中科宇航
CAS SPACE

Kinetica 1 Launch Vehicle User's Manual
(Version e1.0)

CAS SPACE

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Contents

1 Version History

English Version	Original Chinese Version	Date	Change Description
e1.0	1.0	Feb. 2023	First issue

2 Acronyms and Abbreviations

ACS	Attitude Control System
CLT	Coupled Load Test
EMC	Electro-Magnetic Compatibility
GSE	Ground Support Equipment
GTP	Ground Testing Phase
JSLC	Jiuquan Satellite Launch Center
LEO	Low-Earth Orbit
LV	Launch Vehicle
OASPL	Overall Acoustic Sound Pressure Level
PAC	Payload Assembly Composite
PIH	Payload Integration Hall
PSD	Power Spectral Density
PTH	Payload Testing Hall
RCS	Reaction Control System
RF	Radio Frequency
SRS	Shock Response Spectrum
SSO	Sun-Synchronous Orbit
TT&C	Telemetry, Tracking, and Command
VTH	Vehicle Testing Hall
VTR	Vehicle Transfer Review
WDR	Wet Dressed Rehearsal

3 Overview

Kinetica-1 Launch Vehicle (LV) is the first four-stage solid LV developed by CAS Space. Kinetica-1 is the most potent solid-propellant LV in China to date. The launcher is designed to offer a range of advantages for commercial space launches:

- Class-leading high payload capacity and cost-effectiveness
- Precise and accurate orbit insertion
- Rapid launch cadence with a short lead time
- Flexible and convenient launch scheduling
- Low cost per kilogram of payload and minimum logistics requirements
- Excellent environmental adaptability

Kinetica–1 is designed to launch small to medium-sized spacecraft to low Earth orbits (LEO) and sun-synchronous orbits (SSO). Typical missions include the launch of single or multiple satellites into such orbits, rapid constellation construction, and replenishment. On July 27, 2022, the inaugural flight successfully put six scientific payloads into designated orbits from Jiuquan Satellite Launch Center (JSLC).

A portrait of Kinetica-1 is shown in Figure 1. The LV measures 30 meters in length, weighs 135 tonnes, and has a maximum diameter of 2.65 meters.

Fairing	
Dimensions	Diameter: 3350 mm / 2650 mm
Structure	Honeycomb
Stage IV	
Dimensions	Inverted cone-shaped Diameter: 2650 mm / 2000 mm
Structure	Skin-stringer
Power	100 kN solid-propellant engine Monopropellant attitude control system (ACS)
Avionics	Major flight avionics
Stage III	
Dimensions	Diameter: 2000 mm
Structure	Skin-stringer
Power	500 kN solid-propellant engine
Stage II	
Dimensions	Diameter: 2650 mm
Structure	Skin-stringer
Power	1000 kN solid-propellant engine
Stage I	
Dimensions	Diameter: 2650 mm
Structure	Skin-stringer
Power	2000 kN solid-propellant engine

Figure1 Schematic Diagram of Kinetica–1 Launch Vehicle

4 Payload Capacity and Orbit Insertion Accuracy

4.1 Sample Flight Profile

A sample flight profile is illustrated in Table 1 and Figure 2, where a launch mission from JSLC to 500 km SSO is demonstrated.

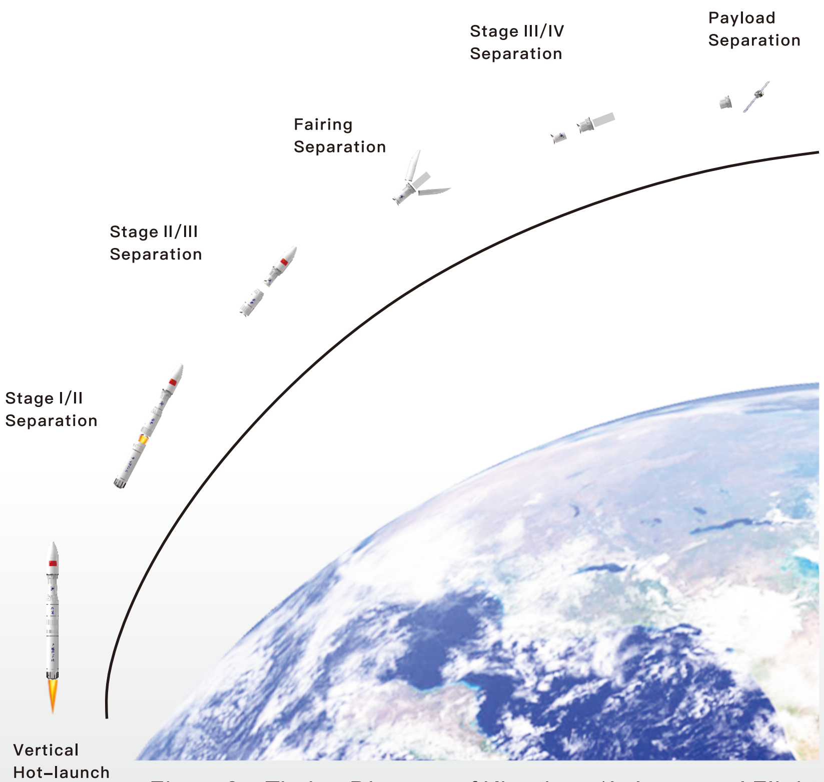

Figure2 Timing Diagram of Kinetica-1's Inaugural Flight

Table1 Nominal Event Sequence of the Sample Flight Profile

S/N	Theoretical Time (s)	Event Description
1	0.000	Stage I ignition
2	0.275	Lift-off
3	11.275	Pitchover maneuver
4	84.755	Stage I burn-out (Apparent axial acceleration < 3.0 m/s^2)
5	84.915	Stage II ignition
6	85.085	Stage I/II separation
7	179.205	Stage II burn-out (Apparent axial acceleration < 1.0 m/s^2)
8	180.705	Stage II/III separation
9	205.705	Fairing separation
10	225.705	Stage III ignition
11	292.140	Stage III burn-out (Apparent axial acceleration < 1.0 m/s^2)
12	305.140	Stage III/IV separation
13	605.610	Stage IV ignition
14	675.830	Stage IV burn-out (Apparent axial acceleration < 3.0 m/s^2)
15	743.840	Payload separation

The axial G-load curve for the sample flight profile is shown in Figure 3.

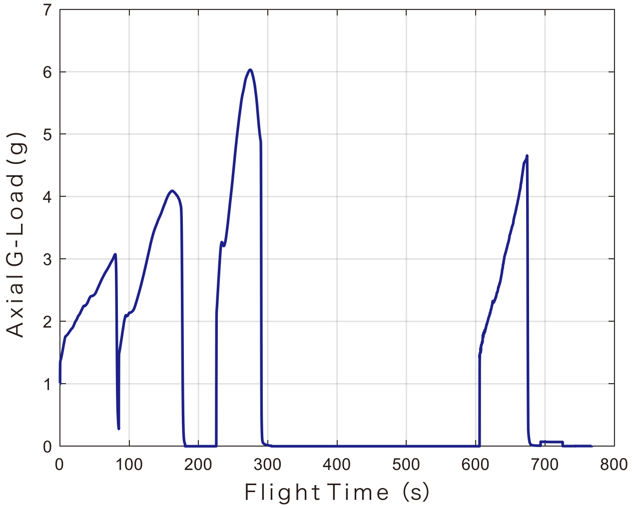

Figure3 Axial G-Load Curve against Flight Time

4.2 Payload Capacity

The payload capacity of Kinetica-1 LV corresponding to different orbits is shown in Table 2 and Figure 4.

Table2 Payload Capacity

Orbital Altitude	SSO	50°circular	80°circular	130°circular
(km)	(kg)	(kg)	(kg)	(kg)
500	1500	1898	1644	1284
700	1295	1667	1432	1101
900	1108	1462	1243	936
1100	942	1273	1071	790

Note: a) TT&C and landing constraints are not considered.
b) Satellite adapters and separation devices are included in the payload mass.
c) "50°Circular" refers to circular orbit with an inclination of 50°.

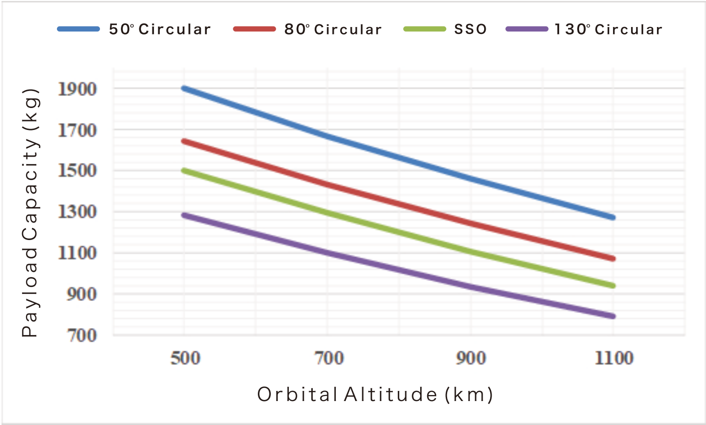

Figure 4 Payload Capacity against Orbital Altitude

4.3 Orbit Insertion Accuracy

Orbit insertion accuracy (3σ) under typical conditions is shown in Table 3.

Table 3 Orbit Insertion Accuracy

Symbol	Parameter Name	Deviation
Δa	Semi-major axis altitude deviation	±5 km
Δe	Eccentricity deviation	±0.002
Δi	Orbital inclination deviation	±0.08°

4.4 Satellite Attitude Adjustment

Before payload separation, Kinetica-1 can adjust the attitude of the satellite and the top stage according to mission requirements. The deviation of the pitch, yaw, and roll angle is no more than 2° (3σ), and that of the corresponding angular velocity is no more than 2°/s (3σ).

4.5 Launch Window

The Kinetica-1 LV can achieve zero-window launching.

5 Fairing

The fairing provides a suitable operating environment for the payload (satellite) during ground transfer and in flight. Kinetica-1 LV provides 3350 mm or 2650 mm fairings diameter options for missions.

5.1 Available Fairing Volume

The usable volumes of the 3350mm-diameter fairing and the 2650mm-diameter one are shown in Figure 5 and Figure 6, respectively. The column length of available volume in the fairing can be adjusted.

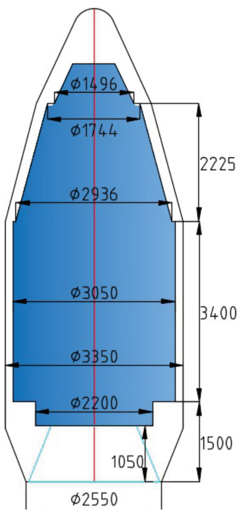

Figure5 Available Volume for Φ3350 mm Fairing

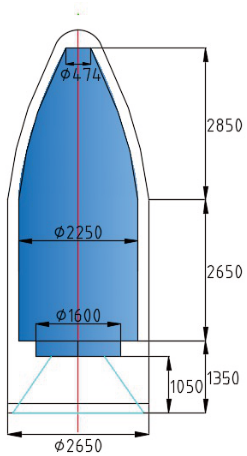

Figure6 Available Volume with Φ2650 mm Fairing

5.2 Radio Frequency (RF) Transparent Windows

RF-transparent windows may be opened as per mission requirements along the fairing column section except for the ±5°interval on both sides of quadrants I and III (longitudinal plane of fairing separation).

6 Payload Interface

6.1 Mechanical Interface

The mechanical interface enables connection, unlocking, and separation functions between the payload satellite and LV.

An integrated separation system is recommended for connecting and separating the satellite and vehicle's mechanical interfaces. The integrated separation system combines pyrotechnic fastener and spring separation for rapid satellite deployment.

6.1.1 Integrated Separation Device

Figure 7 shows the integrated separation device. It can be connected to the reserved satellite interface through four interfacing bolts. The separation spring provides the mechanical force for satellite separation.

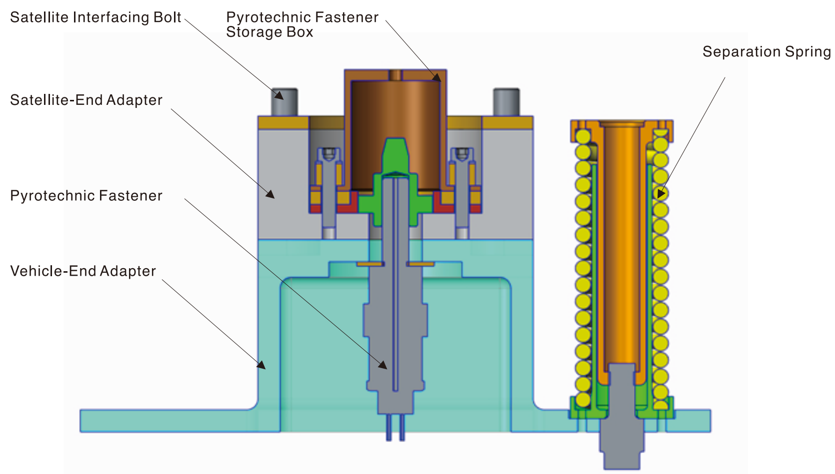

Figure7 Schematic Diagram of the Integrated Separation Device

6.1.2 Interface Dimensions

Typical dimensions of the satellite interface in the separation plane are shown in Figure 8, where four Φ12 holes are designed at the satellite end and space reserved for spring operation.

In addition, the connection layout can be customized according to the satellites' specific structures and load capacities.

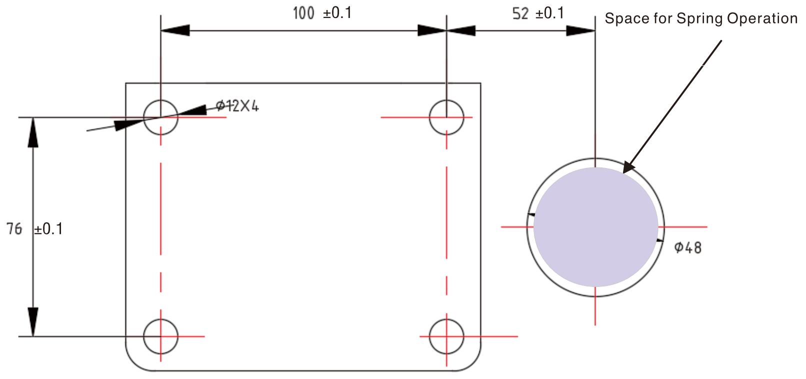

Figure 8 Schematic Diagram of Mechanical Interface Dimensions in the Plane of Separation (Satellite-End)

6.1.3 Separation Switch

The separation switch provides feedback for separation. The number of monitoring and interface points should be coordinated in advance.

6.2 Electrical Interface

The electrical interface can be customized for communication between the satellite and the LV.

6.2.1 In Case of Communication Requirements from Satellite

Two types of electrical interfaces for the satellite are provided: one in the form of an electrical umbilical cord may be used in the Ground Testing Phase (GTP); another provides critical feedback signals to the satellite during flight.

6.2.1.1 Satellite Electrical Umbilical

An umbilical interfaced with the fairing is used for the ground test of the satellite. The connectors at the satellite end are separated manually before lift-off or automatically during satellite separation.

The umbilical shall be designed and manufactured by the satellite provider, and CAS Space shall provide its length. The umbilical should be delivered to the launch service before the final assembly.

6.2.1.2 Signal Ports

The signal ports transmit monitoring signals from the LV to the satellite. Such signals include lift-off and emergency power-off. Satellite separation may be controlled electronically with a highly reliable mechanical backup.

6.2.2 In Case of No Communication Requirement from the Satellite

The satellite provider may use an umbilical for ground testing after interfacing with the payload fairing. The fly-away umbilical can be pinned out through the upper stage or the fairing for connection with ground support equipment (GSE) and manually disconnected at 2 h 15 min before ignition. The umbilical shall be designed and manufactured by the satellite provider, and CAS Space shall provide its length.

7 Environmental Conditions

These include payload-related environmental conditions, including temperature, humidity, operational, electromagnetic, and mechanical conditions.

7.1 Temperature and Humidity Environment

The temperature and humidity in the fairing are controlled by the air conditioning system until 1 h before ignition; these conditions are shown in Table 4.

Table 4 Ambient Temperature and Humidity in the Fairing

Temperature	15℃~25℃
Relative Humidity	35%~55%
Cleanliness Control	100,000

Pressure variation inside payload fairing is shown in Figure 9. During the flight, the static pressure change in the fairing is not more than 4000 Pa/s.

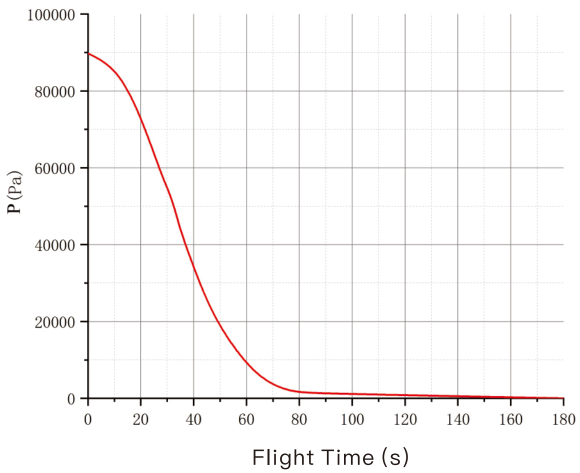

Figure 9 Static Pressure inside Payload Fairing

7.2 Operating Environment

The maximum axial acceleration load at the satellite interface is ± 1.0 g, or 2.0 g laterally.

7.3 Thermal Environment

Free molecular heating is expected to be below 1135 W/m^2 at fairing jettison.

7.4 Electromagnetic Environment

A list of RF equipment onboard the LV is shown in Table 5.

Table 5 Parameters of RF Equipment Onboard

Number	Name	Frequency (MHz)	Power (W)	Sensitivity (dBW)	Polarization Mode
1	Transmitter	2200~2300	10	\	Linear
2	Transponder	5550~5650	100 (instantaneous)	-90	Linear
3	GNSS Receiver	GPS L1 BD2 B1 BD2 B3	\	-160	Circular
4	Flight Safety Control Combination	610~660	\	-130	Linear

A list of ground RF equipment used in pre-launch is shown in Table 6.

Table 6 Parameters of Ground RF Equipment

Number	Name	Frequency (MHz)	Power Output (dBW)
1	Telemetry Tester	2200~2400	-
2	Transponder Tester	5550~5650	15
3	Flight Safety Control Tester	630~660	-50 ~ -15
4	Same-Frequency Transponder	GPS L1 BD2 B1 BD2 B3	< -100

Intentional and additional RF emissions are shown in Table 7.

Table 7 Intentional and Additional RF Emissions

Frequency (MHz)	Electrical Field Level (dBμV/m)
10~2200	50
2200~2300	140
2300~5500	60
5500~5900	140
5900~18000	69

RF emissions from the satellite must adhere to the maximum threshold listed in Table 8.

Table 8 Sensitivity Characteristics of RF Emissions

Frequency (MHz)	Electrical Field Level (dBμV/m)
10~600	140
600~700	15
700~1200	140
1200~1600	20
1600~2200	140
2200~2300	140
2300~5500	140
5500~5900	20
5900~18000	140

The satellite provider shall provide RF-emitting devices onboard for EMC testing.

The following information shall be provided by the satellite provider to CAS Space:

a)Device components, performance parameters, working period, antenna position, and orientation of the RF-emitting devices within the satellite;

b)Characteristic curves of narrow-bandwidth electric field and additional emissions, electromagnetic sensitivity values, and curves for satellite RF emissions at the plane of separation

CAS Space will conduct an EMC analysis based on the data provided by the satellite provider and determine whether they need to provide further data and analysis in light of the analysis results.

7.5 Mechanical Environment

7.5.1 Acceleration Load

In the design of the satellite structure, the following payload conditions at the interface during flight must be considered. The safety margins required by the load conditions are given in the note of Table 9. In addition, the load capacity of the satellite's main structure should be verified with static load identification tests. And the identified magnitude from the static load test should not be lower than the design load of the satellite.

Table 9 Worst–case Load Conditions for Satellite Structures

	Flying Conditions	Maximum Dynamic Pressure	Maximum Acceleration Load
Longitudinal Load (g)	Static	+2.6	+7.0
	Dynamic	±1.0	±1.0
	Combined	+3.6	+8.0
Lateral Load (g)		2.0	1.0

Note: a) Designed Loads = worst-case load × safety factor *

* The safety factor shall be determined by the satellite provider, with a recommended value ≥1.25.

b) "Lateral load" indicates the load perpendicular to the longitudinal direction.

c) Both longitudinal and lateral loads exist.

d) In longitudinal load, "+" indicates compressive loads.

7.5.2 Sinusoidal Vibration

See Table 10 for the sinusoidal vibration environment of the satellite interface. During the test, the payload is rigidly connected to the test bench.

Table 10 Sinusoidal Satellite Vibration Test Conditions

	Frequency Range (Hz)	Acceptance Test
Longitudinal	5~8	3.88 mm
	8~100	1.0 g
Lateral	5~8	3.11 mm
	8~100	0.8 g
Scanning Frequency (oct/min)		4

Note: a) Allowable frequency deviation: ±2%.

b) Allowable amplitude deviation: 0~±10%.

c) Under the condition that the satellite is not under-tested, the test method of "notching" is allowed in order to ensure that the satellite is not damaged due to over-testing. The "notching" test conditions shall be determined by the satellite provider, but the coupled load test (CLT) results must be taken into account, with sufficient safety margin (safety factor ≥1.25 suggested by the launch provider), and determined after consultation with the launch provider.

7.5.3 Random Vibration

Random vibration results from the vibration of the LV body caused by engine operation and aerodynamic noise. A 60-second duration of vibration environment with given intensity is shown in Table 11 and Figure 10.

Table 11 Three-dimensional Random Vibration Conditions

Frequency Range (Hz)	Vibration Acceleration PSD (g^2/Hz)
20	0.001
40	0.01
500	0.01
700	0.03
1200	0.03
2000	0.004

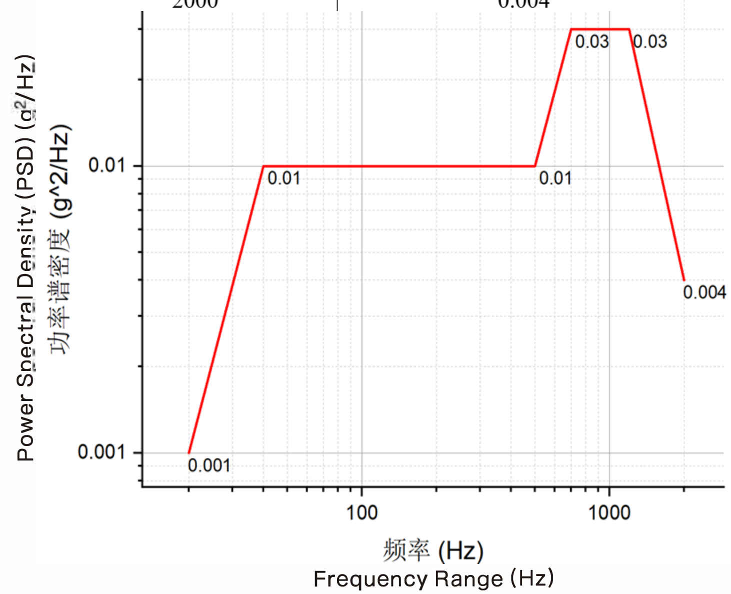

Figure 10 Random Vibration Curve

7.5.4 Noise

The maximum noise value in the fairing is shown in Table 12. The OASPL (Overall Acoustic Sound Pressure Level) corresponding to 0 dB is 2×10^{-5}Pa for a duration of 60 seconds.

Table 12 Fairing Noise

1/3 Octave Bandwidth Center Frequency (Hz)	Sound Pressure Spectrum Level (dB)
20	99.6
25	106.9
31.5	108.5
40	113.9
50	119.1
63	119.4
80	118.7
100	122.4
125	120.3
160	124.6
200	123.7
250	130.1
315	131
400	132.6
500	130.9
630	132.5
800	134.3
1000	133.5
1250	131
1600	126
2000	121.9
2500	121
3150	117.3
4000	115.2
5000	115.7
6300	115.1
8000	112.6
The total sound pressure level	141.5

7.5.5 Shock Environment

The maximum shock on the satellite caused by pyrotechnics activation and separation spring occurs at the instant of satellite separation. The maximum shock at the plane of separation does not exceed the levels shown in Table 13 and Figure 11.

Table 13 Three-dimensional Shock Parameters at Plane of Separation

Frequency Range (Hz)	Shock Response Spectrum (SRS) (Q=10)
50~1000	9 dB/oct
1000~5000	4000 g

Note: Shock conditions can be adjusted according to the separation method.

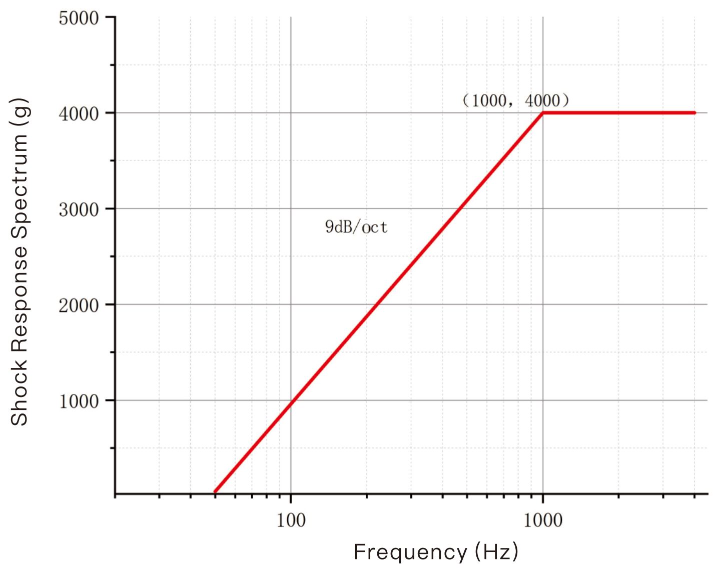

Figure 11 Shock Response Spectrum at the Plane of Separation (Q=10)

8 Launch Site Organization and Process

8.1 Launch Site Operations

Kinetica-1 LV adopts the horizontal assembly, testing, transportation, erection, and vertical launch for its test and launch process. The whole process takes 30 days, including 25 days in the technical area and 5 days in the launch area; after mass production the period is reduced to 15 days, including 12 days in the technical area and 3 days in the launch area.

At the Vehicle Testing Hall (VTH) in the technical area, the primary operations involve LV check-in and unpacking, self-inspection of each system, inspection of functions, comprehensive testing, overall examination and testing, security code installation, mating and testing of each LV stages, RCS fuelling, payload assembly composite (PAC) mating, encapsulation and testing. At the Payload Testing Hall (PTH), operations include unloading, check-in, testing of the satellite, and mating with PAC. A detailed launch schedule can be found in Table 15.

The primary objectives at the launch pad area are comprehensive testing, overall examination and testing, rehearsal, and final launch. Detailed procedures are shown in Table 16.

Table 15 Test and Launch Process at the Technical Area

S/N	Operations
1	LV unpacking
2	Assembly of each LV stage Installation of pyrotechnics products at each LV stage
3	Preparation before the test
4	Function inspection
5	Comprehensive testing
6	Overall examination and testing
7	Security code installation
8	RCS fueling
9	Cold gas thruster system filling
10	Mating of LV stages Satellite encapsulation and PAC setup
11	RCS gas filling PAC mating and flipping
12	PAC transferred to VTH PAC mating with LV
13	Feedback-loop resistance testing
14	Post-integration inspection and testing
15	LV final preparation and sealing; Vehicle Transfer Review (VTR) Loading and transfer of ground launch and TT&C equipment
16	LV transferred to logistical transportation vehicle Launch pad area equipment testing preparation
17	LV transferred to launch pad Launch pad area equipment testing

Table 16 Test and Launch Process at the Launch Pad Area

S/N	Operations
1	Comprehensive testing of the launch pad area
2	Overall examination and testing of the launch pad area
3	Launch pad WDR
4	Launch

8.2 Satellite-LV Integration

8.2.1 Satellite Mating with LV and Fairing Mating

The satellite provider will complete all satellite operations in the Payload Integration Hall (PIH), where satellite is mated with LV and one half of the fairing is mated with another. CAS Space will perform the mating procedure and install the satellite separation devices. A typical operational procedure for a three-satellite payload is as follows:

(1) CAS Space transports the satellite adapter and fairing to PIH, fixes the adapter vertically onto the interfacing platform, and the fairing horizontally onto the fairing docking vehicle.

(2) The satellite provider hoists each satellite on top of the adapter.

(3) CAS Space is responsible for mating the satellite with the adapter and installing the satellite separation devices.

(4) The fairing encapsulates vertically to form a PAC.

(5) The PAC flips into a horizontal stance.

(6) The PAC is transferred horizontally to VTH.

(7) CAS Space is responsible for mating the PAC with LV.

A typical payload integration flowchart is shown in Figure 13. The operating procedures for the satellite are determined through consultation.

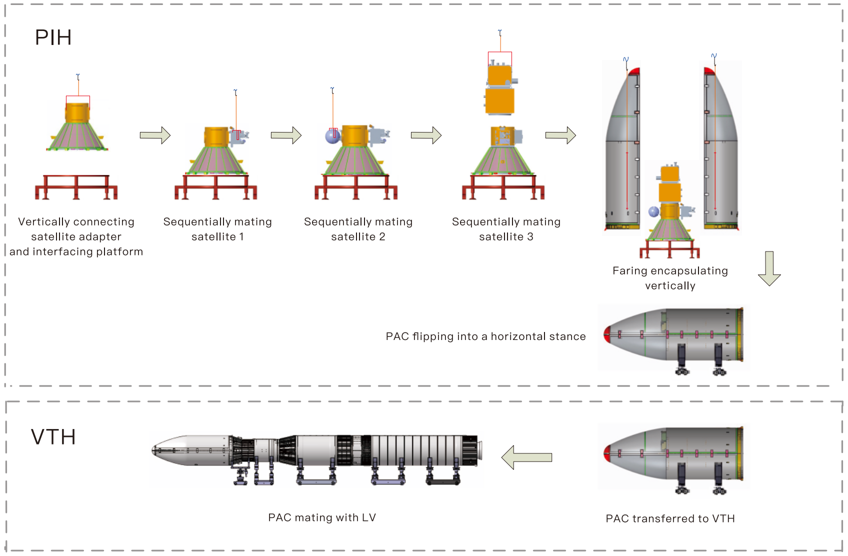

Figure 13 Flowchart of Joint Payload Integration Operations

8.2.2 Post-integration Testing

After payload integration with the LV, tests will be performed.

Upon completion of the tests, the LV is hoisted to a logistical transportation vehicle as a whole for a horizontal transfer to the launch pad area for further tests.

Attachment A Kinetica-1 Y1 Flight Test Report

At 12:12 on July 27, 2022, "Kinetica-1" successfully sent six satellites into designated orbits from JSLC with a total payload of 1068.63 kg, including a satellite of 899 kg. The LV performed nominally during all flight phases. Six satellites were deployed into orbit accurately, and complete telemetry data were obtained, including acceleration loads, vibration, shock, and noise. The inaugural flight was declared a complete success.

Fig. 1 Flight Test of Kinetica-1 Carrier Rocket

Table 1 compares design parameters with actual parameters for orbit insertion accuracy, satellite attitude, and mechanical environments at the plane of satellite separation.

Table 1 Kinetica–1 LV Design Parameters vs. Y1 Actual Parameters

Project		Design Parameters	Y1 Actual Parameters
Orbit Insertion Accuracy	Semi-major axis altitude deviation	Δa is not greater than 5 km (3σ)	Δa: 545 m
	Orbital inclination deviation	Δi is not greater than 0.08°(3σ) 0.05° (3σ)	Δi: 0.0005°
	Eccentricity deviation	Δe is not greater than 0.002 (3σ)	Δe: 1×10^{-6}
Satellite Attitude	Three-dimensional attitude and angular velocity deviation	No more than 2.0°/s (3σ) before separation	Payload A before separation: 0.2°/s Other payloads before separation: 0.6°/s
Mechanical Environment	Random vibration	3D RMS: 7.33 g 5.74g	Axial RMS: 3.3 g Lateral RMS: 3 g
	Shock	1000 Hz 4000 g 1000Hz 3000g	Axial: 1600 Hz 2350 g Lateral: 2690 Hz 1650 g
	Noise	OASPL 141.5 dB	OASPL 141.5 dB
	Axial acceleration loads	7 g Max	6.2 g Max
	Lateral acceleration loads	2 g Max	0.45 g Max

Y2
Δa: 2.391km
Δi: 0.004°
Δe: 2.96×10^{-4}
1.0×10^{-4}
0.0034°
0.2
0.4
0.61
0.51
Axial RMS: 0.71g Lateral RMS:1.45g
Axial: 5080Hz 2857g Lateral: 3390Hz 2529g
Total Acoustic Lv: 133.3 dB
Max: 6.15g
Min: 0.307g