PLANETARY INTERIOR STRUCTURE AND DYNAMICS: NEW DIRECTIONS FOR RESEARCH AT JPL

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Program: Strategic

Project Objective:

The project focuses on 4 objectives related to planetary interior structure focused on seismology.

1. Development of interior models of planetary bodies – Improvement and application of state-of-the-art seismic inversion techniques, initially focused on Mars and Europa.
2. Improved modeling of anticipated planetary seismic data – Simulation of seismic waves using a variety of methods ranging from computationally simple approaches for low frequencies to state of the art parallel numerical techniques.
3. Prediction and interpretation of seismic activity on planetary bodies – 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.

FY19 Results:

Objective 1: Interior modeling

- The proposed FY19 plan for this was to continue ongoing work on seismic inversion. PI Panning contributed to a study published in Nature [B] interpreting Martian interior structure and Phobos orbital evolution in relation to thermal evolution models.

Objectives 2 and 3: Improved modeling of anticipated planetary seismic data and prediction and interpretation of seismic activity.

- Work with Co-Is T. Hurford and N. Schmerr extended previous work from this project modeling Europa tidal ice cracking signals to consider temporally and spatially variable seismicity on any planetary body (figure 1 and [D]).
- New work was initiated to improve modeling of seismic signals by including realistic effects of 3D topography and structure on icy ocean worlds in collaboration with postdoc Saikiran Tharimena.
- In collaboration with Simon Stähler of ETH Zürich, we modeled a different likely noise and signal source for Titan: microseismic excitation due to wave motion on the Mare [C].

Objective 4 focused on approaches to enable future planetary seismic deployments.

- We considered the effects of possible planetary seismic deployments without surface installation on the recoverability of data [A]. Follow-on work incorporating InSight on-deck data is in a manuscript currently in preparation (figure 2).
- Future Co-I C. Nunn has focused on existing lunar seismic data and future potential lunar deployments, including a comprehensive review of the Apollo Seismic Experiment instrumentation [E]. Work on the potential for detection of lunar events using a MEMS seismometer based on the InSight SP sensor has been presented at meetings

Figures of results

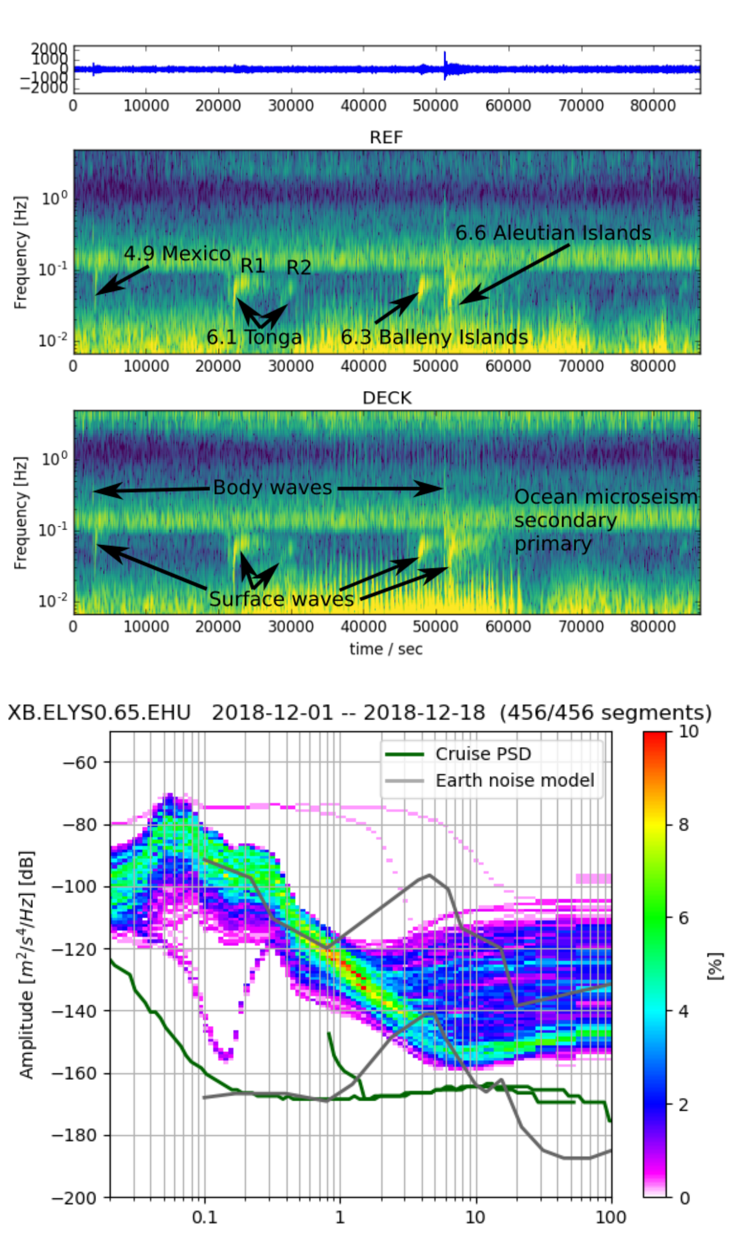

Figure 1: (Top) recordings of seismic signals on MSL engineering model and on ground show capability to record signals below resonances [A], while low noise portions of InSight SP seismometer on-deck recordings show potential in low wind and airless environments.

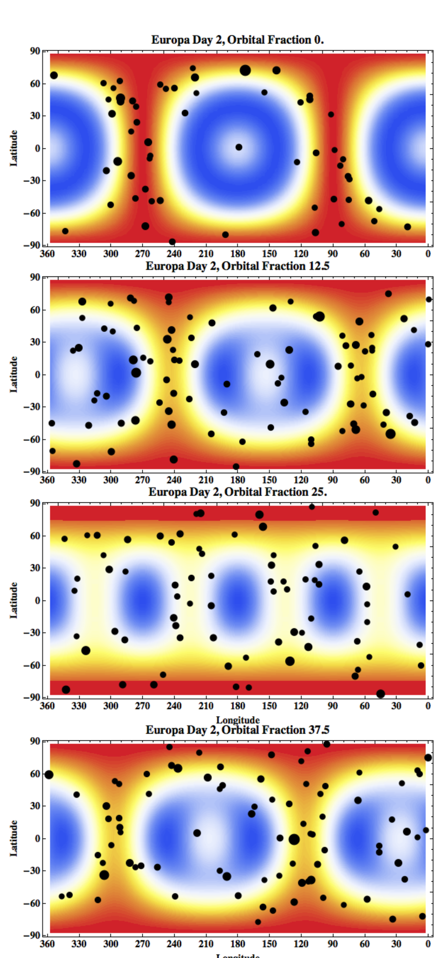

Figure 2 (on left): Distribution of tidal dissipation energy and simulated seismic events over a Europa tidal cycle. Figure from [D].

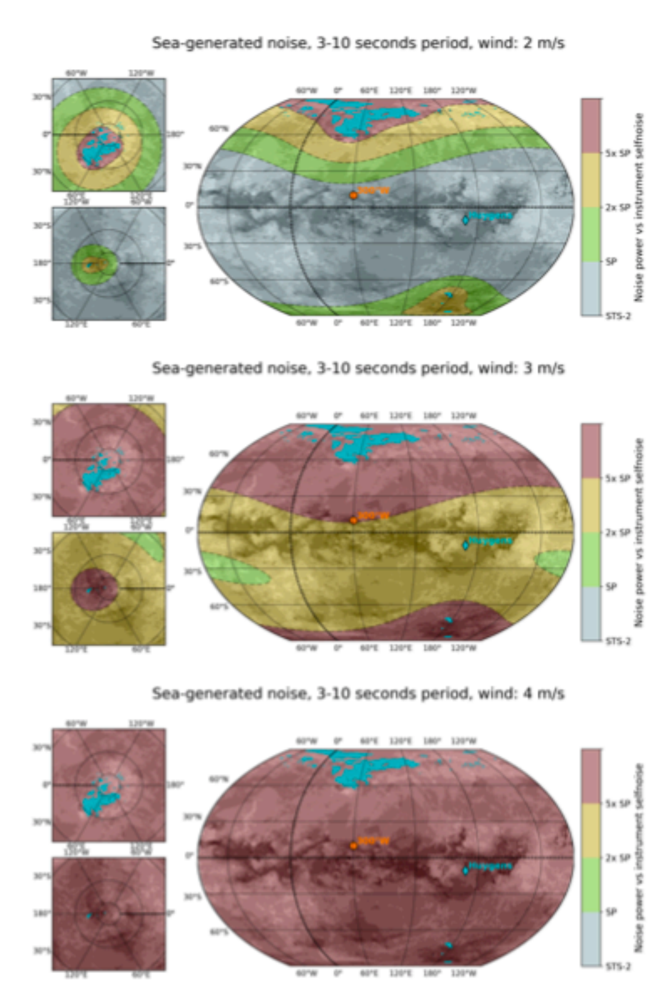

Figure 3 (on right): Expected seismic shaking due to varying wind speeds above Titan's seas plotted relative to InSight SP sensitivity. Figure from [C]/

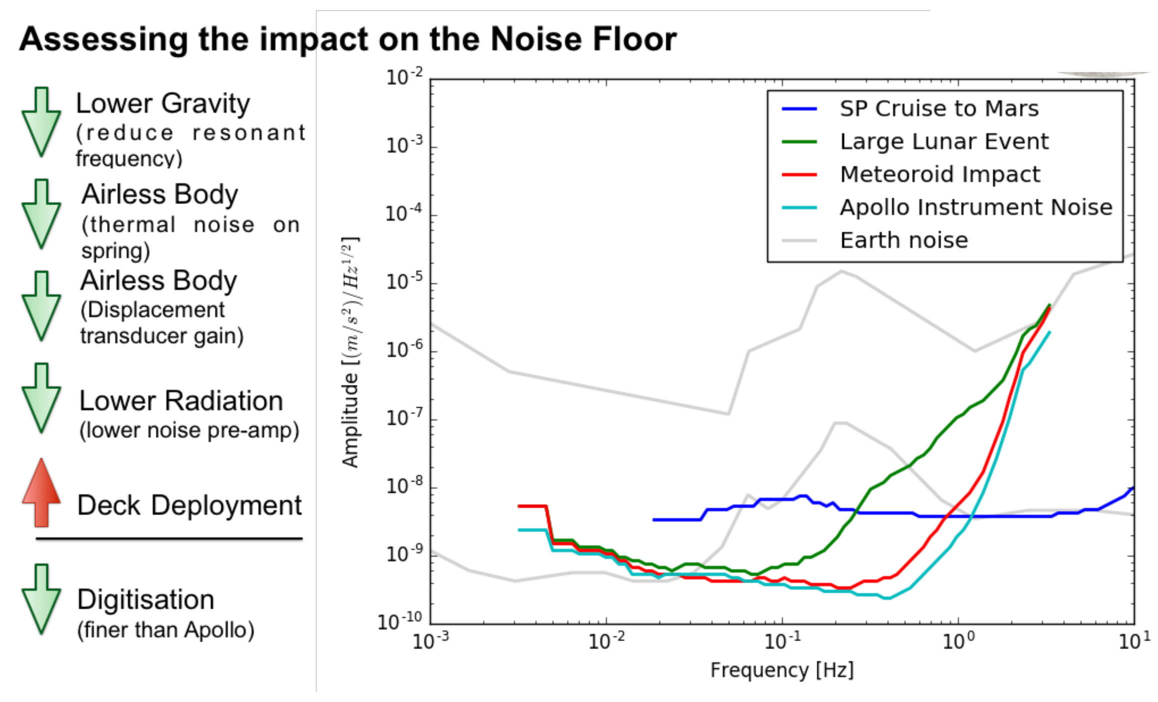

Figure 4☹on left): Comparing InSight SP performance (blue) to Earth noise (gray), Apollo LP noise (cyan), and recorded events (green, red). SP lunar performance can exceed that for Mars.

Benefits to NASA and JPL and significance of results:

The results from this project have advanced our understanding of the likely interior structure of planetary bodies, particularly icy ocean worlds. The modeling of likely seismic waveforms and anticipated seismicity have set important baseline expectations for future missions which hope to take advantage of passive recording of seismic signals in order to determine interior structure. This sets constraints on the duration of potential future missions, and the required sensitivity of instruments to be delivered to these bodies. Understanding the impact of deployment mechanism on recovered seismic data also has important implications for future mission design, opening the door to the frequent inclusion of seismic instruments on landed science missions without a specific focus on seismology.

Acknowledgments:

Results discussed here include work from collaborators S. Tharimena (322) and S. Stähler (ETH Zürich). C. Nunn (322) has been added as a Co-I for FY20, and also has results included here.

Publications:

[A] Mark Panning and Sharon Kedar, "Seismic response of the Mars Curiosity Rover: Implications for future planetary seismology," Icarus 317, 373.-378, 2019, doi: 10.1016/j.icarus.2018.06.017.

[B] Henri Samuel, Philippe Lognonné, Mark P. Panning, and Valéry Lainey, "The rheology and thermal history of Mars revealed by the orbital evolution of Phobos," Nature 569, 523-527, 2019, doi: 10.1038/S41586-019-1202-7.

[C] Simon C. Stähler, Mark P. Panning, Céline Hadziioannou, Ralph D. Lorenz, Steve Vance, Knut Klingbeil, and Sharon Kedar, "Seismic signal from waves on Titan's seas," Earth Planet. Sci. Lett. 520, 250-259, 2019, doi: 10.1016/j.epsl.2019.05.043.

[D] Hurford, T. A., Henning, W. G., Maguire, R., Lekic, V., Schmerr, N., Panning, M. P., Bray, V.J., Manga, M., Kattenhorn, S. A., Quick, L. C., Rhoden, A. R., "Seismicity on Tidally Active Solid-Surface Worlds," Icarus, 2019, revision submitted.

[E] Nunn, C., Garcia, R.F., Y. Nakamura, Marusiak, A.G., Kawamura, T., Sun, D., L. Margerin, R. C. Weber, M. Drilleau, M. A. Wieczorek, A. Khan, A. Rivoldini, P. Lognonné, P. Zhu, "Lunar Seismology: a data and instrumentation review," Space Science Reviews, 2019, submitted.

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