VULCAN: A CONCEPT STUDY FOR A NEW FRONTIERS-CLASS VENUS LANDER.

A. M. STICKLE[1], M.E. BANKS[2], S.D. BENECCHI[3], B.K. BRADLEY[4], C. J. BUDNEY[5], G.B. CLARK[6], B.A. CORBIN[7], P.B. JAMES[7], K. KUMAR[8], R.C. O'BRIEN[9], E.G. RIVERA-VALENTIN[10], A. SALTMAN[11], N. SCHMERR[12], C.R. SEUBERT[4], J.V. SILES[5], A.M. STOCKTON[5], C. TAYLOR[13], M. ZANETTI[14]

[1]Brown University, Providence, RI, angela_stickle@brown.edu; [2]Smithsonian Institution, Washington DC; [3]Carnegie Institute DTM, Washington DC; [4]CU Boulder, Boulder, CO; [5]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA; [6]UT at San Antonio, San Antonio, TX and Southwest Research Institute, San Antonio, TX; [7]Massachusetts Institute of Technology, Cambridge MA; [8]UC Berkeley, Berkeley CA; [9]CSNR/Idaho National Laboratory, Idaho Falls, ID; [10]University of Arkansas, Fayetteville, AR; [11]Office of Congressman Adam Schiff, Washington, DC; [12]NASA GSFC, Greenbelt, MD; [13]Georgia Institute of Technology, Atlanta GA; [14]Washington University in St. Louis, St Louis MO

Introduction: A concept study for a New Frontiers-class mission to Venus was performed at the 2011 NASA Planetary Science Summer School Session 1, which was hosted by Team X at NASA JPL. This program provides a unique opportunity for graduate students and early-career scientists/engineers to learn about the mission design process. Participants selected a mission target in response to the NASA Science Directorate Announcement of Opportunity (AO) from 2009 [1]. Using the AO as a guide, participants worked with members of Team X at JPL for one week to generate science goals and develop an early-mission concept within the constraints of a New Frontiers-class mission with a cost cap of $965 million (without launch vehicle, FY11).

The proposed mission concept, VenUs Lander for Compositional ANalysis (VULCAN), would take *in situ* measurements to analyze the surface and atmospheric composition of Venus (Fig. 1). At the completion of the summer school, we selected an instrument payload and developed mission requirements to deliver a lander to Venus to accomplish our science goals. This poster discusses those science goals, the instrument payload, and the proposed lander-and-carrier satellite design for this New Frontiers-class mission to Venus. VULCAN would provide approximately one hour of atmospheric descent data collection and approximately two hours of surface data collection.

Science Objectives: Venus, often termed Earth's "sister planet", has evolved very differently from the Earth. Venus is our closest (and only) planetary analog for important climate processes. Contrasts between the two bodies have challenged fundamental understanding of how terrestrial planets evolve, but there are still many unanswered questions about the composition and evolution of Venus' atmosphere and crust [1-3]. Unlike the other terrestrial planets, Venus' extremely dense cloud cover prohibits investigation of the mineralogical and chemical composition of the surface from orbit, making a lander a necessity. Further, a lack of recent missions means that few young scientists study Venus, increasing the necessity for a new mission.

Atmospheric Science. During descent through the atmosphere, the proposed VULCAN mission would provide new data to determine the composition of Venus' atmosphere, to understand the physics and chemistry that drive the planet's atmosphere and its evolution (including trace gas species and light stable isotopes), and measure noble gas isotopic abundance in the atmosphere from 70-km to the surface. Meteorological data would include: temperature and pressure profiles and wind speeds from 70 km, measurement of suspended particles in the atmosphere and the extinction coefficient, characterizing the interplay of chemistry, dynamics, meteorology and radiative physics in the atmosphere, and general atmospheric circulation and dynamics. This would allow for a better understanding of how sunlight, thermal radiation, and clouds drive the greenhouse effect.

Surface Science. The surface science goals encompass two main categories: detailed imaging of the Venusian surface during descent (from 40 km to the surface) and mission operations on the surface (at multiple wavelengths, including surface texture and stereo images), and accurate measurement of elemental abundances and mineralogy of the Venusian crust. These would provide the first broadscale visible images of the surface, including surface morphology at scales of 1-10 m. Images and chemistry would further provide ground truth for Magellan radar data, constraints on the weathering environment, and clues into the recent geological history, plains formation and the role of volcanism in shaping the atmosphere and surface of Venus.

Instruments: The instrument payload was carefully chosen to address the stated science goals as well as to satisfy the mass, power and budget constraints. The instrument suite takes advantage of flight heritage, and re-tasks engineering sensors to obtain desired information, to perform new and exciting science at Venus.

Neutral Mass Spectrometer. A quadrupole mass spectrometer, similar to the spectrometers flown on Galileo and Cassini [4], would provide detailed atmospheric composition, including information about the lower atmosphere.

LIBS-Raman Spectrometer. A LASER-Induced Breakdown Spectrometer (LIBS) would measure atomic abundances of surface material. This would be coupled with a Raman spectrometer to determine mineralogy of the surface, which has not been gathered on Venus previously. Additionally, the LIBS-Raman spectrometer would be used as a "drill" to obtain subsurface chemistry and mineralogy information. The LIBS-Raman laser could achieve an ablation rate of ~8 µm/min [5], which would provide mineralogy data to a depth of 7.2 cm over the course of the surface mission.

Imagers. A suite of cameras would be used to provide descent images of the surface and detailed images of the landing site. The descent imagers would collect images from the lower atmosphere (40 km) to the surface; the panoramic imager would provide broad context of the landing site with multiple filters in the visible and near-infrared with stereo capabilities. The context imager would provide local context around the lander and guidance for the LIBS/Raman pointing; and the microscopic imager would provide surface texture and grain size.

Gamma Ray Spectrometer. A gamma-ray spectrometer would measure radioactive elements in the upper crust to determine geologic history. This data would provide comparative analysis against sites visited by the USSR Venera landers.

Atmospheric Meteorology Payload. A suite of instruments would be used to provide meteorological information, including: a nephelometer to provide new constraints on cloud structure and the sizes of suspended particulate matter within the lower atmosphere; a relay doppler to measure wind velocities at multiple altitudes; an accelerometer from the attitude control system to obtain temperature and pressure at multiple altitudes; and temperature sensors from the thermal system to obtain a temperature profile through the atmosphere and at the surface.

Mission Design Overview: The proposed mission design utilizes an Atlas V 401 launch vehicle and a minumum-energy trajectory to Venus, with launch scheduled around June/July 2018. The carrier spacecraft will separate from the lander en route, and act as a relay for data transmission to Earth during the scientific mission at the proposed landing site (Mielikki Mons). The total mission duration is 150 days, with primary science obtained during the 1-hour descent through the atmosphere and 2-hour projected lifetime at the surface.

Along with the carrier spacecraft and lander, our mission proposal budgets for the creation of a Venus environment chamber as a unique test facility to attract a new generation of scientists and engineers to Venus exploration. This study demonstrates that the cost basis and risk mitigation strategies employed by the design team ensure that the proposed VULCAN mission exceeds all requirements for a New Frontiers-class mission and provides exciting new opportunities in Venus Science.

A successful mission would provide 80 images of the Venusian surface (at varying resolution) from ~40 km to the surface, 30 panoramic images (at 9 wavelengths) of the area surrounding the landing sight, surface texture information to 30 µm, 14 samples of atomic abundance and chemical mineralogy of the surface to a depth of 7 cm, composition of radioactive elements indicative of weathering on Venus' surface, particle size and density at various locations in the atmosphere, and bulk and trace chemical composotion of the atmosphere.

This document was created by students as an educational activity at the Jet Propulsion Laboratory, California Institute of Technology, and does not represent an actual mission.

Acknowledgements: The 2011 Planetary Science Summer School was held at the Jet Propulsion Laboratory, California Institute of Technology. We would like to thank the members of the education office who made this experience possible: Trisha Steltzner, Leslie Lowes and Andrea Urban; and the members of Team X for their assistance in this design study: Enrique Baez, Harry Balian, David Brown, Charles Budney, Bjorn Cole, Douglas Equils, Dwight Geer, Ronald Hall, David Hansen, Daniel Harvey, Casey Heeg, Gary Kinsella, Chris Landry, Ryan Lim, Keith Novak, Evgeniy Sklyanskiy, Paul Stella, Frank Picha, Leigh Rosenberg, Alexandre Tsapin, and Mark Wallace.

References: [1] *Announcement of Opportunity, New Frontiers Program* (2009), NASA SMD; [2] Opening New Frontiers in Space: Choices for the Next New Frontiers AO (2008); [3] Visions and Voyages for Planetary Science in the Decade 2012-2022 (2011); [4] National Space Science Data Center Master Catalogue: http://nssdc.gsfc.nasa.gov/nmc/; [5] Arp, Z.A. *et al.* (2004) *Spectrochimica Acta B, (59)*7: 987-999.

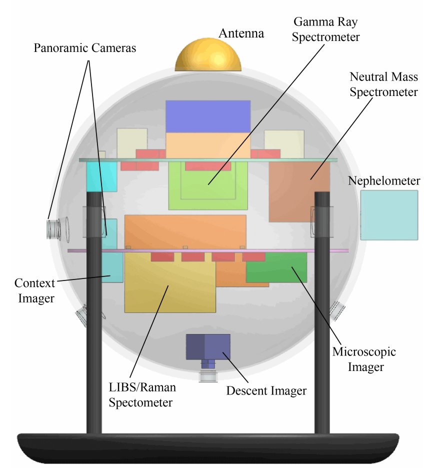

Figure 1. Proposed lander design to investigate Venusian atmosphere, mineralogy, and surface composition *in-situ*.