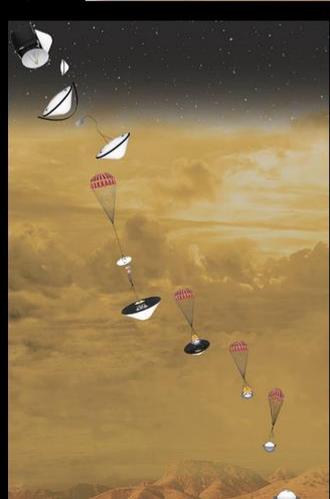


Venus Exploration Roadmap

Members of the VEXAG Venus Exploration Roadmap Focus Group Lead Jim Cutts¹

Presentation to
VEXAG Annual Meeting



Nov 6-8, 2018

(1) Jet Propulsion Laboratory, California Institute of Technology.
© 2018 California Institute of Technology. Government sponsorship acknowledged.



- Overview
- Decade of Venus
- VEXAG Roadmap Focus Group - Members
- Roadmap Development Process
- Roadmap Development – Topics Assessed
- Venus Goals Objectives and Investigations
- Venus Roadmap 2018
 - Near Term – 2019 to 2022
 - Mid Term – 2023 to 2032
 - Far Term – 2033 to 2042
- Work in Progress
- Summary



Overview



- The three guiding documents for Venus Exploration were written in 2014. Only the Goals Objectives and Investigations has been updated since then
- VEXAG initiated a revision to the three documents in the spring of 2018 with the goal of completing the revision by the end of the calendar year.
- The Roadmap Team was formed in April and had its kickoff meeting in May. Fifteen additional telecons have been held since then leading up to the VEXAG annual meeting
- This is a status report on the Venus Exploration Roadmap

Decade of Venus!



- Venus exploration, particularly in the U.S., has lagged seriously in recent decades with no missions since Magellan (1989 launch) and no mission selections despite many highly competitive proposals.
- Venus science is now poised for a renaissance in exploration driven by
 - Increasing importance of understanding the evolution of Venus with respect to its sister planet Earth and the multitude of Earth & Venus-sized exoplanets
 - Need to bring the study of Venus into the 21st century to enable meaningful comparative planetology for the terrestrial planets
 - Growing interest from early career scientists and engineers in exploring Venus
 - Extensive advances in technologies and experimental techniques for unveiling Venus's scientific secrets
 - Potential of international partnerships for exploring the most accessible of the planets
- The Decade of Venus (2023 to 2032) beckons!



VEXAG Roadmap Focus Group - Members



- James A. Cutts, JPL, Lead
- Michael Amato, GSFC
- Candace Gray, NMSU
- Scott Hensley, JPL
- Gary Hunter, GRC, (Lead, Technology Focus Group)
- Noam Izenberg, JHUAPL, (Member, Technology Focus Group)
- Walter Kiefer, LPI
- Tibor Kremic, GRC
- Kevin McGouldrick, U. Col. , (Member, GOI Focus Group)
- Joseph O'Rourke, ASU
- Sue Smrekar, JPL

Other Contributors

- Bob Grimm, SWRI, VEXAG Chair
- Marty Gilmore, Wesleyan U., VEXAG Co-Chair



VEXAG Venus Exploration Roadmap – Process



Venus Goals, Objectives and Investigations (GOI) Focus Group

Venus Technology Focus Group

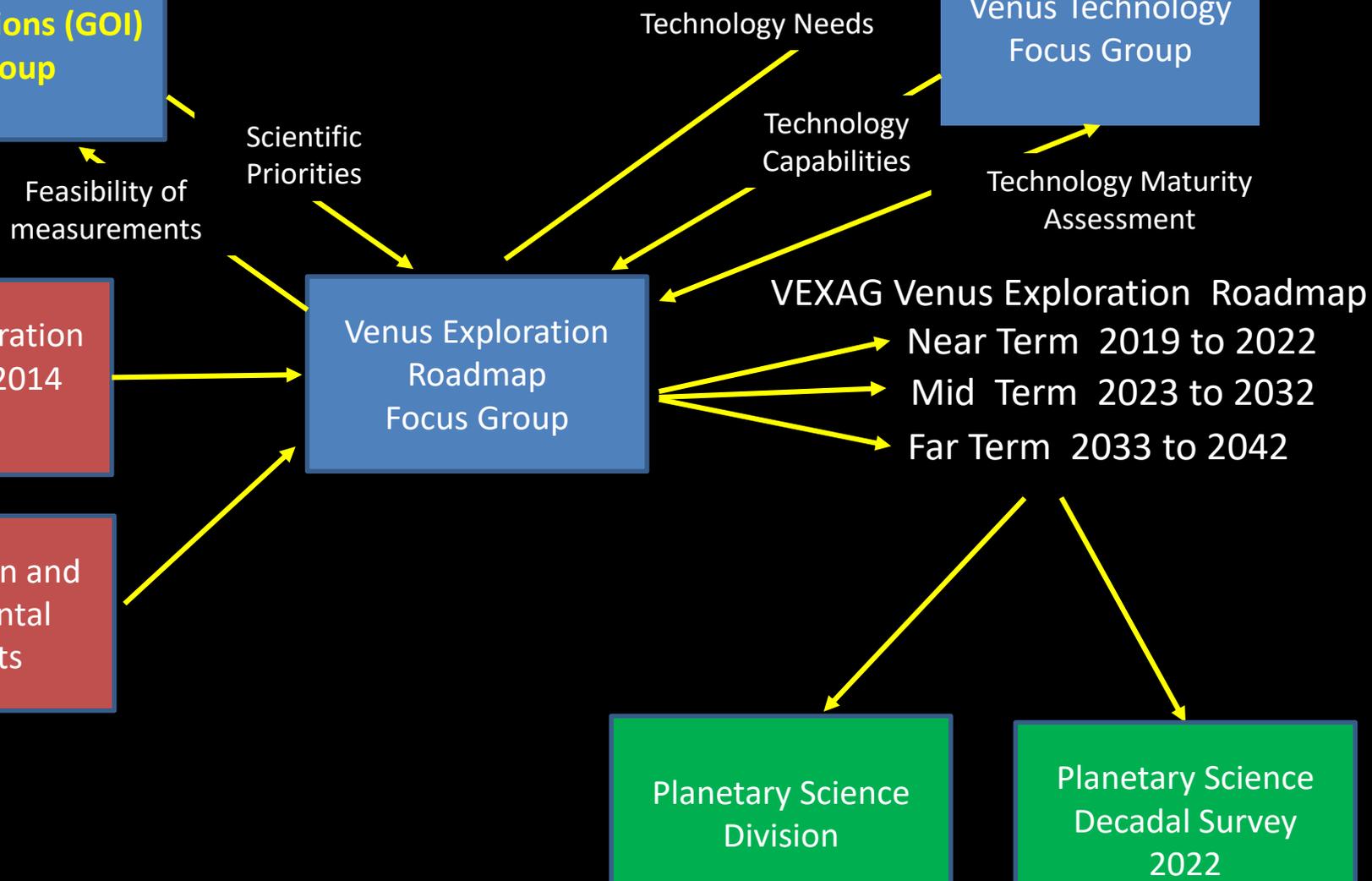
Venus Exploration Roadmap Focus Group

Venus Exploration Roadmap 2014

New Mission and Experimental Concepts

Planetary Science Division

Planetary Science Decadal Survey 2022



VEXAG Roadmap Focus Group – Topics Assessed



WEEK	DATE	TOPIC	Lead Presenter
1	29-May	Kick Off Meeting	Cutts
2	5-Jun	Discussion of current roadmap	Smrekar
5	26-Jun	Venus Bridge - Implications for Roadmap	Izenberg
7	10-Jul	International Missions - Venera D	Kremic
10	1-Aug	International Collaboration/GOI and Tech update	Cutts, McGouldrick, Hunter
11	8-Aug	Venus Flagship Mission Studies	Amato/Gilmore
12	15-Aug	GOI Team update	Treiman/McGouldrick
13	22-Aug	International Missions/ 2014 Roadmap Revisited	Hensley/Cutts
14	29-Aug	Orbiters and Landers for Surface and Interior Science	Smrekar/Kiefer
15	5-Sep	Orbiters for Atmospheric Science	McGouldrick/Gray
17	19-Sep	Aerial Platforms - Technology and Science Capabilities	McGouldrick/Hall
18	26-Sep	Long Lived Surface Platform - Technology and Science Capabilities	Hunter/Izenberg
20	10-Oct	Review Powerpoint Presentation of Roadmap for VEXAG	Cutts/Smrekar
21	17-Oct	Review alignment of GOI with Roadmap	Treiman/Smrekar
22	24-Oct	Review Alignment of Technology Plan with Roadmap	Hunter/Cutts
23	31-Oct	Review PowerPoint Presentation for VEXAG	Cutts
24	6-Nov	Presentation at VEXAG	Cutts

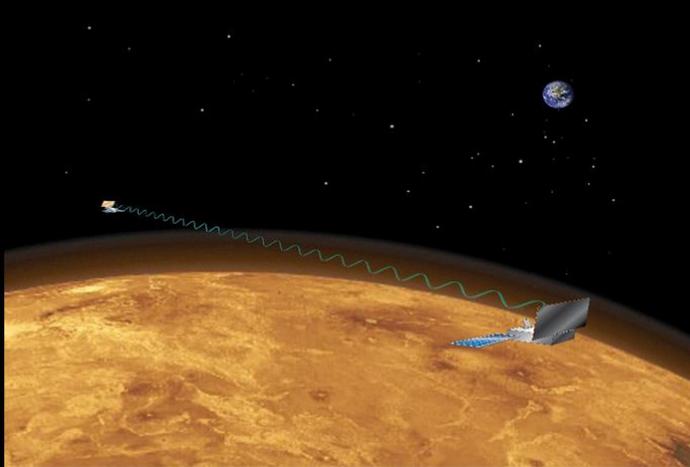


- The initial planning of the Venus Roadmap 2018 relied on the scientific guidance in the 2016 GOI.
- When the GOI focus group developed a consensus around the new GOI, they briefed the Roadmap focus group on the changes and the Roadmap Focus group responded
- The Roadmap Focus Group emphasized the importance of **Actionable Investigations** in the GOI:
 - Prefers investigations with an explicit or implied platform and experimental approach
 - Recognizes exceptions -high priority science questions with no obvious solution but where identification as an investigation may stimulate creative solutions

VEXAG Roadmap – Emerging Capabilities



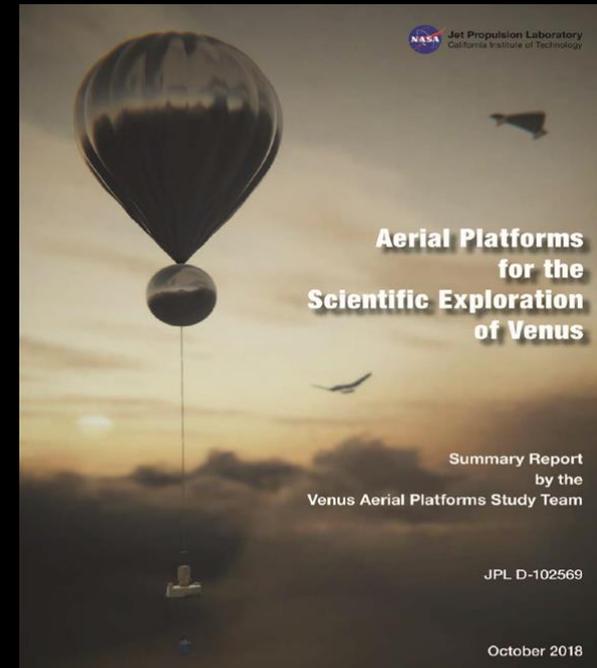
- Since the 2014 Venus Exploration Roadmap significant developments have occurred in three exploration modes and their associated technologies



**SmallSats and CubeSats
Venus Bridge**



**Long-Lived Surface
Platforms**



Aerial Platforms



Venus Roadmap – Near Term 2019 to 2022



- This time frame includes the announcement of opportunities for competitive programs including
 - Discovery
 - New Frontiers (NF 5)
 - Venus Bridge (were it to be approved)
- Two types of missions have been rated Category 1 and/or advanced to step 2 in the last several Discovery and New Frontiers opportunities
 - Atmospheric composition probe with surface composition/mineralogy and descent imaging
 - Orbiters conducting radar (topo/imaging/deformation) and infrared surface observations, one with an atmospheric skimmer
- Other concepts have been developed which are slightly less mature scientifically or technically
 - Venus landers of the VISE class
 - Four SmallSat or CubeSat concepts selected for study under the PSDS3 program



Venus Roadmap – Mid Term 2023 to 2032



- This is the planning time frame for the next Planetary Science Decadal Survey
- Concepts considered for this time frame include candidates for Discovery and New Frontiers missions
- This is also an opportunity for a Venus Flagship class mission
 - Studies will begin in the fall of 2018
 - Can draw on past work on Flagship mission studies including the Venus Climate Mission, the Venus Flagship Design Reference Mission, and Venera D
 - These are multiplatform missions including an orbiter, short duration lander, long-lived lander, aerial platforms, probes, sondes and subsatellites.
 - Can incorporate some level of new technology



Venus Roadmap – Near to Mid Term to 2032 Preliminary



Orbiter -Surface and Interior

- Radar
- IR Spectroscopy
- Gravity

Orbiter -Atmosphere

- Targeted atmos investigation
- Seismic infrasound signatures

Orbiter - Smallsat

- Telecom relay navigation
- Synergistic with in situ science
- Potential Venus Bridge concept

Atmospheric Skimmer

- Noble Gas composition

Aerial Platform

- Atmospheric and geophysics
- Fixed altitude
- May include Sondes

Aerial Platform

- Atmospheric geophysics surface
- 50 to 60 km altitude
- Mid cloud exploration

Entry Probes

- Composition, structure
- Descent imaging

Short Lived Lander

- Stand off sample analysis
- Sample acquisition and analysis

Long-Lived In Situ Exploration System

- Package or Station
- Seismo tech demo

Technology Maturity



These platforms are candidates for Discovery and New Frontiers missions: they may be combined into synergistic combinations as Flagship Missions



Venus Roadmap – Far Term 2033 to 2042 and Beyond Preliminary



Advanced Orbiters for Surface and Interior

Smallsats for Targeted Atmospheric Investigations

Aerial Platform

- 40 to 60 km altitude
- Access below clouds

Enhanced-Capability Landers

- Lifetime up to 24 hours?
- Precision Landing?
- Advanced Instrumentation

Seismology Network

- Technology feedforward from Long Lived In Situ System

Beyond 2042
→

Venus Surface Sample Return

Surface or near surface platform with regional mobility

Concepts from VEXAG 2014 Roadmap

Technology Maturity



Concepts for this time frame can consider a greater level of new technology than for the prior period but the size and complexity and hence cost should still be commensurate with current ground rules.



- Mapping GOI to capabilities of the roadmap platforms.
 - Continuing to work with GOI Focus Group
- Technology maturity of the roadmap platforms
 - Continuing to work with the Technology Focus group
- International missions – planned and potential.
 - Will be addressed in the narrative report
- Scientific and technology feedforward
 - Will be addressed in the narrative report



- The Roadmap Focus group has been evaluating the candidate missions to enable a renaissance in Venus exploration - the Decade of Venus
- Our approach has been to look critically at concepts in terms of their technical realism and their ability to address priority Venus science
- We are working closely with the GOI Focus Group and the Technology Focus group to bring our assessments into alignment
- Following VEXAG our attention will turn to completing the narrative report which is in early draft form and requires major revision from the 2014 report