The Science Case for Spaceborne Radar Observations at Io. J. M. Christoph[1] and D. A. Williams[2], [1,2]School of Earth and Space Exploration, Arizona State University [1](jmchri17@asu.edu) [2](David.Williams@asu.edu)

Introduction:

In a previous LPSC presentation [1] and ongoing work, we have explored the feasibility of Synthetic Aperture Radar instrumentation for a future spacecraft mission to Io, the moon of Jupiter. In this presentation, we discuss key science questions pertinent to Io for which radar would be a useful investigative tool.

Geologic Background:

Io is the innermost of the Galilean satellites of Jupiter, and is the most volcanically active object in the solar system. Over 300 known active hot spot volcanoes are scattered across Io's surface [2], driven by extreme tidal heating due to the interactions between Io, Jupiter, and the other Galilean satellites [3]. The overwhelming majority of Io's volcanic vents are calderae rather than edifices with substantial topographic relief, although mountains with up to 17 km relief are present on Io [4]. Eruptions on Io consist of two compositional variants: mafic-to-ultramafic silicate lavas similar to ancient terrestrial komatiites, and sulfur volcanism largely consisting of molten cyclo-S_8 accompanied by volatile SO_2. Sixty percent of Io's surface is covered in plains deposits [5], consisting of cyclo-S_8, S_3, S_4, and SO_2 which originate from sulfur eruptions.

Radar at Io:

The motivation for considering a radar instrument for Io stems from the success of spaceborne imaging radar systems conducting ground-penetrating observations of Earth, exemplified by SIR-C images of structural features [6] and river channels [7] which are buried beneath meters of Sahara Desert sand and thus obscured in visible-wavelength images. Although radar observations of surface features are also of scientific interest, we concern ourselves primarily with ground-penetrating capabilities for the purposes of this study. Our goals have been to determine whether ground penetration capability beneath the sulfur plains deposits at Io is possible [1], and what science would be enabled by such an instrument capability.

Our concept study (presently in review) considers two architectures with different science use cases. First: an L-band or UHF radar operating as an add-on to a spacecraft's high-gain antenna (similar to Cassini SAR at Titan), capable of penetrating plains deposits to depths of order 1 meter. Second: a VHF or HF radar operating with a dedicated antenna (similar to MARSIS or SHARAD at Mars), capable of penetrating plains deposits to depths exceeding 10 meters.

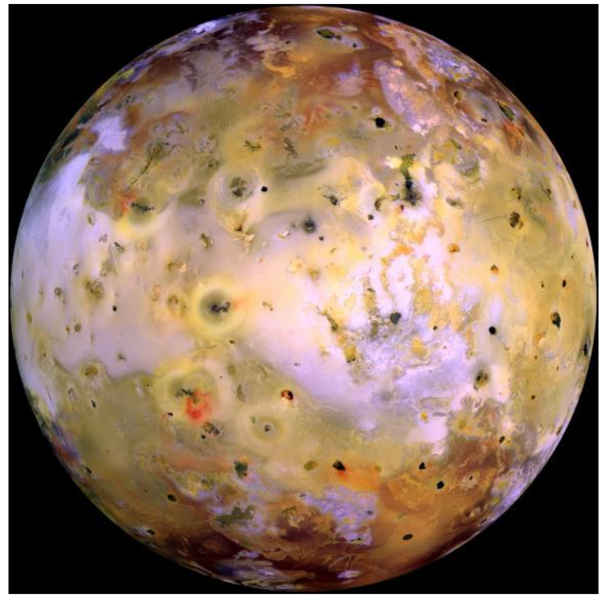

Fig. 1: Galileo false-color mosaic of Io, showing volcanic vents, tectonically formed mountains, and grey-white, yellow, and red-brown sulfur plains materials. NASA PIA02309

The first architecture permits targeted observations of specific locations on Io where plains deposits can be expected to be relatively thin due to proximity to bedrock features protruding onto the surface. A key example is tectonically-bounded mountains, ranges, and other topographic highs such as Hi'iaka Patera [8] and Scythia Montes [9]. These features are common across Io's surface, in nearly all cases bounded by scarps interpreted to be faults [5], and in some cases exhibit clear evidence of regional tectonism (Fig. 2). If such large-scale edifices were indeed tectonically formed, they would be expected to be accompanied by other tectonic or deformation features, such as shear zones or graben. However, the low-lying areas immediately surrounding most of these topographic highs are overlain by sulfur plains deposits. The ability to directly image faults or other structural features that are inferred to underlie the plains deposits at these locations would enhance structural studies of mountain-building and regional crustal deformation on Io, which in turn holds implications for Io's lithospheric thickness and heat flow [10].

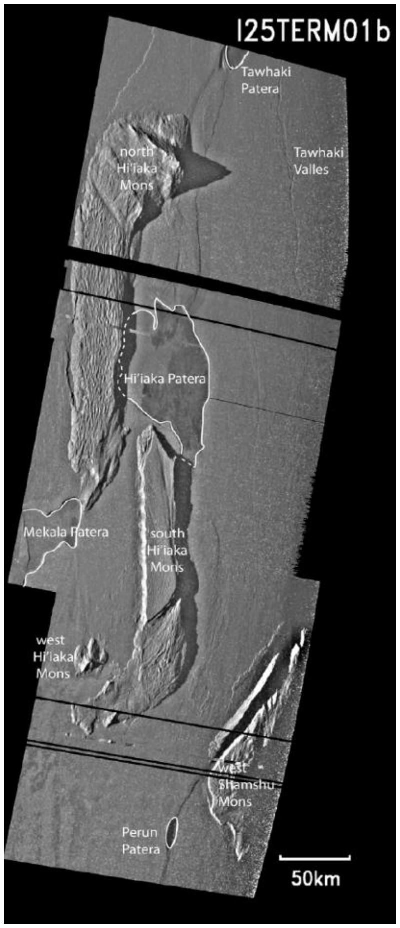

Fig. 2: interpreted Galileo image of Hi'iaka Patera and surrounding mountains, modified from [2]

The second architecture permits global characterization of the subsurface beneath plains deposits, irrespective of depth. The goal of global subsurface observations would be to determine the thickness of the plains deposits and look for any geologic features in the underlying bedrock. In this regard there is less certainty as to what features we might expect to find than is the case with the regional studies enabled by the first architecture. Are there older volcanic edifices, moon-wide tectonic features, or ancient impact craters buried beneath the plains deposits? We do not presently have enough information to predict such putative features. However, because the plains deposits are thought to date from the start of large-scale volcanism on Io [2], any characterization of the underlying bedrock will aid in reconstructing the geologic history of Io prior to the current epoch of extreme volcanism. Additionally, site-specific studies similar to those enabled by the first architecture will likely also be feasible, although the use of longer radio wavelengths in the second architecture may reduce the spatial resolution of the radar images [11], unless a more powerful synthetic aperture processing technique is employed for the longer-wavelength radar.

In addition to the study of bedrock features beneath plains deposits, the second architecture also enables a broader array of studies of the plains deposits themselves. Due to the different radar reflective properties of different phases and temperatures of sulfur, any subsurface reservoirs of fluid sulfur or SO_2-fers [12] should be distinguishable in the radar return signal. Furthermore, any stratigraphic layering of the plains deposits will produce multiple radar echoes, and properties of different stratigraphic layers (e.g. thickness, roughness, grain sizes) may be inferred from the intensity of each echo [11].

Summary:

We believe that a spaceborne radar instrument with ground penetrating capability at Io can provide observations unobtainable with other remote sensing instrumentation, which would help us answer key questions about Io's surface structure, geologic history, and thermal evolution. We suggest that such an instrument capability would merit consideration for a future mission to Jupiter's volcanic moon.

References:

[1] Christoph and Williams (2017) *LPSC XLVIII* Abstract #2325 [2] Lopes and Spencer (2007) *Io after Galileo, A New View of Jupiter's Volcanic Moon*, Springer [3] Peale et al. 1979. *Science 203*, 892-894 [4] Jaeger et al. (2003) *JGR 108*, 5039 [5] Williams et al. (2011) Geologic Map of Io, *USGS Scientific Investigations Map* 3168 [6] Abdelsalaam and Stern (1996) *JGR 101*, 23063-23076 [7] McCauley et al. (1982) *Science 318*, 1004-1020 [8] Bunte et al. (2010) *Icarus 60*, 868-886 [9] Williams et al. (2007) *Icarus 186*, 204-217 [10] O'Reilly and Davies (1981) *Geophysical Research Letters 8*, 313-316 [11] Sabins (1976) *Remote Sensing Principles and Interpretation*, Waveland Press [12] Kargel and Soderblom (1997) *LPSC XXVIII* 695-696