

3. PERFORMANCE

Overview

The Land Launch vehicles, the Zenit-2SLB and the Zenit-3SLB, can deliver spacecraft to a broad set of orbits. These include low, medium and high Earth orbits (LEO, MEO and HEO), geosynchronous transfer orbits (GTO), highly elliptical orbits, direct geostationary insertion (GEO) and Earth escape trajectories. Data presented in this section is intended to enable prospective users to make preliminary performance assessments. Please contact Boeing Launch Services for a performance quote specific to your mission requirements.

Characteristics of performance are covered in Sections 3.1 through 3.8, including:

- Launch Window Availability
 - Launch Site and Accessible Orbits
 - Generic Ascent Trajectories
 - Mass Performance
 - Coast Phase Maneuvers
 - Injection Accuracy
 - Spacecraft Separation Conditions
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**Performance
Ground Rules**

Performance data in this section is based on the following set of ground rules:

- Payload capability, defined in terms of Payload Systems Mass (PSM), consists of the combined mass of the separated spacecraft and the spacecraft adapter including wire harnesses.
 - For preliminary planning of missions manifesting a single payload, spacecraft adapter (and harness) masses of 140 kg and 200 kg are assumed for the Zenit-3SLB and Zenit-2SLB respectively. The masses of dispensers for multiple payloads, typical for Zenit-2SLB missions to LEO, are application unique.
 - The maximum PSM for Zenit-3SLB is 5,000 kg due to structural limitations. For Zenit-2SLB the structural limit is not a factor since it exceeds the vehicle's maximum performance.
 - To achieve orbit within the desired accuracy, and perform Contamination and Collision Avoidance Maneuver (CCAM), sufficient propellant reserves are assured for each individual stage to account for all launch vehicle dispersions and possible ambient conditions at any time of day on any day of the year with at least 99.65% probability.
 - The spacecraft is injected into orbit via trajectories that are consistent with existing, approved launch corridors and drop zones.
 - At the time of fairing jettison, the free molecular heating (FMH) is less than $1,135 \text{ W/m}^2$, accounting for all launch vehicle dispersions and possible ambient conditions at any time of day on any day of the year.
 - Orbital altitudes are specified with respect to an Earth radius of 6,378 km.
 - The Zenit-3SLB uses its standard payload fairing that is 4.1 m in diameter and 10.4 m long.
 - The Zenit-2SLB uses its standard payload fairing that is 3.9 m in diameter and 13.65 m long.
 - Mission-unique customer requirements that may affect performance (e.g. specific argument of perigee, restricted mission duration, ground station visibility, extended launch windows) are not factored.
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Launch Window Availability

The launch vehicle and associated ground systems can support a launch window any day of the year at any time of the day. Furthermore, inherent features of the Land Launch system enable it to provide the maximum flexibility to accommodate shifting satellite readiness dates with little or no perturbation to the launch schedules of other customers (*Table 3-1*).

- Minimal Turn-Around Time - the Zenit launch complex was designed for maximum throughput and minimum refurbishment between launches. The complex can support launches as little as 10 days apart. Factory output limits the theoretical launch rate to twelve per year, of which seven may be Zenit-3SLB.
- Robust Flight Hardware – Both the Zenit and Block DM launch systems were designed to withstand environmental conditions at Baikonur.
- Heritage Hardware – The Land Launch configurations are composed of heritage systems with as many as 220 flights to their credit. This maturity, combined with robust commit criteria, give Sea Launch and Land Launch the highest launch-on-time probability for heavy and medium lift launch services, respectively. All but two of twelve Sea Launch launches to date have taken place in the first second of the first launch window on the first attempt.

Table 3-1. Launch Operational Features

Dates	Available year around
Times	Available at any hour
Ambient Temperature	-29 °C to +45 °C (-20 °F to +113 °F)
Average Ground Winds (at 10m above ground surface)	Zenit-2SLB: 20 m/s (45 miles/hour) Zenit-3SLB: 18 m/s (40 miles/hour)
Pad Turn-around Time Between Launches	10 Days
Nominal Turn-around Time After Launch Scrub	1 Day (if scrub precedes LV fueling) ≤ 3 Days (scrub after LV is fueled)
Maximum Annual Launch Rate (Factory Limited)	Twelve (of which no more than seven Zenit-3SLB)
Launch-on-Time Probability	Zenit-2SLB: 98% Zenit-3SLB: 97%

3.1 Launch Site and Accessible Orbits

Site Location

The coordinates for the Zenit Launch Complex are: latitude = 46 ° North, longitude = 63 ° East. The currently approved launch azimuths available from this complex, as constrained by overflight and drop zone considerations, are shown below in Table 3-2 and Figure 3-1.

Table 3-2. Zenit Launch Azimuths and Inclinations from Baikonur

Azimuth	Inclination of Initial Orbit
64.2°	51.4°
35.0°	63.9°
194.2°	98.8°

For special cases, arrangements can be made to open a corridor and allocate drop-zones for the launch azimuths of $A_0 = 82.1^\circ$ ($i = 46.2^\circ$) and $A_0 = 178.8^\circ$ ($i = 88.1^\circ$). Approval of new launch corridors for Land Launch is eased by its use of environmentally-friendly fuels.

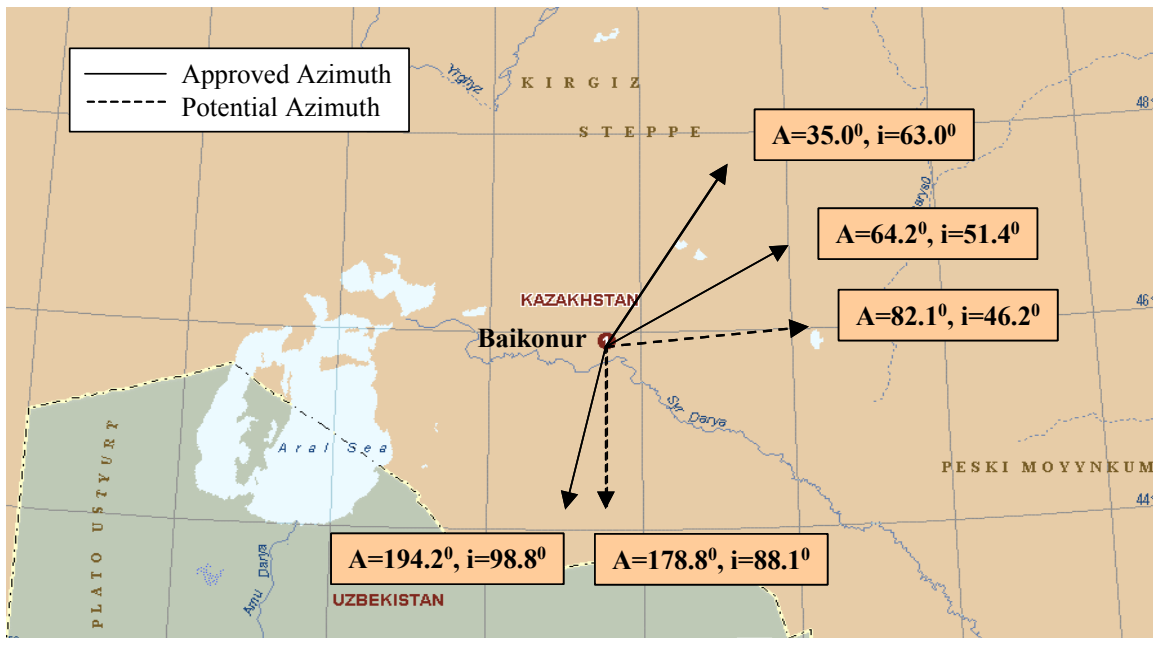


Figure 3-1. Flight Corridors for Land Launch from Baikonur

Accessible Orbits

Table 3-3 shows the orbit inclinations (i) that can be reached by Land Launch from its three approved launch corridors. LEO orbit inclinations several degrees different from the three approved launch corridors can be obtained by cross-range yawing maneuvers (“doglegs”) of the second stage commencing after fairing jettison. Such maneuvers are generally associated with missions provided by the Zenit-2SLB, where LEO is the final destination. For Zenit-3SLB missions involving higher orbits in which the desired inclination differs from the three approved corridors, it is typically most efficient for plane changes to be carried out primarily by the Block DM-SLB third stage. In these cases, the first two stages usually perform a direct ascent into a parking orbit inclination coinciding with one of the approved corridors.

Table 3-3. Accessible Orbits on Land Launch

Orbit Type	Accessible Inclinations	Vehicle	Usual Plane Change Method
LEO	$46.2 < i < 71^\circ$ $84.0 < i < 105^\circ$	Zenit-2SLB	Second Stage Yaw
MEO, HEO, GTO, Elliptical, escape trajectories	$0.0 < i < 110^\circ$	Zenit-3SLB	Third Stage Perigee, Apogee or Post-Perigee Burn (mission-specific)

Performance losses due to plane changes are highly sensitive to a variety of mission parameters. Consequently, prospective Land Launch customers are encouraged to contact Boeing Launch Services for a performance estimate that is specific to their needs.

3.2 Ascent Trajectory – Generic Zenit-3SLB GTO Mission

Mission Profile For GTO missions the Zenit-3SLB flies a classic three-burn Block DM mission profile (*Figure 3-2*) using the approved corridor and drop zones at $A_0=64.2^\circ$, $i=51.4^\circ$ (*Figure 3-3*).

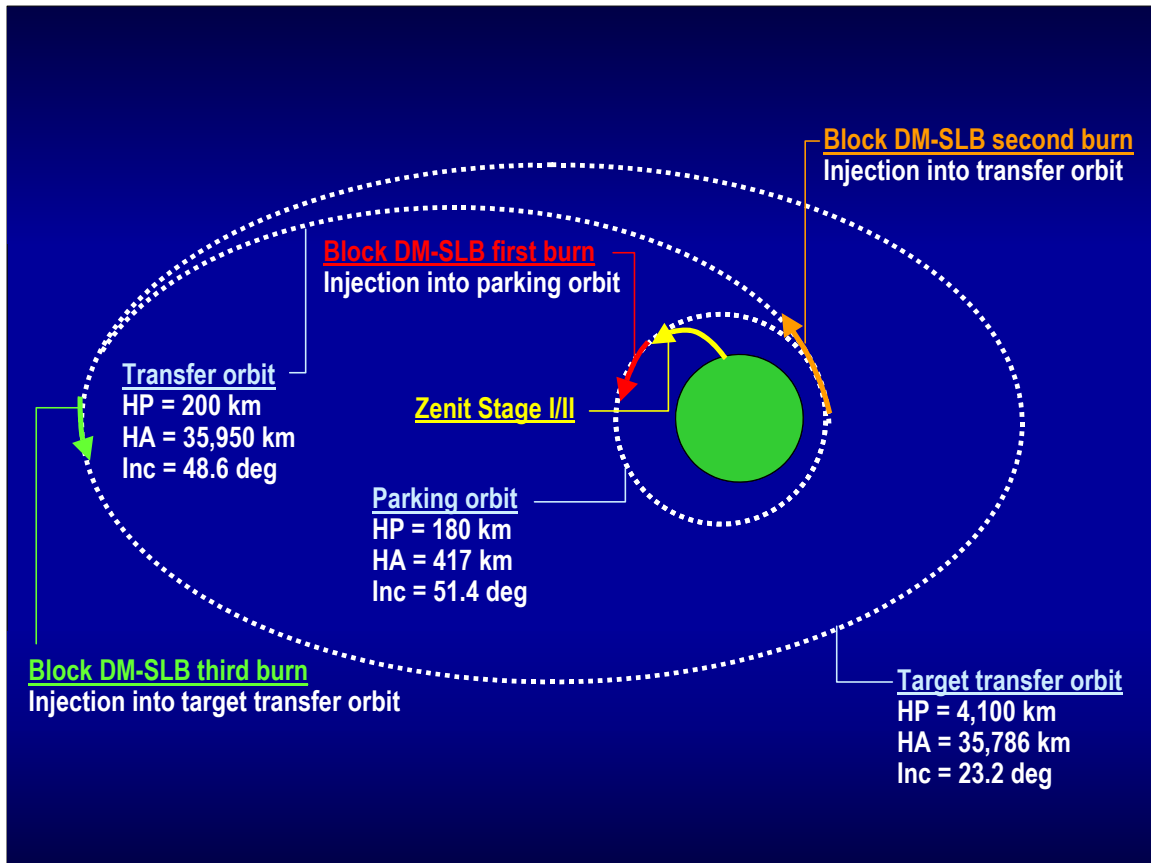


Figure 3-2. Land Launch Uses the Proven Three-Burn Block DM Mission Profile From Baikonur for GTO Launches (orbit parameters correspond to PSM=3600 kg)



Figure 3-3. Approved Land Launch Ground Track and Drop Zones for GTO Missions

Stage 1 Flight

The Zenit first stage provides the thrust for the first 149 seconds of flight. The roll maneuver begins at 10 seconds after launch. During the final seconds of its burn the engine is throttled to limit the maximum axial acceleration. The approved drop zone for the separated first stage is at distance of approximately 884 km from the launch point, within the Republic of Kazakhstan as shown in Figure 3-3. Throughout this phase of the mission, telemetry is received by ground stations within Baikonur cosmodrome.

Stage 2 Flight

The Zenit Stage 2 vernier engine ignites just prior to first stage separation. Upon first/second stage separation, the first stage solid retrorockets fire and second stage main engine ignition occurs. The second stage main and vernier engines continue to operate in tandem for the next five minutes of flight. After second stage main engine cut-off, the vernier engine continues to function for 75 seconds to provide attitude control up through second/third stage separation.

Payload fairing jettison occurs at approximately 320 seconds into flight (175 seconds into second stage operation) with the drop zone located in Siberia approximately 1924 km downrange of the launch site. At this point the free molecular heating rate has dropped to below 30 W/m^2 , well below the industry norm of $1,135 \text{ W/m}^2$. Cross-range yaw maneuvers by the second stage, if required, take place after fairing separation.

Telemetry coverage during second stage flight is typically provided by ground stations at Baikonur cosmodrome, and at Krasnoyarsk in Russia.

The second stage drop zone is located within the neutral waters of the Pacific Ocean at a downrange distance of 6850 km.

**Block DM-SLB
Powered Flight**

At approximately 65 to 90 seconds after second stage main engine shutdown and an altitude of 180 to 400 km, the second stage vernier engine shuts down. This event is quickly followed by second/third stage separation and the subsequent jettison of the middle adapter surrounding the Block DM-SLB.

The Block DM-SLB can perform one to three burns. For most multiple-burn missions, including the generic three-burn GTO mission described here, the initial burn establishes a stable parking orbit, begins approximately ten seconds after separation of the second stage and lasts approximately 200 seconds, with telemetry coverage provided from Krasnoyarsk. The Block DM-SLB then begins a coast in the parking orbit lasting about 64 minutes. Attitude control during Block DM-SLB coast phases is provided by its two attitude control/ullage engines.

The second Block DM-SLB burn occurs at the first ascending node of the parking orbit, over the Atlantic Ocean, to transfer to an intermediate elliptical orbit with a synchronous or super-synchronous apogee as dictated by customer requirements and the capabilities of the satellite platform. Ignition starts at approximately 75 minutes after launch and typically continues for approximately 6 minutes, with telemetry coverage provided by a mobile receiving station.

After a 5-hour coast the Block DM-SLB and payload reach GTO apogee, where a third burn is performed to optimize the delivery orbit by raising perigee and reducing inclination. Telemetry coverage during the third burn is simplified by the altitude at which it occurs, and is typically provided by multiple sites located at Moscow, Baikonur, Krasnoyarsk and elsewhere.

The target injection orbit for a payload mass of 3600 kg features a perigee of 4100 km, an apogee of 35786 km and inclination of 23.2°, resulting in a velocity shortage of 1500 meters/second required to achieve GEO.

Payloads lighter than 3600 kg are delivered to orbits requiring progressively less than 1500 meters/second delta-velocity to GEO to the point that payloads weighing 1,600 kg and less are inserted directly into GEO, a mission that the Block DM family has already performed more than one hundred times.

Spacecraft separation conditions and post-separation events including collision avoidance maneuvers are described in Section 3.8.

Flight Timeline Table 3-4 provides a typical sequence of events for a representative three-burn Zenit-3SLB mission to GTO for a 3600-kg payload. Event timing is only slightly dependent on payload mass. Apart from spacecraft separation, variation (dispersion) of any planned event timing for a nominal mission is typically within 15 seconds from the reference sequence.

Table 3-4. Flight Timeline— GTO Mission by the Zenit-3SLB with Three Burns of the Block DM-SLB

Time [seconds]	Event
0	Ignition
~3.9	Liftoff
12	Begin pitch over
14	Roll to launch azimuth
59	Maximum dynamic pressure
115	Maximum axial acceleration
115 to 132	Stage 1 engine throttle down to 74%
144	Stage 2 vernier engine ignition
147	Stage 1 engine shutdown
149	Stage 1 separation
154	Stage 2 main engine ignition
319	Payload fairing jettison
432	Stage 2 main engine shutdown
507	Stage 2 vernier engine shutdown
508	Stage 2 separation
509	Block DM-SLB middle adaptor jettison
517	Block DM-SLB main engine ignition #1
707	Block DM-SLB main engine shutdown #1
4534	Block DM-SLB main engine ignition #2
4864	Block DM-SLB main engine shutdown #2
23562	Block DM-SLB main engine ignition #3
23631	Block DM-SLB main engine shutdown #3
Mission-Specific	Spacecraft separation

Ground Track

Figure 3-4 presents the predicted ground track of injection for a generic, representative *Zenit-3SLB* three-burn GTO mission.

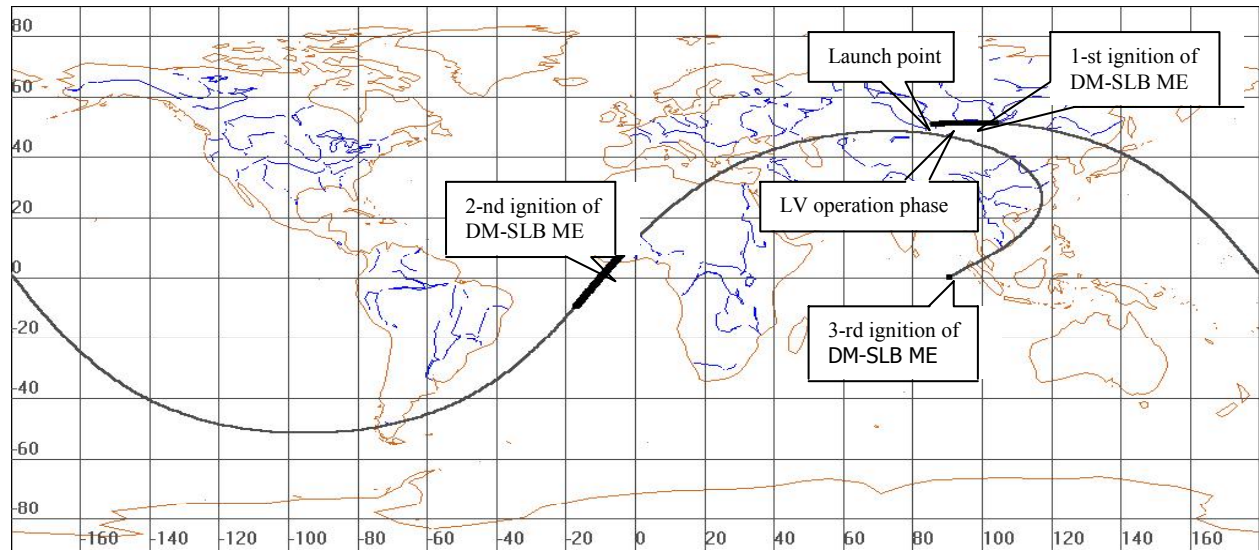


Figure 3-4. Injection ground track for a generic Zenit-3SLB GTO mission.

3.3 Ascent Trajectory – Generic Zenit-2SLB Mission to 51.6° LEO

Stage 1 Flight

The two-stage Zenit-2SLB is optimized for LEO missions inclined at 51.6°, including potential flights to the International Space Station (ISS). For such missions, the Zenit Stage 1 uses the same approved launch corridor and drop zone that is used for GTO missions, along launch azimuth 64.2° (inclination 51.4°). Liftoff occurs 3.9 seconds after ignition, upon release of the hold-downs. The roll maneuver begins at 10 seconds into flight. Main engine thrust is provided for the first 140 -150 seconds of flight, and the engine is throttled during its last seconds of operation in order to limit maximum axial acceleration. The drop zone for the first stage is 884 km down range from the launch point, within the Republic of Kazakhstan. Throughout this phase of the mission, telemetry is received by ground stations within Baikonur cosmodrome.

Stage 2 Flight

The Zenit Stage 2 steering engine ignites prior to first stage separation. Upon first/second stage separation, the first stage solid retrorockets fire and second stage main engine ignition occurs. The main engine and vernier engine continue to operate in tandem for the next four minutes of flight.

Fairing jettison occurs at about 295 seconds of flight (150 seconds into second stage operation), consistent with the approved drop zone located in Siberia approximately 1924 km downrange of the launch site. At this point the free molecular heating rate has dropped to below 30 W/m², well below the industry norm of 1,135 W/m². After fairing jettison, the second stage performs a cross-range yaw maneuver to adjust the inclination to 51.6°.

After second stage main engine cut-off, the vernier engine continues to function for an additional 500 seconds (as long as 890 seconds on other missions) to provide attitude control up through payload separation.

Throughout this phase of flight, telemetry is received by the ground stations within Baikonur and Krasnoyarsk.

Spacecraft separation conditions and post-separation events including collision avoidance maneuvers are described in Section 3.8.

Flight Timeline

Table 3-5 provides a typical sequence of events for a representative Zenit-2SLB mission that delivers 12,000 kg to a 51.6°-inclined, 400 km low Earth orbit, i.e. – one compatible with ISS access .

Table 3-5. Flight Timeline—Zenit-2SLB ISS Mission

Time [seconds]	Event
0	Ignition
~3.9	Liftoff
10	Begin roll maneuver
11	Begin pitch over
14	Roll to launch azimuth
60	Maximum dynamic pressure
113	Maximum axial acceleration
113 to 132	Stage 1 engine throttle to 50%
145	Stage 2 vernier engine ignition
147	Stage 1 engine shutdown
149	Stage 1 separation
155	Stage 2 main engine ignition
295	Payload fairing jettison
397	Stage 2 main engine shutdown
893.5	Stage 2 vernier engine shutdown
893.8	Spacecraft separation pyrotechnic firing
893.86	Solid-propellant retro rocket burn

Flight Profile

Figure 3-5 graphically portrays the flight profile defined in Table 3-5, along with other key trajectory events and parameters.

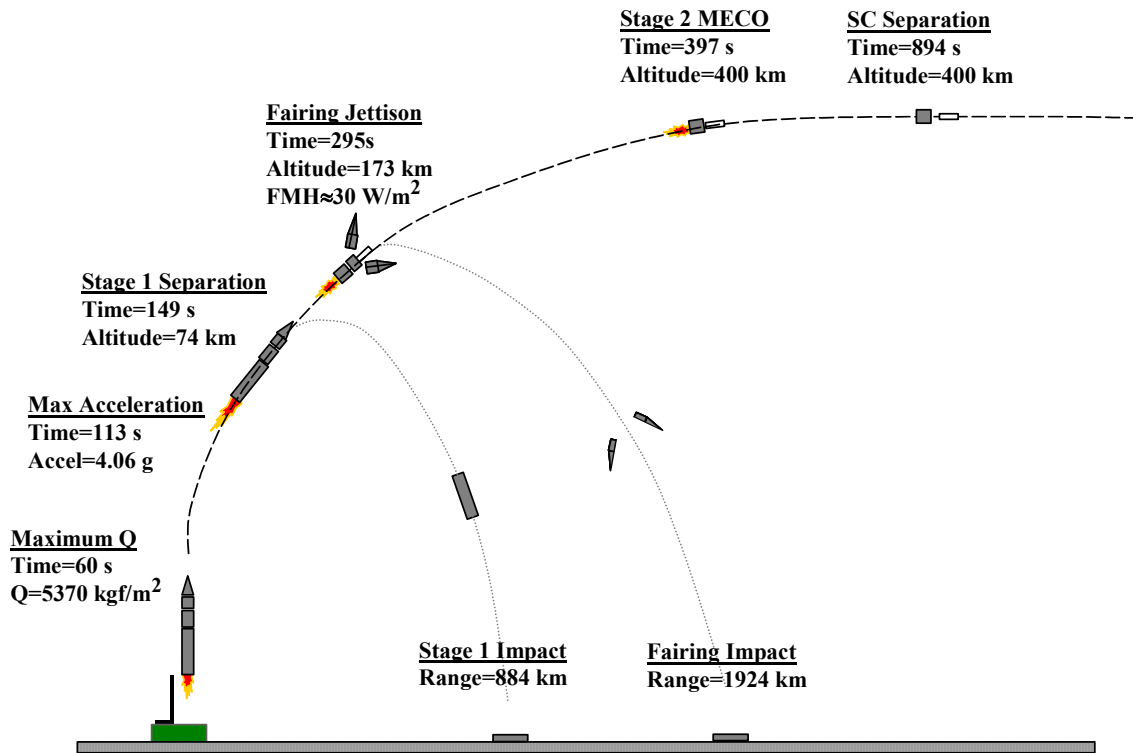


Figure 3-5. Typical Ascent Profile to the International Space Station Orbit at 51.6° with Payload Mass 12000 kg

Ground Track

Figure 3-6 presents the predicted ground track for a Zenit-2SLB mission to the International Space Station.

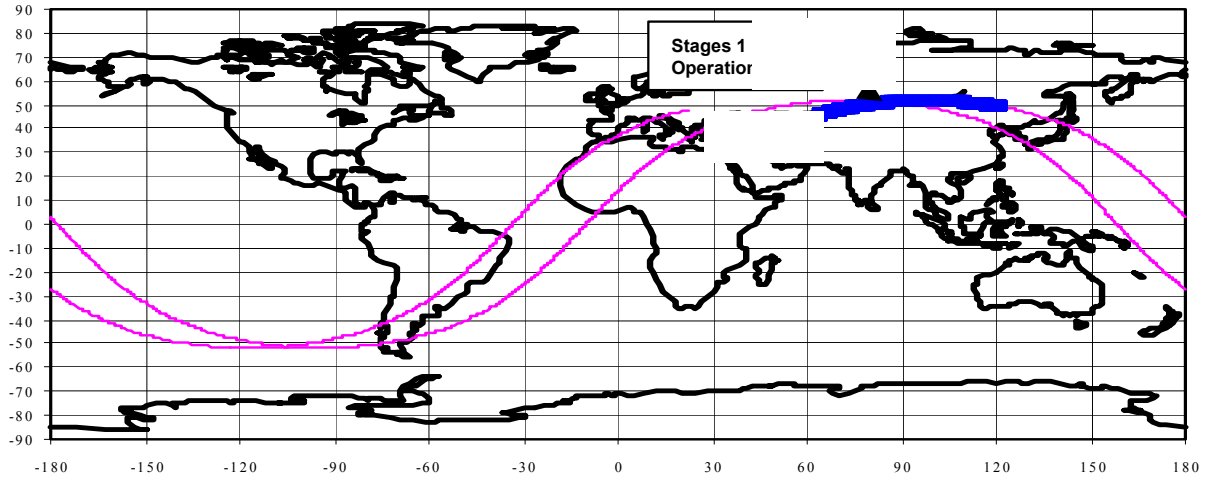


Figure 3-6. Flight Ground Track for a Zenit-2SLB Mission to 51.6° LEO

3.4 Payload Capability – Three Stage Zenit-3SLB

Geosynchronous Transfer Orbit

The Land Launch Zenit-3SLB is a medium-lift vehicle to GTO. Employing three burns of the Block DM-SLB, it can deliver payloads weighing 3.6 metric tons to a GTO featuring a high perigee and reduced inclination, requiring 1500 m/s in additional velocity to attain geostationary or geosynchronous orbit (GEO). Performance improves rapidly for lighter satellites because correspondingly less fuel is off-loaded from the Block DM-SLB to meet a second stage drop zone constraint.

Table 3-6 and Figure 3-7 show the GTO payload capability.

Table 3- 6. Zenit-3SLB Payload Capability to GTO

Delta-V to GEO [meters/second]	Inclination [degrees]	Perigee Altitude [kilometers]	Payload Systems Mass [kilograms]
0	0.00	35,786	1,600
1,000	13.0	9,430	2,830
1,500	23.2	4,100	3,600
1,800	31.0	2,120	4,120

Notes and Assumptions:

- Apogee altitude of 35,786 km
- Three burns of the Block DM-SLB
- Mission duration approximately 6.6 hours

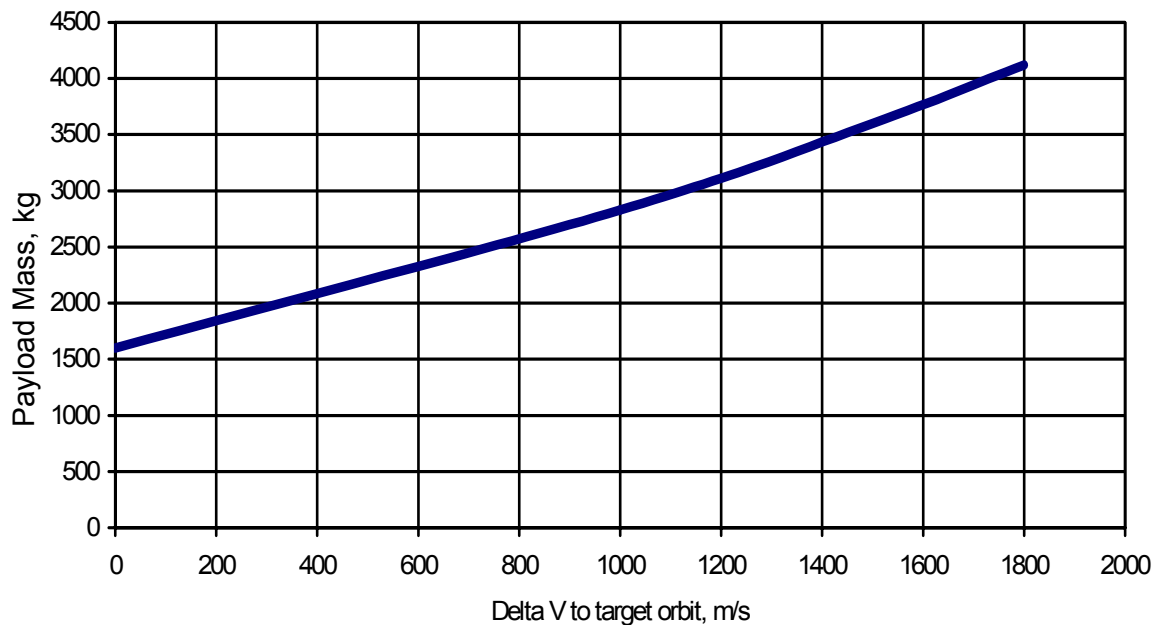


Figure 3-7. Zenit-3SLB Payload Capability to GTO

**MEO, HEO,
Circular and
Elliptical Orbits**

The Land Launch Zenit-3SLB is a heavy lift vehicle to Middle Earth and High Earth (MEO and HEO, respectively) circular and elliptical orbits that coincide with its approved launch corridors, as shown in Tables 3-7 and 3-8 and in Figures 3-8 and 3-9. MEO, HEO and elliptical orbits at other inclinations can also be obtained, typically with an additional burn of the Block DM-SLB, at a cost in performance that varies with altitude and the extent of plane change required. LEO (altitude < 1000 km) and low-perigee elliptical orbits are more optimally performed by a Zenit-2SLB, as shown in a later section of this chapter. Customers are encouraged to contact Boeing Launch Services for a specific performance quotation.

Table 3-7. Zenit-3SLB Performance to Circular Orbits

Height [km]	Payload Capability [kg]		
	Inclination 51.4 °	Inclination 63.9 °	Inclination 98.8 °
1,000	5000	5000	5000
5,000	5000	5000	5000
10,000	4830	4340	3890
20,000	3400	3020	2570
30,000	2880	2540	2110

Note: Two burns of the Block DM-SLB main engine

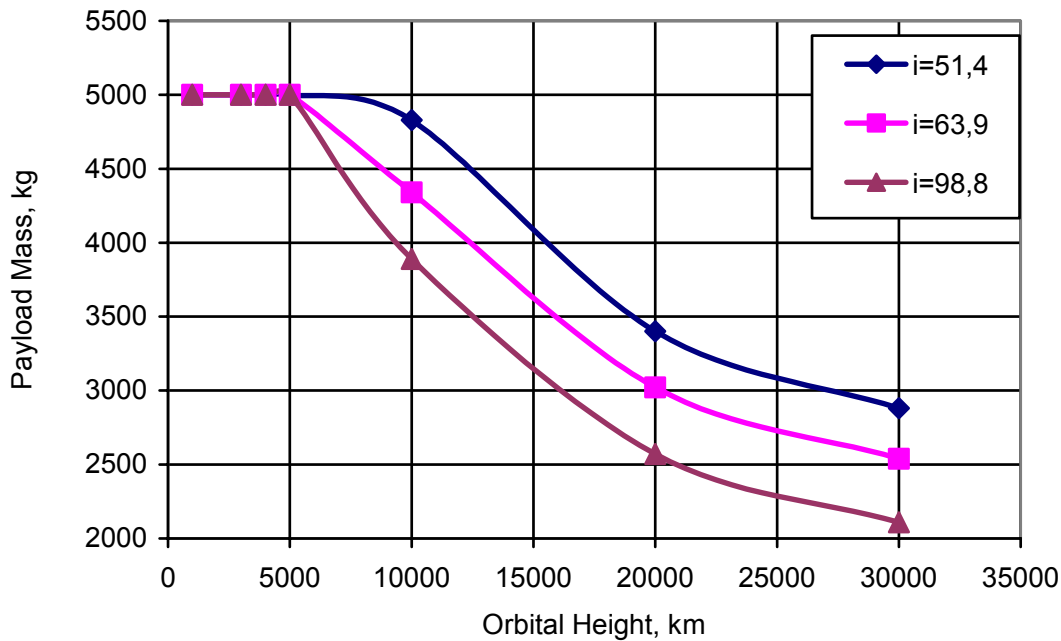


Figure 3-8. Zenit-3SLB Performance to Circular Orbits

Table 3-8. Zenit-3SLB Performance to Elliptical Orbits

Apogee Height [km]	Payload Capability [kg]		
	Inclination 51.4 °	Inclination 63.9 °	Inclination 98.8 °
10,000	5000	5000	5000
20,000	5000	5000	5000
30,000	5000	4850	4680
40,000	5000	4540	4320
50,000	4810	4320	4090
60,000	4650	4170	3920
70,000	4530	4050	3810

Assumptions:

- Single Block DM-SLB burn
- Perigee altitude of ~200 km

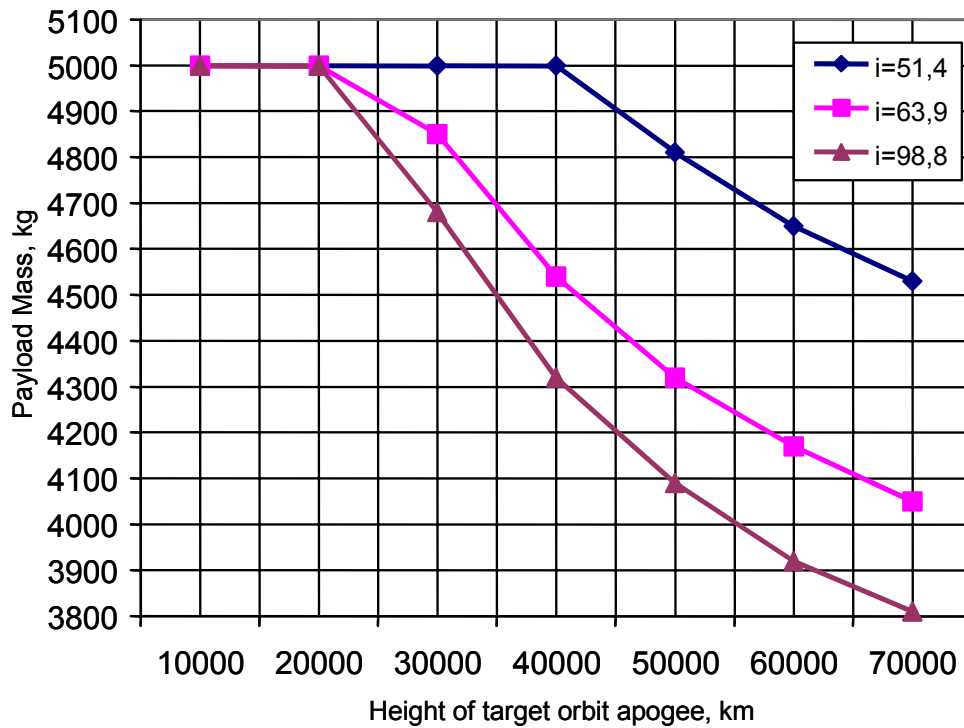


Figure 3-9. Zenit-3SLB Performance to Elliptical Orbits (Perigee 200 km)

High-Energy and Earth-Escape Trajectories

Table 3-9 and Figure 3-10 show the Zenit-3SLB payload capability to high-energy orbits and Earth escape. These are presented as a function of C_3 (velocity-at-infinity squared).

Table 3-9. Zenit-3SLB High-Energy and Earth Escape Payload Capability

C_3 [km^2/s^2]	Payload Capability [kg]
-20	5000
-10	4620
0	3780
15	2740
30	1900

Notes and Assumptions:

- Inclination = 51.4°
- Perigee altitude = 300-450 km
- Single Block DM-SLB burn

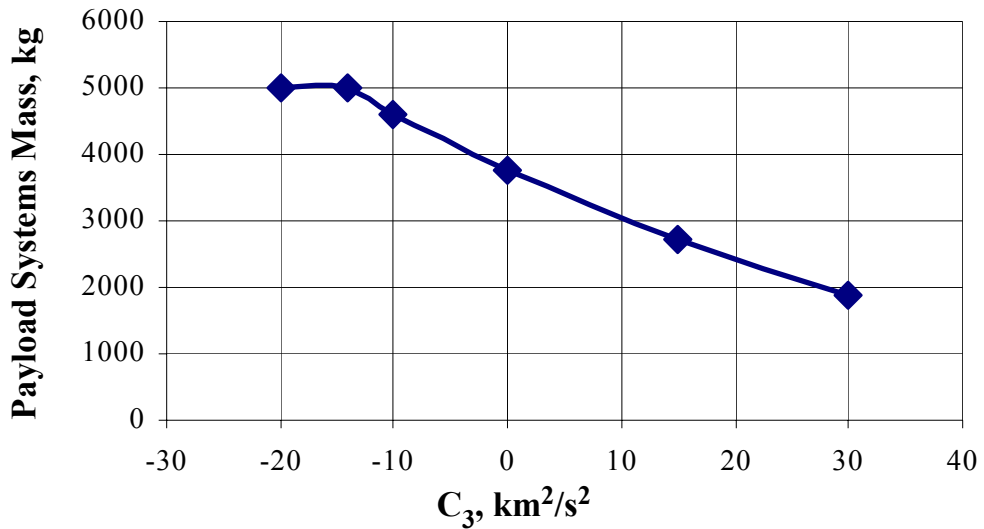


Figure 3-10. Zenit-3SLB High-Energy and Earth Escape Payload Capability

3.5 Payload Capability - Two Stage Zenit-2SLB

Circular LEO Orbits

Table 3-10 and Figure 3-11 present Zenit-2SLB payload performance as a function of both circular orbit altitude and inclination.

Table 3-10 Zenit-2SLB Payload Capability for Circular Low Earth Orbits

Altitude [km]	Payload Mass [kg]		
	Inclination 51.4°	Inclination 63.9°	Inclination 98.8°
200	13,920	13,330	10,610
300	12,940	12,410	9,790
400	11,930	11,500	8,870
500	10,890	10,550	7,910
600	9,820	9,570	6,930
700	8,730	8,560	5,930
800	7,630	7,550	4,940
900	6,530	6,510	3,940
1,000	5,420	5,480	3,320
1,100	4,660	4,560	2,920
1,200	4,250	4,190	2,530
1,300	3,810	3,750	2,320
1,400	3,390	3,310	2,030
1,500	2,930	2,340	1,520

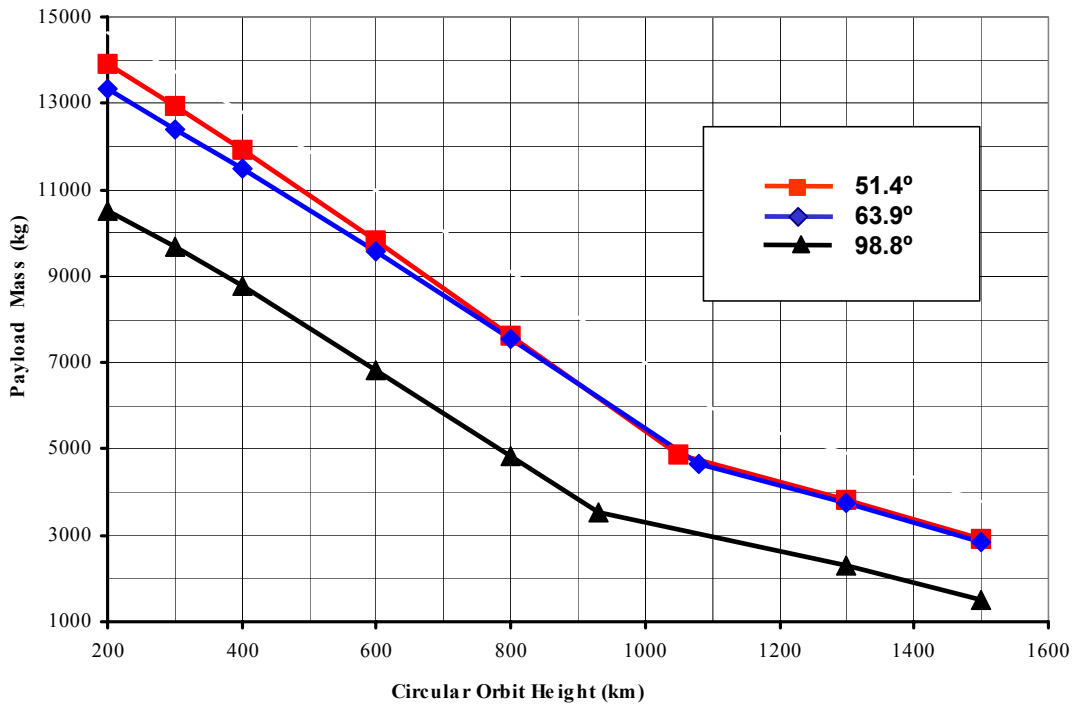


Figure 3-11. Zenit-2SLB Payload Capability for Circular Low Earth Orbits

Elliptical Orbits Table 3-11 and Figure 3-12 define the performance parameters for the two-stage Zenit-2SLB to various elliptical earth orbits.

Table 3-11. Zenit-2SLB performance to Elliptical Orbits

Apogee [km]	Payload Mass [kg]		
	Inclination 51.4°	Inclination 63.9°	Inclination 98.8°
500	13280	12730	10070
1,000	12320	11800	9250
2,000	10710	10230	7870
4,000	8290	7900	5830
6,000	6560	6290	4380
8,000	5260	5120	3310
10,000	4250	4230	2480

Note: Perigee altitude = 200 km

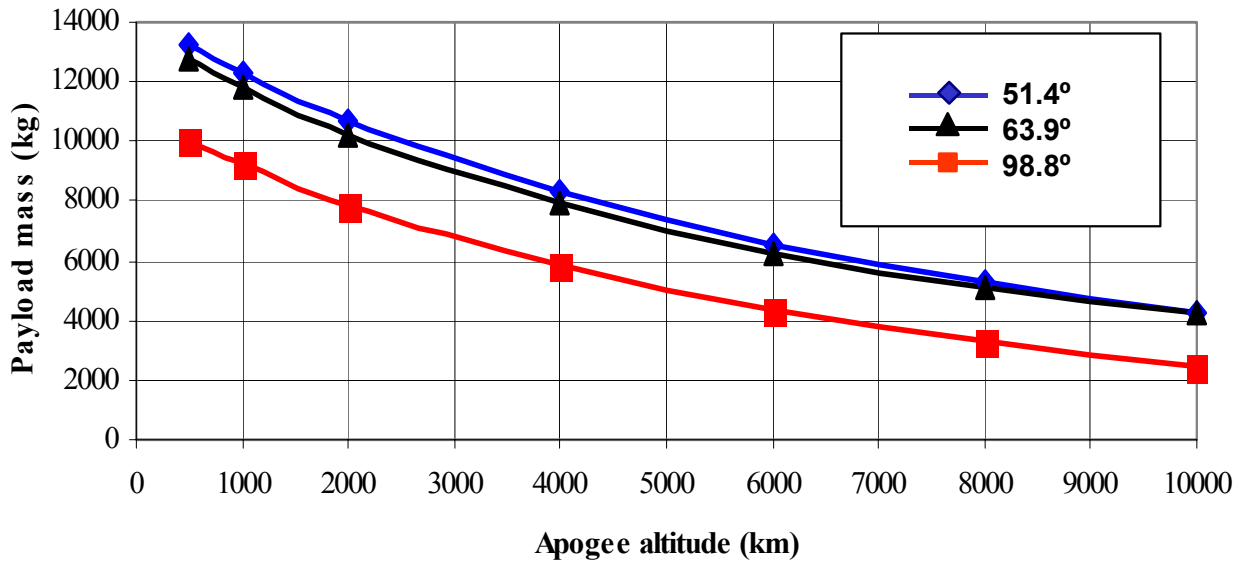


Figure 3-12. Zenit-2SLB Performance to Elliptical Orbits (Perigee 200 km)

3.6 Coast Phase Attitude Maneuvers

Zenit-3SLB

During coast phases the Block DM-SLB control system can provide three axes pointing (pitch, yaw and roll) with accuracy up to ± 3 deg in all three axes. The control system of the Block DM-SLB, unlike other versions of the Block DM, can also provide continuous roll around the longitudinal axis or one of the lateral axes at a rate up to 5 degrees per second. Forty minutes of any coast phase are nominally reserved for Block DM-SLB attitude maneuvers

Zenit-2SLB

Zenit-2SLB missions do not feature extended coasts. Stage 2 operation immediately succeeds stage 1 operation, and payload separation occurs between 0.3 and 5 seconds after cut-off of the second stage vernier (steering) engine.

3.7 Injection Accuracy

Tables 3-12 and 3-13 show 3σ orbital injection accuracy of the Land Launch family of vehicles to representative orbits.

Table 3-12. Land Launch Zenit-2SLB and Zenit-3SLB Provide Accurate Orbital Insertion

Orbital Parameter	Zenit-2SLB		Zenit-3SLB	
	Circular (1)	Circular (2)	Circular (3)	GTO (4)
Altitude [km]	± 8	± 9	± 25	-
Perigee [km]	-	-	-	± 40
Apogee [km]	-	-	-	± 100
Inclination [deg]	± 0.04	± 0.07	± 0.06	± 0.1
Longitude of Ascending Node [deg]	± 0.1	± 0.07	± 0.2	± 0.3
Perigee Argument [deg]	-	-	-	± 0.2
Period [sec]	± 3.5	± 4.5	± 45	
(1) 400 km x 400 km, inclination = 51.6° (2) 600 km x 600 km, inclination = 98° (3) 10,000 km x 10,000 km, inclination = 51.4° (4) 4,000 km x 35,786 km, inclination = 23°				

Table 3-13. The Zenit-3SLB Also Provides Accurate Direct GEO Insertion

Orbit Type	Orbital Altitude	Inclination	Period
Geostationary	± 200 km	± 0.2 deg.	± 450 s

3.8 Spacecraft Separation and Post-Separation Events

3.8.1 Zenit-3SLB

Separation Event Spacecraft separation typically occurs 10-15 minutes after the final Block DM-SLB main engine shutdown. This allows for reorientation to the required spacecraft separation attitude.

Separation Capabilities The separation system provides a relative velocity between the Block DM-SLB and the spacecraft, typically on the order of 0.3 meters/second. The separation springs can provide a straight push-off or a transverse angular rate.

Attitude and attitude rate accuracy depend heavily on spacecraft mass properties and spin rate, and may be assumed to be ± 2.5 degrees and ± 0.5 degrees/second in all three axes for a non-spinning separation (2.3σ). The Block DM-SLB attitude control system can provide a longitudinal spin rate up to 5 degrees per second if desired. For spacecraft requiring a transverse spin at separation, this may be provided up to 2 degrees per second within ± 0.5 degrees per second about each axis.

CCAM After spacecraft separation, the Block DM-SLB performs a Collision and Contamination Avoidance Maneuver (CCAM), which prevents future contact with the spacecraft. The timing of this maneuver is determined for the specific mission. The Block DM-SLB then vents all residual propellant and gasses, and depletes any remaining charge in its batteries.

State Vector Delivery The state vector at time of spacecraft separation may be delivered to the customer 35-50 minutes after the event.

The format of the state vector, means of its delivery and the parameters of the spacecraft injection orbit are agreed in advance between the parties. The time of delivery of data can be updated for the specific mission.

3.8.2 Zenit-2SLB

Separation Event Separation begins between 0.3 and 5 seconds after shutdown of the second stage vernier (steering) engine.

Separation Capabilities The Zenit-2SLB employs a typical three-axis stabilized method for payload separation along the second stage's longitudinal axis. The actual separation is initiated by the firing of pyrotechnic ordnance charges in the spacecraft attachment assembly. The separation impulse to the spacecraft is typically provided by springs in the separation system. Nearly simultaneously, solid propellant retro-rockets on the aft end of the second stage are fired, adding to the relative separation velocity.

Launch vehicle stabilization errors at the moment of spacecraft separation command generation can be kept within +/- 2 degrees for pitch and yaw and within +/- 1 degree for roll. Angular velocities at release can be kept within +/- 1.5 degrees/sec for all three axes. Table 3-14 presents typical parameters for payload motion after separation in the case of a single spacecraft, while Table 3-15 presents similar data for missions involving multiple payloads with individual masses that exceed 500 kg.

Table 3-14 Typical Spacecraft Motion After Separation - Single Payload

Parameter	Value
Relative separation velocity	≥ 2.8 m/s
Spacecraft angular rate around any of its axes	≤ 2.5 deg/s
Spacecraft attitude error	± 2 deg

Table 3-15 Typical Spacecraft Motion After Separation - Multiple Payloads (each > 500 kg)

Parameter	Value
Relative separation velocity	≥ 0.3 m/s
Spacecraft angular rate around any of its axes	≤ 4.0 deg/s
Spacecraft attitude error	± 5 deg

CCAM for second stage Collision avoidance is achieved by firing four solid-propellant retrorockets on the aft end of the second stage for a burn time on the order of 0.5 to 1.1 seconds, slowing the second stage and moving it out of the spacecraft orbit. After a delay, the oxidizer tank is vented.

State Vector Delivery The timing of state vector delivery depends on the mission profile as well as the location and the availability of ground stations. For a typical ascent to 51.4°, it is possible to arrange for delivery of such data to the customer between 35 and 50 minutes after payload separation.
