

2. VEHICLE DESCRIPTION

Overview Land Launch uses either two or three in-line, liquid oxygen (LOX) and kerosene stages. The three-stage Zenit-3SLB configuration (Figure 2-1) is used for medium-lift missions to medium and high, circular or elliptical orbits including GTO and GEO, as well as escape trajectories. The two-stage Zenit-2SLB configuration (Figure 2-2) is used for missions to low earth circular and elliptical orbits. Each configuration uses a different fairing. All elements of either configuration have extensive flight heritage.

The principal components of the Land Launch vehicles are:

- Zenit Stage 1
- Zenit Stage 2
- Block DM-SLB upper stage (Zenit-3SLB configuration)
- Fairing and Payload Support Structure

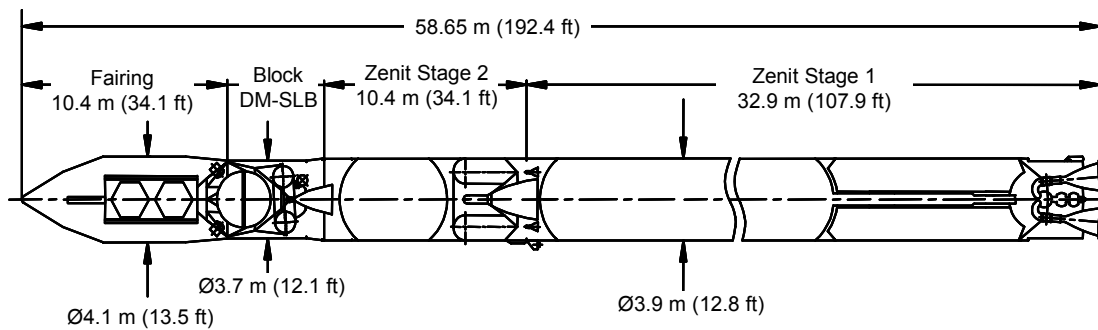


Figure 2-1. The Zenit-3SLB

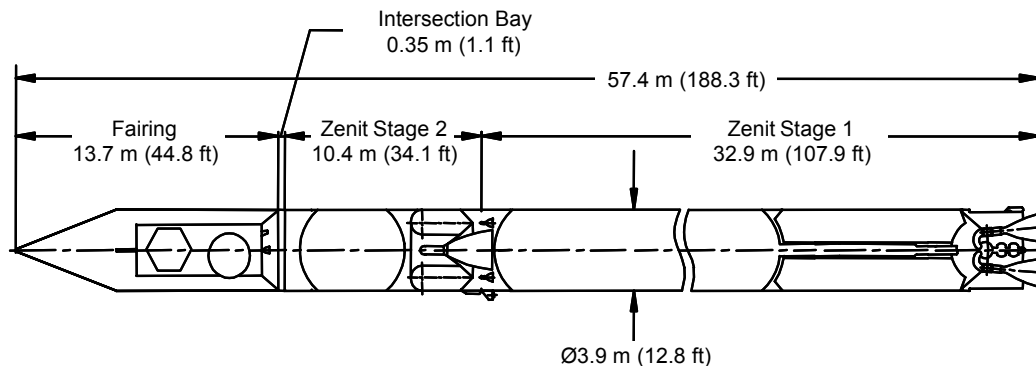


Figure 2-2. The Zenit-2SLB

Design

The Zenit first and second stages used on Land Launch are interchangeable with the Sea Launch first and second stages. They are manufactured by PO Yuzhmash in Ukraine, with design oversight provided by SDO Yuzhnoye. The Block DM-SLB third stage, used only on the Zenit-3SLB, is closely adapted from the Block DM-SL used by the Sea Launch program (the differences are described in section 2.2) and is manufactured by RSC Energia in Russia.

The fairing for the Zenit-3SLB is 4.1 meters in diameter and is manufactured by NPO Lavochkin in Russia. It was designed specifically for the Block DM and has an unblemished flight history dating to 1996. The Zenit-2SLB fairing is 3.9 meters in diameter and is manufactured by PO Yuzhmash. It was designed specifically for the two-stage Zenit configuration and has a flight history dating to 1985.

The payload support structure for the Zenit-3SLB is provided by RSC Energia. It consists of a spacecraft adapter (SCA) typically procured from Saab Ericsson Space (937, 1194 or 1666 interfaces) and a transfer compartment manufactured by Energia. The payload support structure for the Zenit-2SLB is provided by SDO Yuzhnoye and will typically consist of a Saab SCA mounted on a truss manufactured by PO Yuzhmash. Unique interfaces and multi-satellite dispensers can also be provided if required.

**Zenit
Flight History**

The original Zenit-2 was first launched in 1985 from Baikonur Cosmodrome. As of March 2004, it has completed 30 successful missions in 35 launch attempts. The Zenit first-stage booster also served as the strap-on for the Energia launch vehicle (four per launch) and logged an additional eight successes in two flights in this capacity. The modified and improved Zenit-2S, the version used on Sea Launch, has flown twelve times as of February 2004. Land Launch also uses the Zenit-2S.

**Block DM
Flight History**

From its introduction in 1974 through March 2004 the Block DM has completed 222 successful missions in 228 attempts in various versions, including eleven successes in eleven attempts for the Block DM-SL version used on Sea Launch, making it far and away the most proven, reliable and mature upper stage in the launch industry. Past missions have included GTO and direct insertion GEO for commercial and for government customers, high elliptical orbits, low and high circular orbits, dedicated launches and launches of multiple satellites, and escape trajectories (to Halley's Comet, Venus and Mars).

Flight Success Ratios

Tables 2-1 and 2-2 list flight records for each of the three Zenit-3SL stages as of March 2004, as well as engineering reliability estimates. The closely-related Zenit-3SLB stages are expected to achieve identical reliability levels.

The engineering reliability estimates account for:

- Extensive testing performed when modifications are made to flight hardware or ground support equipment
- Expected reliability growth, using statistics of other boosters using similar processes and procedures that were also built and launched in the former USSR
- An exhaustive failure analysis team that investigates any flight anomalies and implements measures to ensure that the anomalies never recur
- The Sea Launch mission assurance and audit process currently in place and operating at the factory level in Ukraine and Russia

Table 2-1. Sea Launch Stages, Cumulative Flight History, All Related Configurations

Stage	Year Introduced	Versions Flown	Cumulative Flight Record
Zenit Stage 1	1985	3	53 of 55
Zenit Stage 2	1985	2	41 of 44
Block DM	1974	9	222 of 228

Table 2-2. Reliability and Flight History, Sea Launch Configuration Only

Stage	Year Introduced	Flight Record	Reliability Estimate
Zenit Stage 1	1999	12 of 12	} 98.0%
Zenit Stage 2*	1999	11 of 11	
Block DM-SL	1999	11 of 11	98.5%
* The one Sea Launch failure (mission 3) occurred during second stage operation, but was not caused by the second stage and no design changes to the second stage resulted from the failure investigation. The failure cause was a fault in ground software that left open a second stage valve.			

2.1. The Land Launch Zenit

Design Heritage Land Launch uses the Sea Launch configuration of the Zenit, retaining the improvements and modifications that were made for Sea Launch to the heritage Zenit-2. SDO Yuzhnoye designed the original two-stage Zenit-2 during the late 1970s and early 1980s in response to requirements from the Soviet Ministry of Defense for a launch system that would be able to quickly and efficiently reconstitute military satellite constellations. Consequently, the design emphasizes robustness, ease of operation and fast reaction times, which are achieved through extensive automation. It incorporates state-of-the-art launch and processing technologies, developed by Land Launch partner KBTM, in contrast to systems developed during previous decades. A second intended use for the original Zenit-2 was manned launches to space station MIR (figure 2-3). Though ultimately it was never used for this purpose due to the break-up of the Soviet Union, in order to be man-rated, the Zenit was designed with a significant degree of internal redundancy and other features to ensure high reliability.



Figure 2-3. Cosmonaut Access Tower at the Zenit Launch Complex

Changes Made for Sea Launch

Significant configuration differences between the heritage Zenit-2 and the Sea Launch Zenit-2S, which are also retained on the Land Launch Zenit-2SLB, are:

- New navigation system
- Next generation flight computer
- Increased performance due to mass reductions and an increase in second stage main engine thrust from 87 tonnes force to 93 tonnes force

Avionics

Just as on Sea Launch, the Land Launch Zenit contains its own complete complement of avionics for telemetry, guidance and navigation functions even when lifting an upper stage in a three-stage configuration. The on-board Sirius telemetry packages transmit telemetry data on separate RF links to existing ground stations located in Russia and, for sun-synchronous missions, to a remote ground station located on the Arabian Peninsula. For three-stage missions, these Zenit links are complemented by an independent set of data that is provided simultaneously by the Block DM-SLB telemetry system.

Overall Specifications and Configurations

Zenit specifications and performance parameters are shown in Table 2-3. Stage 1 and Stage 2 configurations are pictured in Figure 2-4. With propellant mass fractions exceeding 90%, the designs of both stages rank among the most structurally efficient in the world. In the case of the first stage, this is due in large part to the highly efficient RD-171M engine and the lack of strap-on boosters.

The absence of strap-on boosters greatly simplifies pre-launch processing and is a major feature distinguishing Zenit from most other large launch systems. Without strap-ons, the stage structure is more efficient, ordnance count is reduced and overall reliability is enhanced by eliminating exposure to the failure of booster separation mechanisms or of the boosters themselves. Furthermore, the streamlined configuration lends itself to robust control margins during all phases of flight which enable the Zenit to fly through a broad range of wind and weather conditions, further ensuring on-time and on-target launch performance.

Table 2-3. Land Launch Zenit Specifications

Zenit	Stage 1	Stage 2	
	Zenit-2SLB and -3SLB	Zenit-2SLB	Zenit-3SLB
Burn Time	140 - 150 s	300 - 1,100 s	360 - 370 s
Inert Mass	27,564 kg (60,768 lb)	8,367 kg (18,446 lb)	8,307 kg (18,314 lb)
Fueled Mass	354,350 kg (781,200 lb)	90,854 kg (200,297 lb)	90,794 kg (200,164 lb)
Fuel (kerosene)	90,219 kg (198,897 lb)	23,056 kg (50,829lb)	
Oxidizer (LOX)	236,567 kg (521,536 lb)	59,431 kg (131,022 lb)	
Length	32.9 m (108 ft)	10.4 m (34 ft)	
Diameter	3.9 m (12.8 ft)	3.9 m (12.8 ft)	
Engines	One RD-171 (four thrust chambers)	One RD-120 Main Engine One RD-8 Vernier Engine (four thrust chambers)	
Thrust (sea level)	740,000 kgf (1.63 million lbf)	Not applicable	
Thrust (vacuum)	806,400 kgf (1.78 million lbf)	Main Engine: 93,000 kgf (205,028 lbf) Vernier Engine: 8,100 kgf (17,857 lbf)	
Specific impulse (sea level)	309.5 s	Not applicable	
Specific impulse (vacuum)	337.2 s	Main Engine 350 s Vernier Engine 342.8 s	
Attitude Control	Nozzle gimbal \pm 6.3 deg	Vernier engine nozzle gimbal \pm 33 degrees	

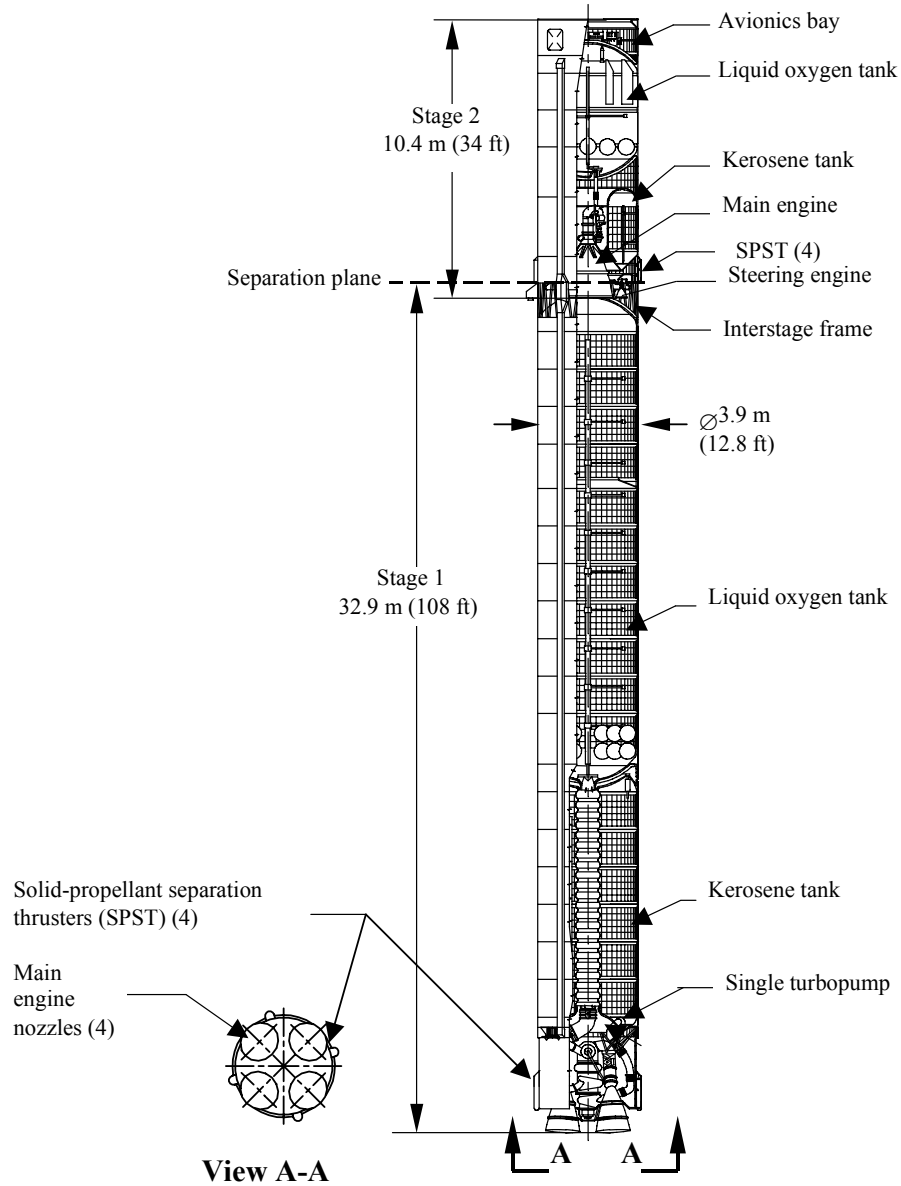


Figure 2-4. Land Launch Uses the Same Zenit Stages that are Used on the Sea Launch Zenit-3SL

2.1.1 Zenit Stage 1

Overall Configuration

The Land Launch Zenit Stage 1 (Figure 2-5) features an aluminum primary structure with integrally machined stiffeners, and environmentally-friendly LOX/kerosene propellants. The upper LOX tank fits in a concave depression at the top of the kerosene tank, and the LOX feed line runs through the middle of the lower tank. With a Zenit-2SLB gross lift-off mass of 450,000 – 460,000 kg, and a Zenit-3SLB gross lift-off mass of 462,000 – 466,000 kg, the 740,000 kgf produced by the first stage yields a very healthy ~1.6 take-off thrust-to-weight ratio for both vehicles. Separation is achieved with four solid retro-rockets located at the base of the stage.

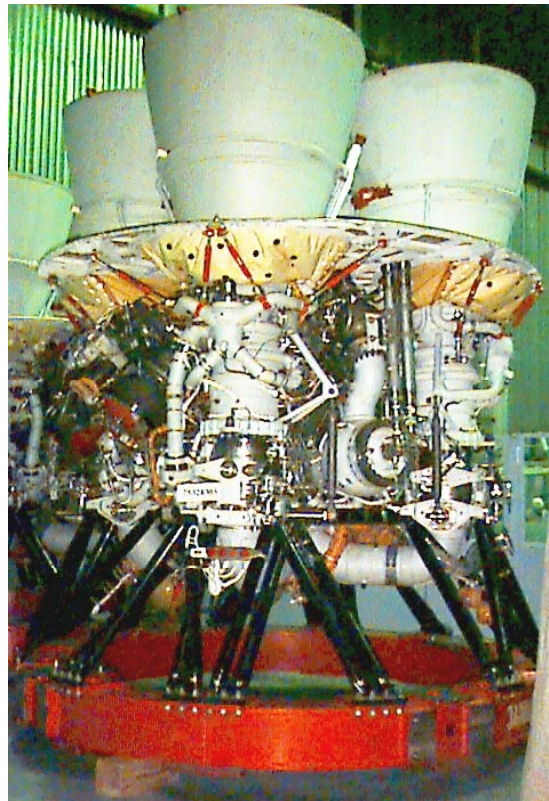
The Land Launch Zenit first stage design is intentionally kept common to that of the Sea Launch stage. Both are manufactured on the same production line at PO Yuzhmash.



Figure 2-5. PO Yuzhmash Achieves Significant Economies of Scale by Manufacturing Both Land Launch and Sea Launch Zenit Stages on the Same Production Line

RD-171M Engine

The RD-171M engine (Figure 2-6), which powers Zenit Stage 1, burns liquid oxygen (LOX) and kerosene. It provides an impressive 740,000 kgf (1.6 million lbf) of thrust at sea level and is one of the most powerful rocket engines in the world, featuring advanced rocket engine technologies developed by leading Russian propulsion organizations. It was developed specifically for the Zenit, in parallel with the closely related RD-170 that served as the strap-on booster for the Energia/Buran. An exhaustive test program consuming more than 200 test engines preceded first flight in the mid 1980's. The four thrust chambers are fed by a single, vertically mounted turbopump, which in turn is powered by two gas generators feeding hot oxidizer-rich gas to a single turbine. Flight control is achieved by gimbaling the independently suspended combustion chambers, while the ability to throttle down to ~ 74 % of nominal full-engine thrust provides great flexibility in trajectory design.



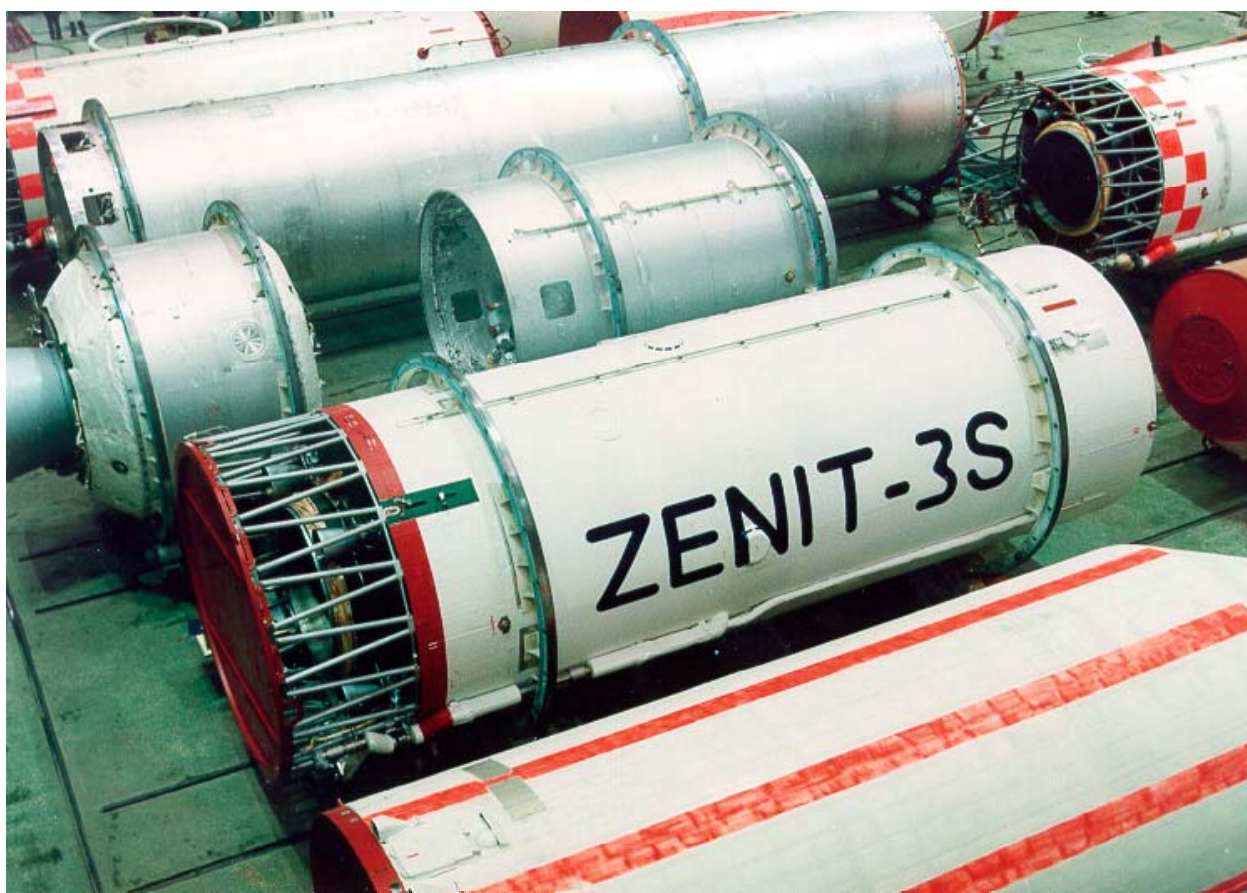
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Figure 2-6. The RD-171M is the Most Powerful Liquid Rocket Engine Presently in Operation

2.1.2 Zenit Stage 2

Overall Configuration

Like the first stage, the Zenit second stage (Figure 2-7) features an integrally stiffened aluminum construction and environmentally-friendly LOX/kerosene propellants. Propulsion is provided by an RD-120 main engine with steering provided by an RD-8 vernier engine fed from the same propellant tanks. The lower kerosene tank is toroidally shaped and surrounds the main engine, while the upper LOX tank is a domed cylinder. The stage is topped by an instrument compartment containing the avionics. The Sea Launch and Land Launch Zenit second stages, like the first stages, are manufactured on a common Yuzhmash production line, thereby benefiting from common inventory and Boeing quality oversight processes. The second stage generates 101,000 kg (222,887 lbs) of thrust (RD-120 and RD-8 engines combined). As on the first stage, separation is achieved with four aft-mounted solid retrorockets.



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Figure 2-7. The Second Stage's Toroidally-Shaped Fuel Tank Results in a Shorter, More Efficient Vehicle Structure

**RD-120
Main Engine**

The 2nd stage main engine is a single-chamber, fixed nozzle liquid-propellant rocket engine that uses LOX and kerosene to generate 93,000 kg_f (205,028 lbf) of thrust. The RD-120 is throttled down to ~ 78% of nominal full-engine thrust at the end of flight. The RD-120 was developed specifically for the Zenit launch system.

**RD-8
Vernier Engine**

The RD-8 vernier engine mounted in the aft end of Stage 2 provides three-axis attitude control. The RD-8 uses the same propellants and propellant storage system as the RD-120, with one turbo-pump feeding four gimbaling thrusters spaced around the outside of the RD-120. The RD-8 produces 8,100 kg_f (17,900 lbf) of thrust, and was specifically developed for Zenit. The ability to modulate its operation from 65 to 900 seconds following main engine cut-off provides flexibility in mission design for Zenit-2SLB launches to a wide range of circular LEO orbits.

2.2 The Block DM-SLB Upper Stage

Overall Configuration	<p>The Block DM-SLB (Figure 2-8) used on the Zenit-3SLB is closely derived from the Block DM-SL used on Sea Launch. It is a LOX/kerosene upper stage capable of igniting up to three times during a mission. Basic specifications are provided in Table 2-4.</p> <p>The basic structure of the Block DM-SLB is provided by the upper adapter together with an internal truss. The middle and lower adapters that enclose the stage are jettisoned before first ignition of the Block DM-SLB. Kerosene is contained in a toroidal tank connected by a truss to the upper adapter which encircles the turbopump of the 11D58M main engine. The spherical LOX tank and the avionics/payload truss are located above the kerosene tank, and also connect to the upper adapter. Two attitude control/ullage engines, which provide stabilization during coast periods, are located on the bottom of the kerosene tank.</p>
11D58M Main Engine	<p>The Block DM-SLB upper stage is powered by the 11D58M engine, which operates on liquid oxygen and kerosene. Its carbon-carbon nozzle is gimballed to provide pitch and yaw control during powered flight, with turbopump bleed gas used for roll control.</p>
Attitude Control/Ullage Engines	<p>Three-axis stabilization and attitude control during coast periods, including continuous rolls, are provided by two attitude control/ullage engines using hypergolic propellants that are located on the aft end of the main engine kerosene tank, on either side of the main engine nozzle.</p>
Avionics	<p>The Land Launch Block DM-SLB uses the same avionics as the Sea Launch Block DM-SL, with the exception of differences in the telemetry system more suitable for launches from Baikonur using associated fixed and mobile Russian ground receiving stations.</p>
Changes Made for Sea Launch	<p>Significant configuration differences between the heritage Block DM and the Sea Launch Block DM-SL, which are also retained on the Land Launch Block DM-SLB, are:</p> <ul style="list-style-type: none"> • New navigation system • Next generation flight computer • The autonomous control system provided by the R&D and Production Center for Automation and Instruments Manufacturing (NPT's AP) – the premier Russian avionics and space software company • An extended nozzle and various mass reductions for performance improvement

**Block DM-SLB
Versus the
Block DM-SL**

The main differences between the Block DM-SLB and the Block DM-SL are:

- The Block DM-SLB forward structural interfaces are made to be compatible with the Russian-made fairing and payload structure that are used on Land Launch, while the Block DM-SL forward interfaces are compatible with the Boeing-made payload unit hardware that is used on Sea Launch
- The single, large (and heavy) toroidal avionics bay on the Block DM-SL is replaced on the Block DM-SLB with several discrete avionics containers for a net reduction in launch mass
- Some sensors and harnesses are removed that are a legacy of early qualification flights and are no longer needed
- A deployable antenna and telemetry system are replaced with a lighter system also used on Zenit that features fixed antennas with two independent radio links
- An uplink command system and its antenna are removed
- One set of fuel tanks for the attitude control/ullage engines are removed. Previously, these tanks were routinely under-filled by the equivalent of one set of tanks.
- The LOX tank is pressurized with helium instead of an oxygen/helium mixture
- The minimum useable propellant criterion for the final re-start is lowered from 4000-kg to 1500-kg, by adding two 10-kgf thrusters to ensure settling prior to ignition
- An external heat radiator is removed with this function being assumed by the upper adapter structure

Table 2-4. Block DM-SLB Specifications

Length ¹	5.93 m (19.4 ft)
Diameter (primary)	3.7 m (12.1 ft)
Maximum Launch Mass ^{2, 3} (fueled)	17,800 kg (39,240 lb)
Maximum ³ Useable Propellant Reserve	14,580 kg (32,140 lb)
Thrust (vacuum)	8,103 kgf (17,864 lbf)
Note 1:	The fairing overlays 1.03 m (3.4 ft) of the length of the Block DM-SLB, as shown in Figure 2-8
Note 2:	Includes the lower and middle adapters, which are jettisoned prior to first burn of the Block DM-SLB
Note 3:	Fuel is off-loaded for heavier payloads launching east (includes GTO missions), due to drop zone constraints

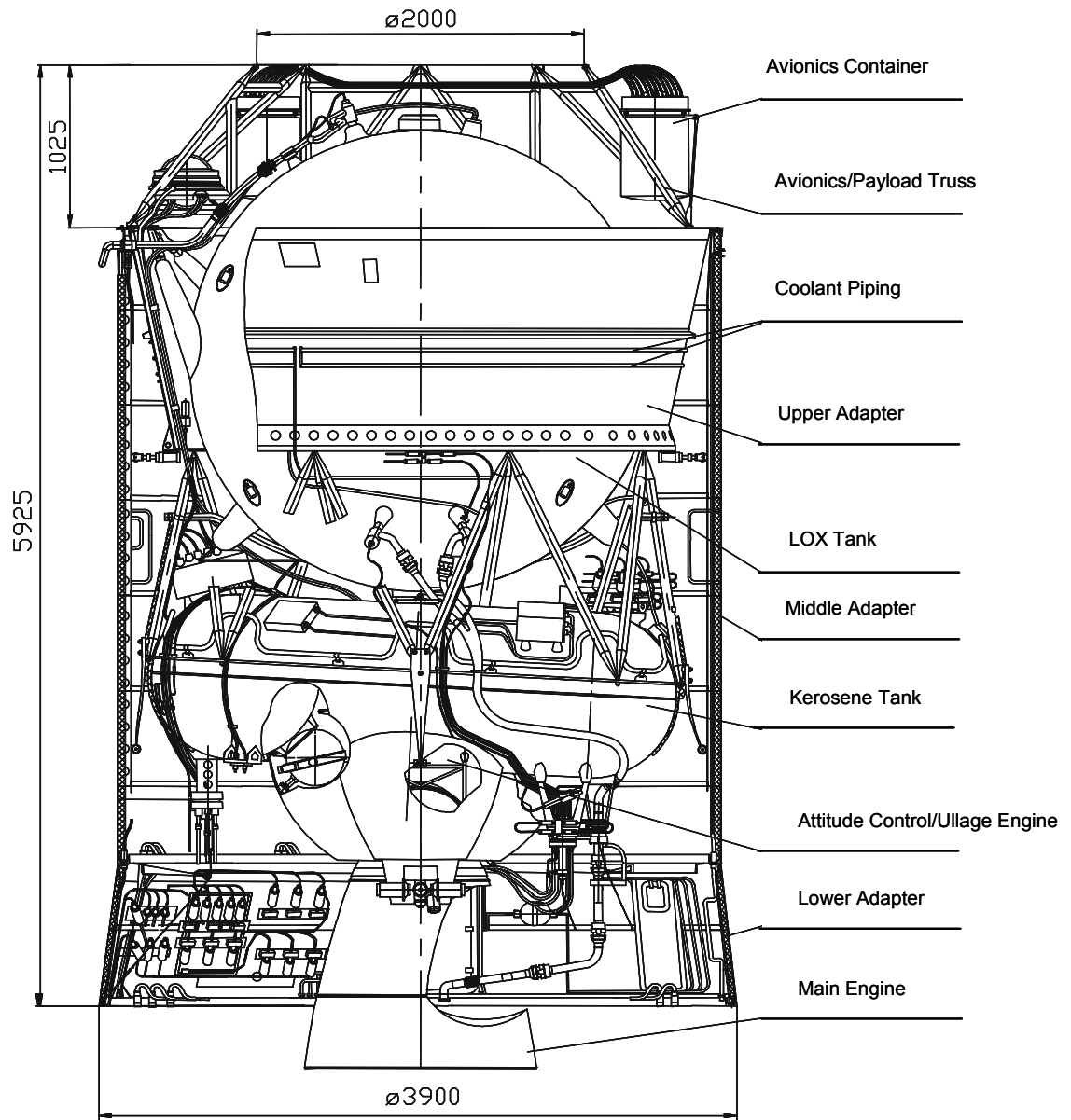


Figure 2-8. Block DM-SLB (dimensions in millimeters)

2.3 Zenit-3SLB Ascent Unit

Components and Integration

The Zenit-3SLB Ascent Unit (figure 2-9) consists of the spacecraft, Block DM-SLB, fairing and payload support structure (PSS). These elements are integrated in a Class 100,000 clean environment during ground processing. The PSS is comprised of an industry-standard spacecraft adapter typically procured from Saab Ericsson Space and a transfer compartment provided by RSC Energia.

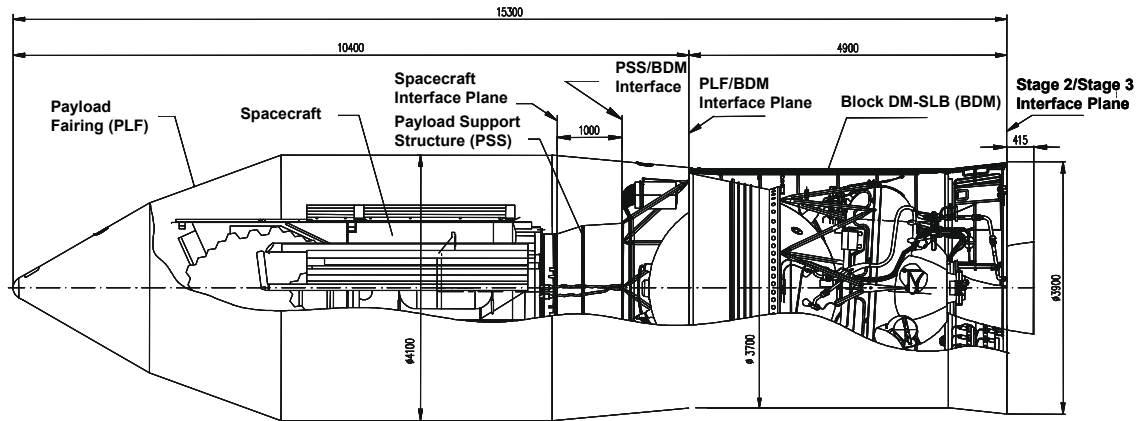


Figure 2-9 Zenit-3SLB Ascent Unit
(dimensions in millimeters)

Payload Fairing

The payload fairing (PLF) provides environmental protection for the spacecraft from encapsulation in the payload processing facility through launch and ascent. The PLF for the Zenit-3SLB is based on the 17S72 fairing manufactured by NPO Lavochkin. It was designed specifically for the Block DM and has an unblemished flight record on Block DM missions dating to 1996. The fairing is a bi-conic, aluminum construction that is 10.4 meters (34.1 feet) in length by 4.1 meters (13.5 feet) in its primary diameter. Spacecraft interfaces provided by the PLF are described in further detail in Section 5.

Fairing Access Characteristics

Once inside the PLF, physical access to the spacecraft is gained through fairing doors. Two doors are standard, one in each fairing half, up to 420 mm x 420 mm (16.5 inches x 16.5 inches) in size. Further information about access doors including allowable locations is provided in Section 5. Because there is no access tower at the Zenit launch pad, the customer/user can directly access their Land Launch payload(s) as late as 28 hours before launch, inside a clean enclosure at the Launch Vehicle Integration Facility. This capability improves opportunities for final adjustments, battery installation and other spacecraft-unique pre-launch operations.

Conditioned Air Supply to the Fairing	Clean, conditioned air is provided to the payload fairing volume from encapsulation until launch including during transport between facilities. Flow rates, cleanliness, temperatures, humidity levels and other details of the clean air supply to the payload volume are provided in Section 4.
Fairing Thermal Protection	The internal and external thermal insulation of the PLF nose cone protects the PLF structure against overheating and preserves acceptable thermal conditions for the spacecraft during ascent. Spacecraft environments are described in Section 4. Payload fairing jettison is constrained to ensure that the free molecular heating does not exceed the allowable limit defined in Section 4 and that the fairing elements land in pre-approved drop zones.
Payload Support Structure	The payload support structure for the Zenit-3SLB is provided by RSC Energia. It consists of a transfer compartment manufactured by Energia and an industry-standard spacecraft adapter (SCA) typically procured from Saab Ericsson Space Company (PAS937, PAS1194 or PAS1666) that interfaces with the spacecraft. Further details are provided in Section 5. Unique spacecraft base interfaces can normally be accommodated within the standard integration time span.

2.4 The Zenit-2SLB Payload Unit

Components and Integration

The Zenit-2SLB payload unit (PLU), shown in Figure 2-10, consists of the spacecraft, fairing, intersection bay, interface truss and spacecraft adapter. These elements are integrated in a Class 100,000 clean environment during ground processing.

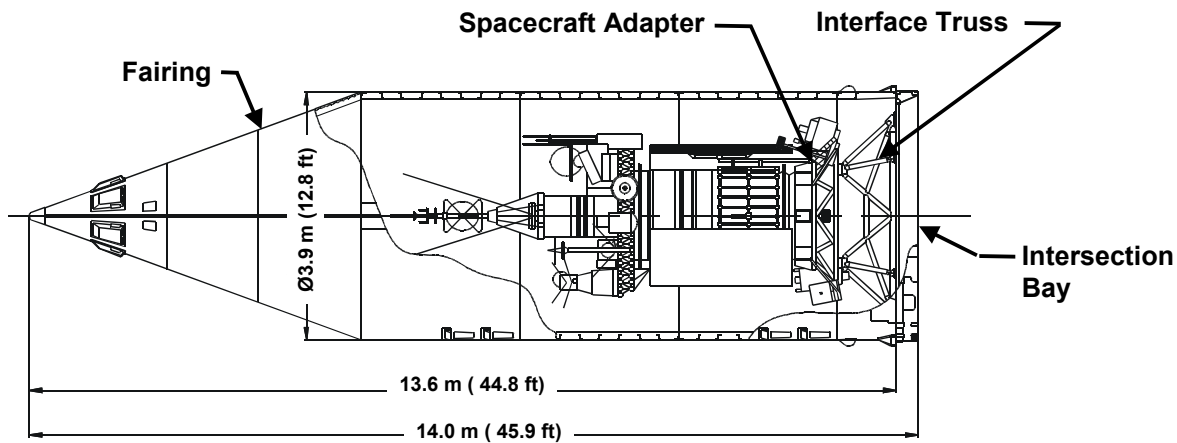


Figure 2-10 Zenit-2SLB Payload Unit

Payload Fairing

The PLF for the Zenit-2SLB is based on the Zenit-2 fairing manufactured by PO Yuzhmash. It was designed specifically for the two-stage Zenit and has an extensive and unblemished flight record dating to 1985. The fairing is a mono-conic, aluminum construction that is 13.65 meters (44.8 feet) in length by 3.9 meters (12.8 feet) in its primary diameter, and provides a 3.48 meter (11.4 feet) useable diameter. Spacecraft interfaces provided by the PLF are described in further detail in Section 5.

Alternative and modified fairings are also available. Interested customers are encouraged to contact Boeing Launch Services for further information.

Fairing Access Characteristics

Access doors up to 500 mm x 500 mm (19.7 inches x 19.7 inches) can be provided in the Zenit-2SLB fairing for this purpose. Additional information can be found in Chapter 5. Because there is no access tower at the Zenit launch pad, the customer/user can directly access their Land Launch payload(s) as late as 28 hours before launch, inside a clean enclosure at the Launch Vehicle Integration Facility. This capability improves opportunities for final adjustments, battery installation and other spacecraft-unique pre-launch operations.

Conditioned Air Supply to the Fairing	Clean, conditioned air is provided to the payload fairing volume from encapsulation until launch including during transport between facilities. Flow rates, cleanliness, temperatures, humidity levels and other details of the clean air supply to the payload volume are provided in Section 4.
Fairing Thermal Protection	External thermal insulation protects the payload structure from overheating and the internal thermal insulation limits the interior payload fairing surface temperature. Payload fairing jettison is constrained to ensure that the free molecular heating does not exceed the allowable limit defined in Section 4 and that the fairing elements land in pre-approved drop zones.
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Intersection Bay	The intersection bay serves to preserve the mating interfaces on the forward end of Zenit Stage 2 for the Block DM, thus maximizing inventory flexibility by allowing each stage 2 to be used on any Sea Launch or Land Launch configuration as needed. On Zenit-2SLB the intersection bay also provides a solid base for the payload support structure (truss and adapter) and enables full encapsulation of the spacecraft while in the payload processing facility, creating an enclosed payload volume for easy cleanliness and environmental control with a conditioned air supply.
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Spacecraft Adapters	For dedicated launches of a single spacecraft on the Zenit-2SLB, Land Launch can provide the customer any of the available standard adapters manufactured by Saab Ericsson Space, or an adapter provided by SDO Yuzhnoye and PO Yuzhmash using their experience in developing, testing and manufacturing adapters and separation systems for past Zenit-2 missions (Fig. 2-11) and for other launchers produced by Yuzhnoye and Yuzhmash (Cyclone, Dnepr). Further information on interfaces is provided in Section 5.
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Unique Interfaces and Multi-Spacecraft Launches	For spacecraft that have unique interface and separation requirements, Land Launch can examine other heritage spacecraft adapter designs, including those that incorporate bolt-type attachment and separation mechanisms. Yuzhnoye and Yuzhmash also have extensive experience designing and launching multi-spacecraft mechanisms on several launch systems. Unique spacecraft base interfaces, or multi-spacecraft dispensers, can normally be accommodated within the standard integration time span.
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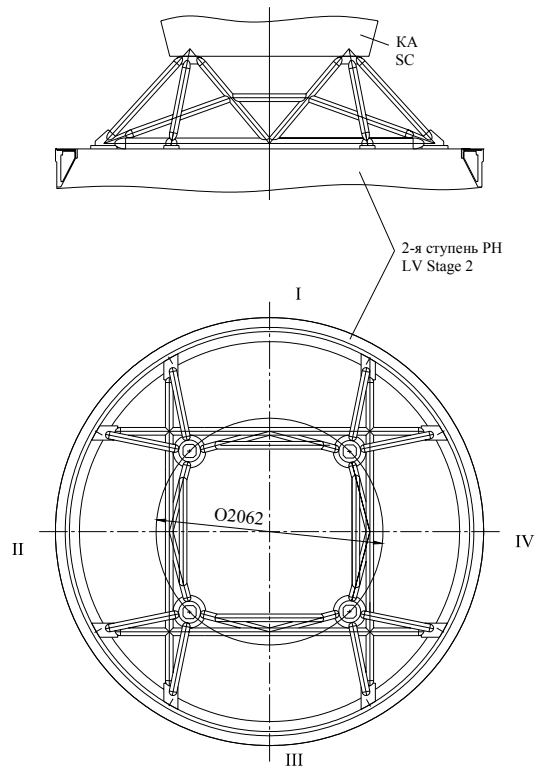


Figure 2-11. Zenit 2 Spacecraft Adapter Developed by Yuzhnoye and Yuzhmash

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