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Supply chain Landscape of Satellite manufacturing in India



November, 2026

भारत सरकार / Government of India

अंतरिक्ष विभाग, / Department of Space

भारतीय राष्ट्रीय अंतरिक्ष संवर्द्धन एवं प्राधिकरण केन्द्र

Indian National Space Promotion and Authorization Centre

अहमदाबाद - 380058 / Ahmedabad - 380058

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Preface

The global satellite manufacturing industry is undergoing a transformative phase, driven by the rising demand for space-based services such as communication, navigation, Earth observation, and climate monitoring. With the emergence of commercial space players and the proliferation of small satellite constellations, the traditional government-dominated space sector has evolved into a vibrant ecosystem characterized by private sector participation, technological innovation, and competitive global supply chains. This transformation offers significant opportunities for nations aspiring to establish themselves as reliable suppliers in the international satellite market.

India, with its proven space heritage under the leadership of the Indian Space Research Organization (ISRO), has made remarkable achievements in designing, developing, and launching satellites for diverse applications. Over the past decades, India has emerged as a cost-effective and dependable launch service provider. However, its role in the global satellite manufacturing supply chain remains limited, with most critical components and high-end subsystems still imported. The Indian space manufacturing ecosystem has traditionally been government-centric, with private industries largely confined to providing structural assemblies, propulsion components, and fabrication services.

The satellite manufacturing supply chain in India faces several challenges, including limited indigenous production of space-grade microelectronics, optical and radar payloads, high-power amplifiers, and electric propulsion systems. The Government of India has introduced several policy reforms, including the establishment of Indian National Space Promotion and Authorization Center (IN-SPACe) aimed at opening the space sector to private participation. The emergence of Indian start-ups and MSMEs, coupled with global demand for low-cost satellite solutions, has created a unique window of opportunity for India to position itself as a significant exporter of satellite systems, subsystems, and components.

Indian companies can leverage their cost advantage, skilled engineering workforce, and proven reliability in space missions to tap into the growing international demand. Opportunities lie in small satellite platforms, CubeSat components, optical and SAR payloads, high-throughput communication transponders, miniaturized electronics,

deployable antennas, and electric propulsion units. Establishing commercially operated testing and qualification facilities, strengthening R&D in space-grade semiconductors and advanced materials, and forming strategic partnerships with global OEMs will be crucial for building credibility and global acceptance.

With focused investments, innovation-driven manufacturing, and a collaborative ecosystem of established aerospace companies, start-ups, and research institutions, India can evolve from being primarily a satellite assembler to a global hub for satellite manufacturing and exports. By building capabilities in high-end subsystems and ensuring compliance with international quality standards, Indian companies can play a pivotal role in the global space economy and contribute to the country's vision of becoming a leading space power.

This document explores the present status of India's satellite manufacturing supply chain, identifies existing gaps, and highlights emerging opportunities for Indian companies to expand their role as key suppliers in the international market.

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Chapter 1 : Introduction

The global space industry is witnessing an unprecedented transformation, fueled by the increasing demand for satellite-based services, rapid advancements in technology, and the growing participation of private players in what was once a government-dominated domain. The surge in requirements for high-speed communications, real-time Earth observation, navigation, and climate monitoring has resulted in a significant expansion of the satellite manufacturing sector. With the emergence of mega-constellations of small satellites, high-throughput communication systems, and advanced scientific payloads, the satellite manufacturing supply chain has become highly specialized and globally interconnected.

India's satellite manufacturing sector is undergoing a transformative phase, emerging as a key contributor to the rapidly evolving global space economy. Satellite manufacturing has a huge growth potential for the country across different sectors – EO, Navigation, Communication, in addition to the manufacturing of alternate platforms and satellite sub-systems. With the sector projected to grow from $8.4 billion in 2023 to $44 billion by 2033, capturing approximately 8% of the global market share, India faces both significant opportunities and substantial supply chain challenges that require immediate attention and strategic intervention.

India, with its remarkable legacy in space exploration and satellite launches under the leadership of the Indian Space Research Organization (ISRO), has established itself as a reliable and cost-effective space-faring nation. The successful deployment of a wide range of satellites—spanning communication, navigation, Earth observation, and scientific research—demonstrates India's technological prowess. However, when it comes to satellite manufacturing for the global market, India's role has so far been limited. India's satellite manufacturing sector faces several critical supply chain challenges that limit its growth potential and global competitiveness. These challenges span across technical, market, policy, and infrastructure dimensions. Dependency on components & material import, long lead time, compatibility of quality standards, limited domestic demand, limited skilled manpower are few of the major supply chain challenges.

The opportunities, however, are immense. The global demand for low-cost, reliable satellite platforms, components for mega-constellations, and turnkey satellite solutions for emerging space nations offers Indian industries a unique chance to establish themselves as major exporters. With its inherent strengths of cost competitiveness, skilled engineering talent, and proven reliability in space missions, India can aspire to replicate its success in cost-effectiveness in field of satellite manufacturing. The recent policy reforms, including FDI liberalization, technology transfer acceleration, and the establishment of dedicated funding mechanisms, provide a strong foundation for addressing supply chain gaps.

Satellite Subsystems:

The satellite is generally constituted into the subsystems which have specific functional requirement for nominal functioning of the satellite. The development of a typical satellite involves integrating multiple subsystems, a process that requires rigorous verification through environmental and functional test facilities.

This is depicted in following figure.

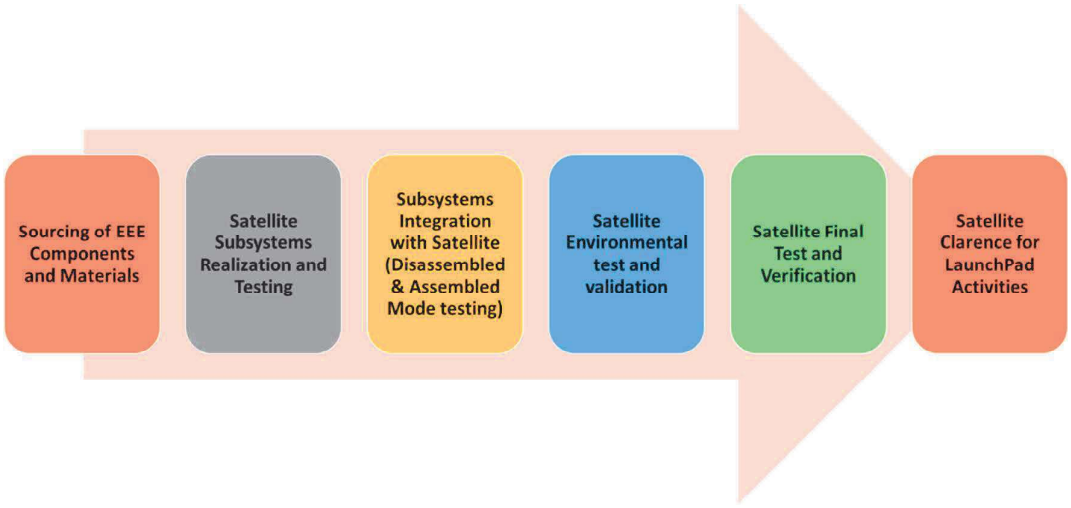


Figure 1: Typical Satellite development Value Chain

The major subsystems of a typical satellite are described briefly in the following section

Structures subsystem- Act as base for mounting of all requisite subsystems and optimally transfer load during launch avoiding any subsystem damage/failure.

Thermal subsystem – The design objective is to provide optimal thermal environment for all subsystems through active and passive measures throughout the life of the satellite.

Communication subsystem – These involve configuring links between satellite and ground station whether it is for housekeeping or payload data transmission.

Power subsystem – This system encompasses the power generation, storage and distribution within satellite for various operational modes of a satellite.

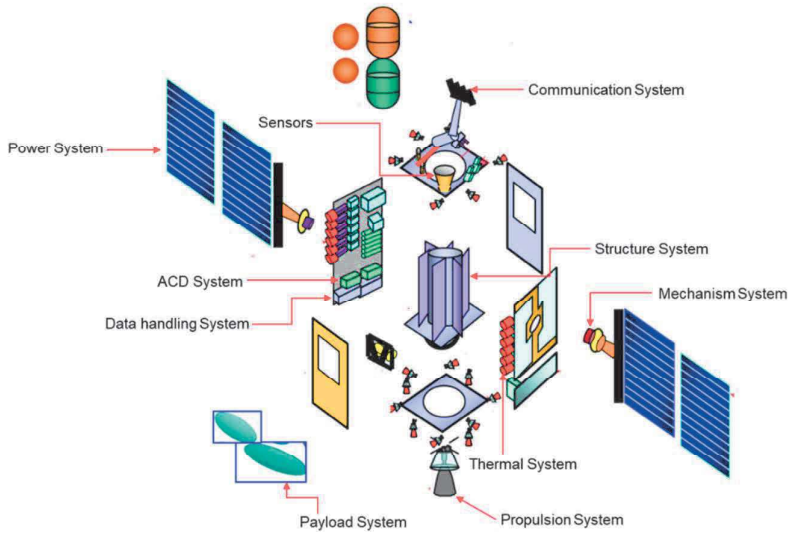


Figure 2: Typical Satellite Subsystems and Configuration

Attitude and Orbital Control subsystem- This system is the brain of the satellite processing inputs from ground command and sensors to achieve the desired orientation.

Baseband Data handling subsystem- Through this the satellite archives the data obtained through payloads and appropriately channelizes and manages the data to be transmitted to ground.

Mechanism subsystems- These subsystems are configured for deployment of appendages such as reflectors, solar arrays and achieving requisite pointing and such.

Propulsion subsystem- The task/ functional objective of this system is to provide the required impulse for achieving the movement to desired orbit, desired attitude and, station-keeping.

Payload subsystem: This broadly refers to a class of instruments encompassing optical cameras, transponders, active antennas, and atomic clocks. These instruments are defined based on the intended end use of the satellite across domains such as Earth observation, communication, and navigation.

The key components of the satellite subsystems are shown in figure 3.

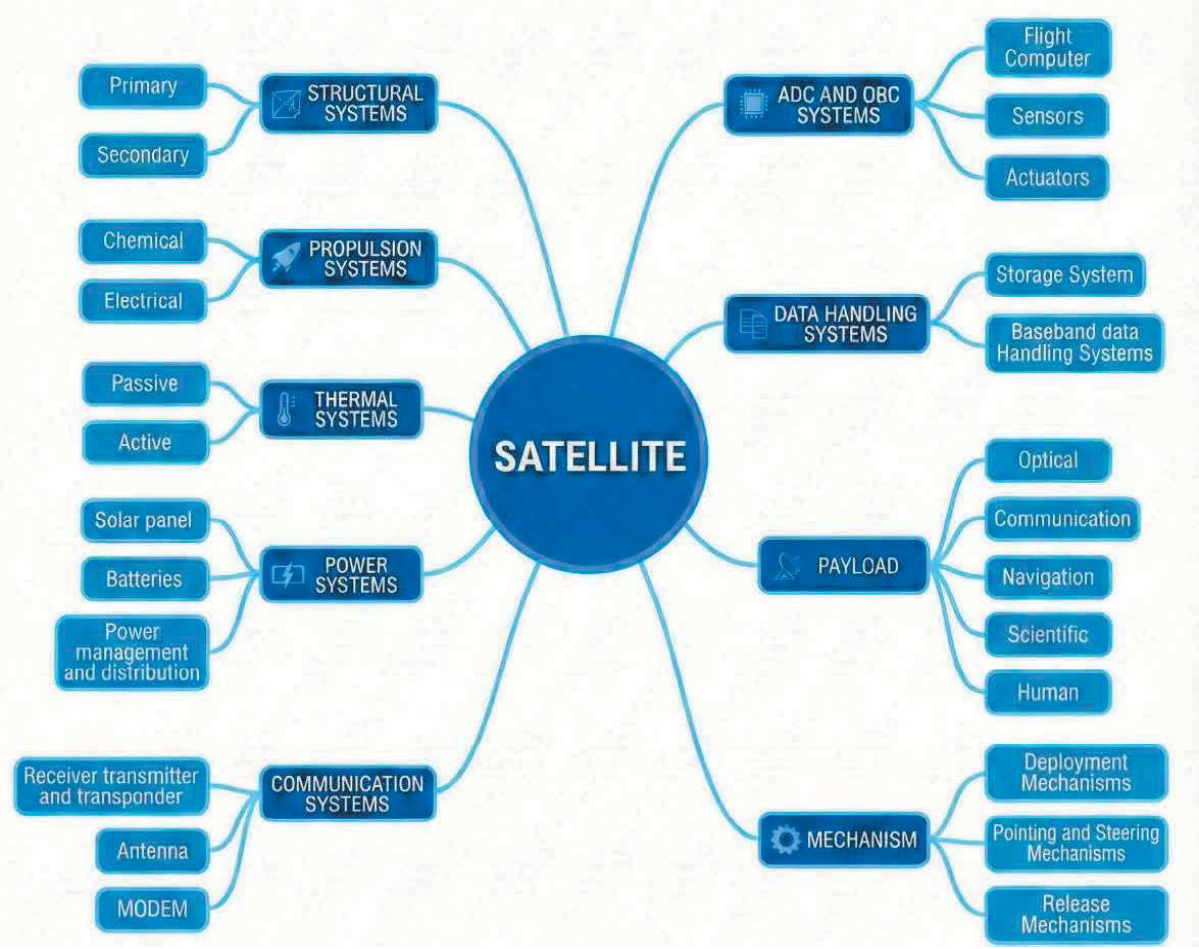


Figure 3: Key Components of satellite Sub systems

For realization of a satellite, apart from the subsystems, various facilities and equipment are employed to qualify the sub system before integration to the satellite. This specialized equipment is sourced from OEMs all around the world.

Post reforms few of the Indian NGEs has built and launched satellites, this reflects the development progressive maturity by Indian Private Sector.

This report highlights the current status, existing gaps, and emerging opportunities in India's satellite manufacturing supply chain. With sustained collaborations, robust policy support, and innovation-driven manufacturing, Indian companies can soon become key players in supplying satellite systems and subsystems to the world, reinforcing the nation's vision of becoming a leading space power.

Chapter 2 : Satellite Realisation Methodology

India's space ecosystem has undergone a dramatic transformation since the 2020 space sector reforms, creating two distinct but increasingly complementary approaches to satellite development. The Indian Space Research Organization (ISRO) employ its time-tested, heritage-driven methodology, while India's burgeoning private space sector has embraced agile, commercially-oriented approaches that prioritize speed, cost-efficiency, and rapid innovation.

Supply Chain and Manufacturing Strategies:

The following figures depicts the satellite realization methodology of both the entities.

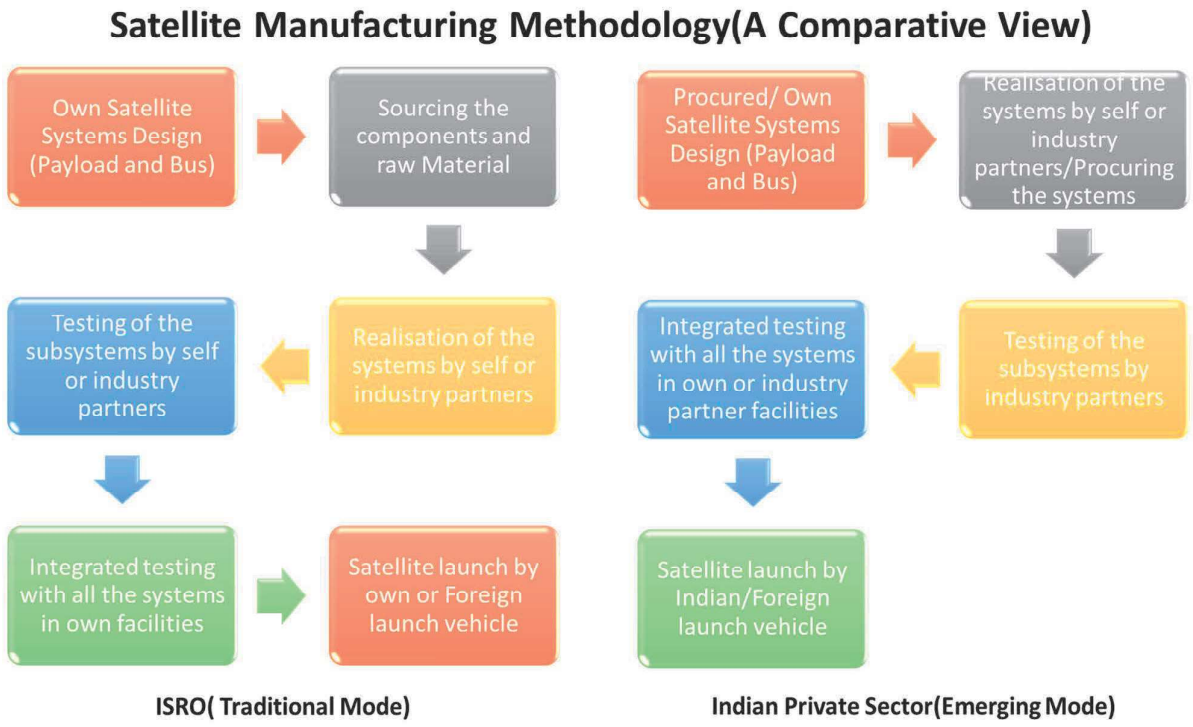


Figure 4: Satellite Manufacturing Methodology(A Comparative View)

The core differences in both the approaches are development of the systems and establishment of the processes inhouse by ISRO, whereas private sector relay on procurement of the technologies, systems from the already established entities including ISRO. Additionally private sector tests the satellites at the procured or shared test facilities, as to own and establish the facilities requites a lot of time and huge

capital. In summary ISRO is highly dependent on import of components and materials, which are used to realize inhouse systems, whereas Private sector is dependent on import of the tested and qualified subsystems.

These approaches are evolving into complementary pillars of India's space ecosystem. ISRO provides the foundational infrastructure, technical standards, and deep space capabilities, while private companies inject commercial dynamism, innovative technologies, and rapid scalability.

Cost Components of a typical satellites:

To leverage the skilled manpower available in India for the space sector, it is essential to understand the typical cost structure involved in satellite realization. The overall cost generally comprises satellite components and subsystems (including payload, power, communication, propulsion, avionics and structural systems), raw materials and consumables, manpower and engineering, facilities, assembly, integration and testing (AIT), and miscellaneous and indirect costs. The chart below depicts the indicative distribution of these cost elements in the realization of a typical satellite.

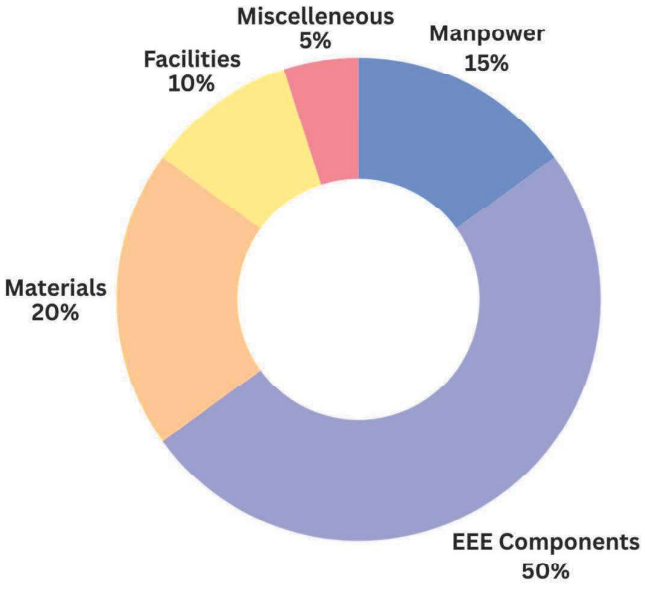


Figure 5:Cost elements for a typical satellite realisation

Considering India's cost competitiveness, strong engineering capabilities and substantial pool of skilled technical manpower, the country has a significant competitive advantage in the indigenous development and realisation of satellite components and subsystems. These strengths position India favorably to emerge as a globally competitive hub for satellite manufacturing.

Chapter 3 : Present scenario of satellite subsystems supply chain

The global satellite industry is experiencing unprecedented growth, driven by the demand for global connectivity, earth observation, and scientific exploration. This rapid expansion places immense pressure on the satellite systems supply chain, making efficient and resilient management crucial for success. In this section supplier details of the satellite systems, its subsystems and associated components and facilities has been summarised.

***The supplier details provided in the tables of this section are non-exhaustive**

a) Satellite Structural System

The satellite structural system is the primary framework that provides mechanical support, protection, and stability to all satellite subsystems and payloads. It is designed to withstand the extreme mechanical loads, vibrations, and shocks experienced during launch, while ensuring the satellite's integrity and functionality in the harsh space environment.

The structure performs key functions such as load bearing, alignment of components, and protection from micrometeoroids, thermal fluctuations, and space debris. It also facilitates easy integration, testing, and deployment of subsystems before and after launch.

Satellite structural systems are typically divided into primary and secondary structures. The primary structure, such as the central cylinder or main bus, carries major loads and connects to the launch vehicle. Secondary structures hold lighter components like electronics and sensor.

The honeycomb core, face sheets, fasteners, CFRP skin, vibration isolators, fabricated connector ring, etc, are structural sub systems which are also part of Satellite structural systems.

Structural subsystems—such as honeycomb cores, face sheets, CFRP skins, fasteners, vibration isolators, and fabricated connector rings—constitute critical elements of satellite structural systems and represent key opportunities for indigenous manufacturing and supply-chain development.

The supplier details of the satellite structure and its subsystems are tabulated in the following table.

Table 1: Satellite Structure and its subsystems suppliers

Systems	Primary and Secondary Structurers, honeycomb cores, Face sheets, CFRP skins, fasteners, vibration isolators, and fabricated connector rings
Indian Suppliers	NSIL, HAL, TASL, Data Pattern, Azista Industries, Dhruva Space, L&T, TakeMe2Space, Newtech Aerospace, Ankit Fasteners
Foreign Suppliers	ISISPACE (Netherlands), Beyond Gravity (Switzerland), OHB SE (Germany), INASCO HELLAS (Greece), Space Structures (Germany), INVENT GmbH (Germany), INVENT GmbH (Germany), German Orbital Systems (Germany), Endurosat (Bulgaria), Kongsberg Nano Avionics (Lithunia), Lockheed Martin (USA), Hexcel (USA), VMC group (USA), Isolation Dynamics Corp (USA), Rocket Lab (USA)

The details of the test systems and equipment required to test satellite structures and systems are tabulated in the following table.

Table 2: Test systems and equipment required to test satellite structure systems

Key Tests	Test Facilities	Test Equipment
Static Load Test (Proof & Ultimate)	Static Load Test Facility	Hydraulic/Pneumatic Actuators & Load Cells Electrodynamic/Hydraulic Shakers
Static Bending Test Modal Analysis Ultrasonic Inspection	Static Load Benches Modal Analysis Facility NDE Laboratory	Hydraulic Test Benches Modal Hammers, Laser Vibrometers Ultrasonic Flaw Detectors, X-ray

Proof Load Test Fatigue Test	Static Load Test Facility Fatigue Test Benches	Mini-hydraulic Actuators & Strain Gauges High-cycle Fatigue Test Machines Shakers
Outgassing Test	Outgassing Test Facility	Vacuum Chambers with RGA (Residual Gas Analyzer)

b) Satellite Propulsion System

Satellite propulsion systems are critical for orbital insertion, station-keeping, attitude control, and end-of-life disposal. They provide the necessary thrust to maneuver satellites in space and maintain their designated orbits. Propulsion systems are broadly classified into chemical propulsion and electric propulsion.

Chemical propulsion uses the combustion of propellants to generate high thrust. It includes liquid propulsion systems (bi-propellant and mono-propellant thrusters) and solid propulsion systems. Liquid engines are commonly used for orbit raising and large maneuvers due to their high thrust, while monopropellant thrusters are used for attitude control and station-keeping. Solid propulsion, though less controllable, is used for initial orbital transfers or as kick motors.

Electric propulsion systems use electrical energy to accelerate ions or plasma, providing high specific impulse but low thrust. Types include ion thrusters, Hall-effect thrusters, and plasma thrusters. Electric propulsion is highly efficient for long-duration station-keeping, deep-space missions, and geostationary satellites.

The supplier details of the satellite Propulsion and its subsystems are tabulated in the following table.

Table 3:Satellite Propulsion and its subsystems suppliers

Systems	Propulsion System, Propellent tanks, Thrusters, Flow control valves, Propellent, Electric propulsion
Indian Suppliers	NSIL, MANASTU Space, Bellatrix, Azista Industries, Godrej Aerospace

Foreign Suppliers	Dawn Aerospace (Netherlands, RAFAEL (Israel), IHI Aerospace (Japan), Orbital Propulsion Centre (Germany), MT Aerospace (Germany), AST Advanced Space Technologies (Germany), AAC Clyde Space (USA), Benchmark Space Systems (USA), Northrop Grumman Corporation (USA), Moog (USA), VACCO Industries (USA), Aerojet Rocketdyne (USA), Busek Co. (USA), Safran Aircraft Engines (France), ThrustMe (France), Airbus Defence and Space (France)

The details of the test systems and equipment required to test satellite propulsion systems are tabulated in the following table.

Table 4:Test system and equipment required to test satellite propulsion systems

Key Tests	**Test Facilities Required**	**Test Equipment Required**
Thrust Measurement & Isp Test Ignition & Firing Stability Life Cycle & Endurance Test	Propulsion Test Stand / Hot-Fire Facility	Vacuum Thrust Stand / Load Cells Mass Flow Meters High-speed DAS Ion Beam Diagnostics (for electric propulsion)
Proof & Burst Pressure Test Leak Test (Helium) Material Compatibility Test	Hydrostatic / Burst Test Facility Helium Leak Test Facility Material Compatibility Lab	Hydrostatic Pressure Pumps & Gauges Burst Pressure Test Rigs Helium Mass Spectrometer Leak Detectors Chemical compatibility chambers
Leak Test Proof Pressure Test	Helium Leak Test Facility	Helium Leak Detectors Mini-hydraulic Pressure Rigs

Actuation & Response Time Test Leak & Proof Pressure Test Life Cycle Fatigue Test	Valve Test Bench Endurance & Fatigue Test Facility	Electro-pneumatic Actuation Controllers Helium Leak Detectors High-cycle Fatigue Test Rigs
Purity Analysis Material Compatibility Contamination Test	Propellant Storage & Handling Lab	Gas Chromatographs Compatibility Test Chambers
Gimbal Actuation Test	Chamber with firing capability TVAC Chamber with motion tracking	Torque & Position Sensors, High-speed Cameras

c) Satellite Thermal System

Satellite thermal systems are essential for maintaining the temperature of spacecraft components within their operational limits in the harsh space environment. Satellites are exposed to extreme temperature variations, ranging from intense solar heating to deep cold in the Earth's shadow. The thermal control system functions based on the passive and active thermal control methods.

Passive thermal control relies on materials and design features that regulate temperature without using additional power. Common elements include thermal coatings, multi-layer insulation (MLI) blankets, thermal tapes, and heat pipes. Radiators are used to dissipate excess heat, while MLI blankets minimize heat loss or gain.

Active thermal control uses powered systems to maintain precise temperature control. This includes heaters, thermostats, louvers, and pumped fluid loops. Electric heaters are frequently used to keep batteries, propulsion systems, and sensitive instruments within operational temperatures.

The supplier details of the satellite thermal and its subsystems are tabulated in the following table.

Table 5: Satellite thermal systems and its subsystems suppliers

Systems and Subsystems	Active and Passive thermal control systems consist of: Heat pipes, Pumps, Multi-Layer Insulation, Thermofoil heaters, Thermal radiators and louvers, Bonding Adhesives, Thermal Paints, Kapton sheets and Tapes, Tape Heaters, Thermistors, Thermostats Velcro
Indian Suppliers	NSIL Thermal Management Technologies, Avasarala Technologies Limited, Thakerson, Takeme2Space, Anabond, Pushpak Products, Claybond
Foreign Suppliers	Zoppas Industries (Italy), Thermal Management Technologies (USA), Paragon Space Development Corporation (USA), Barber-Nichols (USA), Advanced Cooling Technologies (ACT) (USA), Boyd corporation (USA), Collins Aerospace (USA), Sheldahl(USA), Dunmore(USA), Dupont (USA), 3M (USA), Arquimea (Spain), Mitsubishi Electric (Japan)

The details of the test systems and equipment required to test satellite thermal systems are tabulated in the following table.

Table 6:Test system and equipment required to test satellite thermal systems

Key Tests	Test Facilities Required	Test Equipment Required
Thermal Vacuum Test (TVAC)	Thermal Vacuum Chamber	Thermal Vacuum Chamber, Infrared heaters / shrouds, Cryo-pumps / Turbo pumps, Temperature sensors (thermocouples, RTDs), Vacuum gauges
Thermal Balance Test	Space Simulation Chamber	Shrouds with temperature control, Calibrated heaters, IR cameras,

		Thermocouples / RTDs
Thermal Cycling Test	Thermal Vacuum Chamber or Thermal Cycling Chamber	Programmable thermal chamber, Data acquisition system, Temperature monitoring sensors
Hot/Cold Soak Test	Environmental Test Chamber	Controlled temperature chamber, Data logger, Thermocouples
Heat Pipe Performance Test	Vacuum chamber or custom thermal bench setup	Heater plates, Temperature sensors, IR camera, Vacuum pump
MLI (Multi-Layer Insulation) Efficiency Test	Calorimetric test bench or TVAC chamber	Calorimeter, IR sensors, Thermal insulation measurement system
Heater Functionality Test	Thermal Bench Setup	Power supply for heaters, DAQ system, Thermocouples, Control electronics
Component Thermal Shock Test	Thermal Shock Chamber	Dual zone chamber (hot and cold zones), Rapid transfer mechanism, Data logger
Outgassing Test	Vacuum Outgassing Test Facility	Microbalance, Quartz Crystal Microbalance (QCM), Residual Gas Analyzer (RGA)
Thermal Conductivity and Interface Test	Laboratory Thermal Interface Test Bench	Heat flux sensors, Thermal conductivity meter, Controlled heater and cooler

d) Satellite Power System

Satellite power systems are designed to generate, store, and distribute electrical energy required for all onboard subsystems and payload operations. Since satellites operate in space without direct access to conventional power sources, reliable and long-duration power generation is crucial for mission success.

The primary source of power for most satellites is solar energy. Solar panels (photovoltaic arrays) convert sunlight into electricity. Modern satellites use high-efficiency solar cells, such as gallium arsenide (GaAs) or multi-junction cells, which offer high power-to-weight ratios and resistance to radiation damage.

Since satellites pass through Earth's shadow, energy storage systems are essential. Rechargeable batteries, typically lithium-ion or nickel-hydrogen, store excess energy generated by solar panels during sunlight periods and supply power during eclipses.

The power conditioning and distribution unit (PCDU) regulates, converts, and distributes power to various subsystems. It ensures stable voltage levels, overload protection, and efficient energy management.

The supplier details of the satellite power and its subsystems are tabulated in the following table.

Table 7:Satellite power and its subsystems suppliers

Systems and Subsystems	Power Systems consisting of Solar cells, Battery, DC-DC convertors, Power distribution and control units, Solar panel substrates
Indian Suppliers	NSIL, Data Patterns, Dhruva Space. Centum, Takeme2Space,n Azista Industries, Ananth Technologies, BHEL, TASL
Foreign Suppliers	Airbus Defense and Space (France), Saft Groupe S.A. (France), Kongsberg NanoAvionics (lithuania), Dragonfly Aerospace (South Africa), Endurosat (Bulgaria), GS Yuasa (Japan), Panasonic (Japan),Argotec(Italy), EnerSys Advanced Systems (USA), EaglePicher Technologies (USA), Mitsubishi

	Electric(Japan), Azur(Germany), Spectrolab (USA), Rocketlab (USA), Emcore Corporation(USA), International rectifiers(USA)

The details of the test systems and equipment required to test satellite power systems are tabulated in the following table.

Table 8:Test system and equipment required to test satellite power systems

Specific Tests	**Test Facilities Required**	**Test Equipment Required**
Maximum Power Point Tracking (MPPT) verification Power generation efficiency under varying illumination Shadowing & degradation simulation	Solar Array Simulator Laboratory	Solar Array Simulator (SAS) I-V curve tracers Precision multimeters Power analyzers
Thermal cycling & vacuum exposure	Thermal Vacuum (TVAC) chamber	TVAC chamber with solar simulation lamps Thermocouples & IR sensors
Life cycle degradation test (UV & temperature exposure) Electrical insulation breakdown test Abuse & safety tests (overcharge/short-circuit)	Solar exposure chamber Thermal cycling chambers Burn-in test setup	UV lamps Thermal cycling ovens Automated burn-in racks Automated cycling racks with safety cutoffs Fire-suppression integrated test racks
Voltage regulation & load sharing Short-circuit & overcurrent protection Efficiency characterization under variable loads	Electrical Integration Laboratory (EIL)	Programmable power supplies Electronic programmable loads Oscilloscopes Data acquisition systems
Charge-discharge cycling	Battery Test Facility	Battery cyclers /

Depth of discharge (DoD) characterization State of Charge (SOC) & State of Health (SOH) monitoring		programmable charge-discharge units Battery impedance analysers SOC/SOH analysers

e) Satellite TTC Communication Systems

The Telemetry, Tracking, and Command (TTC) communication system is a crucial interface between a satellite and its ground control segment, ensuring mission success and satellite health monitoring throughout its operational life. The main role of TTC systems is

a) Telemetry: Collects health and status data of onboard subsystems such as power, thermal, propulsion, and payload systems. This data is formatted and transmitted to ground stations for real-time monitoring and post-processing.
b) Tracking/Ranging: Provides satellite position and velocity information using range, Doppler, and angle measurements, essential for orbit determination, station-keeping, and collision avoidance.
c) Command: Receives, decodes, and executes commands from the ground to control satellite modes, payload operations, software updates, and emergency recovery functions.

TTC systems consists of TTC Transceivers, Command and ranging demodulators, Telemetry and Ranging modulator, and Antenna Systems.

Transceivers, consists of active RF systems, i.e. Amplifiers, up/down converters, Local Oscillators, etc. which enable uplink command reception and downlink telemetry transmission, with redundant units for reliability.

Suitable Antennas configuration consists of Omni-directional antennas and High-gain global antennas for precise tracking and commanding operation during transfer orbit and on orbit operations.

The supplier details of the satellite communication and its subsystems are tabulated in the following table.

Table 9: Satellite communication and its subsystems suppliers

Systems and Subsystems	Communication Systems consisting of Transmitters, Receivers, Antenna, Modulators & demodulators, TWTA, SSPA, Waveguides ans Cables
Indian Suppliers	NSIL, ASTRA Microwave, Centum, Ananth Technologies, Data Pattern, Avasarala, Azista Industries
Foreign Suppliers	C3S Electronics Development (Hungary), GomSpace (Denmark), Satlab(Denmark), HPS (Germany), IQ spacecom (Germany), Rosenberg(Germany),Kongsberg NanoAvionics (lithuania), ISISPACE (Netherlands), Rocket Lab (USA), Tethers Unlimited (USA), CesiumAstro (USA), Honeywell Aerospace (USA), Akash Systems (USA), Innoflight (USA),Harris Corporation(USA), QORVO(USA), Vulcan Wireless Inc (USA), Augustus Aerospace Company (USA),Radiall (USA), Amphenol (USA), Elbit Systems (Israel), Mitsubishi Electric(Japan), Cubecom (SA), Safran Data Systems(France), Airbus(France), Thales Alenia Space (France and Italy), Axon Cable (France), Argotec(Italy), Beyond Gravity (Switzerland), Huber Suner(Switzerland)

The details of the test systems and equipment required to test satellite communication systems are tabulated in the following table.

Table 10:Test system and equipment required to test satellite communication systems

Key Tests	Test Facilities	Key Equipment
Radiation Pattern, Gain, Polarization	Anechoic Chamber / CATF	Near-field scanner, VNA, Positioners
High-Power RF / Multifactor Test	RF-TVAC Integrated Test	TVAC with RF windows/feed-throughs, RF Signal Source and Spectrum

	Facility	Analyser
Sensitivity, BER, Modulation Accuracy	RF Lab / Ground Station Simulator	Spectrum Analyzer, BER Tester, Signal Generator
EIRP, Linearity, Frequency Stability	RF Lab	RF Power Meter, VNA, Modulation Analyzer
Bit Synchronization, Data Integrity	Baseband Integration Lab	PCM/BPSK Test Set, Bit Sync Analyzer
End-to-End RF Link, Redundancy	Ground Station Simulator	TTC Modulators/Demodulators, RF Switch Matrix

f) Data Handling System (DHS)

The Data Handling System (DHS) of a satellite is responsible for managing, processing, storing, and distributing all onboard data, making it a critical subsystem for mission success. It serves as the central hub that interconnects payloads, sensors, and other subsystems.

Key Functions of DHS:

a) Data Acquisition and Processing: The DHS collects data from various subsystems, such as telemetry, attitude sensors, and payload instruments. It performs pre-processing, including filtering, compression, and formatting, before storage or transmission.

b) Data Storage: Since real-time transmission to ground stations is not always possible, DHS stores large volumes of scientific or imaging data in solid-state recorders (SSRs) or radiation-hardened memory units for later downlink.

c) Command and Telemetry Handling: The DHS receives commands from the ground, decodes and distributes them to relevant subsystems, and packages telemetry data for transmission back to Earth.

d) Error Detection and Correction: To ensure reliability in the harsh space environment, DHS uses error detection and correction (EDAC) algorithms to protect data from radiation-induced bit flips.

Modern data handling systems use radiation-hardened high-speed processors, field programmable Gate Arrays (FPGA), microcontrollers, memories, various interfaces converters and transformers etc,

The supplier details of the satellite data handling systems are tabulated in the following table.

Table 11: Satellite data handling and its subsystems suppliers

Systems and Subsystems	Data handling Systems, SSD Storage (radiation hardened), Interfaces and cables
Indian Suppliers	NSIL, Ananth Technologies, Centum, Data pattern, Azista Industries
Foreign Suppliers	Berlin Space Technologies (Germany), Kongsberg NanoAvionics (Lithuania),VECTRONIC Aerospace GmbH (Germany), DSI Aerospace Technologies GmbH (Germany), CAVU Aerospace (UK), Exascend (Taiwan), Mercury Systems (USA), Axon Cable (France),TE Connectivity (Raychem / Tyco Electronics) (USA),Carlisle Interconnect Technologies (USA), Radiall (USA), Amphenol (USA)

The details of the test system and equipment required to test satellite data handling systems are tabulated in the following table.

Table 12:Test system and equipment required to test satellite data handling systems

Key Tests	Test Facilities	Key Equipment
Processor & RTOS: Functional Validation, Timing Accuracy	Software Validation Lab, HIL	EGSE, Debuggers, Code Coverage Tools
Memory (EEPROM/Flash): Read/Write Cycles, EDAC, Radiation	Radiation Test Lab, Burn-in Lab	Radiation Sources, Memory Testers

Data Handling Bus Interfaces: Protocol Compliance, BER	Protocol Test Lab	MIL-1553 / CAN / SpaceWire Analyzers
Failover & FDIR	HIL Test Facility	Fault Injection Systems, DAS

g) Satellite Attitude Determination and Control(ADC), Satellite On-Board Computer(OBC)

The Attitude Determination and Control (ADC) system is crucial for maintaining a satellite's orientation in space. Proper attitude control ensures that antennas, sensors, and payloads point accurately toward their targets, enabling effective communication, imaging, or scientific measurements. The ADC system consists of two major functions: attitude determination and attitude control.

a) Attitude Determination: This involves calculating the satellite's orientation with respect to Earth, the Sun, or stars. Sensors used for this purpose include:

   I. Sun sensors and Earth sensors for coarse orientation.
   II. Star trackers and gyroscopes for precise measurements.
   III. Magnetometers for detecting Earth's magnetic field direction.

b) Attitude Control: Once the attitude is determined, control actuators adjust the orientation. Common actuators include:

   I. Reaction wheels and control moment gyroscopes (CMGs) for fine control.
   II. Magnetorquers for using Earth's magnetic field.
   III. Thrusters for large manoeuvres or momentum dumping.

ADC systems operate in either three-axis stabilization or spin stabilization, depending on the mission type.

The On-Board Computer (OBC) is the central control unit of a satellite, functioning as its "brain." It manages and coordinates all satellite operations, ensuring proper functioning of subsystems and execution of mission objectives.

The OBC performs critical functions such as:

a) Telemetry and Command Processing: It collects health and status data from various subsystems and formats it for downlink to ground stations. It also decodes and executes commands received from the ground.
b) Attitude and Orbit Control: The OBC processes sensor data to determine the satellite's orientation and position. It issues commands to actuators, thrusters, or reaction wheels for attitude stabilization and orbit correction.
c) Payload Management: For remote sensing, communication, or scientific satellites, the OBC schedules and controls payload operations, data acquisition, and storage.
d) Fault Detection and Autonomy: The OBC continuously monitors subsystem performance, isolates faults, and can autonomously switch to redundant units, ensuring mission safety and longevity.

Modern ADC and OBC systems use radiation-hardened high-speed processors, Field programmable Gate Arrays (FPGA), microcontrollers, memories, various interfaces converters and transformers etc,

The supplier details of the satellite ADC and OBC systems are tabulated in the following table.

Table 13: Satellite ADC and OBC and its subsystems suppliers

Systems and Subsystems	ADC and OBC Systems consisting of Sensors, Actuators(Star Trackers, Sun Sensors, Magnetometer, Reaction wheels , Gyroscopes and control Moment Gyros, Processors)
Indian Suppliers	NSIL, Ananth Technologies, Centum, Data pattern, Azista Industries, Takeme2space, SCL
Foreign Suppliers	AAC Clyde Space (USA), Berlin Space Technologies (Germany), Blue Canyon Technologies (USA), Argotec(Italy), D-Orbit (Italy), Antaris (USA), Honeybee Robotics (USA), Serenum Space (Czech republic), Sodern (France), Honeywell(USA), Airbus Defense & Space (France), Sinclair Interplanetary(CANADA), Rocket Lab(USA), Rockwell Collins(Germany), Emcore Corporation

	(USA),AAC Clyde Space (USA), Exail technologies (France), BAE Systems (USA), Microchip Technology / Microsemi (USA), Cobham / CAES (Cobham Advanced Electronic Solutions) (USA), Teledyne e2v (UK), CubeSat Pointing (Belgium)

The details of the test systems and equipment required to test satellite ADC and OBC are tabulated in the following table.

Table 14:Test system and equipment required to test satellite ADC and OBC Systems

Key Tests	**Test Facilities**	**Key Equipment**
Processor & RTOS: Functional Validation, Timing Accuracy	Software Validation Lab, HIL	EGSE, Debuggers, Code Coverage Tools
Memory (EEPROM/Flash): Read/Write Cycles, EDAC, Radiation	Radiation Test Lab, Burn-in Lab	Radiation Sources, Memory Testers
Data Handling Bus Interfaces: Protocol Compliance, BER	Protocol Test Lab	MIL-1553 / CAN / SpaceWire Analyzers
Failover & FDIR	HIL Test Facility	Fault Injection Systems, DAS
Integrated OBC System	EGSE / HIL Facility	Simulators for TTC, ADCS, Payload
Star Tracker:Star field accuracy, lost-in-space recovery	Optical Star Sensor Facility	Star field projector, collimators
Gyroscopes: Bias, scale factor, drift	Precision Rate Table Lab	3-axis rate table, thermal chamber
Sun Sensor: FOV, thermal drift	Sun Simulator Lab	Solar simulator
Magnetometer: Sensitivity, cross-axis	Magnetic Test Facility	Helmholtz coils
GPS Receiver: PVT accuracy	GPS Simulation Lab	GPS signal simulators
Reaction Wheels / CMG: Torque,	Endurance Test	Torque transducers,

imbalance, life	Benches	balancing machine
Magnetic Torquer: Dipole accuracy	Magnetic Test Facility	Helmholtz coils
Integrated AOCS: Closed-loop pointing accuracy	HIL AOCS Simulator	Orbital dynamics simulator, DAS

h) Satellite Mechanism System

Satellite mechanism systems are essential mechanical subsystems that enable the deployment, movement, and operation of various satellite components in space. These systems ensure that appendages such as solar arrays, antennas, and payload instruments function as intended after launch, despite being stowed during the launch phase.

The key functions of satellite mechanism systems are

a) Deployment Mechanisms: To fit within the launch vehicle fairing, many satellite components are folded or stowed. Mechanisms such as hinges, latches, springs, and motors are used to deploy solar panels, antennas, radiators, and booms once in orbit.
b) Pointing and Steering Mechanisms: High-precision mechanisms are used to orient antennas, sensors, and payload instruments toward specific targets. Gimbals, stepper motors, and rotary actuators are common in Earth observation and communication satellites.
c) Release Mechanisms: Separation mechanisms, such as pyrotechnic devices or non-explosive actuators, are used to release satellite stages, protective covers, or payloads

The supplier details of the satellite Mechanism and its sub systems are tabulated in the following table.

Table 15: Satellite Mechanism and subsystems supplier

Systems and Subsystems	Satellite mechanism systems (deployment, Pointing and Steering, release) consisting of Electric Motors, Harmonic gears,

	Potentiometers
Indian Suppliers	NSIL, L&T, Data Pattern, System Controls, Vita Technology, Hical, Ananth Technologies, Avasarala Technologies,
Foreign Suppliers	Kinematics (USA), Moog (USA), EBAD (USA), Sierra Nevada Corporation (USA), Moog (USA),Harmonic Drive LLC (USA), BEI Sensors / Sensata Technologies (USA), Dupont(USA), Honeybee Robotics (USA), Thermal Management Technologies (USA), Thales Alenia (France), Airbus (France), Comat (France), Faulhaber (Germany), Maxon group (Switzerland), Wittenstein (Germany), Harmonic Drive SE / Nidec-Shimpo (Japan), TGB Group Technologies (Spain), Samputensili / Inmoco (Italy, UK), Variohm EuroSensor (UK), Novotechnik (Germany),

The details of the test systems and equipment required to test satellite Mechanism systems are tabulated in the following table.

Table 16:Test system and equipment required to test satellite Mechanism Systems

Key Tests	Test Facilities	Key Equipment
Solar Array Deployment Mechanism: Deployment, torque, life test	Deployment Test Facility, TVAC	High-speed cameras, torque sensors, DAS
Antenna Deployment Mechanism: Deployment sequence, alignment	TVAC, Zero-G Simulation	Laser alignment tools, optical trackers
Hold-Down & Release Mechanisms (HDRM): Release shock, actuation force, pyroshock	Shock Test Facility, Vibration Lab	Pyroshock simulators, force sensors
Rotary Actuators / Hinges: Torque,	Torque Calibration,	Torque transducers,

backlash, fatigue	Life Cycle Test Facility	life cycle rigs
Robotic Arms : Multi-axis movement, zero-G functionality	Neutral Buoyancy / Air-bearing Tables	Motion capture systems, load sensors
General Mechanisms: Outgassing, thermal, vibration Quasi-static Load Test Deployment Test under Thermal Vacuum Shock/Pyroshock Test	Outgassing Lab, TVAC, Vibration Tables Quasi-static Test Facility TVAC Chamber with Deployment Setup Shock Test Facility	Torque & Load Sensors High-speed Cameras Pyroshock Simulator or Hammer Test Rig

i) Satellite Optical and SAR Payload Systems

Satellite payload systems are designed to capture and transmit data for Earth observation, scientific research, or reconnaissance. Two major types are optical payloads and Synthetic Aperture Radar (SAR) payloads, each with distinct capabilities.

a) Optical Payload Systems: Optical payloads use visible, infrared (IR), or multispectral/hyperspectral sensors to capture high-resolution images of Earth. These systems include telescopes, lenses, mirrors, and detectors that operate based on reflected sunlight or emitted thermal radiation. .

b) SAR Payload Systems: Synthetic Aperture Radar uses microwave radar signals to image Earth's surface, independent of weather or sunlight. SAR payloads consist of active phased-array antennas or slotted waveguide antennas operating in microwave bands. SAR transmits radio waves and measures their reflected signals to generate high-resolution images, even though clouds or vegetation.

The supplier details of the satellite Earth observation Optical Payloads are tabulated in the following table.

Table 17: Satellite Earth observation Optical Payloads supplier

Systems and Subsystems	Earth observation Optical Payloads supplier
Indian Suppliers	NSIL, Kaleido, PIXXEL Space, Dhruva Space, XDLINX, GalaxEye Space Space, Paras-defence, EON Space, CENTUM, Ananth Technologies
Foreign Suppliers	Satlantis (USA), Teledyne (USA), L3 Harris (USA) Scanway (Poland), Leonardo (Italy), Officina Stellare(OS), Simera sense (Belgium), Safran (France), Airbus(France), MDA (Canada), Dragonfly Aerospace (South Africa), Thales Alenia Space (France & Italy)

The supplier details of the satellite Earth observation SAR Payloads are tabulated in the following table.

Table 18: Satellite Earth observation SAR Payloads supplier

Systems and Subsystems	Earth observation SAR Payloads supplier
Indian Suppliers	NSIL, Data Pattern, Piersignt, GalaxEye Space Space, SISIR Radar, CENTUM, Astra Microwave
Foreign Suppliers	Lucix Corporation (USA), Aresys(Italy), Airbus Defence(France), Alenia Space (France & Italy), Lockheed Martin (USA), Northrop Grumman (USA), OHB System (Germany), MetaSensing (Italy), ICEYE (Finland), Synspective (Japan), Officina Stellare (Italy)

The details of the test system and equipment required to test satellite EO Payload(Optical and SAR) are tabulated in the following table.

Table 19:Test system and equipment required to test satellite EO Payload(Optical and SAR)

Key Tests	Facilities	Equipment
Optical Telescope / Cameras: MTF, geometric & radiometric calibration	Optical Calibration Lab, Collimator Facility	MTF analysers, integrating spheres
Optical coating qualification	Ultra-Clean Optical Coating & Characterization Laboratory	ISO Class 5 or better cleanroom with large-aperture vacuum deposition systems
Focal Plane Array: Spectral response, noise & dark current	Optical Test Benches	Spectroradiometers, CCD test systems
SAR Antenna Panels: Pattern, gain, beam steering	CATF, Anechoic Chamber	VNA, positioners, near-field scanner
T/R Modules: RF power, linearity, thermal stability	RF Integration Lab, TVAC	RF signal generators, power meters, Spectrum Analyser
Optical & SAR Integration: End-to-end imaging & RF link test	Payload Integration & HIL Facility	DAS, SAR processors, image analysers

j) Satellite Communication Payload

The satellite communication payload is the core subsystem that enables the relay of voice, video, and data signals between ground stations or user terminals. It functions as a space-based repeater, receiving signals from Earth (uplink), processing them, and transmitting them back to the ground (downlink).

The payload mainly consists of antennas, transponders, amplifiers, and signal processing units.

a) Antennas: Uplink antennas receive signals from Earth, while downlink antennas transmit processed signals back. Configurations include parabolic reflectors, phased-array antennas, and multiple spot beams to provide wide or targeted coverage.

b) Transponders: The heart of the payload, each transponder performs frequency conversion, amplification, and filtering. Low Noise Amplifiers (LNAs) boost weak uplink signals, while High Power Amplifiers (HPAs) strengthen downlink transmissions. Filters remove noise and interference

The supplier for satellite communication payload and satellite TTC communication systems are identical and tabulated in table 8.

The details of the test system and equipment required to test satellite communication payload and satellite TTC communication systems are identical and tabulated in table 10.

k) Satellite Navigation Payload

The satellite navigation payload is a critical subsystem that enables precise positioning, navigation, and timing (PNT) services for users on Earth. It generates and transmits navigation signals that allow receivers to calculate their exact location and time using trilateration.

The navigation payload mainly consists of atomic clocks, navigation signal generators, frequency synthesizers, and antennas.

a) Atomic Clocks: High-stability rubidium or cesium atomic clocks (and sometimes hydrogen masers) provide accurate time references, essential for precise positioning. Even a nanosecond error can lead to significant location inaccuracies.

b) Navigation Signal Generators: These generate pseudo-random codes (PRN codes) and navigation messages, which include satellite ephemeris, clock corrections, and system health status.

c) Frequency Synthesizers: They convert precise clock signals into required transmission frequencies, typically in L-band (e.g., L1, L2, L5 for GPS and similar systems).

d) Antennas: High-gain antennas broadcast navigation signals uniformly across large coverage areas.

The supplier details of the satellite navigation payload are tabulated in the following table.

Table 20:Satellite Navigation Payload supplier

Systems and Subsystems	Satellite Navigation Payload supplier
Indian Suppliers	NSIL
Foreign Suppliers	Excelitas Technologies (USA), Accubeat (Israel), LKD Aerospace (USA), Leonardo(Italy), Airbus(France)

The details of the test system and equipment required to test satellite navigation payload are tabulated in the following table.

Table 21:Test system and equipment required to test Satellite Navigation Payload

Key Tests	**Facilities**	**Equipment**
Atomic Clocks : Frequency stability, TDEV, radiation	Time & Frequency Metrology Lab, Radiation Test Facility	Allan deviation analyzers, frequency counters
Navigation Signal Generation Unit (NSGU): Modulation accuracy, PRN code validation	Navigation Payload Test Lab	Vector signal generators/analyzers
Navigation Transponder: Gain, C/N, spurious emissions	RF Payload Integration Lab	Spectrum analyzer, noise figure meter, Signal Generator
Antenna: Gain, pattern,	CATR, Anechoic	Near-field scanner, RHCP

phase center stability	Chamber	probes
Integrated Navigation Payload: End-to-end PNT accuracy, time transfer	PNT Test Facility	GNSS simulators, BER testers

I) Overview of electrical and mechanical components and their supplier details

The above sections described supplier details for each subsystem in detail. The following tables describe the details of electric and mechanical components and their supplier.

Table 22:Electric and mechanical components and their Source

Electronic Components	
Resistor, capacitor, inductors, Processors, FPGA, Microcontrollers, memories, Diodes, transistors, ASIC, Connectors (ITT, SMA, coaxial), fuses, RF Components (HEMT, MMIC, LNA, TWTA, mixer, Power transistors, Antenna, local oscillators, crystals, dividers, demodulator, modulators, transformers, switches, isolators, RF cables, semi-rigid cables), solar cells, batteries, sensor, Optoelectronics & Sensors, High-resolution detectors (CCDs/CMOS image sensors), Single-Photon Avalanche Diodes (SPADs), space-qualified lasers, and integrated photonics, Micro-Electro-Mechanical Systems (MEMS) gyros/accelerometers	Import
Wires, cable, Connectors, RF Connectors thermistor, thermocouple, heater	Import and Local Industries
Fabrication of Electronic Sub systems	Local Industries
Material for the Satellite Systems	
Non-Metallic Materials Epoxy, Potting, Conformal coating, Eco bond, RTV, Resin, PCB Material and RF Substrates, composite material, MLI,	Import and Local Industries

Kapton sheet, RF Absorbers, EMI Shield, Precursor chemicals	
Metallic Materials Al-Alloy, Aluminium Honeycomb Cores, Titanium Screw, Aluminium Alloy Forged Rings, Helicoil insert	Import and Local Industries
Optical Materials Optical glass and ceramic Substrates, Mirror Coating and Processing Materials	Import
Fabrication of Mechanical Systems, Thermal paint and coating	Local Industries

The following tables describe the details of manufacturers of satellite components, materials and corresponding manufacturers used in the satellites.

Table 23: Satellite Components, Material and Manufacturers

Component	Manufacturers
FPGA	Xilinx, Microchip, Cobham, NanoXplore, Teledyne, BAE Systems
Processors	BAE Systems , Cobham , Microchip Technology (formerly Atmel), Texas Instruments (TI) , SCL
Memories	Micron Technology, Cobham, 3D Plus, Honeywell Aerospace, BAE Systems, DDC, HONEYWELL
Microcontrollers	Micron Technology, Cobham, STMicroelectronics, Texas Instruments, Teledyne e2v,
Interfaces	Texas Instruments
RF Components	Infineon Technologies, Cobham, Analog Devices, Qorvo, Microchip Technology, Teledyne e2v, Thales, Marki Microwave, Trak, Smith Interconnect, MA-COM, RAKON, TI, Perigrine, L3Communications, Rosenberg, Huber Suhner, Amphenol, Laird, Rf Lambda, Centum Electronics, Xsis, Vectron, Q Tech, RFMD, Temex, , SUMITUMO,

	Massachusetts Bay Technologies, Zarlink Semiconductors, Networks International Corp.Com-Dev, Microsemi, Spectrum Electrotechnik, Hittite, Mica Microwave, Mercury Commercial Electronic, Minicircuits, Dowkey, Radial, Logus Manufacturing Corporation, Mesa MW Corporation, Solitron Vector Microwave, Cinch Conectivity Solutions, Avago Technologies, Avnet, GAETEC, SCL, Qorvo
Passive Components	AVX, VISHEY, Huber Suhner, Amphenol
Diode, Transistors, ICs, Relay	SCL, International rectifier, Microsemi, Aeroflex Metelics, MACOM, SENSITRON, BEL, Analog Devices, National Semiconductor, Hybridtek Composants, TEXAS Instruments, BAE Systems, STMICROELECTRONICS, Intersil, SGS Thomson, Cobham Semiconductor, Harris Semiconductor, M.S.KENADY, Infineon, Frontgrade, Vpt Components, Teledyne, Rel, Leach , International, GEPE, Semicoa Semiconductor, Solitron Devices, Harris Semiconductor
Wires and Cables	Sanghvi Aerospace, TE Connectivity, AXON Cables, Gore, Radial, Huber Suhner
Solar Cells	Azur, Spectrolab, solaero, Emcore Corporation, Mitsubishi Electric, Rocketlab, Emcore Corporation
Battey Cell	Saft, GS Yuasa Lithium Power, EaglePicher Technologies
Reaction Wheels	NSIL, Takeme2Space, Data pattern, Azista BST aerospace Honeywell, Blue Canyon Technologies, Airbus Defense & Space, Sinclair Interplanetary, Rocket Lab, Rockwell Collins
Sensors	NSIL, Ananth Technologies, Centum, Data pattern, Azista Industries, Takeme2space, SCL, AAC Clyde Space (USA), Berlin Space Technologies (Germany), Blue Canyon Technologies (USA), Argotec(Italy), D-Orbit (Italy), Antaris (USA), Honeybee Robotics (USA), Serenum Space (Czech

	republic), Sodern (France), Honeywell(USA), Airbus Defense & Space (France), Sinclair Interplanetary(CANADA), Rocket Lab(USA), Rockwell Collins(Germany), Emcore Corporation (USA),AAC Clyde Space (USA), Exail technologies (France), BAE Systems (USA), Microchip Technology / Microsemi (USA), Cobham / CAES (Cobham Advanced Electronic Solutions) (USA), Teledyne e2v (UK), CubeSat Pointing (Belgium)
Metallic and Non-Metallic Materials	Henkel, Huntsman Advanced Materials, Solvay, 3M, Dow, Shin-Etsu, Master Bond, Rogers Corporation, Taconic, 3DGS, Isola Group, DuPont, Saint-Gobain, Toray Advanced Composites, Boyd Corporation, Parker Chomerics, Laird Performance Materials, AZ Technology, Sheldahl, Arconic (Alcoa), Kaiser Aluminum, Constellium, TIMET, ATI (Allegheny Technologies), Materion, thyssenkrupp Materials, TW Metals, United Performance Metals, Mishra Dhatu Nigam (MIDHANI), Hindalco Industries, Hexcel Alcore, Plascore, Permali, Euro-Composites, PCC Forged Products, Aubert & Duval, LISI Aerospace, SPS Technologies, KAMAX Aerospace, Bollhoff, Agescan International, Honeycomb International, Sachiya Steel International, Arconic, Bay-Forge, FOMAS Group, Noble Aerospace, Harishrum Engineers, Garuda Aerospace, Ecoearth Solutions, Honeycomb India, The Gill Corporation, Corex Honeycomb, Argosy International, Micro Metals, Royal Industrial Suppliers, Paolo Astori, Ketan Engineering, Stanley Engineered Fastening

Details of Indian Supplier who can deliver the systems on Built to print specifications

Table 24:Satellite Subsystems Built to Print manufacturers

Build to print manufacturers	Centum Electronics
	Ananth technologies
	Astra Microwave
	Alpha Design technologies
	Azista Industries
	AIDIN Technologies
	Kaynes Technologies
	KOMOLINE
	Keltron

Details of common tests and their facilities are tabulated in following table

Table 25: Common test and facilities for Satellite Systems testing

Key Tests	**Facilities**	**Equipment**
Vibration Test	Vibration Facility	Vibration Shakers, accelerometers
Thermal Cycling Test	Thermal Cycling	Thermal Cycling Ovens
Acoustic Test	Acoustic Chamber	High-power Acoustic Speakers Accelerometers & Strain Gauges
Thermal Vacuum Test	Thermal Vacuum (TVAC) Chamber	Thermal shrouds, Thermocouples
EMIEMC	EMI/EMC Lab	EMI receivers, Spectrum Analyser, Antenna
Radiation Test	Radiation test facility	Particle accelerator/gamma radiation source

In addition to the above, it may be noted that mechanical and electrical Ground Support Equipment (GSE), as well as custom test and measurement equipment, are being developed and produced by primality domestic industries.

Chapter 4 :Gaps and Opportunities in satellite subsystems supply chain

From the previous sections it is evident that, India has built a strong foundation in satellite technology. Under the leadership of ISRO, successfully deploying communication (INSAT/GSAT), navigation (NavIC), Earth observation (Cartosat, RISAT) and Science Mission (Chandrayaan-III, Astrosat) satellites. The private sector's contribution so far has been primarily limited to structural assemblies, propulsion components, and fabrication services, supplied by established firms like HAL, BEL, L&T, and Godrej Aerospace.

The emergence of start-ups, along with reforms introduced through IN-SPACe, marks the beginning of private sector participation in end-to-end satellite manufacturing. However, India's satellite supply chain is still highly dependent on imports for critical components and materials like space-grade semiconductors, high-efficiency solar cells, optical and SAR payloads, high-power amplifiers, high-modulus Carbon Fiber Reinforced Polymers (CFRP), high-density Aluminum Honeycomb cores, specialized thermal interface materials (TIMs) and Optical Solar Reflectors (OSRs). Testing and qualification facilities remain centralized within ISRO, though private sector facilities are emerging and IN-SPACe is setting up a technical centre.

The Gap analysis and recommendation Interventions for Strengthening India's Satellite Manufacturing Eco system are tabulated in table 26.

Table 26: Gap Analysis and Recommended Interventions for Strengthening India's Satellite Manufacturing Ecosystem

Sl. No.	Identified Gap	Impact on Ecosystem	Recommended Efforts / Interventions
1	**Dependency on Imports for Critical Components**	Nearly 60% of satellite cost is attributable to EEE components and specialized materials, many of which are imported. Limited indigenous production exposes the sector to	• Launch a dedicated programme for indigenous development of space-grade EEE components, sensors, semiconductors, materials, and subsystems • Provide financial incentives, technology development

		supply-chain disruptions, geopolitical risks, foreign exchange fluctuations, and long lead times.	grants, and production-linked support. • Facilitate technology partnerships and joint ventures with global suppliers. • Aggregate demand across Government and private programmes to improve business viability.
2	**Testing and Certification Limitations**	Limited availability of internationally accredited commercial test facilities restricts qualification of products and reduces acceptance in global markets. Startups and MSMEs face high costs and long waiting periods for testing.	• Establish commercially operated common testing facilities for vibration, thermal vacuum, EMC/EMI, radiation, reliability, and environmental testing. • Develop accreditation mechanisms aligned with ECSS, NASA, and ESA standards. • Support certification and compliance programmes to enhance global acceptance of Indian products.
3	**Low Production Scale and Limited Domestic Demand**	Most industries operate on project-based manufacturing rather than serial production. Limited domestic demand visibility discourages investments in automation and production capacity expansion.	• Promote Government procurement of indigenous space products and services. • Create long-term demand forecasts and programme pipelines.

			• Encourage participation in satellite constellation projects and export markets. • Support industrial automation and scalable manufacturing practices.
4	**Long Procurement Lead Times**	Procurement of critical components often requires 12–16 months, resulting in project delays, increased costs, and reduced responsiveness to market opportunities.	• Develop domestic supply chains for critical components and materials. • Encourage strategic inventory management and stocking of long lead-time and ITAR/EAR-controlled components to mitigate supply disruptions. • Establish framework procurement agreements and vendor development programmes. • Implement digital supply-chain management platforms for improved visibility and planning. • Simplify approval process for Imports
5	**Skill and Infrastructure Gaps**	Shortage of trained manpower in satellite systems engineering, AIT operations, quality assurance, and mission operations. Limited testing and qualification infrastructure creates	• Launch national skilling programmes focused on space technologies and satellite manufacturing. • Introduce industry-oriented curricula, certification programmes, internships, and apprenticeships.

		bottlenecks and increases costs.	• Establish regional centres for AIT, cleanrooms, and testing infrastructure. • Promote industry-academia collaboration for workforce development.
6	**Limited R&D and Technology Transfer**	Private-sector R&D investment remains low. Access to advanced technologies, particularly Earth Observation payload technologies and critical subsystems, is limited, slowing innovation and commercialization.	• Strengthen technology transfer mechanisms between ISRO, industry, and academia. • Expand funding support for technology maturation and commercialization. • Promote joint R&D programmes and co-development initiatives. • Encourage private-sector investment in advanced technology development and product innovation.

The key opportunities for Indian Industries in satellite manufacturing are

a) Component Manufacturing

As briefed in the earlier section, where it was highlighted that there is a huge import dependency of EEE component and mechanical components. Prioritizing production of high-value components (such as semiconductors, advanced alloys, and batteries) can reduce import dependence. India's semiconductor policy and creation of specialized fabs (e.g., SCL, upcoming fab) can enable radiation-hardened chip development for space applications.

b) AIT Facilities by Private Sector

It is expected that huge number of satellite manufacturing requirements is expected to come to India, in this scenario requirements of creation of satellite testing infrastructure

is very much essentials. It also can be achieved through establishment of shared testing infrastructure (e.g., plug-and-play cleanrooms, thermal-vacuum and shock/vibration test beds) on PPP basis in industrial parks or near spaceports.

c) Local Manufacturing of Satellite systems

It is expected that globally more than twenty thousand satellites are going to be launched in coming decade. In order to meet the requirements of subsystems for these satellites there is potential opportunities for Indian industries that can supply the required subsystems.

d) Local Manufacturing of test systems

Satellite testing is a critical stage in the lifecycle of a space mission, ensuring the reliability, safety, and performance of all satellite subsystems before launch. A wide range of test systems are required for testing the individuals satellite subsystems and the overall satellite. These test systems are sometime custom made to the sophisticated tests that are being indigenously developed or imported. As India aims to expand satellite manufacturing across public and private sectors, there is a huge opportunity to industries to scale and produce these test systems locally.

e) Skill and Manpower opportunities

As India expands its space ambitions and opens the sector to private players, the satellite manufacturing ecosystem will demand a highly skilled, multi-disciplinary workforce. This includes not only scientists and engineers but also technicians, quality professionals, test operators, and project management professionals.

Considering the above aspects, the opportunities are tabulated in the following table.

Table 27: Summary of Supply Chain Opportunities

Systems/Component	**opportunities**
EEE Components and Materials	Yes
Mechanical Components and Materials	Partial
Optical payload Components and Materials	Yes

Electronic Fabrication	Yes
Mechanical Fabrication	Partial
Satellite Subsystems	Yes
Facilities	Partial
Test Equipment	Yes

Indian industries possess substantial export potential across the satellite manufacturing value chain. Table 28 presents a representative list of products and services with export opportunities based on existing industrial capabilities and market demand.

Table 28: Export Potential Available for Indian Industries for satellite Manufacturing

Category	**Exportable Products / Services**
Satellite Platforms	Small satellites, microsatellites, nanosatellites, CubeSat platforms and modules, EO/ISR satellites, turnkey Mission-as-a-Service solutions, satellite buses, satellite integration services
Power Systems	Electrical Power Systems (EPS), solar panels and arrays, solar array drive mechanisms (SADM), battery management electronics, power conditioning units, DC-DC converters, voltage regulators, power distribution units
Structures & Mechanical Systems	Composite and metallic structures, honeycomb panels, equipment mounting panels, solar panel substrates, deployable structures, precision machined aerospace components
ADCS Components	Reaction wheels, magnetic torquers, magnetometers, gyroscopes, sun sensors, inertial systems, attitude control electronics'
Thermal Control Systems	Ammonia-filled heat pipes, thermal straps, radiators, MLI blankets, thermal coatings, thermal hardware

	assemblies, Thermistors
Deployment & Release Mechanisms	Solar array deployment mechanisms, hold-down and release mechanisms (HDRM), antenna deployment systems, separation systems, release actuators
Electronics & Space-Grade Components	ADCs, DACs, processors, Memory devices, Sensors, LVDS drivers/receivers, ASICs, CCD processors, Radiation-tolerant electronics
Payloads & RF Systems	SAR subsystems, TR modules, Frequency generation modules, Local oscillators, Communication and navigation payload electronics, TTC transponders, AIS payloads, Hyperspectral cameras, Antennas
Ground Segment Infrastructure	Ground stations, TT&C systems, Mission control centres, Tracking antennas, Data processing systems, Satellite communication infrastructure
Engineering & Specialized Services	Satellite AIT services, Environmental testing, Qualification testing, Dry film lubrication, Tungsten disulphide coating, Reliability testing, Engineering design services
Wiring & Interconnect Products	Space-qualified wires and cables, Kapton-insulated wires, PTFE composite wires, ribbon cables, bonding braids, RF Connectors

The assessment indicates that India has export-ready capabilities across satellite platforms, power systems, structures, ADCS components, thermal systems, payload electronics, semiconductor devices, ground infrastructure, and specialized manufacturing services.

With stronger certification, testing infrastructure, and market access support, these capabilities can position India as a significant global supplier in the satellite manufacturing supply chain. The list is illustrative and not exhaustive, as several additional products, subsystems, components, and services may also be suitable for export depending on technological maturity, qualification status, and market requirements.

Chapter 5 : Conclusion

With its unique combination of cost-effectiveness, technical expertise, and proven reliability, India's private sector has the potential to transition from being primarily a satellite assembler to a leading exporter of satellite systems and subsystems. The rapidly growing global demand for low-cost small satellites, advanced communication payloads, and high-resolution imaging systems provides Indian industries with a historic opportunity to secure a significant share of the international market.

If the identified gaps are addressed through policy interventions, strategic investments, and international collaborations, India can, within the next decade, establish itself as a trusted global supplier of space-grade components, satellite platforms, and turnkey solutions. This transformation will not only strengthen India's position in the global space economy but also contribute to its broader vision of becoming a leading space power.

The path forward demands collaborative efforts between government, private industry, and academia, underpinned by innovation and long-term strategic planning. With sustained focus, Indian companies can confidently aim to become key contributors to the global satellite supply chain, exporting not just hardware but also knowledge, expertise, and technology to the world.

Appendix-1

Sr.No.	Company Name	Official Website
	Indian Suppliers	
1.	AIDIN Technologies	aidintech.com
2.	Alpha Design Technologies Pvt Ltd	adtl.co.in
3.	Anabond	anabond.com
4.	Ananth Technologies Limited	ananthtech.com
5.	Ankit Fasteners	ankitgroup.com
6.	Astra Microwave Products Limited	astramwp.com
7.	Astrome Technologies	astrome.co
8.	Avasarala Technologies Limited	avasarala.com
9.	Azista Industries	azistaindustries.com
10.	Bay-Forge	bayforge.com
11.	Bellatrix Aerospace	bellatrixaerospace.com
12.	Bharat Heavy Electricals Limited	bhel.com
13.	Centum Electronics	centumelectronics.com
14.	Data Patterns (India) Pvt Ltd	datapatternsindia.com
15.	Dhruva Space	dhruvaspace.com
16.	Ecoearth Solutions	ecoearthsolutions.com
17.	EON Space Labs	eonspacelabs.com
18.	GAETEC	gaetec.org
19.	GalaxEye Space Space Space	GalaxEye Space Space.space
20.	Garuda Aerospace	garudaaerospace.com
21.	Godrej Aerospace	godrej.com
22.	Harishrum Engineers	harishrum.com
23.	Hical Technologies	hical.com
24.	Hindalco Industries	hindalco.com
25.	Hindustan Aeronautics Limited (HAL)	hal-india.co.in
26.	Honeycomb India	honeycombindia.com
27.	Honeycomb International	honeycombint.com
28.	Kaleida	kaleideo.co
29.	Kaynes Technology	kaynestechnology.co.in

30.	Keltron	keltron.org
31.	Ketan Engineering	ketan-engg.com
32.	Komoline Aerospace	indiamart.com/komoline-aerospace
33.	Larsen & Toubro (L&T)	larsentoubro.com
34.	Manastu Space	manastuspace.com
35.	Micro Metals	micrometals.in
36.	Mishra Dhatu Nigam (MIDHANI)	midhani-india.in
37.	New Space India Limited (NSIL)	nsilindia.co.in
38.	Newtech Aerospace	newtechaerospace.com
39.	Noble Aerospace	nobleaerospace.com
40.	Paras Defence & Space Technologies	parasdefence.com
41.	Piersight Space	piersight.space
42.	Pixxel Space	pixxel.space
43.	Pushpak Products	pushpak.com
44.	Royal Industrial Suppliers	royalfasteners.com
45.	Sachiya Steel International	sachiyasteel.com
46.	Sanghvi Aerospace	sanghviaerospace.com
47.	Scope Metal India	scope-metal.in
48.	Semi-Conductor Laboratory (SCL)	scl.gov.in
49.	Sisir Radar	sisirradar.com
	System Controls	systemcontrolstspl.com
50.	TakeMe2Space	tm2.space
51.	Tata Advanced Systems Limited (TASL)	tataadvancedsystems.com
52.	Thakerson	tcaepl.com
53.	Vita Technology	vitatechindia.com
54.	XDLINX Labs	xdlinx.com
Foreign Suppliers		
1.	ISISPACE	isispace.nl
2.	3M	3m.com
3.	AAC Clyde Space	aac-clyde.space

4.	AccuBeat	accubeat.com
5.	Advanced Cooling Technologies	1-act.com
6.	Aerojet Rocketdyne (L3Harris)	l3harris.com
7.	Argotec	argotecgroup.com/
8.	Agescan International	agescaninternational.com
9.	Airbus Defence and Space	airbus.com
10.	Akash Systems	akashsystems.com
11.	All Metal Services	allmetal.co.uk/markets/space-metals/
12.	Amphenol	amphenol.com
13.	Antaris	antaris.space
14.	Arconic (Alcoa)	arconic.com
15.	Aresys	aresys.it
16.	Argosy International	argosyinternational.com
17.	Arquimea	arquimea.com
18.	ATI (Allegheny Technologies)	atimaterials.com
19.	Aubert & Duval	aubertduval.com
20.	Augustus Aerospace	augustusaerospace.com
21.	AZ Technology	aztechnology.com
22.	Azur Space	azurspace.com
23.	BAE Systems	baesystems.com
24.	Barber-Nichols	barber-nichols.com
25.	BEI Sensors (Sensata)	sensata.com
26.	Benchmark Space Systems	benchmarkspacesystems.com
27.	Berlin Space Technologies	berlin-space-tech.com
28.	Beyond Gravity	beyondgravity.com
29.	Blue Canyon Technologies	bluecanyontech.com
30.	Bollhoff	boellhoff.com
31.	Boyd Corporation	boydcorp.com
32.	Busek Co.	busek.com
33.	C3S Electronics Development	c3s.hu
34.	Carlisle Interconnect Technologies	carlisleit.com

35.	CAVU Aerospace	cavuaerospace.com
36.	CesiumAstro	cesiumastro.com
37.	Cobham / CAES	caes.com
38.	Collins Aerospace	collinsaerospace.com
39.	Comat	comat-ag.com
40.	Constellium	constellium.com
41.	Corex Honeycomb	corex-honeycomb.com
42.	Cubecom	cubecom.co.za
43.	Dawn Aerospace	dawnaerospace.com
44.	D-Orbit	dorbit.space
45.	Dow	dow.com
46.	Dragonfly Aerospace	dragonflyaerospace.com
47.	DSI Aerospace Technologies	dsi-as.de
48.	Dunmore	dunmore.com
49.	DuPont	dupont.com
50.	EaglePicher Technologies	eaglepicher.com
51.	Elbit Systems	elbitsystems.com
52.	Emcore Corporation	emcore.com
53.	EnduroSat	endurosat.com
54.	EnerSys Advanced Systems	enersys.com
55.	Ensign-Bickford (EBAD)	ebad.com
56.	Euro-Composites	euro-composites.com
57.	Exail Technologies	exail.com
58.	Exascend	exascend.com
59.	Excelitas Technologies	excelitas.com
60.	Faulhaber	faulhaber.com
61.	FOMAS Group	fomasgroup.com
62.	Fry Steel	frysteel.com/
63.	German Orbital Systems	orbitalsystems.de
64.	GomSpace	gomspace.com
65.	GS Yuasa	gs-yuasa.com
66.	Harmonic Drive	harmonicdrive.net

67.	Henkel	henkel.com
68.	Hexcel Alcore	hexcel.com
69.	Honeybee Robotics	honeybeerobotics.com
70.	Honeywell Aerospace	aerospace.honeywell.com
71.	HPS GmbH	hps-gmbh.com
72.	Huber+Suhner	hubersuhner.com
73.	Huntsman Advanced Materials	huntsman.com
74.	ICEYE	iceye.com
75.	IHI Aerospace	ihi.co.jp
76.	INASCO HELLAS	inasco.com
77.	Innoflight	innoflight.com
78.	INVENT GmbH	invent-gmbh.de
79.	IQ spacecom	iq-spacecom.com
80.	Isola Group	isolagroup.com
81.	Isolation Dynamics Corp	isolationdynamics.com
82.	Kaiser Aluminum	kaiseraluminum.com
83.	KAMAX Aerospace	kamax.com
84.	Kongsberg NanoAvionics	nanoavionics.com
85.	L3Harris	l3harris.com
86.	Laird Performance Materials	laird.com
87.	Leonardo	leonardo.com
88.	LISI Aerospace	lisi-aerospace.com
89.	LKD Aerospace	lkdaerospace.com
90.	Lockheed Martin	lockheedmartin.com
91.	Lucix Corporation	lucix.com
92.	LumiaWay BV	hlumiaway.com/aerospace-defense-grade-raw-materials/
93.	Master Bond	h.masterbond.com
94.	Materion	materion.com
95.	Maxon Group	maxongroup.com
96.	MDA	mda.space
97.	Mercury Systems	mrcy.com

98.	Metalco Extrusions Global LLP	metalcoglobal.com/space-metals/
99.	MetaSensing	metasensing.com
100.	Microchip Technology	microchip.com
101.	Mitsubishi Electric	mitsubishielectric.com
102.	Moog Inc.	moog.com
103.	MT Aerospace	mt-aerospace.de
104.	Northrop Grumman	northropgrumman.com
105.	Novotechnik	novotechnik.de
106.	Officina Stellare	officinastellare.com
107.	OHB SE	ohb.de
108.	Panasonic	panasonic.com
109.	Paolo Astori	paoloastori.com
110.	Paragon Space Development Corp	paragonsdc.com
111.	Parker Chomerics	parker.com
112.	PCC Forged Products	pccforgedproducts.com
113.	Permali	permali.co.uk
114.	Plascore	plascore.com
115.	Qorvo	qorvo.com
116.	Radiall	radiall.com
117.	RAFAEL	rafael.co.il
118.	Rocket Lab	rocketlabusa.com
119.	Rogers Corporation	rogerscorp.com
120.	Rosenberger	rosenberger.com
121.	Safran	safran-group.com
122.	Saft Groupe S.A.	saftbatteries.com
123.	Saint-Gobain	saint-gobain.com
124.	Samputensili	samputensili.com
125.	Satlab	satlab.com
126.	Satlantis	satlantis.com
127.	Scanway	scanway.pl
128.	Serenum Space	serenum.cz
129.	Sheldahl	sheldahl.com

130.	Shin-Etsu Chemical	shinetsu.co.jp
131.	Sierra Nevada Corporation	sncorp.com
132.	Simera Sense	simera-sense.com
133.	Sinclair Interplanetary	rocketlabusa.com
134.	Smiths Advanced Metals	smithsadvanced.com
135.	Sodern	sodern.com
136.	Solvay	solvay.com
137.	Space Structures	spacestructures.de
138.	Spectrolab	spectrolab.com
139.	SPS Technologies	spstech.com
140.	Stanley Engineered Fastening	stanleyengineeredfastening.com
141.	Synspective	synspective.com
142.	TE Connectivity	te.com
143.	Teledyne e2v	teledyne-e2v.com
144.	Tethers Unlimited	tethers.com
145.	TGB Group Technologies	tgbgroup.es
146.	Thales Alenia Space	thalesaleniaspace.com
147.	The Gill Corporation	thegillcorp.com
148.	Thermal Management Technologies	tmt-inc.com
149.	ThrustMe	thrustme.fr
150.	thyssenkrupp Materials (Aerospace division)	thyssenkrupp-materials-na.com/industries/aerospace-industry/
151.	TIMET	timet.com
152.	Titanium Sponge Plant [KMML]	kmml.com/
153.	Toray Advanced Composites	toraytac.com
154.	TW Metals	twmetals.com/
155.	United Performance Metals	upmet.com/
156.	VACCO Industries	vacco.com
157.	Variohm EuroSensor	variohm.com
158.	VECTRONIC Aerospace	vectronic-aerospace.com
159.	VMC Group	thevmcgroup.com

160.	Vulcan Wireless	vulcanwireless.com
161.	Wittenstein	wittenstein.de
162.	Zoppas Industries	zoppas.com

Appendix-2

Details of the Satellites launched by Indian NGEs

NGEs	Satellites
Pixxel	D2, Shakuntala, Anand, Firefly 1, Firefly 2, Firefly 3, Firefly 4, Firefly 5, Firefly 6
SpaceKidz	AzaadiSAT 1, AzaadiSAT 2, SR-0 DEMOSAT
Dhruva Space	Thybolt 1, Thybolt 2, LEAP-1, CGUSAT, DSUSAT, LACHIT, Thybolt-3, LEAP-2
Digantara	Pushan-Alpha, SCOT satellite
Azista	AFR-1
TASL	TSAT-1A
XDLINX Space Labs	Janus, Elevation-1
HEX-20	Nila, Kinetic Optical Yaw Observer (KOYO)
Grahaa Space	Solaras S2, Solaras
Bellatrix	Harbinger
TakeMe2Space	MOI-1, MOI-1A
GalaxEye Space	Mission Drishti
Laxman Gyanpith	Sanskarsat
OrbitAid	AyulSat
Skyroot	Scope

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