中国长城工业集团有限公司
CHINA GREAT WALL INDUSTRY CORP.

Launch Vehicle and Launch Services

Oct. 21, 2016
Thailand


中国航天

Subject

- Launch Vehicle
- The Main Launch Vehicles in the Market
- Launch Services and Long March Launch Services
- Launch Services Selection

About the Launch Vehicle

The purpose of the LV: Deliver the Satellite into the required Orbit;

The main characters of the LV: powered by the LV engine, rises above Earth's atmosphere and can escape from earth's gravitation at velocity(cosmic velocity 7.9km/s, 11.2km/s, 16.6km/s);

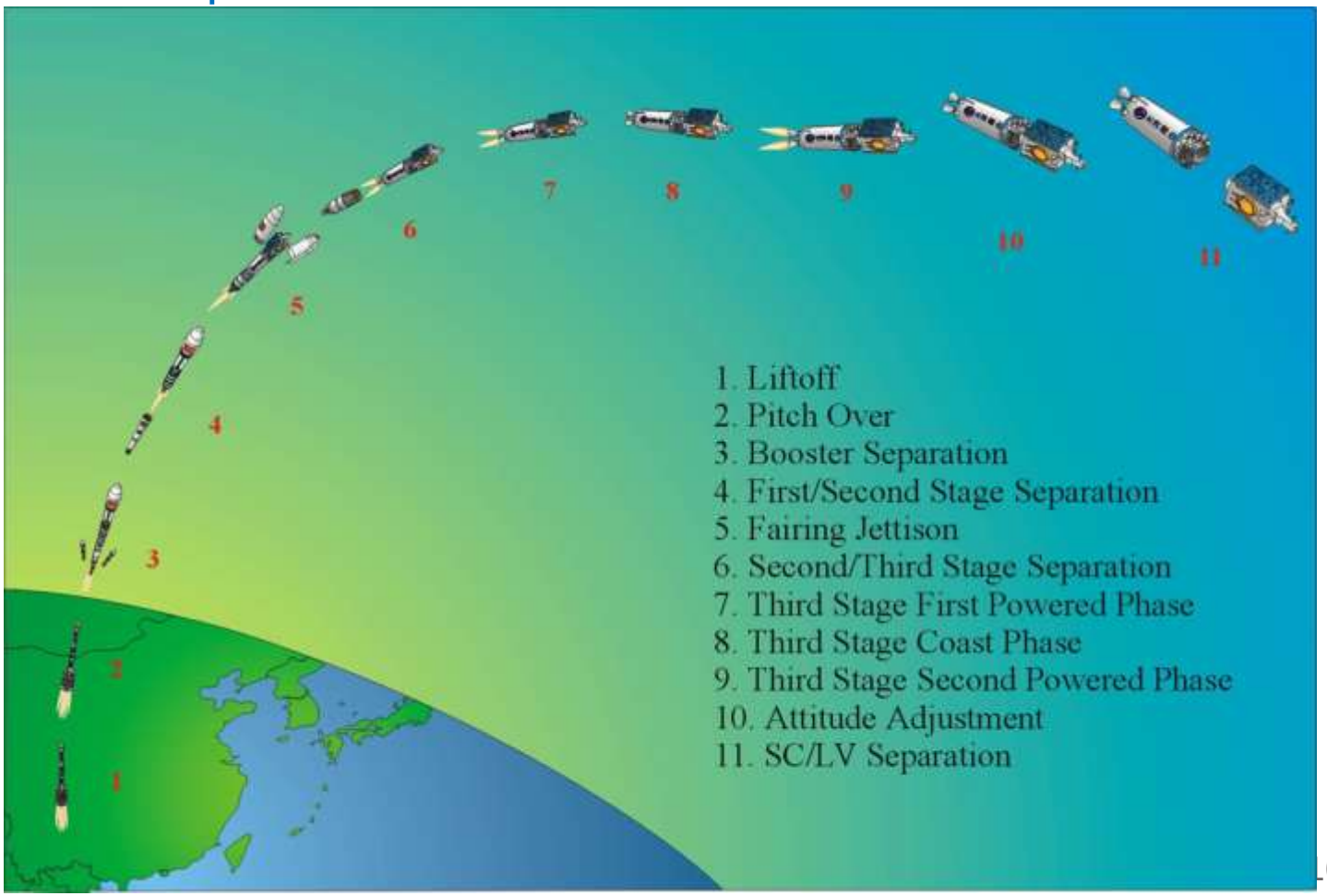
The Launch Site: most LV (except the air launch) are launched from the launch pad in the launch site, launch site location has influence on the LV capability:

Xichang Launch Center:

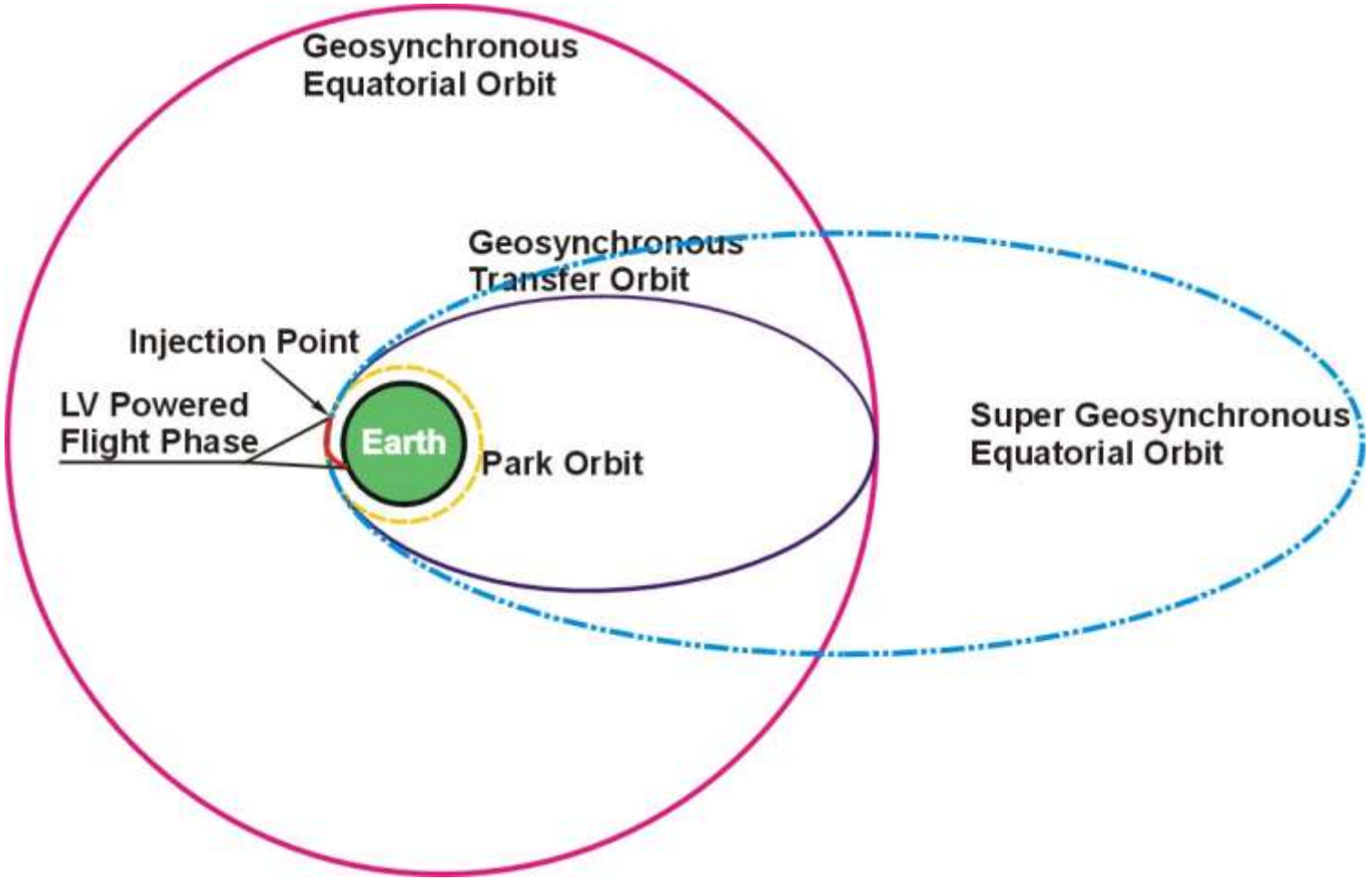
- ✓ Latitude 28.25° N
- ✓ Longitude 102.025° E
- ✓ Elevation 1,825m

The working process of LV

after designing and manufacture, erecting on the launch pad, ignition, lift-off, powered flight (separating stage one by one), coast flight and separates the SC



Launch Orbit Schematic Diagram



Perigee: 200km
Apogee: 35786km
Inclination: 28.5°

About the Launch Vehicle

The type of the LV:

- ✓ Solid LV, Liquid LV and hybrid LV (in series or in parallel);
- ✓ Signal stage LV and multiple stages LV;
- ✓ LEO, SSO, GTO LV, moon orbit
- ✓ Expendable LV and Reusable LV

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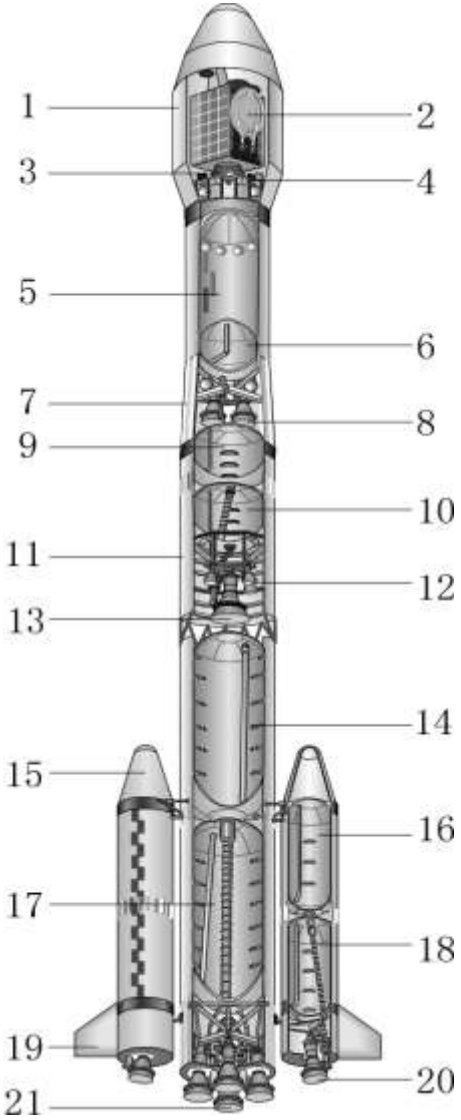
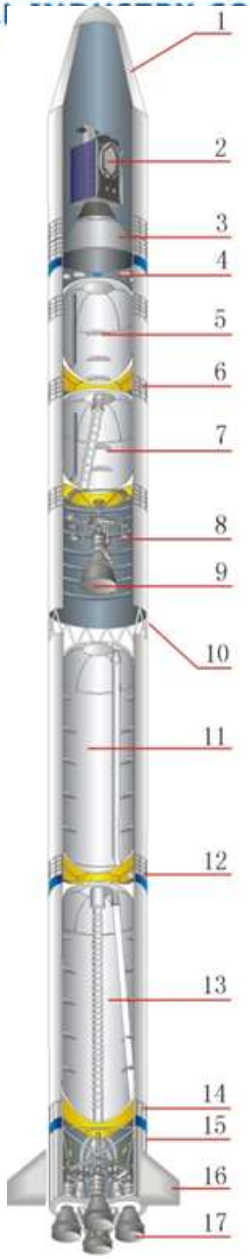
The main Structure of LV



1. Payload Fairing
2. Payload
3. Payload Adapter
4. Vehicle Equipment Bay
5. 3rd Stage LH Tank
6. 3rd Stage LOX Tank
7. Inter-stage Section
8. 3rd Stage Engine
9. 2nd Stage Oxidizer Tank
10. 2nd Stage Fuel Tank
11. Inter-stage Section
12. 2nd Stage Vernier Engine
13. 2nd Stage Main Engine
14. 1st Stage Oxidizer Tank
15. Liquid Boosters
16. Booster's Oxidizer Tank
17. 1st Stage Fuel Tank
18. Booster's Fuel Tank
19. Tail Fin
20. Booster's Engine
21. 1st Stage Main Engine

The main Structure of LV



1. Fairing
2. Satellites
3. Adapter
4. Vehicle Equipment Bay
5. Second Stage Oxidizer Tank
6. Second Stage Inter-tank Section
7. Second Stage Fuel Tank
8. Second Stage Vernier Engines
9. Second Stage Main Engine
10. Inter-stage Shell Section and Strut Structure
11. First Stage Oxidizer Tank
12. First Stage Inter-tank Section
13. First Stage Fuel Tank
14. First Stage Rear Transition Section
15. First Stage Rear Section
16. Stabilizing Fin
17. First Stage Engines

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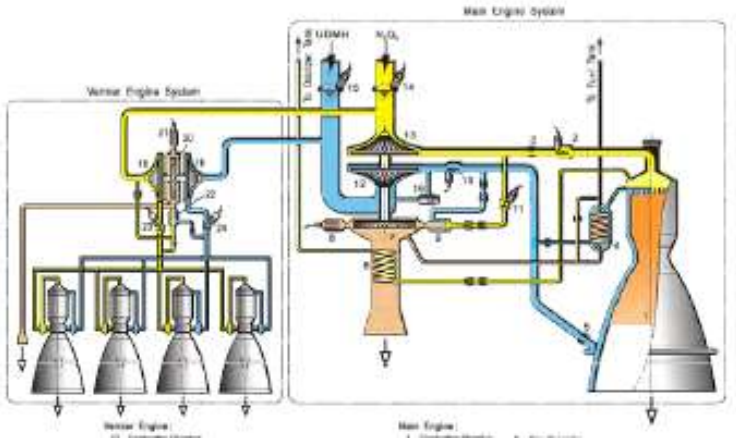
The main subsystems of the LV

- The Propulsion System: generates the flight thrust and control forces
  - ✓ Engine and pressurization system



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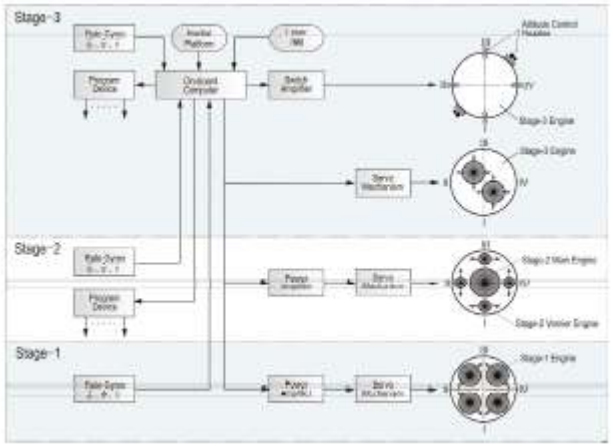
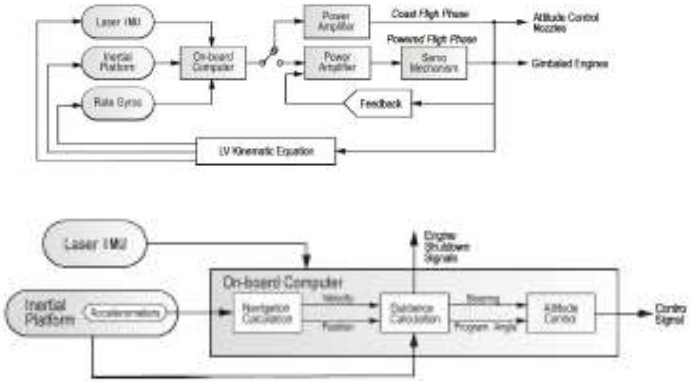
The main subsystems of the LV

- Control System: maintain the flight stability, perform the navigation and guidance functions to deliver the satellite into the predetermined orbit
  - ✓ Inertial platform or laser IMU, combined with computer-controlled guidance and digital attitude control





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The main subsystems of the LV

- Measurement System
  - ✓ Telemetry System: to measure the transmit the parameters of the LV in flight;
  - ✓ Tracking and Range Safety System: measure the trajectory data and final injection parameters and provide safety assessment information.

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The main Subsystems of the LV

- The separating system: is to unlock the connection mechanism and separation the connected sections:
  - ✓ LV stage separation;
  - ✓ Fairing separation;
  - ✓ SC/LV separation

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The Main LVs in the Market

- ULA: Atlas 5, Delta 2, Delta 4
- Orbital Science ATK Pegasus, Antares
- Arianesapce: Ariane 5, Vega, Soyuz, Ariane 6;
- Space X: Falcon 9, Reusable LV;
- ILS: Proton;
- ISRO: PSLV, GSLV;
- Sea Launch: Zenit 3SL, Zenit 3SLB;
- JAXA: H2A
- CGWIC: LM-3B, LM-2C, LM-2D, LM-4B, LM-6, LM-11,LM-5, LM-7;

Small LV underdevelopment

- ✓US& New Zealand Rocket Lab: Electron ;
- ✓US Firefly Space System: Firefly ∂ ;
- ✓Virgin Galaxy: Launcher One ;

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The Main LV in the Market

ArianeSpace: Ariane5/Vega/Soyuz

CGWIC: LM-3B/LM-2C/LM-2D

ILS: Proton

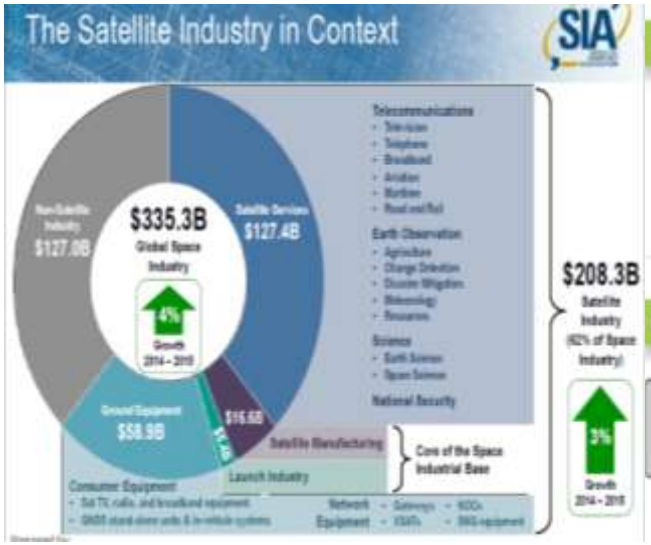
ISRO：PSLV， GSLV；

ULA: Atlas5/Delta 4

SpaceX: Falcon9

- 2015 Data
  - ✓ SIA: Space Industry: US$335b, Launch Industry:US$5.4b, 1.6%;
  - ✓ EuroConsult: Space Industry: US$220b, Launch Industry: US$2.2b, 1%

- Flight Number:
  - ✓ Total Number: 70-90
  - ✓ GTO Number: around 20



SIA Report 2015

EuroConsult 2015

Launch Number

The Characters of the Launch Vehicle:

- LV is not a very profitable industry, percentage: around 1%;
- The LV development driven by the satellite and end users' requirement
- The flight number almost keep stable;
- LV is one of the most important strategic product for one country;
- It's not easy to cooperate to manufacture the LV due to the regulation of MTCR (Missile Technology of Control Regime, 300km/500kg);
- The launch services market is not the full competitive market due to restrictions such as ITAR (International Traffic in Arm Regulations).

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Launch Services

- Launch services is different with the LV:
  - ✓ LV is the hardware
  - ✓ Launch Services:
    - ✓ Launch Services is the services process, including the hardware and software, launch site operation, TT&C and logistic services ;
    - ✓ Launch Services Provider is required to deliver the Customer's satellite to the predetermined orbit by using the LV at the launch site;
    - ✓ The Services, with the exception of the post-Launch Services, is deemed to have been accomplished immediately upon Launch, whether the Launch is successful or not;
    - ✓ There is not LV ownership transaction during the launch services processing, LV always belongs to the Launch services provider

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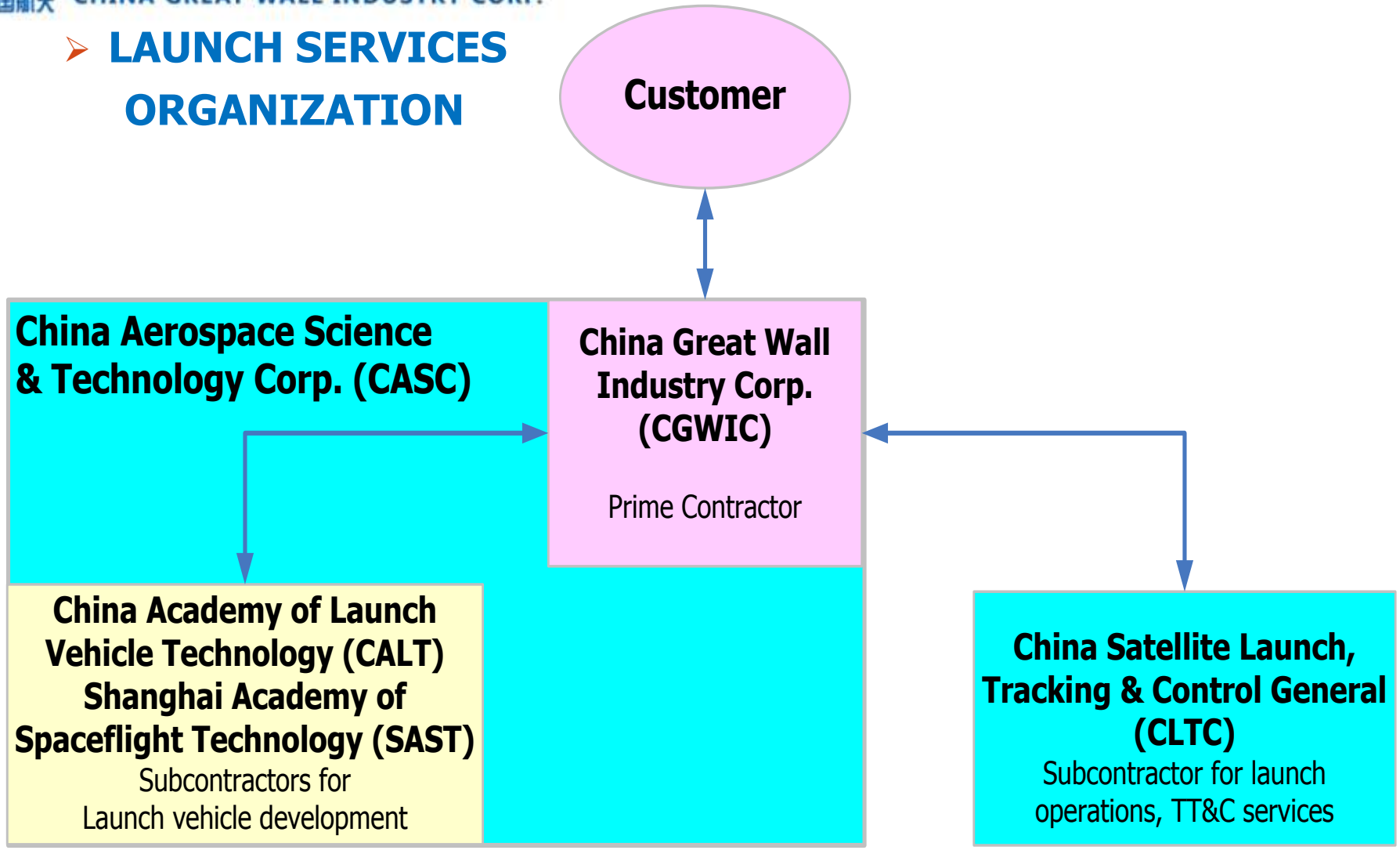
CGWIC Launch Services

➢ LAUNCH SERVICES ORGANIZATION



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CGWIC Launch Services

Subcontractor	Prime Contractor CGWIC	Subcontractor
➢ XSLC,JSLC, TSLC ➢ Launch Site Technical Interface Coordination ➢ Launch Site Operations ➢ Launch Control TT&C Launch Site & Launch Safety ➢ Launch Campaign ➢ Planning & Organization	➢ Exclusive Marketing, Sales of Long March Launch Services ➢ Mission management and support that all aspects of launch activities and preparation from contract signature to launch and post launch services; ➢ Insurance and financing services on a case by case basic	➢ Launch vehicle Design Development Manufacture Testing ➢ Mission Analyses ➢ LV Technical Interface Coordination ➢ Quality Control and Flight Safety Engineering

The Milestone of the Launch Services

- The technical feasibility confirmation;
  - Enough Launch capability
  - Mechanical Interface (adapter interface, fairing envelop, etc.)
  - Electrical interface
  - The environment conditions (Coupled Load Analysis CLA):
    - ✓ Payload processing Environment(facility, transportation, encapsulation, inside the fairing);
    - ✓ Electromagnetic environment;
    - ✓ Mechanical Environment
      - Steady state acceleration;
      - Vibration environment (Sinusoidal Vibration, random vibration, acoustic vibration, shock environment)
      - Thermal environment;
      - Pressure Environment

The Milestone of the Launch Services

- The Customer issues the RFP;
- The Launch Services Provide submit the Proposal, both technical and financial;
- Contract signed
- The Customer issues the IRD;
- The ICD discussion and signature, several versions, final version before the Launch
- Mission Analysis
  - ✓ Dynamic Coupled Load Analysis based on SC dynamic model;
  - ✓ Thermal Analysis based on the SC thermal model;
  - ✓ Trajectory analysis;
  - ✓ Separation analysis;
  - ✓ Interface Compatibility Analysis(EMC analysis, electrical interface analysis, mechanical interface analysis);
  - ✓ Venting Analysis
- Safety requirement and discussion
- Launch site survey
- Fit-check and separation test
- Combined Operation plan

Launch Services

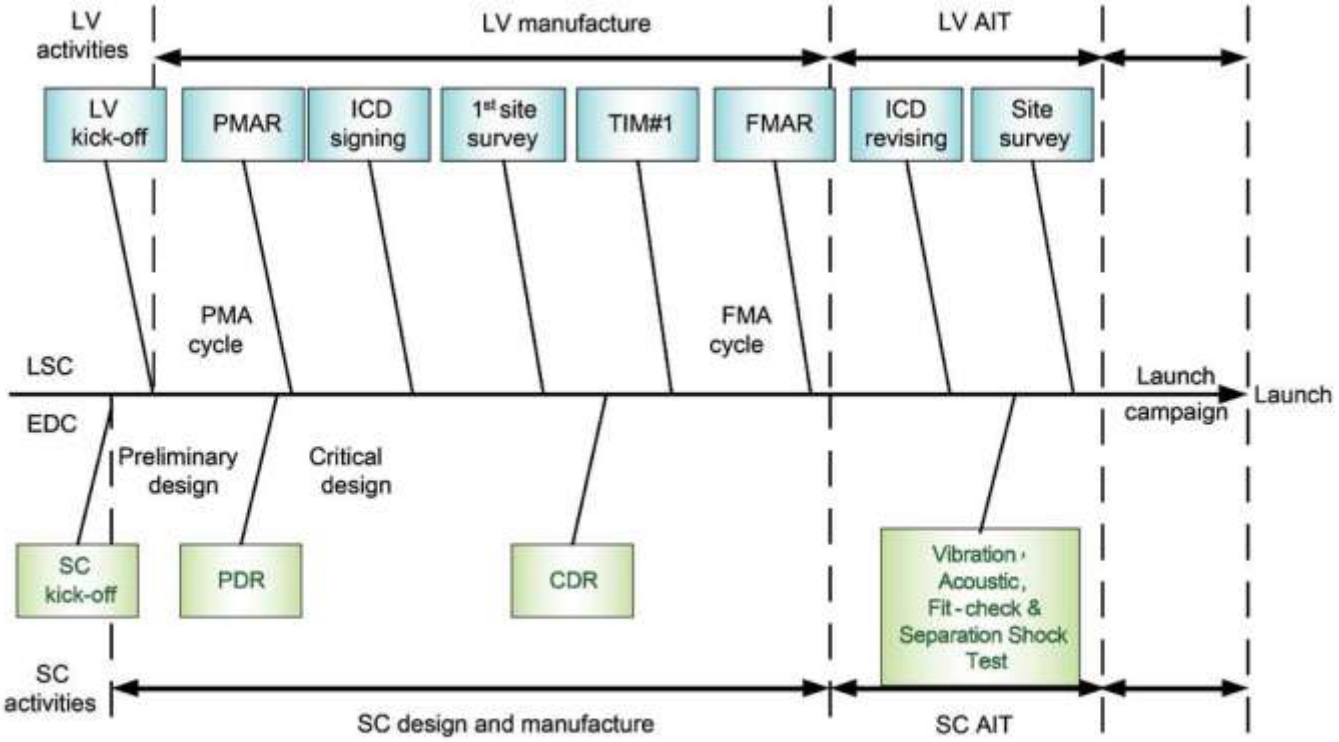

Figure 11-2 Typical Launch Services Program Schedule

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CGWIC & LM OVERVIEW

Development History

26 Oct. 1985

Announcement to provide international launch services

1 Nov. 1988

1st Performed commercial launch services contract

7 Apr. 1990

1st commercial launch

12 Apr. 2005

1st launch of unrestricted satellite.

14 May 2007

1st launch of Chinese comsat for int'l customer

CGWIC & LM OVERVIEW

Commercial Launches

- 43 international commercial launch missions and 15 piggyback missions since 1987.
  - ✓ 26 US-built Satellites (launched in 1990-1999)
  - ✓ 8 Europe-built Satellites
  - ✓ 5 China-made Satellites
- China-made Satellites, communication and remote sensing to be launched.

- Chinese domestic launch demand increased steadily:
  - ✓ 1st 50 launches in 28 years
    From April 24, 1970 to March 26, 1998;
  - ✓ 2nd 50 launches in 9 years
    From May 2, 1998 to June 7, 2007;
  - ✓ 3rd 50 launch in 4 years
    From July 5, 2007 to Non. 9, 2011
  - ✓ 4th 50 launches in within 3 years
    From Nov.20, 2011 to No. 7, 2014
  - ✓ The latest 35 in one and half a year
    Dec. 11, 2014 to date
  - ✓ Around 20 flights scheduled each year in the following 5 years

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Long March LV Flight Record

211 in-service Long March flights success rate: 209/214=97.66%

(Total Long March flights success rate: 226/237=95.36%)

	Launch Vehicle	Success/Flight	Total Success/Total Flight
LEO&SSO Missions	LM-2C & LM-2C/CTS	43/44	134 / 136 = 98.53%
	LM-2D	29/29	
	LM-2F	11/11	
	LM-4B & LM-4C	48/49	
	LM-6	1/1	
	LM-7	1/1	
	LM-11	1/1	
GTO Missions	LM-3A	25/25	73 / 75 = 97.33%
	LM-3B & LM-3BE	34/36*	
	LM-3C	14/14	
			Total Successful Rate: 207/211=98.10%

* Except its maiden flight (failure) in 1996 and Palapa-D launch anomaly in 2009 (the satellite finally achieved a 10+years remaining in-orbit life), all the remaining 34 flights are all successful.

LONG MARCH FAMILY IN SERVICE

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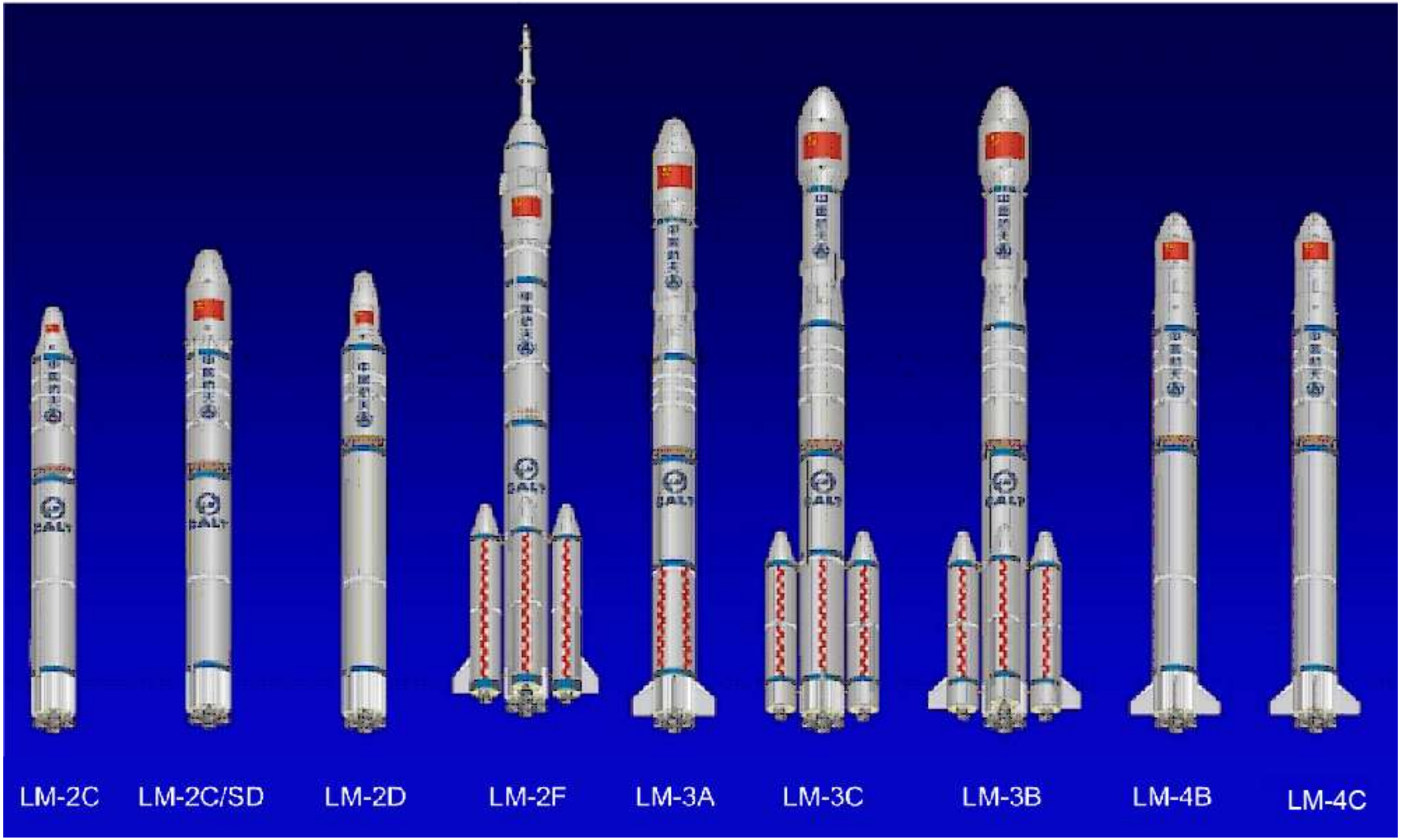

Items	LM-2D	LM-4B LM-4C	LM-2C	LM-2C CTS1	LM-2C CTS2	LM-2F	LM-3A	LM-3B	LM-3BE	LM-3C
Height (m)	41	48	43	43	43	58.3/52.0	52.5	54.8	56.3	54.8
Lift-off Mass (t)	250	250	245	245	245	497.9	241	425.8	456	345
Lift-off Thrust (kN)	2,962	2,962	2,962	2,962	2,962	5,923	2,962	5,923	5,923	4,443
Fairing Diameter (m)	3.35/3.80	2.90/3.35/ 3.80	3.35	3.35	3.35	3.80/4.20	3.35	4.00	4.00/4.20	4.00
Stage-1 Propellant	N_2O_4 / UDMH									
Stage-2 Propellant	N_2O_4 / UDMH									
Stage-3 Propellant	N/A	N_2O_4 UDMH	N/A	Solid propellant	Solid propellant	N/A	LOX / LH_2			
Main Mission	LEO/SSO	SSO	LEO/SSO	SSO	GTO	LEO	GTO			
Launch Capability (kg)	4,000/1,150	2,230 2,950	3,850/900	2,100	1,250	8,080/8,600	2,600	5,100	5,500	3,800
Launch Site	JSLC/TSLC	JSLC/TSLC	JSLC/TSLC/ XSLC	JSLC/TSLC/ XSLC	JSLC/TSLC/ XSLC	JSLC	XSLC			

Table 1-1 Main Characteristics of Long March Family

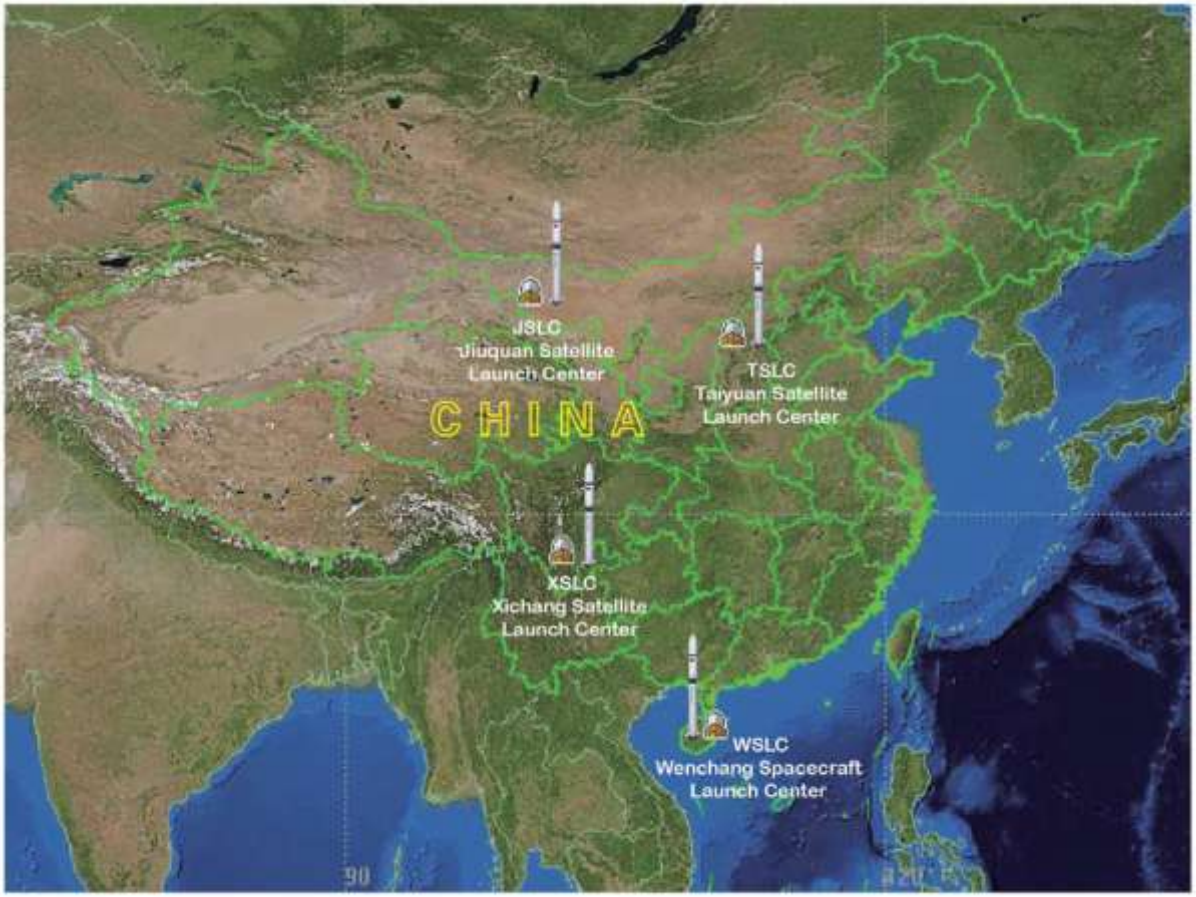

Figure 1-4 Satellite Launch Centers

XICHANG SATELLITE LANCH CENTER

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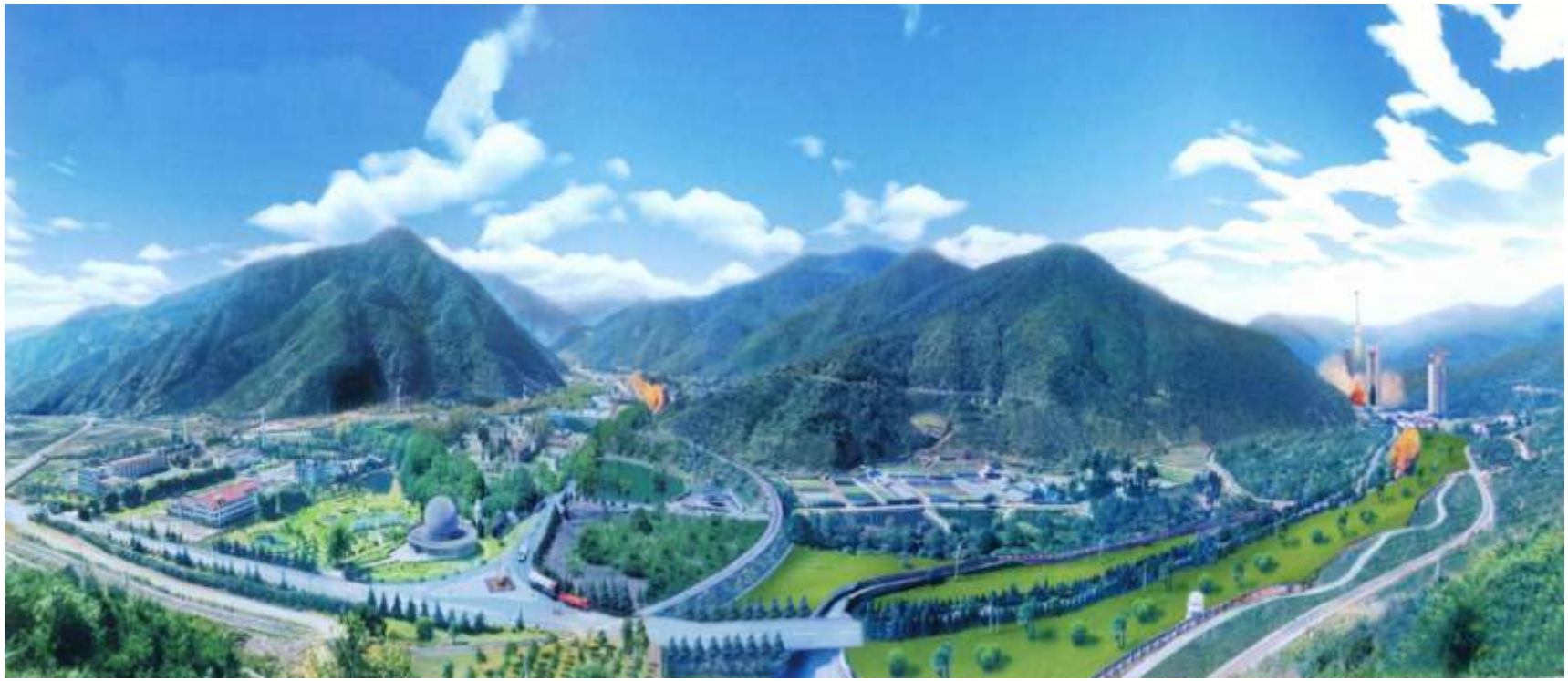

Xichang Satellite Launch Center (XSLC) has two launch complexes, one for LM-3A launch vehicles and the other for LM-3B & LM-3C launch vehicles. XSLC has well-equipped launch vehicle and satellite test, preparation facilities, making it a state-of-the-art launch center.

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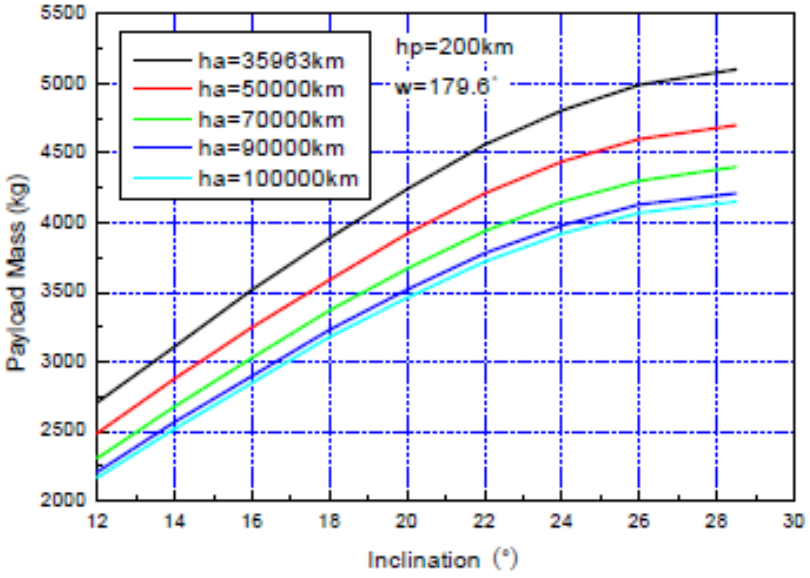
Launch Feasibility

- Enough Launch Capability
  - ✓ For dedicated launch: big enough
  - ✓ For piggyback launch: enough margin
- Mechanical Interface Compatibility
  - ✓ Fairing is big enough
    - ✓ For dedicated launch: enough envelop;
    - ✓ For piggyback launch: configuration is enough
  - ✓ Adapter
    - ✓ For dedicated launch: 937, 1194, 1666;
    - ✓ For piggyback launch: POD(ISIS, Astro, SFL, etc.), specific adapter designed for customer
- Sustain the Mechanical Environment of the LV in different phases

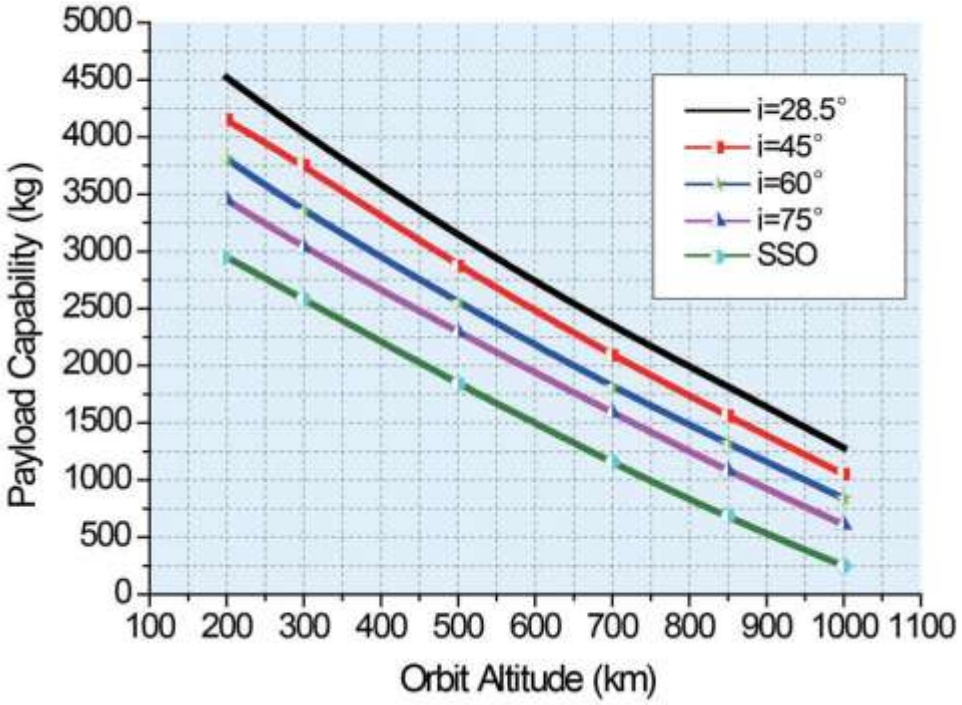
Launch Capability

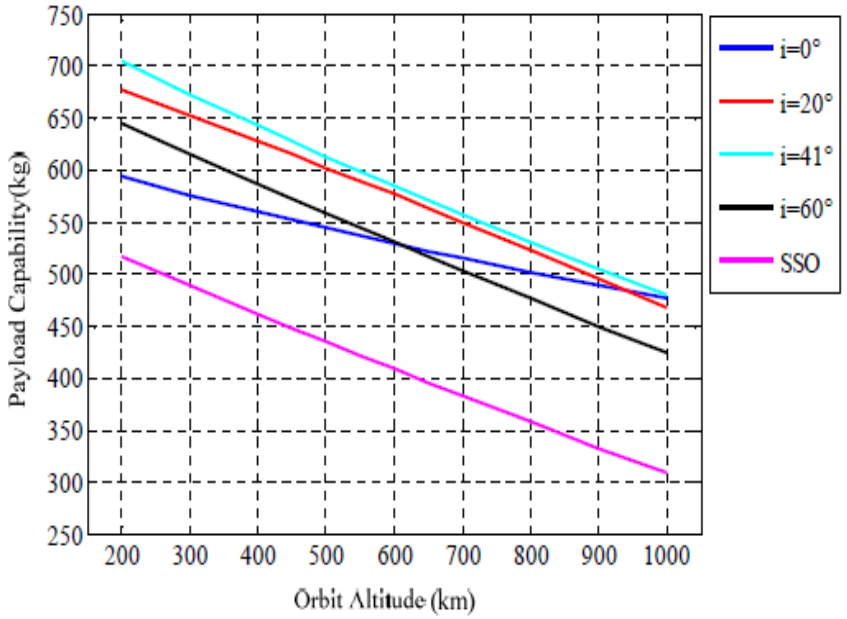


Inclination(°)	Apogee Altitude (km)				
I	35963	50000	70000	80000	100000
12	2710	2490	2310	2210	2170
14	3110	2880	2680	2570	2520
16	3520	3250	3030	2900	2850
18	3890	3590	3370	3230	3180
20	4240	3920	3670	3520	3460
22	4560	4210	3940	3780	3720
24	4805	4440	4150	3980	3920
26	4990	4600	4300	4130	4070
28.5	5100	4700	4400	4210	4150
55	3470	3100	2800	2620	2550

Figure 3-1a LM-3B GTO Performance (CS & Encapsulation-on-Pad)

Launch Capability





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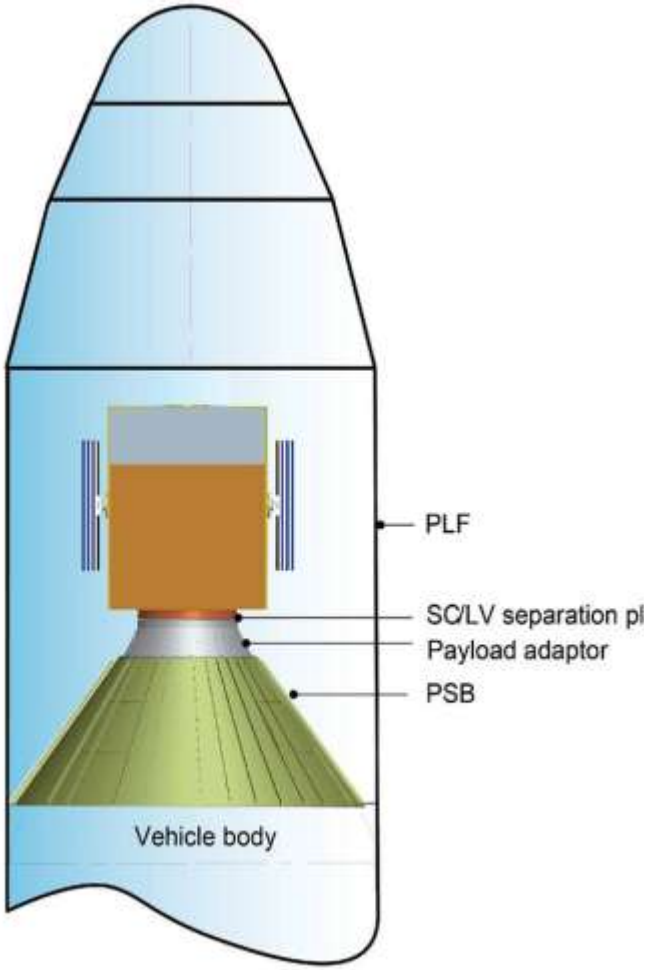
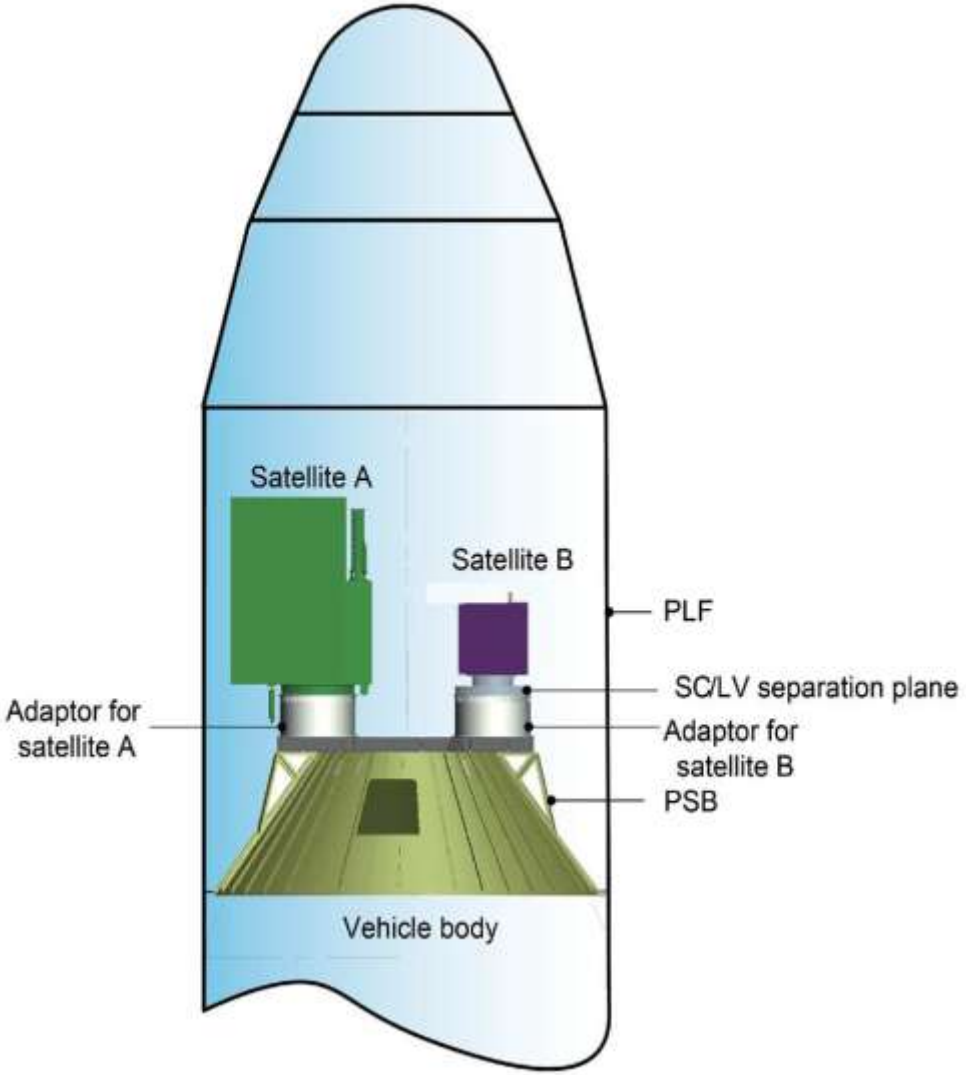
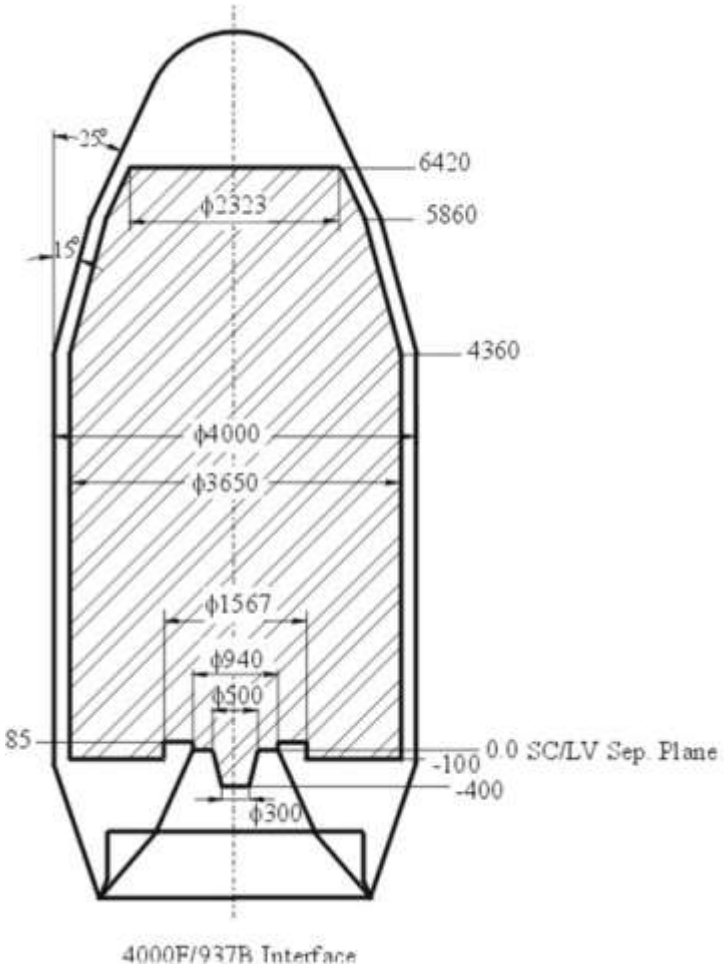
Fairing & Envelop

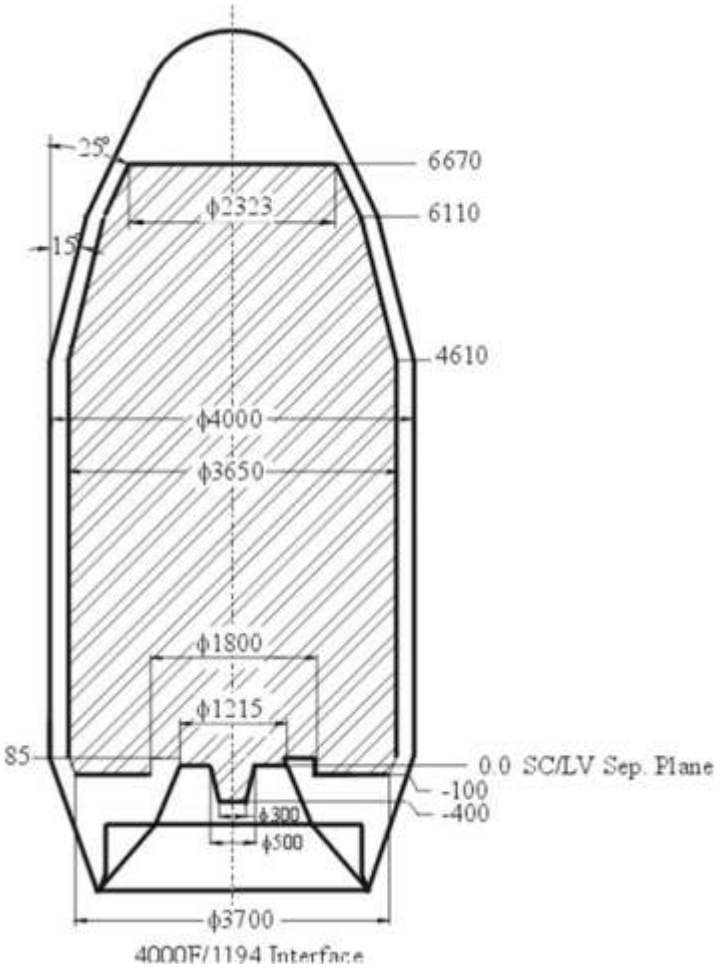




Fairing & Envelop



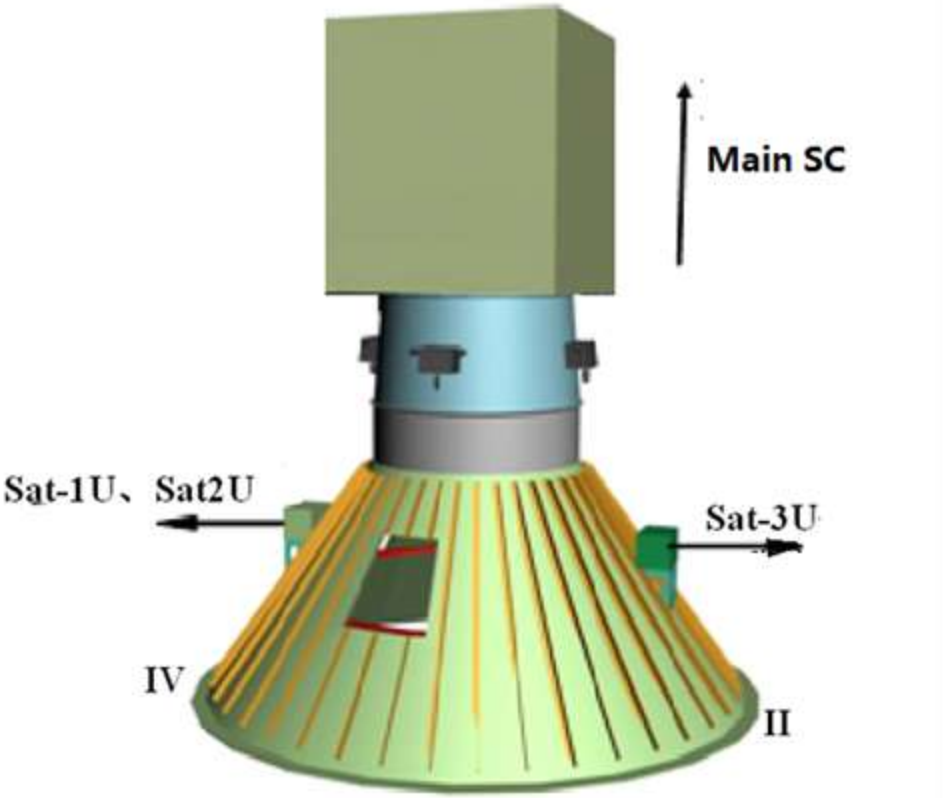
4000F/937B Interface

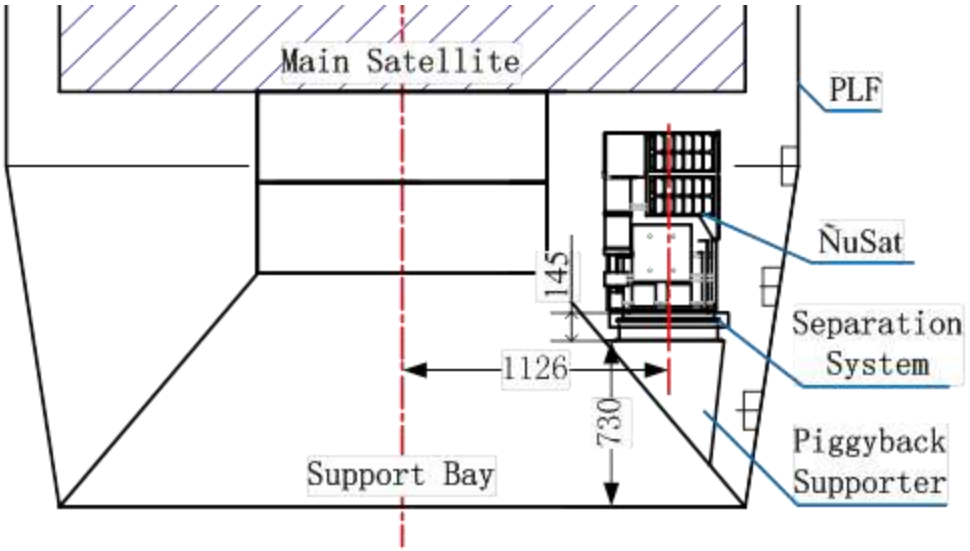


4000F/1194 Interface

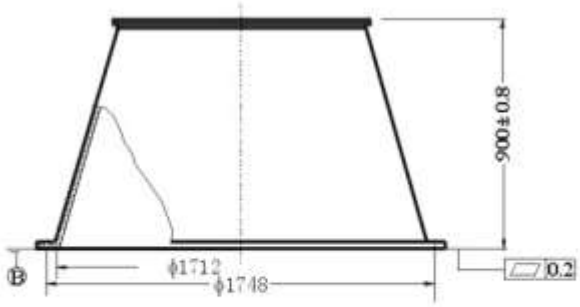
Fairing & Envelop

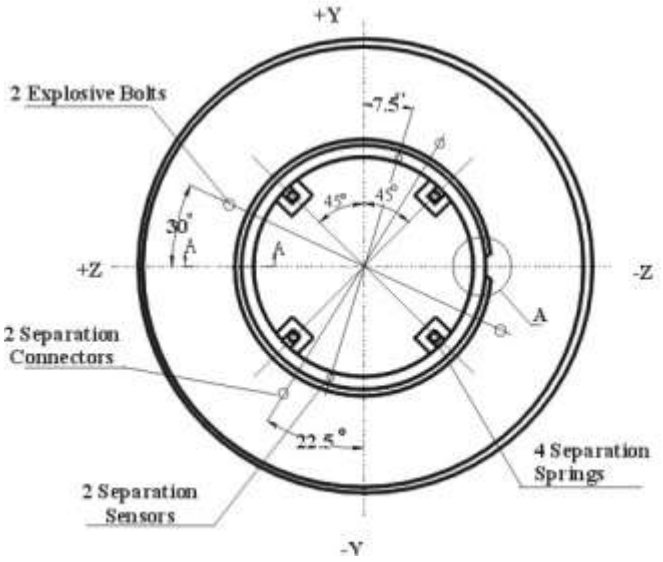
Piggyback Adapter

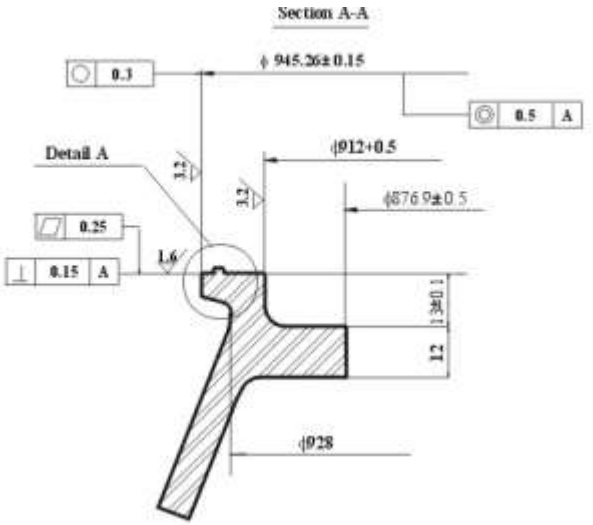


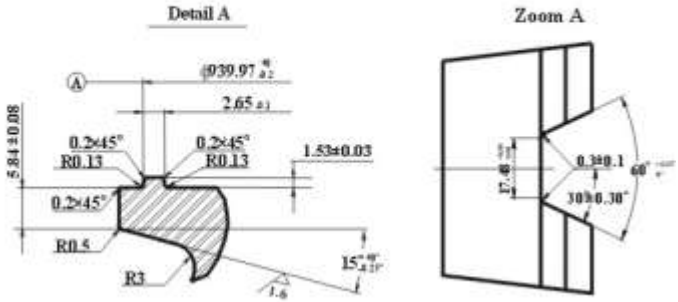

Main Satellite
PLF
NuSat
145
Separation
System
1126
730
Piggyback
Supporter
Support Bay

Adapter


900±0.8
ϕ1712
ϕ1748
0.2

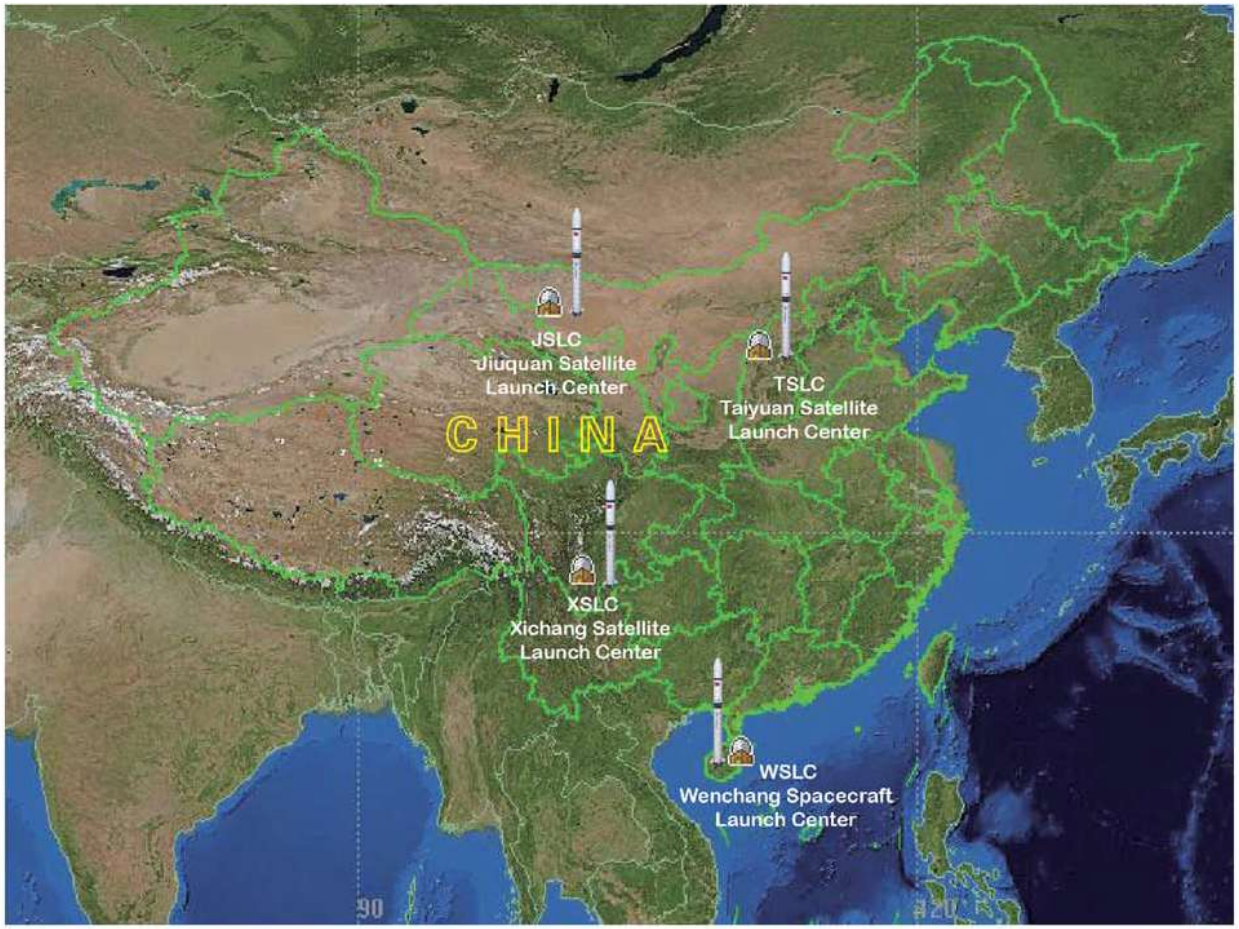

+Y
2 Explosive Bolts
7.5°
30°
45°
45°
+Z
-Z
A
2 Separation Connectors
22.5°
4 Separation Springs
2 Separation Sensors
-Y


Section A-A
0.3
ϕ945.26±0.15
0.5 A
Detail A
3.2
ϕ912+0.5
3.2
ϕ876.9±0.5
0.25
0.15 A
1.6
1.3±0.1
12
ϕ928


Detail A
Zoom A
A
ϕ39.97
2.65
5.84±0.08
0.2×45°
R0.13
0.2×45°
R0.13
1.53±0.03
0.2×45°
R0.5
R3
15°
1.6
0.3±0.1
60°
30±0.30'

Other Factors

- High reliability
- Good compatibility between LM & SC
- Assured launch schedule
- Flexibility with dedicated launch
- Favorable terms & conditions
- Experienced launch services provider
- Competitive pricing in the market
- Optimized orbit: launch capability margin to optimize the orbit to extend satellite's in-orbit life without extra charge


JSLC
Jiuquan Satellite
Launch Center
CHINA
TSLC
Taiyuan Satellite
Launch Center
XSLC
Xichang Satellite
Launch Center
WSLC
Wenchang Spacecraft
Launch Center

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