CHAPTER 2

GENERAL DESCRIPTION TO LM-2E

2.1 Summary

Long March 2E (LM-2E) is developed based on the mature technologies of LM-2C. China Academy of Launch Vehicle Technology (CALT) started the conceptual design of LM-2E in 1986, when LM-2C had a high success rate, 7 consecutive successful flights. LM-2E takes the lengthened LM-2C as the core stages, which is strapped with four liquid boosters. The diameter of the fairing is 4.2 meters.

LM-2E was put into the launch service market in 1992, after its demonstration flight in July 1990. LM-2E is mainly used for low earth orbit (LEO) missions, of which the launch capacity is 9500kg for the standard orbit (h=200km, i=28.5°).

LM-2E launch vehicle consists of three versions:
- Basic version: Two-stage LM-2E for LEO missions;
- Three-stage version-1: LM-2E/ETS for LEO (h>400km) and SSO missions; ETS is a three-axis stabilized upper stage which is capable of delivering one or more satellites.
- Three-stage version-2: LM-2E/EPKM for GTO missions; EPKM is a spin stabilized upper stage.

LM-2E provides flexible interfaces, both mechanical and electrical, for various SCs. The launch environment impinging on SC, such as vibration, shock, pressure, acoustics, acceleration and thermal environment, meets the common requirements in the commercial launch services market.

2.2 Technical Description

2.2.1 Major Characteristics of LM-2E

LM-2E is a two-stage launch vehicle with four strap-on boosters. The total length of LM-2E is 49.686 meters. The diameter of the fairing is 4.2 meters. The storable propellants of N₂O₄/UDMH are fueled. The lift-off mass is 460 tons, and lift-off thrust is 5880 kN. Table 2-1 shows the major characteristics of LM-2E.
Table 2-1 Technical Parameters of LM-2E

<table>
<thead>
<tr>
<th>Stage</th>
<th>Boosters</th>
<th>First Stage</th>
<th>Second Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mass of Propellant (t)</td>
<td>37.768×4</td>
<td>186.306</td>
<td>84.777</td>
</tr>
<tr>
<td>Engine</td>
<td>DaFY5-1</td>
<td>DaFY6-2</td>
<td>DaFY20-1(main)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>DaFY21-1(verniers)</td>
</tr>
<tr>
<td>Thrust (kN)</td>
<td>740.4×4</td>
<td>2961.6</td>
<td>741.4 (main)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>11.8×4(verniers)</td>
</tr>
<tr>
<td>Specific Impulse (N.s/kg)</td>
<td>2556.2 (On ground)</td>
<td>2556.5 (On ground)</td>
<td>2922.37(main)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2834.11(verniers) (In vacuum)</td>
</tr>
<tr>
<td>Stage Diameters (m)</td>
<td>2.25</td>
<td>3.35</td>
<td>3.35</td>
</tr>
<tr>
<td>Stage Length (m)</td>
<td>15.326</td>
<td>28.465</td>
<td>15.188</td>
</tr>
</tbody>
</table>

2.3 LM-2E System Composition

LM-2E consists of rocket structure, propulsion system, control system, telemetry system, tracking and safety system, separation system, etc.

2.3.1 Rocket Structure

The rocket structure functions to withstand the various internal and external loads on the launch vehicle during transportation, hoisting and flight. The rocket structure also combines all sub-systems together. The rocket structure is composed of first stage, second stage and boosters.

The first stage includes inter-stage section, oxidizer tank, inter-tank section, fuel tank, rear transit section, tail section, propellant feeding system, etc. The second stage includes payload adapter, vehicle equipment bay (VEB), oxidizer tank, inter-tank section, fuel tank, propellant feeding system, and fairing etc. The payload adapter connects the SC with LM-2E and conveys the loads between them. The booster consists of nose dome, oxidizer tank, inter-tank section, fuel tank, rear transit section, propellant feeding system, etc.

See Figure 2-1 for LM-2E/ETS configuration.
Figure 2-1 LM-2E/ETS Configuration

1. Fairing
2. Satellites
3. Dispenser
4. Payload Adapter
5. ETS Solid Motor
6. Vehicle Equipment Bay
7. Second Stage Oxidizer Tank
8. Inter-tank Section
9. Second Stage Fuel Tank
10. Inter-stage Section
11. Second Stage Vernier Engines
12. Second Stage Main Engine
13. Exhaust Vents
14. First Stage Oxidizer Tank
15. Inter-tank Section
16. First Stage Fuel Tank
17. Tail Section
18. First Stage Engine
20. Booster's Fuel Tank
21. Inter-tank Section
22. Booster's Oxidizer Tank
23. Booster's Cone
2.3.2 Propulsion System

The propulsion system, including engines and pressurization/feeding system, generates the thrust and control moments for flight. Refer to Figure 2-2a&b.

The first stage, boosters and second stage employ storable propellants, i.e. nitrogen tetroxide (N\textsubscript{2}O\textsubscript{4}) and unsymmetrical dimethyl hydrazine (UDMH). The propellant tanks are pressurized by the self-generated pressurization systems. There are four engines in parallel attached to the first stage. The four engines can swing in tangential directions. The thrust of each engine is 740.4kN. The boosters use the same engines. There are one main engine and four vernier engines on the second stage. The total thrust is 788.5kN.

The propulsion system has experienced a lot of flights and its performance is excellent. Figure 2-2a indicates the system schematic diagram of the first stage engines, Figure 2-2b shows the system schematic diagram of the second stage engine.

2.3.3 Control System

The control system is to keep the flight stabilization of launch vehicle and to perform navigation and/or guidance according to the preloaded flight software. The control system consists of guidance unit, attitude control system, sequencer, power distributor, etc. See Figure 2-3a,b&c for the system schematic diagram of the control system.

The guidance unit provides movement and attitude data of the LV and controls the flight according to the predetermined trajectory. The attitude control system controls the flight attitude to ensure the flight stabilization and SC injection attitude. The system re-orient LM-2E following the shut-off of vernier engines on Stage-2. The launch vehicle can spin up the SC according to the requirements from the users. The spinning rate can be up to 10rpm. The sequencer and power distributor are to supply the electrical energy for control system, to initiate the pyrotechnics and to generate timing signals for some events.

2.3.4 Telemetry System

The telemetry system functions to measure and transmit some parameters of the launch vehicle systems. The telemetry system consists of two segments, on-board system and ground stations. The on-board system includes sensors/converters, intermediate devices, battery, power distributor, transmitter, radio beacon, etc. The ground station is equipped with antenna, modem, recorder and data processor. The telemetry system provides initial
injection data and real-time recording to the telemetry data. Totally, 460 telemetry parameters are available from LM-2E. Refer to Figure 2-4.

2.3.5 Tracking and Range Safety System

The tracking and range safety system works along with the ground stations to measure the trajectory data and final injection parameters. The system also provides range safety assessment. The range safety system works in automatic mode and remote-control mode. The trajectory measurement and range safety control design are integrated together. See Figure 2-5, and refer to Chapter 9.
Figure 2-2a First Stage Propulsion System Schematic Diagram
Claim's Proprietary

Figure 2-2b Second Stage Propulsion System Schematic Diagram
Figure 2-3b Attitude-control System Schematic Diagram

- Rate Gyros
- Inertial Platform
- On-board Computer
- Power Amplifier
- Servo Mechanism
- Gimbal Engines
- Nozzle
- LV Kinematic Equation
- Feedback
- ETS Coast Phase
- Powered Phase
- Attitude Control
Accelerometers
Attitude Angles
Apparent Accelerations
X, Y, Z
Inertial Platform
Velocity
Position
Guidance Calculation
On-board Computer
Engine Shutdown
Guidance Signal
Navigation
Figure 2-3c: Guidance System Schematic Diagram
2.3.6 Separation System

There are four separation events during two-stage LM-2E flight phase, i.e. Booster Separations, Stage-1/Stage-2 Separation, Fairing Jettisoning and SC/LV Separation.

- **Booster Separations:** The boosters are mounted to the core stage through three sets of pyro-mechanisms at the front section and separation mechanism at the rear section. Four small rockets generate outward separation force following the simultaneous unlocking of the separation mechanisms.

- **Stage-1/Stage-2 Separation:** The stage-1/stage-2 separation takes hot separation, i.e. the second stage is ignited first and then the first stage is separated away under the jet of the engine after the 14 explosive bolts are unlocked.

- **Fairing Jettisoning:** During the fairing separation, the 12 explosive bolts connecting the fairing with the second stage and 4 ones connecting two halves unlocked firstly and then the pyrotechnics attached to the zippers connecting the two fairing shells are ignited, and the fairing separated longitudinally. The fairing turn outward around the hinges under the spring force.

- **SC/Stage-2 Separation:** Following the shut-off of the vernier on Stage-2, the SC/LV stack is re-oriented to the required attitude. The SC is generally bound together with the launch vehicle through clampband. After releasing, the SC is pushed away from the LV by the separation springs. The separation velocity is in a range of 0.5~0.9m/s.

For LM-2E/EPKM, there is a SC/EPKM separation after SC/EPKM stack separates from LV.

- **SC/EPKM Separation:** The SC is connected with EPKM by clampband and separation springs. After releasing, the SC is pushed away from the EPKM by the separation springs.

For LM-2E/ETS, there is a SC/ETS separation after SC/ETS stack separates from LV. See Figure 2-6 for LM-2E/ETS separation events.

- **SC/ETS Separation:** Typically, the SCs are connected with ETS by explosive nuts and separation springs. After the shut-off of the ETS, the explosive nuts are ignited and released, the separation springs push the SCs away according to requirements. Refer to Paragraph 2.4 for ETS introduction.
Figure 2-6  LM-2E/ETS Separation Events
2.4 ETS Introduction

ETS is a three-axis stabilized upper stage compatible with two-stage LM-2E. ETS consists of Spacecraft Dispenser and Orbital Maneuver System (OMS). LM-2E/ETS can deliver the spacecrafts into the LEO or SSO.

LM-2E injects SC/ETS stack into a transfer orbit (Hp=200km, Ha=400~2000km). ETS is ignited at the apogee and enters the target orbit of 400~2000km. ETS re-orient the stack according to the requirements and deploys the spacecrafts. ETS is capable of de-orbiting after spacecraft separation. See Figure 2-7 for typical ETS configuration.

![Figure 2-7 Typical ETS Configuration](image)

2.4.1 Spacecraft Dispenser

The spacecraft dispenser functions to install and deploy the spacecrafts. LM-2E/ETS provides two types of the dispensers (Type A and Type B). Refer to Chapter 5. The typical dispenser (Type A) is composed of a cylinder and a cone, taking frame-skin semi-monocoque structure as shown in Figure 2-7. The specific design is program dependent.
2.4.2 Spacecraft Separation System

The separation system can separate the spacecrafts following the insertion to the target orbit. The separation system will be designed to meet the user's requirements on separation velocity, pointing direction and angular rates, etc.

The spacecrafts are generally bound to the dispenser through low-shock explosive nuts. The separation springs provide the relative velocity. The explosive nuts can be provided by either CALT or SC side.

2.4.3 Orbital Maneuver System

The orbital maneuver system consists of main structure, solid rocket motor (SRM), control system, attitude control thrusters and telemetry system. See Figure 2-8 for its configuration.

![Figure 2-8 Orbital Maneuver System](image)

- The main structure is composed of central panel, load-bearing frame and stringers. The lower part of the panel is attached with the SRM and the upper part connected with the load-bearing frame forms a mounting plane for avionics. The cylinder takes frame-skin semi-monocoque structure.

- The total impulse of SRM will depend on the specific mission requirements. The typical characteristics are as follows.
ETS is equipped with an independent control system. It has the following functions.

- To keep the flight stabilization during the coast phase and re-orient the SC/ETS stack to the SRM ignition attitude;
- To ignite SRM and control the attitude during the powered period;
- To perform the terminal velocity correction according to the accuracy requirements;
- To re-orient the stack and separate the spacecrafts;
- To adjust the orientation of ETS and start de-orbiting.

The system redundancy is taken to guarantee the reliability.

- The attitude-control thrusters carry out the commands from the control system. The thrusters use pressurized mono-propellant controlled by solenoid valves. There are four tanks, two gas bottles and 16 thrusters.

- The telemetry system functions to measure and transmit some environmental parameters of ETS on ground & during flight. The telemetry also provides some orbital data at SC separation.

### 2.5 Perigee Kick Motor (EPKM) Introduction

Developed by Hexi Chemical Corporation, EPKM is a powerful solid rocket motor specially designed for LM-2E. LM-2E/EPKM can send the payloads up to 3500kg into GTO. LM-2E/EPKM has successfully launched AsiaSat-2 and EchoStar-1 into orbits in 1995.

LM-2E injects SC/EPKM stack into a parking orbit (h≈200km). EPKM is ignited near the descending node and send the spacecraft into the GTO (Hp=200 km, Ha=35786 km). There is thermal insulation on the inner wall of EPKM to ensure that the case temperature at burn-out moment meets the requirement. Figure 2-9 shows configuration of EPKM.

<table>
<thead>
<tr>
<th>Diameter</th>
<th>0.99m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Length</td>
<td>1.5m</td>
</tr>
<tr>
<td>Total Mass</td>
<td>940kg</td>
</tr>
<tr>
<td>Impulse in Vacuum</td>
<td>2744N.s/kg</td>
</tr>
<tr>
<td>Mean Thrust</td>
<td>2200kg</td>
</tr>
<tr>
<td>Working Time</td>
<td>75s</td>
</tr>
</tbody>
</table>
2.5.1 Major Character of EPKM

Table 2-2 lists the major characteristics of EPKM for the previous missions.

Table 2-2 Major Characteristics of EPKM

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Nominal Value</th>
<th>Flight #1</th>
<th>Flight #2</th>
<th>Deviations (3σ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter (mm)</td>
<td>1700</td>
<td>1701.6</td>
<td>1704</td>
<td>/</td>
</tr>
<tr>
<td>Length (mm)</td>
<td>2936</td>
<td>2932.7</td>
<td>2931</td>
<td>/</td>
</tr>
<tr>
<td>Total Mass (kg)</td>
<td>6001</td>
<td>6000.3</td>
<td>6001.4</td>
<td>±15</td>
</tr>
<tr>
<td>Burn-out Mass (kg)</td>
<td>529</td>
<td>519.3</td>
<td>520.4</td>
<td>±14</td>
</tr>
<tr>
<td>Charge Mass (kg)</td>
<td>5444</td>
<td>5444</td>
<td>5444</td>
<td>/</td>
</tr>
<tr>
<td>Specific Impulse (s)</td>
<td>292</td>
<td>291.2</td>
<td>291.2</td>
<td>±1.86</td>
</tr>
<tr>
<td>Total Impulse(kg.s)</td>
<td>1589648</td>
<td>1585293</td>
<td>1585293</td>
<td>±0.75%</td>
</tr>
<tr>
<td>Burning Time (s)</td>
<td>87</td>
<td>86.9</td>
<td>86.1</td>
<td>±3</td>
</tr>
<tr>
<td>Spin Rate (rpm)</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>/</td>
</tr>
</tbody>
</table>
2.5.2 Adjustment to Charge Mass

The propellant quantity can be decreased considering the specific mission requirements.

- In technical center: \( \leq 15\text{kg} \)
- Eight months before launch: \( \leq 350\text{kg} \)

2.5.3 Safety-Arm and Ignition

EPKM is armed 60 minutes prior to launch by the ground arming box. The cartridge is attached with two squibs, of which the ignition signal should be as follows. (Refer to Figure 2-10).

- Current: \( 5\sim10\text{A for each} \)
- Powering Duration: \( >200\text{ms} \)
- Test Current: \( 50\sim100\text{mA} \)

2.5.4 Miscellaneous

Any operations to EPKM should be performed under the temperature of \( 0\sim40\degree\text{C} \). The storage temperature should be \( 15\sim25\degree\text{C} \).

Figure 2-10 EPKM Safe and Arm Device
2.6 Missions To Be Performed by LM-2E

LM-2E is a powerful and versatile rocket, of which the LEO launch capability is 9500kg (h=200km, i=28.5°). Furnished with suitable upper stages, LM-2E can perform various missions, such as LEO, SSO and GTO. LM-2E can carry out multiple launches.

- To inject spacecrafts into LEO, which is the prime mission of Two-stage LM-2E.
- To send spacecrafts to LEO or sun synchronous orbit (SSO), if LM-2E is equipped with ETS.
- To project spacecraft into GTO, if LM-2E is furnished with the perigee kick motor (EPKM).

Table 2-3 lists the typical specification for various missions.

Table 2-3 Typical Specification for Various Missions

<table>
<thead>
<tr>
<th>Mission</th>
<th>Version</th>
<th>Orbital Requirements</th>
<th>Launch Capacity</th>
<th>Launch Site</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEO</td>
<td>Two-stage LM-2E</td>
<td>Hp=185<del>400km, Ha=185</del>2000km</td>
<td>9500kg (200km/28.5°)</td>
<td>XSLC</td>
</tr>
<tr>
<td>LEO</td>
<td>Two-stage LM-2E</td>
<td>Hp=185<del>400km, Ha=185</del>2000km</td>
<td>8400kg (200km/53°)</td>
<td>JSLC</td>
</tr>
<tr>
<td>LEO</td>
<td>LM-2E/ETS</td>
<td>Hp=400<del>2000km, Ha=400</del>2000km</td>
<td>6060kg (1000km/53°)</td>
<td>JSLC</td>
</tr>
<tr>
<td>SSO</td>
<td>LM-2E/ETS</td>
<td>H=400~2000km</td>
<td>4340kg (1000km)</td>
<td>JSLC</td>
</tr>
<tr>
<td>GTO</td>
<td>LM-2E/EPKM</td>
<td>Hp=200km, Ha=35786km</td>
<td>3500kg (28.5°)</td>
<td>XSLC</td>
</tr>
</tbody>
</table>
2.7 Definition of Coordinate Systems and Attitude

The Launch Vehicle (LV) Coordinate System OXYZ origins at the LV’s instantaneous mass center, i.e. the integrated mass center of SC/LV combination including adapter, propellants and fairing, etc. if applicable. The OX coincides with the longitudinal axis of the launch vehicle. The OY is perpendicular to axis OX and lies inside the launching plane opposite to the launching azimuth. The OX, OY and OZ form a right-handed orthogonal system.

The flight attitude of the launch vehicle axes is defined in Figure 2-11. Spacecraft manufacturer will define the SC Coordinate System. The relationship or clocking orientation between the LV and SC systems will be determined through the technical coordination for the specific projects.

![Figure 2-11 Definition of Coordinate Systems and Flight Attitude](image)

Figure 2-11 Definition of Coordinate Systems and Flight Attitude
2.8 Spacecrafts Launched by LM-2E

Till December 28, 1995, LM-2E has successfully launched five spacecrafts listed in Table 2-4.

Table 2-4 Spacecrafts Launched by LM-2E

<table>
<thead>
<tr>
<th>Flight #</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC</td>
<td>BADR-1</td>
<td>Optus B1</td>
<td>Optus B3</td>
<td>AsiaSat-2</td>
<td>EchoStar-1</td>
</tr>
<tr>
<td>Builder</td>
<td>SUPARCO</td>
<td>HUGHES</td>
<td>HUGHES</td>
<td>LMCO</td>
<td>LMCO</td>
</tr>
<tr>
<td>Launch Date</td>
<td>07/16/90</td>
<td>08/14/92</td>
<td>08/28/94</td>
<td>11/28/95</td>
<td>12/28/95</td>
</tr>
<tr>
<td>Orbit</td>
<td>LEO</td>
<td>LEO</td>
<td>LEO</td>
<td>GTO</td>
<td>GTO</td>
</tr>
</tbody>
</table>