A VENUS FLAGSHIP MISSION: REPORT OF THE VENUS SCIENCE AND TECHNOLOGY DEFINITION TEAM. M. A. Bullock[1], D. A. Senske[2], T. S. Balint[2], A. Benz[2], B. A. Campbell[3], E. Chassefiere[4], A. Colaprete[5], J. A. Cutts[2], L. Glaze[6], S. Gorevan[7], D. H. Grinspoon[8], J. Hall[2], G. L. Hashimoto[9], J. W. Head[10], G. Hunter[11], N. Johnson[6], V. V. Kerzhanovich[2], W. S. Kiefer[12], E. A. Kolawa[2], T. Kremic[6], J. Kwok[2], S. S. Limaye[13], S. J. Mackwell[12], M. Y. Marov[14], A. Ocampo[15], G. Schubert[16], E. R. Stofan[17], H. Svedhem[18], D. V. Titov[19], A. H. Treiman[12], [1]Southwest Research Institute, Boulder, Colorado (bullock@boulder.swri.edu), [2]Jet Propulsion Laboratory, [3]Smithsonian Institution, [4]Service d'Aéronomie, France, [5]NASA Ames Research Center, [6]NASA Goddard Space Flight Center, [7]Honeybee Robotics, [8]Denver Museum of Nature & Science, [9]Kobe University, Japan, [10]Brown University, [11]NASA Glenn Research Center, [12]Lunar and Planetary Institute, [13]University of Wisconsin, [14]Keldysh, Russian Federation, [15]NASA Headquarters, [16]University of California, [17]Proxemy Research, [18]European Space Agency, Netherlands, [19]Max Planck Institute, Germany.

Introduction: The Venus Science and Technology Definition Team (STDT) was created by NASA's Science Mission Directorate to formulate the science goals and objectives, and to design the mission architecture, science investigations, and instrument payload for a Flagship-class mission to Venus. It was also tasked to develop a prioritized technology roadmap to bring the necessary technologies and instruments to sufficient technology readiness levels. This $3-4B mission, to launch in the 2020-2025 timeframe, should revolutionize our understanding of how climate works on terrestrial planets, including the close relationship between volcanism, tectonism, the interior, and the atmosphere [1, 2].

Science Themes: Why is Venus so different from Earth? Previous missions have revealed a planet with curious similarities but vast differences from our world. For the first time, NASA has the opportunity to fly a large mission to another Earth-sized planet with the explicit intention of better understanding our own. The Venus Flagship mission science can be summarized by its three themes, (1) What does the Venus greenhouse tell us about climate change? (2) How active is Venus? (3) When and where did the water go?

Mission Architecture: The Venus STDT evaluated a wide range of mission architectural elements, from orbiters to aerial vehicles at all atmospheric levels, to landers and rovers. Mission science objectives were derived largely from the extensive community effort, through the Venus Exploration and Analysis Group (VEXAG), to prioritize Venus exploration objectives [3]. A detailed study of the investigations that could be done from each of the architectural elements in order to address the mission objectives was performed (Fig 1). The result was a science figure of merit for each investigation, and also an index of its technological difficulty.

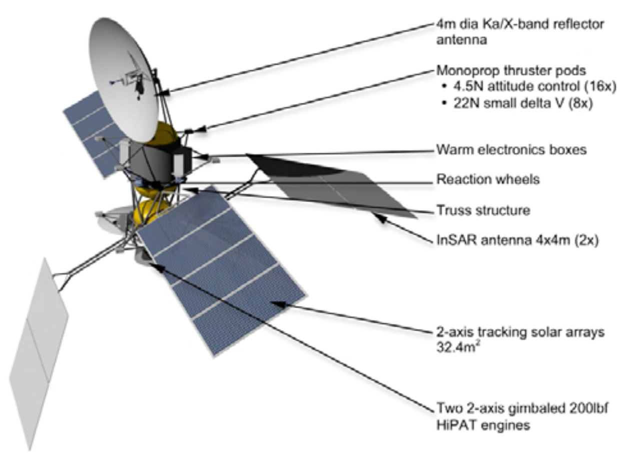
We found a scientifically synergistic combination of mission architecture elements had the greatest potential for the detailed exploration of Venus that only a Flagship mission can do. To address a broad range of science questions this mission will be composed of flight elements that include an orbiter that is highlighted by an interferometric SAR to provide surface topographic and image information at scales one to two orders of magnitude greater that that achieved by any previous spacecraft to Venus (Fig. 2). The remaining payload of the orbiter consists of an ion and neutral mass spectrometer, a UV-VIS-IR imaging spectrometer, a sub-mm sounder, magnetometers, and a Langmuir probe. Two balloons with a projected lifetime of weeks will probe the structure and dynamics of the atmosphere in the region at an altitude of 50 to 70-km (Fig 3). Balloon gondolas will house mass spectrometers, nephelometers for cloud studies, net flux radiometers, atmospheric structure investigations, magnetometers, and optical lightning detectors. In addition, two descent probes will collect data synergistic with those from the balloon and analyze the geochemistry of surface rocks over a period of hours (Fig 4). The descent instruments are identical to those carried by the balloons. In addition, descent cameras will enable the acquisition of landing site images. At the surface, the landers will perform meteorology experiments, geochemistry with an X-ray diffraction/X-ray fluorescence spectrometer and a γ-ray spectrometer. The landers also each carry a radar reflector for accurate determination of planetary angular momentum, a heat flux plate for the geothermal heat flux measurements, and cameras.

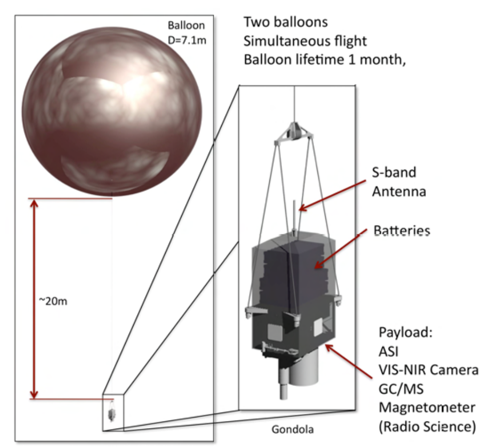
Technology Roadmap: The Venus STDT developed a prioritized set of technological challenges that must be solved to bring all instruments and spacecraft systems to a Technological Readiness Level (TRL) of 6 by 2016. In addition, it studied more advanced technologies that could enable greatly enhanced science, and pave the way for an eventual Venus sample return mission. Key to enabling a Venus Flagship mission is the ability to conduct investigations and tests in Venus simulation chambers. Pressure and temperature mitigation technologies, whether high temperature electronics or efficient cooling mechanisms, must also be developed to a high level of readiness. Sensors and transducers that operate for long periods under ambient Venus conditions will also be required. Sample handling and acquisition over periods of hours on the surface is a major technological challenge that can be addressed immediately.

Conclusions: A Flagship-class mission to Venus is NASA's first opportunity to fly a large mission to another Earth-sized planet with the explicit intention of better understanding our own. A deep understanding of how atmospheric greenhouses work, how geological processes in a general sense operate, and the fate of oceans on terrestrial planets is within reach.

References: [1] Bullock, M.A., et al. (2008) B.A.A.S. **40** 32.08. [2] Senske, D.A., et al. (2008) Fall AGU, P22A-08. [3] VEXAG (2007) ed. J. Luhmann and S. Atreya.

Science Theme	Science Objective	Instrument type	Observation Platform
What Does the Venus Greenhouse tell us about Climate Change?	Characterize the dynamics, chemical cycles, and radiative balance of the Venus atmsphere	Vis-NIR Imaging Spectrometer	Orbiter
		Sub-millimeter sounder	Orbiter
		Langmuir probe	Orbiter
		Atmospheric Structure (P/T/winds/accel)	Balloon, Lander (on descent)
		Nephelometer	Balloon, Lander (on descent)
		Net Flux Radiometer	Lander (on descent)
		Radio (with USO)	Balloon
	Place constraints on the evolution of the Venus atmosphere	Neutral and Ion Mass Spectrometer (INMS)	Orbiter
		GC/MS	Balloon, Lander (on descent)
How Active is Venus?	Identify evidence of active tectonism and volcanism and place constraints on evolution of tectonic and volcanic styles	InSAR	Orbiter
		Radio (with USO)	Orbiter
	Characterize the structure and dynamics of the interior and place constraints on resurfacing	Magnetometer	Orbiter, Balloon, Lander
		Heat flux plate	Lander
		Seismometer	Lander
	Place constraints on stratigraphy, resurfacing and other geologic processes	Vis-NIR camera	Balloon, Lander (on descent)
When and where did the water go?	Identify evidence of past environmental conditions, including oceans	GC/MS	Balloon, Lander (on descent)
	Characterize geologic units in terms of chemical and mineralogical composition of the surface rocks in context of past and current environmental conditions	Microscopic Imager	Lander
		XRD/XRF	Lander
		Passive Gamma-ray detector	Lander
		Drill and sample acquisition, transfer and preparation	Lander





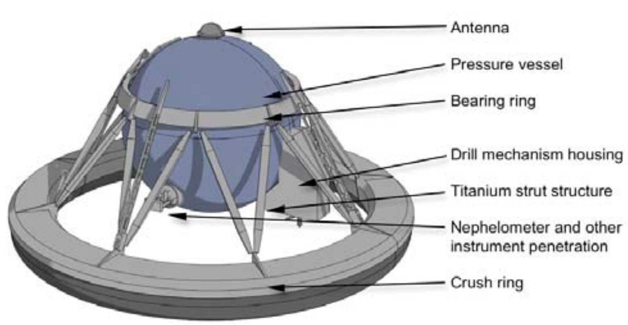


Figure 1. (Top) The instruments and their observation platforms trace to the mission science objectives and overall themes of the Venus Flagship mission.

Figure 2. (Upper Left) Orbiter.

Figure 3. (Upper Right) Balloon and gondola.

Figure 4. (Left) Descent Probe/Lander.