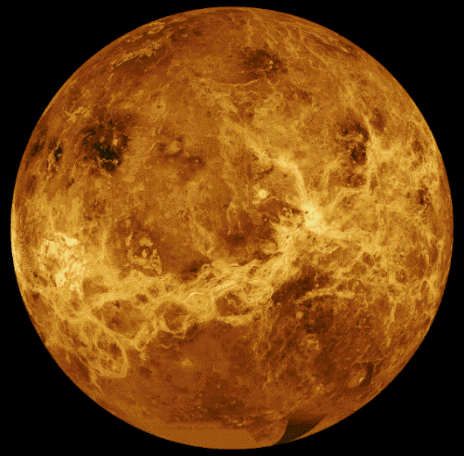

VENUS EXPLORATION
VEXAG
ANALYSIS GROUP

VEXAG and Venus Strategic Plan Briefing for Venus Panel Meeting October 20, 2020

VEXAG Steering Committee

Darby Dyar (PSI, Mount Holyoke College, UMass Amherst), Chair

Outline

1. VEXAG: who we are
2. Current VEXAG initiatives
    1. Structural reorganization
    2. Input to New Frontiers language for Decadal Survey
    3. Support of interdisciplinary workshops
    4. Support of Venus missions, large and small
    5. Findings from 2019
3. Venus Big Picture Questions
4. Venus Strategic Plan
    1. Goals, Objectives, and Investigations
    2. Technology Plan
    3. Venus Roadmap

VEXAG Steering Committee

Darby Dyar (PSI, Mount Holyoke College), Chair
Noam Izenberg (Applied Physics Laboratory), Deputy
Giada Arney (NASA GSFC), Early-Career Representative
Jeff Balcerski (Ohio Aerospace Institute)
Paul Byrne (North Carolina State University), Early-Career Representative
Lynn Carter (University of Arizona)
James Cutts (JPL), Roadmap Focus Group
Candace Gray (NM State University) Early-Career Representative
Natasha Johnson (NASA GSFC)
Stephen Kane (University of California at Riverside)
Pat McGovern (Lunar & Planetary Institute)
Joseph O'Rourke (ASU), Early-Career Representative
Emilie Royer (University of Colorado)
Jennifer Whitten (Tulane), Early-Career Representative
Colin Wilson (University of Oxford)
Tommy Thompson (JPL), Scribe

Megan Ansdell (NASA HQ) ex officio

VEXAG Near-Term Goals

- Provide **support for the Decadal Survey**
  - 3 strategic planning documents, paper submitted to *Space Science Reviews*
- Build a **Venus program**!
  - **Engage the community** to come together with a common vision
  - **Improve communication** within Venus community and among the general public: listserve has >500 members, media outreach
  - Open meetings and public forums
  - Expand **visibility of Venus science** at conferences and at NASA: 67 Venus papers at DPS/EPSC, AGU session, Exoplanets in Our Backyard

Ongoing Reorganization to Streamline VEXAG Management

VEXAG Monthly Meeting Schedule	
Month	**Activities***
January	Review and approve Findings, submit to HQ. Two new members begin.
February	Plans for annual interAG meeting
March	Prepare for LPSC
April	Committee updates
May	Committee updates
June	Committee updates
July	Two new members begin.
August	Committee updates
September	Plan for annual meeting(s)
October	Review of CAPS and PAC presentations from Fall meetings; finalize planning for annual meeting; assign tasks for SC members at meeting
November	Annual meeting in person (Virtual 2020)
December	Review and vote on new Steering Committee members and committee assignment for the coming year. Plan for AGU Town Hall, if any.
*Each month will begin with reports HQ Liaison (if any) and from the standing Study Analysis Workgroups and other current Venus-related bodies.	

VEXAG Steering Committee Rotation Schedule

	2020		2021		2022		2023		2024		2025		2026	
Name, starting	1/1	7/1	1/1	7/1	1/1	7/1	1/1	7/1	1/1	7/1	1/1	7/1	1/1	7/1
Darby Dyar														
Noam Izenberg														
Emeritus Chair														
Gary Hunter	1													
Kevin McGouldrick	1													
Colin Wilson	1	1	1	1										
Pat McGovern	1	1	1	1	1									
Candace Gray	1	1	1	1										
Joe O'Rourke	1	1	1	1										
Emilie Royer	1	1	1	1										
Giada Arney	1	1	1	1										
Jeff Balcerski		1	1	1	1	1								
Paul Byrne		1	1	1	1	1								
Jenny Whitten		1	1	1	1	1								
Natasha Johnson		1	1	1	1	1	1							
Stephen Kane		1	1	1	1	1	1							
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									1	1	1	1	1	1
									1	1	1	1	1	1
TOTALS	10	11	13	15	11	13	12	12	12	10				

New 6-month rotation established, with 30% early career investigators required at all times.

VEXAG Subcommittees

1. Nugget Officers: Pat and Jenny
2. Committee Organization Document Committee: Darby, Noam, Colin
3. Working Group for Next Off-season VEXAG meeting (2021): **AGU special session from Exoplanets in our Backyard**
   Noam, Giada, Stephen
4. Working Group for next VEXAG meeting (Nov 2020): Darby, Noam, Natasha
5. VeGASO committee: Joe, Paul, Emilie, Candace
6. Venus Surface Platform Study: Tibor, Darby, Noam
7. Venus Technology group: Jeff and others
8. Monthly/quarterly virtual seminar: Jeff and others – joint with other AGs?

Other VEXAG Commitments:

- **NExSS, Nexus for Exoplanet System Science**, is a NASA research coordination network dedicated to the study of planetary habitability. The goals of NExSS are to investigate the diversity of exoplanets and to learn how their history, geology, and climate interact to create the conditions for life.
- **ExoPAG Science Interest Group #3**: Exoplanet / Solar System, coordinates joint activities and an ongoing discussion on how Exoplanet and Solar System science and missions can benefit from each other. This SIG will endeavor to identify multiple initiatives that could be mutually beneficial for both communities and will encourage cross-disciplinary interaction between ExoPAGs and the Planetary AGs.
- **Equity, Diversity, and Inclusion Working Group**

Input to New Frontiers Call in Decadal Document

As formulated in the 2003 decadal document, the primary science objectives of this mission were to examine the physics and chemistry of Venus's atmosphere and crust.

Several subsequent advances in instrument technologies and mission capabilities now present compelling means to achieve overarching Venus science objectives without physically being "in situ" on the surface.

An emphasis on what science is achieved rather than on where it is done is suggested.

In short, the requirement for in situ concepts *as described in the current Decadal survey* is nearly two decades out of date.

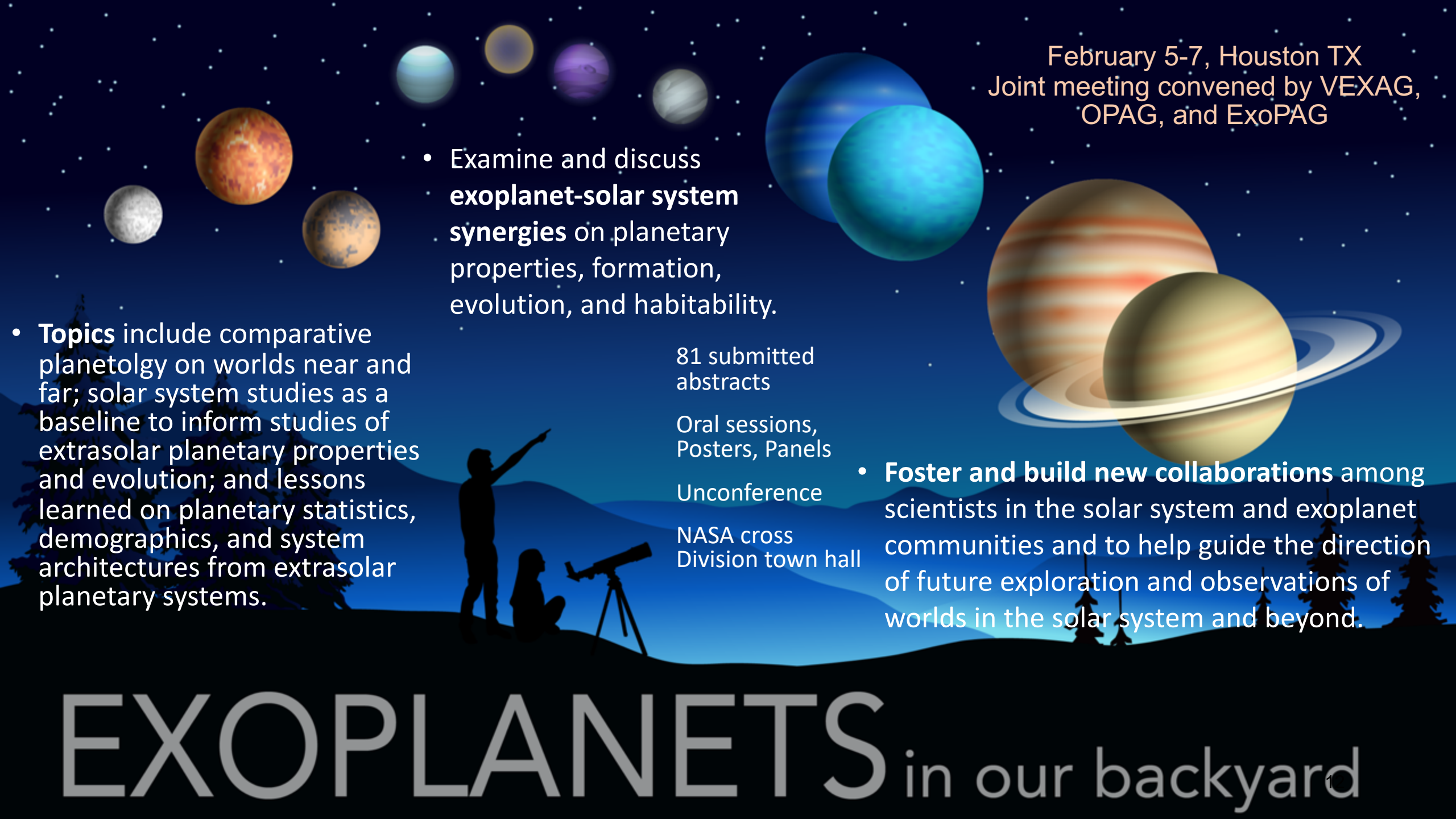
Input to New Frontiers Call in Decadal Document

We propose two new goals to replace the six in the current “VISE” priority investigation. These new goals fully encompass the measurements we list above, and are of equivalent scientific importance. They are:

1. Examine the physics and chemistry of Venus to understand its current state and evolution, including past habitability.
2. Characterize the Venus surface–atmosphere interface and how it is shaped by physical and chemical processes.

Achieving either of these goals would produce transformative science and justify an entire New Frontiers mission. Therefore, we propose that this New Frontiers priority be renamed simply “Venus Explorer” in recognition of the wide variety of *modern* mission types that can address important Venus science questions.

We and the more than 200 cosigners of this letter thank you for your consideration of this proposal.


February 5-7, Houston TX
Joint meeting convened by VEXAG, OPAG, and ExoPAG
• Examine and discuss **exoplanet-solar system synergies** on planetary properties, formation, evolution, and habitability.
• **Topics** include comparative planetolgy on worlds near and far; solar system studies as a baseline to inform studies of extrasolar planetary properties and evolution; and lessons learned on planetary statistics, demographics, and system architectures from extrasolar planetary systems.
81 submitted abstracts
Oral sessions, Posters, Panels
Unconference
NASA cross Division town hall
• **Foster and build new collaborations** among scientists in the solar system and exoplanet communities and to help guide the direction of future exploration and observations of worlds in the solar system and beyond.
EXOPLANETS in our backyard

Venus small-mission opportunities and VeGASO

- Both *Dragonfly* and *Europa Clipper* baseline launch scenarios include Venus gravity assist/flybys.
- Pending final confirmation of launch vehicle and trajectories:
  - ~~Both~~ missions' launches represent perfect opportunities to deliver payloads of opportunity to Venus. (Clipper may be out)
  - Multiple, high science return, low cost cube-sat to small-sat Venus missions have been studied and deemed feasible via PSDS3, Venus Bridge*, and other efforts. (*Venus Bridge study targeted a higher cost point, but resulted in multiple elements within SIMPLEx or SALMON range).
  - Small Venus missions would ride along on launch and separate as early as initial boost to Venus trajectory.
- **SIMPLEx or SALMON calls for these planetary missions should be dedicated to Venus opportunities.**
- **Venus Gravity Assists Science Opportunity document needs updating**
- PSDS3, HOTTech, Venus Bridge concepts: CUVE, Cupid's Arrow, VAMOS, LLISSE, SAEVe, V-BOSS, VB-IRO, -SMO, -RSOC, -UVO, -PFO, -Skim, -Probe, -Balloon.
- Commercial opportunities: Xplore, RocketLab, SpaceX, etc.

DAVINCI+ will explore past and present Venus

Deep Atmosphere Venus Investigation of Noble Gases, Chemistry, and Imaging *Plus*

Dr. James B. Garvin
NASA GSFC, Principal Investigator

Drs. Stephanie Getty and **Giada Arney**
NASA GSFC, Deputy Principal Investigators

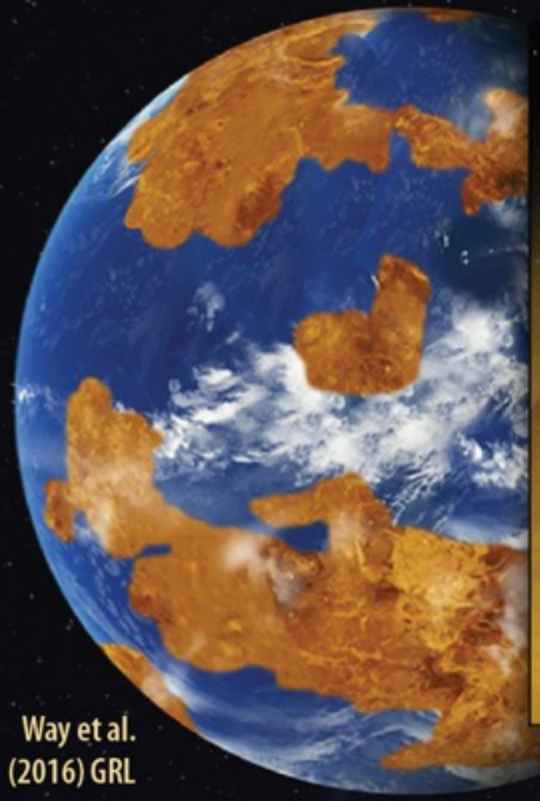
Establishing Venus' place in our Solar System

Enabling exploration of Venus-like exoplanets and Earths

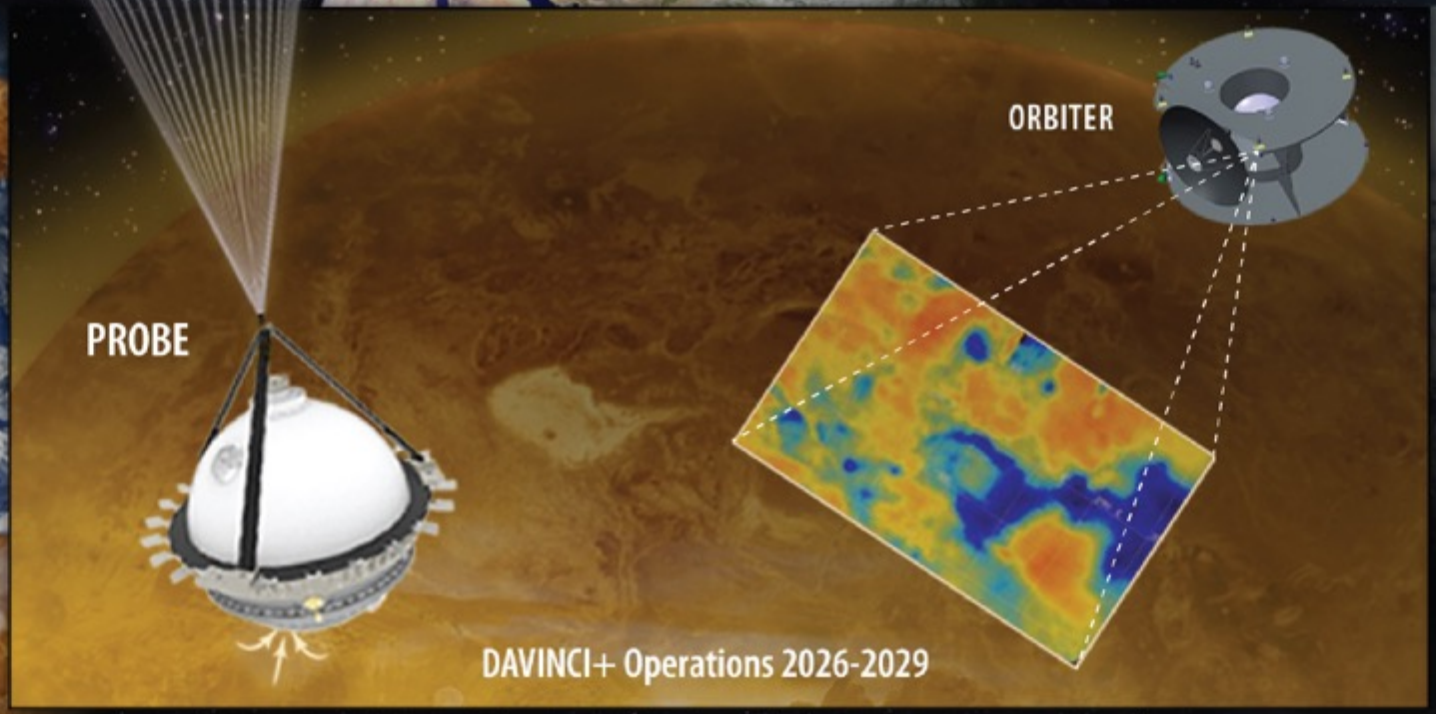
Ancient Oceans on Venus?

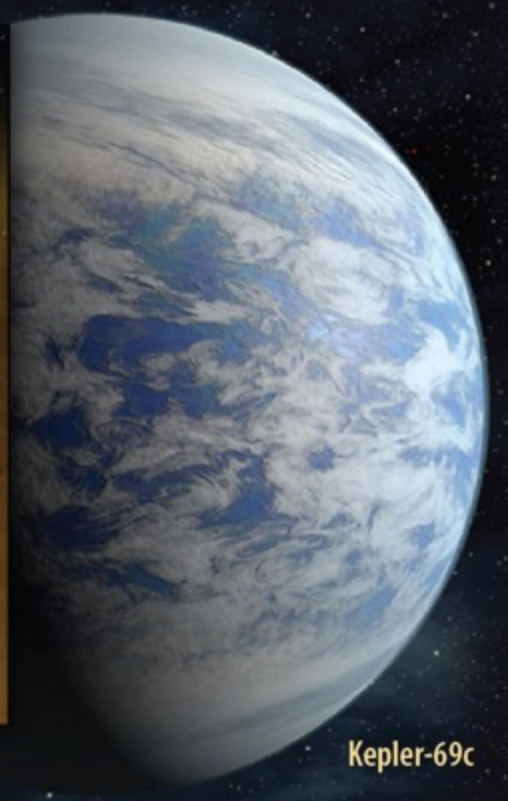
Evolution of Habitability

Venus-like Exoplanets



Way et al. (2016) GRL





Kepler-69c

Major partners: Lockheed-Martin • JPL • MSSS • LaRC • ARC • APL • KinetX • University of Michigan

Venus Emissivity, Radio Science, InSAR, Topography, & Spectroscopy

What makes a rocky planet habitable?

Like Earth, Venus started with all the building blocks of a habitable world. How was habitability lost?

Science Goals

1 Rocky planet evolution

- 1a igneous rock type, surface-atmosphere interaction
- 1b ancient geologic processes
- 1c volcanic history
- 1d subduction, origins of plate tectonics

2 Active processes

Active and recent volcanism, tectonics?

3 Past and present water

- 3a continents from a wetter past?
- 3b current water outgassing?

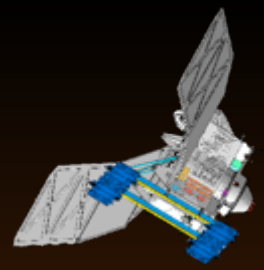
Mission Overview

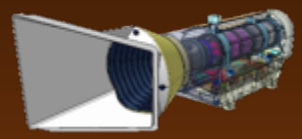
Launch Date: May 2025

Venus Orbit Insertion: Dec 2025

3 years of science operations from orbit

>40 Tb of science data returned





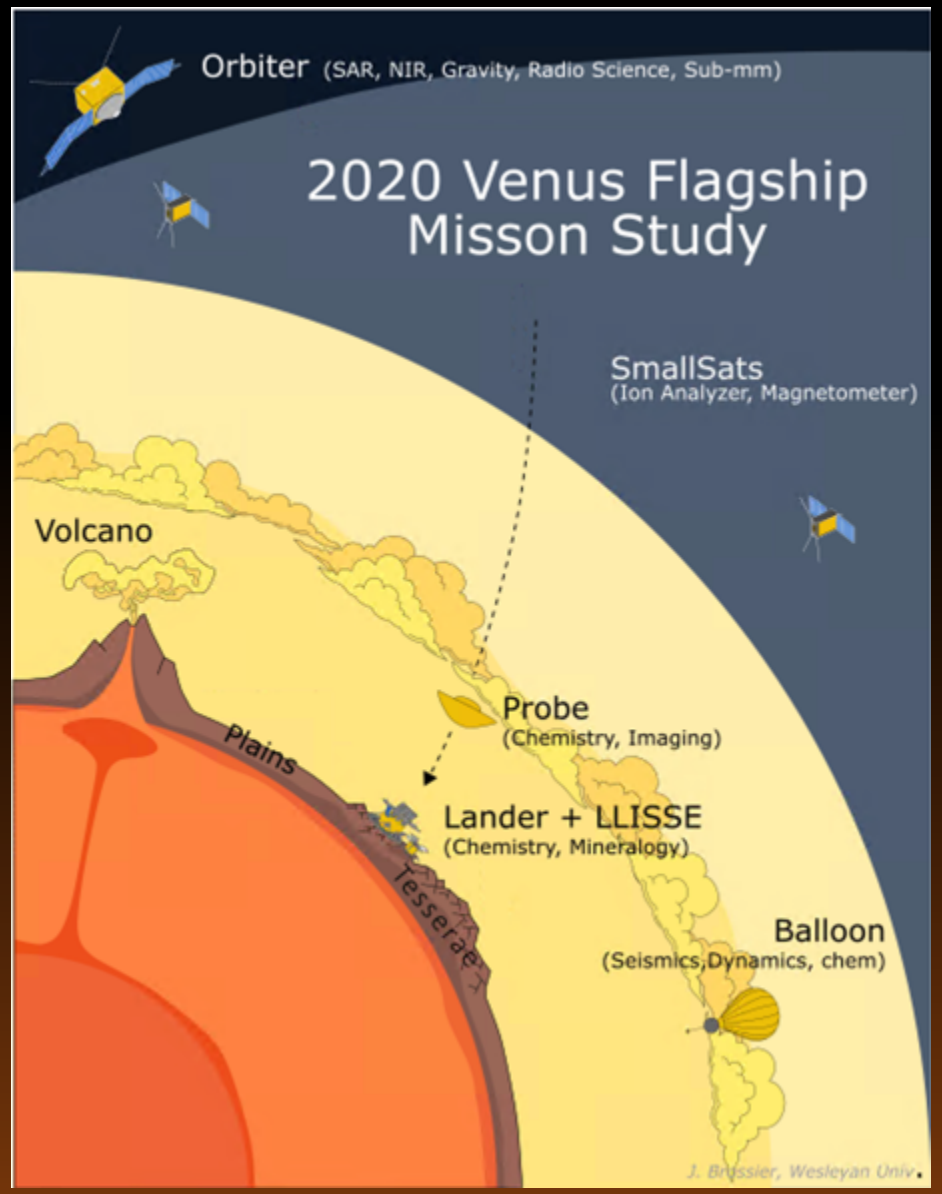
High-Resolution Global Reconnaissance

1. ***VISAR*** (Venus Interferometric Synthetic Aperture Radar)
   - Highest resolution global topography for terrestrial planets
   - 1st planetary active deformation map
   - Global data sets:
     - Topography: 250 m horiz, 5 m vertical
     - SAR imaging: 30 m
   - Targeted data sets:
     - SAR imaging: 15 m
     - Surface deformation: 1.5 cm vertical
2. ***VEM*** (Venus Emissivity Mapper)
   1st near-global map of igneous rock type, weathering
   - 6 NIR surface bands with robust SNR
   - 8 atmospheric bands for calibration / water vapor
3. ***Gravity Science Investigation***
   1st global maps of derived elastic thickness & core size

PI: Sue Smrekar, JPL; Managed by JPL

Venus Flagship –A Mission to Assess the Habitability of Venus

Martha Gilmore, Wesleyan Univ., Pat Beauchamp, JPL, VFM Science Team, GSFC



Science Goals

1. History of volatiles and liquid water on Venus and determine if Venus was habitable.
2. Composition and climatological history of the surface of Venus and the present-day couplings between the surface and atmosphere.
3. The geologic history of Venus and whether Venus is active today.

Key Elements of Current Design

Launch ~2031, Cost target $2B

Synergistic measurements between multiple assets

Orbiter and Small Sats -- support *in situ* assets prior to science campaign

Probe/Lander – 4-8 hour lifetime on tessera terrain

Balloon – 30 days

Long-lived lander (LLISSE) – 60 days

Status: DONE

Feb 28, 2020

VEXAG Findings 2019

1. Careful evaluation of U.S. funding commitments to international missions, and prioritization of U.S.-led missions.
2. VEXAG and the entire Venus community ask to be kept informed as commitments to international partners are considered and selected.
3. Support of ride-along opportunities for Venus missions.
4. Support programmatic balance among mission selections.
5. Continue to support HOTTech, high energy entry capabilities, and long duration surface power systems.
6. New support for suborbital observations of Venus.
7. VEXAG asks for an open reporting of all AG budgets and establishment of equity across them.

Key Justifications for Venus Exploration

- ***Liquid water*** for as long as 3 billion years
- Directly analogous to large numbers of ***exoplanet*** discoveries
- Surface geology and rock type ***nearly unknown***
- Holds the key to understanding solar system formation through **isotopic data**
- Has lower resolution topography data than Pluto
- Has signs of *nascent plate tectonics*
- Not visited by U.S. in >25 years!

VEXAG Big Picture Questions

- **Stated as Goals:**
- 1. Understand Venus' early evolution and potential habitability to constrain the evolution of Venus-size (exo)planets.
- 2. Understand atmospheric dynamics and composition on Venus.
- 3. Understand the geologic history preserved on the surface of Venus and the present-day couplings between the surface and atmosphere

- **Stated as Questions:**
- 1A. Did Venus have temperate surface conditions and liquid water at early times?
- 1B. How does Venus elucidate possible pathways for planetary evolution in general?
- 2A What processes drive the global atmospheric dynamics of Venus?
- 2B. What processes determine the baseline and variations in Venus atmospheric composition and global and local radiative balance?
- 3A. What geologic processes have shaped the surface of Venus?
- 3B. How do the atmosphere and surface of Venus interact

VEXAG Broader Solar System Questions

a. What are the history and distribution of water in the solar system and how do they affect habitability?

b. How and why do chemical compositions vary in radial distance from the Sun? (includes distribution of water and why objects from inner and outer solar system are isotopically different)

c. How do the origin and evolution of planets affect the origin and evolution of habitability?

d. How does atmospheric escape at Venus compare to other objects?

e. How do the origin and evolution of planets affect the potential evolution of life on Earth?

f. Are any of the habitable zones populated by contemporary life?

g. How does exploration of our solar system inform characterization of exoplanets?

h. How does a planetary atmosphere reflect both evolution of the solid body and planet-solar interactions?

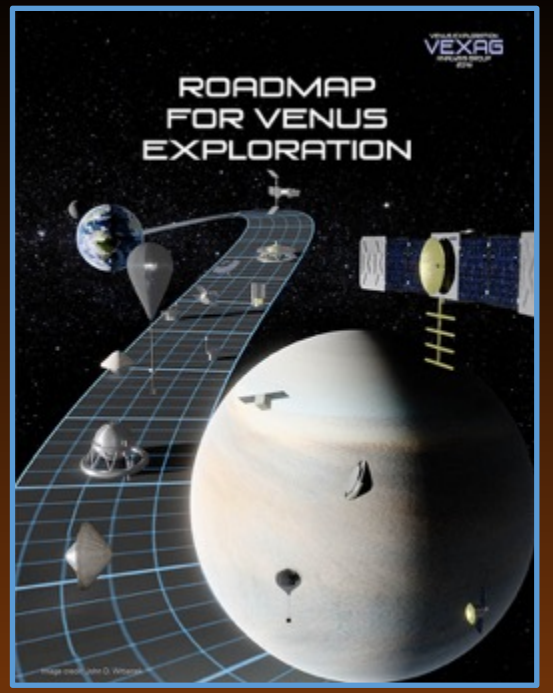
i. What is the range of habitable environments and how do they develop and change over time?

j. What is the thermal evolution of silicate planets? How sensitive are planets to starting conditions?

k. How can we apply a system science approach to the study of the Solar System? In other words, how do interacting systems affect interactions between, e.g., interior and surface, or planets and stars, etc.


VENUS EXPLORATION
VEXAG
ADVISORY GROUP
VENUS
STRATEGIC PLAN
2019


VEXAG
VENUS GOALS,
OBJECTIVES, AND
INVESTIGATIONS


VEXAG
ROADMAP
FOR VENUS
EXPLORATION


VEXAG
VENUS
TECHNOLOGY
PLAN

Path to Prepare for Decadal Survey

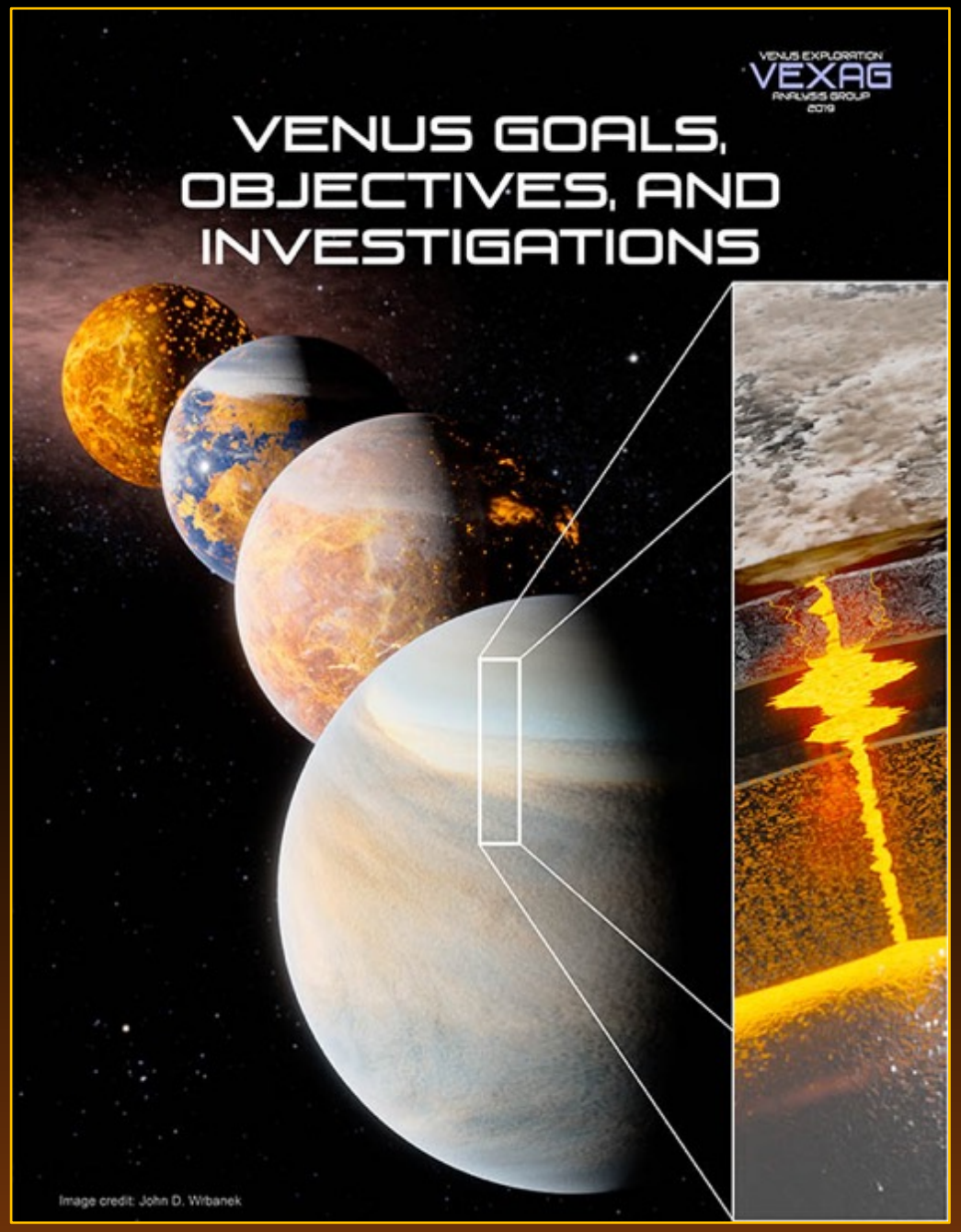
VEXAG — Venus Exploration Analysis Group

2018
March — 3 teams formed
April — weekly meetings, writing
December — 1st draft versions posted
January — Virtual Town Hall to discuss
February — 2nd draft versions posted
March — Pre-LPSC public meeting
April — 3rd draft versions posted
May — Virtual Town Hall to discuss
June — Final drafts completed
July — Sent out for review
August — Formatting for consistency
September — Revisions
October — Final edits, proofreading
October 2020 — Space Science Revs paper

Goals, Objectives, and Investigations (GOI)

Joseph O'Rourke and Allan Treiman (Co-Chairs)

- Giada Arney
- Paul Byrne
- Lynn Carter
- Darby Dyar
- James Head III
- Candace Gray
- Stephen Kane
- Walter Kiefer
- Kevin McGouldrick
- Laurent Montesi
- Chris Russell
- Suzanne Smrekar



Goal #1. Understand Venus' early evolution and potential habitability to constrain the evolution of Venus-sized (exo)planets

A. Did Venus have temperate surface conditions and liquid water at early times?
B. How does Venus elucidate possible pathways for planetary evolution in general?

Goal #2. Understand atmospheric composition and dynamics on Venus

A. What processes drive the global atmospheric dynamics of Venus?
B. What processes determine the baseline and variations in Venus atmospheric composition and global and local radiative balance?

Goal #3. Understand the geologic history preserved on the surface of Venus and the present-day couplings between the surface and atmosphere.

A. What geologic processes have shaped the surface of Venus?
B. How do the atmosphere and surface of Venus interact?

Goal #1: Early evolution and potential habitability

A. Did Venus have temperate surface conditions and liquid water at early times?

- **HO. Hydrous Origins (1).** Determine whether Venus shows evidence for abundant silicic igneous rocks and/or ancient sedimentary rocks.
- **RE. Recycling (1).** Search for structural, geomorphic, and chemical evidence of crustal recycling on Venus.
- **AL. Atmospheric Losses (2).** Quantify the processes by which the atmosphere of Venus loses mass to space, including interactions between magnetic fields and incident ions and electrons.
- **MA. Magnetism (3).** Characterize the distribution of any remanent magnetism in the crust of Venus.

Goal #1: Early evolution and potential habitability

B. How does Venus elucidate possible pathways for planetary evolution in general?

- **IS. Isotopes (1).** Measure the isotopic ratios and abundances of D/H, noble gases, oxygen, nitrogen, and other elements in the atmosphere of Venus.
- **LI. Lithosphere (1).** Determine lithospheric parameters on Venus that are critical to rheology and potential geodynamic transitions, including: stress state, water content, physical structure, and elastic and mechanical thicknesses.
- **HF. Heat flow (2).** Determine the thermal structure of the lithosphere of Venus at present day and measure in situ heat flow.
- **CO. Core (2).** Measure the size of the core of Venus and determine whether it remains partially liquid.

Goal #2: Atmospheric dynamics and composition

A. What processes drive the global atmospheric dynamics of Venus?

- **DD. Deep Dynamics (1)**. Characterize the dynamics of the lower atmosphere (below about 75km) of Venus, including: retrograde zonal super-rotation, meridional circulation, radiative balances, mountain waves, and transfer of angular momentum.
- **UD. Upper Dynamics (1)**. In the upper atmosphere and thermosphere of Venus, characterize global dynamics and interactions between space weather and the ionosphere and magnetosphere.
- **MP. Mesoscale Processes (2)**. Determine the role of mesoscale dynamics in redistributing energy and momentum throughout the atmosphere of Venus.

Goal # 2: Atmospheric dynamics and composition

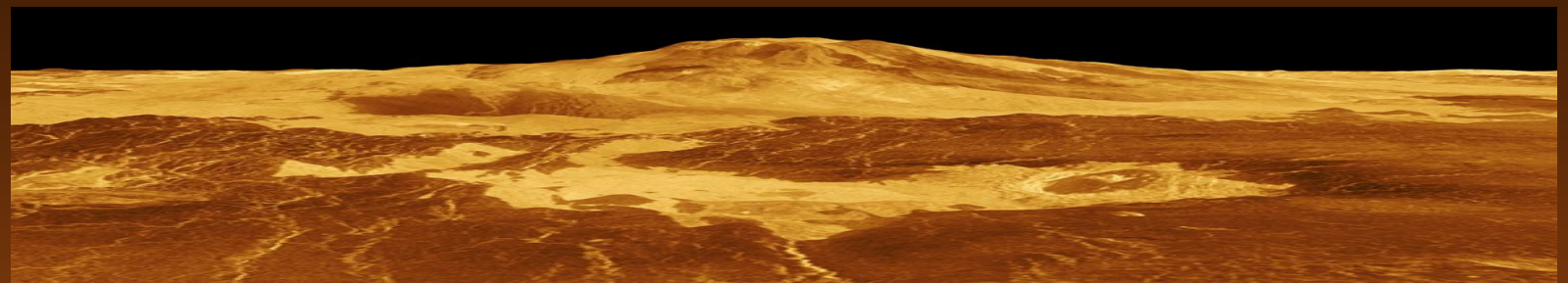
B. What processes determine the baseline and variations in Venus atmospheric composition and global and local radiative?

- **RB. Radiative Balance (1)**. Characterize atmospheric radiative balance and how radiative transport drives atmospheric dynamics on Venus..
- **IN. Interactions (1).** Characterize the nature of the physical, chemical, and possible biological interactions among the constituents of the Venus atmosphere.
- **AE. Aerosols (2)**. Determine the physical characteristics and chemical compositions of aerosols in Venus atmosphere as they vary with elevation, including discrimination of aerosol types/components.
- **UA. Unknown Absorber (2)**. Characterize the unknown shortwavelength absorber in the upper atmosphere of Venus and its influence on local and global processes.
- **OG. Outgassing (3)**. Determine the products of volcanic outgassing on Venus and their effects on atmospheric composition.

Goal #3: Geologic history and present-day surface-atmosphere couplings

A. What geologic processes have shaped the surface of Venus??

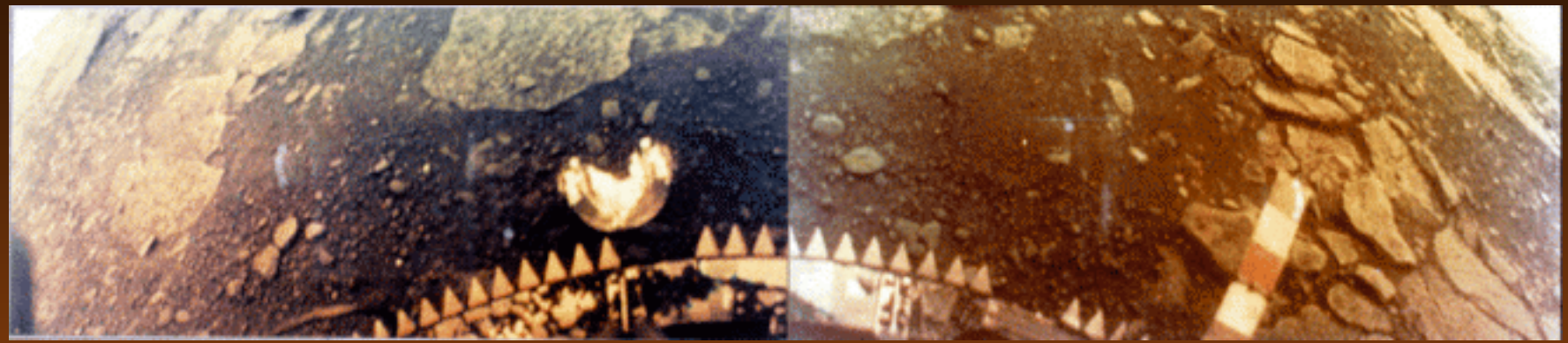
- **GH. Geologic History (1).** Develop a geologic history for Venus by characterizing the stratigraphy, modification state, and relative ages of surface units.
- **GC. Geochemistry (1).** Determine elemental chemistry, mineralogy, and rock types at localities representative of global geologic units on Venus.
- **GA. Geologic Activity (1).** Characterize current volcanic, tectonic, and sedimentary activity that modifies geologic units and impact craters and ejecta on Venus.
- **CR. Crust (2).** Determine the structure of the crust of Venus in three dimensions and thickness across the surface.



Goal #3: Geologic history and present-day surface-atmosphere couplings

B. How do the atmosphere and surface of Venus interact?

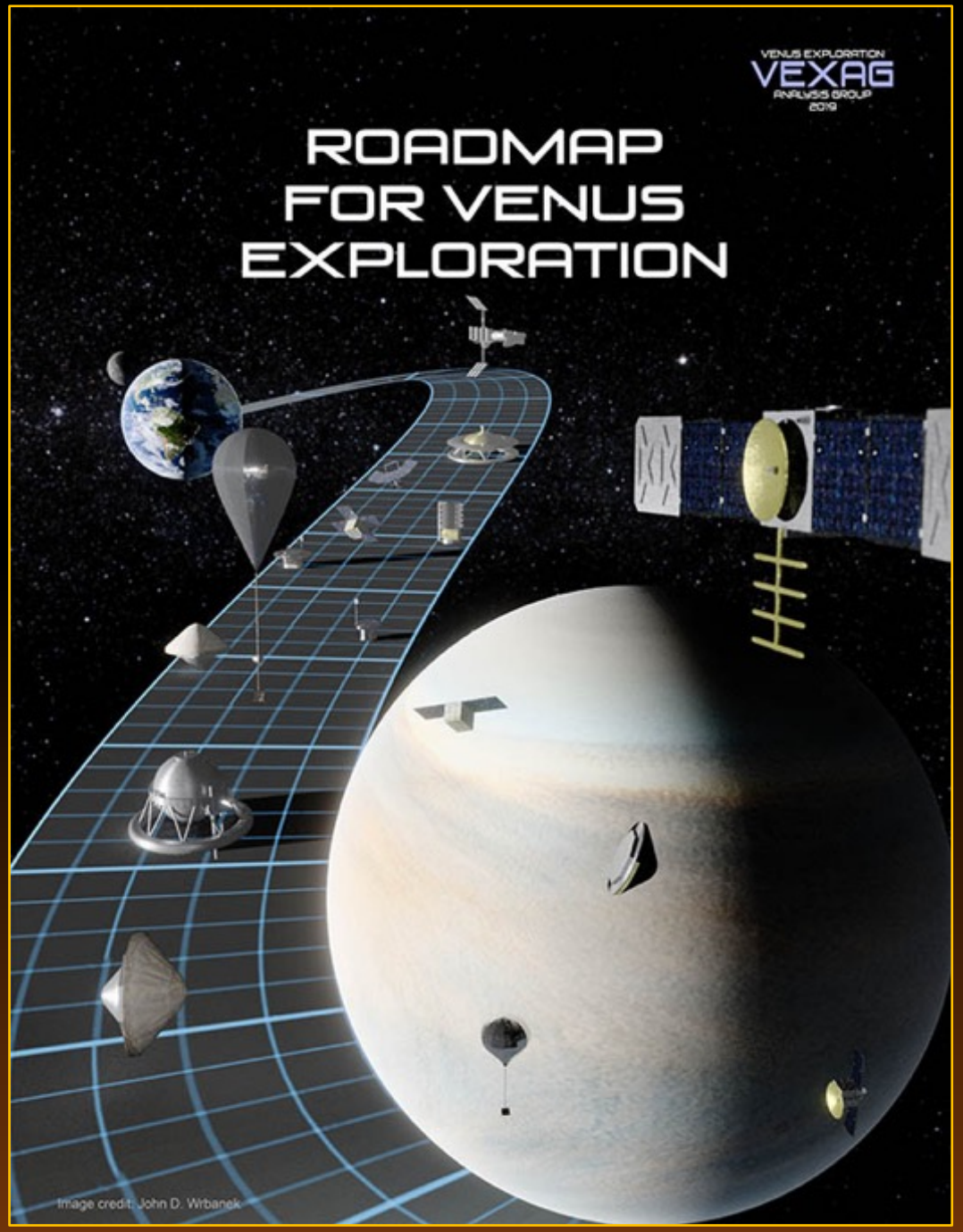
- **LW. Local Weathering (1).** Evaluate the mineralogy, oxidation state, and changes in chemistry of surface-weathered rock exteriors at localities representative of global geologic units on Venus.
- **GW. Global Weathering (2).** Determine the causes and spatial extents of global weathering regimes on Venus.
- **CI. Chemical Interactions (3).** Characterize atmospheric composition and chemical gradients from the surface to the cloud base both at key locations and globally.



Roadmap for Venus Exploration

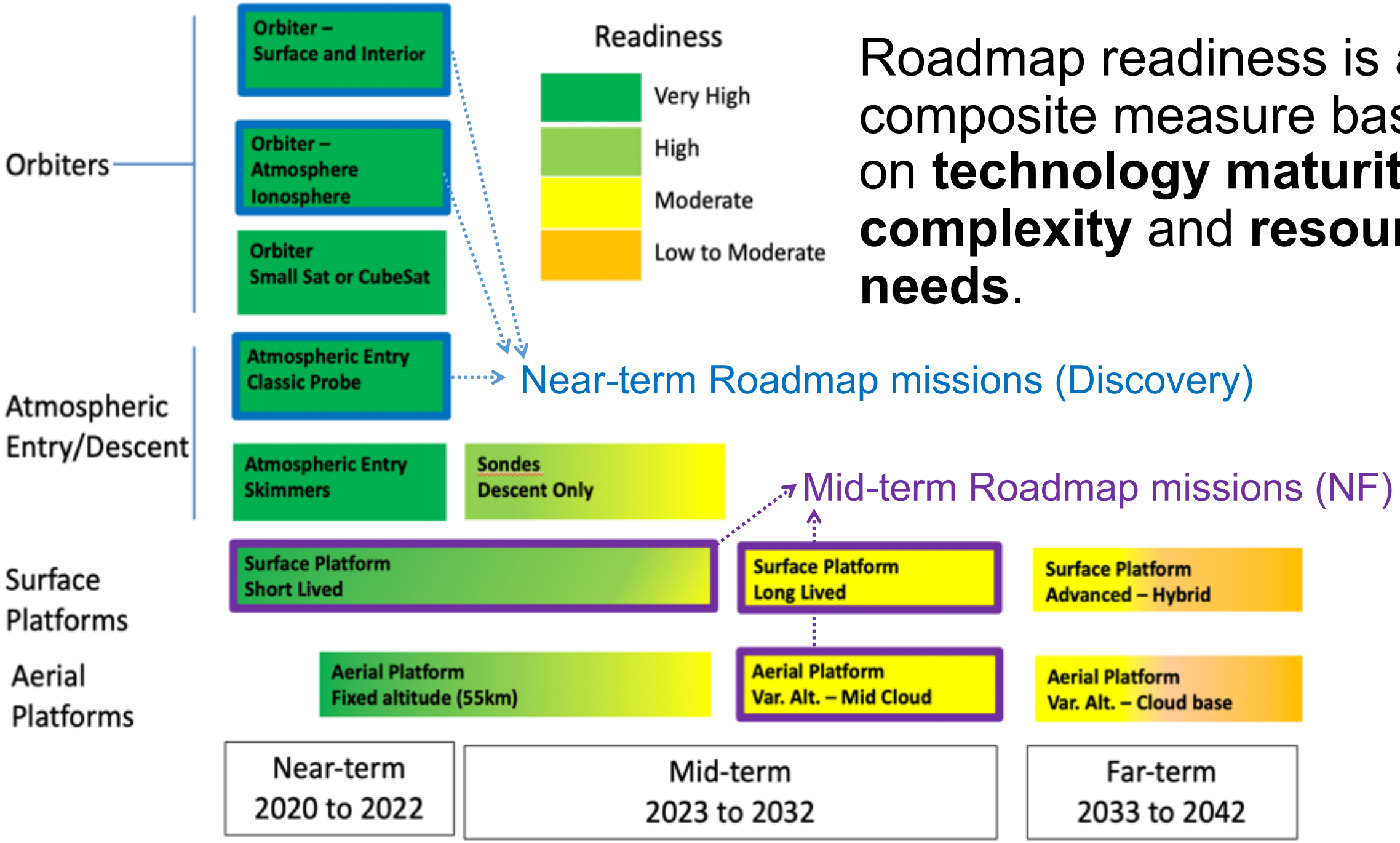
Jim Cutts (Chair)

- Michael Amato
- Tibor Kremic
- Candace Gray
- Scott Hensley
- Gary Hunter
- Noam Izenberg
- Walter Kiefer
- Kevin McGouldrick
- Joseph O’Rourke
- Suzanne Smrekar

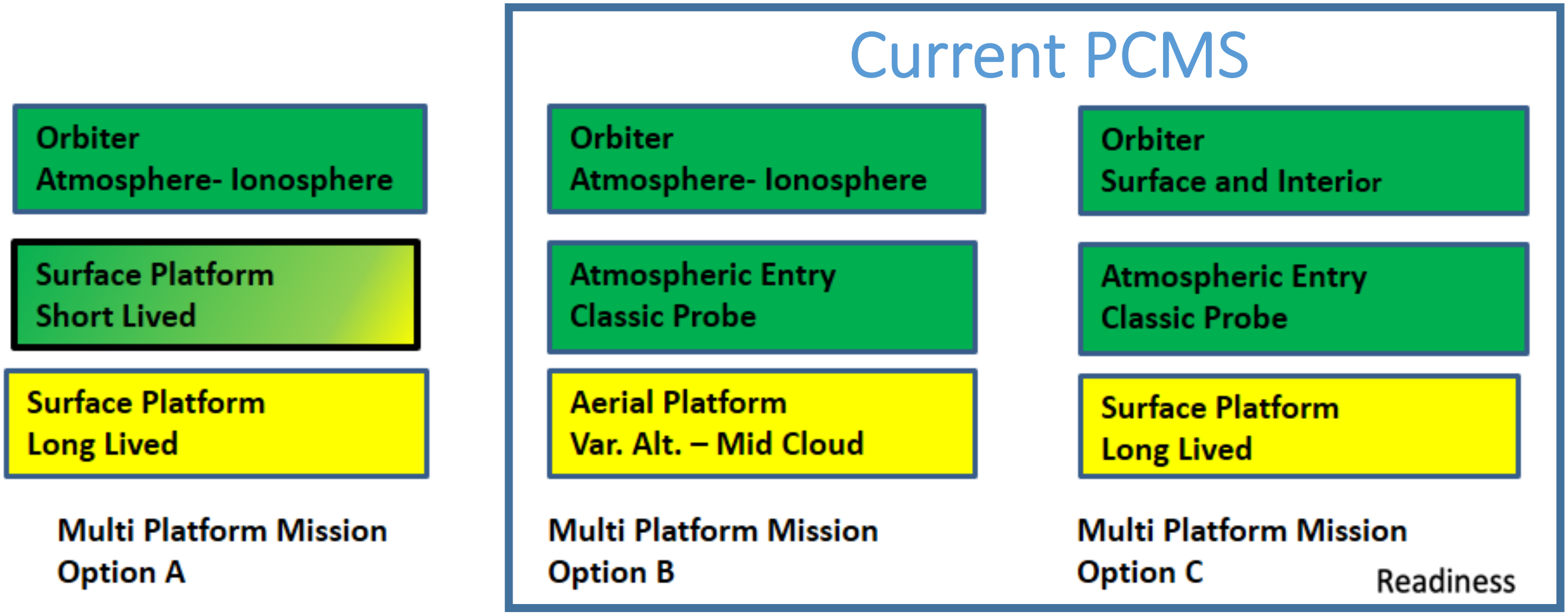


The Roadmap for Venus Exploration lays out a framework for pursuing its unique and extraordinary science opportunities, encompassing observations of the atmosphere, surface, and interior using a variety of mission modes ranging from orbiters, aerial platforms, long-duration landers, and probes, as well as opportunistic leveraging of events such as flybys of non-Venus missions.

The Roadmap seeks to account for both the unknown outcomes of competitive small and medium class NASA missions, technology and science development, and programmatic large scale efforts (*i.e.*, flagships and programs).



Roadmap readiness is a composite measure based on **technology maturity**, **complexity** and **resource needs**.



Multi-Platform Missions for the Decadal Survey Period (2023 to 2032).

Each mission includes three exploration platforms delivered to Venus with a single spacecraft.

Mission Modalities mapped to GOI

VEXAG GOI			Roadmap Mission Modalities											
			Orbiter	Orbiter	Orbiter	Atmospheric Entry			Surface Platform			Aerial Platform		
Goal	Objective	Investigation	Surface/Interior	Atmosphere	SmallSat	Skimmer	Probe	Sonde	Short-lived	Long-lived (Pathfinder)	Long-lived (Advanced)	Fixed Altitude	Variable Altitude	Variable+ Altitude
			Near-term	Near-term	Near-term	Near-term	Near-term	Mid-term	Near-term	Mid-term	Far-term	Near-term	Mid-term	Far-term
I. Early evolution and potential habitability	Did Venus have liquid water?	I.A.HO. (1)	V	S	S				V		V			V
		I.A.RE. (1)	V						V		V	S	S	S
		I.A.AL. (2)		V	V									
		I.A.MA. (3)		S	S				S	S	S	V	V	V
	How does Venus inform pathways for planets?	I.B.IS. (1)				V	V	V	V		V	V	V	V
		I.B.LI. (1)	V	S	S					S	V	V	V	V
		I.B.HF. (2)	V								V			
		I.B.CO. (2)	V		S					S	V			
II. Atmospheric dynamics and composition	What drives global dynamics?	II.A.DD. (1)		V	V		S	S		V	V	S	S	S
		II.A.UD. (1)		V	V	S								
		II.A.MP. (2)		V	S		S	S				S	V	V
	What governs composition and radiative balance?	II.B.RB. (1)		V	V		S	S	S	V	V	V	V	V
		II.B.IN. (1)		V	S		V	V		S	S	V	V	V
		II.B.AE. (2)		S	S		V	V	S	S	S	V	V	V
		II.B.UA. (2)		V	V		S	S				S	V	V
		II.B.OG. (3)	V	V	V		S	S	S	S	V	S	V	V
III. Geologic history and processes	What geologic processes shape the surface?	III.A.GH. (1)	V											S
		III.A.GC. (1)	S	S	S		S	S	V	V	V			V
		III.A.GA. (2)	V	S	S		S	S		S	V	S	S	S
		III.A.CR. (2)	V	S	S					S	V	V	V	V
	Atmosphere and surface interactions?	III.B.LW. (1)	S	S	S		V	V	V	V	V	S	S	S
		III.B.GW. (2)	V	V	V				S	S	S	S	S	S
		III.B.CI. (3)	S	S	S		V	V	V	V	V	S	S	V

Color Code	Meaning
	Vital: Mission modality enables measurements that are vital (either alone or in combination) to completing the investigation.
	Supporting: Mission modality enables measurements that substantially contribute to completing the investigation.

Venus Technology Plan

Gary Hunter (Chair)

- Jeffery Balcerski
- Samuel Clegg
- James Cutts
- Candace Gray
- Noam Izenberg
- Natasha Johnson
- Tibor Kremic
- Larry Matthies
- Joseph O'Rourke
- Ethiraj Venkatapathy

Notable advancements since last Roadmap

Color		MM
Title	Very High. Ready for flight in this timeframe. Same as TRL 6	Mix of maturity. Some ready for flight, others at various maturity levels
Description	Established for flight. May require resource commitment to maintain readiness or continuity of expertise	

Moderate to High. Limited development and testing still needed	Moderate. Active on-going R&D effort needed for readiness in this given timeframe	Moderate to Low. Significant R&D effort needed for readiness in this timeframe	Low. Major R&D effort needed with notable technical challenges
Defined transition to flight	Presently understood technical pathway to achieve capability by this timeframe	A viable foundation exists, but more than one technical pathway in consideration to achieve capability by this timeframe	It not clear how to achieve the targeted capability and basic research activities in multiple fields may be needed to achieve this capability by this timeframe

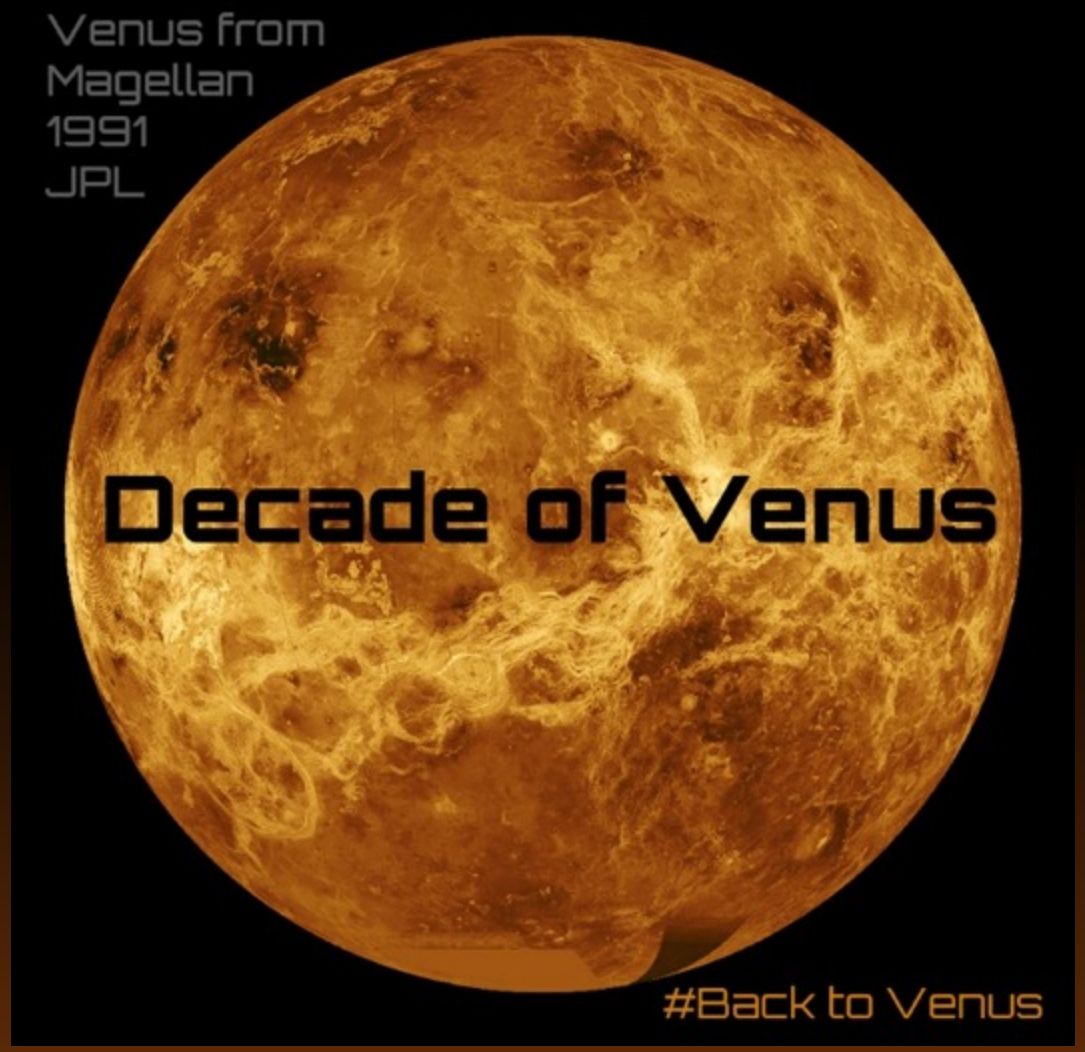
	Mission Mode	Near-term Missions						Mid-Term Missions						Far-Term Missions						
		Orbiters	Small Sat	Deep Probe	Multiple Shallow Probes	Short Lived Large Lander	Aerial Platform Fixed	Advanced Orbiters	Subsatellite/ Small Sat Platforms	Multiple Deep Probes and Sondes	Increased Duration Large Lander	Small Platform Lander- Long Duration	Aerial Platforms Altitude. Control Upper and Mid Cloud	Advanced Orbiter /Smallsat Networks	Aerial Platforms Altitude Control All Cloud	Lander - Cooled, Long Duration	Lander Network- Long Duration		Mobile Surface	Sample Return Clouds	Sample Return Surface
System Technologies	Aerobraking																			
	Aerocapture																			
	Entry																			
	Descent and Deployment																			
	Landing																			
	Aerial Platforms																			
	Flight																			
	Landers																			
	Mobility																			
	Ascent Vehicle																			
	Small Platforms																			
	Automation and Autonomy																			
Subsystem Technologies	Energy Storage- Batteries																			
	Energy Generation- Solar																			
	Energy Generation - Radioisotope Power																			
	Energy Generation-Alternative Sources																			
	Thermal Control - Passive																			
	Thermal Control - Active																			
	High temperature mechanisms																			
	Moderate temperature electronics																			
	High temperature electronics																			
	Communications																			
	Guidance, Navigation, and Control			MM		MM	MM													
Instrument	Remote Sensing - Active																			
	Remote Sensing - Passive																			
	Remote Sensing - Surface																			
	Remote Sensing - Atmosphere																			
	In-Situ Aerial Platform and Probe																			
	In Situ Surface - Short Duration																			
	In Situ Surface - High Temperature Sensors																			
	In Situ Surface - Long Duration Mobile Lab																			

Technology Needs I

Area	Need
Entry Technology	Ensure the entry technology capability does not atrophy
Subsystems	Increase capability of high temperature electronics, sensors, and high-density power sources for the Venus environment
Aerial Platforms	Programmatic determination of which Variable Altitude balloons approach is most viable
In situ Instruments	Adapt flight-demonstrated technology and develop new instrument systems designed for the Venus environment
Communications and Infrastructure	Study the feasibility of and methods for establishing a Venus communications and navigation infrastructure
Advanced Cooling	Invest in high-efficiency mechanical thermal conversion and cooling devices

Technology Needs II

Area	Need
Descent and Landing	Precision descent and landing hazard avoidance technologies to operate in Venus' dense atmosphere
Autonomy	Transition of automation and autonomous technologies to Venus-specific applications
Small Platforms	Develop small platform concepts in addition to larger missions. Develop new mission *type* designed around small platforms
Facilities and Infrastructure	Support of laboratory facilitiies and capabilities for instrument and flight systems, and critical technologies. Avoid atrophy of capabilities
Modeling and Simulations	Establish a system science approach to Venus modeling
Unique Venus Technology	Continue and expand support for programs such as HOTTech, and other technology development


Venus from
Magellan
1991
JPL
Decade of Venus
#Back to Venus


VENUS
THE ORIGINAL
OCEAN WORLD