DEVELOPMENT OF THE VENERA-D SPACECRAFT DESIGN.* A. Kosenkova[1], I. Lomakin[1], A. Martynov[1], P. Pisarenko[1]. [1]*Lavochkin Assoc., Russia.*

Background: Building on the results of the highly successful Soviet Venera and VEGA missions [1], along with the Pioneer, Magellan [2,3], and more recent Venus Express and Akatsuki missions [4,5], a joint NASA-IKI/Roscosmos Science Definition Team (JSDT) was established in 2015. Within the overarching goal of understanding why Venus and the Earth took divergent evolutionary paths, the JSDT has the task of defining the science and architecture of a comprehensive Venera-D (Venera-Dolgozhivuschaya (long-lasting)) mission. The baseline Venera-D concept includes two elements, orbiter and a lander, with payload for distance and contact analysis, including detachable elements such as aerial platforms that can flow in the atmosphere, small long-lived surface stations, small satellite. In January of 2017, the JSDT completed the first phase and generated a report to NASA - IKI/Roscosmos of its findings [6]. The second phase of the JSDT activities is currently underway with a focus on refining the science investigations, undertaking a compressive development of the core orbiter and Lander mission architecture, a detailed examination of contributed elements and aerial platforms that could address key Venus science [7, 8].

Venera-D spacecraft design: Lavochkin Association creating the spacecraft design. This work includes: (1) Development of the general design and configuration for the spacecraft; (2) Accommodation of systems and standalone devices within the spacecraft; (3) Assessment of orbit options along with the strategy for descent and landing and long term observation long-lived stations; (4) Forming the radio communications between Earth, spacecraft, surface stations, satellites. Launch dates between 2026 and 2031 have been evaluated.

References: [1] Sagdeev, R. V., *et. al*. (1986).*Science*. 231**,** 1407-1408. [2] Colin, L., *et al*. (1980), *JGR*, 85, A13, [3] Saunders, R. S. *et al*. (1992) *JGR* , 97, 13067. [4] Svedhem, H. *et al.* (2009), *JGR*, 114, E00B33. [5] Nakamura, M. *et al.* (2011) *Earth, Planets and Space*, 63, 443. [6] Venera-D JSDT, (2017), http://iki.rssi.ru/events/2017/venera_d.pdf [7] Cutts, J. et al. (2017), Planetary Science Vision 2050 Workshop, 1989. [8] Cutts, J. (2017), 15th Meeting of the Venus Exploration Analysis Group (VEXAG), 8015.

Development of the "Venera-D" spacecraft design

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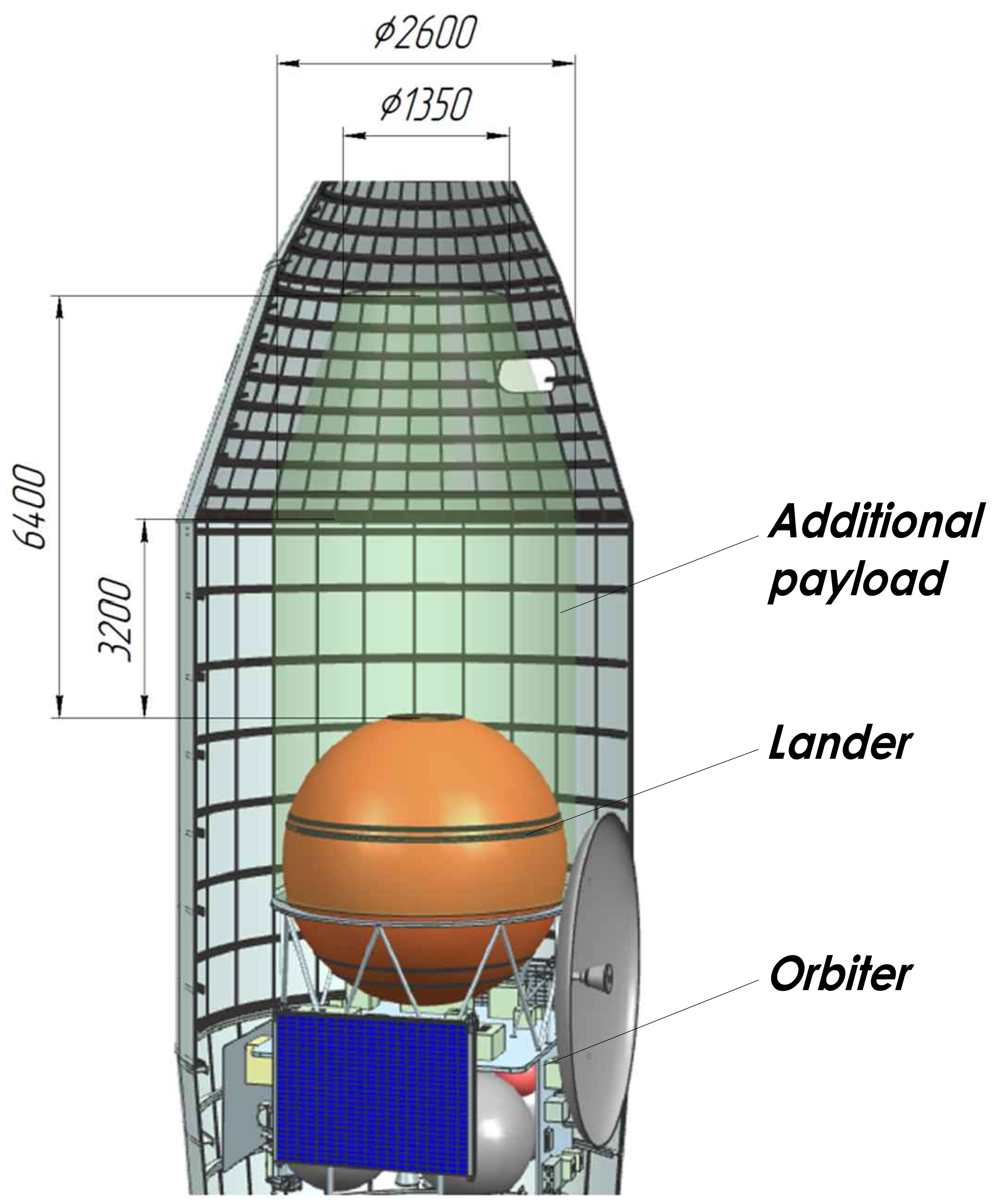
VENERA-D SPACECRAFT (SC) is designed for remote sensing and in situ research of Venus using scientific equipment that can operate in Venus orbit, in the dense atmosphere during descent to the surface and on the surface of Venus

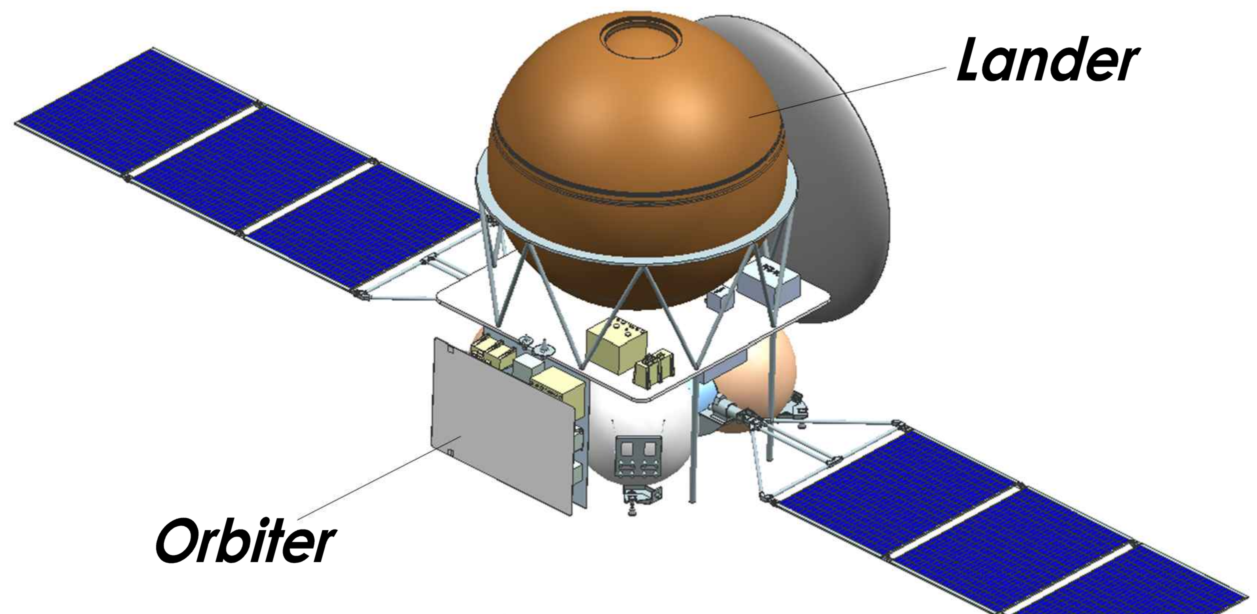
GENERAL VIEW OF THE SPACECRAFT under fairing

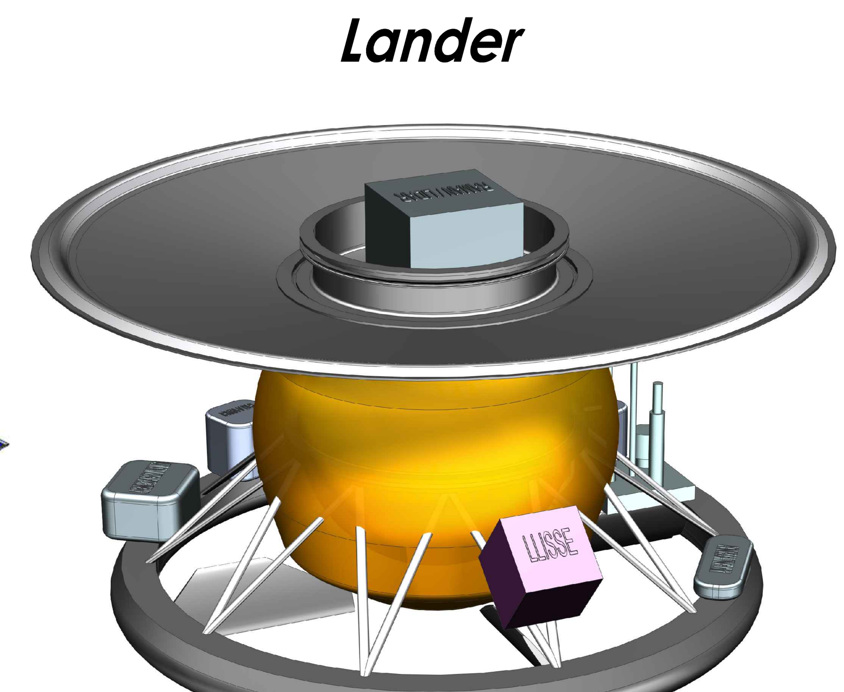
(with the volume available for additional payload beyond the baseline mission)

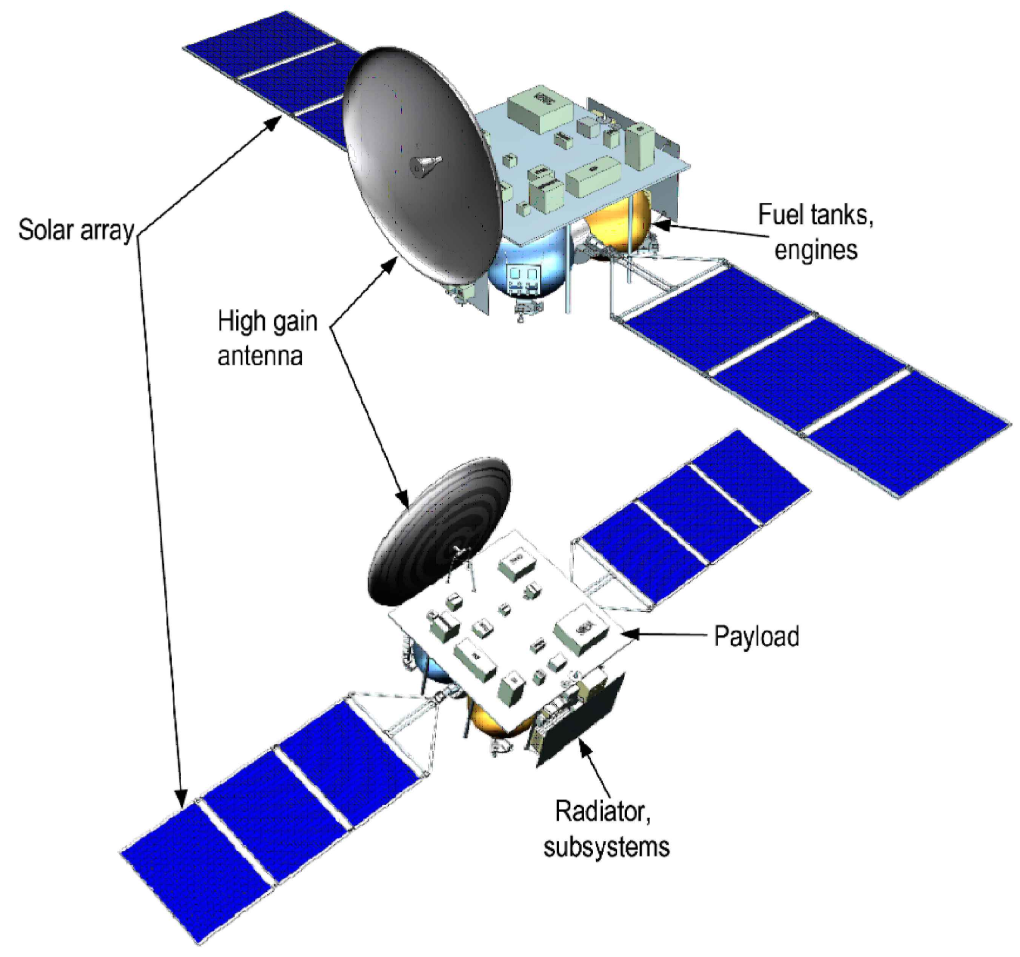


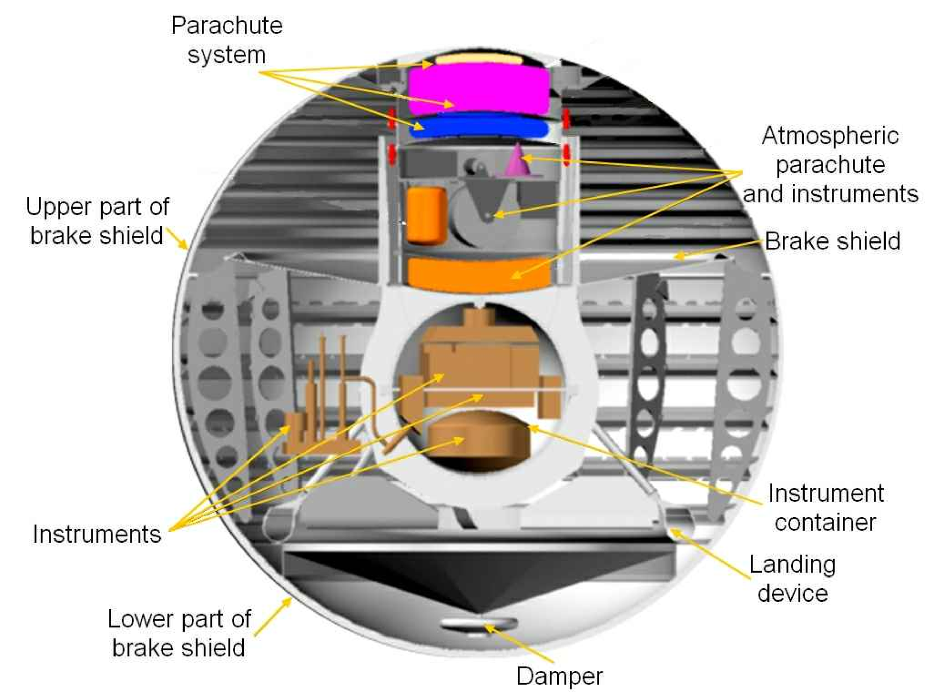
THE BASELINE VENERA-D concept includes

(with the payload for distance and contact analysis, including potential contributions to the baseline architecture – detachable elements such as aerial platforms that can flow in the atmosphere, long-lived in situ solar system explorer LLISSE, small sattelites around Lagrange points L1 and L2)









Mass budgets for 2029 (November 8 or 18)

Worst-Case Scenario shown

Part of the Spacecraft	Mass, kg
1. Orbiter	**4,700**
1.1 Orbiter Dry mass	1,169
1.2 Orbiter Payload (including detachable payload)	1,333
1.3 Fuel	1,851
1.4 Reserve for Orbiter dry mass	347 (30 %)
2. Lander	**1,600**
2.1 Lander Dry mass	521
2.2 Lander detachable system	710
2.3 Lander Payload	120
2.4 Reserve for Lander dry mass (of 2.1+2.2)	249 (20 %)
Total spacecraft mass	**6,300**

Orbiter, designed for:

- *transportation of the SC to Venus ;*
- *functioning in the Venus orbit ;*
- *transmitting information received from all components of the SC to Earth .*

Orbiter : 300-500 × 72,000 km orbit with lifetime ~3 years.

Transmission rate of SC-Earth radio line:
X-band – 256-512 Kbit/s, Ka-band – 16 Mbit/s.

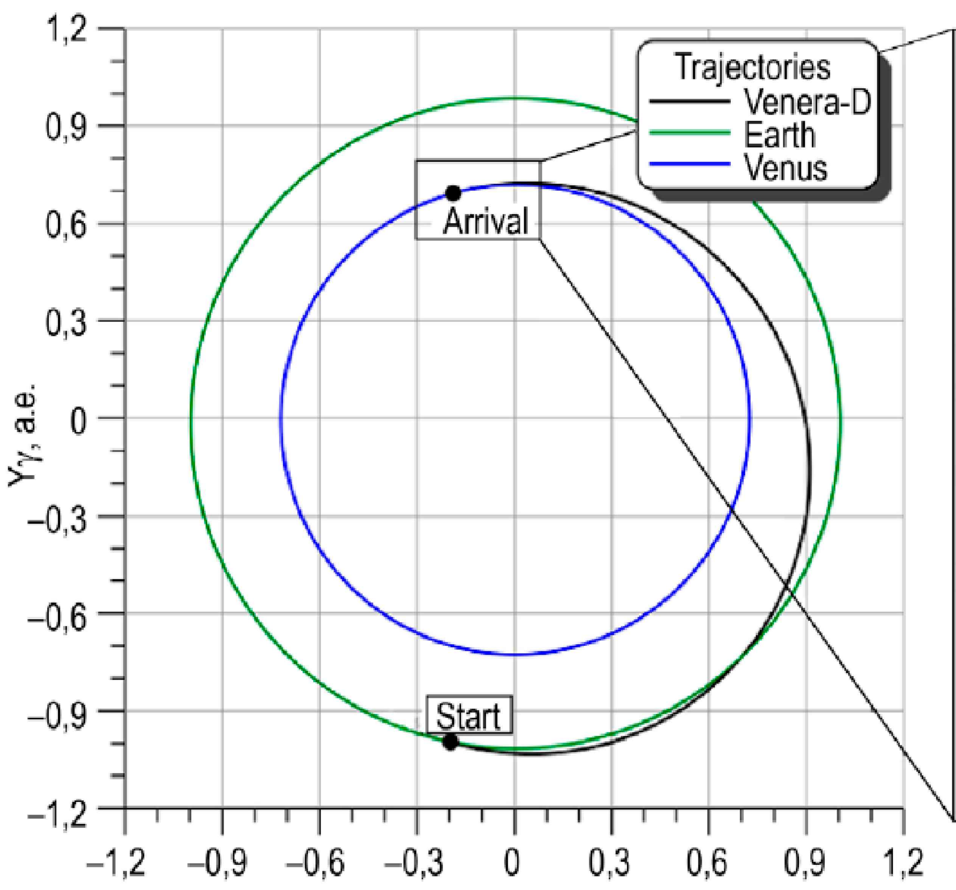
Volume of transmitting science information:
300 MB for the Lander lifetime.

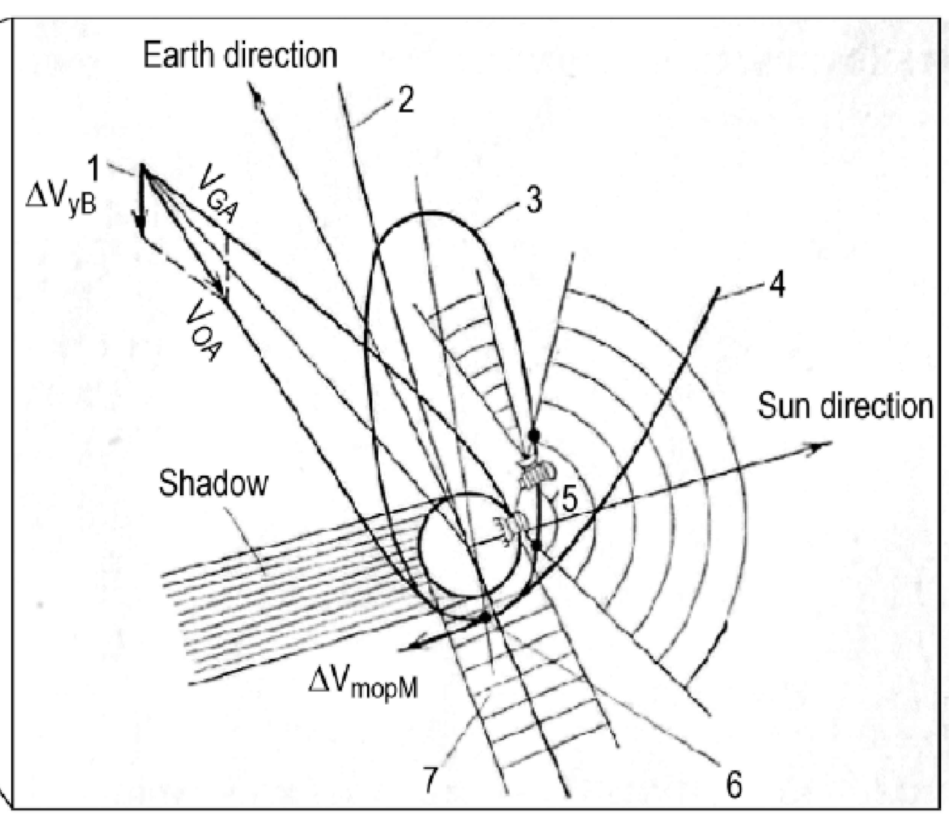
Lander, designed for:

- *landing and functioning on the surface of Venus ;*
- *carring a LLISSE which would continue to operate after the main lander stops ;*
- *transmitting science information to the orbiter.*

Lander : "Vega" type (updated); lifetime ~3 hours.

Launch date	2026, June	2028, January	2029, November	2031, July
Transit mass to Venus (Angara-A5, KVTK), kg	7,000	6,300	6,400	7,000
Transit mass to Venus (Angara-A5, DM-03), kg	6,900	6,200	6,300	6,900

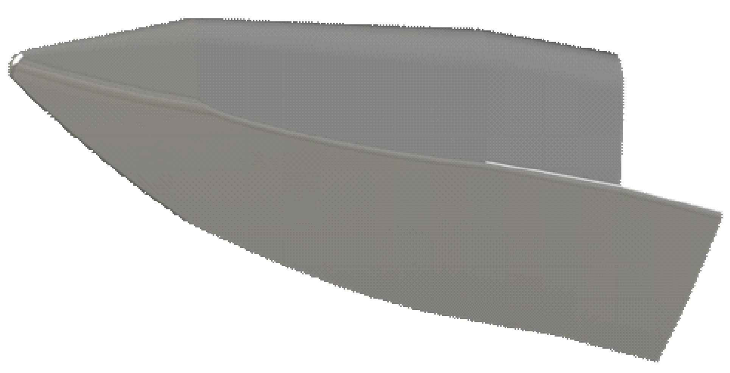


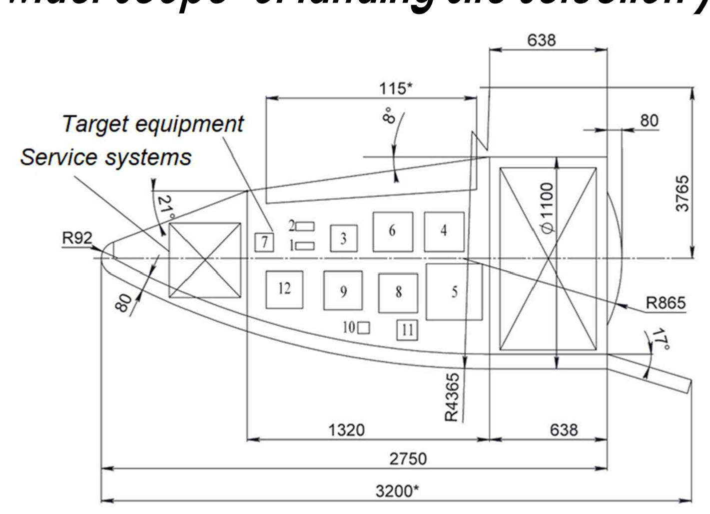


Phase	dV, m/s	Reserve, %	dV with Reserve, m/s	Isp, s	Fuel, kg	Duration, s
1st correction	80	50	120	327	235.7	180
2nd correction, lander separation	20	50	30	302	60.3	304
Braking into Venus orbit, payload separation	1,017	3	1090	327	1,194.7	818
Orientation, stabilization, maneuvers	425	7	455	290	346.3	2,886
Total:	**1,542**	–	**1,653**	–	**1,829**	**4,056**

Maneuverable Entry Vehicle

(able to perform maneuvering and provide a wider scope of landing site selection)





Parameters and evaluation criteria	Parameter	Classification of LM types: I Ballistic	II «Gliding descent»	III «Lifting body»
Aerodynamic quality at hypersonic velocity (M>6)	$K_{hyp} = C_{ya}/C_{xa}$ range, average value	0 0	0.15...0.5 0.3	0.8...1.5 1.0
Range of aerodynamic quality change during transition from hypersonic to subsonic descent mode	K_{subs} $\overline{K} = K_{subs} / K_{hyp}$	0 1	0...0.5 1.5	2...3.5 2.5
Comparative mass characteristics	$K_m = G_{lander} / G_{lander\text{-}ballist}$	1	1.2	1.5
Volume efficiency (fill factor)	$K_{ff} = 4.836 \cdot \frac{V_\Sigma^{2/3}}{S_\Sigma}$	1...0.85	0.95...0.75	0.75...0.6
Relative mass of thermal protection	$\overline{K}_{tp} = G_{tp} / G_{lander}$	0.15...0.28	0.12...0.25	0.12...0,2
Overload	n	120…130	100…110	<85
Lateral maneuver in atmosphere, km	L_{lat}	0	80...100	1000...2000