CHAPTER 2

GENERAL DESCRIPTION TO LM-3B

2.1 Summary

Long March 3B (LM-3B) is a powerful three-stage launch vehicle using liquid propellants. LM-3B is mainly used for Geo-synchronous Transfer Orbit (GTO) missions. LM-3B takes the mature LM-3A as the core stage with 4 strap-on boosters.

China Academy of Launch Vehicle Technology (CALT) started to design LM-3A in mid-1980s. LM-3A is also a three-stage launch vehicle with the GTO capability of 2600kg. Its third stage is fueled with cryogenic propellants, i.e. liquid hydrogen and liquid oxygen. Three consecutive successful launches have been made since its maiden mission in February 1994.

The GTO launch capability of LM-3B reaches 5100kg by using strap-on boosters and the longer second stage.

LM-3B provides four types of fairing, (see **Chapter 4**), and four different payload interfaces, which provide the users with more flexibility.

2.2 Technical Description

2.2.1 Major Characteristics of LM-3B

Table 2-1 shows the major characteristics of LM-3B.

Table 2-1 Technical Parameters of LM-3B

Stage	Booster	First Stage	Second Stage	Third Stage
Lift-off Mass (t)	426			
Propellant	N_2O_4/UDMH			LOX/LH_2
Mass of Propellant (t)	37.746×4	171.775	49.605	18.193
Engine	DaFY5-1	DaFY6-2	DaFY20-1(Main) DaFY21-1(Vernier)	YF-75

Thrust (kN)	740.4×4	2961.6	742 (Main) 11.8×4(Vernier)	78.5×2
Specific Impulse (N.s/kg)	2556.2	2556.2	2922.57(Main) 2910.5(Vernier)	4312
Stage Diameters (m)	2.25	3.35	3.35	3.0
Stage Length (m)	15.326	23.272	9.943	12.375
Fairing Length (m)	9.56			
Fairing Diameter (m)	Φ4.0			
Total Length (m)	54.838			

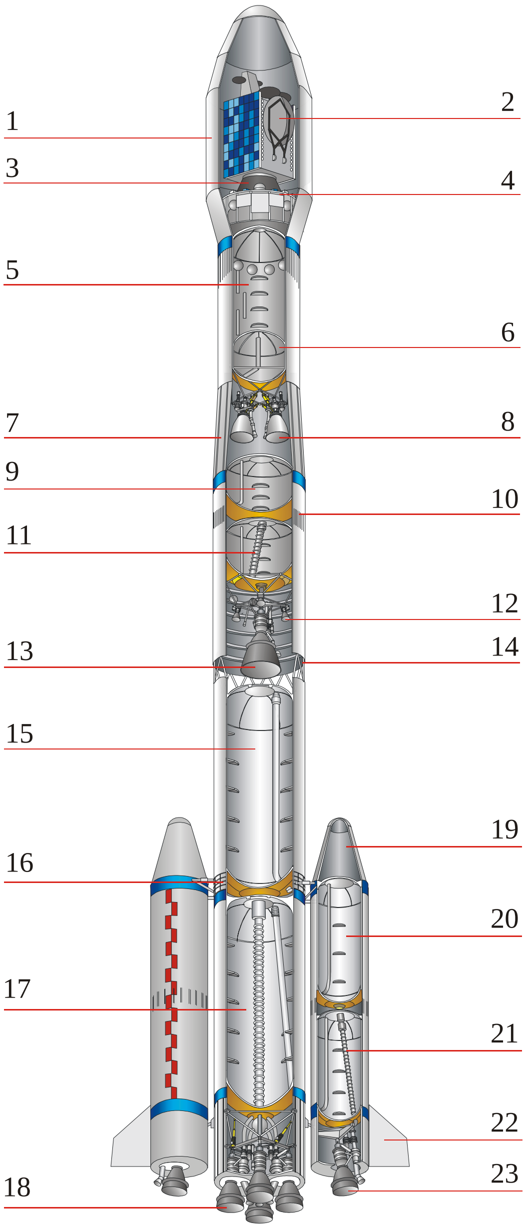
There are two different fairing encapsulation methods for LM-3B, i.e. Encapsulation-on-Pad and Encapsulation-in-BS3. They are described in **Chapter 8**. The statements inside this Manual are applicable for Encapsulation-on-Pad, if there is no special notice.

2.3 LM-3B System Composition

LM-3B consists of rocket structure, propulsion system, control system, telemetry system, tracking and safety system, coast phase propellant management and attitude control system, cryogenic propellant utilization system, separation system and auxiliary 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 boosters, first stage, second stage, third stage and payload fairing. See **Figure 2-1**.



1. Fairing
2. SC
3. Payload Adapter
4. Vehicle Equipment Bay
5. LH_2 Tank
6. LOX Tank
7. Inter-stage Section
8. Third Stage Engine
9. Second Stage Oxidizer Tank
10. Inter-tank Section
11. Second Stage Fuel Tank
12. Second Stage Vernier Engine
13. Second Stage Main Engine
14. Inter-stage Section
15. First Stage Oxidizer Tank
16. Inter-tank Section
17. First Stage Fuel Tank
18. First Stage Engine
19. Booster's Nose
20. Booster's Oxidizer tank
21. Booster's Fuel Tank
22. Stabilizer
23. Booster's Engine

Figure 2-1 LM-3B Configuration

The booster consists of nose, oxidizer tank, inter-tank, fuel tank, rear transit section, tail section, stabilizer, valves and tunnels, etc.

The first stage includes inter-stage section, oxidizer tank, inter-tank, fuel tank, rear transit section, tail, valves and tunnels, etc.

The second stage includes oxidizer tank, inter-tank, fuel tank, valves and tunnels, etc..

The third stage contains payload adapter, vehicle equipment bay (VEB) and cryogenic propellant tank. The payload adapter connects the payload with LM-3B and conveys the loads between them. The interface ring on the top of the adapter can be 937B, 1194, 1194A or 1666 international standard interfaces. The VEB for Encapsulation-on-pad method is a circular plate made of metal honeycomb and truss, where the launch vehicle avionics are mounted. See **Figure 2-2**. If the fairing is encapsulated in BS3, the VEB will be a cylinder-shaped structure of 900mm high seated on the third stage. See **Figure 2-3**. The propellant tank of stage three is thermally insulated with a common bulkhead, convex upward in the middle. The common bulkhead structurally takes dual-layer honeycomb vacuum thermal insulation. Liquid hydrogen is fueled in the upper part of the tank and liquid oxygen is stored inside the lower part.

The payload fairing consists of dome, bi-conic section, cylindrical section and reverse cone section.

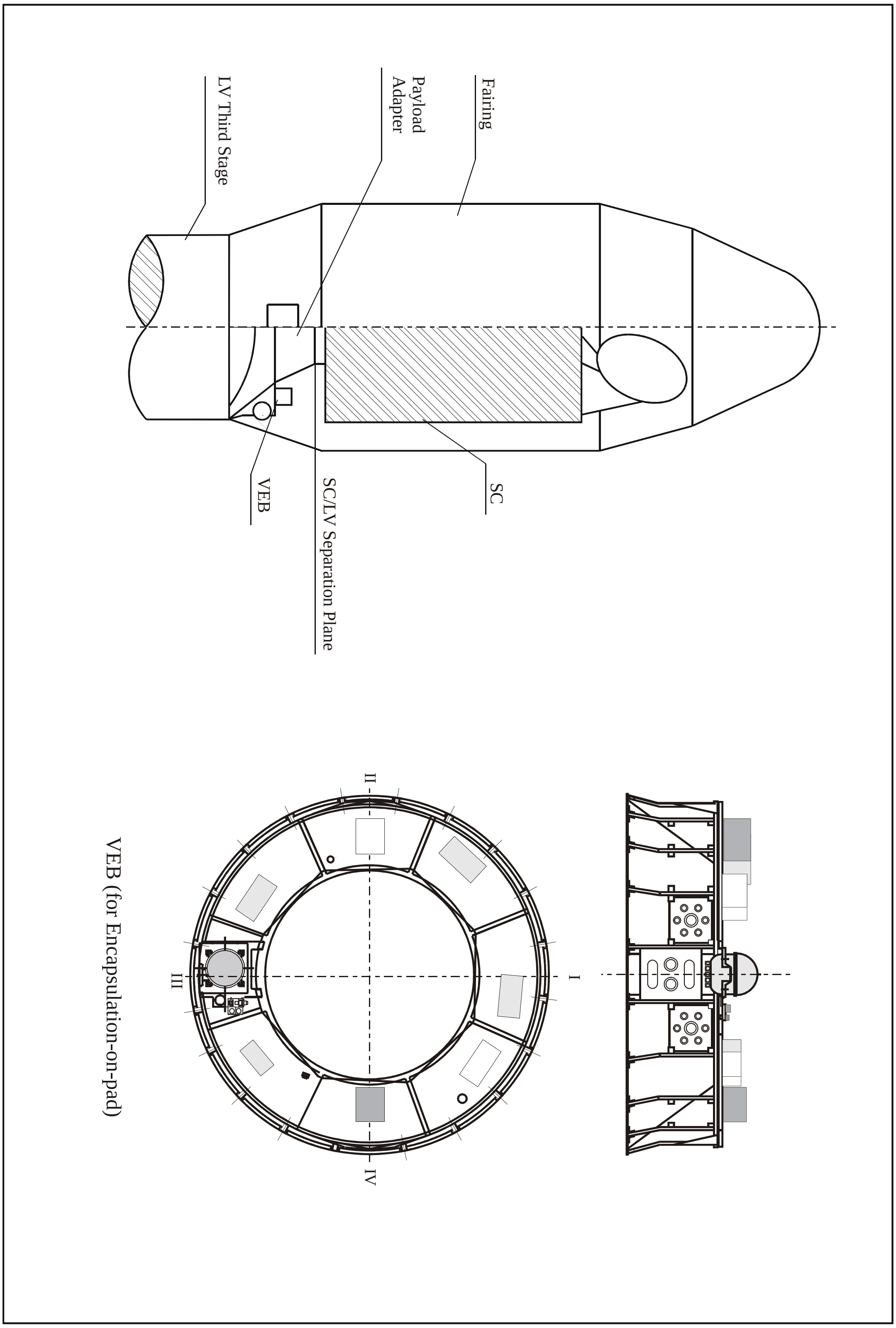


Figure 2-2 VEB Configuration (for Encapsulation-on-pad)

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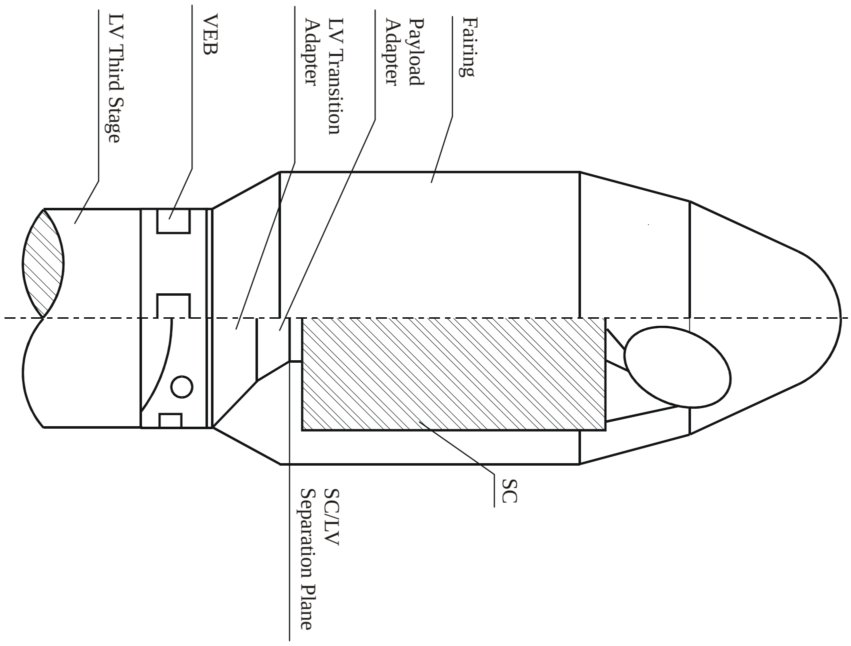
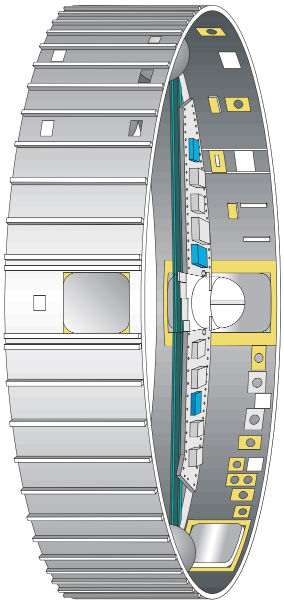




VEB (for Encapsulation-in-BS3)

Figure 2-3 VEB Configuration (for Encapsulation-in-BS3)

2.3.2 Propulsion System

The propulsion system, including engines and pressurization/feeding system, generates the forward flight thrust and control force. Refer to **Figure 2-4(a,b&c).**

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 regenerated 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 four boosters use the same engines. There are one main engine and four vernier engines on the second stage. The total thrust is 789.1kN.

The third stage uses cryogenic propellants, i.e. liquid hydrogen (LH_2) and liquid oxygen (LOX). Two universal gimballing engines provide the total thrust of 157kN. The expansion ratio of the engines is 80:1 and the specific impulse is 4312N·s/kg. The LH_2 tank is pressurized by helium and regeneration system, and the LOX tank is pressurized by heated helium and regeneration system.

2.3.3 Control System

The control system is to keep the flight stability 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. The control system adopts four-axis inertial platform, on-board computer and digital attitude control devices. Some advanced technologies are applied in the control system, such as programmable electronic sequencer, triple-channel decoupling, dual-parameter controlling, real-time compensation for measuring error. These technologies make the launch vehicle quite flexible to various missions. Refer to **Figure 2-5(a,b&c)**.

2.3.4 Telemetry System

The telemetry system functions to measure and transmit some parameters of the launch vehicle systems. Some measured data can be processed in real time. The telemetry system is locally powered considering sensor distribution and data coding. The measurements to the command signals are digitized. The powering and testing are performed automatically. The on-board digital converters are intelligent. Totally about 700 parameters are measured. Refer to **Figure 2-6**.

2.3.5 Tracking and Range Safety System

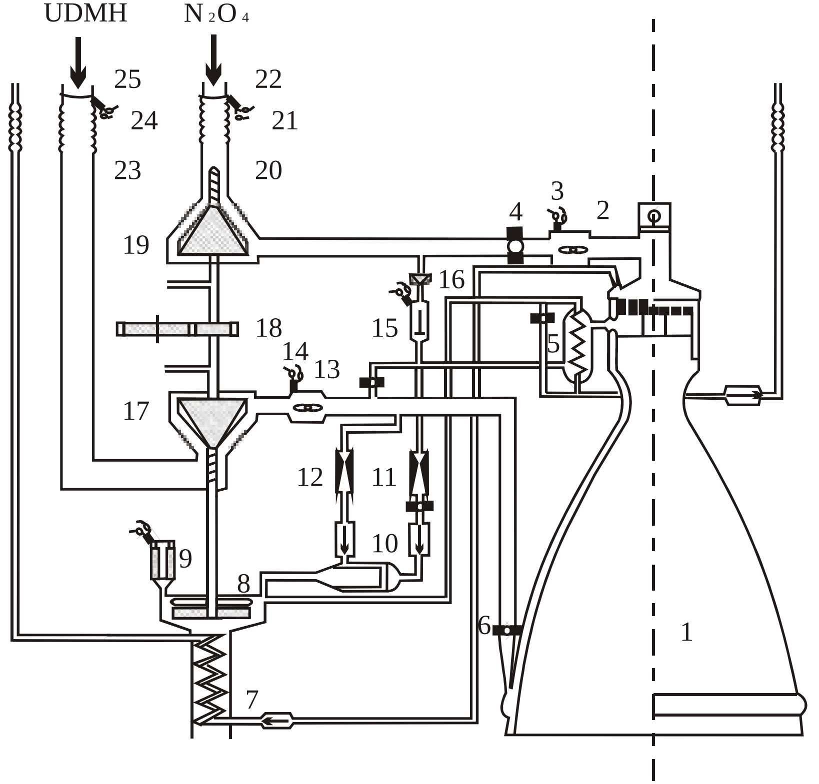
The tracking and range safety system works to measure the trajectory dada and final injection parameters. The system also provides safety assessment information. A self-destruction would be remotely controlled if a flight anomaly occurred. The trajectory measurement and safety control design are integrated together. A sampling check system is equipped on the ground part. Refer to **Figure 2-7**.

2.3.6 Coast Phase Propellant Management and Attitude Control System

This system is to carry out the attitude control and propellant management during the coast phase and to re-orient the launch vehicle prior to payload separation. An engine fueled by squeezed hydrazine works intermittently in the system. The system can be initiated repeatedly according to the commands. See **Figure 2-8**.

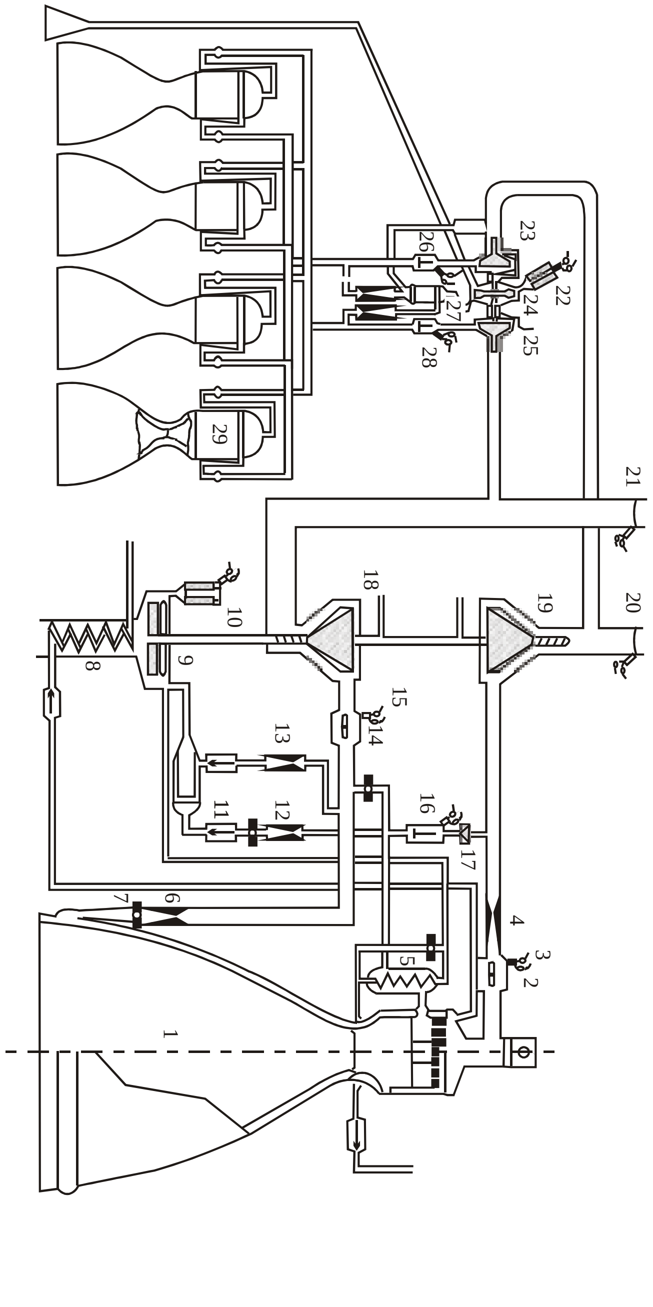
2.3.7 Cryogenic Propellant Utilization System

The propellant utilization system measures in real time the level of propellants inside the third stage tanks and adjusts the consuming rate of liquid oxygen to make the residual propellants in an optimum proportion. The adjustment is used to compensate the deviation of engine performance, structure mass, propellant loading, etc, for the purpose to get a higher launch capability. The system contains processor, propellant level sensors and adjusting valves. Refer to **Figure 2-9**.



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

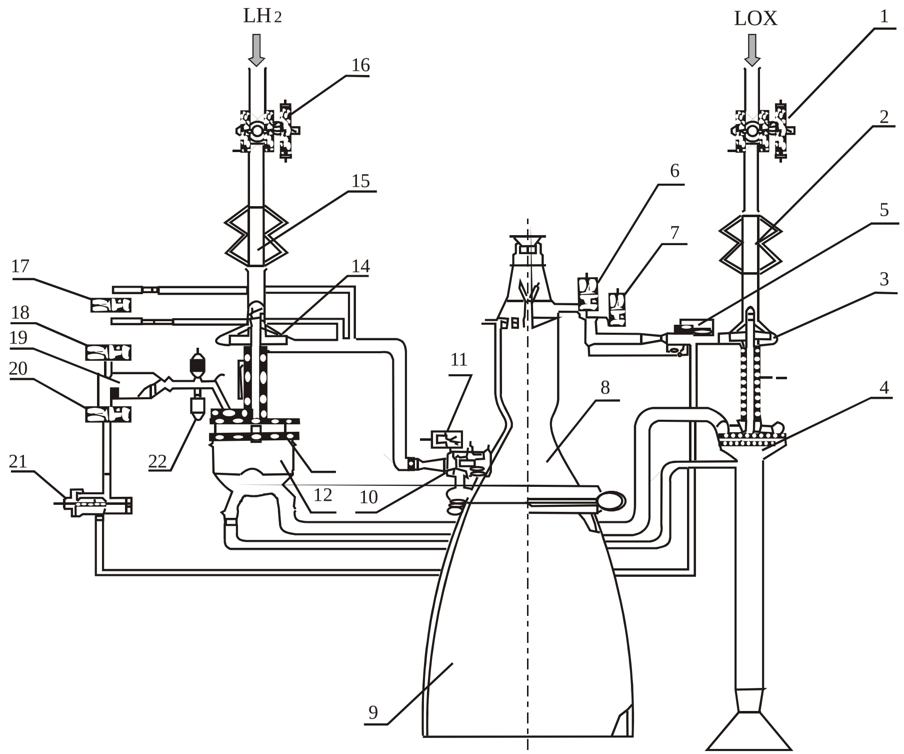
Figure 2-4a First Stage Propulsion System Schematic Diagram



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 2-4b Second Stage Propulsion System Schematic Diagram

2-10



1. LOX Pump Front Valve
2. LOX Swinging Hose
3. LOX Pump
4. LOX Pump Turbine
5. Propellant Utilization Valve
6. LOX Main Valve
7. LOX Precooling Drain Valve
8. Thrust Chamber
9. Nozzle
10. LOX Main Valve
11. LH Precooling Drain Valve
12. LH and Helium Heater
13. LH Pump Turbine
14. LH Pump
15. LH Pump Front Swinging Hose
16. LH Pump Front Valve
17. LH Subsystem Bypass Valve
18. LH Subsystem Control Valve
19. Gas Generator
20. LOX Subsystem Control Valve
21. LOX Pressure Regulator
22. Solid Ignitor

Figure 2-4c Third Stage Propulsion System Schematic Diagram

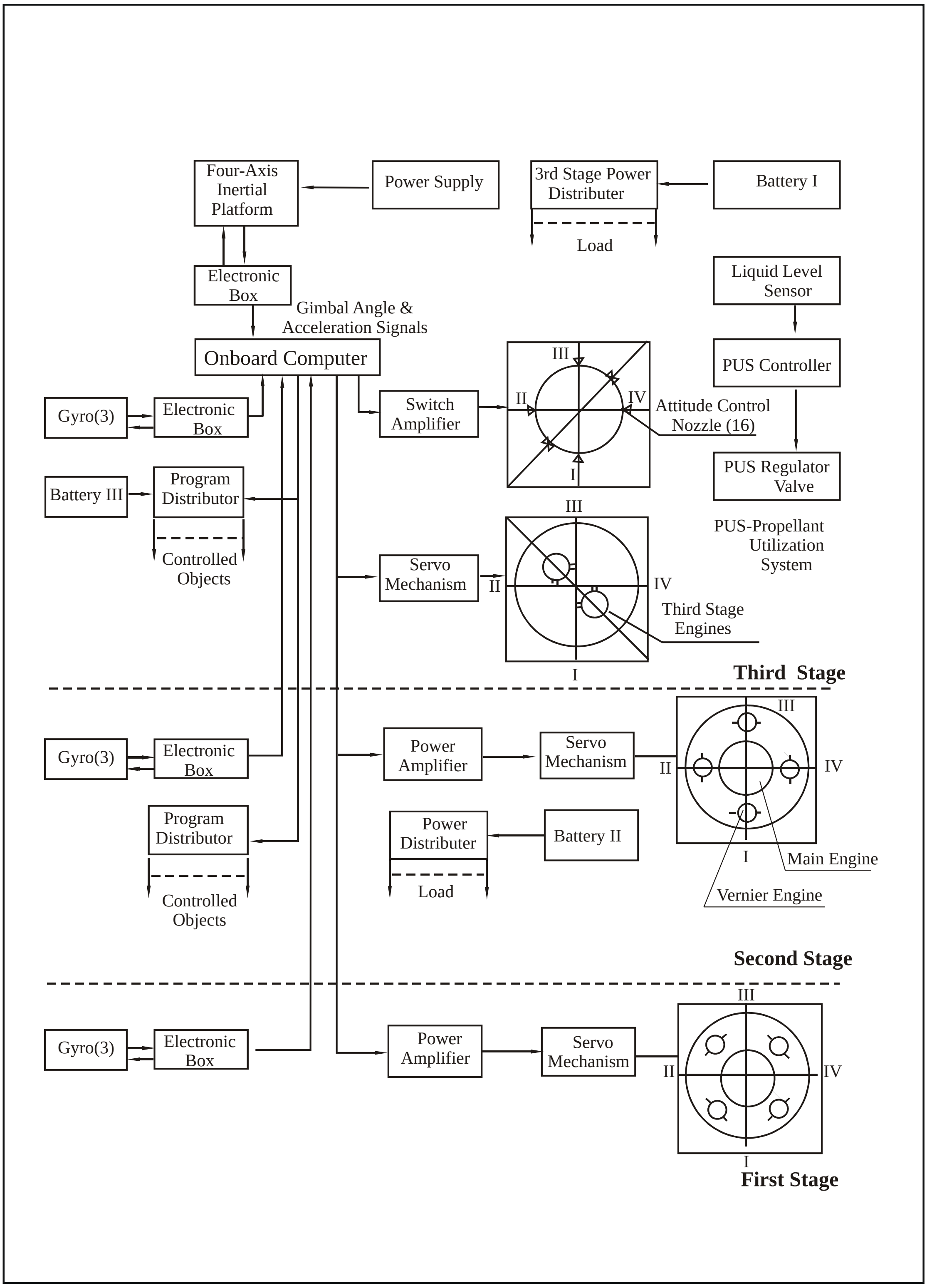


Figure 2-5a Control System Schematic Diagram

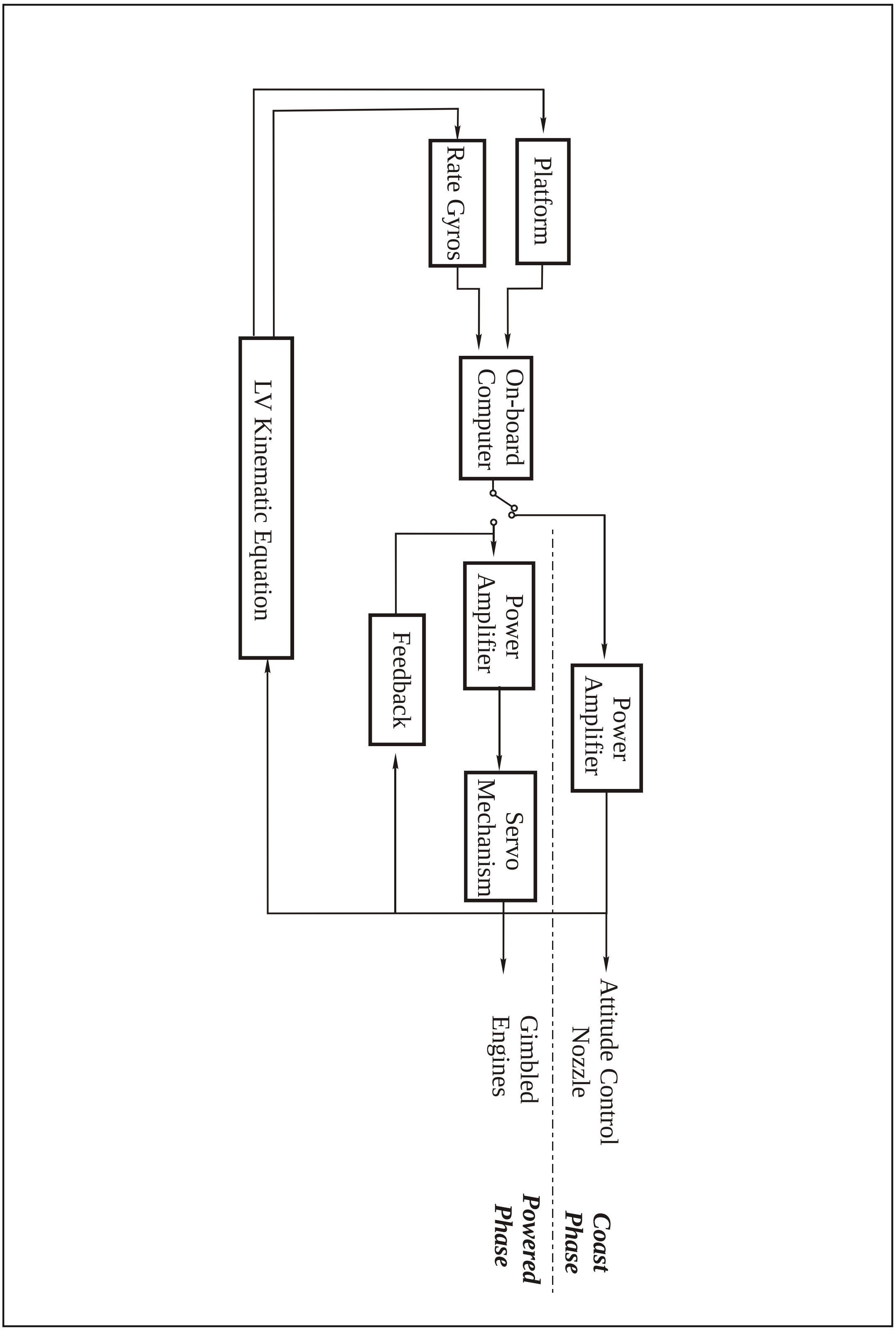


Figure 2-5b Attitude-control System Schematic Diagram

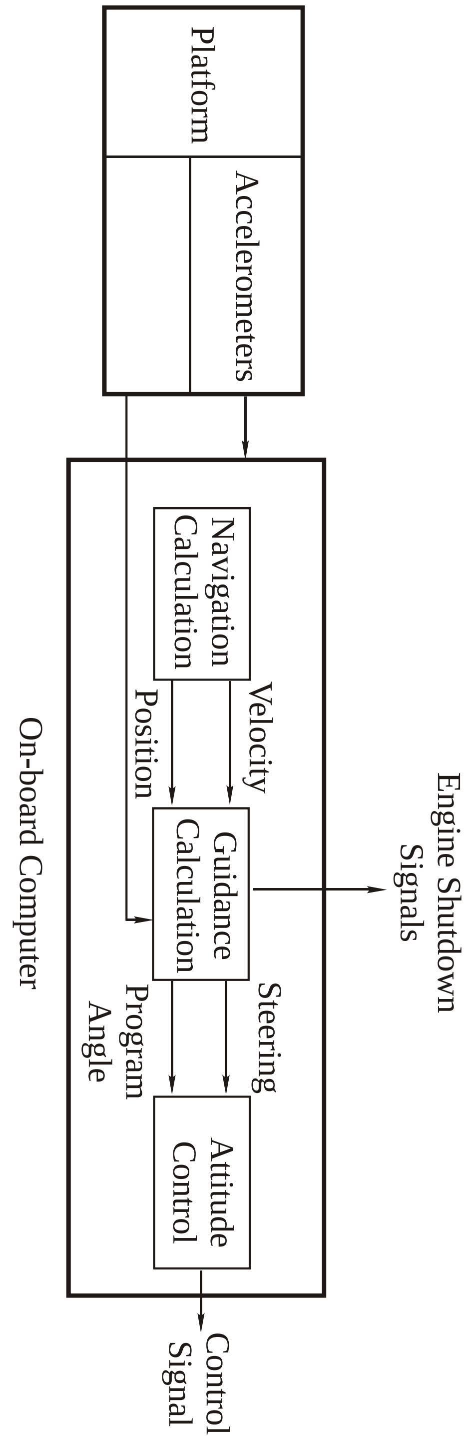


Figure 2-5c Guidance System Schematic Diagram

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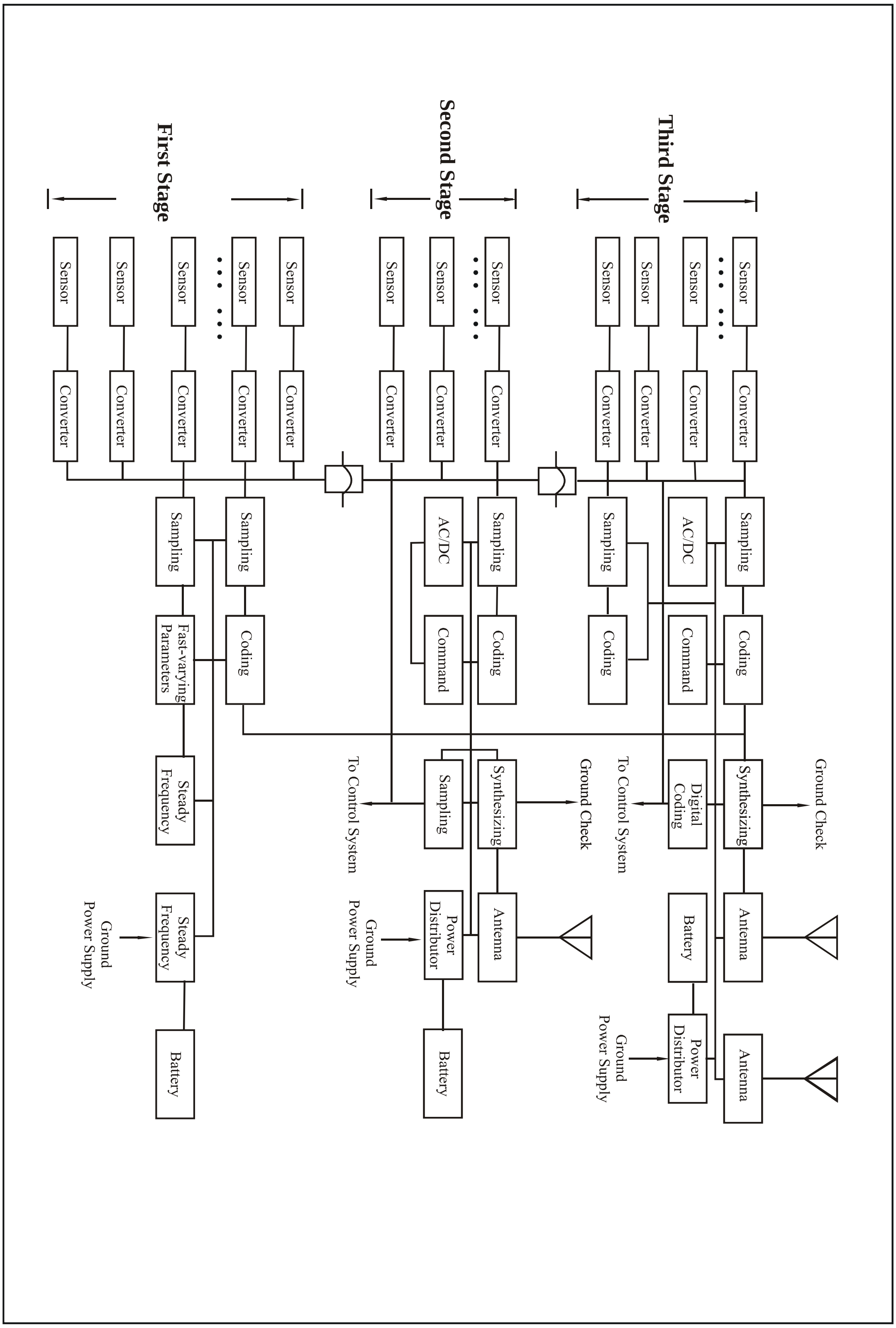

Figure 2-6 Telemetry System Schematic Diagram

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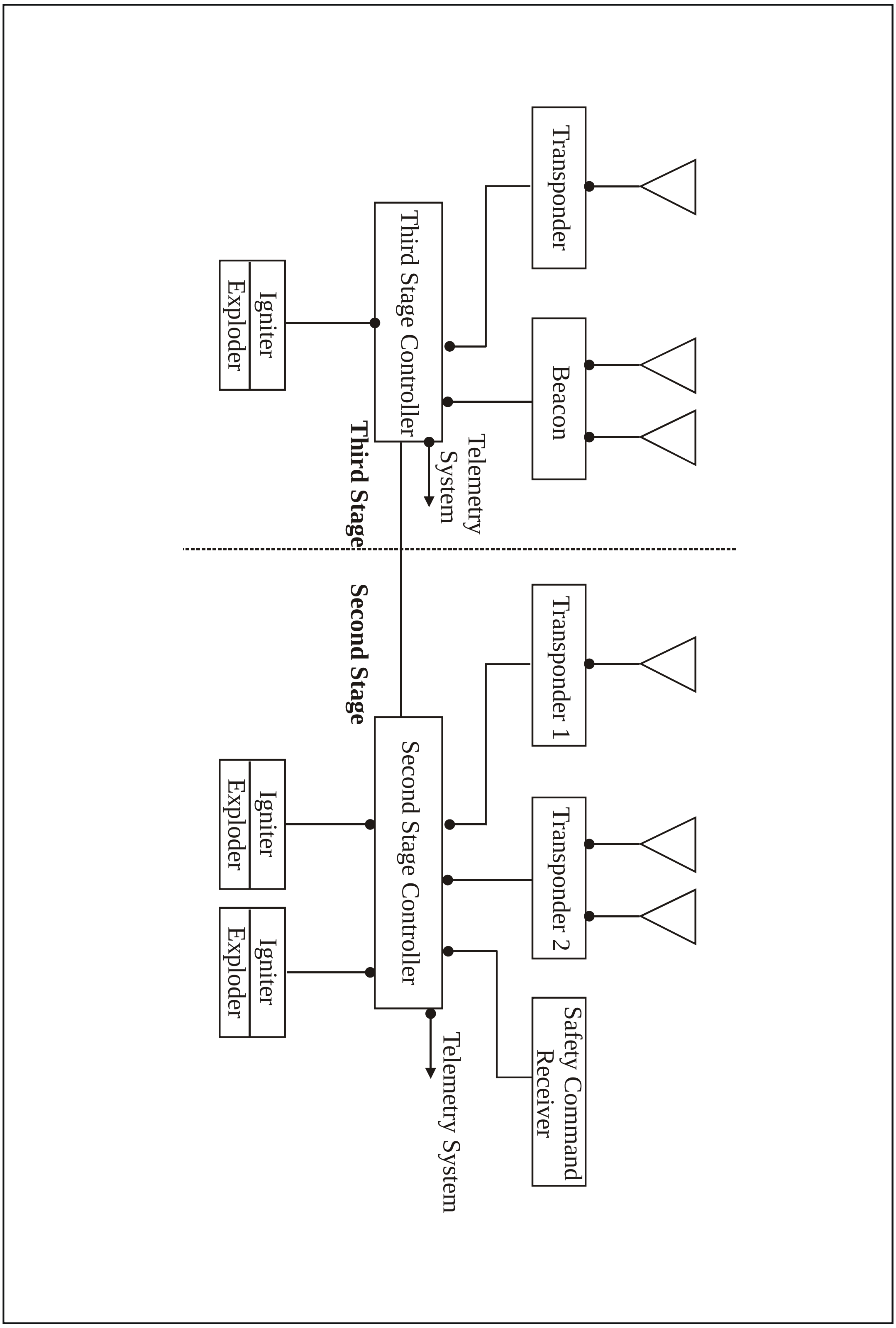

Figure 2-7 Tracking and Range Safety System Schematic Diagram

2-16

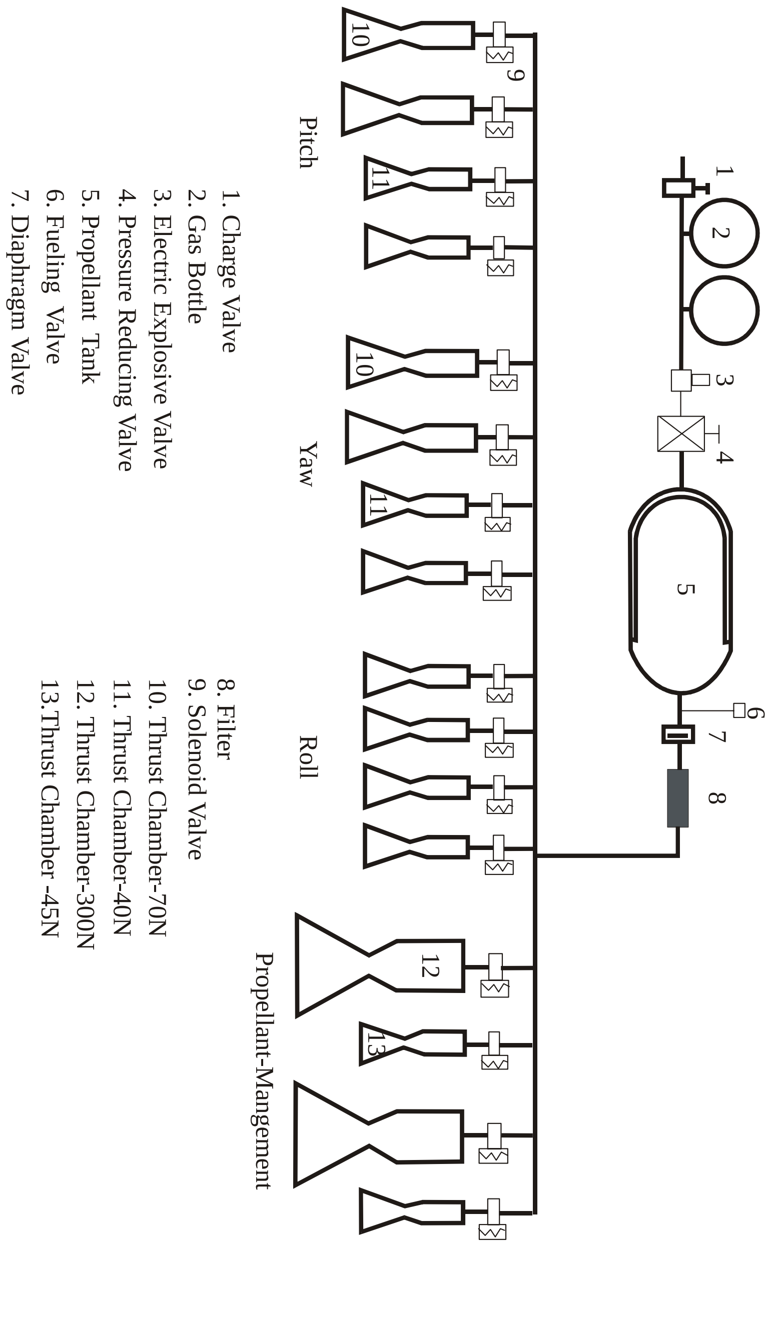

Figure 2-8 Coast Phase Propellant Management and Attitude Control System

2-17

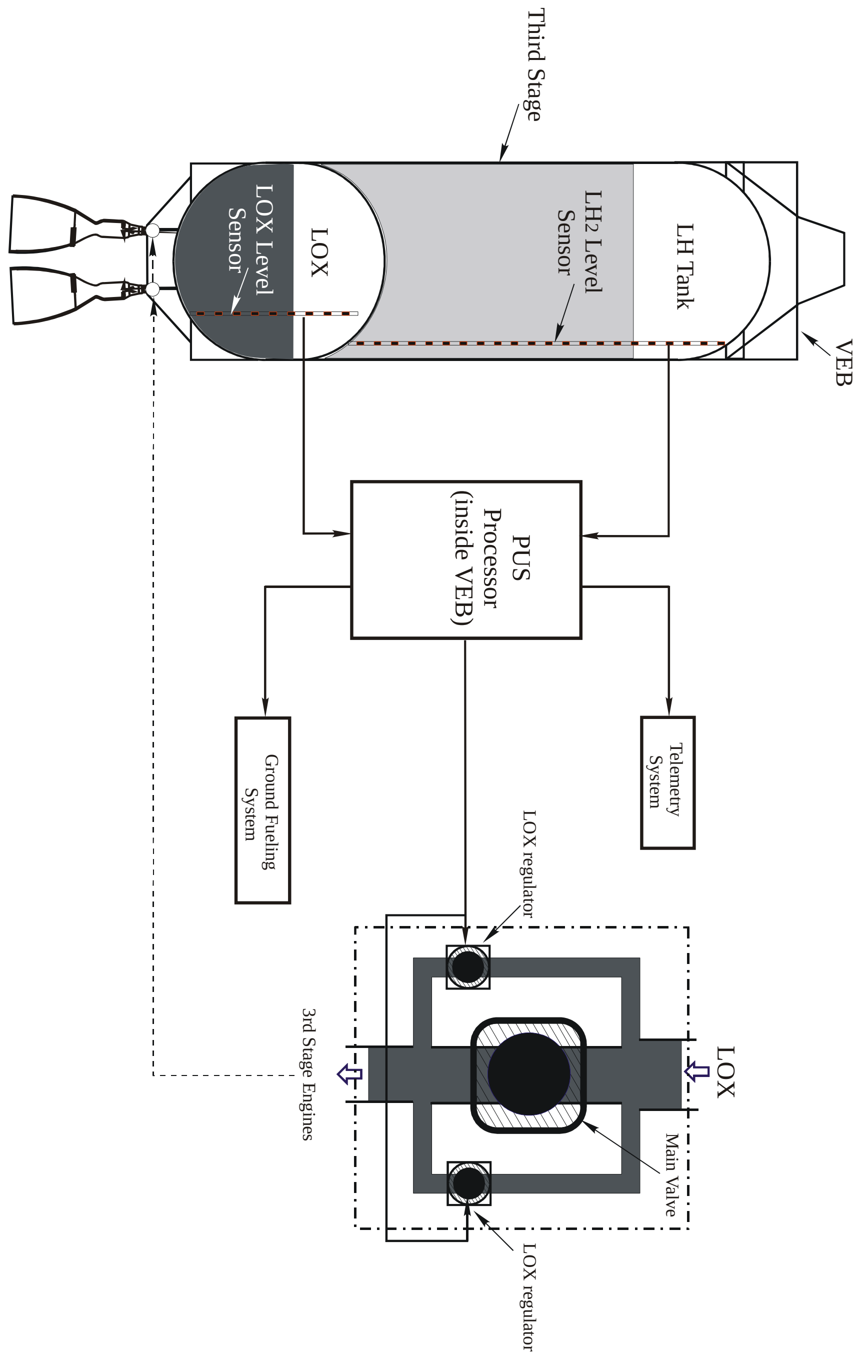

Figure 2-9 Cryogenic Propellant Utilization System Schematic Diagram

2.3.8 Separation System

There are five separation events during LM-3B flight phase, i.e. booster separations, first/second stage separation, second/third stage separation, fairing jettisoning and SC/LV separation. See **Figure 2-10**.

- **<u>Booster Separations:</u>** The boosters are mounted to the core stage through three 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.

- **<u>First/Second Stage Separation:</u>** The first/second stage 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.

- **<u>Second/Third Stage Separation:</u>** The second/third stage separation is a cold separation. The explosive bolts are unlocked firstly and then the small retro-rockets on the second stage are initiated to generate separation force.

- **<u>Fairing Jettisoning:</u>** During the payload fairing separation, the explosive bolts connecting the fairing and the third stage unlocked firstly and then all the pyrotechnics connecting the two fairing shells are ignited, and the fairing separated longitudinally. The fairing turn outward around the hinges under the spring force.

- **<u>SC/LV Separation:</u>** The SC is bound together with the launch vehicle through clampband. After separation, the SC is pushed away from the LV by the springs.

2.3.9 Auxiliary System

The auxiliary system works before the launch vehicle lift-off, which includes ground monitoring and measuring units such as the propellant loading level and temperature, air-conditioner to fairing and water-proof measure, etc.

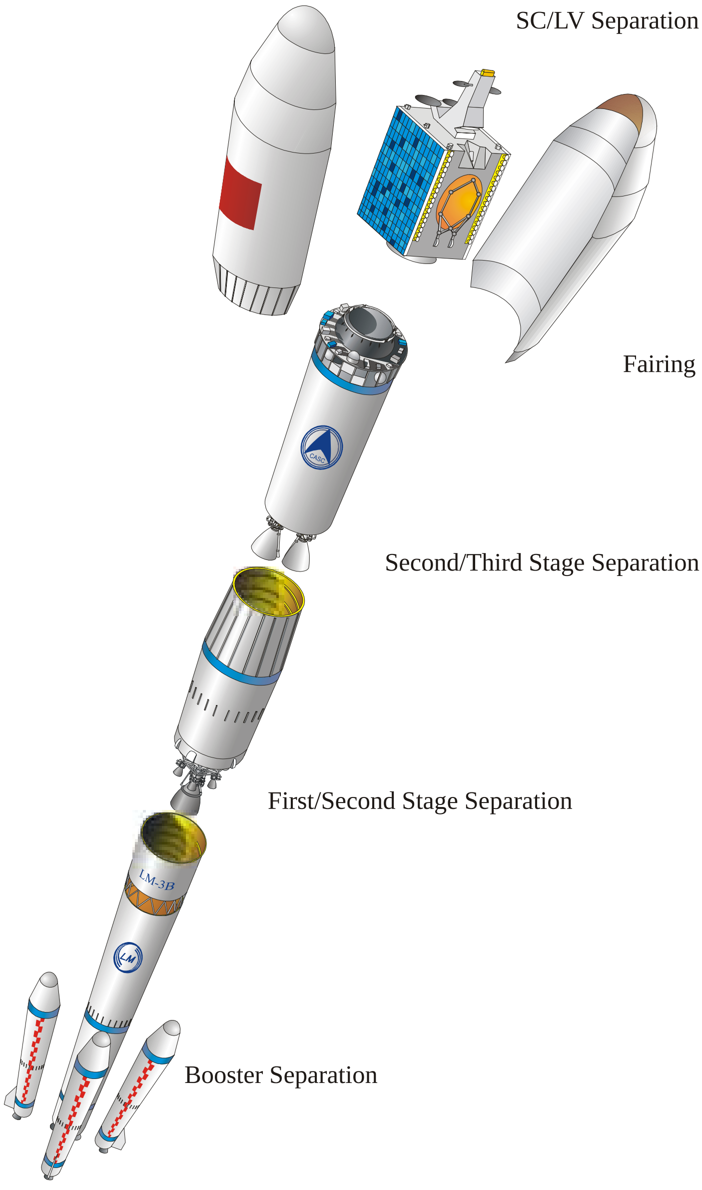

Figure 2-10 LM-3B Separation Events

2.4 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 payload 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 180° away 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**. Satellite 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.

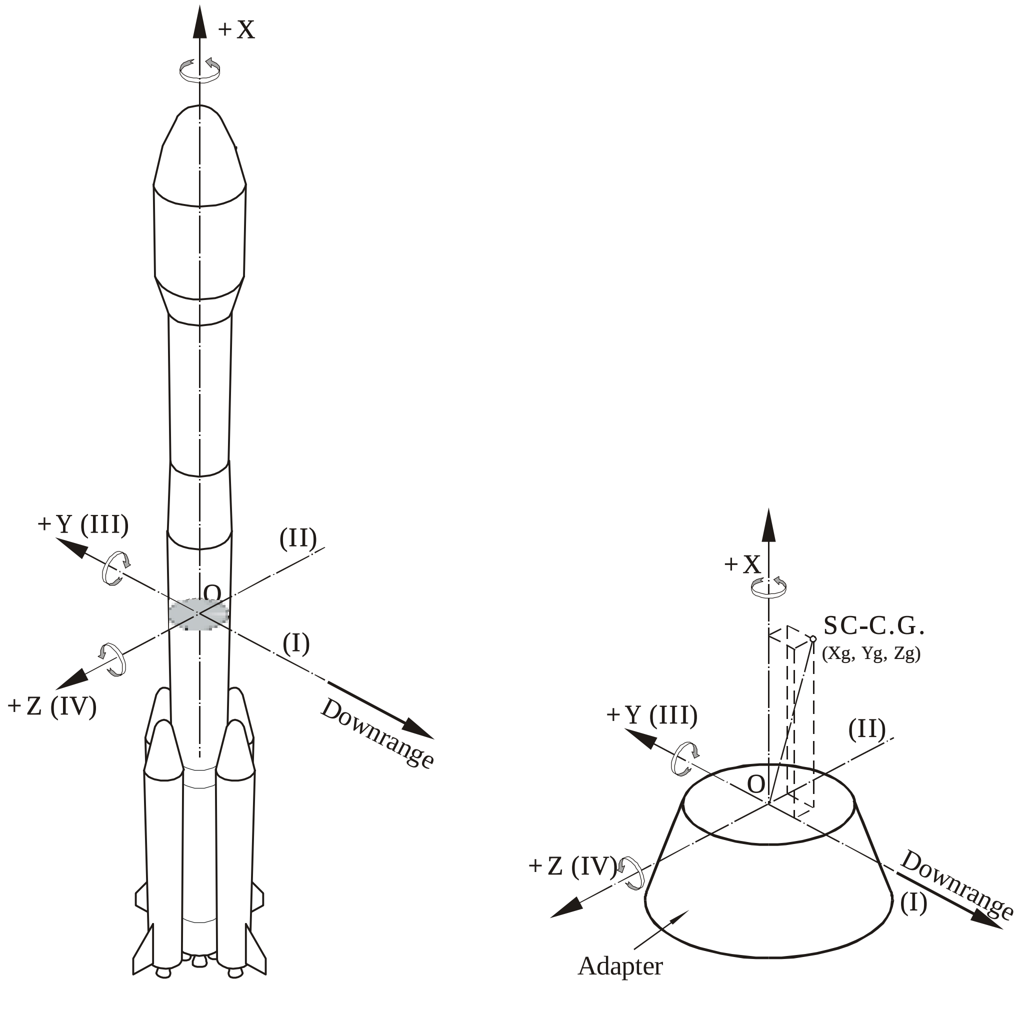

Figure 2-11 Definition of Coordinate Systems and Flight Attitude

2.5 Missions To Be Performed by LM-3B

LM-3B is a powerful and versatile rocket, which is able to perform the following missions.

- To send payloads into geo-synchronous transfer orbit (GTO). This is the primary usage of LM-3B and its design objectives. Following the separation from LM-3B, the SC will transfer from GTO to Geo-synchronous Orbit (GEO). GEO is the working orbit, on which the SC has the same orbital period as the rotation period of the Earth, namely about 24 hours, and the orbit plane coincides with the equator plane; See **Figure 2-12**.
- To inject payloads into low earth orbit (LEO) below mean altitude of 2000km;
- To project payloads into sun synchronous orbits (SSO). SSO plane is along with the rotation direction of the Earth rotation axis or points to the earth rotation around the Sun. The angular velocity of the SC is equal to the average angular velocity of the Earth around the Sun;
- To launch spaceprobes beyond the earth gravitational field (Escape Missions).

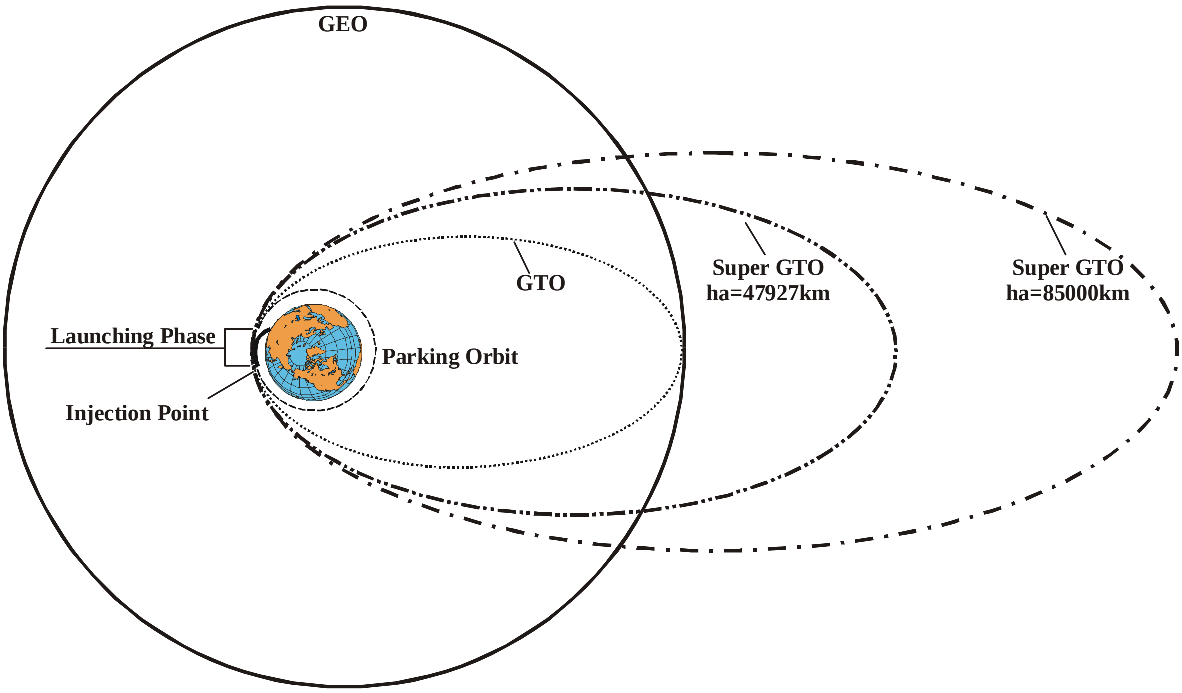

Figure 2-12 Launching Trajectory

2.6 Satellites Launched by LM-3B

Till July 18, 1998, LM-3B has launched five payloads from different manufacturers in the world. The successes of the missions indicate that LM-3B is compatible with all the commercial satellites in the launch service market. **Table 2-2** lists the payloads and launch requirements.

Table 2-2 Satellites Launched by LM-3B

Flight No.		1	2	3	4	5
Payload		Intelsat-708	MABUHAY	Apstar-IIR	ChinaStar-1	SINOSAT
Builder		SS/Loral	SS/Loral	SS/Loral	LMCO	Aerospatiale
Platform		FS1300	FS1300	FS1300	A2100	SpaceBus3000
Launch Date		02/15/96	08/20/97	10/17/97	05/30/98	07/18/98
Mass		4593.7	3775.1	3746	2916.8	2832
Required Injection Data	i	24.5	24.5	24.5	19	24.5
	Hp	200	200	200	600	200
	Ha	35786	47924	47924	35786	85000

See **Figure 2-13**.

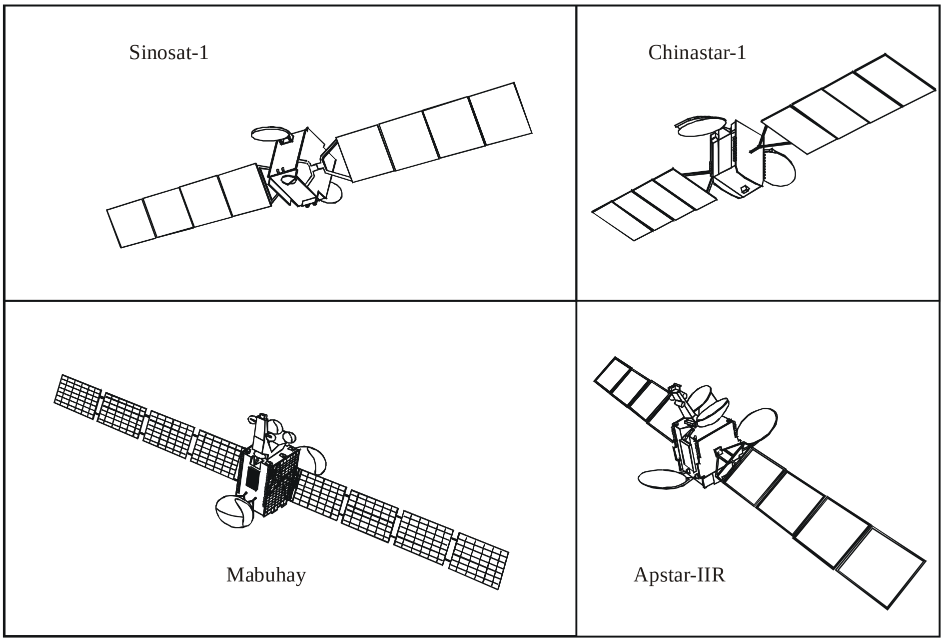

Figure 2-13 Satellites Launched by LM-3B