CHAPTER 3

PERFORMANCE

3.1 Introduction

The LM-3C performance figures given in this chapter are based on the following assumptions:

- Launching from XSLC (Xichang Satellite Launch Center, Sichuan Province, China), taking into account the relevant range safety limitations and ground tracking requirements;
- Initial launch azimuth being 97.5°;
- Mass of the payload adapter and the separation system not included in the payload mass;
- The third stage of LM-3C launch vehicle carrying sufficient propellant to reach the intended orbit with a probability of no less than 99.7%;
- At fairing jettisoning, the aerodynamic flux being less than 1135 W/m^2;
- Orbital altitude values given with respect to a spherical earth with a radius of 6378.14 km.

3.2 Mission Description

3.2.1 Standard Geo-synchronous Transfer Orbit (GTO)

LM-3C is mainly used for conducting GTO mission. The standard GTO is recommended to the User. LM-3C launches Spacecraft (SC) into the standard GTO with following injection parameters from XSLC.

Perigee Altitude	Hp	=200 km
Apogee Altitude	Ha	=35959 km
Inclination	i	=28.5°
Perigee Argument	ω	=178°

✧ The above data are the parameters of the instant orbit that SC runs on when SC/LV separation takes place. *Ha* is equivalent to true altitude of 35786 km at first apogee, due to perturbation caused by Earth oblateness.

3.2.2 Flight Sequence

The typical flight sequence of LM-3C is shown in **Table 3-1** and **Figure 3-1**.

Table 3-1 Flight Sequence

Events	**Flight Time (s)**
Liftoff	0.000
Pitch Over	10.000
Boosters Shutdown	127.491
Boosters Separation	128.991
Stage-1 Shutdown	145.159
Stage-1/Stage-2 Separation	146.659
Fairing Jettisoning	258.659
Stage-2 Main Engine Shutdown	328.000
Stage-2 Vernier Engine Shutdown	333.000
Stage-2/Stage-3 Separation, and Stage-3 First Start	334.000
Stage-3 First Shutdown	650.605
Coast Phase Beginning	654.105
Coast Phase Ending, and Stage-3 Second Start	1323.242
Stage-3 Second Shutdown, Velocity Adjustment Beginning	1474.866
Velocity Adjustment Ending	1494.866
SC/LV Separation	1574.866

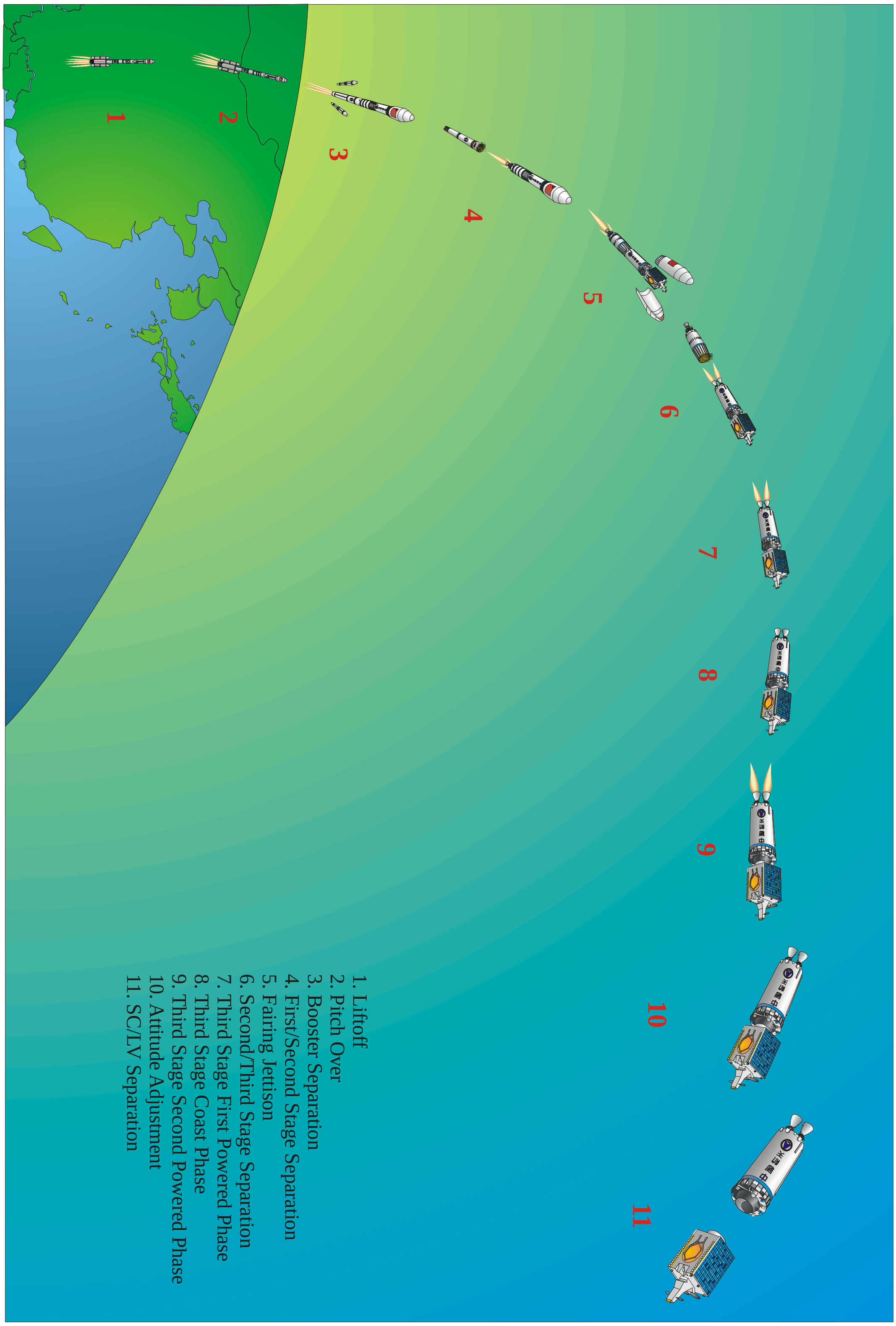


Figure 3-1 LM-3C Flight Sequence

3-3

3.2.3 Characteristic Parameters of Typical Trajectory

The characteristic parameters of typical trajectory are shown in **Table 3-2**.The flight acceleration, velocity, Mach numbers and altitude vs. time are shown in **Figure 3-2a** and **Figure 3-2b**.

Table 3-2 Characteristic Parameters of Typical Trajectory

Event	Flight Altitude (km)	Ground Distance (km)	SC projection Latitude (°)	SC projection Longitude(°)
Liftoff	1.825	0.000	28.246	102.027
Booster Shutdown	48.695	50.554	28.184	102.537
Boosters Separation	49.987	52.901	28.181	102.560
Stage-1 Shutdown	64.658	82.016	28.144	102.854
Stage-1/Stage-2 Separation	66.083	85.079	28.140	102.885
Fairing Jettisoning	147.509	374.700	27.723	105.790
Stage-2 Main Engine Shutdown	181.940	640.597	27.275	108.433
Stage-2 Vernier Engine Shutdown	184.323	663.370	27.233	108.659
Stage-2/Stage-3 Separation	184.786	667.927	27.225	108.704
Stage-3 First Shutdown	208.710	2464.996	22.775	125.847
Coast Phase Beginning	208.570	2490.003	22.699	126.076
Stage-3 Second Start	194.809	7295.242	3.232	165.880
Stage-3 Second Shutdown	215.792	8541.619	-2.454	175.552
Terminal Velocity Adjustment Ending	226.394	8730.789	-3.301	177.030
SC/LV Separation	295.051	9478.806	-6.626	182.908

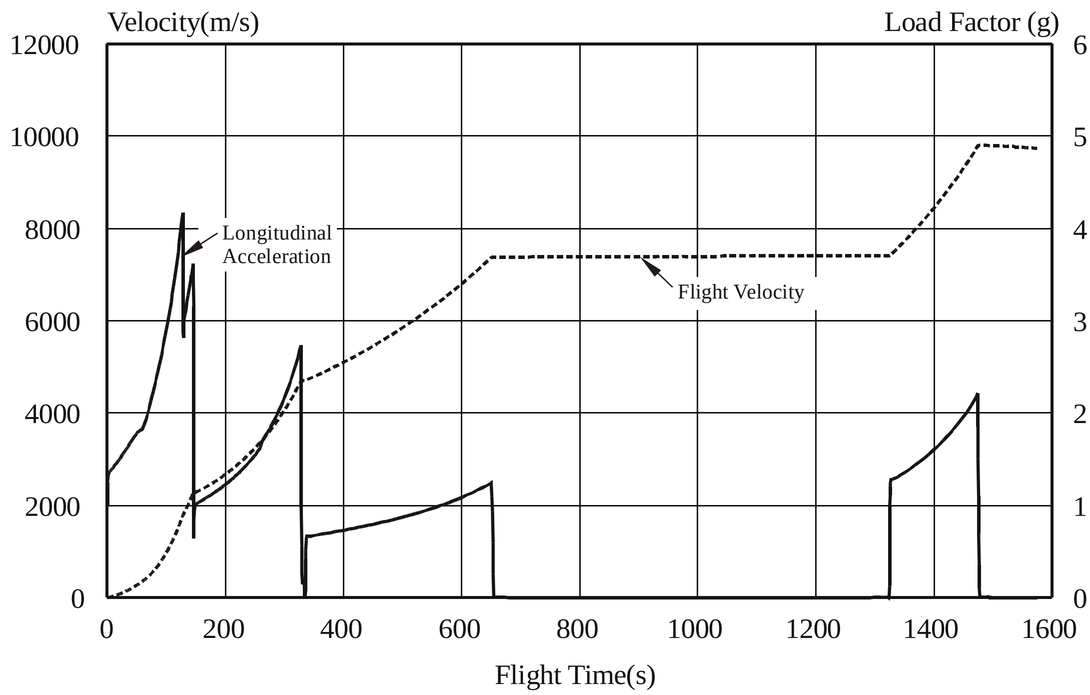


Figure 3-2a LV Flight Acceleration and Flight Velocity vs. Flight Time

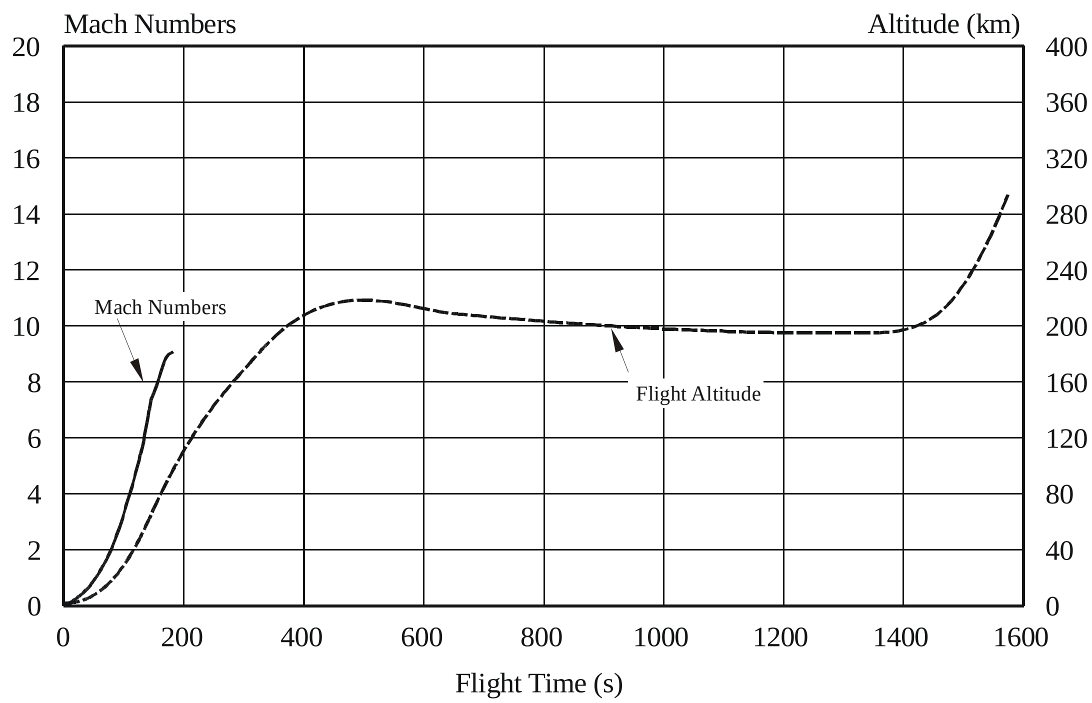


Figure 3-2b LV Flight Altitude and Mach Numbers vs. Flight Time

3.3 Standard Launch Capacities

3.3.1 Basic Information on XSLC

LM-3C launch vehicle conducts GTO mission from Xichang Satellite Launch Center (XSLC), which is located in Sichuan Province, China. LM-3C uses Launch Pad #2 of XSLC. The geographic coordinates are listed as follows:

Latitude:	28.2 °N
Longitude:	102.02 °E
Elevation:	1826 m

Launch Direction is shown in **Figure 3-3**.

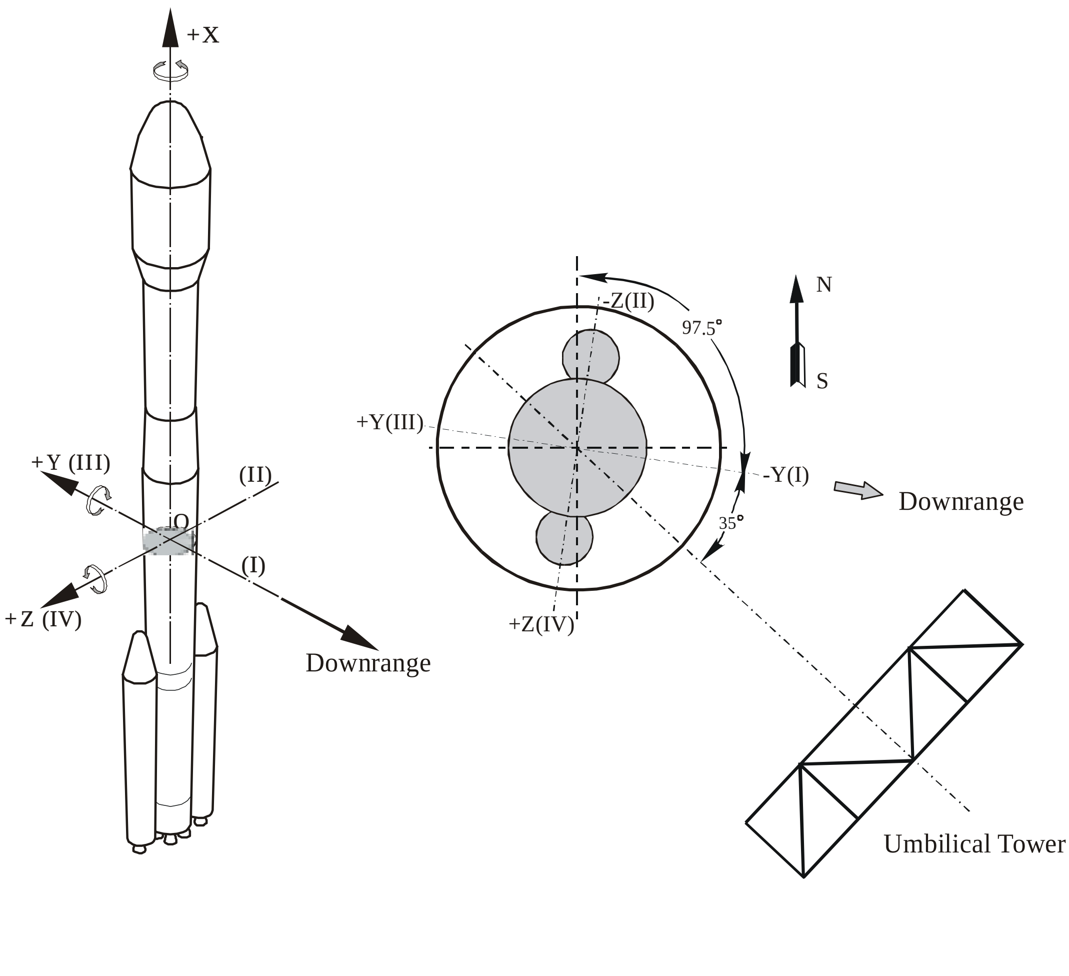


Figure 3-3 Launch Direction

3.3.2 Launch Capacity to Standard GTO

The LM-3C Standard GTO is defined in **Paragraph 3.2.1**, and see also **Figure 2-12** of **Chapter 2**.

LM-3C provides two kinds of fairing encapsulation methods: Encapsulation-on-pad and Encapsulation-in-BS3. Refer to **Chapter 8**. Therefore, LM-3C has different launch capacities corresponding to different encapsulation methods.

The launch capabilities corresponding to different Encapsulation Methods are listed as follows:

Encapsulation-on-pad:	3800 kg (recommended)
Encapsulation-in-BS3:	37000 kg

LM-3C provides 4 different types of fairings with different diameters (Φ4m and Φ4.2m) and different encapsulation methods. Refer to **Chapter 4**. For same encapsulation methods, the launch capacities will remain unchanged, because the structure mass difference between the Φ4m fairing and Φ4.2m fairing can be ignored.

If there is no special explanation, the standard GTO launch capacity (3800kg) stated in this User's Manual is corresponding to the LV with Encapsulation-on-pad method.

3.3.3 Mission Performance

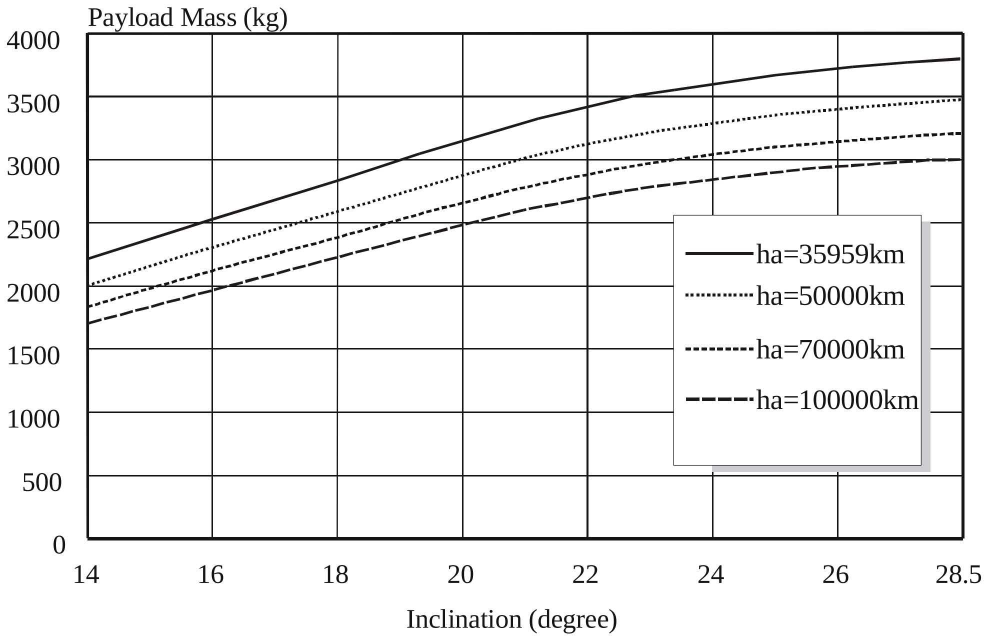
LM-3C can conduct various missions. The launch capacities for the four typical missions are introduced as follows, in which GTO mission is the prime mission.

- **GTO Mission**

The launch capacity of LM-3C for standard GTO mission is 3800kg. The different GTO launch capabilities vs. different inclinations and apogee altitudes are shown in **Figure 3-4** and **Figure 3-5**.

- **Low-Earth Orbit (LEO) Mission**

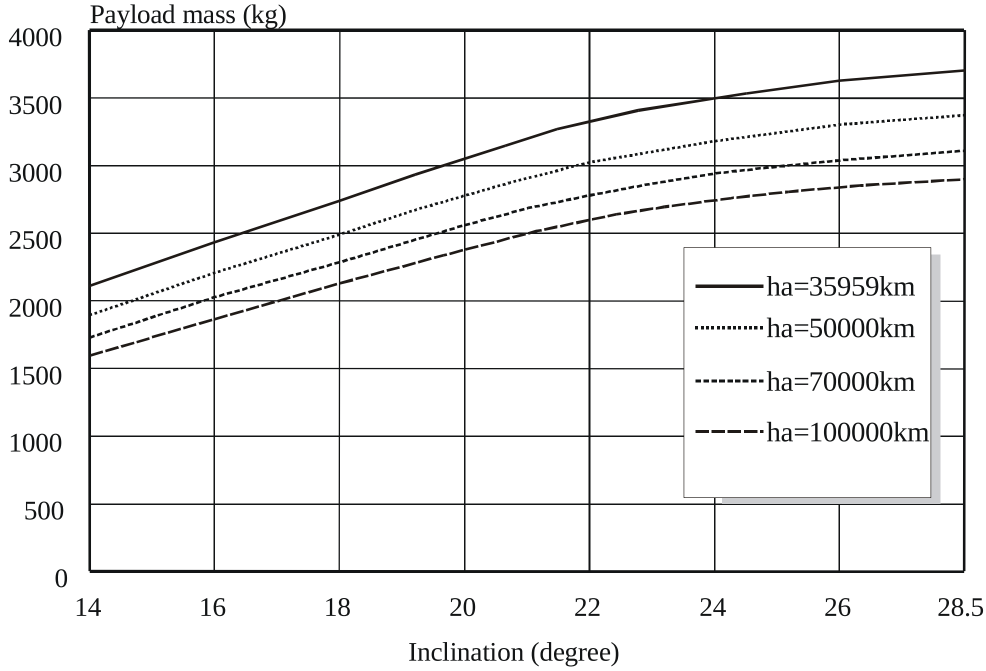
The Launch Capacity of LM-3C for LEO Mission (h=200 km, i=28.5°) is 9,100 kg.



(kg)

Inclination (deg.)	Apogee Altitude (km)			
	Ha=35959	Ha=50000	Ha=70000	Ha=100000
14.0	2215.0	2004.0	1835.0	1702.0
16.0	2532.0	2304.0	2121.0	1971.0
18.0	2834.0	2585.0	2385.0	2228.0
20.0	3150.0	2876.0	2658.0	2480.0
22.0	3420.0	3120.0	2882.0	2697.0
24.0	3600.0	3287.0	3039.0	2845.0
26.0	3721.0	3402.0	3141.0	2944.0
28.5	3800.0	3471.0	3210.0	3001.0

Figure 3-4 LM-3C GTO Launch Performance (Encapsulation-on-Pad)



(kg)

Inclination (deg)	Apogee Altitude (km)			
	35959	50000	70000	100000
14.0	2115	1904	1735	1602
16.0	2432	2204	2021	1871
18.0	2734	2485	2285	2128
20.0	3050	2776	2558	2380
22.0	3320	3020	2782	2597
24.0	3500	3187	2939	2745
26.0	3621	3302	3041	2844
28.5	3700	3371	3110	2901

Figure 3-5 LM-3C GTO Launch Performance (Encapsulation-in-BS3)

- **Sun-Synchronous Orbit (SSO) Mission**

LM-3C is capable of sending SC to SSO directly. The launch performance of LM-3C for SSO Mission is shown in **Figure 3-6**.

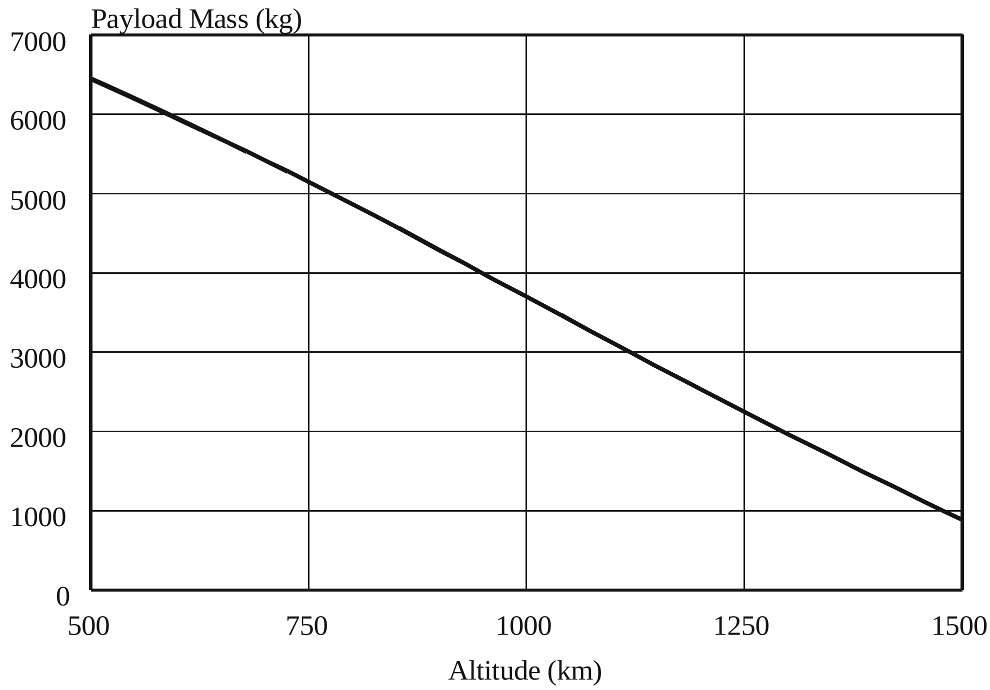


Figure 3-6 LM-3C SSO Launch Performance

- **Earth-Escape Mission**

The Earth-Escape Performance of LM-3C is shown in **Figure 3-7**. C3 is the square of the velocity at unlimited distance with unit of km^2/s^2.

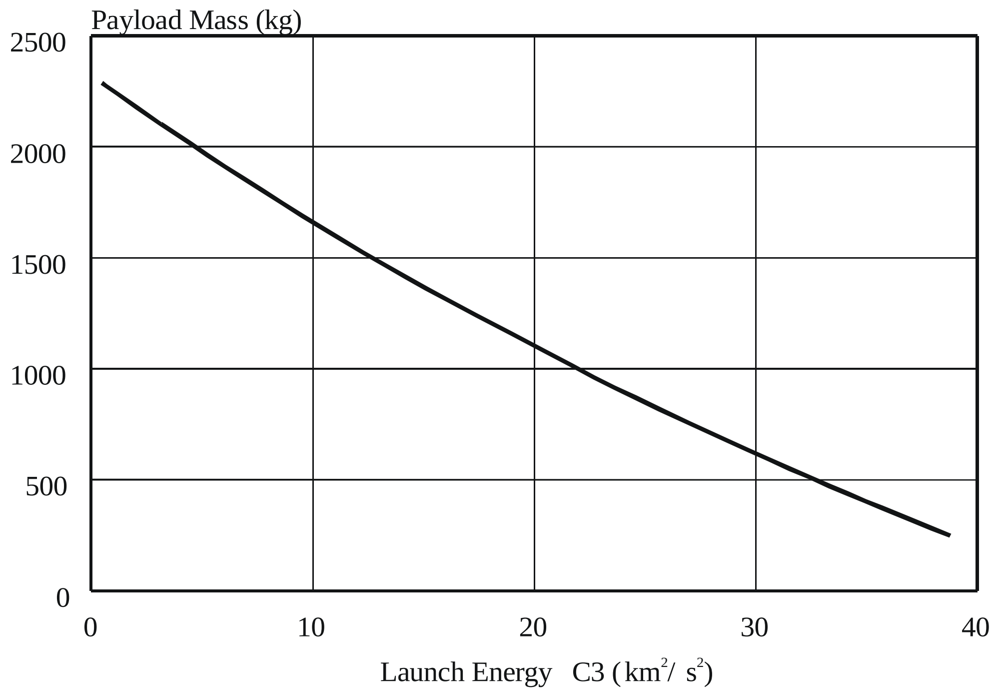


Figure 3-7 LM-3C Earth-Escape Mission Performance

3.4 Optimization Analysis on Special Missions

3.4.1 Ways to Enhance Mission Performance

3.4.1.1 Minimum Residual Shutdown (MRS)

The launch capacities given in **Paragraph 3.3** are gotten under condition of Commanded Shutdown (CS). Commanded Shutdown means, the third stage of LM-3C launch vehicle carries sufficient propellant allowing the payload to enter the predetermined orbit with probability no less than 99.73%. Commanded Shutdown is the main shutdown method that LM-3C adopts.

If the reserved propellants are reduced, the propellants will be used adequately, and the launch capability will be increased. However, the commanded shutdown probability will also be lower. The relationship between commanded shutdown probability and corresponding increased launch capability is shown in the following table.

Table 3-3 Relationship between Shutdown Probability and Launch Capability

Commanded Shutdown Probability	Increased Launch Capability (kg)
99.7%	0
95.5%	33
68.3%	67
50%	78

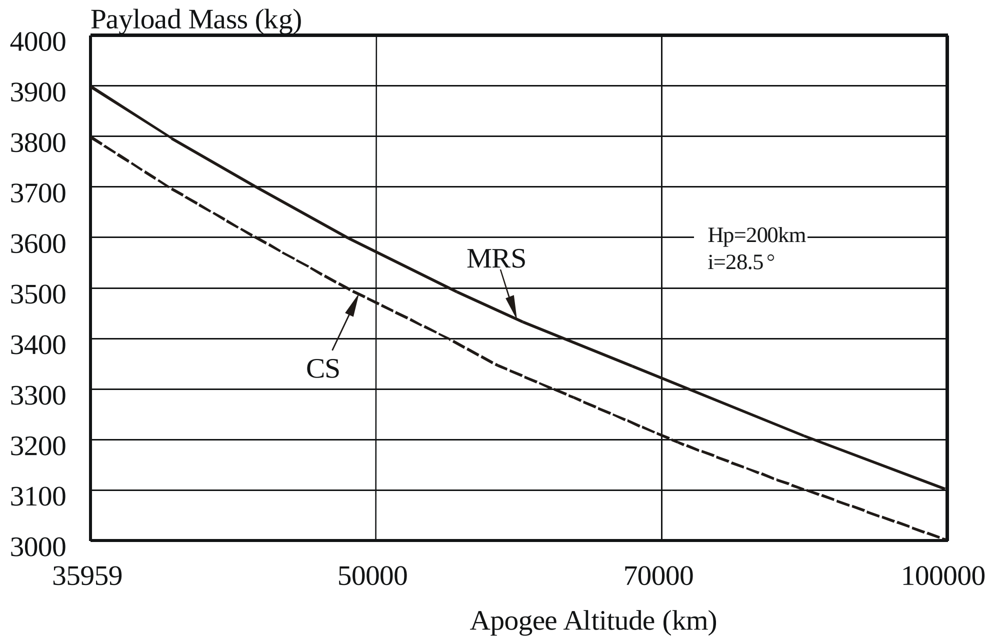
Minimum Residual Shutdown (MRS) means, the propellants of third stage is burned to minimum residuals for a significant increase in nominal performance capability. MRS is the designed capability of LM-3C.

The third stage of LM-3C is equipped with Propellant Utilization System (PUS). The deviation of LOX/LH2 mixture ratio can be compensated by PUS. The propellants can be consumed adequately, and the LV is under control and reliable. In this case, if the SC carries liquid propellants, it can flexibly execute orbit maneuver according to ground tracking data after SC/LV separation. Therefore, the third stage of LM-3C may be burned to minimum residuals to provide more LV energy to SC and to reduce the maneuver velocity of SC from GTO to GEO.

By using MRS and CS method, the different launch capacities of LM-3C with Encapsulation-on-pad configuration for GTO (i=28.5°) mission are shown in **Figure 3-8**.

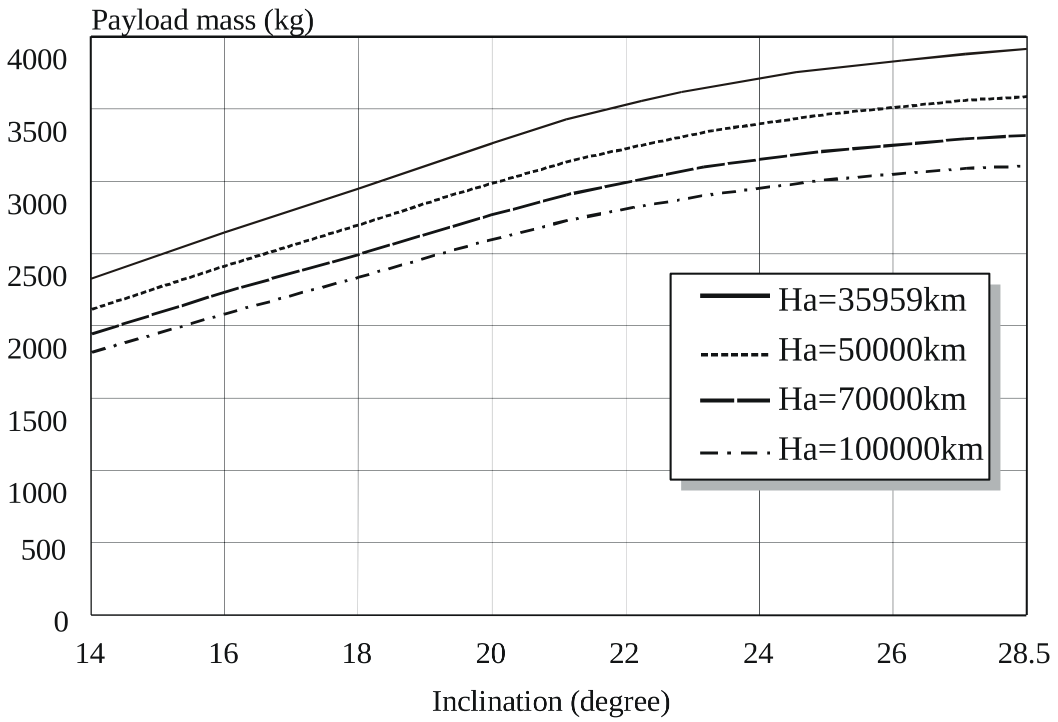
Under the condition of adopting MRS method, the launch capacity of LM-3C with Encapsulation-on-pad configuration for standard GTO mission is 3900kg, see **Figure 3-9**.

Under the condition of adopting MRS method, LM-3B provides users with more LV launch capacity. However, the orbital injection accuracy should be tolerated. If user is interested in this shutdown method, please contact CALT.



Apogee Altitude (km)	SC Mass (kg)	
Ha	CS	MRS
35959	3800.0	3900.0
50000	3471.0	3571.0
70000	3210.0	3321.0
100000	3001.0	3101.0

Figure 3-8 Launch Capacities under Different Shutdown Method (Encapsulation-on-pad)



Inclination (deg)	Apogee Altitude (km)			
	35959	50000	70000	100000
14.0	2315	2104	1935	1802
16.0	2632	2404	2221	2071
18.0	2934	2685	2485	2328
20.0	3250	2976	2758	2580
22.0	3520	3220	2982	2797
24.0	3700	3387	3139	2945
26.0	3821	3502	3241	3044
28.5	3900	3571	3310	3101

Figure 3-9 LM-3C GTO Mission Launch Capacity Under the Condition of MRS (Encapsulation-on-pad)

3.4.1.2 Super GTO Performance

For the same launch mission, different launch trajectories can be selected. For example, one method is to decrease the inclination by keeping apogee altitude unchanged, and the other method is to increase the apogee altitude i.e. “Super GTO launching method”.

Because the velocity of SC is relative low when the SC travels to the apogee of Super GTO, it is easier for SC to maneuver to 0°-inclination orbit. In this case, the propellants in SC are consumed less, and the lifetime of SC is longer. LM-3B has successfully launched Mabuhay, Apstar-IIR, ChinaStar-1 satellites to Super GTO.

When the SC mass is relative light, the remaining launch capacity of LM-3C can be used either for increasing apogee altitude or for reducing inclination. The injection accuracy for such a mission is different from that of Standard GTO mission.

The LM-3C launch capacities for Super GTO mission are shown in **Figure 3-4**, **Figure 3-5, Figure 3-9**.

3.4.2 Special Mission Requirements

The prime task of LM-3C is to perform standard GTO mission. However, LM-3C can be also used for special missions according to user’s requirement, such as Super GTO mission, SSO mission, LEO mission or lunar mission, Martian mission etc.

LM-3C is capable of Dual-launch and piggyback for GTO mission and multiple-launch for LEO mission.

3.5 Injection Accuracy

The injection accuracy for Standard GTO mission is shown in **Table 3-4a**.

Table 3-4a Injection Accuracy for Standard GTO Mission (1σ)

Symbol	Parameters	Deviation
Δa	Semi-major Axis	40 km
Δi	Inclination	0.07°
Δω	Perigee Argument	0.20°
ΔΩ	Right Ascension of Ascending Node	0.20°*
ΔHp	Perigee Altitude	10 km

Note: * the error of launch time is not considered in determining ΔΩ.

The covariance matrix of injection for Injection Accuracy of Standard GTO mission is shown **Table 3-4b**:

Table 3-4b covariance matrix of injection for Standard GTO mission

	a (Semi-major axis)	e (eccentricity)	i (inclination)	ω (argument of perigee)	Ω (ascending node)
a	1524	0.02492	0.5266	3.2344	-0.09688
e		0.52706E-6	0.8615E-5	0.6146E-4	0.5314E-8
i			0.4752E-2	0.1237E-3	-0.4212E-2
ω				0.03897	-0.01780
Ω					0.03927

3.6 Pointing Accuracy

3.6.1 Perigee Coordinate System Definition

During the period from 20 seconds after the third stage shutdown to SC/LV separation, the attitude control system on the third stage adjusts the pointing direction of the SC/LV stack to the pre-determined direction. It takes about 80 seconds to complete the attitude-adjustment operation. The pointing requirements are defined by the perigee coordinate system (U, V, and W). The user shall propose the pointing requirements. Before SC/LV separation, the attitude control system can maintain attitude errors of SC/LV stack less than 1°.

The perigee coordinate system (OUVW) is defined as follows:

- The origin of the perigee coordinate system (O) is at the center of the earth,
- OU is a radial vector with the origin at the earth center, pointing to the intended perigee.
- OV is perpendicular to OU in the intended orbit plane and points to the intended direction of the perigee velocity.
- OW is perpendicular to OV and OU and OUVW forms a right-handed orthogonal system.

See **Figure 3-10**.

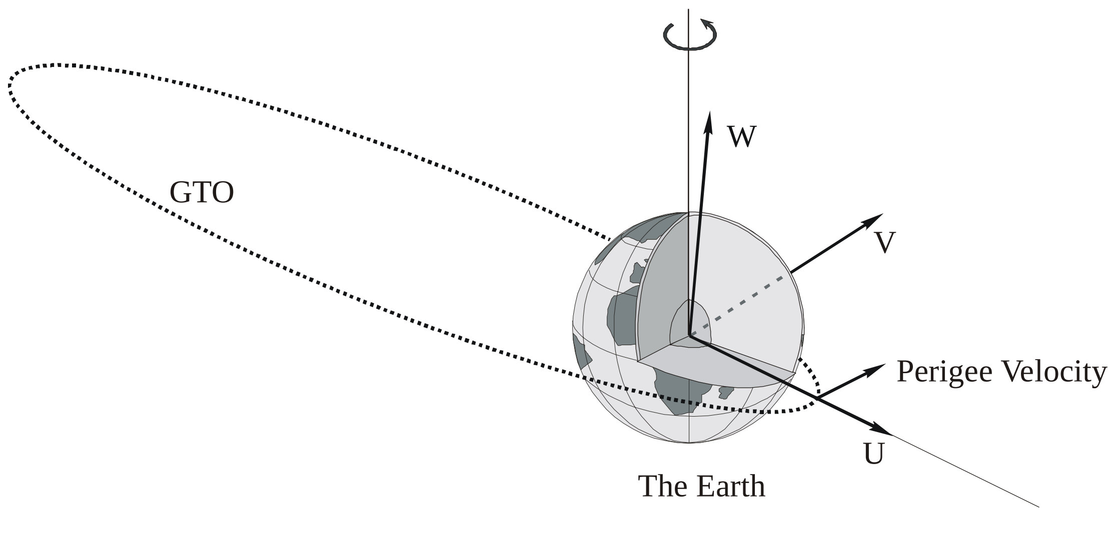


Figure 3-10 Perigee Coordinate System (OUVW)

3.6.2 Separation Accuracy

- For the SC needs spin-up rate along LV longitude axis (the spin-up rate from 5 rpm to 10 rpm), the post-separation pointing parameters are as follows:
  If: lateral angular rate: ω<2.5°/s
  Angular momentum pointing direction deviation: **δH**<8°

- For the SC needs spin-up rate along SC lateral axis (the spin-up rate less than 3°/s), the post-separation pointing parameters are as follows:
  If: lateral angular rate: ω<0.7°/s
  Angular momentum pointing direction deviation: **δH**<15°

- For the SC doesn't need spin-up, the post-separation pointing parameters are as follows:
  If: lateral angular rate: ω <1°/s (Combined in two lateral main inertial axes)
  Instant deviation at geometry axis: δx<3°

See **Figure 3-11**.

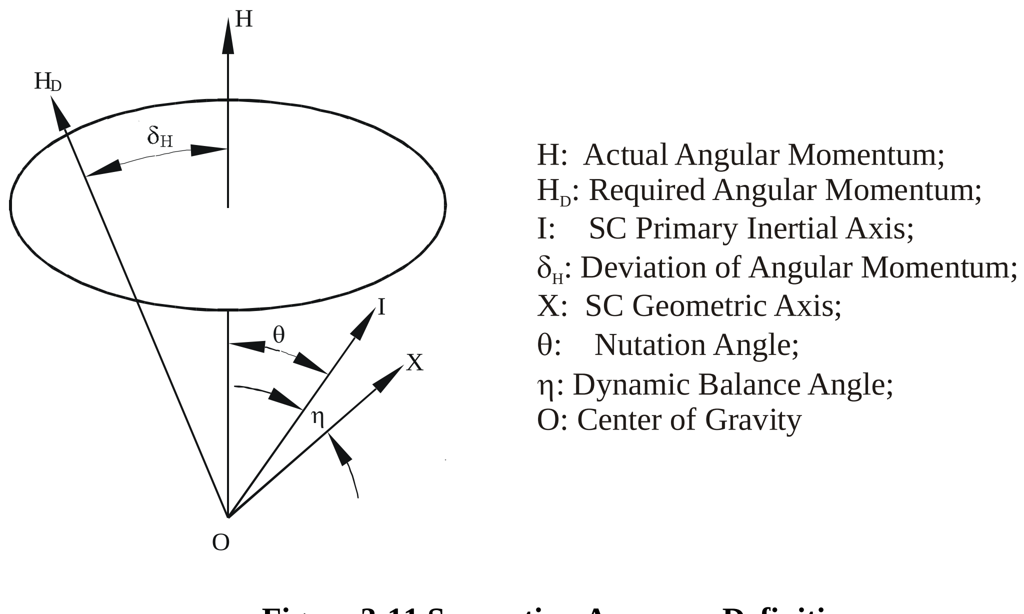


Figure 3-11 Separation Accuracy Definition

3.7 Spin-up Accuracy

3.7.1 Longitudinal Spin-up Accuracy

The attitude-control system of the third stage can provide the SC with spin-up rate of up to 10 rpm along LV longitude axis.

For the SC with longitudinal spin-up rate of 10rpm, the spin-up accuracy can be controlled in the range of 0~0.6rpm.

3.7.2 Lateral Spin-up Accuracy

By using of separation springs, the SC/LV separation system can provide SC with lateral spin-up rate of up to 3°/s along later axis of the SC.

For the SC with lateral spin-up rate of 3°/s, the spin-up accuracy can be controlled in the range of 2.2±0.8 °/s.

3.8 Launch Windows

Because the third stage of LM-3C uses cryogenic LH_2 and LOX as propellants and the launch preparation is relative complicated, the SC is expected to have at least one launch window within each day of the launch. In general, each launch window should be longer than 45 min. If the requirements are not complied by the payload, the user can consult with CALT.