National Aeronautics and Space Administration

RETH Workshop

NASA TubeX Project

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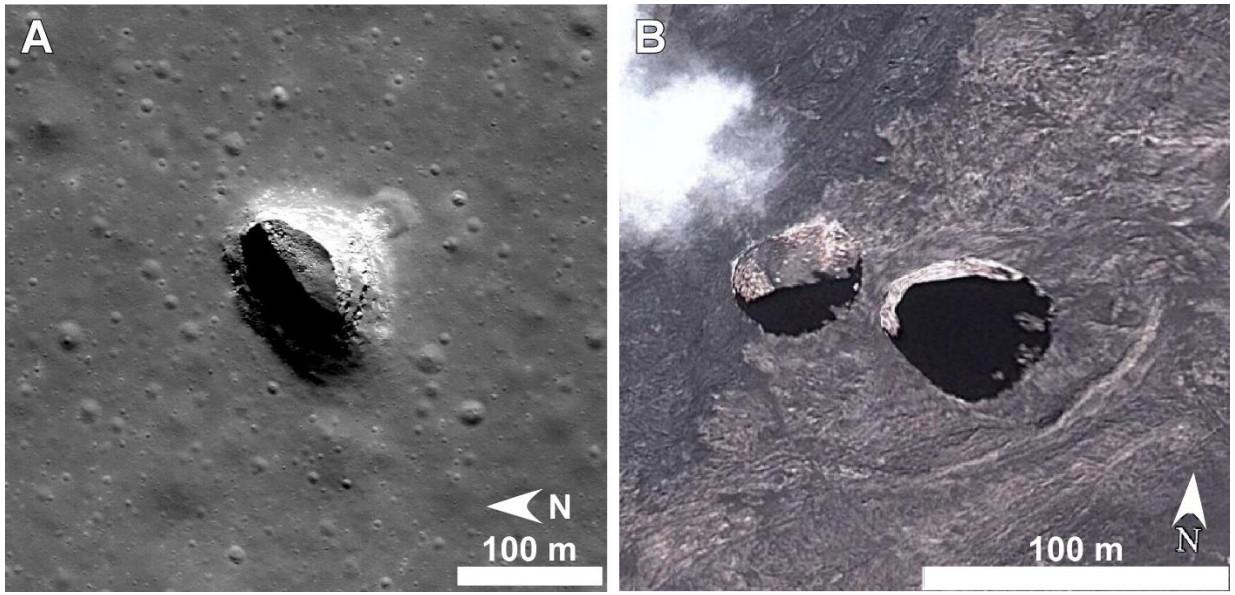
Lava Tubes as Potential Habitat Location

- Common in mafic lava flows throughout the Solar System, especially on bodies with potential for human exploration
- Long been discussed as potential safe havens for astronauts and life support equipment
  - Shielding from radiation, surface temperature fluctuations, impact events, etc.
  - Potential volatile reservoirs
- Form by multiple mechanisms
  - Roofed over channels, preferred pathways in inflated flows, etc.
  - [Greeley, 1970; Peterson et al., 1994]
- Despite being an interesting science and exploration target, only recently has work begun on how to explore lava tubes on planetary surfaces

Lava Tubes as Potential Habitat Location

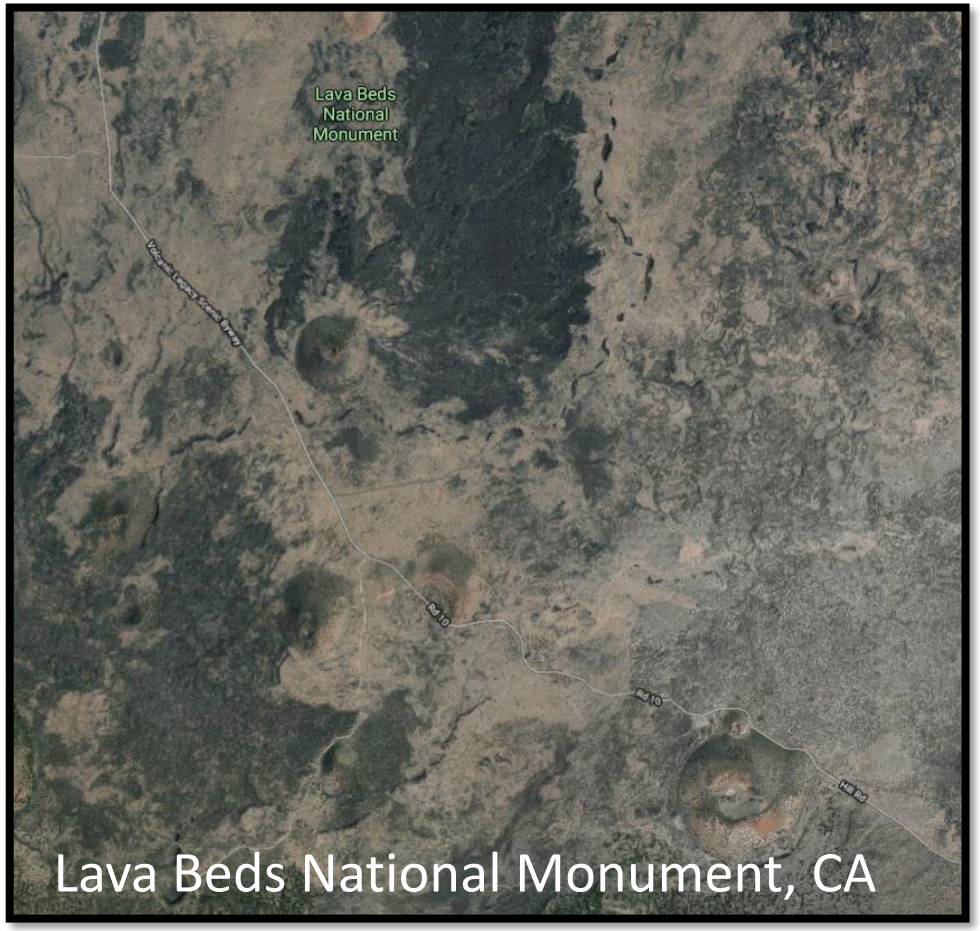


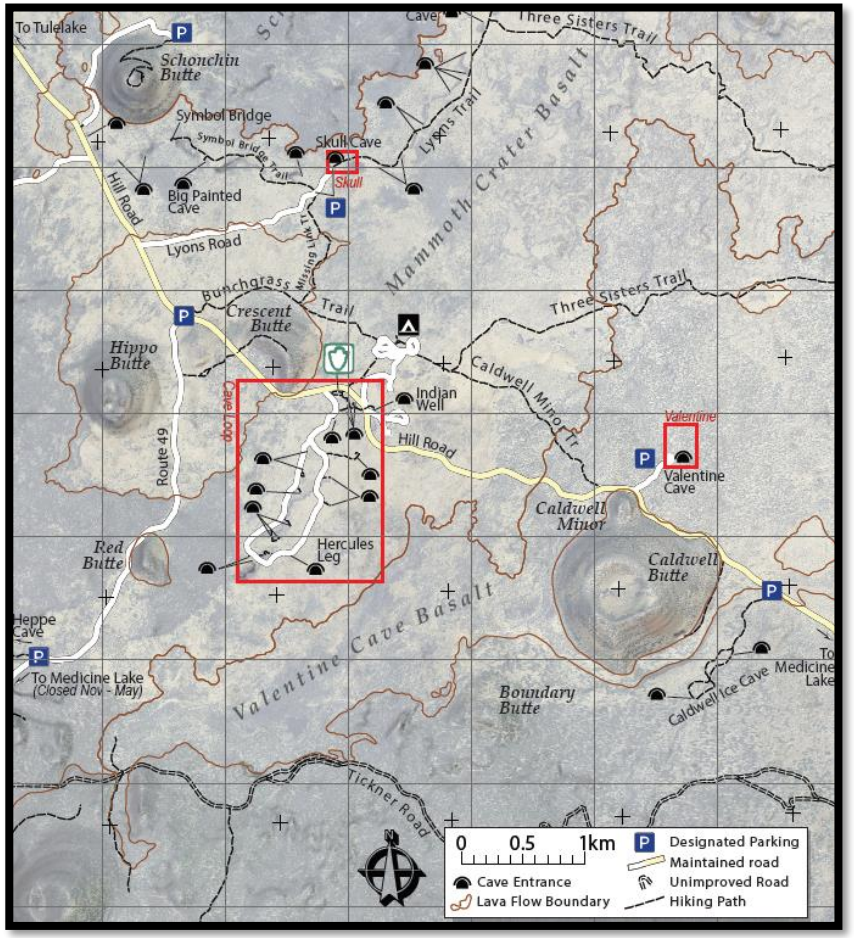
A: Mare Ingenii lunar pit
LROC image: M123485893RE
[NASA/ASU/LROC]
B: Two pits on Kilauea
Google Earth

Credit W.B. Garry

- Collapse features identified on the Moon and Mars
  - [i.e. Cushing et al., 2007; Haruyama et al., 2009; Wagner and Robinson, 2014; etc.]
- No way to map out from a pit to determine the size, shape, geometry, and therefore the habitability from orbit
- Other strategies have been investigated for modes of tube exploration
  - Flying explorers, smaller robots, etc. [e.g. Robinson et al., 2014]
- Bottom line: we need a way to characterize these features from the ground

NASA TubeX Project





NASA-funded TubeX project uses surface deployable instrumentation (Ground Penetrating Radar, Magnetometry, Gravimetry, Seismics), calibrated against interior surface models generated from LiDAR data, to determine which surface instruments are most valuable in mapping lava tubes from above

NASA TubeX Project

Lava Beds National Monument, CA

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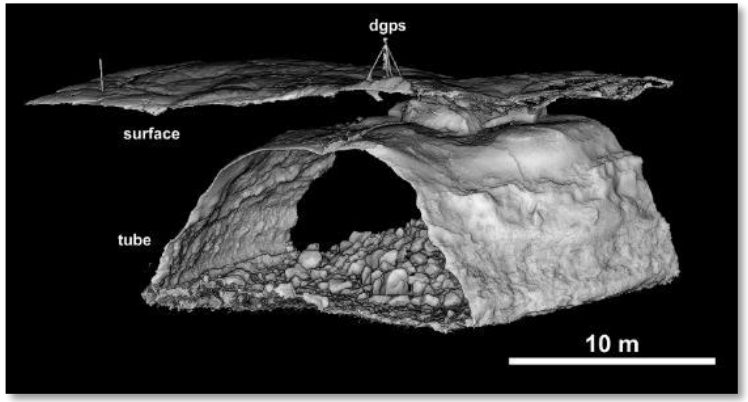
Lava Tubes as Potential Habitat Location

JSC tools engineer crawling out of tube skylight



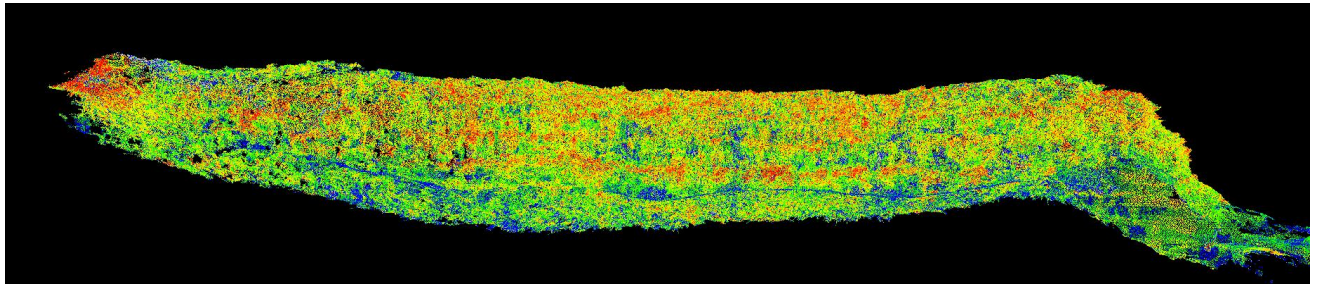
LiDAR data showing surface and interior of a tube

N. Schmerr collecting magnetometry data above a tube opening, Hawaii

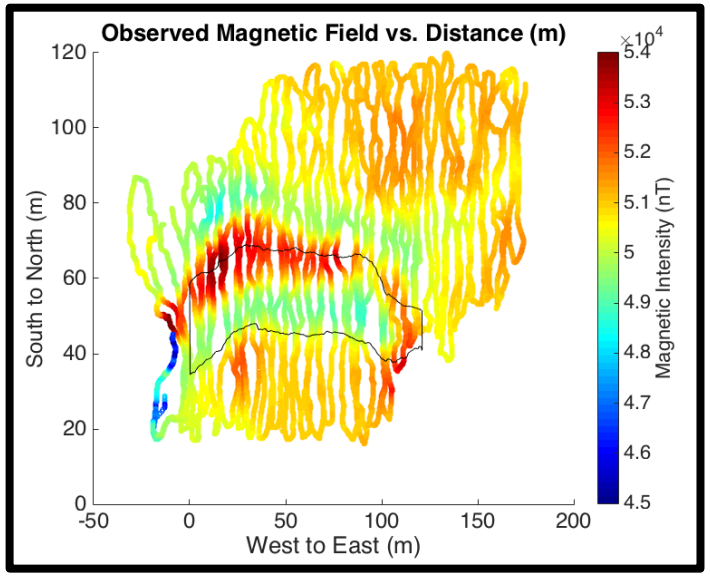
- Major engineering hurdles
  - Tubes of dramatically different shapes, sizes, geometries
- Must figure out a way to high grade explorable tubes from the surface without endangering human or robotic assets
- The Tube-X project seeks to develop an exploration and characterization strategy for a pit-rich environment that involves only surface-deployable assets

Lava Tubes as Potential Habitat Location

Skull Cave, Lava Beds Nat'l Monument, CA



LiDAR data produces high resolution tube geometry (Credit: P. Whelley and B. Garry, NASA GSFC)



Aerial view of surface magnetic survey of Skull Cave, showing absolute recorded magnetic values (Credit: E. Bell, UMD)

See Bell et al. poster this evening

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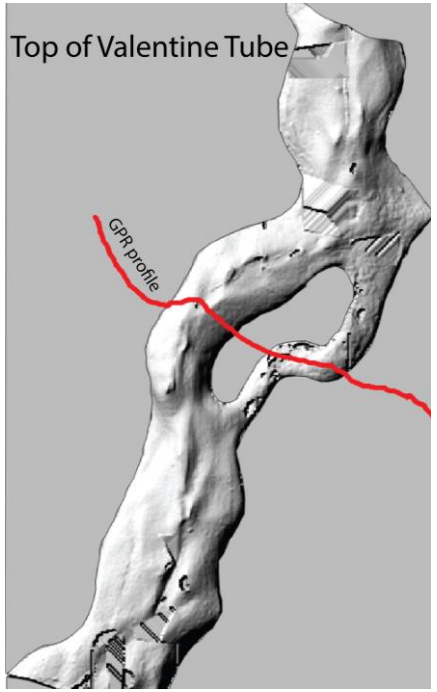
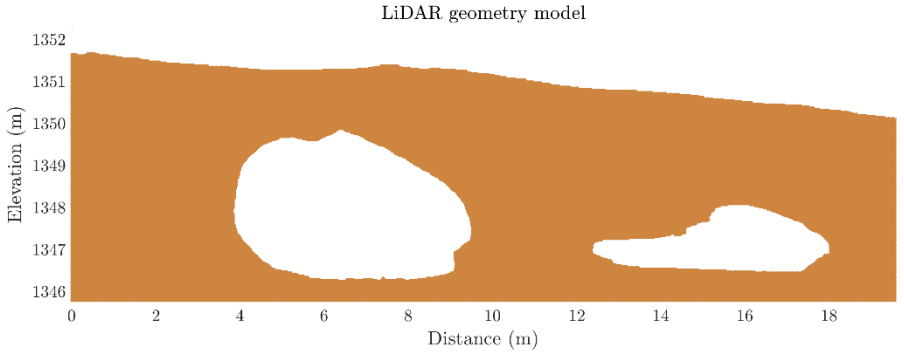
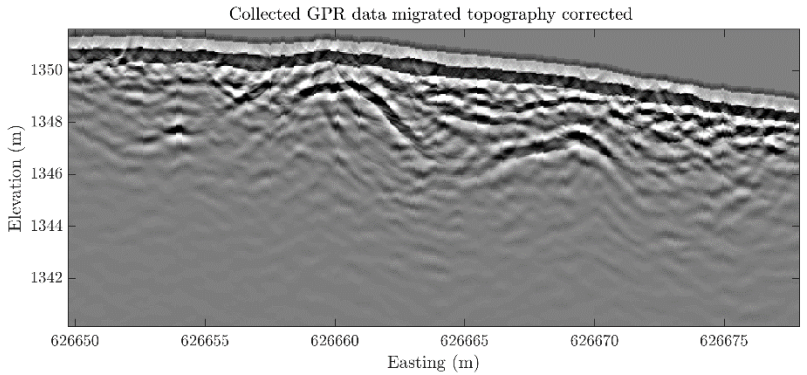
Lava Tubes as Potential Habitat Location

Valentine Cave, Lava Beds Nat'l Monument, CA







Geometry model of lava tube created from LiDAR used to refine GPR transmitter/receiver set-up (GPR Credit: S. Esmaeili and S. Kruse, USF)

- Initial results are promising, and show that GPR, magnetometry, and gravity will be promising in identifying and mapping subsurface void space
- More work is needed to develop engineering strategies for lava tubes
- Need to evaluate methods for entry/exit considering hardware reliability and redundancy in addition to the variety of terrain.
- **Equipment could include: ruggedized spelunking gear, deployable ladders, ramps, telescoping staircases, rover mounted winch and boom, ropes, carabineers, suit/helmet protection, etc.**