SEISMOMETER TO INVESTIGATE ICE AND OCEAN STRUCTURE (SIIOS)

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WHAT IS SIIOS?

• The Seismometer to Investigate Ice and Ocean Structure (SIIOS) is a NASA-funded instrument maturation effort to develop a seismometer for inclusion on a landed mission to Europa.

• The Europa Lander Mission includes a seismic instrument in the baseline in both the 2012 and 2016 JPL Lander Studies.

• Objectives for this instrument usually include:
  • Measuring the depth of the ice and water layers (and hence the internal structure of Europa).
  • Determining the proximity to any intermediate water layers.
  • Determining the local properties of the ice shell proximal to the landing site.

• ~30 day surface mission.
QUAKES ON EUROPA?

- Naturally-generated low-frequency seismic waves resulting from fracture propagation, fault movements, and tidal effects propagate over great distances in ice.
- This enables detection of the ice-water boundary and the sounding of liquid water pockets within the ice layer, at distances on the scale of Europa.
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EXPECTATIONS FOR SEISMICITY ON EUROPA

• Estimates from tensile cracks, normal and strike slip faults suggest potential Mw 5.2 events

• Deep “moonquakes” related to tidal stresses (Mw~3) were revealed in the Apollo seismic data

• Tidal stresses on Europa are estimated to be 8-20x larger than on the Moon

• Detectable impacts are estimated at 0-20 per year are not likely to be observed be a seismic instrument deployed for less than one year

• Quakes generated in the rocky part?

• Seismic noise models of Europa are an area of on-going research (e.g. we really don’t know!)
• The Silicon Audio instrument integrates the mechanics of a conventional geophone with a miniaturized laser interferometer system

• Captures signals across a wide bandwidth of frequencies (0.005–600 Hz)

• Large dynamic range —183 dB compared to Apollo’s 60 dB.

• Ultralow distortion (≤ 0.03%)

• 40-degree tilt-insensitive in Europa’s low-gravity field and calibrated to work in any orientation (omni-tilt).

• Low self-noise

• Low mass
ANALOG FIELD EXPERIMENTS

• Our team has conducted field analog measurements of terrestrial seismic events in ice, with the following goals:
  • Assess performance of an ‘in-vault’ seismometer
  • Demonstrate the ability of a small aperture (< 4 m) seismic array in a “lander-like” configuration
  • Develop protocols and requirements for spacecraft onboard-generation of data products
  • Assess the effectiveness of passive seismicity for constraining crustal thickness on Europa
  • Deploy flight candidate Silicon Audio broadband seismometers

• We deployed our candidate seismometer on a purpose-built lander simulator on a glacier in Gulkana, Alaska and on a subglacial lake in northwest Greenland.

• In each experiment, we compared on-lander (as an analog to the Europa lander’s vault) to in-ice measurements.

• Both deployments demonstrated the ability of our instrument to detect seismic phases unique to ice-water interfaces in an analog environment, and also constrain the thickness of an ice column.
GULKANA GLACIER, ALASKA
GULKANA, ALASKA EXPERIMENT

Date & Time: Sat Sep 9 15:00:20 AKST 2017
Position: 60.3.2009A N 146.41258 E
Altitude: 14494m
Datum: WGS-84
Azimuth/Bearing: 049° N48° 07'11mi True/Zoom 1X

Silicon Audio seismometers in sand-filled buckets on Lander simulator

Rothek 130s & batteries in weather boxes

Trillium 120PH buried and vaulted beneath table

Silicon Audio seismometer Sercel L-28-3D (HF) Trillium Compact buried and vaulted in shallow ice pits

Ground-based

Deck-mounted
PASSIVE SEISMICITY COMPARISON: GULKANA

- Sept 19th 2017 MW 7.1
- Bandpass filter 1-50s, instrument response removed, vertical component
- Deck-mounted instrument exhibits more background noise and obscured arrivals
“CAMP EUROPA”
GREENLAND
GREENLAND EXPERIMENT
LANDER RESPONSE

finite element modeling of our lander simulator showing the response to a simulated seismic signal

Response is sensitive to mounting location
SUMMARY/DISCUSSION

- Single-station or small arrays can be powerful tools
  - Can detect both large global events, and small local events
  - Located events can be used to invert for structure
  - Special techniques for recovering distance and azimuth of events now being employed on Mars with InSight

- Deck mounted deployment can be as powerful as grounded (with precautions)
  - Necessary to quantify the response and self-noise of the lander & sensor as a combined system
LUNAR CASE

• SIIOS team is also developing the Silicon Audio seismometer for use on the Moon

• Includes subsurface gas-jet deployment system for sub-surface burial

• Provides thermal isolation and mitigates the effects of scattering in the lunar regolith

• Candidate instrument for future lunar geophysical network