Status Report of the Venera-D Joint Science Definition Team

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Overview

- Venera-D JSDT Phase 2 Tasks
- Venera-D Mission Concept Architecture
- Status briefing to the Directors (Jim Green and Lev Zelenyi)—2 October 2017
- Moscow Venus Modeling Workshop
- Schedule of JSDT Activities
**GOAL**: Definition of a focused Venera-D mission architecture concept based on the January 2017 JSDT report, including a prioritized list of potentially contributed elements and down-select options.
## Summary of Venera-D Phase 2 Tasks

<table>
<thead>
<tr>
<th>Task</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>MISSION CONCEPT</td>
<td>Assessment ongoing and to continue work in 2018</td>
</tr>
<tr>
<td>MISSION OPERATIONS</td>
<td>Assessment ongoing and to continue work in 2018</td>
</tr>
<tr>
<td>CONTRIBUTED ELEMENT ACCOMMODATION</td>
<td>Assessment ongoing and to continue work in 2018</td>
</tr>
<tr>
<td>RISK ASSESSMENT</td>
<td>To be worked in 2018</td>
</tr>
<tr>
<td>MISSION CONCEPT SCIENCE REFINEMENT</td>
<td>Workshop at GRC completed, Moscow Workshop in October 2017</td>
</tr>
<tr>
<td>LANDING SITE IDENTIFICATION</td>
<td>Input from Phase 1 study and Moscow Workshop</td>
</tr>
<tr>
<td>PAYLOAD REFINEMENT</td>
<td>Assessment ongoing and to continue work in 2018</td>
</tr>
<tr>
<td>POTENTIAL CONTRIBUTED ELEMENT(S)</td>
<td>Status reported to the Directors; continued assessment of key development milestones ongoing</td>
</tr>
<tr>
<td>FINAL REPORT</td>
<td>Outlining and assignments to be focus of March JSDT meeting</td>
</tr>
</tbody>
</table>
Venera-D Concept Architecture: Mission Elements

- **Baseline:**
  - Orbiter: Polar 24 hour orbit with a lifetime greater than 3 years—Can trade orbiter period for communication with other elements
  - Lander (VEGA-type, updated) 2+ hours on the surface (one hour to conduct baseline science and one hour of margin)

- **Other components discussed as potential augmentations:**
  - Free flying aerial platform and balloons
  - Sub-satellite
  - Small long-lived stations (also considered as an instrument on the lander)
### Proposed Architectural Options for Assessment

<table>
<thead>
<tr>
<th></th>
<th><strong>Maximum Capability Mission</strong></th>
<th><strong>Intermediate Capability Mission</strong></th>
<th><strong>Moderate Capability Mission</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Flight Elements</strong></td>
<td>Baseline Orbiter and Lander; Aerial Platform; Small long-lived station</td>
<td>Baseline Orbiter and Lander; Aerial Platform</td>
<td>Baseline Orbiter and Lander</td>
</tr>
<tr>
<td><strong>Science Enabled</strong></td>
<td>Comprehensive Atmosphere and Surface Science</td>
<td>Core science objectives with enhanced atmospheric science</td>
<td>Core science objectives (High and Medium priority)</td>
</tr>
<tr>
<td><strong>Challenges</strong></td>
<td>Large number of flight elements and deployments resulting in potentially high technical and scientific risk; Multiple flight elements</td>
<td>Integration, validation, testing, and operation of multiple flight elements</td>
<td>Integration, validation, testing, and operation of flight system</td>
</tr>
<tr>
<td><strong>Potential Contribution Options</strong></td>
<td>DSN Support; Instrument(s); Flight Element; Test facilities</td>
<td>DSN support; Instrument(s); Flight Element; Test facilities</td>
<td>DSN support; Instrument(s); Test facilities</td>
</tr>
</tbody>
</table>

**Focus of work in 2017**

*Pre-Decisional — For Planning and Discussion Purposes Only*
Venera-D Concept Architecture: General Spacecraft Configuration

- Launch on Angara 5 in the 2026 to 2031 time frame
- Accommodation of VAMP aerial vehicle
Venera-D Concept Architecture: Spacecraft Configuration

Baseline Orbiter & Lander

VAMP

VAMP Adapter

Scientific instruments

Propulsion system

Adapter

HGA
Venera-D Concept Architecture: Lander Components

- Landing module (ПМ)
- Onboard cable network
- Onboard control complex
- Onboard radio complex
- Structure
- Thermal control tools
- Power supply system
- Telemetric system
- Scientific equipment

Long-lived station

Pre-Decisional — For Planning and Discussion Purposes Only
Venera-D Concept Architecture: Orbiter Components

- Orbiter
- Cable network
- Board control complex
- Board radiocomplex
- Propulsion system
- Structure
- Thermal control devices
- Power supply system
- Telemetry system
- Scientific equipment

Pre-Decisional — For Planning and Discussion Purposes Only
Venera-D Concept Architecture: Delivery of Flight System to Venus

1) Injection of SC into departure trajectory in 2026 (alternative launch dates – 2028, 2029, 2031); transfer to transit Earth-Venus trajectory using a booster; separation of booster and adapter.

2) Interplanetary stage of 4 month duration including trajectory corrections and finishing at the arrival at Venus.

3) Separation of the lander from SC 2 days before arrival at Venus.

4) Maneuvering of SC to prevent the orbiter from entering the Venus atmosphere.

5) Maneuvering the orbiter to inject it into a 24 hour elliptical orbit; separation of VAMP, other scientific separable equipment; fulfillment of scientific program:
   - Orbiter duration of 3 years after injection into orbit;
   - Lander duration of 3 hours after landing.
## Technical characteristics of the SC

<table>
<thead>
<tr>
<th>№</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Functional orbits</td>
<td>300-500 km</td>
</tr>
<tr>
<td>2</td>
<td>SC mass</td>
<td>5800…7000 kg</td>
</tr>
<tr>
<td>3</td>
<td>Mass of OM without fuel</td>
<td>990 kg</td>
</tr>
<tr>
<td>4</td>
<td>Mass of scientific equipment on orbiter</td>
<td>1200 kg</td>
</tr>
<tr>
<td>5</td>
<td>Mass of scientific equipment on lander</td>
<td>120 kg</td>
</tr>
<tr>
<td>6</td>
<td>Transmission velocity of radio line SC-Earth (X-band)</td>
<td>256 Kbit/sec</td>
</tr>
<tr>
<td>7</td>
<td>Transmission velocity of radio line SC-Earth (Ka-band)</td>
<td>16 Mbit/sec</td>
</tr>
<tr>
<td>8</td>
<td>Transmission velocity of radio line orbiter – lander (420 MГц)</td>
<td>128…256 Kbit/sec</td>
</tr>
<tr>
<td>9</td>
<td>Active lifetime of the orbiter</td>
<td>3 years</td>
</tr>
<tr>
<td>10</td>
<td>Active lifetime of the lander on the surface</td>
<td>3 hours</td>
</tr>
<tr>
<td>11</td>
<td>Maximum fill-up</td>
<td>2100 kg</td>
</tr>
<tr>
<td>12</td>
<td>Maximum power consumption</td>
<td>1700 Watt</td>
</tr>
<tr>
<td>13</td>
<td>Electrical power consumption of scientific equipment of the orbiter</td>
<td>250 Watt</td>
</tr>
</tbody>
</table>
Status Briefing to the Directors

• Meeting took place at IKI on 2 October 2017

• Briefing Topics:
  - Overview of NASA Venus activities
  - Venera-D architecture
  - Report on NASA aerial platform study
  - Report on Venus Workshops
  - Discussion of work to go

• Key Direction provided:

An architecture has been identified that provides the maximum possible capability. To constrain the resource trade space, the JSDT should focus on a core architecture consisting of an orbiter and lander. The lander should include an attached long-lived station.
Moscow Modeling Workshop

• The Workshop took place from 5-7 October 2017 at IKI

• Workshop topics (see Backup for full agenda):
  - General Circulation Models
  - Results from Akatsuki
  - Chemistry and Clouds
  - Aerial platforms
  - Plasma
  - Interior, surface, and landing sites
  - Mission architecture
  - Laboratory experiments
Moscow Modeling Workshop

• Thanks to NASA invited participants!
  Michael Way (GISS)  Amanda Brecht (ARC)
  Thomas Navarro (UCLA)  Lori Glaze (GSFC)
  Allan Treiman (LPI)  Kevin McGouldrick (LASP)
  Glyn Collinson (GSFC)  Sara Port (U. of Ark.)

• Extra thanks to our early career recording secretaries!
  Dmitry Gorinov (IKI)  Amanda Brecht (ARC)
  Mikhail Luginin (IKI)  Sara Port (U. of Ark.)
  Evgeniy Guseva (GEOKHI)  Gly Collinson (GSFC)
  Kevin McGouldrick (LASP)

• Notes from the proceedings of the workshop are under review and will be made available
### Venera-D Mission Concept Study Phase 2 Tasks—High-Level Schedule

<table>
<thead>
<tr>
<th>Date Range</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>14 to 16 March 2017</td>
<td>JSDT meeting to finalize Phase 2 plan and protocol between IKI and the Lavochkin Association</td>
</tr>
<tr>
<td>2 October 2017</td>
<td>Briefing to Directors</td>
</tr>
<tr>
<td>March/April 2018</td>
<td>JSDT meeting (Moscow)—Outline of report and writing assignments</td>
</tr>
<tr>
<td>Summer 2018</td>
<td>JSDT meeting at COSPAR (Pasadena)*</td>
</tr>
<tr>
<td>October 2018</td>
<td>JSDT meeting (Moscow)—Review of draft of report. Briefing to Directors</td>
</tr>
<tr>
<td>January 2019</td>
<td>Deliver Report to Directors</td>
</tr>
</tbody>
</table>

- **Full JSDT telecons every two weeks**
- **Technology and Engineering telecons every 2 weeks**

*It is not clear possibility of participation of all Russian team members*
Conclusion

- The JSDT identified priorities for the science goals and objectives and estimated possibility of realisation of the “maximal mission”, which architecture provides the maximum possible capability.

- From mass budget (Lavochkin Assoc.) it is possible to realize with Angara 5/Proton launch on 2026 and after.

- Task from Directors for 2018:
  - to constrain the resource trade space, the JSDT should focus on a core architecture consisting of a high capable orbiter and high capable lander. The lander should include an attached long-lived station.
  - to estimate the scientific gaps, and create recommendations of inclusion additional elements of mission, experiments

- Study possibility and problems of implementation of the additional elements (orbit, links, landing sites)
Together to Venus!
Backup
VENERA-D Venus Modeling Workshop
5/10/2017
10:00 Welcome
Lev Zeleny, James Green, Sergey Lemeshevskii
11:00 Ludmila Zasova, David Senske, and JSDT, Status of Venera-D
11:20 T. Kremic, Briefing from VEXAG Venus Modeling Workshop
11:35 Coffee break

General circulation models
11.50 Alexander Rodin Gas dynamics general circulation model of the Venus atmosphere
12:20 Sebastien Lebonnois Behavior of Venus planetary boundary layer as predicted by the Venus GCM

12:40 Josette Bellan Usefulness Of Supercritical Fluid Modeling To Understanding The Venus Lower Atmosphere And Boundary Layer (poster)

12:45 Amanda Brecht the Latest on the Venus Thermospheric General Circulation Model: Capabilities and Simulations
13:10 Lunch

Akatsuki
14:00 Takehiko Satoh New Views of Venus as Obtained From Akatsuki
14:30 Yeon Joo Lee Venus seen from the UV imager onboard Akatsuki
15:00 Sanjay Limaye Multispectral Day and Night Cloud Morphology of Venus from Akatsuki Cameras

Chemistry, clouds
15:20 Vladimir Krasnopolsky Modeling of Chemical Composition in the Lower and Middle Atmospheres of Venus
15:40 Franklin Mills Simulations of Vertical Profiles of SO and SO$_2$ in Venus’ Mesosphere
16:00 Kevin McGouldrick Microphysical Modeling of the Sulfuric Acid Venus Cloud System
16:30 Coffee break
16:50 Cristopher Parkinson on Understanding the Nature and Variation of the Venussian Middle Atmosphere via Observations and Numerical Modeling of Key Tracer Species
17:10 Sara Port Metal Sulfides and their Relation with Gaseous Sulfur on Venus
17:40 Discussion of results of the 1st day sessions

Pre-Decisional — For Planning and Discussion Purposes Only
Aerial platforms

10:00 James Cutts Venus Aerial Platforms and Engineering and Scientific Modeling Needs
10:30 Siddharth Krishnamoorthy Infrasound Detection from Balloons – Perspectives from Simulations
10:50 Sebastien Lebonnois, Exploring Balloon Trajectories in a Modeled Venus Atmosphere (poster)
10:55 Alexander Rodin, LIDAR spectroscopic sounding of the ambient atmosphere and cloud layer onboard Venus atmospheric platform (poster).
11:00 Coffee Break
11:20 Thomas Navarro Large Stationary Gravity Waves: A Game Changer for Venus’ Science

Posters:
11:50 Igor Khatuntsev Cloud level circulation according to UV and near-IR VMC imaging onboard Venus Express
11:55 Dmitry Gorinov Circulation of Venustian atmosphere at 95-100 km from apparent motions of 1.27 μm O2 nightglow
12:00 Ludmila Zasova Effects of surface topography in atmosphere from middle clouds to mesopause
12:05 Vladimir Gubenko High-Latitude Zonal Winds In The Venus's Atmosphere From Venera-15 And -16 Radio Occultation Data

5. Plasma
12:10 Glyn Collinson Mysteries of Atmospheric Escape and Evolution at Venus
12:40 Lev Zeleny, A. Petrukovich, O. Vaisberg Solar wind interaction with Venus – implication to atmosphere and lessons from Mars
13:00 Anatoly Gavrik Radio-Occultation Measurements Of Plasma Layers In Venustian Ionosphere (poster)
13:05 Lunch

Interior, surface, landing sites
14:00 Philippe Lognonné, Venus Seismic Interior-Atmosphere Coupling: Theory and Orbital Perspectives
14:30 Tamara Gudkova, Interior Structure Models Of Venus (poster)
14:35 Lori Glaze Scientific Rationale For Selecting Landing Sites On Venus: So Many Choices, So Few Opportunities!
15:05 Richard Ernst Venera-D Landing Site Selection Based on Detailed Geological Mapping Using Magellan Radar Images
15:25 Piero D'Incecco. lmdr Regio as the landing site of the Venera-D mission: a geologic perspective (poster)
15:30 Thanasis Economou Venus Surface Elemental and Mineralogical Composition
16:00 Mikhail Ivanov Estimates Of The Frequency Distribution Of Short-Baseline (1-3 m) Slopes For Different Terrains On Venus Using Terrestrial Analogs

16:30 Coffee break
16:45 Allan Treiman Venus’ Radar-Bright Highlands: Different Causes at Low- and High-Latitudes
17:15 Michael Way Modeling Venus through Time and its Implications for the Habitable Zone
17:35 Splinter meeting 1. Atmospheric platforms, priority of scientific goals, experimental capability, VAMP, balloons.
18:35 Discussion of the results of the 2nd day
19:00 Adjourn
7/10/2017

Mission architecture
10:00 Sergey Lemeshevskii “To Venus together”: international project implementation on Venus planet research
10:40 Natan Eismont Venera-D Project: Scenario and Trajectory Design Problems
11:00 Alexandr Kosov Venera D. Radio Link Lander-Orbiter (poster)

Experiments
11:05 V. Mikhalsky, Mikhail Gerasimov A Prototype of the Soil Sampling System for the Venera-D
11:15 Maxim Litvak Active gamma ray spectrometer proposed for future Venus surface ugene
11:25 Coffee Break
11:45 Eugene Maksimov Possible application of Raman Spectroscopy for future space missions
11:50 Vladimir Gromov Radiometer for Thermal Sounding of Low Atmosphere and Sulfur Compound Detection
12:00 Eugene Ustinov. Cloud Internal Field Radiometer (CIFR)
12:10 Leonid Ksanfomality Lightning on Venus – unsolved puzzle
12:20 Discussion of the results of the 2nd day
13:00 Lunch
14:00 Discussion of workshop report
15:00 Splinter meeting 2: GCMs, Dynamics, gravity waves, superrotation, boundary layer, experiments, preferable orbits etc.
16:00 Splinter meeting 3. Architecture, landing sites, orbits, geology, geochemistry, evolution, interior.

18:00 Adjourn
- General Welcome L. Zasova/D. Senske
- 15:10 Opening statements from the Directors L. Zelenyi, J. Green
- 15:20 NASA overview of Venus Activities A. Ocampo
- 15:35 Overview of the charge to the JSDT for Phase 2 D. Senske/L. Zasova
- 15:50 The Venera-D Mission Architecture Team members from the Lavochkin Association
- 16:50 Report on Aerial platform Activities in Support of the JSDT J. Cutts
- 17:10 Venus Modeling Workshops:
  2. Plans and expected outcome from the Moscow Modeling Workshop L. Zasova
- 17:30 Venera-D JSDT path forward D. Senske/L. Zasova
- 17:50 Discussion
- 18:00 Adjourn