CHAPTER 3

PERFORMANCE

The launch performance given in this chapter is based on the following assumptions:

- The LV system parameters being all nominal values;
- Mass of the LV adapter and the separation system are included in LV mass;
- The LV carrying sufficient propellant to reach the intended orbit with a probability of no less than 99.73%;
- The standard Φ4.2m fairing being adopted;
- At fairing jettisoning, the aerodynamic heating being less than 1135 W/m^2;
- Orbital altitude values given with respect to a mean radius of equator of 6378.140 km.

The LV can be launched from either JSLC or XSLC according to different mission requirements. JSLC is suitable for high-inclined LEO and SSO missions and XSLC for low-inclined LEO and GTO missions.

The launch capacity is related to range safety limitations and ground tracking requirements. For the specific missions, CALT will propose the launch capacities in the trajectory reports based on detailed performance optimization analyses.

Part A: Performance of Two-stage LM-2E and LM-2E/ETS

A3.1 LEO & SSO Mission Description

A3.1.1 Typical LEO & SSO Mission

- **Two-stage LM-2E Typical Mission**

Two-stage LM-2E is mainly used for conducting Low Earth Orbit (LEO) missions. Two typical LEO missions are recommended to the User.

✧ Two-stage LM-2E launches Spacecraft (SC) into a typical circular orbit with following injection parameters from JSLC.

Orbit Altitude	h	=200 km
Inclination	i	=53°

✧ Two-stage LM-2E can also launch Spacecraft (SC) into a typical LEO with following injection parameters from XSLC.

Orbit Altitude	*h*	=200 km
Inclination	*i*	=28.5°

- **LM-2E/ETS Typical Mission**

LM-2E/ETS is mainly used for Low Earth Orbit (LEO) and Sun-synchronous Orbit (SSO) missions. The typical LEO and SSO are recommended.

✧ LM-2E/ETS launches Spacecraft (SC) into a typical circular LEO with following injection parameters from JSLC.

Orbit Altitude	*h*	=1000km
Inclination	*i*	=53°

✧ LM-2E/ETS launches Spacecraft (SC) into a typical circular LEO with following injection parameters from JSLC.

Orbit Altitude	*h*	=1000km
Inclination	*i*	=86°

✧ LM-2E/ETS launches Spacecraft (SC) into a typical SSO with following injection parameters from JSLC.

Orbit Altitude	*h*	=1000km
Inclination	*i*	=99.5°

A3.1.2 Flight Sequence

- **Two-stage LM-2E Flight Sequence**

The typical flight sequence of LM-2E launching from JSLC is shown in **Table A3-1a**.

Table A3-1a LM-2E Flight Sequence

Events	Flight Time (s)
Liftoff	0
Pitch Over	12.000
Boosters Shutdown	139.336
Boosters Separation	140.836
Stage-1 Shutdown	158.411
Stage-1/Stage-2 Separation	159.911
Fairing Jettisoning	200.911
Stage-2 Main Engine Shutdown	464.637
Stage-2 Vernier Engine Shutdown	574.637
End of Attitude Adjustment	677.637
SC/LV Separation	680.937

- **LM-2E/ETS Flight Sequence**

The typical flight sequence of LM-2E/ETS launching from JSLC is shown in **Table A3-1b** and **Figure A3-1**.

Table 3-1b LM-2E/ETS Flight Sequence

Events	Flight Time (s)
Liftoff	0
Pitch Over	12.000
Boosters Shutdown	139.336
Boosters Separation	140.836
Stage-1 Shutdown	158.411
Stage-1/Stage-2 Separation	159.911
Fairing Jettisoning	200.911
Stage-2 Main Engine Shutdown	464.603

Stage-2 Vernier Engine Shutdown	574.603
Stage-2/ETS Separation	577.603
End of Coast Phase	3223.983
ETS Solid Motor Ignition	3223.983
ETS Solid Motor Shutdown	3283.580
Terminal Velocity Adjustment	3353.580
SC/LV Separation	3403.580

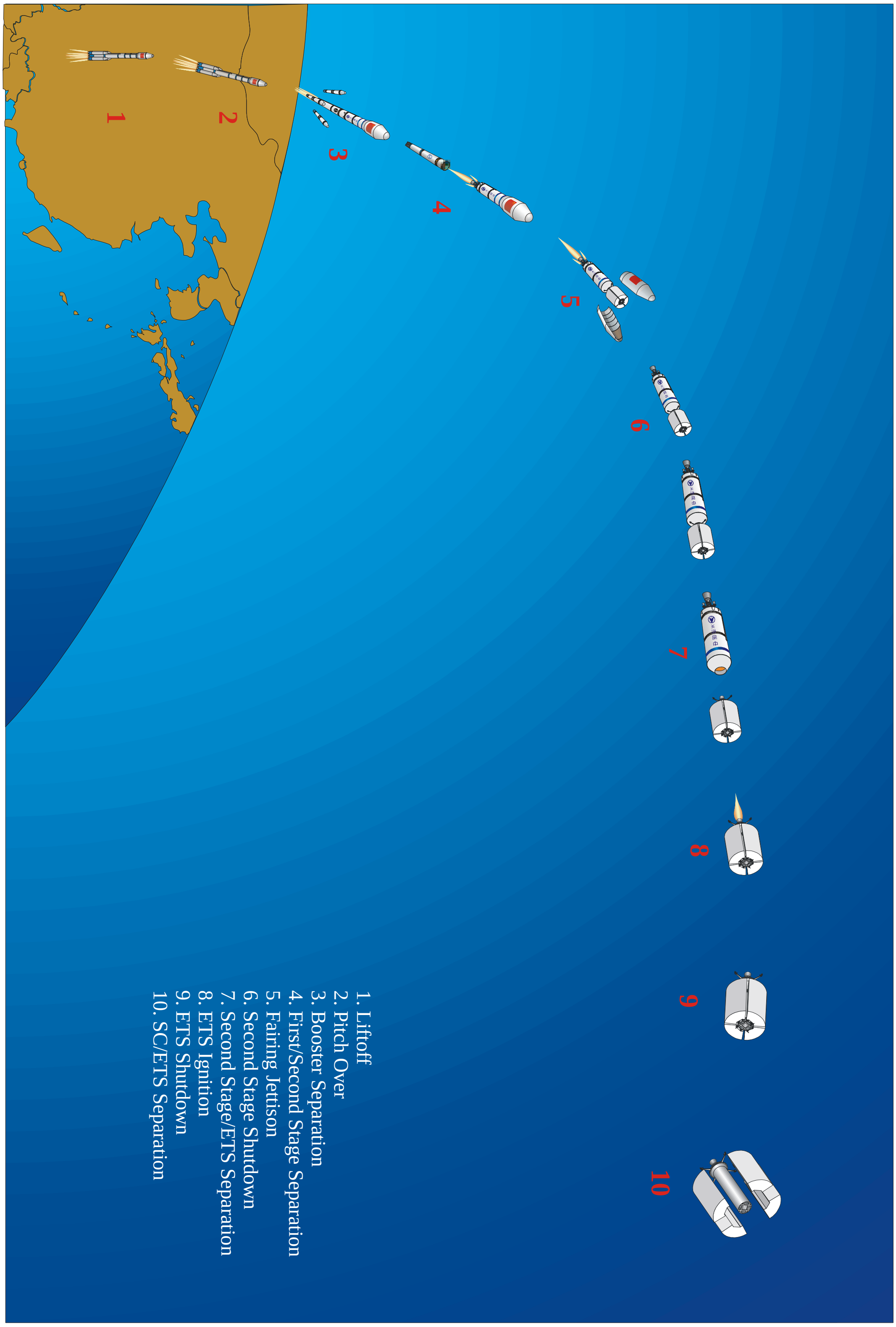

Figure A3-1 LM-2E/ETS Flight Sequence

3-5

A3.1.3 Parameters of Typical Trajectory

- **Two-stage LM-2E Characteristic Parameters**

The flight acceleration and altitude vs. time are shown in **Figure A3-2a**.

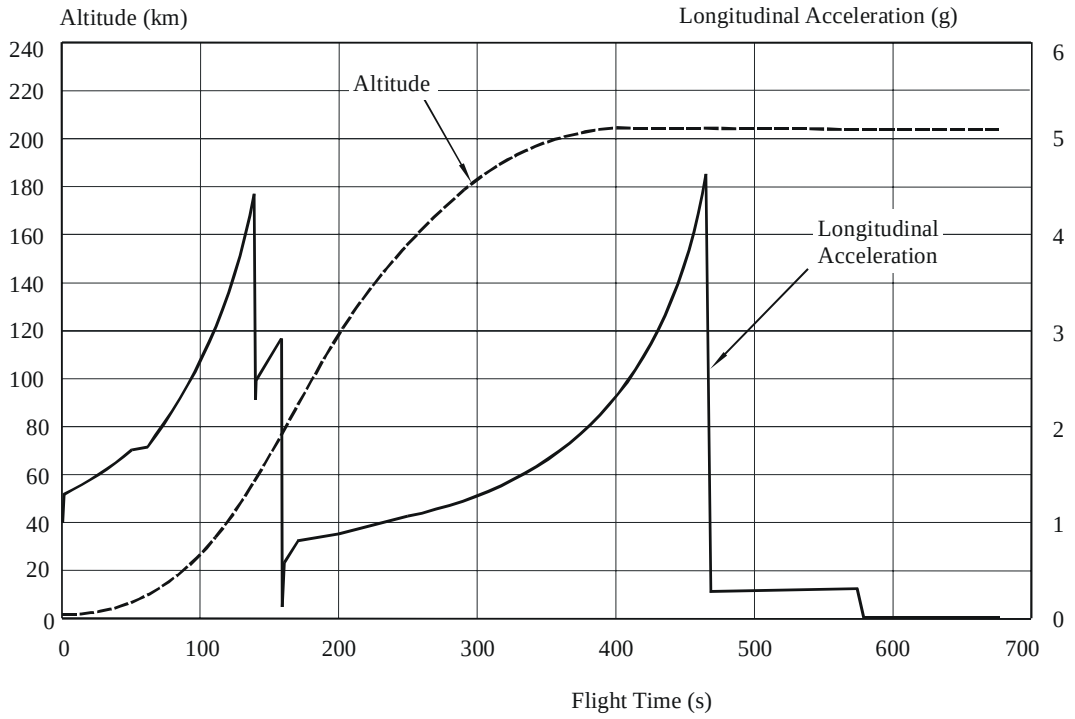

Figure A3-2a LM-2E Trajectory Parameters vs. Flight Time (200km Circular Orbit Mission from JSLC)

- **LM-2E/ETS Characteristic Parameters**

The flight acceleration and altitude vs. time are shown in **Figure A3-2b**.

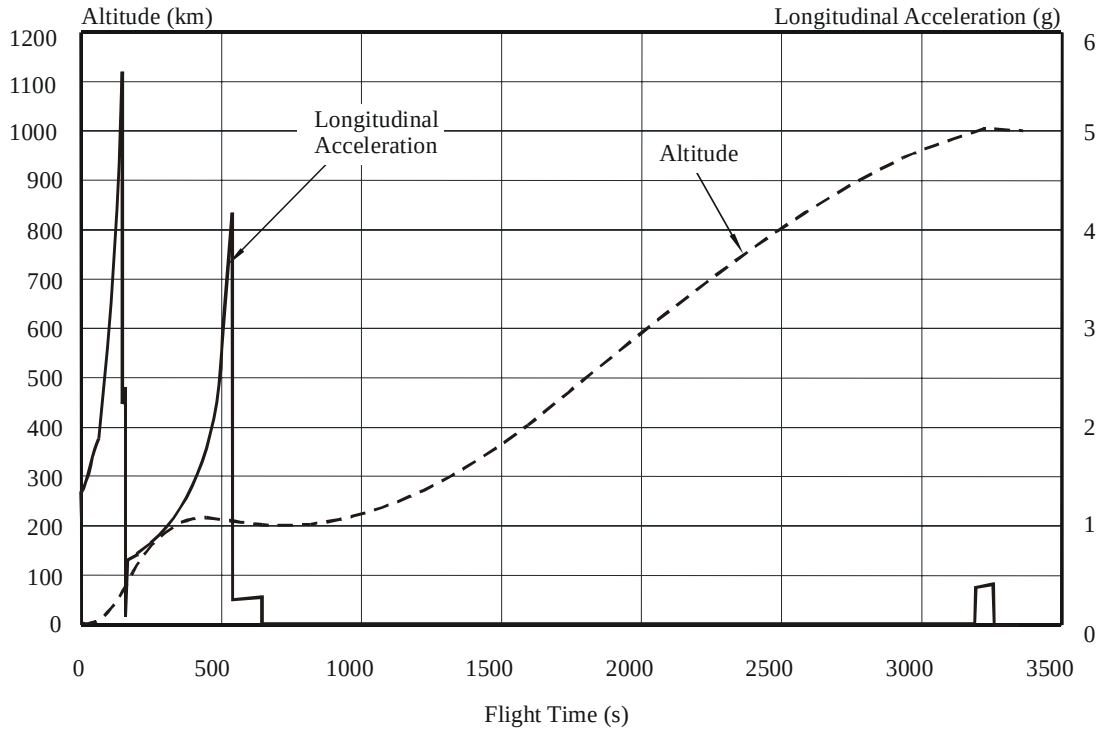

Figure A3-2b LM-2E/ETS Trajectory Parameters vs. Flight Time (1000km Circular Orbit Mission from JSLC)

A3.2 Launch Capacities

A3.2.1 Basic Information on Launch Sites

- **Jiuquan Satellite Launch Center (JSLC)**

Two-stage LM-2E and LM-2E/ETS conduct LEO and SSO missions from Jiuquan Satellite Launch Center (JSLC), which is located in Gansu Province, China. The geographic coordinates are listed as follows:

Latitude:	40.96°N
Longitude:	100 .29°E
Elevation:	1072m

The launch azimuth of LM-2E or LM-2E/ETS varies with different missions.

- **Xichang Satellite Launch Center (XSLC)**

Two-stage LM-2E conducts LEO mission from Xichang Satellite Launch Center (XSLC), which is located in Sichuan Province, China. LM-2E uses Launch Pad #2 of XSLC. The geographic coordinates are listed as follows:

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

The launch azimuth of LM-2E/EPKM at XSLC is 97.5°.

A3.2.2 Mission Performance

The launch capacities for the typical missions are introduced as follows.

- **Launch Capability of Two-stage LM-2E**

The launch capacity of Two-stage LM-2E for typical LEO mission (h=200km, i=28.5°) is 9500kg, and for typical LEO mission (h=200km, i=53°) is 8400kg. The different LEO launch capabilities vs. different inclinations and apogee altitudes are shown in **Figure A3-3a,b,c&d**.

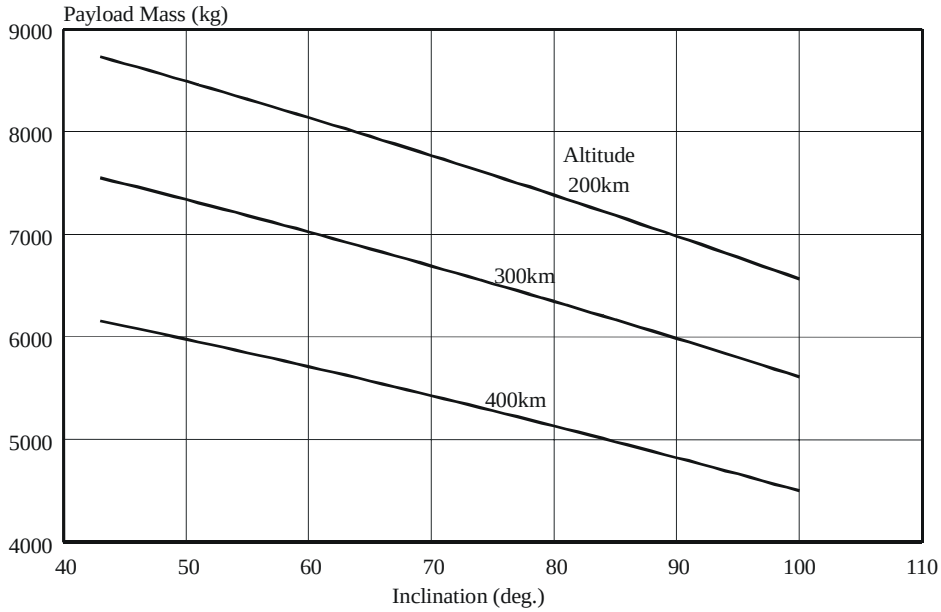

Figure A3-3a Two-stage LM-2E's Capability for Circular Orbit Mission (From JSLC)

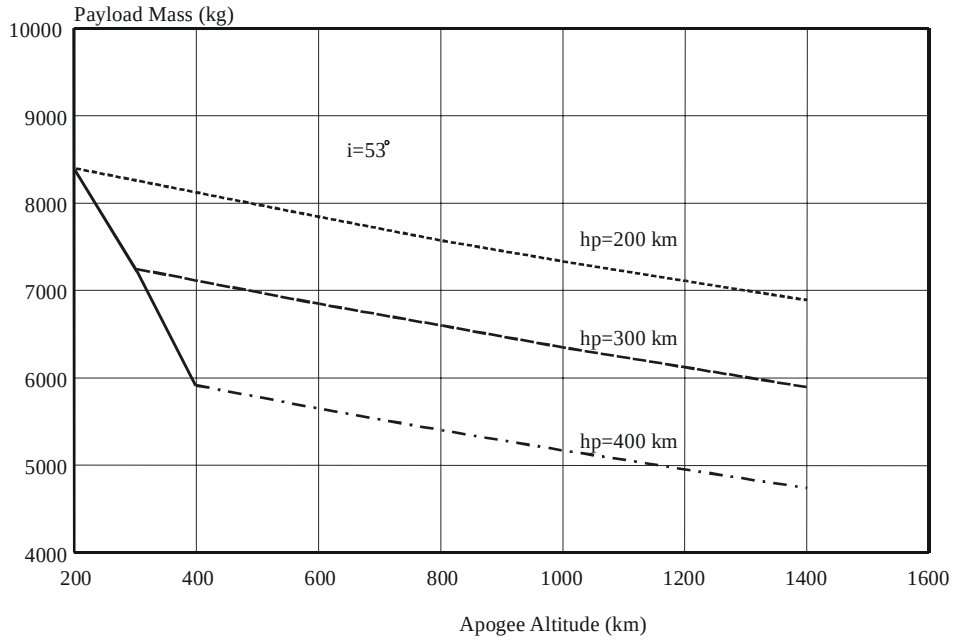

Figure A3-3b Two-stage LM-2E's Capability for Elliptic Orbit Mission (From JSLC)

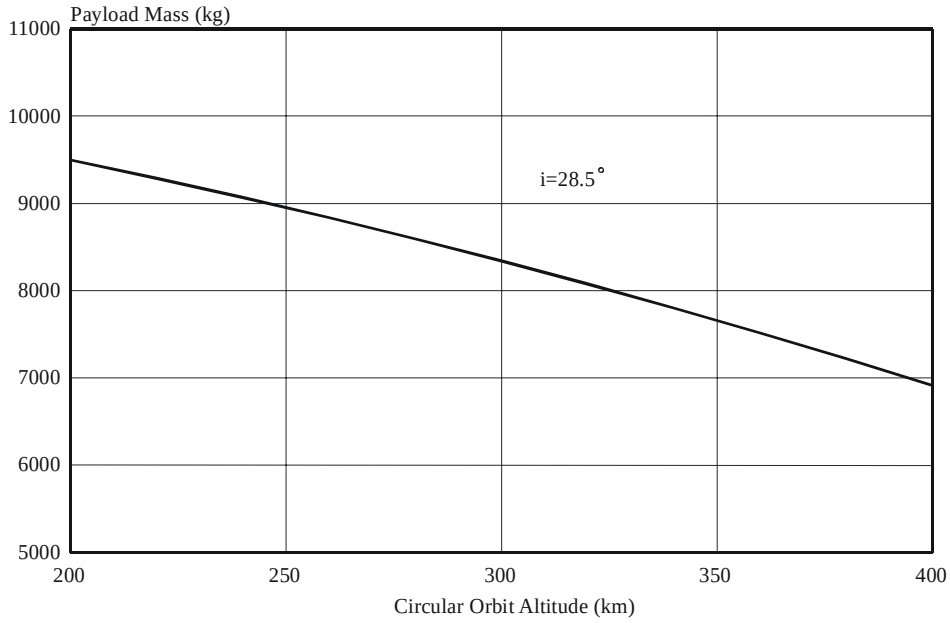

Figure A3-3c Two-stage LM-2E's Capability for Circular Orbit Mission (From XSLC)

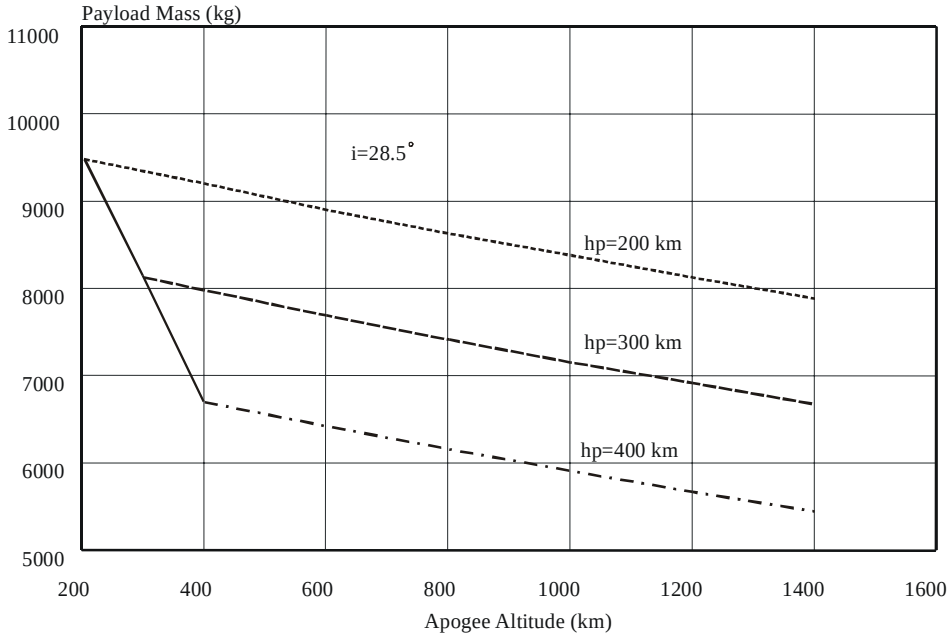

Figure A3-3d Two-stage LM-2E's Capability for Elliptic Orbit Mission (From XSLC)

- **LM-2E/ETS Launch Capability**

The launch capacity of LM-2E/ETS for typical LEO mission (h=1000km, i=53°) is 6060kg, and for typical LEO mission (h=1000km, i=86°) is 4930kg, and for SSO mission (h=1000km) is 4340kg. The different LEO and SSO launch capabilities vs. different inclinations and apogee altitudes are shown in **Figure A3-4a&b.**

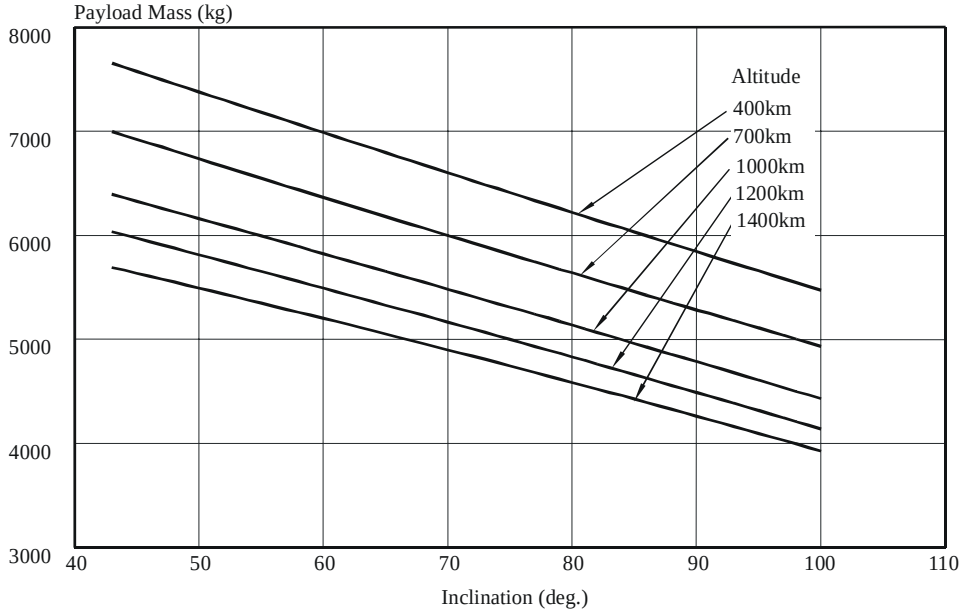

Figure A3-4a LM-2E/ETS' Capability for Circular Orbit Mission (From JSLC)

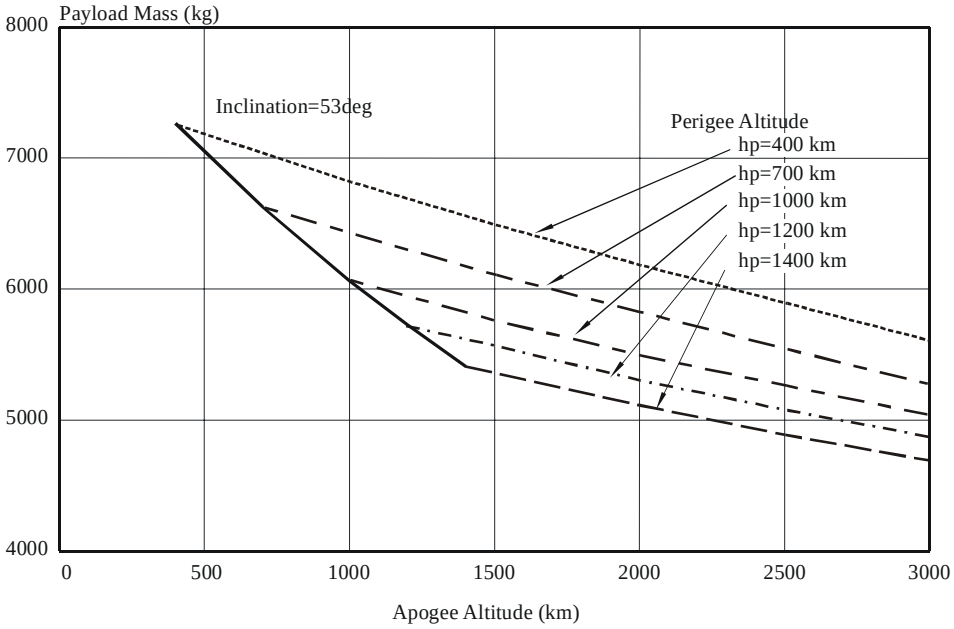

Figure A3-4b LM-2E/ETS' Capability for Elliptic Orbit Mission (From JSLC)

A3.3 Injection Accuracy

The injection accuracy is different for the different missions.

- **Two-stage LM-2E Injection Accuracy**

The injection accuracy for typical LEO (h=200km, i=53° and i=28.5°) missions launching from JSLC and XSLC is shown in **Table A3-2**.

Table A3-2 Injection Accuracy for Typical LEO Mission from JSLC (h=200km, i=53° and i=28.5°)

Symbol	Parameters	Deviation (1σ)
Δa	Semi-major Axis	***2.3 km***
Δi	Inclination	***0.05°***
ΔΩ	Right Ascension of Ascending Node	***0.10°***
ΔHp	Perigee Altitude	***2.0 km***

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

- **LM-2E/ETS Injection Accuracy**

The injection accuracy for typical LEO (h=1000km, i=53° and i=86°) missions launching from JSLC is shown in **Table A3-3**.

Table A3-3 Injection Accuracy for Typical LEO Mission from JSLC (h=1000km, i=53° and i=86°)

Symbol	Parameters	Deviation (1σ)
Δa	Semi-major Axis	***4.0 km***
Δi	Inclination	***0.05°***
ΔΩ	Right Ascension of Ascending Node	***0.10°***
ΔHp	Perigee Altitude	***3.0 km***

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

CALT will improve the injection accuracy in the future launches.

A3.4 Separation Attitude

For Two-stage LM-2E, the LV attitude control system adjusts the pointing direction of the SC/LV stack according to user's requirements. It will take about 100 seconds. The pointing error at separation is less than 1.5 degree.

For LM-2E/ETS, the ETS attitude control system adjusts the pointing direction of the SC/ETS stack according to user's requirements. The pointing error at separation is less than 1.5 degree.

A3.5 SC Tip-off Rates

The angular rates introduced into the SC at separation consist two parts: one from the separation system and the other from the residual rates of ETS or LV second stage. The angular rates depend on the separation scenarios of the SC separation system.

For spin-up separation scenario, the total angular rate shall not exceed 10 deg./sec in x-axis and 2 degrees/sec in y & z-axis.

For non-spin-up separation scenario, the residual rates of ETS or LV stage-2 will not exceed 0.5 degrees/sec in all axes, and the angular rates from the dispenser (separation system) shall not exceed 1.5 degrees/sec in x, y & z-axis, so that the total angular rate shall not exceed 2.0 degrees/sec in x, y & z-axis.

A3.6 Separation Velocity

For Two-stage LM-2E, the separation force generated by LV separation mechanism will give the SC a velocity in a range of 0.5~0.9m/s when conducting single launch. When conducting multiple-launch, LM-2E can provide the SCs with different separation velocities in order to avoid re-contact after separation.

For LM-2E/ETS, the separation force generated by ETS separation mechanism will give the SC a velocity in a range of 0.5~0.9m/s when conducting single launch. When conducting multiple-launch, The ETS can provide the SCs with different separation velocities in order to avoid re-contact after separation.

A3.7 Spin-up

For Two-stage LM-2E, the attitude-control system of the LV can spin up the SC to 7 rpm along LV longitude axis.

For LM-2E/ETS, the attitude-control system of the ETS is able to spin up the ETS/SC stack according to user's need.

A3.8 Collision and Contamination Avoidance Maneuver

Following SV/LV separation, the LV will perform a series of maneuvers to prevent re-contact with the SVs and minimize SVs exposure to LV contaminants. The maneuvers to be performed by LV are different for the different LV configurations which consist of stage-2 insertion and ETS insertion.

A3.8.1 Stage-2 Insertion

For stage-2 insertion, the maneuvers are performed by the second stage.

The second stage flight can be divided into 5 phases: main engine working phase, vernier engines working phase, re-orientation phase, SC/LV separation phase and vehicle de-orbit phase.

At the time of main engine shut-off, LV control system send signals to shut off the valves of the engine for the propellant supply so as to shut the engine.

The sub-sequence after shut-off of the vernier engines is:

- to adjust the SC to the attitude of separation;
- to separate the SC;
- to adjust the LV stage-2 to the attitude of de-orbit;
- to re-open the valves.

At the time of vernier engines shut-off, there are residual propellants and pressurization gas in the tanks. After the stage-2 is re-orientated to the de-orbiting direction, the deorbiting of stage-2 will be carried out by depletion of the propellants.

A3.8.2 ETS Insertion

For ETS insertion, the maneuvers are performed by the ETS.

After the SC separate from the ETS, the ETS will re-orient to deorbiting direction. The deorbiting of ETS will be carried out by depletion of the attitude control system.

A3.9 Launch Windows

If weather permitted, Two-stage LM-2E or LM-2E/ETS can be launched at any time of the day. The recommended launch window is longer than 45 min.

Part B: Performance of LM-2E/EPKM

B3.1 GTO Mission Description

B3.1.1 Typical GTO Missions

LM-2E/EPKM is mainly used for conducting Geo-synchronous Transfer Orbit (GTO) missions. The typical GTO is recommended to the User.

✧ LM-2E launches Spacecraft (SC) into the typical GTO with following injection parameters from XSLC.

Perigee Altitude	*Hp*	=200km
Apogee Altitude	*Ha*	=35786km
Inclination	*i*	=28.5°

B3.1.2 LM-2E/EPKM Flight Sequence

The typical flight sequence of LM-2E/EPKM is shown in **Table B3-1**.

Table B3-1 LM-2E/EPKM Flight Sequence

Events	Flight Time (s)
Liftoff	0
Pitch Over	12.000
Boosters Shutdown	139.336
Boosters Separation	140.836
Stage-1 Shutdown	158.411
Stage-1/Stage-2 Separation	159.911
Fairing Jettisoning	200.911
Stage-2 Main Engine Shutdown	464.637
Stage-2 Vernier Engine Shutdown	574.637
End of Attitude Adjustment	677.637
Stage-2/EPKM Separation	680.937
End of Coast Phase	1320.755
EPKM Solid Motor Ignition	1320.755
EPKM Solid Motor Shutdown	1401.848
SC/LV Separation	1404.848

B3.1.3 Parameters of Typical Trajectory

The flight acceleration and altitude vs. time are shown in **Figure B3-1**.

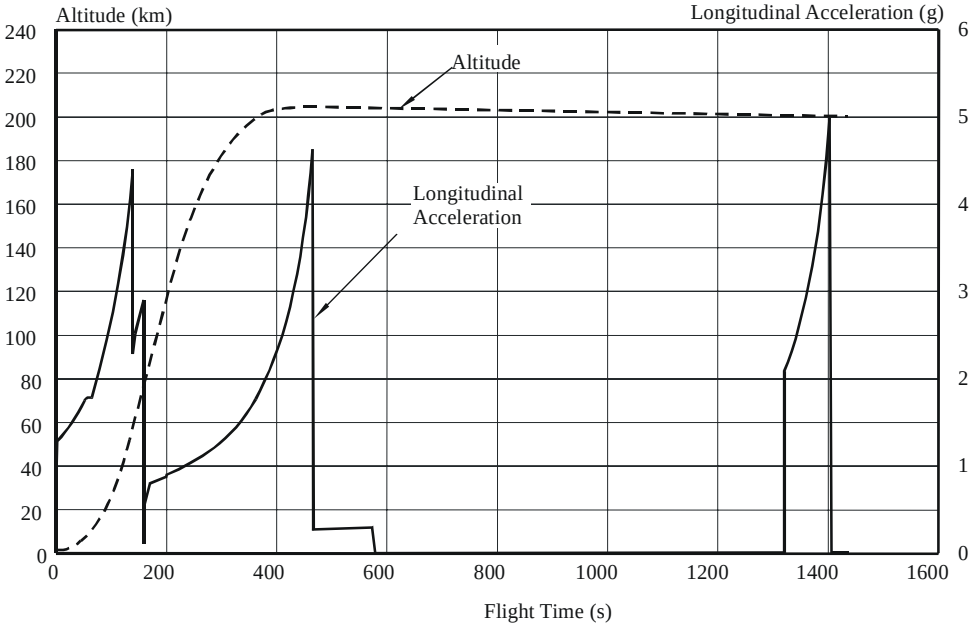

Figure B3-1 LM-2E/EPKM's Trajectory Parameters vs. Flight Time (GTO Mission from XSLC)

B3.2 Launch Capacities

B3.2.1 Basic Information on Launch Sites

- **Xichang Satellite Launch Center (XSLC)**

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

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

The launch azimuth of LM-2E/EPKM at XSLC is 97.5°.

B3.2.2 Mission Performance

- **GTO Mission**

The launch capacity of LM-2E/EPKM for Typical GTO mission (hp=200km, ha=35786km, i=28.5°) is 3500kg. The different GTO launch capabilities vs. different inclinations and apogee altitudes are shown in **Figure B3-2.**

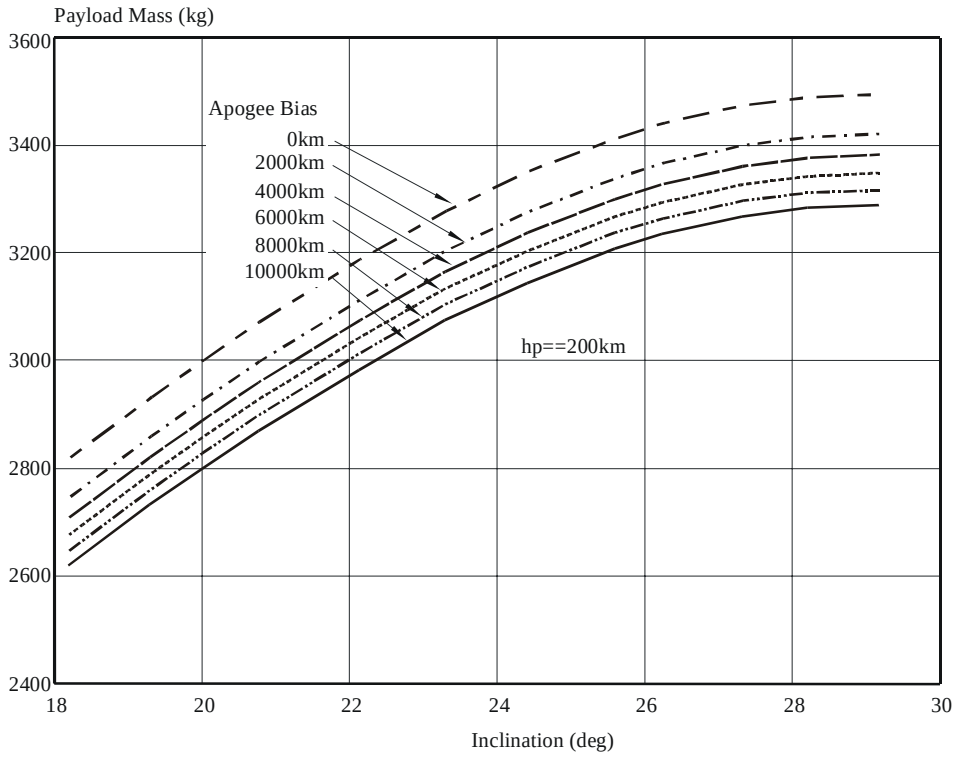

Figure B3-2 LM-2E/EPKM GTO Capability (From XSLC)

- **Planetary Mission**

LM-2E/EPKM can also conduct planetary mission, its capability is shown in **Figure B3-3.**

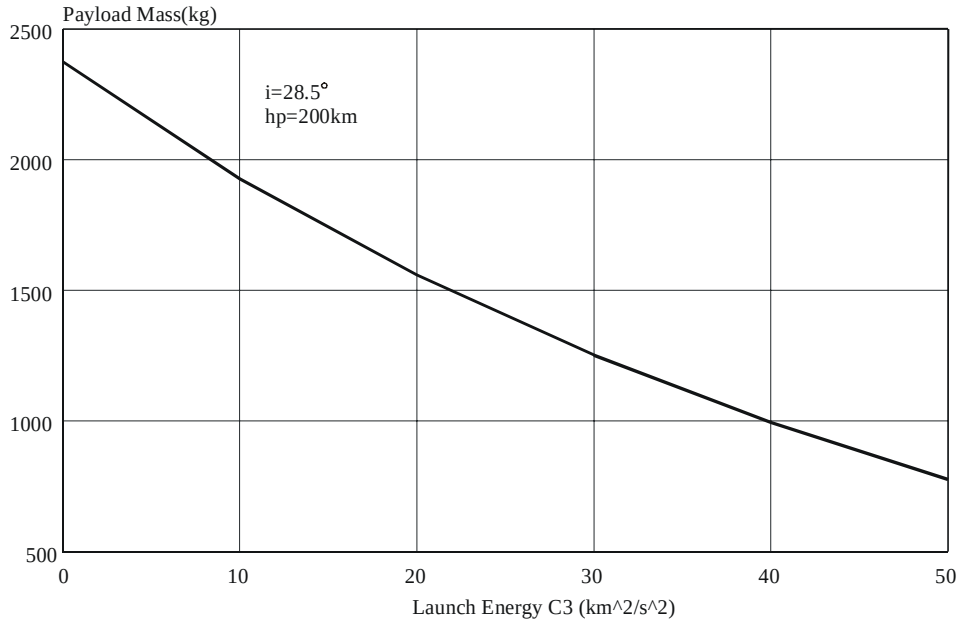

Figure B3-3 LM-2E/EPKM Capability for Planetary Mission (From XSLC)

B3.3 LM-2E/EPKM Injection Accuracy

The injection accuracy for typical GTO (hp=200km, ha=35786km, i=28.5°) mission from XSLC is shown in **Table B3-2**.

Table B3-2 Injection Accuracy for Typical GTO Mission (hp=200km, ha=35786km, i=28.5°)

Symbol	Parameters	Deviation (1σ)
Δa	Semi-major Axis	***650 km***
Δi	Inclination	***0.3°***
Δω	Perigee Argument	***0.7°***
ΔΩ	Right Ascension of Ascending Node	***0.4°***
ΔHp	Perigee Altitude	***6.0 km***

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

B3.4 Separation Attitude

The pointing error and attitude angular rate error at separation can meet user's requirements.

B3.5 Separation Velocity

The separation velocity generated by LM-2E/EPKM can meet user's requirements.

B3.6 Spin-up

LM-2E/EPKM can spin up the SC according to user's need.

B3.7 Launch Windows

If weather permitted, LM-2E/EPKM can be launched at any time of the day. The recommended launch window is longer than 45 min.