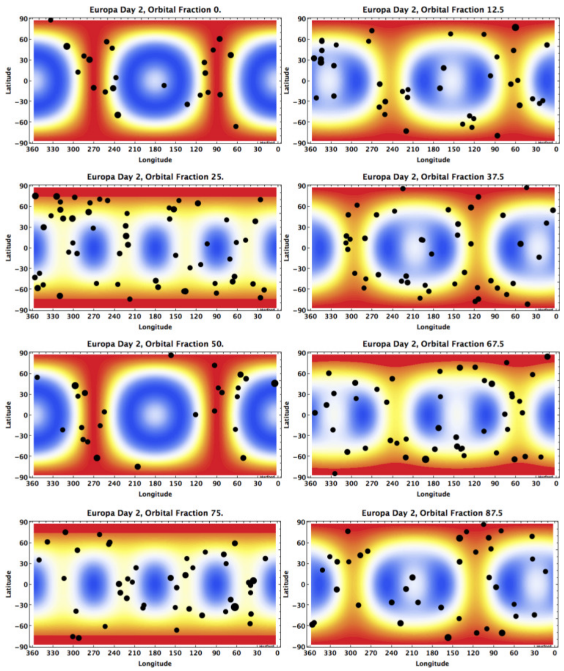
- 3 peer-reviewed publications published and 1 submitted
- 8 conference presentations



48 hours of data gathered on-deck for InSight before deployment was analyzed to explore effectiveness of instruments not on the ground (Panning et al., 2020)



A detailed summary of geophysical instrumentation from the Apollo missions was assembled, which is key for preparing for future lunar missions (Nunn et al., 2020)



A general model for tidally-driven seismicity which varies in space and time based on tidal dissipation was develo with application to Europa, Titan and other bodies (Hurford et al., 2020)

Publications and References

[A] TA Hurford, WG Henning, R Maguire, V Lekic, N Schmerr, M Panning, VJ Bray, M Manga, SA Kattenhorn, LC Quick, AR Rhoden, "Seismicity on Tidally Active Solid Surface Worlds," Icarus 338, 113466 (2020).

[B] Mark P Panning, W Tom Pike, Philippe Lognonné, W Bruce Banerdt, Naomi Murdoch, Don Banfield, Constantinos Charalambous, Sharon Kedar, Ralph D Lorenz, Angela G Marusiak, John B McClean, Ceri Nunn, Simon C Stähler, Alexander E Stott, Tristram Warren, "On-Deck Seismology: Lessons from InSight for Future Planetary Seismology," J. Geophys. Res. 125, e2019JE006353 (2020).

[C] Ceri Nunn, Raphael F Garcia, Yosio Nakamura, Angela G Marusiak, Taichi Kawamura, Daoyuan Sun, Ludovic Margerin, Renee Weber, Mélanie Drilleau, Mark A Wieczorek, Amir Khan, Attilio Rivoldini, Philippe Lognonné, Peimin Zhu, "Lunar seismology: a data and instrumentation review," Space Sci. Rev. 216, 1-39 (2020).

[D] Ceri Nunn, William T. Pike, Ian M. Standley, S. B. Calcutt, Sharon Kedar, and Mark P. Panning, "Standing on Apollo's Shoulders: a Microseismometer for the Moon," submitted to Plan. Sci. J., (2020).

Conference Abstracts

8 abstracts presented at 2019 AGU meeting and 2020 Lunar and Planetary Science Conference