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Presentation to NASA's Planetary Science Subcommittee (PSS), February 26, 2007 by Janet Luhmann (UCB) for the VEXAG Steering Committee(co-chair Sushil Atreya, Steve Mackwell, Kevin Baines, Larry Esposito, Jim Cutts, Ellen Stofan, Tommy Thompson)

(Recent meeting summary, status of the VEXAG Report and related Technology Development issues, and plans for future support of mission planning and scientific activities)

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VEXAG Meetings to Date:

-Kickoff Meeting November 4, 2005, Pasadena

-Related Venus Chapman Conference, Feb. '06

-First working meeting May 1-2, 2006, Pasadena

-Second Meeting held in Crystal City, VA on Jan 11-12, 2007

Current VEXAG Activities:

-Main priority: creation of a "community consensus" report on Venus science priorities and technology development needs for future mission planning

-Providing Messenger flyby, VEX and VCO connections

-Supporting VEP and other international mission planning

-Providing HQ-requested and/or NRC-requested inputs

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Main outcomes of the January meeting:

- Presentations on VEX status and Science, Messenger flyby plans, VCO development, and VEP proposal/planning activity in Europe
- Discussions of the options for technology development activities within NASA with George Komar
- Discussions with Solar System Div. Director Dr. Jim Green re. possibilities for a VDAP, re. SDTs for flagship missions, re. New Frontiers planning and technology development use, and re. possible Venus-Earth climate science collaborations
- Prioritization of the investigations in the Goals-Objectives-Investigations spreadsheets for the VEXAG Report

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VEXAG Report: Venus Exploration Goals and Objectives

Goals for Venus Exploration:

I. Origin and Early Evolution of Venus: How did Venus originate and evolve, and what are the implications for the characteristic lifetimes and conditions of habitable environments on Venus and similar extrasolar planets?

II. Venus as a terrestrial planet: What are the processes that have and still shape the planet?

III. What does Venus tell us about the fate of Earth's environment?

No priority ranking of Goals

VEXAG Web-Site - http://www.lpi.usra.edu/vexag

Draft Report Conclusion on Venus Science

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Finding: Without additional resources, the US Venus science community will fall further behind in leadership in Venus exploration. There will be no opportunity to fully take advantage of the results of either the VEX mission or the Messenger flyby in our future plans for Venus exploration, or to train the next generation of Venus scientists using these mission results as motivation.

Recommendation: In order to fully exploit the results from both the Venus Express and Messenger at Venus, made available via the PDS, funds should be identified to enable **a**mending of the ROSES NRA to include a Venus Data Analysis Program open to all competitors.

Draft Report Conclusion on a Venus Flagship Mission

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Finding: The completion by VEXAG of scientific goals and priorities now makes it timely to initiate a study of the Flagship mission in order to define a concept in more detail, and to identify the technologies needed to implement the mission. A Venus Flagship mission study should not be viewed as part of the competition for the next Flagship mission as it is already clear that a significant and sustained program of technology development is needed to prepare for that mission and a New Frontiers precursor mission to the Venus surface should precede the Flagship mission. However, this study should not be delayed because a path to addressing specific technology challenges the resulting mission concept raises must be embarked upon at the earliest opportunity.

Recommendation: The Planetary Science Division should initiate a study of a Flagship mission to Venus at the earliest opportunity. The study should assess:

- Key scientific questions that can be addressed by a long duration mobile mission to the surface or near surface of Venus.
- Alternative missions architectures for addressing these scientific questions.
- Precursor scientific measurements and technology validation that might be implemented with prior Discovery and New Frontiers missions.
- Technology investments needed to enable the Venus Flagship mission emphasizing the long lead time technologies needing early investment..

Draft Report Conclusion on a New Frontiers Mission

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Finding:

VEXAG considers that a Venus In Situ Explorer (VISE) continues to be a vital mission in the exploration of Venus and should be included in the FY08 New Frontiers AO. The scientific goals stipulated in the FY03 NF AO remain a high priority. In addition to its scientific value, a VISE mission offers a unique opportunity to validate capabilities that would be important to a future Flagship mission. Under the current wording in the call for proposals, any technological capabilities necessary for VISE would have to be sufficiently low risk to pass the technical selection filters, and any purely technology development element of the mission (e.g. for VME) could not be included without the application of standard screening for flight readiness and value to the mission's science.

Recommendation:

A Venus In Situ Explorer (VISE) should be included in the New Frontiers AO for 2008. However, NASA should consider adding a technology validation element to enable development of technologies for a long duration mobile mission-but is not necessary to the success of VISE itself.

Draft Report Conclusion on Technology Investments

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Findings: There are credible technical approaches, leveraging from technologies developed in industry to achieving extended operation in the Venus environment. High temperature electronics can enable systems to operate for extended periods. Advanced radioisotope power systems and active thermal control systems could enable conventional components such as microprocessors or imaging sensors to operate for extended periods on the surface of Venus. While further work on mission architectures will be needed to define specific performance goals and focus the technology, work on the technology can and should begin now. Without NASA direct involvement, it will not be possible to apply the results from industry to the specific needs of in situ exploration .

Recommendations: NASA should initiate a program to develop technologies for operation in the extreme environment of Venus. These should include-

- Passive thermal control technologies for extending the period of operation in the Venus surface and near surface environment from hours to days.
- Active thermal control technologies and power generation systems for extending the period of operation in the Venus environment to many months.
- High temperature electronics and other components capable of extended operation directly exposed to the Venus surface environment
- Mobility systems for operation at the surface and in the lower atmosphere of Venus
- A program of systems analyses to establish performance objectives and evaluate alternative approaches.

If funds were available this could be competed through an amendment to the ROSES NRA, perhaps as part of a larger extreme environments technologies initiative.

Draft Report Conclusion on Venus as a Future Earth

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Finding:

The dialogue between Venus and Earth scientists that could be useful to both is lacking.

Recommendation:

A research program, encouraging conferences and/or workshops, should be initiated that brings together Earth scientists and Venus scientists for a focused study of the evolutionary aspects (past and future) of these terrestrial planet twins. Areas of mutual interest could include extreme climate scenarios, and/or the role of volcanism, tectonics, and a planetary dynamo in determining the fate of a planet and its atmosphere.

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Next Steps:

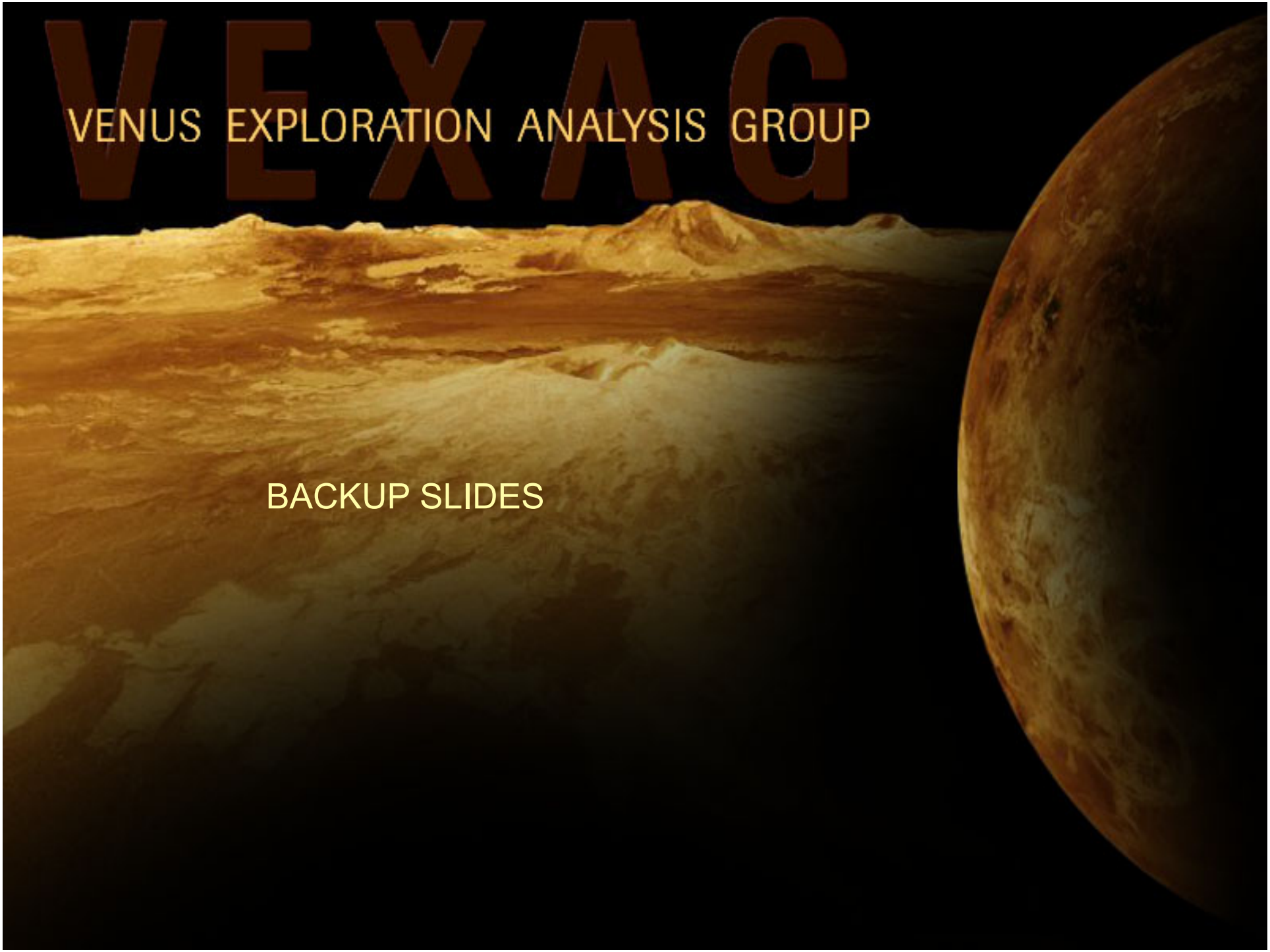
-Full Draft Report to Jim Green by early March

-VEXAG briefing to George Komar on Venus Mission Technologies

-Provide support for any relevant Technology Development activities and possible VME SDT

-Help organize an “extreme climates” or related Venus and Earth science workshop

-Next VEXAG Meeting adjacent to DPS Meeting, October (5-6?) in Orlando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BACKUP SLIDES

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VEXAG's identified goals, objectives, and investigations in aggregate address these basic questions about Venus that can be broadly appreciated:

- Was there a Venus ocean, and if so, when did it exist and how did it disappear?
- Was the early Venus atmosphere like the early atmosphere of Earth, and at what point did it diverge in character so greatly and why?
- Why does Venus rotate so slowly and is the lack of a planetary dynamo magnetic field a consequence? What impact on the evolution of Venus have these properties had?
- What caused the extensive resurfacing of Venus during the last billion years, and what is hidden underneath? Has Venus been an active planet? Are the resurfacing and climate degradation somehow related?
- Did conditions for life or life in some form ever exist on Venus?

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I. Origin and Early Evolution of Venus: How did Venus originate and evolve, and what are the implications for the characteristic lifetimes and conditions of habitable environments on Venus and similar extrasolar planets?

Objective 1: Determine the elemental and isotopic composition of the atmosphere to identify earlier epochs of Venus' history, and clues to Venus' origin, formation and evolution.

Objective 2: Map the mineralogy and chemical composition of Venus' surface on the planetary scale for evidence of past environmental conditions (e.g., cooler and wetter) and for constraints on the evolution of Venus' atmosphere.

Objective 3: Characterize the history of volatiles in the interior, surface and atmosphere of Venus, including volatile additions due to cometary impacts, degassing and atmospheric escape, to understand the planet's geologic and atmospheric evolution.

Objective 4: Characterize stratigraphy that may record geological processes active under different climatic conditions.

Objectives in approximate priority order

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I. Origin and Early Evolution of Venus: How did Venus originate and evolve, and what are the implications for the characteristic lifetimes and conditions of habitable environments on Venus and similar extrasolar planets?

Objective 5: Determine the ages of the various rock units on the surface in order to unravel the past geological history of Venus.

Objective 6: Understand the orbital and rotational history of Venus, including its position relative to the solar system "habitable zone", and past planet-atmosphere interactions that may have led to the retrograde superrotation of the atmosphere.

Objective 7: Seek evidence for biologic markers, including biogenic rock structures and/or other physical evidence of biological organisms (e.g., fossils), isotopic anomalies suggestive of biological activity, and chemical equilibria or disequilibria that may suggest biological activity.

Objective 8: Understand Venus as one potential analogue for terrestrial extra-solar planets.

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II. Venus as a terrestrial planet: What are the processes that have and still shape the planet?

Objective 1: Constrain the coupling of thermochemical, photochemical and dynamical processes in the Venusian atmosphere and between the surface and atmosphere to understand radiative balance, climate, dynamics and chemical cycles.

Objective 2: Constrain the resurfacing history of Venus, and the nature of the resurfacing process(es), including the roles of tectonism, volcanism, impacts of asteroids or comets, sedimentation/erosion, and chemical weathering.

Objective 3: Constrain the nature and timing of volcanic activity on Venus, including thermal evolution, current and past rates of volcanic activity, and the effects of outgassing on atmospheric and interior processes.

Objective 4: Determine the nature and timing of tectonic evolution of Venus, including the style and intensity of current activity, and changes in style and intensity through time.

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II. Venus as a terrestrial planet: What are the processes that have and still shape the planet?

Objective 5: Characterize the meteorological activity in Venus' atmosphere, including convection, cloud formation/dissipation, precipitation, lightning, and sporadic and organized dynamical activity analogous to terrestrial weather systems. In particular, study the roles local gravity waves, planetary-scale waves, and solar-induced tides play in producing meteorological activity. Determine whether a common theoretical treatment can be applied to weather on Venus and Earth.

Objective 6: Determine the history of and current state of interior evolution of Venus, including the internal physical, chemical, thermal and dynamical structure, and possible interactions between dynamic and climatic processes.

Objective 7: Determine the nature of the solar wind interaction with the ionosphere and its role in volatile loss.

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II. Venus as a terrestrial planet: What are the processes that have and still shape the planet?

Objective 8: Characterize three-dimensional atmospheric circulation to understand the zonal super-rotation, the meridional transport of energy and minor constituents, planetary-scale waves, local surface-induced gravity waves, the global distribution and strength of convective activity, and polar vortex dynamics.

Objective 9: Characterize the Venus Greenhouse effect, including the interplay of chemistry and physics of the atmosphere, especially the clouds.

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III. What does Venus tell us about the fate of Earth's environment?

Objective 1: Search for evidence of past global climate change on Venus, including chemical and isotope evidence in the atmosphere, as well as rock chemistry and characteristics of surface weathering. In particular, seek evidence for the presence or absence of past oceans.

Objective 2: Search for evidence of past changes in interior dynamics, volcanics and tectonics, including possible evolution from plate tectonics to stagnant-lid tectonics, which may have resulted in significant changes in the global climate pattern.

Objective 3: Characterize the Venus greenhouse effect, including the interplay of chemistry, dynamics, meteorology, and radiative physics in the atmosphere, especially within the clouds

Objective 4: Using Venus data, determine the evolution of planetary atmospheres in the absence of a shielding magnetosphere, as may have happened in the past or may occur in the future on Earth.

Example of Investigations Prioritization

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I. Origin and Early Evolution of Venus: How did Venus originate and evolve, and what are the implications for the characteristic lifetimes and conditions of habitable environments on Venus and similar extrasolar planets?

Objective 1: Determine the elemental and isotopic composition of the atmosphere to identify earlier epochs of Venus' history, and clues to Venus' origin, formation and evolution.

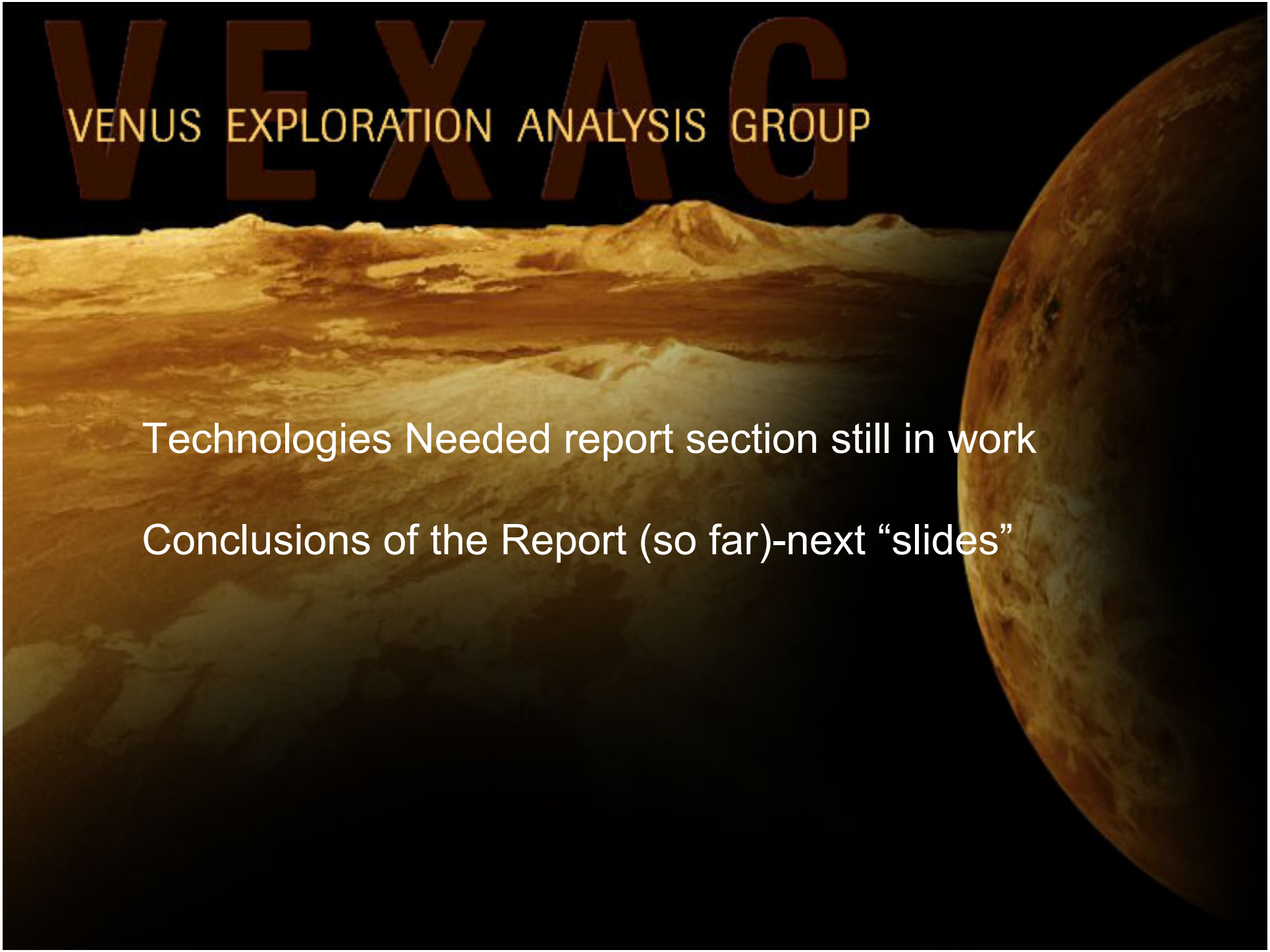
Investigation 1: Characterize noble gases and isotopic composition with a precision sufficient to enable understanding of Venus's origin and early evolution, especially measurements of the isotopes of xenon and krypton. By comparing with Earth and Mars, elucidate the origin, formation and early history of the inner solar system, especially our home world.

Investigation 2: Determine atmospheric H/D, 15N/14N, 17O/16O, 18O/16O, 34S/32S and 13C/12C to a precision of +/-10%

Investigation 3: Determine isotope ratios H/D, 15N/14N, 17O/16O, 18O/16O, 34S/32S and 13C/12C to a precision of +/-10% in solid samples where possible

Investigation 4: Analyze trapped gases in rocks for evidence of relict atmosphere

Investigations in approximate priority order



Technologies Needed report section still in work

Conclusions of the Report (so far)-next “slides”