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 N_2O_4/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

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

2.3 LM-2E System Composition

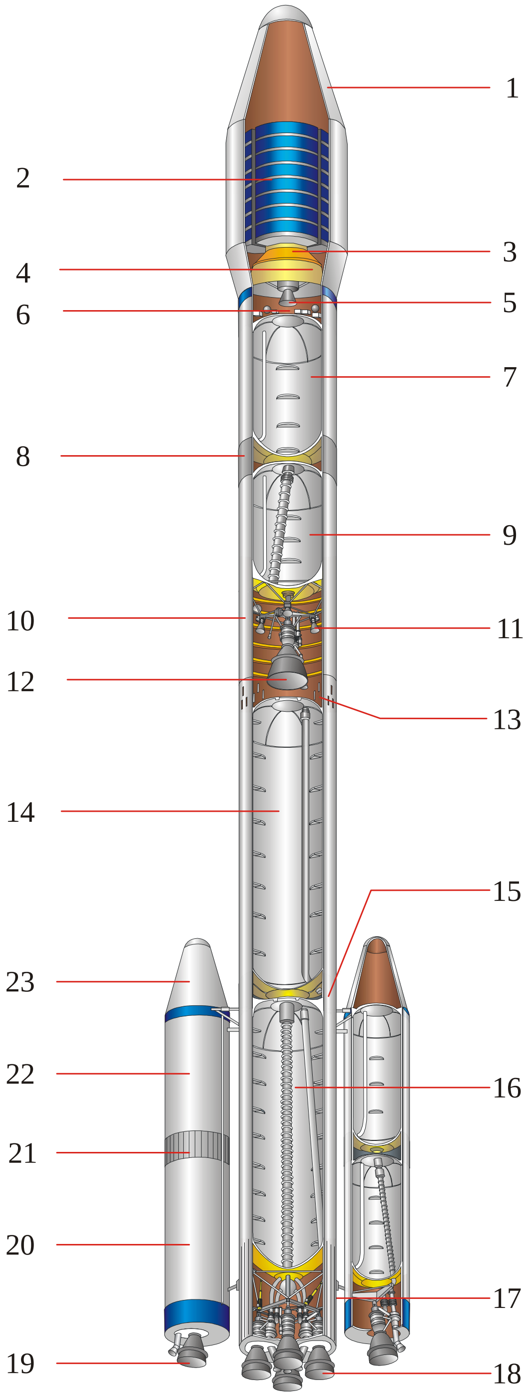
LM-2E consists of rocket structure, propulsion system, control system, telemetry system, tracking and safety system, separation system, etc.

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.



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
19. Booster's Engine
20. Booster's Fuel Tank
21. Inter-tank Section
22. Booster's Oxidizer Tank
23. Booster's Cone

Figure 2-1 LM-2E/ETS Configuration

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_2O_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.

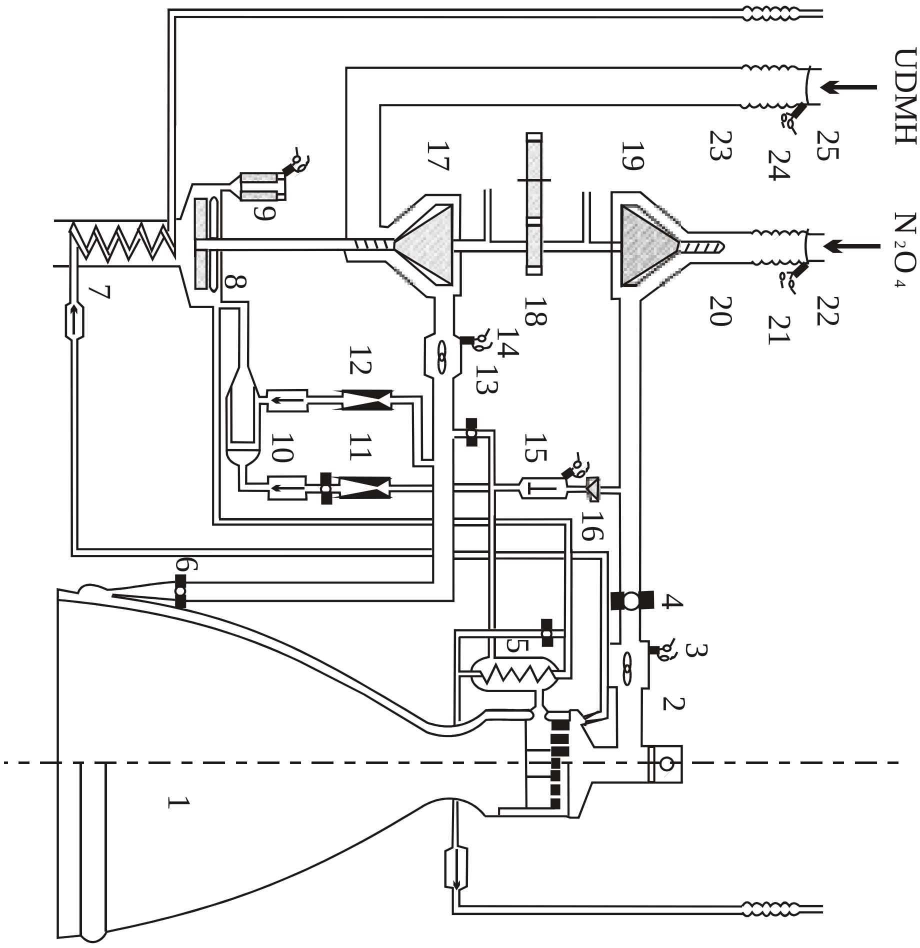
The guidance unit provides movement and attitude data of the LV and controls the flight according to the predetermined trajectory. The attitude control system controls the flight attitude to ensure the flight stabilization and SC injection attitude. The system re-orient LM-2E following the shut-off of 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**.

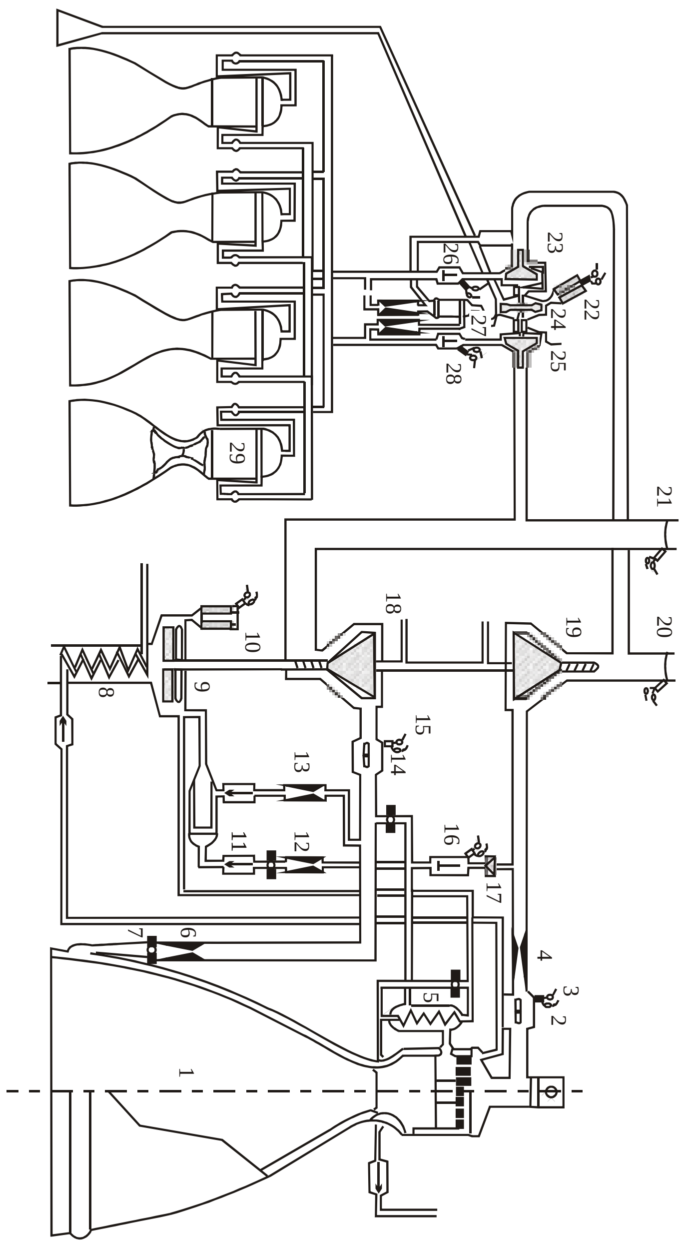
2.3.5 Tracking and Range Safety System

The tracking and range safety system works along with the ground stations to measure the trajectory dada 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**.



1 Thrust Chamber
2 Oxidizer Main Valve
3 Electric Squib
4 Oxidizer Main Throttling Orifice
5 Cooler
6 Fuel Main Throttling Orifice
7 Vapourizer
8 Turbine
9 Solid Start Cartridge
10 Gas Generator
11 Oxidizer Subsystem Cavitating Venturi
12 Fuel Subsystem Cavitaing Venturi
13 Fuel Main Valve
14 Electric Squib
15 Subsystem Cut-off Valve
16 Filter
17 Fuel Pump
18 Gear Box
19 Oxidizer Pump
20 Swing Hose
21 Electric Squib
22 Oxidizer Starting Valve
23 Swing Hose
24 Electric Squib
25 Fuel Starting Valve

Figure 2-2a First Stage Propulsion System Schematic Diagram



1 Thrust Chamber
2 Oxidizer Main Valve
3 Electric Squib
4 Oxidizer Main Venturi
5 Cooler
6 Fuel Main Venturi
7 Throttling Orifice
8 Vapourizer
9 Turbine
10 Solid Start Catridge
11 Gas Generator
12 Oxidizer Subsystem Venturi
13 Fuel Subsystem Venturi
14 Fuel Main Valve
15 Electric Squib
16 Subsystem Cut-off Valve
17 Filter
18 Fuel Pump
19 Oxidizer Pump
20 Oxidizer Starting Valve
21 Fuel Starting Valve
22 Solid Start Cartridge
23 Oxidizer Pump
24 Turbine
25 Fuel Pump
26 Oxidizer Cut-off Valve
27 Gas Generator
28 Fuel Cut-off Valve
29 Vernier Combustion Chamber

Figure 2-2b Second Stage Propulsion System Schematic Diagram

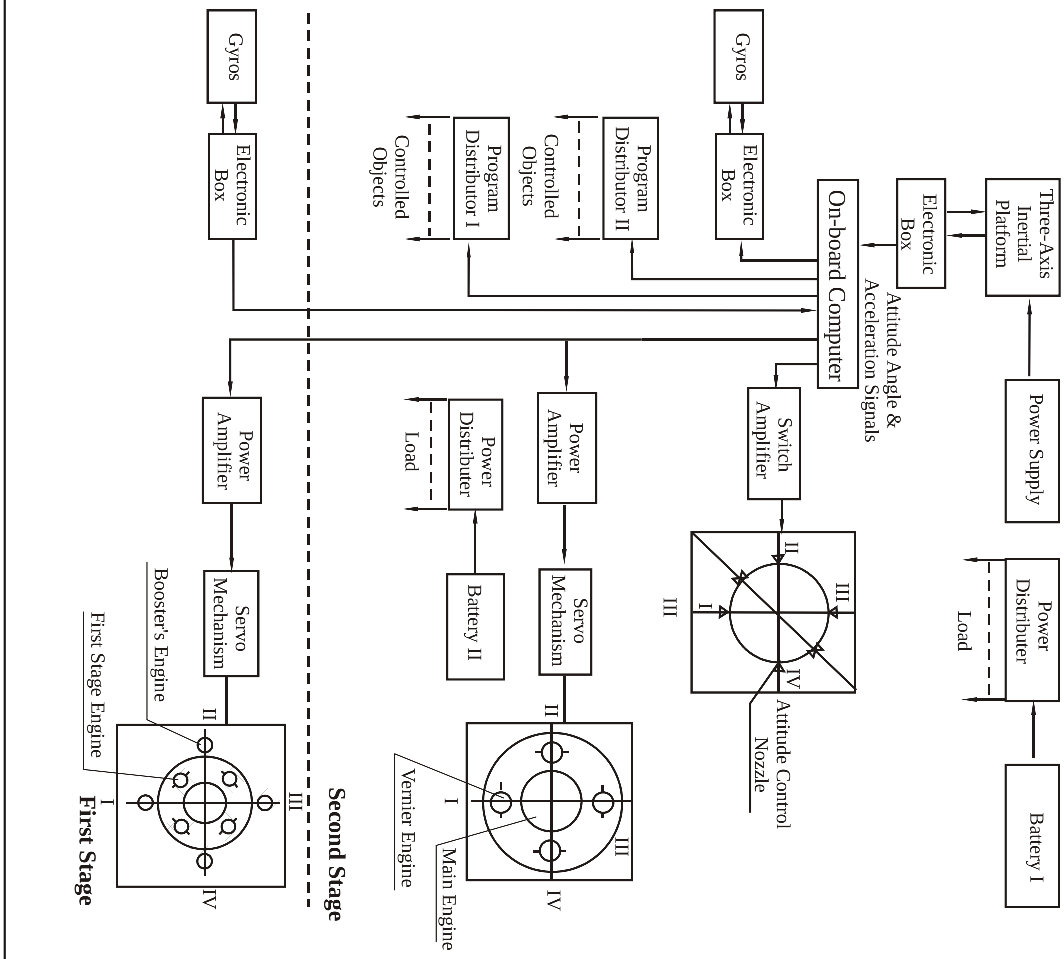


Figure 2-3a Control System Schematic Diagram

2-8

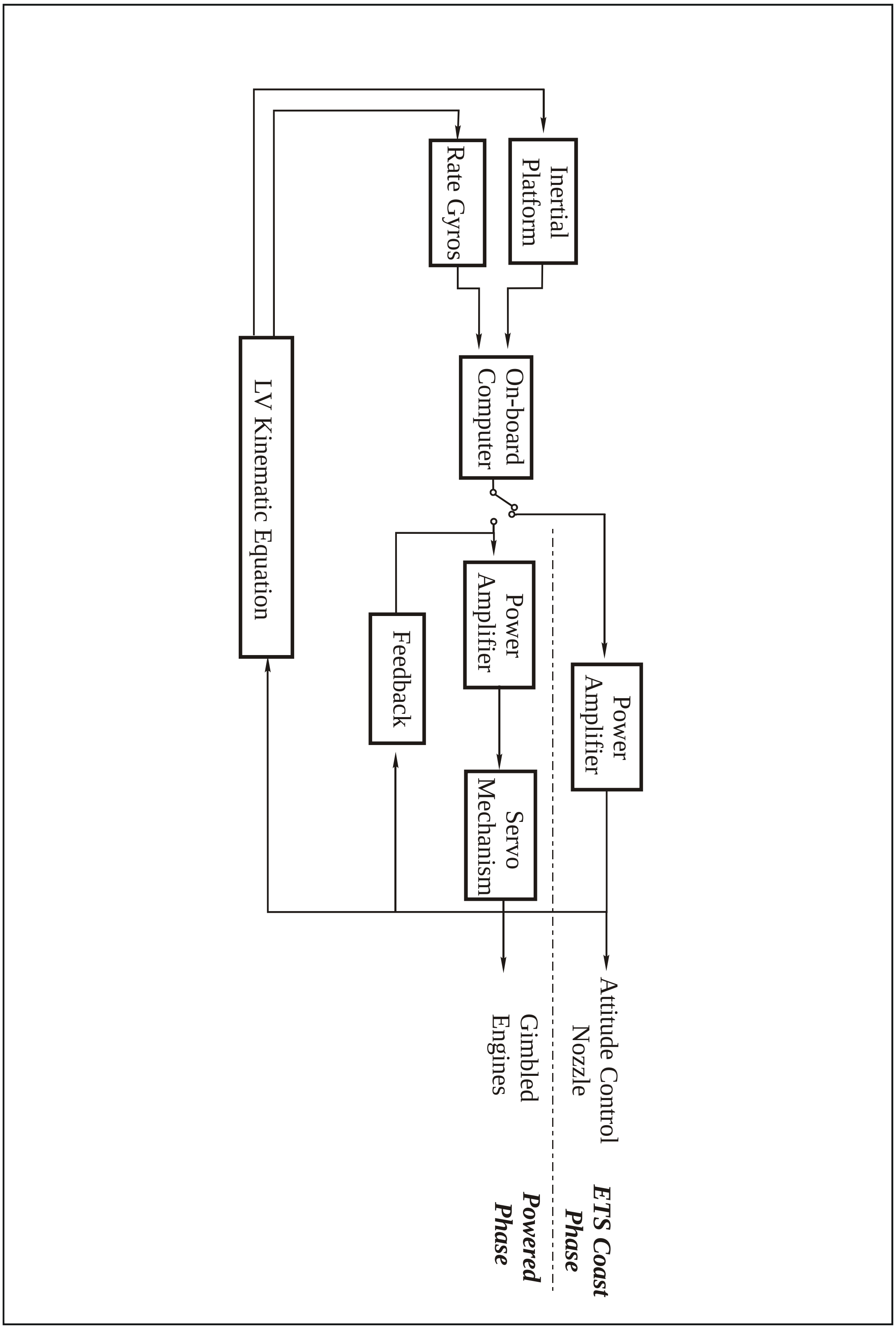


Figure 2-3b Attitude-control System Schematic Diagram

2-9

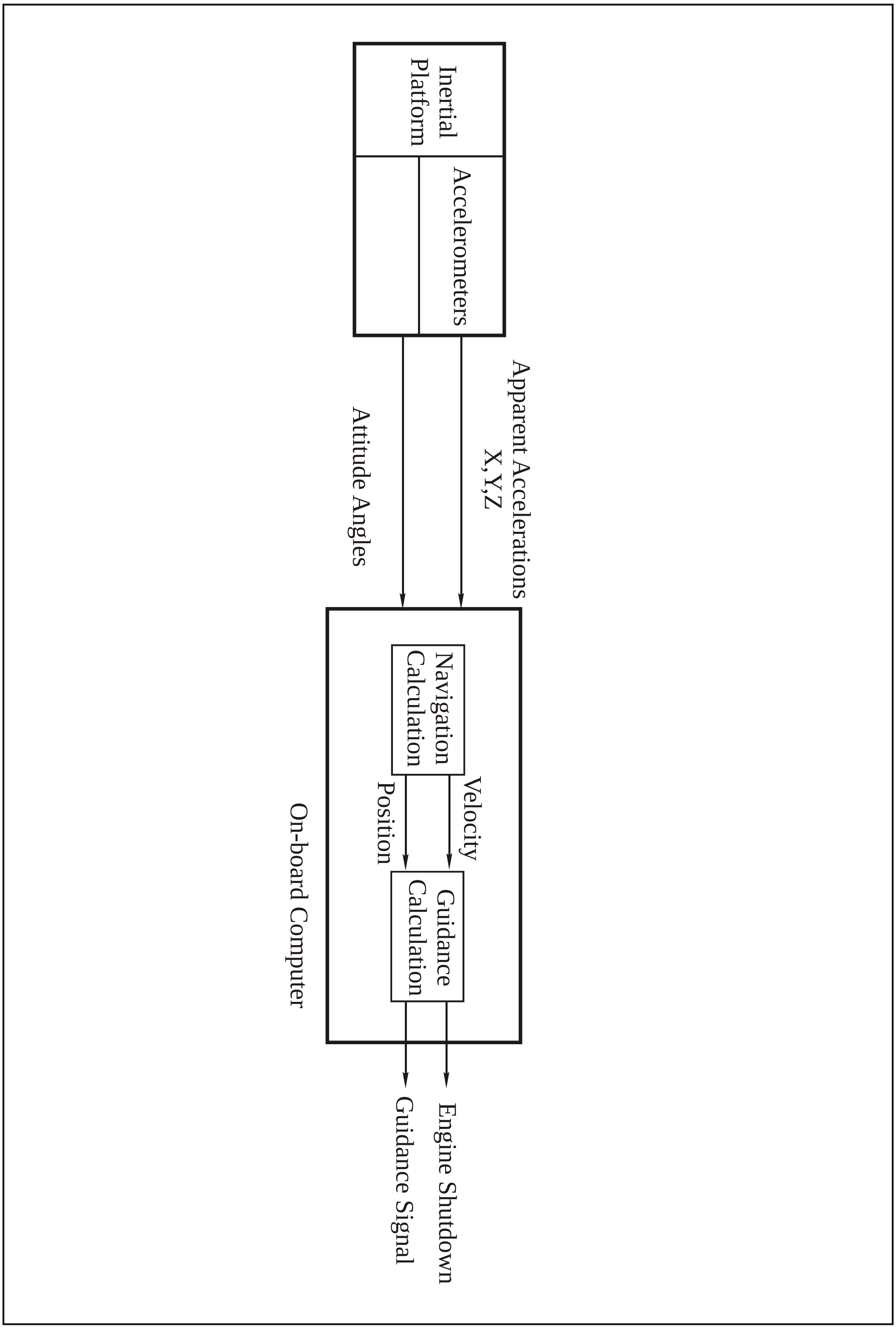


Figure 2-3c Guidance System Schematic Diagram

2-10

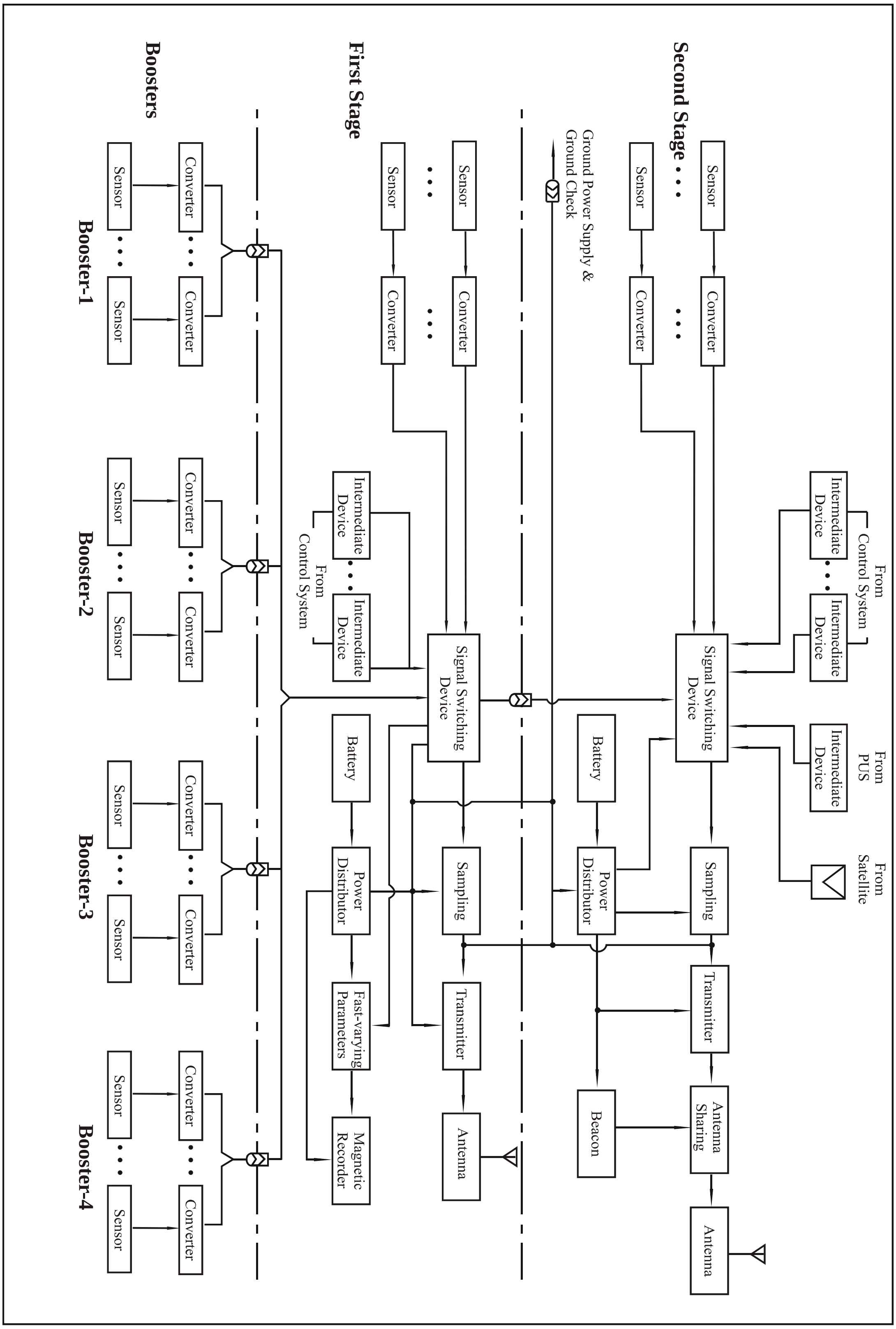


Figure 2-4 Telemetry System Schematic Diagram

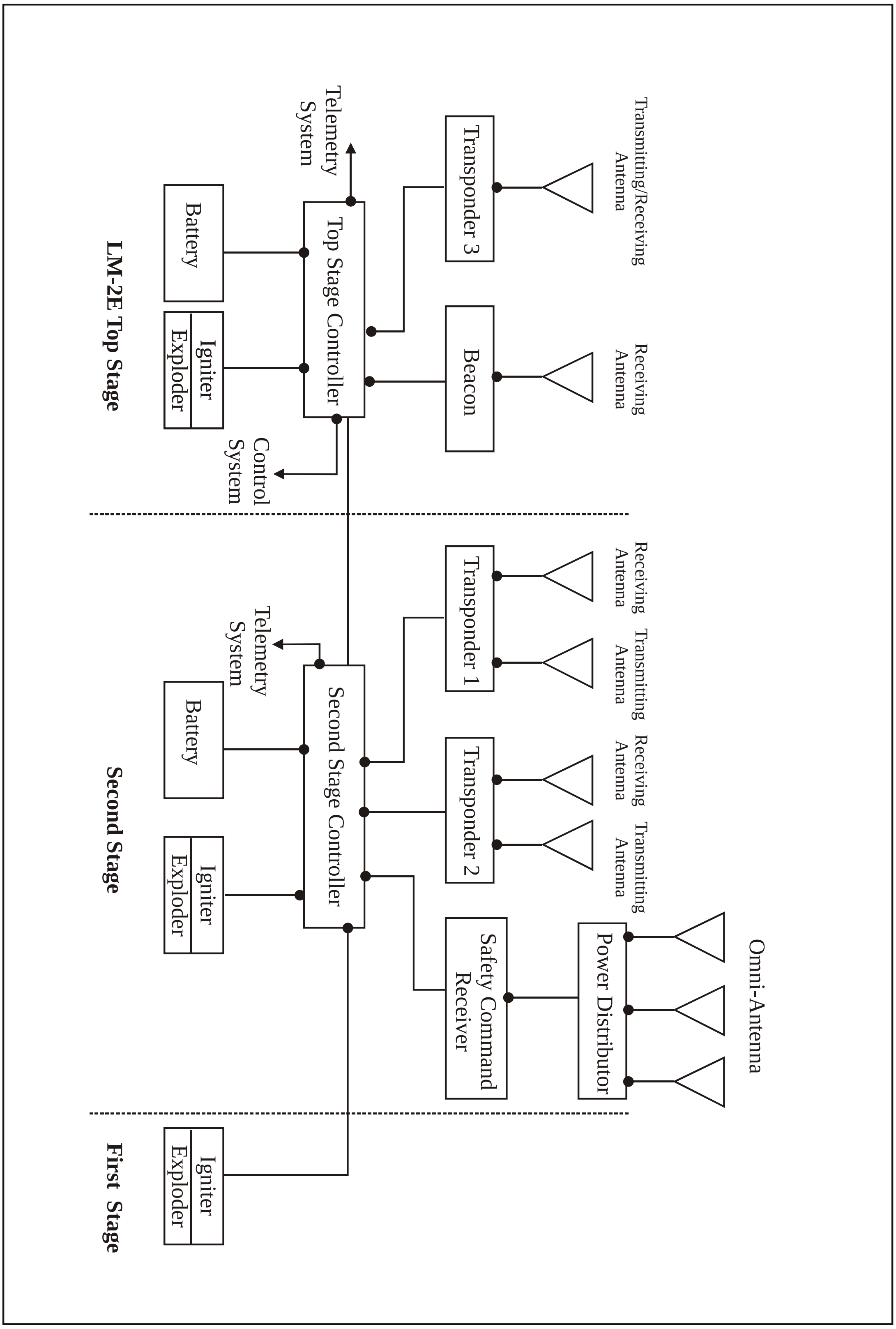


Figure 2-5 Tracking and Range Safety System Schematic Diagram

2-12

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.

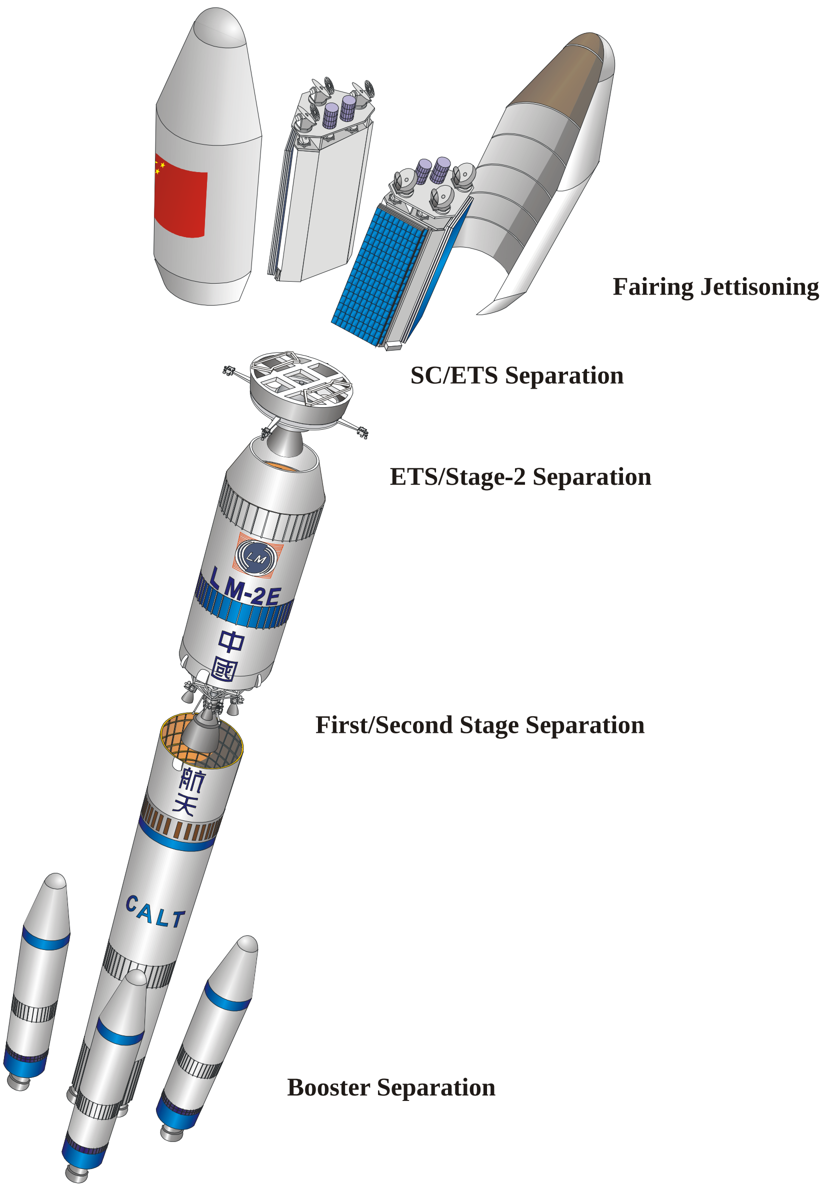


Figure 2-6 LM-2E/ETS Separation Events

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-orients 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.

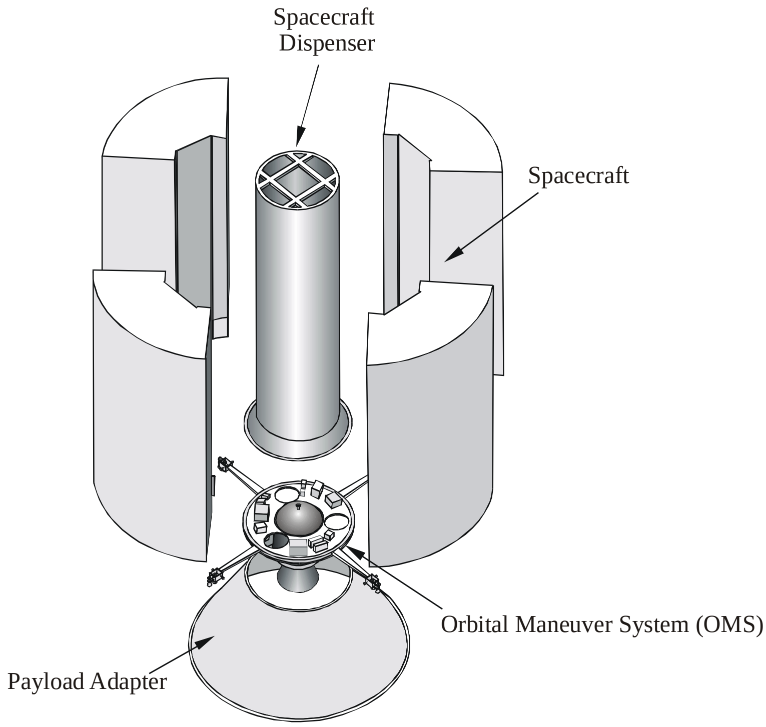


Figure 2-7 Typical ETS Configuration

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.

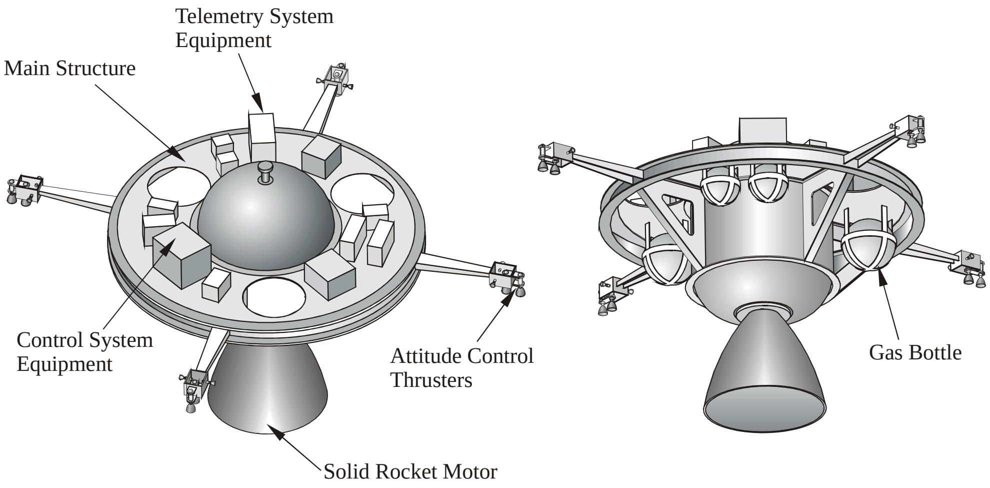


Figure 2-8 Orbital Maneuver System

- 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.

Diameter	0.99m
Total Length	1.5m
Total Mass	940kg
Impulse in Vacuum	2744N.s/kg
Mean Thrust	2200kg
Working Time	75s

- 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.

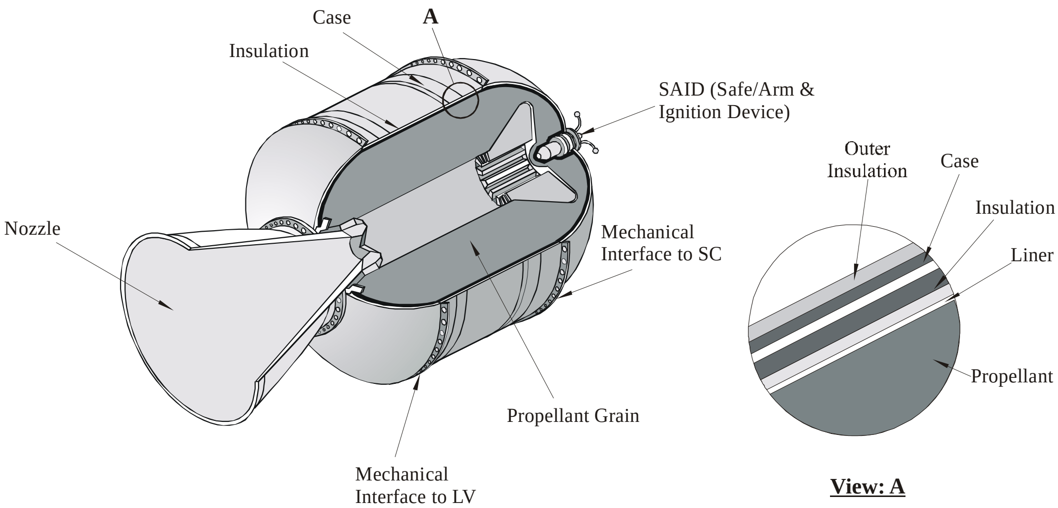


Figure 2-9 EPKM Configuration

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

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

2.5.2 Adjustment to Charge Mass

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

In technical center:	≤15kg
Eight months before launch:	≤350kg

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:	5~10A for each
Powering Duration:	>200ms
Test Current:	50~100mA

2.5.4 Miscellaneous

Any operations to EPKM should be performed under the temperature of 0~40°C. The storage temperature should be 15~25°C.

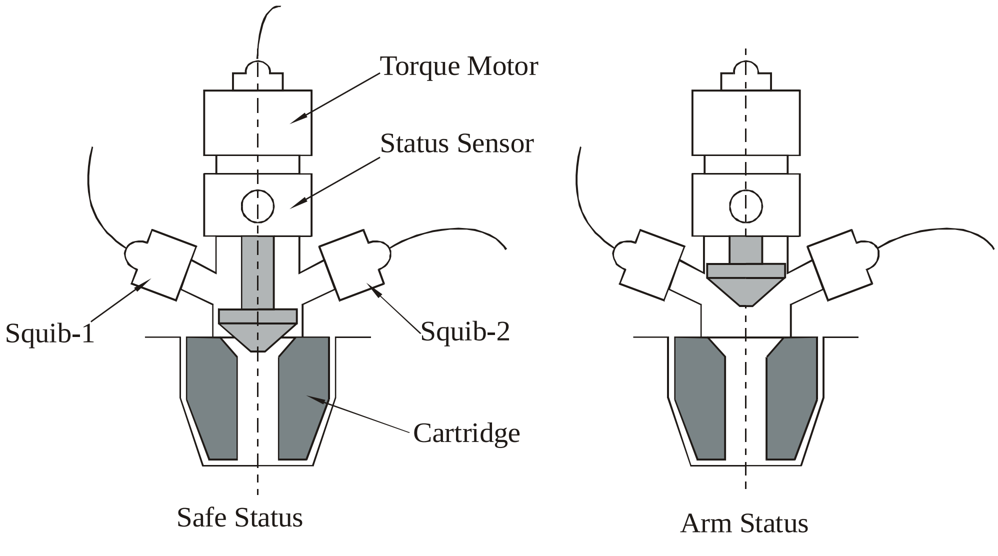


Figure 2-10 EPKM Safe and Arm Device

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

	Version	Orbital Requirements	Launch Capacity	Launch Site
LEO	Two-stage LM-2E	Hp=185~400km Ha=185~2000km	9500kg (200km/28.5°)	XSLC
LEO	Two-stage LM-2E	Hp=185~400km Ha=185~2000km	8400kg (200km/53°)	JSLC
LEO	LM-2E/ETS	Hp=400~2000km Ha=400~2000km	6060kg (1000km/53°)	JSLC
SSO	LM-2E/ETS	H=400~2000km	4340kg (1000km)	JSLC
GTO	LM-2E/EPKM	Hp=200km Ha=35786km	3500kg (28.5°)	XSLC

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.

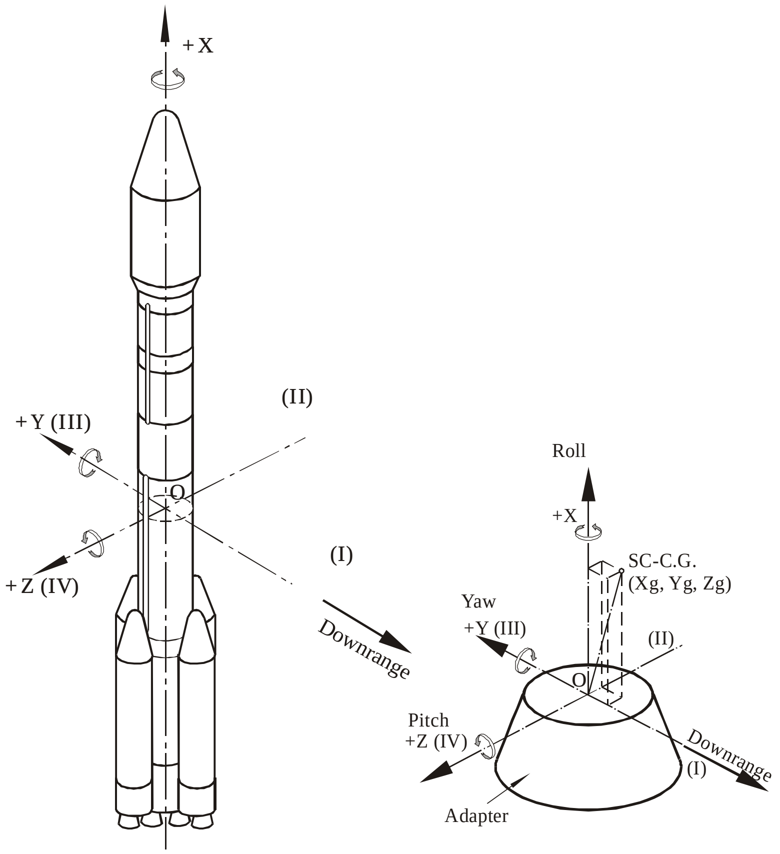


Figure 2-11 Definition of Coordinate Systems and Flight Attitude

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

Flight #	1	2	3	4	5
Launcher	LM-2E	LM-2E	LM-2E	LM-2E/EPKM	LM-2E/EPKM
SC	BADR-1	Optus B1	Optus B3	AsiaSat-2	EchoStar-1
Builder	SUPARCO	HUGHES	HUGHES	LMCO	LMCO
Launch Date	07/16/90	08/14/92	08/28/94	11/28/95	12/28/95
Orbit	LEO	LEO	LEO	GTO	GTO