MuSAR – A novel SAR mission to Venus

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Abstract

The science community is currently considering new missions to explore Venus, focusing on key measurements that will answer the major outstanding questions for Venus that will remain after the current Venus Express mission. A new lightweight X-band SAR mission is being proposed as a Discovery class mission to Venus. This mission will utilize an X-band synthetic aperture radar capable of acquiring imagery at high (~1 m) resolutions for specifically targeted sites. The sensor is based on the Israel Aerospace Industry (IAI) TecSAR sensor that is already orbiting Earth and acquiring spectacular images.

1. Introduction

A host of Venus missions over five decades have given us important insights into the unique structure, composition, and dynamics of the Venus atmosphere and surface morphologies. From the first American mission (Mariner 2) through the highly successful Pioneer Venus Orbiter and Probes followed by Magellan, many initial answers to the question, “How does the Venus atmosphere work?” have been obtained. For example, the Pioneer-Venus Probes provided detailed vertical profiles of temperature and pressure in the 10-100 km altitude range, but only at selected sites on a specific day.

Complementary studies by a host of international missions, from the highly-successful Venera orbiters and landers to the current Venus Express Mission have given additional insights into atmospheric composition, dynamics and structure. For example, the Vega 2 lander gave the first (and only) in-situ measurement of the temperatures in the Venus boundary layer (0-10 km), but at only a single location and time. The currently operating ESA Venus Express Mission has provided significant information on atmospheric composition, dynamics and structure. VeRa has measured altitude profiles of temperature in the 40-50 km height range on both the day side and night side. VIRTIS and VMC images have been used to determine cloud tracked winds on the night side in the lower cloud around 50 km altitude (infrared images), on the day side in the upper cloud around 60 km altitude (visible images), and on the day side in the upper cloud around 70 km altitude [1]. VIRTIS images have retrieved temperature structure on the night side between 65 and 95 km altitude [2] and at the surface [3]. SPICAV spectra provide information on temperature and composition at the cloud tops and above. Venus Express has, however, focused mainly on the southern hemisphere. A new Japanese orbiter mission (Venus Climate Orbiter, or Akatsuki) will arrive at Venus in December 2010, but it will concentrate on low latitude regions due to its equatorial orbit. It has several cameras observing Venus at different wavelengths.

The science community is currently considering new missions to explore Venus, focusing on key measurements that will answer the major outstanding questions for Venus that will remain after the current Venus Express mission. Within this context, we need to consider how current sensor technology will enable fundamental new understanding of the past and current dynamics of the surface and interior of Venus. The topic of this study is to assess the utility

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of cm-scale wavelength imaging of the Venusian surface from the scientific perspective and how these can be fused with the former Magellan data that was at longer wavelengths.

This paper will present an ongoing effort to design and launch a new SAR mission to Venus called MuSAR. We claim that MuSAR will make use of a novel SAR system designed and built by Israel Aerospace Industries (IAI). The SAR payload is extremely light weight (under 100kg for the payload) and achieves high resolution imagery of 1 m/ pixel for select sites or better in X-band.

MuSAR's breakthrough discoveries will advance our knowledge of Venus and enable a better understanding of Earth's past and future. Our Mission Goals and Objectives match previous NASA and Community planning documents for Solar System and Venus exploration. We will: a) gain insight into the early history of Venus and the evolution of potentially habitable environments in the inner solar system; b) characterize atmosphere, surface and interior processes on Venus and compare and contrast them to those on other terrestrial planets past and present; and c) enable future exploration of Venus and other Solar System destinations, providing landing site identification and characterization, as well as critical engineering data for spacecraft aerobraking, descent, and landing.

2. Science and Technology Background

The atmosphere interacts with the Venus surface through both weathering and wind-driven processes. The most dramatic examples of potential surface weathering by the atmosphere are the high-reflectivity, low-emissivity mountaintops. Altitudes above ~6054 km have unusual radar properties that imply very high dielectric constants [4, 5]. There are many possible hypotheses as to how these high-reflectivity regions formed, including chemical weathering, phase transitions, and deposition of a metallic frost [6-9]. Bistatic experiments yield a best-fit dielectric constant with a large imaginary component, which might be explained by lead or bismuth compounds [9, 10]. Questions remain about the material, process and timescale that led to the anomalous radar properties.
Among the outstanding questions are: 1) Did Venus undergo catastrophic resurfacing early in its recorded history, and if so, by what processes? 2) Was Venus characterized by "directional" or "non-directional" evolution during its recorded history? 3) How active is Venus today and how does this help inform us about its earlier history? 4) How do the answers to these questions inform us about the "missing" 80% of the history of Venus, and about the direction that Venus might evolve in the future?
In order to address these questions, the detailed nature of individual mapped units and the relationships among the units (older, younger, and laterally equivalent) are critical.
Significantly increased image resolution, high-resolution topography, and the physical properties of surface units and features are critical to addressing these questions.

The MuSAR payload will be a modified version of the TecSAR satellite which is already orbiting Earth. This sensor built by IAI was launched in 2008 and has been operation since then.
The mission will exploit the TecSAR design. TecSAR is the first spaceborne radar mini-satellite technology demonstration mission of designed and developed by IAI/MBT (Israel Aerospace Industries Ltd.) The spacecraft features a low-mass design and a configuration, to provide a maximum of pointing agility. Combining high maneuverability with electronic antenna beam steering, TecSAR offers high-resolution coverage of large areas in various observation modes.

Operation mode	High Resolution mode
Wide coverage ScanSAR mode	8 m
Stripmap mode	3 m
Super stripmap (mosaic) mode	1.8 m
Spotlight mode	1 m

We will use these unique, state-of-the-art capabilities to (1) understand the present structure and dynamics of the atmosphere, surface and interior of Venus, (2) understand the past history of Venus, and (3) enable future Venus missions. These new data will complement and build on the results of prior missions (for example Magellan) and will lay the groundwork for yet, future exploration of Venus.

NASA's Magellan spacecraft carried an S-band SAR and made a dramatic conclusion to its highly successful mission at Venus when it is commanded to plunge into the planet's dense atmosphere Tuesday, October 11, 1994. During its four years in orbit around Earth's sister planet, the spacecraft has radar-mapped 98 percent of the surface and collected high-resolution gravity data of Venus. Figure 1 shows a sample image of the Venusian surface with one of its unique Corona features.

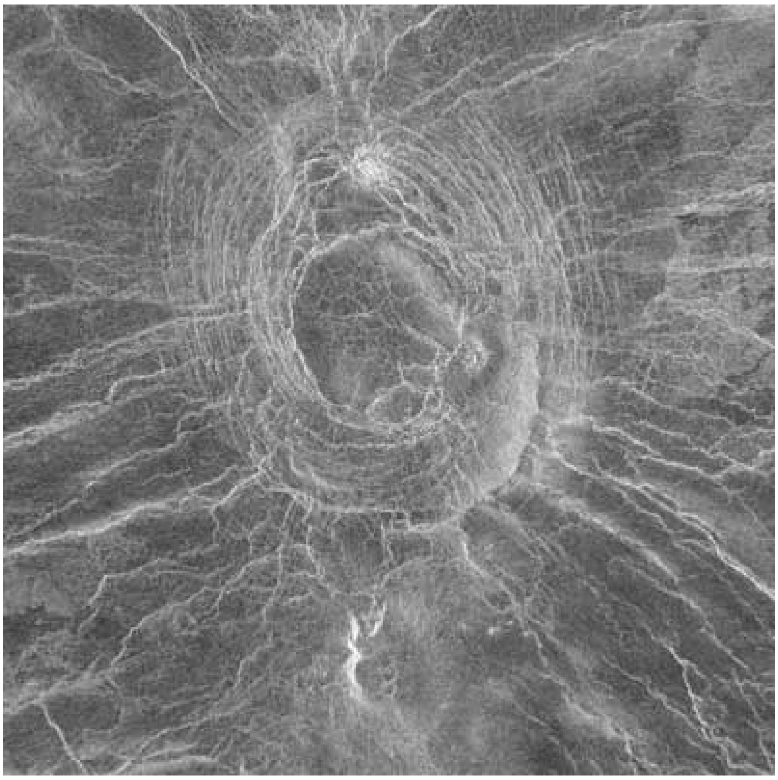

Figure 1: The above figure shows a Corona on Venus as imaged by Magellan radar. Coronae form as the result of hot rising bodies of magma within the crust, generating dome structures during emplacement and subsequent partial collapse (deflation) during cooling. These features are often associated with volcanic flows and have fault patterns that are both concentric with and radiate from the central structure. This image is roughly 100 km (60 mi) on a side.

3. Summary

A new Novel design of a synthetic aperture radar mission to the planet Venus has been proposed. This mission uses a payload based on the TecSAR technology which will yield high resolution images of the surface of Venus. These images will provide immense breakthroughs in our understanding of the planet and its geologic and climatic history.

4. References

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