Feedback on VEXAG Goals, Objectives, and Investigations

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Current VEXAG G/O/I

- Last updated in 2009.
- Overarching Theme: "Venus and Implications for the Formation of Habitable Worlds"
- Three Goals – roughly past/present/future (not prioritized):
  - Origin and Evolution: 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 systems?
  - Venus as a Terrestrial Planet: What are the processes that have shaped and still shape the planet?
  - Climate Change and the Future of Earth: What does Venus tell us about the fate of Earth's environment?

Goal 1: Origin and Evolution

Table 1-1. Venus and Implications for the Formation of Habitable Worlds

Goal	Objective	Investigation
Origin and Evolution	Understand atmospheric evolution	Characterize elemental composition and isotopic ratios of noble gases in the Venus atmosphere, especially Xe, Kr, ^{40}Ar, ^{36}Ar, Ne, ^{4}He, ^{3}He, to constrain origin and sources and sinks driving evolution of the atmosphere.
		Determine isotopic ratios of H/D, $^{15}N/^{14}N$, $^{17}O/^{16}O$, $^{18}O/^{16}O$, $^{34}S/^{32}S$ and $^{13}C/^{12}C$ in the atmosphere to constrain paleochemical disequilibria, atmospheric loss rates, the history of water, and paleobiosignatures.
	Seek evidence for past changes in interior dynamics	Characterize the structure, dynamics, and history of the interior of Venus, including possible evolution from plate tectonics to stagnant-lid tectonics.
		Characterize the nature of surface deformation over the planet's history, particularly evidence for significant horizontal surface movement.
		Characterize radiogenic ^{4}He, ^{40}Ar and Xe isotopic mixing ratios generated through radioactive decay to determine the mean rate of interior outgassing over Venus history.
	Determine if Venus was ever habitable	At the surface, identify major and minor elemental compositions (including H), petrology, and minerals in which those elements are sited (for example, hydrous minerals to place constraints on past habitable environments).
		Characterize gases trapped in rocks for evidence of past atmospheric conditions.

Goal 2: Venus as a Terrestrial Planet

Venus as a Terrestrial Planet	Understand what the chemistry and mineralogy of the crust tell us about processes that shaped the surface of Venus over time	Characterize geologic units in terms of major, minor, and selected trace elements (including those that are important for understanding bulk volatile composition, conditions of core formation, heat production, and surface emissivity variations), minerals in which those elements are sited, & isotopes.
		Characterize the chemical compositions of materials near the Venus surface as a function of depth (beyond weathering rind) to search for evidence of paleochemical disequilibria and characterize features of surface rocks that may indicate past climate or biogenic processes.
		Assess the petrography (shapes, sizes, & mineral grain relationships) & petrology (formation characteristics) of surface rocks to aid in interpretation of chemical and mineralogical characterization.
		Determine the physical properties and mineralogy of rocks located in a variety of geologic settings, including meteoritic and crater ejecta, volcanic flows, aeolian deposits, and trace metals in the high radar reflectivity highlands.
		Characterize surface exposure ages through measurements of weathering rinds.
	Assess the current structure and dynamics of the interior	Characterize the current structure and evolutionary history of the core. Place constraints on the mechanisms and rates of recent resurfacing and volatile release from the interior. Determine the structure of the crust, as it varies both spatially and with depth, through measurements of topography and gravity to high resolution.
		Measure heat flow and surface temperature to constrain the thermal structure of the interior. Measure the magnetic field below the ionosphere and characterize magnetic signature of rocks in multiple locations. Characterize subsurface layering and geologic contacts to depths up to several km.
		Determine the moment of inertia and characterize spin-axis variations over time.

Goal 2: cont.

Venus as a Terrestrial Planet	Characterize the current rates and styles of volcanism and tectonism, and how have they varied over time	Characterize active-volcanic processes such as ground deformation, flow emplacement, or thermal signatures to constrain sources and sinks of gases affecting atmospheric evolution.
		Characterize active-tectonic processes through seismic, ground motion, or detailed image analysis.
		Characterize the materials emitted from volcanoes, including lava and gases, in terms of chemical compositions, chemical species, and mass flux over time.
		Characterize stratigraphy of surface units through detailed topography and images.
		Assess geomorphological, geochemical, and geophysical evidence of evolution in volcanic styles.
	Characterize current processes in the atmosphere	Characterize the sulfur cycle through measurements of abundances within the Venus clouds of relevant gaseous and liquid/solid aerosol components such as SO_2, H_2O, OCS, CO, and sulfuric acid aerosols (H_2SO_4).
		Determine the mechanisms behind atmospheric loss to space, the current rate, and its variability with solar activity.
		Characterize local vertical winds and turbulence associated with convection and cloud-formation processes in the middle cloud region, at multiple locations.
		Characterize superrotation through measurements of global-horizontal winds over several Venus days at multiple-vertical levels (day and night) from surface to thermosphere.
		Investigate the chemical mechanisms for stability of the atmosphere against photochemical destruction of CO_2.
		Characterize local and planetary-scale waves, especially gravity waves generated by underlying topography.
		Measure the frequencies and strengths of lightning and determine role of lightning in generating chemically-active species (e.g., NO_x).
		Search for and characterize biogenic elements, especially in the clouds.

Goal 3: Climate Change and the Future of Earth

Climate Change and the Future of Earth	Characterize the Venus Greenhouse	Determine radiative balance as a function of altitude, latitude, and longitude.
		Measure deposition of solar energy in the atmosphere globally.
		Determine the size, distribution, shapes, composition, and UV, visible, and IR spectra, of aerosols through vertical profiles at several locations.
		Determine vertical-atmospheric temperature profiles and characterize variability.
	Determine if there was ever liquid water on the surface of Venus	Determine isotopic ratios of H/D, 15N/14N, 17O/16O, 18O/16O, 34S/32S 13C/12C in solid samples to place constraints on past habitable environments (including oceans). Identify and characterize any areas that reflect formation in a geological or climatological environment significantly different from present day.
	Characterize how the interior, surface, and atmosphere interact	Determine abundances and height profiles of reactive atmospheric species (OCS, H2S, SO2, SO3, H2SO4, Sn, HCl, HF, SO3, ClO2 and Cl2), greenhouse gases, H2O, and other condensibles, in order to characterize sources of chemical disequilibrium in the atmosphere.
		Determine rates of gas exchange between the interior, surface and atmosphere.

Responded with Feedback

- Robbie Herrick
- Janet Luhman
- Curt Covey
- Jeff Hall
- Young Scholar (unknown)
- Mark Allen
- Jonathan Lunine
- Larry Soderblom
- Walter Kiefer
- Hugh Kieffer

General thoughts

- Feedback response was modest – however, the responses received were very discerning.
- Those who responded indicated that the investigations seem appropriate, but the organization by Goals and Objectives could benefit from re-structuring (Herrick; Grimm)
- Suggested we consider a guiding focus (new theme?) (Luhman)
- Current prioritization is not clear

Specific Recommendations:

- Include specific measurements
- Include technical feasibility as well as science merit metrics for each
- Emphasize link to exoplanet exploration
- Include something about GCM development
- Currently, goals 1 and 2 are very similar
- Each investigation must be defensible – how will measurement lead to determination

Suggested Plan Forward

- Discuss possible new structure with entire group
- Breakout into groups (by new Goals) to
  - Assess which investigations belong and develop 3 – 4 Objectives to encompass those investigations
  - Identify any investigations that need updating/ replacement/adding
- Back in Plenary: discuss breakout group findings for objectives and investigations
- Discuss new overarching theme

Robbie Herrick

- Comparison with MEPAG:
  - VEXAG priorities need to be clear
  - Consider reorganization of top-level goals around science disciplines, for example:
    - Understand the processes and history of climate on Venus
    - Determine the evolution of the surface and interior of Venus
    - Understand the current interaction between the surface and atmosphere on Venus
    - Develop capability for long-lived surface instruments on Venus

Janet Luhman

- “The Mars community got together and even without total agreement made a strong focus on 'follow the water' and then the MSL quest for conditions amenable to life, and then sample return. These few word 'consensus' goals that anyone can relate to from public to researcher have made a big difference for Mars.”

For discussion?

- Possible focus:
  - Climate?
  - Venus evolution?
  - Find/follow the Action (volcanism/tectonism/ atmopshere)?

Backup

- Individual comments

Jeff Hall

- Consider moving away from the “ultimate fate of Earth” wording as a climate Goal.
- More editorial:
  - Tone down emphasis of “hurricane force” winds in intro (makes Venus sounds like a difficult exploration target)
  - Check for consistent quotes of surface temperatures

Young Scholar input via facebook

- I see a similarity between the 1st & 2nd goal, It seems like a same goal defined in two perspectives.
- Either the 2nd goal may be considered as one of the objectives of 1st goal or it may be properly defined such that it stands unique to be considered as a Goal.

Curt Covey

- "VEXAG may want to endorse some of the recommendations to NASA from the recent Comparative Climatology of Terrestrial Planets workshop (see attached PDF). Specifically, re the GCM effort"
- CCTP recommendations:
  - Improve the microphysics and chemistry of cloud and aerosol modeling, and their radiative effects in Earth and planetary GCMs. This would include a more fundamental understanding of cloud condensation nuclei, particle shapes, dust, convection and advection.
  - Develop standard comparisons and testing of components of Earth and planetary GCMs through a formal intercomparison project.
- "Looking over the existing document, I see very little of broadband thermal IR measurements from an orbiter. … Should VEXAG recommend something like the existing CERES instruments orbiting Earth?"

Mark Allen

- Current theme is “implications for formation of habitable worlds”; yet document doesn’t even touch on how Venus informs the search for an understanding of exoplanets.
- Recommends that implications for exoplanets be explicit
- Recommends biting the bullet and specifying measurement accuracies/precisions required to make the measurements worthwhile

Jonathan Lunine

- Message is not as punchy as it could be
- Suggests something up front, “The outstanding question in planetary science of relevance to most people is whether our Earth is rare or common in the cosmos: Is habitability over billions of years a robust outcome of planetary evolution or a fluke? Venus, so close in size and composition to the Earth and yet so different in its surface environment, holds the key to answering that question. …”

Larry Soderblom

- Likes the table: clear and concise
- Introduce and emphasize the possibility of an early benign wet surface environment earlier (in Why Venus Now).
- The 2nd paragraphs under Goals 1 and 2 sound a bit redundant and thereby make the goals sound so as well.
- Provided edits to prose

Walter Kiefer

- Worried that prioritization is based solely on science with no consideration about technical feasibility
- Result is that review panels may conclude that valuable, low cost missions (such as high resolution radar), are not really valued by VEXAG
- Should re-evaluation of VEXAG goals include technical feasibility as well as science merit? May require a committee/focus group – willing to serve
- Provided edits to prose

Hugh Kieffer

- Notes the lack of obvious priorities in the table
- Should indicate there is still work to be done with existing data sets
- Statements that refer to "Determine if..." require some explanation of how the measurements lead to a determination. E.g., it is implicit that [quantitative] criteria exist to determine yes/no!
- Some of investigation statements seem unsupportable. To pick on one: "Characterize surface exposure ages through measurements of weathering rinds“ - go over this table critically so that every box becomes defensible.
- It would be helpful to the "Executive reader" if there were an additional column that indicated technique maturity;