

CHAPTER 2

GENERAL DESCRIPTION TO LM-3A

2.1 Summary

China Academy of Launch Vehicle Technology (CALT) started to design LM-3A in mid-1980s. LM-3A is a powerful 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.

LM-3A provides three types of payload interfaces (937B, 1194 and 1194A), which provide the users with more flexibility.

2.2 Technical Description

2.2.1 Major Characteristics of LM-3A

Table 2-1 Technical Parameters of LM-3A

Stage	First Stage	Second Stage	Third Stage
Lift-off Mass (t)	241		
Propellant	N ₂ O ₄ /UDMH		LOX/LH ₂
Mass of Propellant (t)	171.775	30.752	18.193
Engine	DaFY6-2	DaFY20-1(Main) DaFY21-1(Vernier)	YF-75
Thrust (kN)	2961.6	742 (Main) 11.8×4(Vernier)	78.5×2
Specific Impulse (N.s/kg)	2556.5	2922.57(Main) 2910.5(Vernier)	4312
Stage Diameters (m)	3.35	3.35	3.0
Stage Length (m)	23.272	11.276	12.375
Fairing Length (m)	8.887		
Fairing Diameter (m)	Φ3.35		
Total Length (m)	52.52		

2.3 LM-3A System Composition

LM-3A 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 first stage, second stage, third stage and payload fairing. See **Figure 2-1**.

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-3A and conveys the loads between them. The interface ring on the top of the adapter can be 937B, 1194 or 1194A international standard interfaces. The VEB is a circular plate made of metal honeycomb and truss, where the launch vehicle avionics are mounted. See **Figure 2-2**. 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, forward cone section, cylindrical section and reverse cone section, see **Chapter 4** for details.

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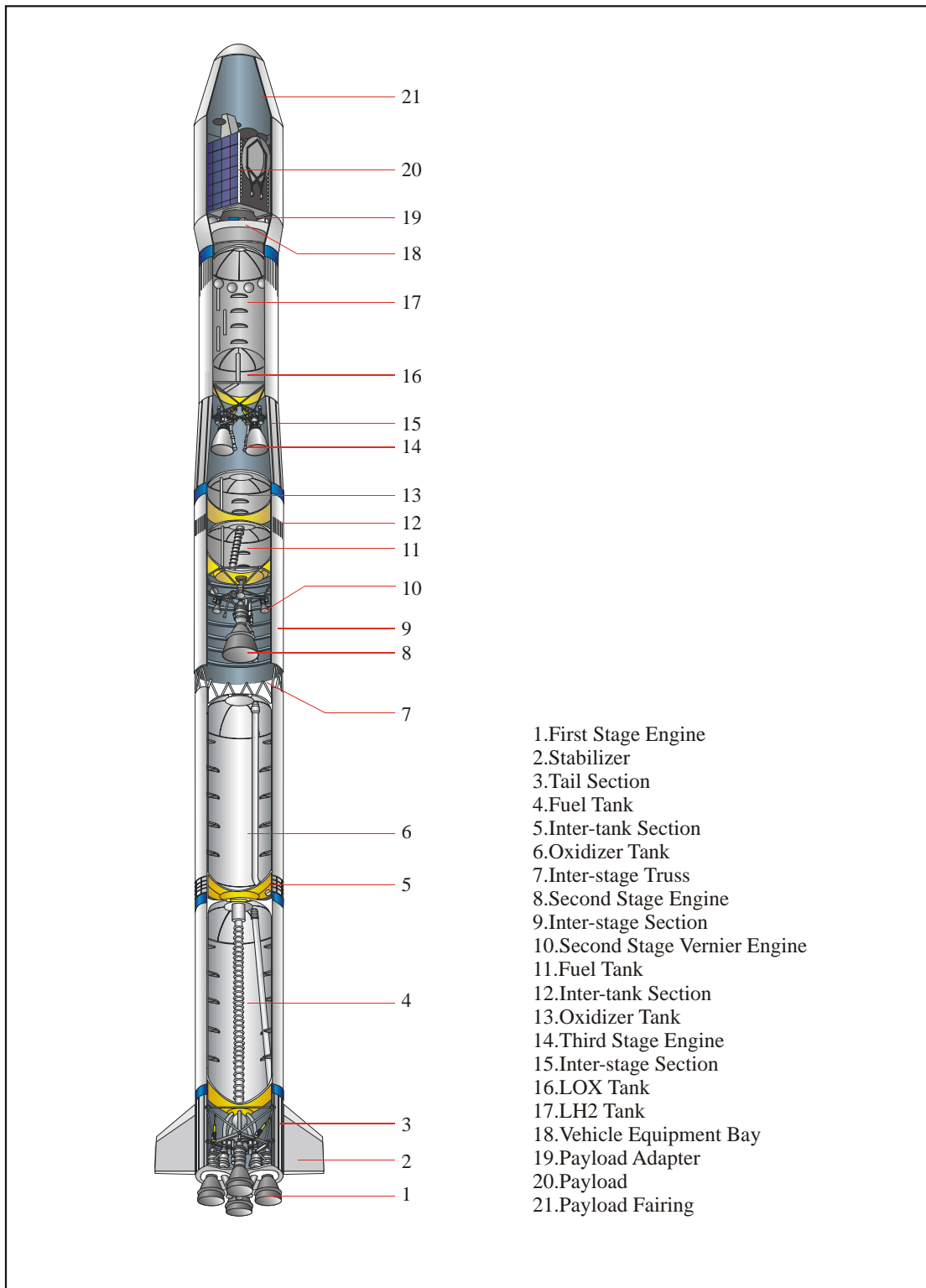


Figure 2-1 LM-3A Configuration

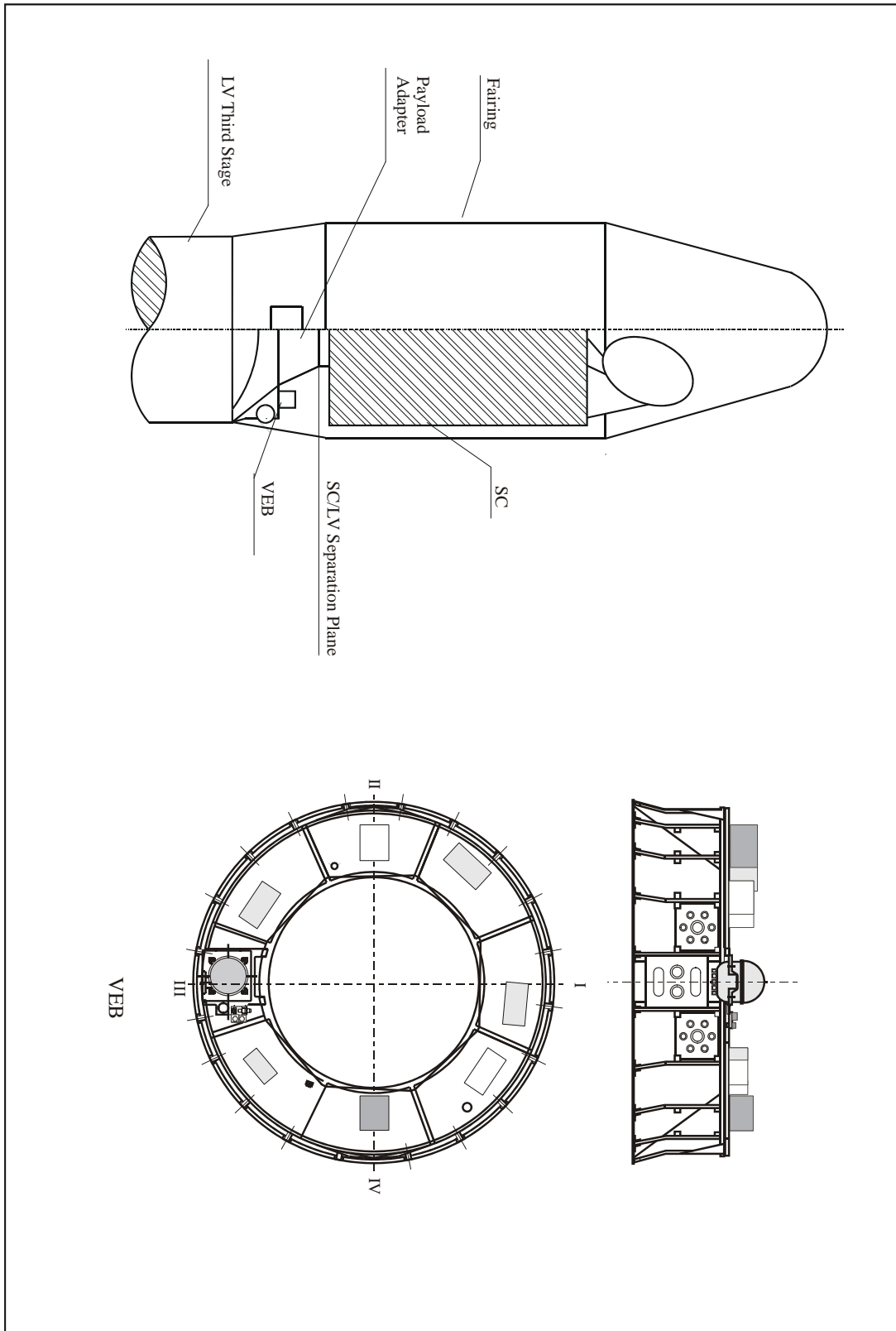


Figure 2-2 VEB Configuration

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 2-3a,b&c**.

The first stage 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. 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 gimbaling 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 2-4a,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 560 parameters are measured. Refer to **Figure 2-5**.

2.3.5 Tracking and Range Safety System

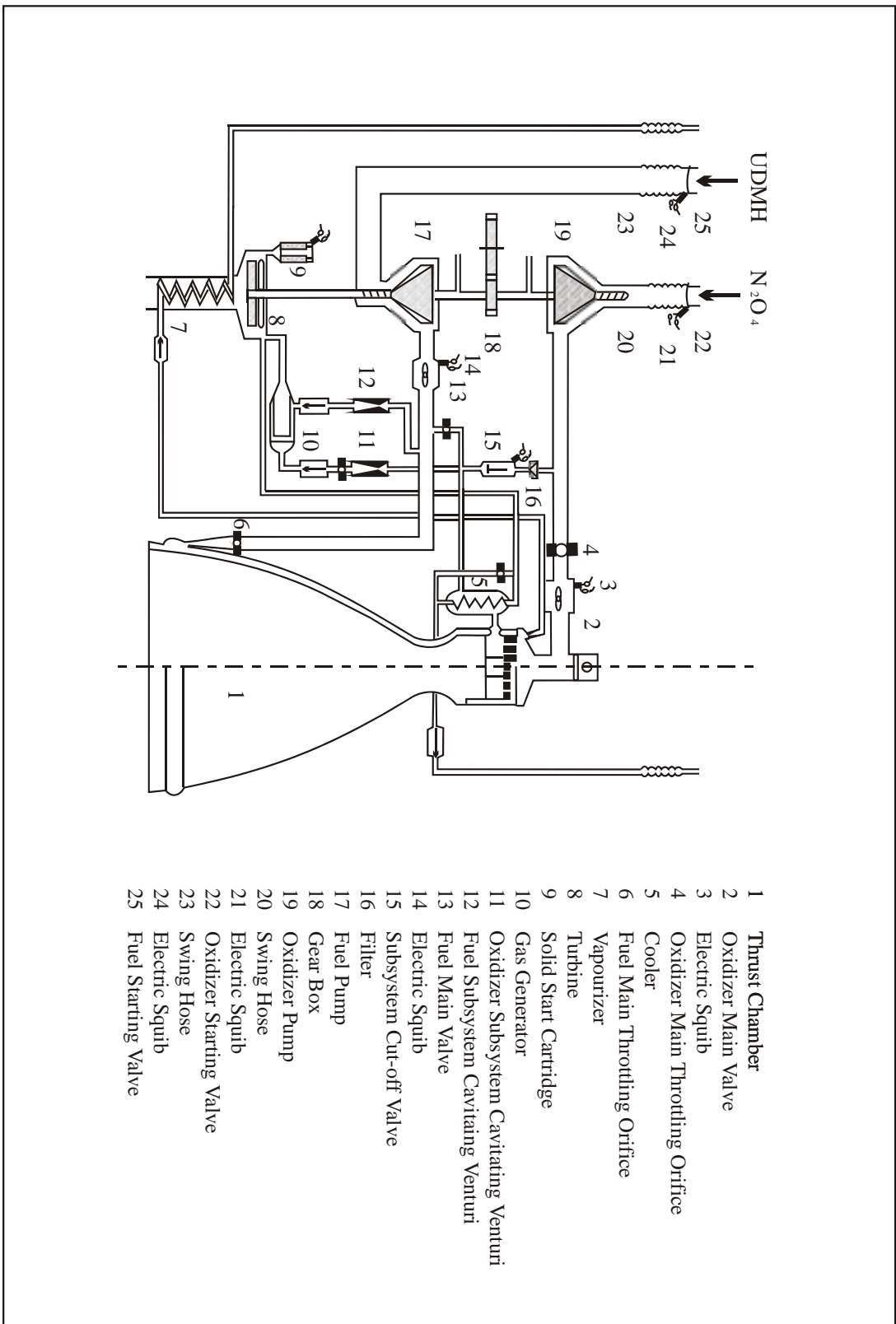
The tracking and range safety system works to measure the trajectory data and final injection parameters. The system also provides safety assessment information. A self-destruction would be remotely controlled if a flight anomaly occurred. The trajectory measurement and safety control design are integrated together. A sampling check system is equipped on the ground part. Refer to **Figure 2-6**.

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 2-7**.

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 2-8**.



- 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 Cavitating 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 2-3a First Stage Propulsion System Schematic Diagram

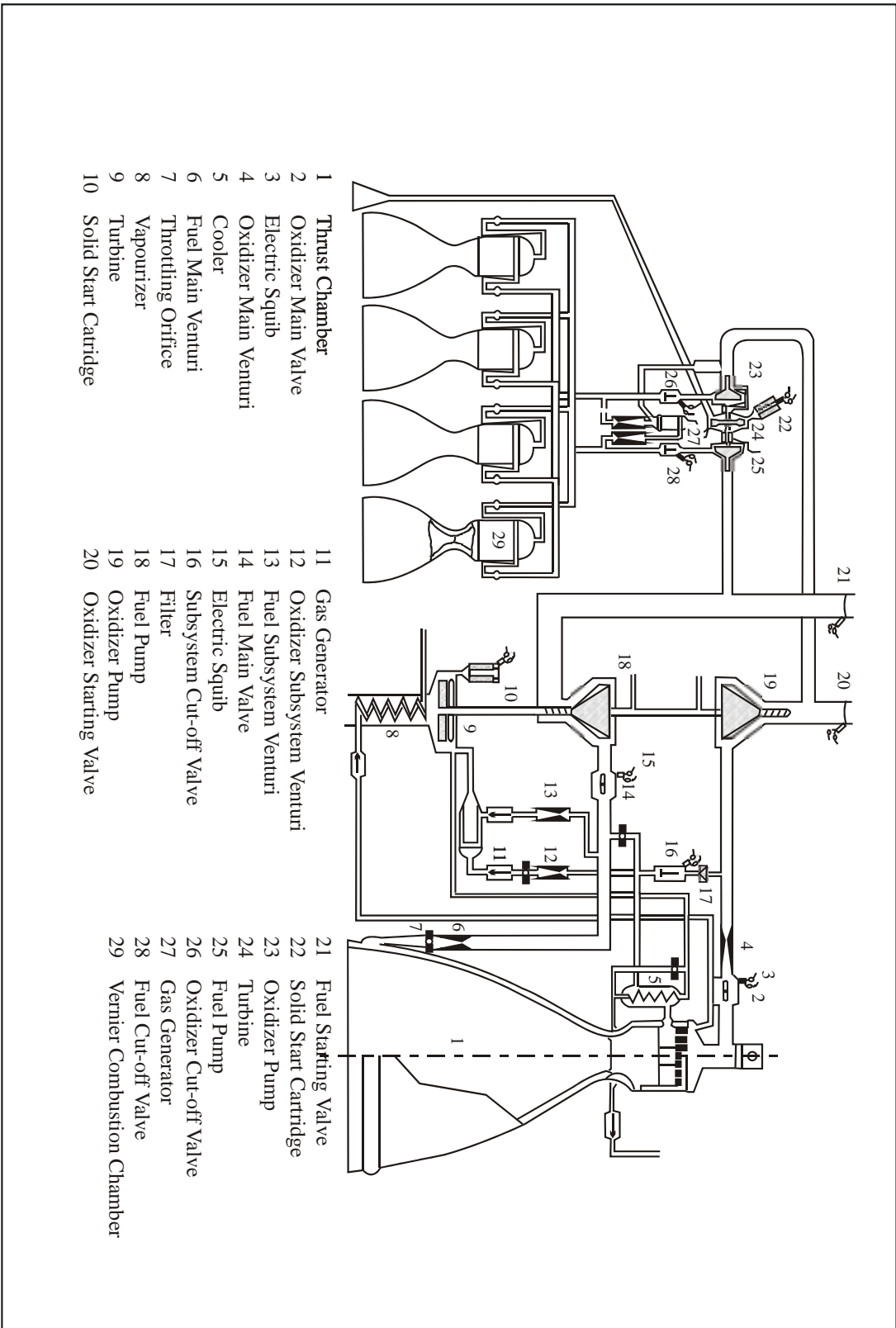


Figure 2-3b Second Stage Propulsion System Schematic Diagram

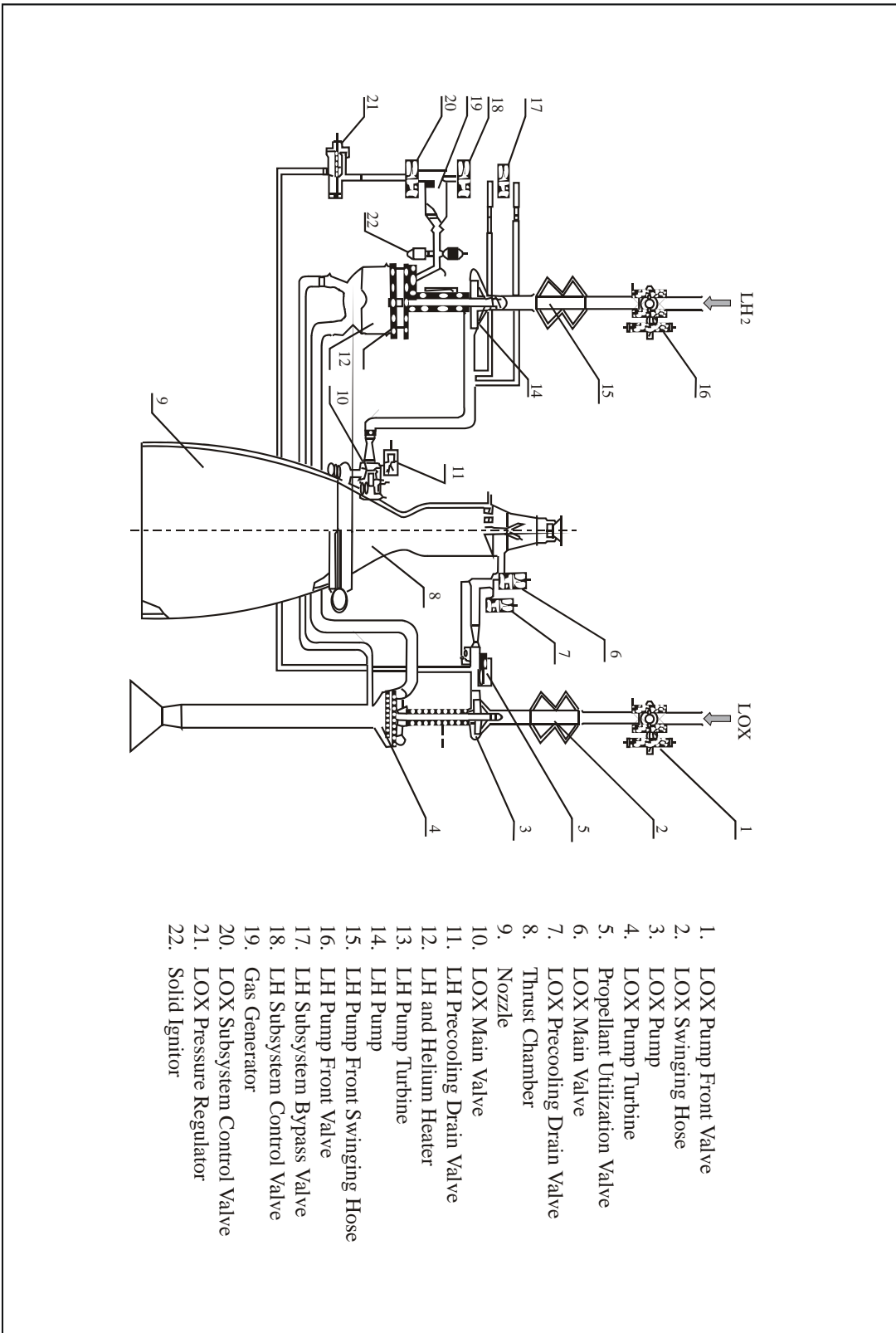


Figure 2-3c Third Stage Propulsion System Schematic Diagram

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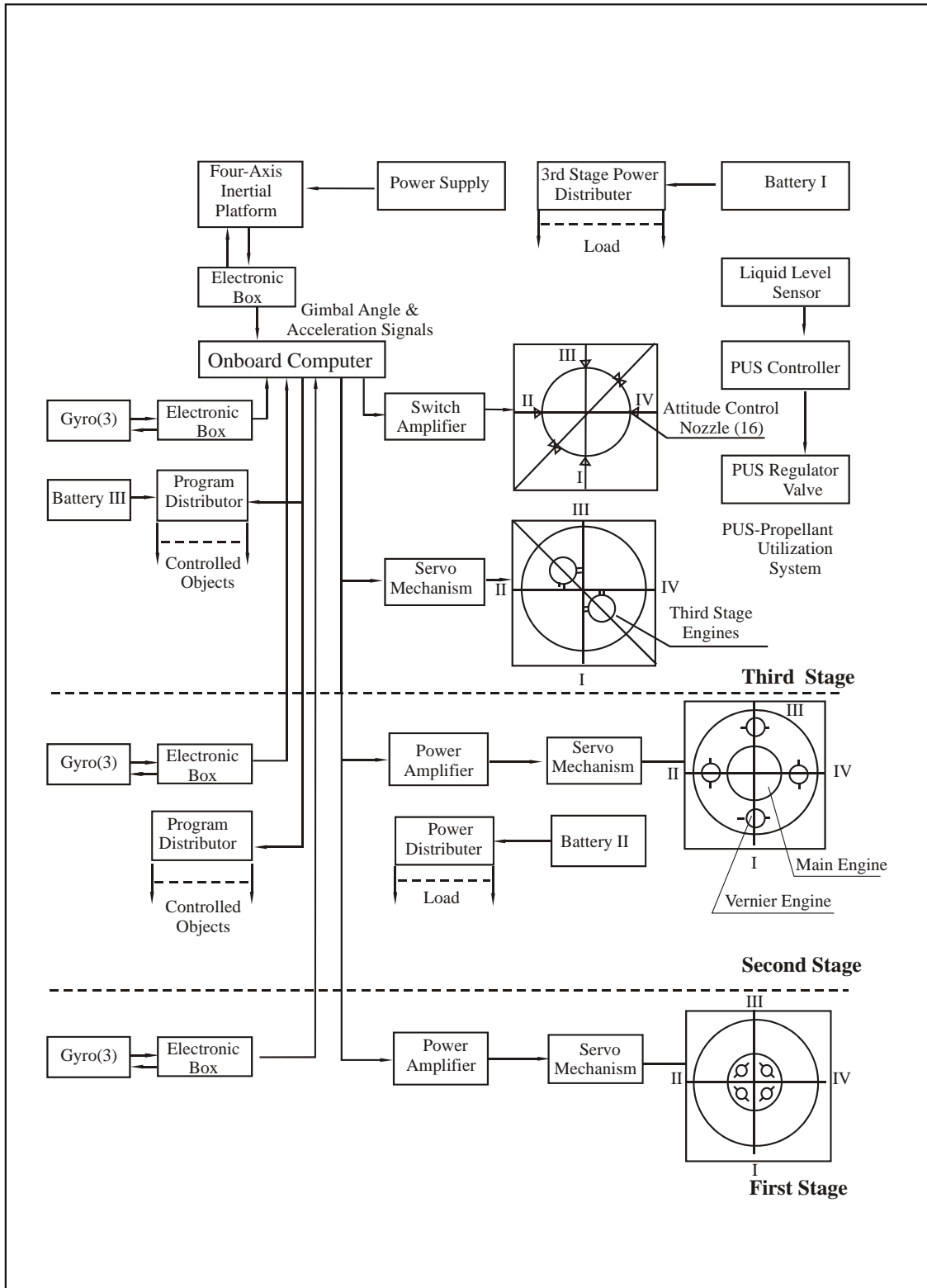


Figure 2-4a Control System Schematic Diagram

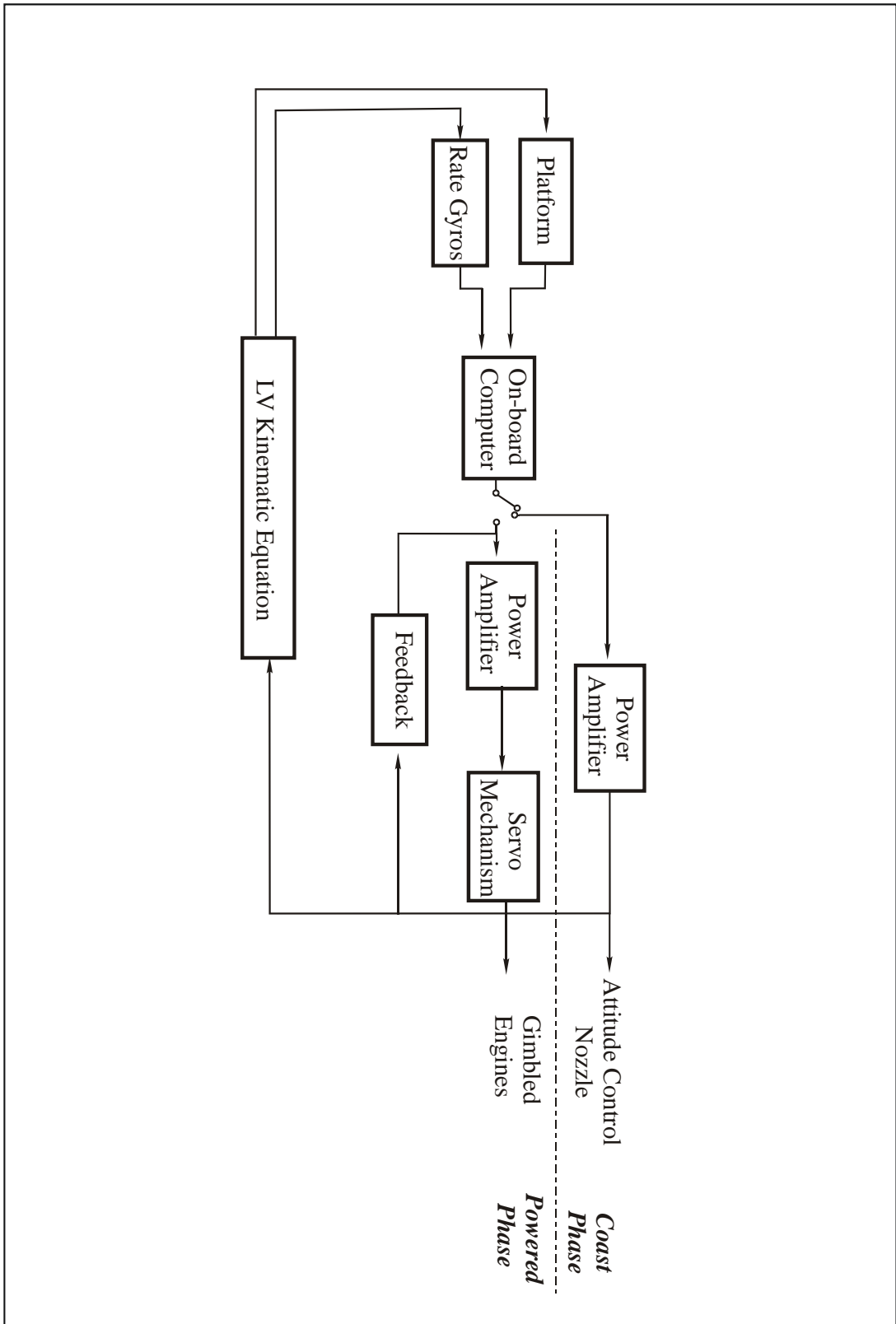


Figure 2-4b Attitude-control System Schematic Diagram

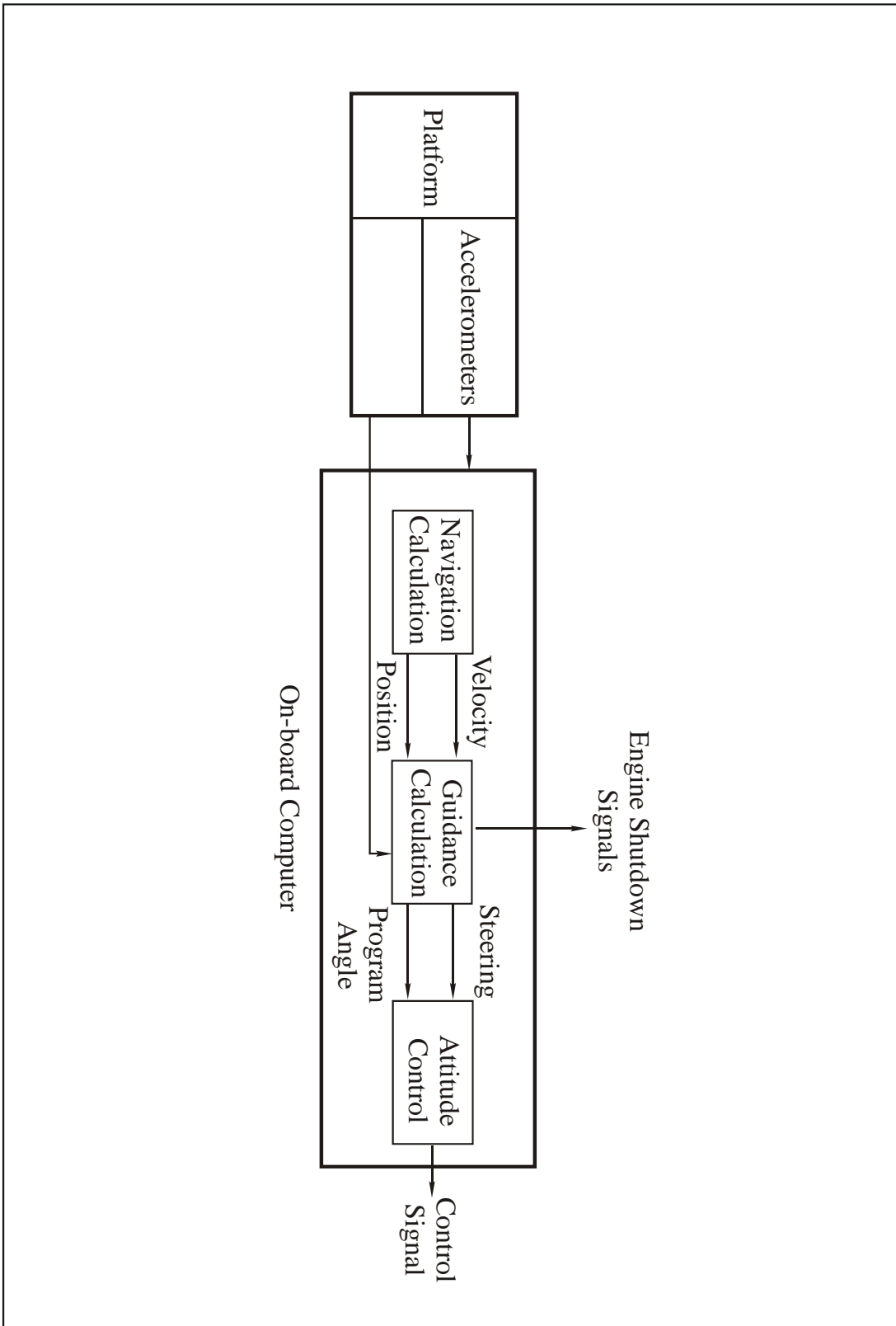


Figure 2-4c Guidance System Schematic Diagram

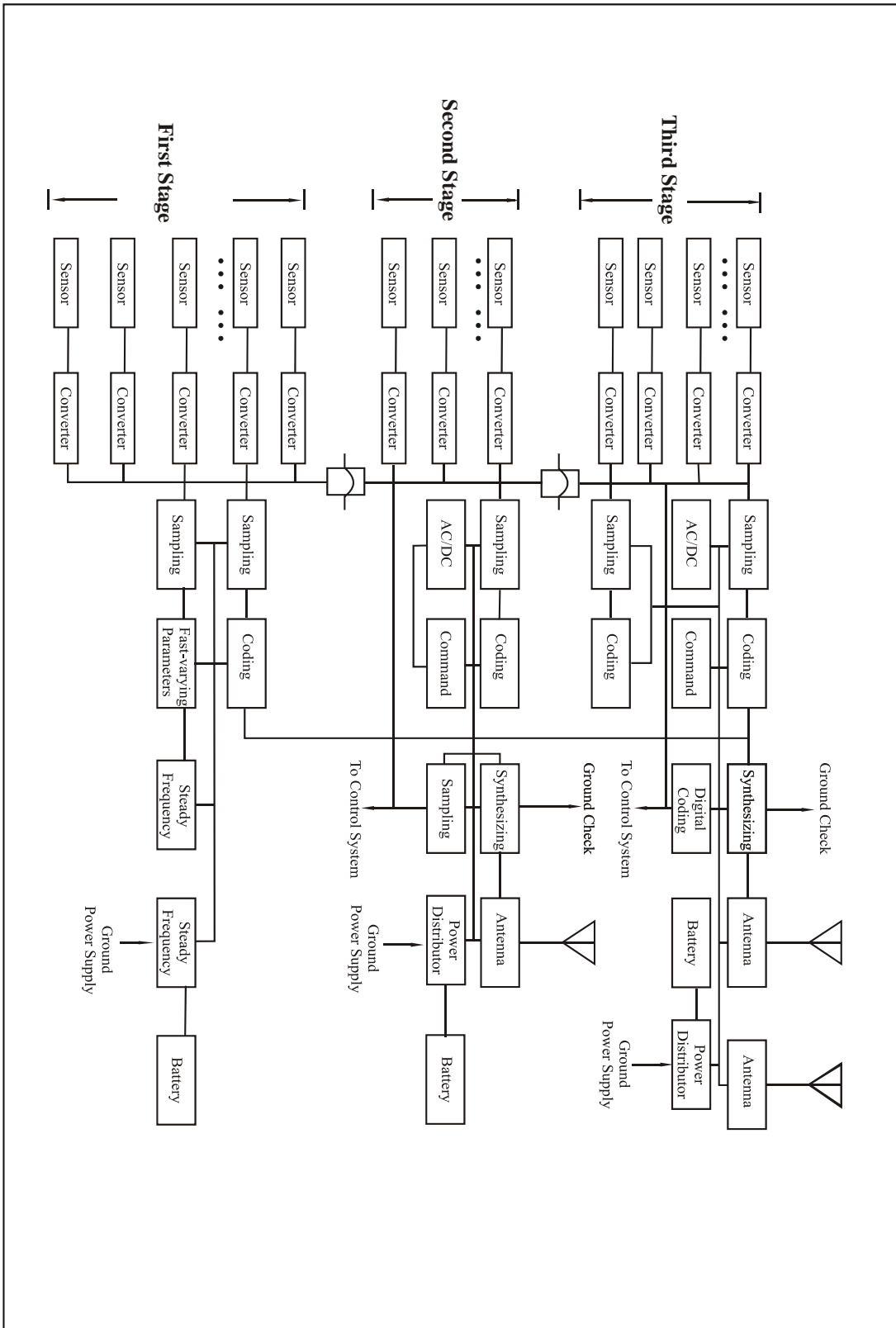


Figure 2-5 Telemetry System Schematic Diagram

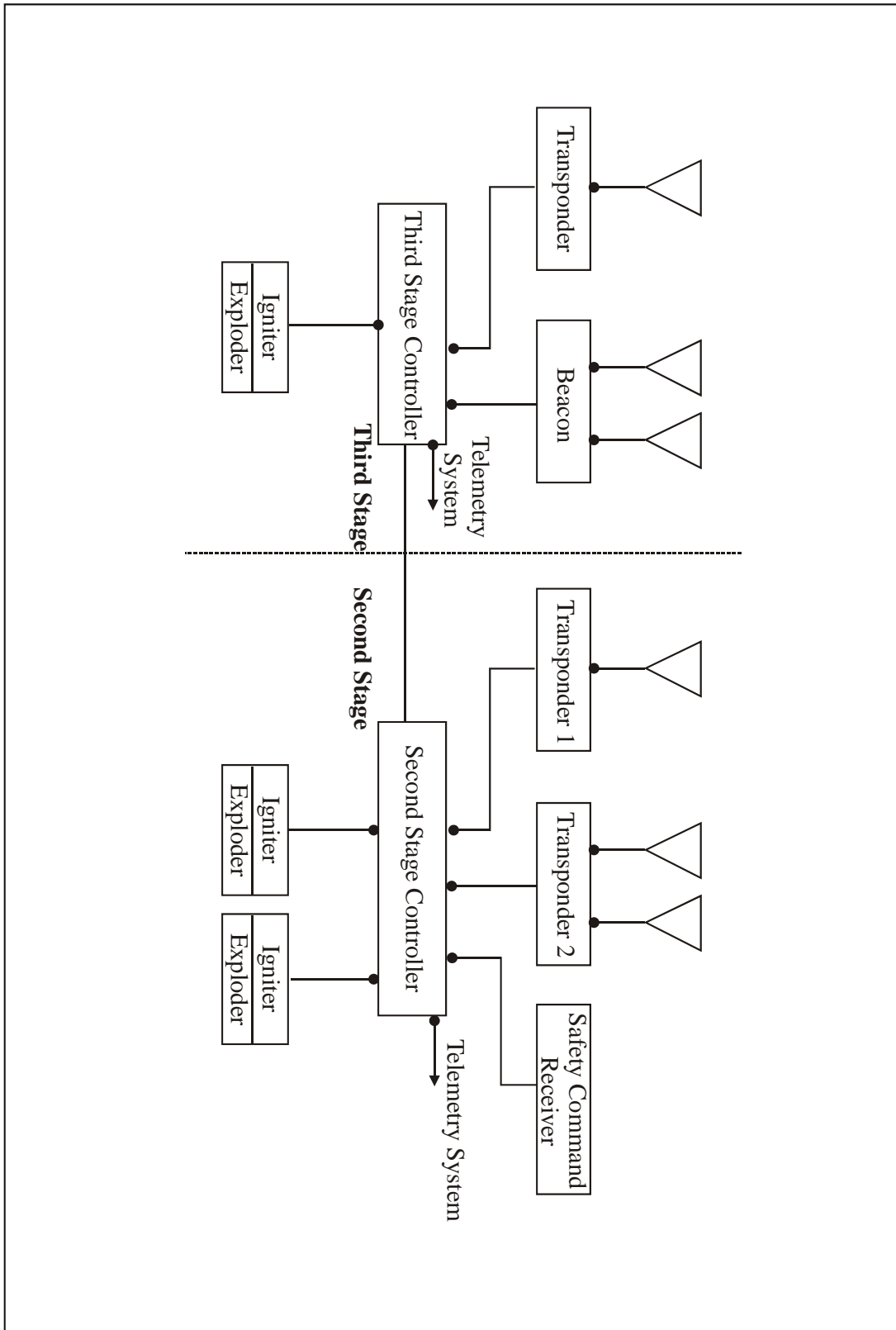


Figure 2-6 Tracking and Range Safety System Schematic Diagram

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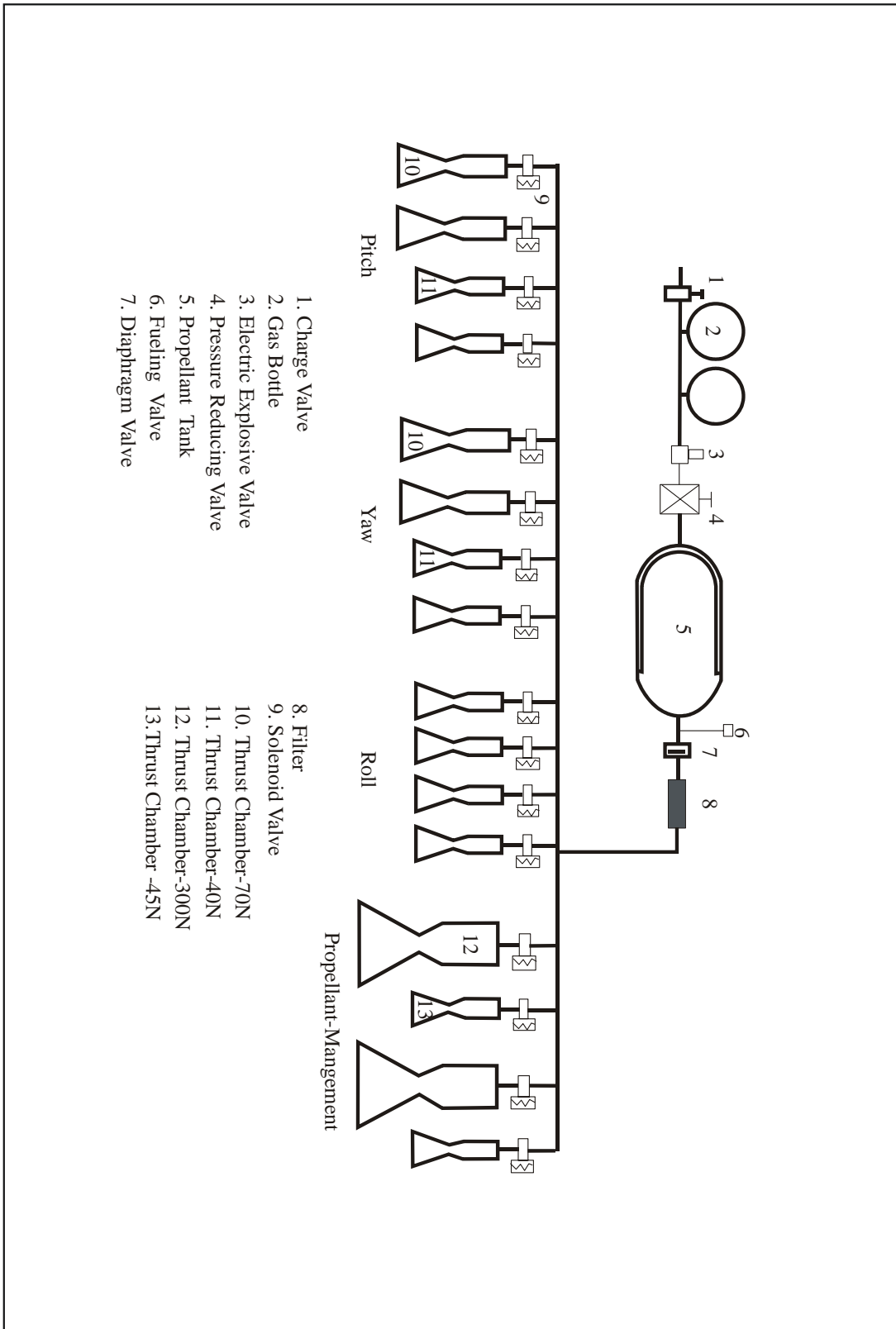


Figure 2-7 Cast Phase Propellant Management and Attitude Control System

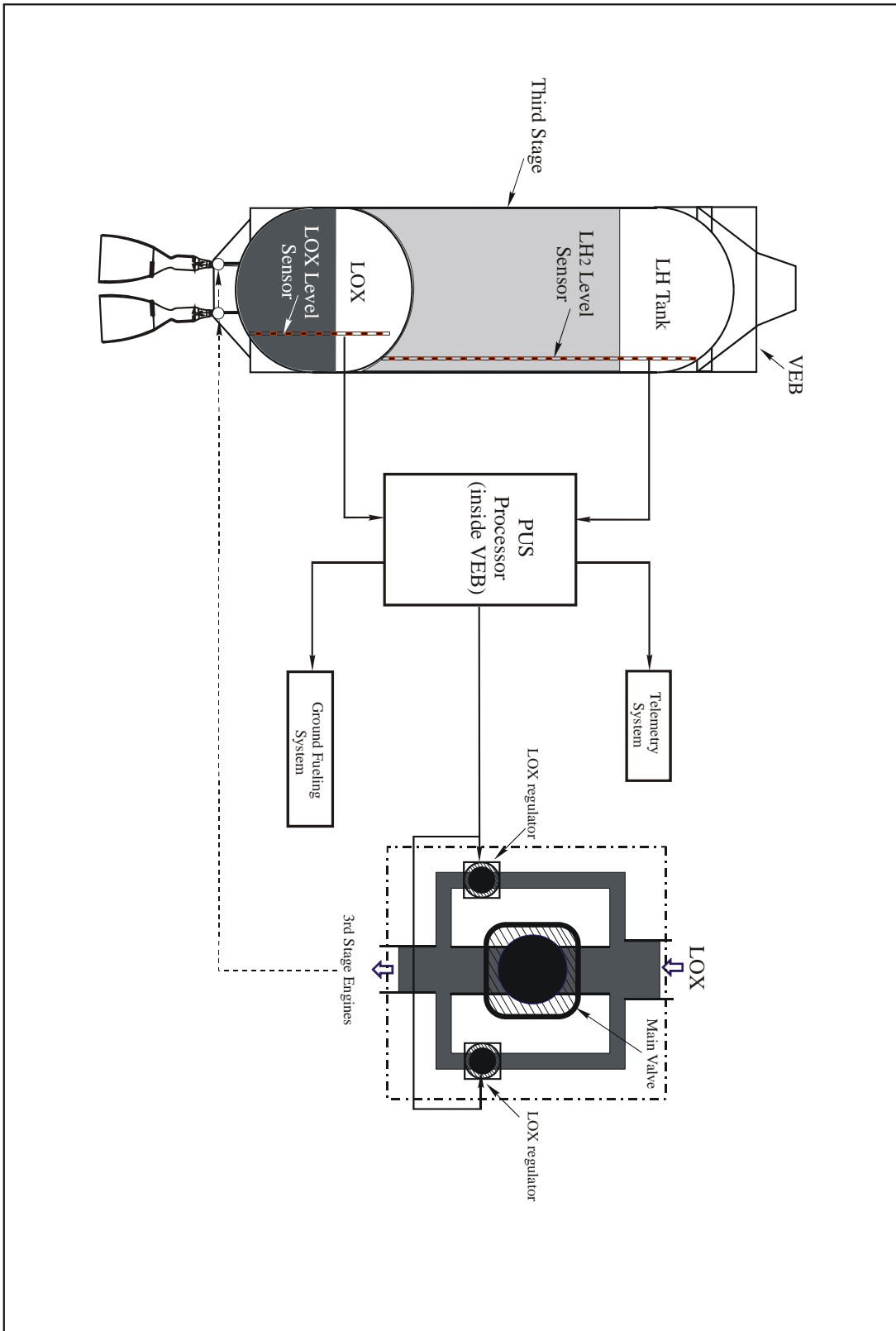


Figure 2-8 Cryogenic Propellant Utilization System Schematic Diagram

2.3.8 Separation System

There are four separation events during LM-3A flight phase, i.e. first/second stage separation, second/third stage separation, fairing jettisoning and SC/LV separation. See **Figure 2-9**.

- **First/Second Stage Separation:** 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.
- **Second/Third Stage Separation:** 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.
- **Fairing Jettisoning:** During the payload fairing separation, the explosive bolts connecting the fairing and the third stage unlocked firstly and then the explosive bolts connecting the two fairing halves are unfastened and the fairing separated longitudinally. The fairing turn outward around the hinges under the spring force.
- **SC/LV Separation:** 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.

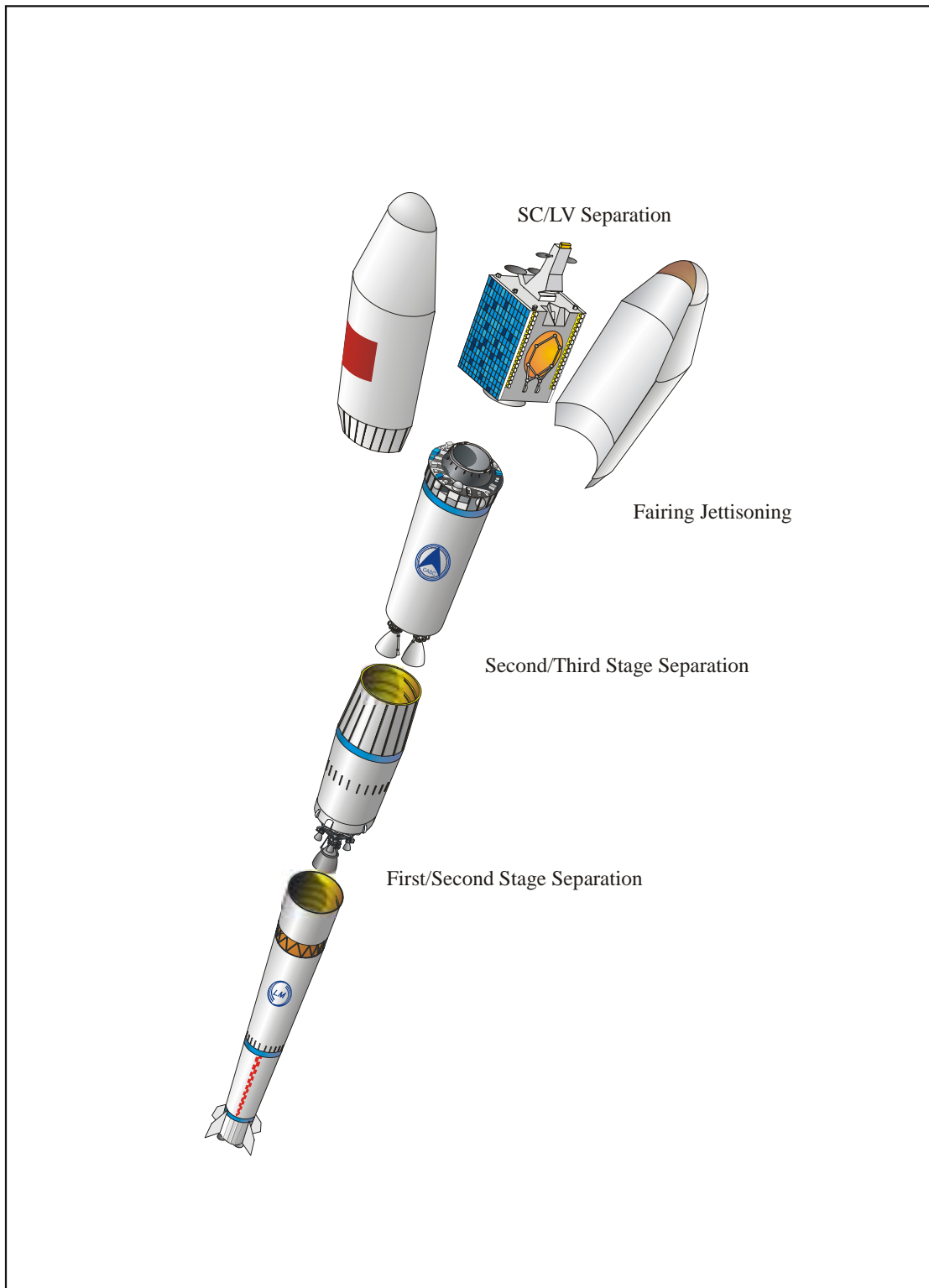


Figure 2-9 LM-3A Separation Events

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 2-10**. 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.

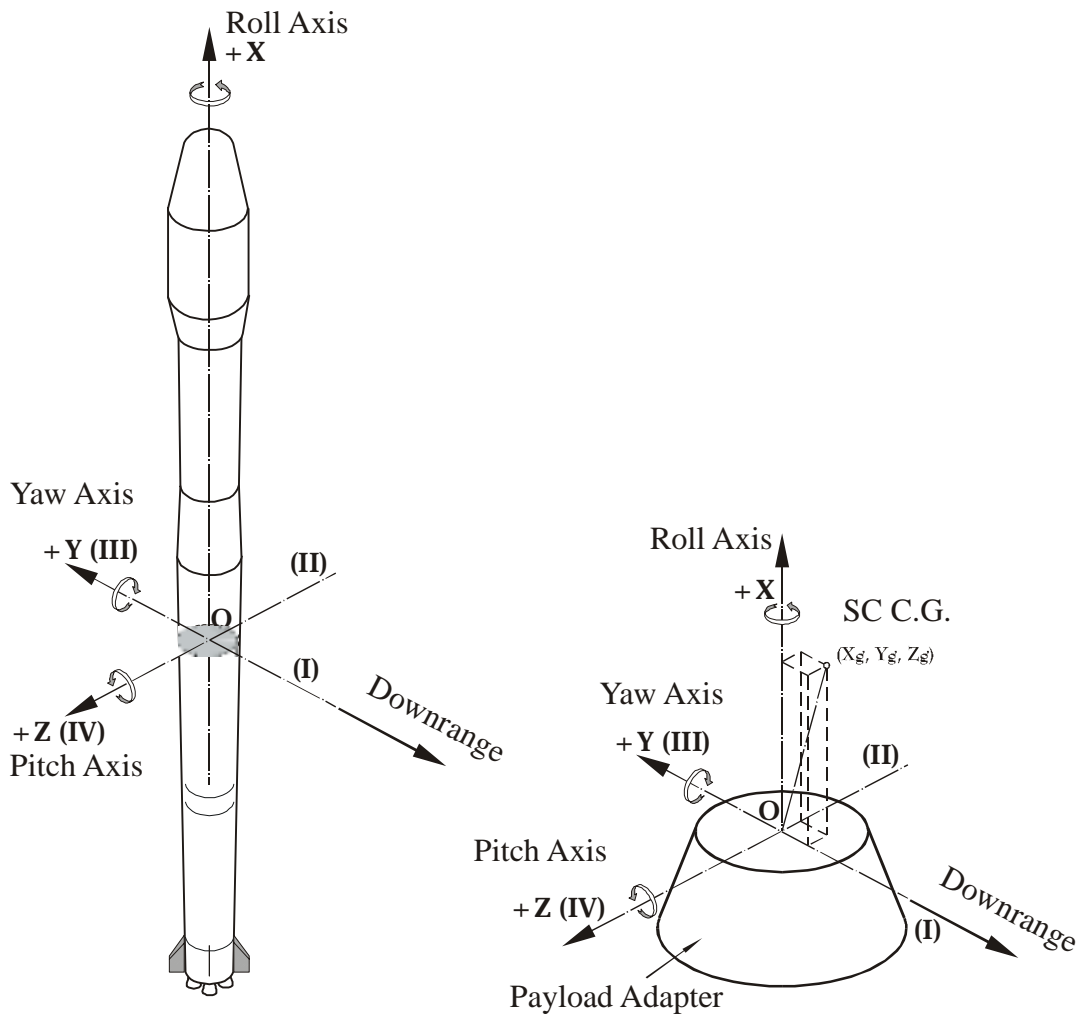


Figure 2-10 Definition of Coordinate Systems and Flight Attitude

2.5 Missions To Be Performed by LM-3A

LM-3A 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-3A and its design objectives. Following the separation from LM-3A, 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 2-11**.
- 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).

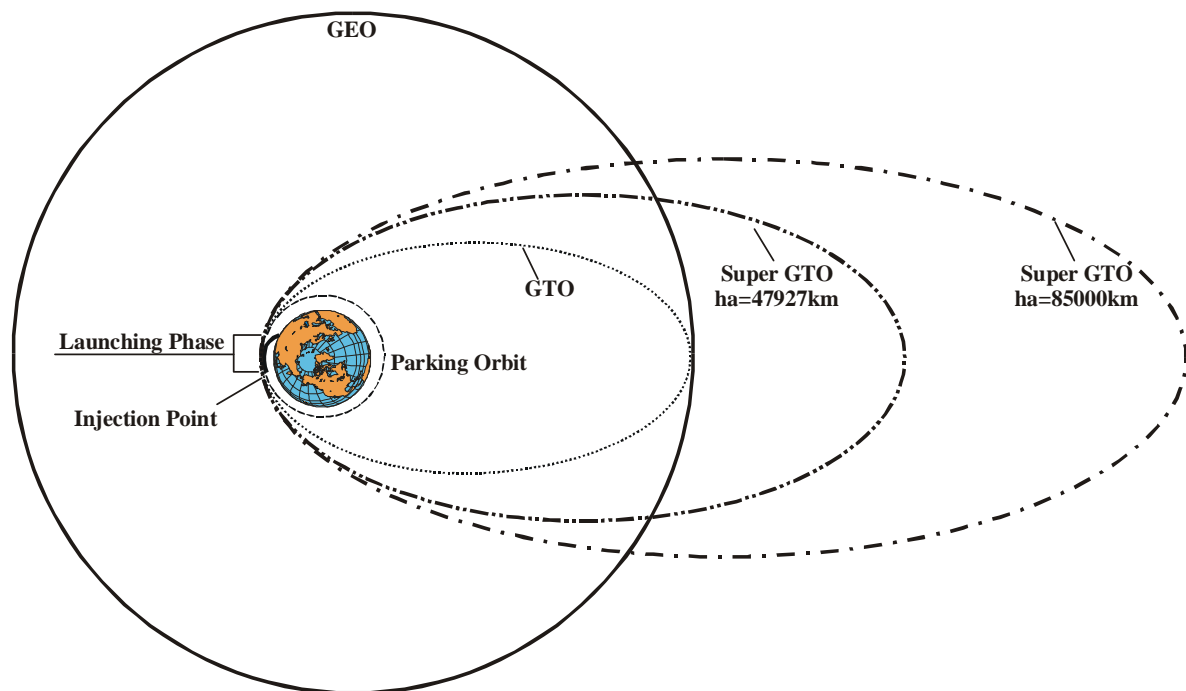


Figure 2-11 Launching Trajectory

2.6 Satellites Launched by LM-3A

Till May 1997, LM-3A has launched three times, in which four satellites have been successfully sent into the predetermined orbit. Four more LM-3A launches have been ordered by 2003. **Table 2-2** lists the orbital injection parameters by LM-3A so far.

Table 2-2 Satellites Launched by LM-3A

Flight No.	1		2	3
Payload	Practice IV	KF-1	DFH-3	DFH-3
Launch Date	02/08/94	02/08/94	11/30/94	05/12/97
Mass	396	1342	2232.4	2266.6
Required Injection Data	i	28.598593	28.5505	28.478
	Hp	203.397	204.362	211.86
	Ha	36311.497	36184.698	36064.6