Status Report of the Venera-D Joint Science Definition Team

D. Senske[1], L. Zasova[2], A. Burdanov[3], T. Economou[4], N. Eismont[2], M. Gerasimov[2], D. Gorinov[2], J. Hall[1], N. Ignatiev[2], M. Ivanov[5], K. Lea Jessup[6], I. Khatuntsev[7], O. Korablev[2], T. Kremic[8], S. Limaye[9], I. Lomakin[7], A. Martynov[7], A. Ocampo[10], S. Teselkin[7], O. Vaisberg[2], V. Vorontsov[7]

[1]Jet Propulsion Laboratory, California Institute of Technology, [2]Space Research Institute RAS,, [3]TSNIIMASH, [4]Enrico Fermi Institute, University of Chicago, [5]Vernadsky Inst. RAS, [6]Southwest Research Institute, [7]Lavochkin Assoc., [8]Glenn Research Center, [9]Univ. of Wisconsin, [10]NASA Headquarters, Washington, DC

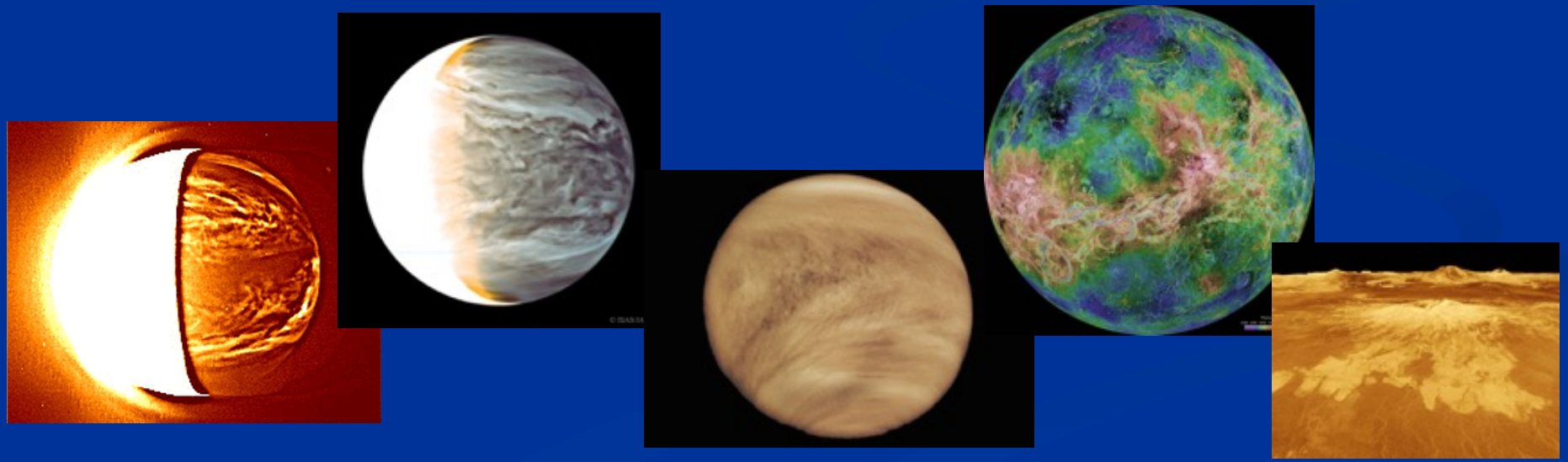
VEXAG
14 November 2017

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

Venera-D Mission Concept Study Phase 2

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.



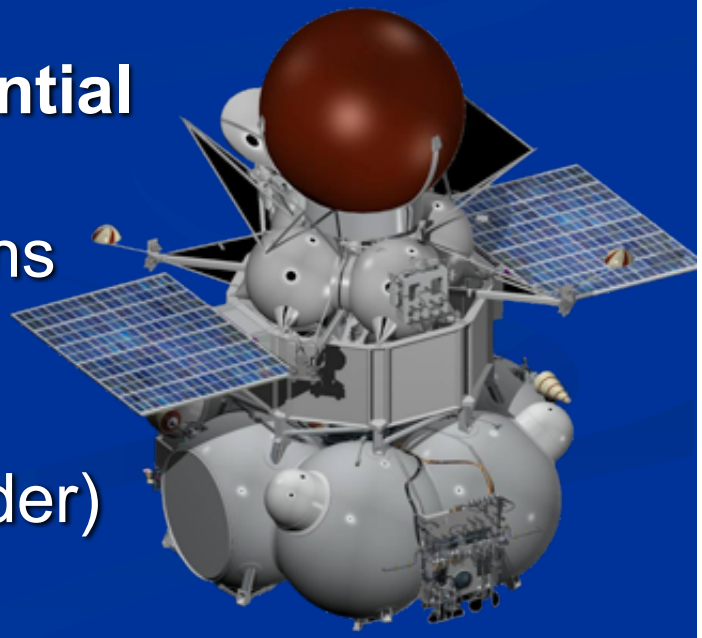
Summary of Venera-D Phase 2 Tasks

Task	Status
MISSION CONCEPT	Assessment ongoing and to continue work in 2018
MISSION OPERATIONS	Assessment ongoing and to continue work in 2018
CONTRIBUTED ELEMENT ACCOMMODATION	Assessment ongoing and to continue work in 2018
RISK ASSESSMENT	To be worked in 2018
MISSION CONCEPT SCIENCE REFINEMENT	Workshop at GRC completed, Moscow Workshop in October 2017
LANDING SITE IDENTIFICATON	Input from Phase 1 study and Moscow Workshop
PAYLOAD REFINEMENT	Assessment ongoing and to continue work in 2018
POTENTIAL CONTRIBUTED ELEMENT(S)	Status reported to the Directors; continued assessment of key development milestones ongoing
FINAL REPORT	Outlining and assignments to be focus of March JSDT meeting

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)



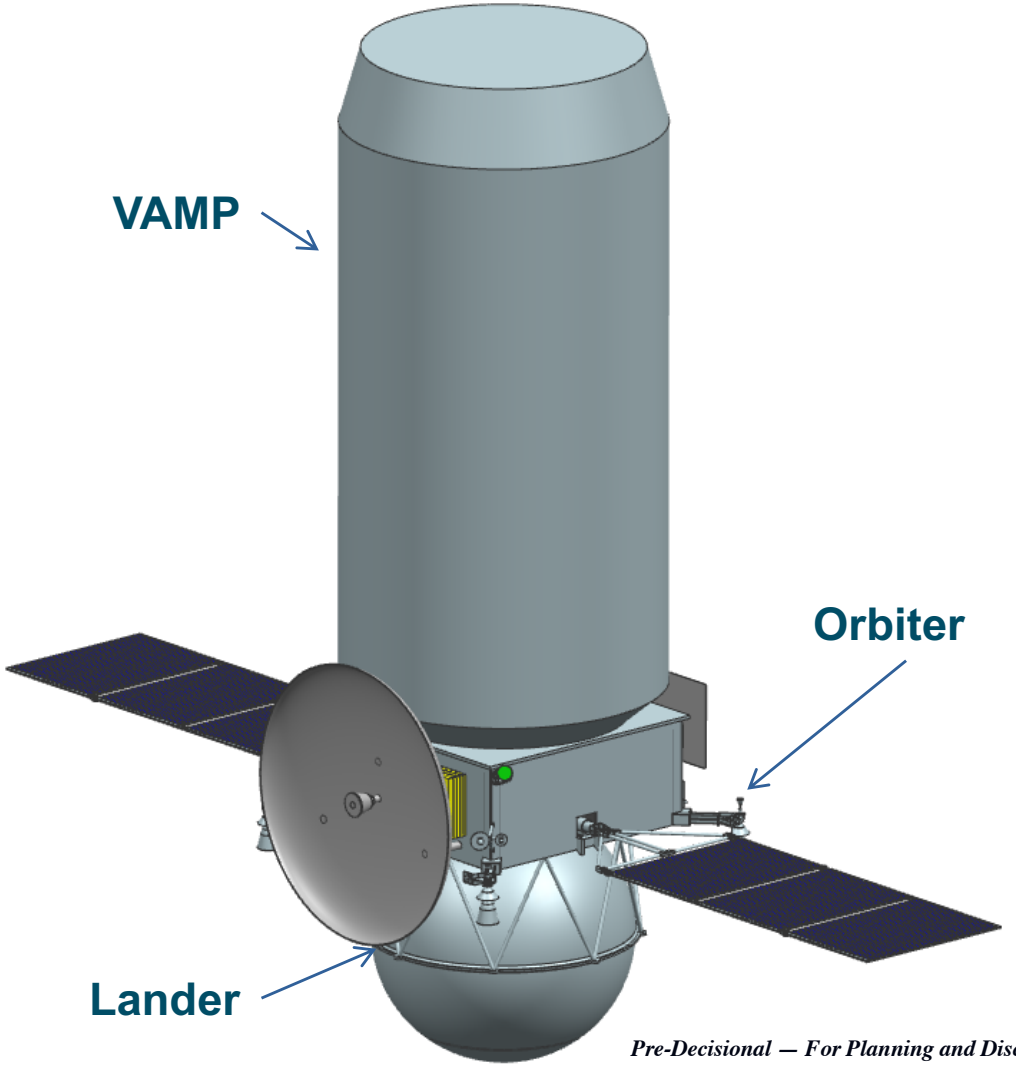
Proposed Architectural Options for Assessment

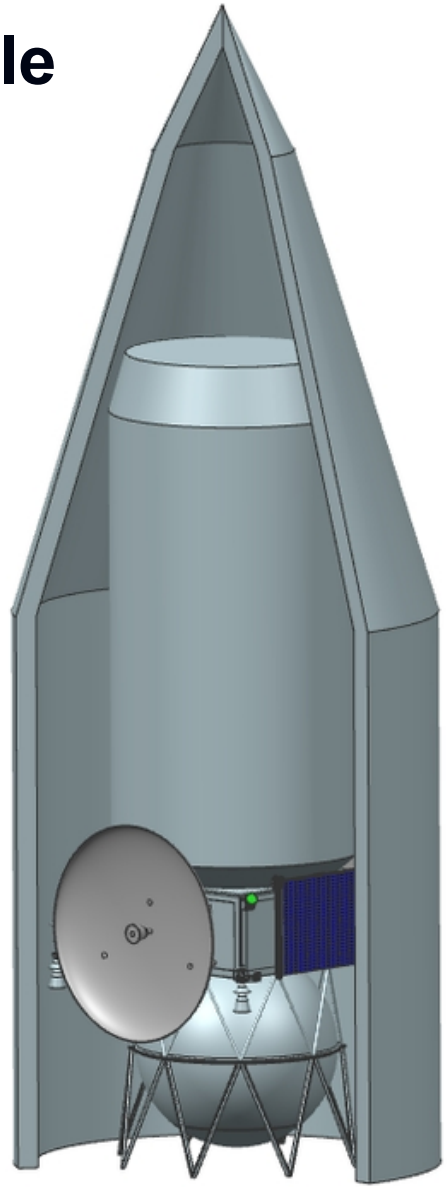
	Maximum Capability Mission	Intermediate Capability Mission	Moderate Capability Mission
Flight Elements	Baseline Orbiter and Lander; Aerial Platform; Small long-lived station	Baseline Orbiter and Lander; Aerial Platform	Baseline Orbiter and Lander
Science Enabled	Comprehensive Atmosphere and Surface Science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

Focus of work in 2017

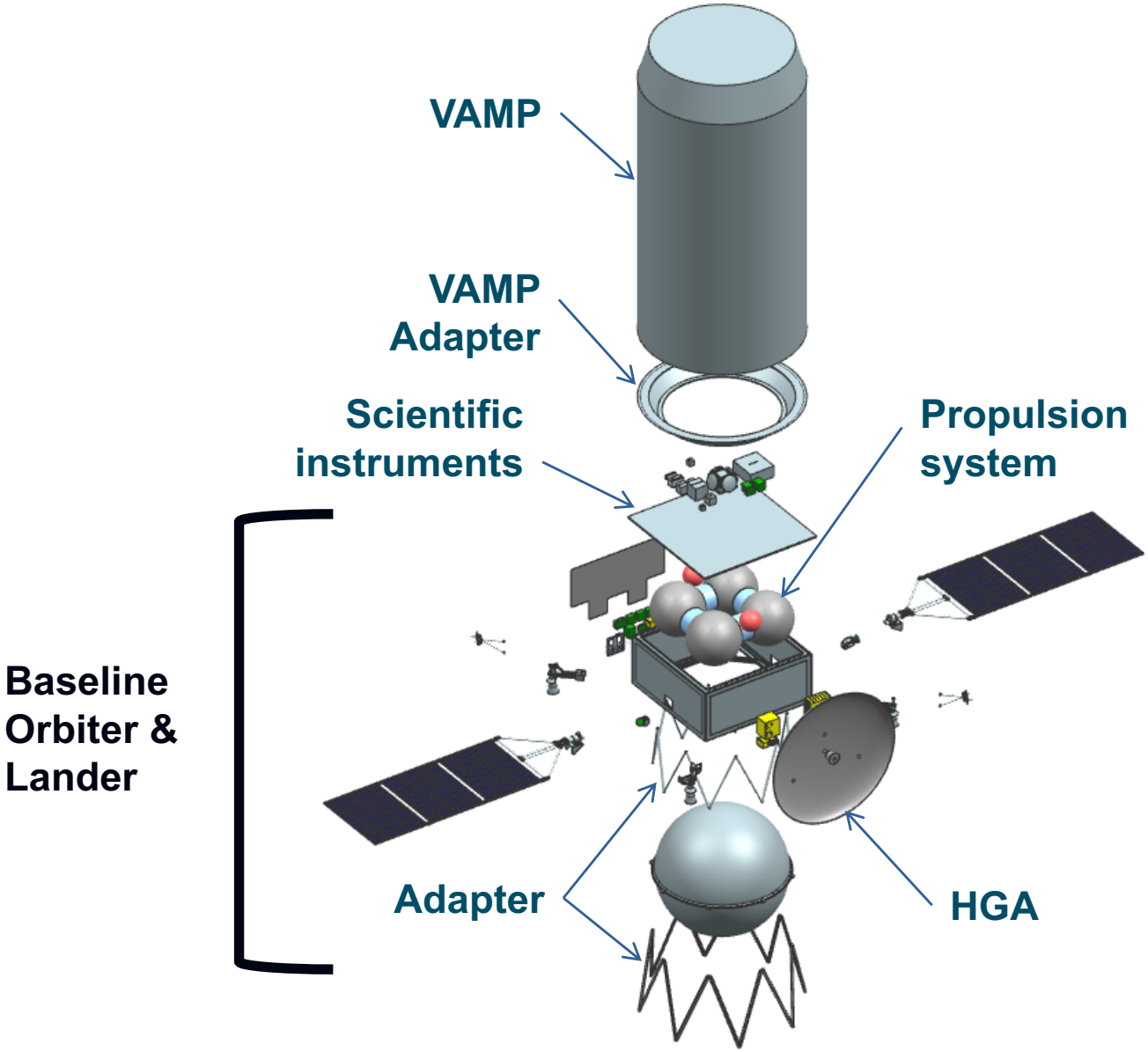
Venera-D Concept Architecture: General Spacecraft Configuration

- Launch on Angara 5 in the 2026 to 2031 time frame
- Accommodation of VAMP aerial vehicle



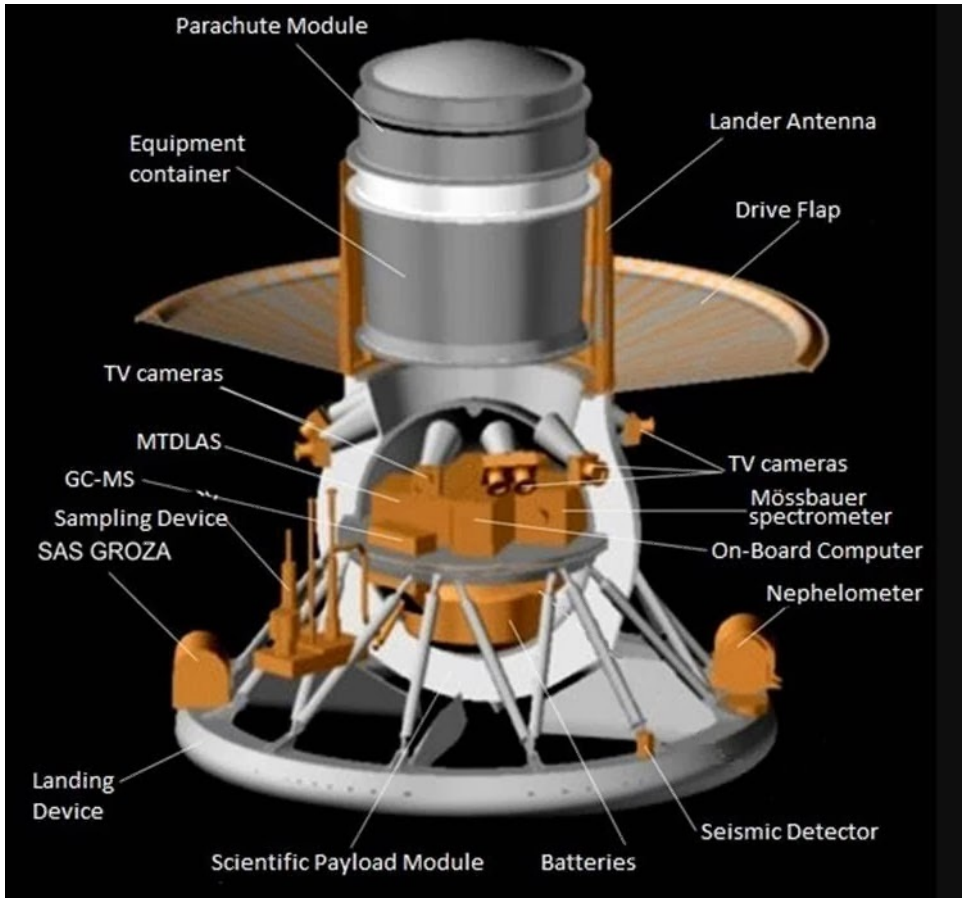


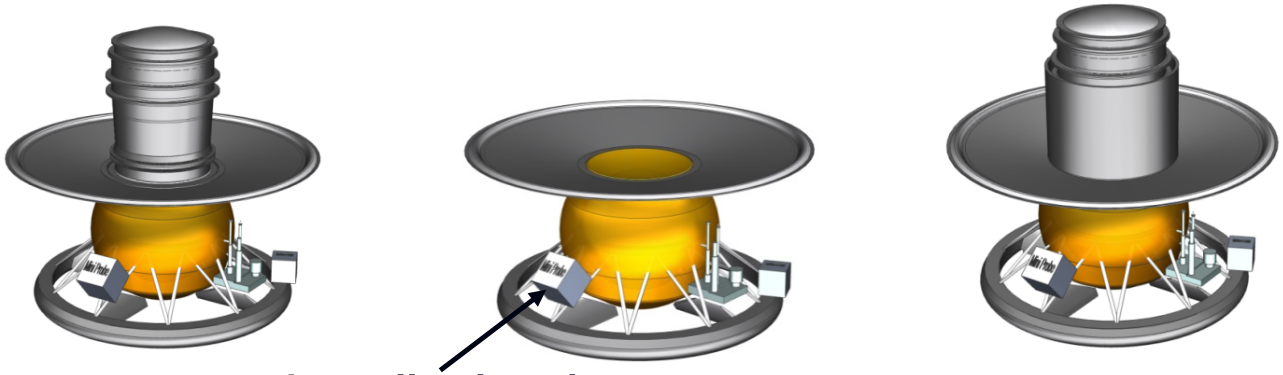
Venera-D Concept Architecture: Spacecraft Configuration



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

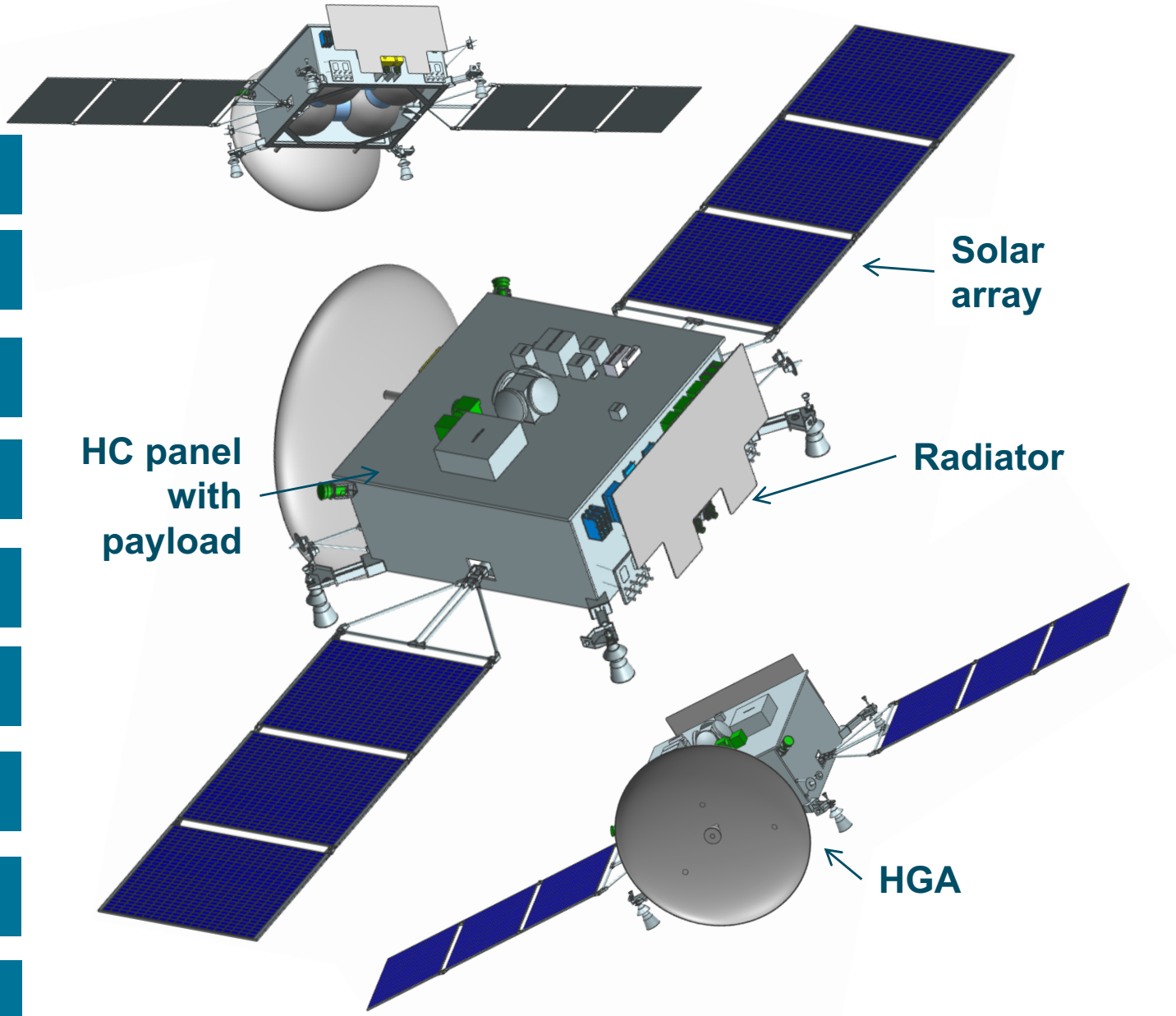




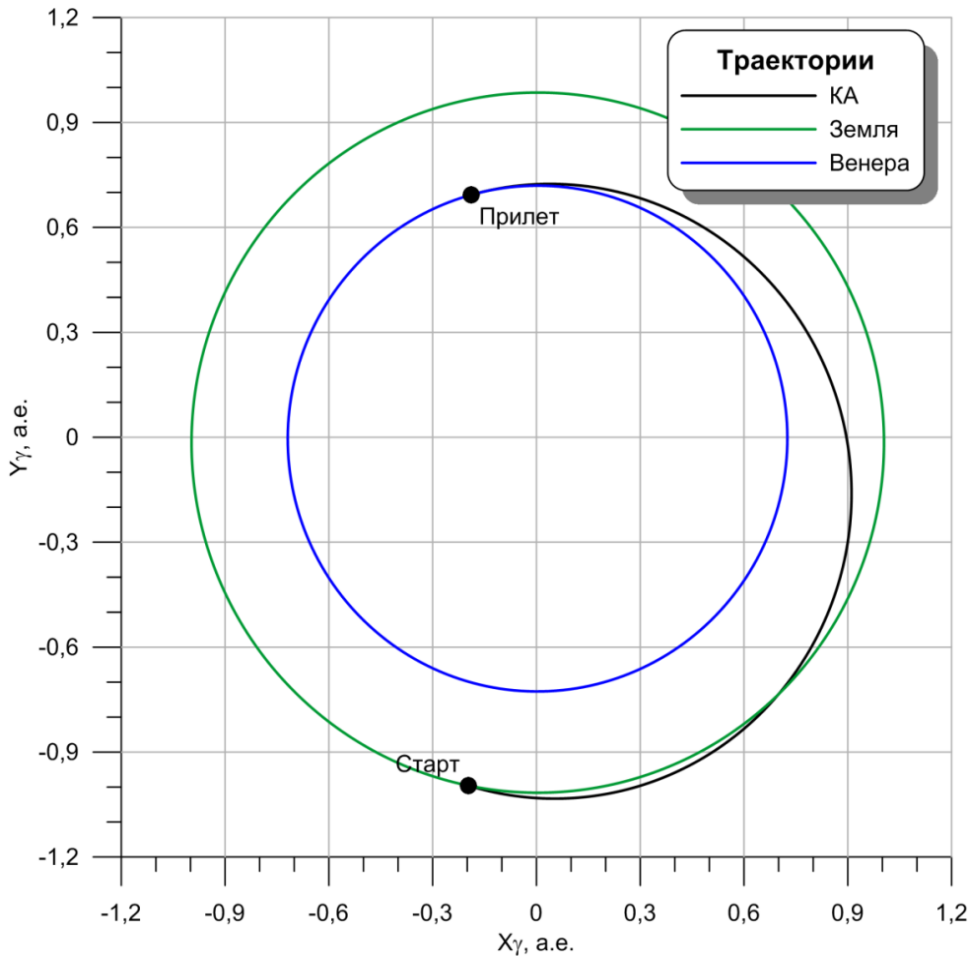
Long-lived station

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



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 durration of 3 years after injection into orbit;**
   - **Lander durration of 3 hours after landing.**

Technical characteristics of the SC

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

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)
  Thomas Navarro (UCLA)
  Allan Treiman (LPI)
  Glyn Collinson (GSFC)
  Amanda Brecht (ARC)
  Lori Glaze (GSFC)
  Kevin McGouldrick (LASP)
  Sara Port (U. of Ark.)

- **Extra thanks to our early career recording secretaries!**

  Dmitry Gorinov (IKI)
  Mikhail Luginin (IKI)
  Evgeniy Guseva (GEOKHI)
  Kevin McGouldrick (LASP)
  Amanda Brecht (ARC)
  Sara Port (U. of Ark.)
  Gly Collinson (GSFC)

- **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

14 to 16 March 2017	JSDT meeting to finalize Phase 2 plan and protocol between IKI and the Lavochkin Association	X
2 October 2017	Briefing to Directors	X
March/April 2018	JSDT meeting (Moscow)—Outline of report and writing assignments	
Summer 2018	JSDT meeting at COSPAR (Pasadena)*	
October 2018	JSDT meeting (Moscow)—Review of draft of report. Briefing to Directors	
January 2019	Deliver Report to Directors	

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

** It is not clear possibility of participation of all russian team memders*

Conclusion

- The JSDT identified priorities for the science goals and objectives and estimated posibility 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 Venusian 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

6/10/2017

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)

10:55Alexander 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 Venusian 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 Venusian 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. Imdr 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*

10:20 Oleg Grafodatskii *"Towards Venus together": The preliminary architecture of "Venus-D" mission on the basis of joint scientific program proposals of Roscosmos-NASA Joint Study Group on Venus researches*

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:
- 1. Report on findings of VEXAG Venus Modeling orkshop . Kremic/K. Lea Jessup
- 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