India's First Manned Mission to Low Earth Orbit

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***Abstract*— India's adventure closer to human spaceflight culminated within the improvement of Gaganyaan, the country's maiden manned space assignment. Initiated by way of the Indian Space Research Organisation (ISRO), Gaganyaan represents a massive milestone in India's space exploration endeavors. This paper chronicles the inception, development, and goals of the Gaganyaan application, tracing its evolution from its conceptualization in 2007 to its contemporary popularity as a flagship venture of ISRO. Key milestones inside the Gaganyaan program encompass the improvement of spacecraft technology, astronaut choice and training, and collaboration with global partners such as Centre National D'Etudes Spatiales (CNES). The paper highlights the objectives of the program, together with clinical studies, technology validation, and the established order of India's prowess in manned spaceflight. Furthermore, the paper delves into the infrastructure and propulsion systems supporting the Gaganyaan project, along with the GSLV Mk III launch automobile and the group module's atmospheric re-access capabilities. It discusses the role of Vyommitra, a humanoid robotic, in assisting astronauts at some stage in space missions, and outlines future for an Indian Space Station.**

Keywords— Gaganyaan, ISRO, manned space mission, astronaut training, GSLV Mk III, Vyommitra, atmospheric re-entry, Bharatiya Antariksha Station, space exploration.

I. INTRODUCTION

In August 2007, G. Madhavan Nair, the Chairman of the Indian Space Research Organisation (ISRO), announced that the agency was "seriously considering" the creation of a Human Spaceflight Program (HSP). This initiative, named GAGANYAAN (Sky Craft), aimed to serve as the foundation for the HSP. Nair indicated that within a year, ISRO would report on its progress in developing new space capsule technologies. Shortly after, the Indian government allocated 95 crore rupees (US $11.9 million) for pre-project initiatives from 2007 to 2008 to develop an autonomous orbital vehicle to carry a three-member crew into Low Earth Orbit (LEO) [1].

The Planning Commission estimated that a budget of 5,000 crore rupees (US $626.2 million) would be required for the initial work on the crewed spaceflight from 2007 to 2012. In February 2009, the Government of India authorized the human spaceflight program but did not fully fund it, which hindered the program's creation. The program was formally announced by the Prime Minister on August 15, 2018, with funding of approximately 10,000 crore rupees. The testing phase was expected to begin in December 2020, with the first crewed mission planned for December 2021. However, the COVID-19 pandemic in India caused delays, and the schedule for the GAGANYAAN launch was revised [2].

The first uncrewed test flight was scheduled for mid-2023, with a second uncrewed flight planned for Q4 2023. A crewed spaceflight is expected to follow in 2024. By March 16, 2021, ISRO had completed the initial review process for essential components such as food, potable water, emergency first aid kits, and health monitoring systems for the GAGANYAAN mission [3].

ISRO is collaborating with the Centre National D'Etudes Spatiales (CNES) on space medicine for the GAGANYAAN project. This partnership includes a joint working group on the Human Spaceflight Program, underscoring the international cooperation and technological advancements necessary for the successful execution of India's ambitious human spaceflight endeavors [4].

II. INFRASTRUCTURE

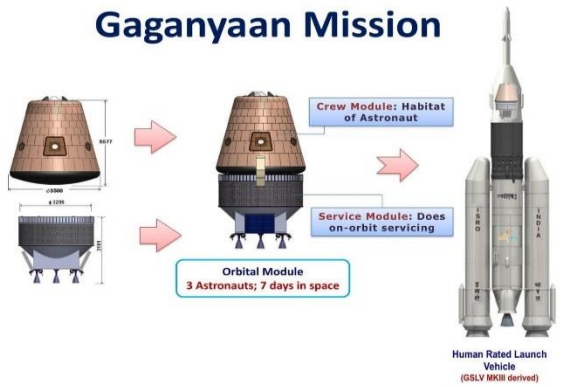

Figure 1. Anatomy of Gaganyaan. (IASbaba, 2022)

In November 2019, ISRO released tenders to augment the second launch pad for the GAGANYAAN project, along with proposing a third launch pad in Sriharikota for future launch vehicles and crewed missions. To validate the human rating of the GSLV-MK III, ISRO is planning to build and launch two missions, while upgrading existing launch facilities to support the Indian Human Spaceflight campaign. The agency successfully conducted a pad abort test to validate its launch escape system, the first in a series of tests to qualify crew escape system technology. Parachute enlargement and new architectural work are ongoing, with parachute tests scheduled before the end of 2019 and multiple in-flight abort tests planned for mid-2020 using a liquid-fueled test vehicle. A new test vehicle was designed in early 2020 to validate the crew escape system, featuring propulsion on top of the module to safely distance the crew module in an emergency.

In 2009, a full-scale mock-up of the crew capsule was delivered to the Satish Dhawan Space Centre for astronaut training, following a memorandum of understanding between ISRO and the Indian Air Force's Institute of Aerospace Medicine (IAM) to research the psychological and physiological needs of the crew. The Indian Human Spaceflight Program was officially announced by Prime Minister Narendra Modi on 15 August 2018. Subsequently, in January 2019, ISRO Chairman K. Sivan announced the creation of India's Human Space Flight Centre in Bangalore, funded with Rs 1,000 crore (US $125.2 million) to train astronauts in various operations. An agreement between ISRO's Human Space Flight Centre and Glavcosmos, a subsidiary of the Russian state corporation Roscosmos, was signed on 1 July 2019 for astronaut selection, support, medical examination, and training. The astronaut selection process began in Bengaluru, and by November 2019, the Indian Air Force had selected 12 potential astronauts.

By December 2019, the selection process concluded, and four candidates began their 12-month-long training at the Gagarin Research & Test Cosmonaut Training Centre (GCTC) on 10 February 2020, including winter survival training in February 2020. ISRO has proposed a Rs 2,700 crore (US $340 million) plan to establish an astronaut training center at Challakere in Chitradurga district. The Defense Food Research Laboratory (DFRL) aims to launch its RTE space food by March 2021, with the initial batch for Gaganyaan carrying sufficient food stuffs for seven days. Unlike other nations, India will not send animals into space as part of its human spaceflight missions.

A. GSLV Mk-III

The Geosynchronous Satellite Launch Vehicle Mark III (GSLV Mk III), also known as the Launch Vehicle Mark 3 (LVM3), is a three-stage medium-lift launch vehicle developed by the Indian Space Research Organisation (ISRO). Primarily designed to launch communication satellites into geostationary orbit, it is also designated as the launch vehicle for crewed missions under the Indian Human Spaceflight Program and for dedicated science missions like Chandrayaan-2. The GSLV Mk III has a higher payload capacity than the GSLV Mk II and has successfully launched CARE, India's space capsule recovery experiment module, as well as Chandrayaan-2, India's second lunar mission. It will also be used to carry GAGANYAAN, the first crewed mission under the Indian Human Spaceflight Program.

B. Orbital Module

Crew Module

The GAGANYAAN crew module is a fully autonomous 5.3-ton spacecraft designed to carry a three-member crew to orbit and safely return to Earth after a mission of up to seven days. It features life support, environmental control systems, and a Crew Escape System (CES) that can be activated during the first or second rocket stage burn for emergency mission aborts. The module is equipped with two parachutes for redundancy, reducing the descent speed from over 216 m/s to under 11 m/s for a safe

splashdown. The primary entry is through a side hatch secured by explosive bolts, with the nose reserved for a docking mechanism.

Service Module

The 2.9-ton service module, powered by liquid propellant engines, is mated to the crew module, and together they constitute the 8.2-ton orbital module. The Service Module Propulsion System (SMPS) will aid in the orbit-raising maneuver of GAGANYAAN to reach 400 km in Low Earth Orbit (LEO) and remain connected during the deorbit burn until atmospheric re-entry. Utilizing a unified bipropellant system of MON-3 and Monomethyl hydrazine as oxidizer and fuel, it includes five main engines, derived from ISRO's liquid apogee motor with 440 N thrust, and sixteen 100 N reaction control system (RCS) thrusters. Upon re-entry, the service module will detach from the spacecraft.

C. Propulsion System

ISRO's Vikas engines are integral to several launch vehicles, including the PSLV's second stage, GSLV Mark I and II boosters and second stage, and GSLV Mark III's core stage. A significant achievement came on July 14, 2021, with ISRO conducting the third long-duration hot test of the Vikas engine for the GSLV Mark III's core L110 liquid stage. This successful 240-second test validated all necessary performance parameters, crucial for qualifying the engine for the demanding requirements of the Gaganyaan mission.

In addition to engine development, ISRO has been advancing critical systems for human spaceflight. On August 28, 2021, ISRO achieved another milestone by testing the System Demonstration Model (SDM) of the Service Module Propulsion System (SMPS). The SDM, firing for 450 seconds at the ISRO Propulsion Complex, utilized five main engines and eight RCS thrusters, matching pre-test predictions. This progress is essential for obtaining human-rating certification, ensuring the reliability and safety of propulsion systems in crewed missions. Individual tests of the 440 N thrust engines are planned to further validate their performance under various conditions, vital for the success of future manned space missions.

C. Vyommitra

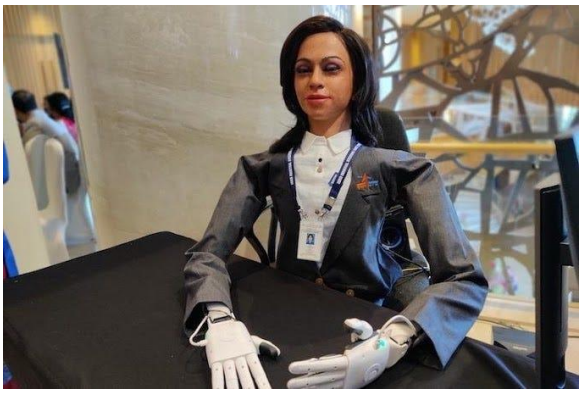

Figure 2. Vyommitra Humanoid Robot. (Ravi, 2023)

On January 22, 2020, ISRO unveiled Vyommitra, a humanoid robot designed to accompany astronauts on missions. Unlike other nations that use animals for experimental space missions, ISRO opts for humanoid robots like Vyommitra to study the effects of weightlessness and radiation on the human body during extended space missions.

Vyommitra, equipped to perform tasks and communicate in Hindi and English, lacks legs but simulates human functions from the waist up. It monitors module conditions, conducts microgravity experiments, detects environmental changes, and autonomously responds to ensure astronaut safety and mission success.

III. CREW MODULE ATMOSPHERIC RE-ENTRY TEST

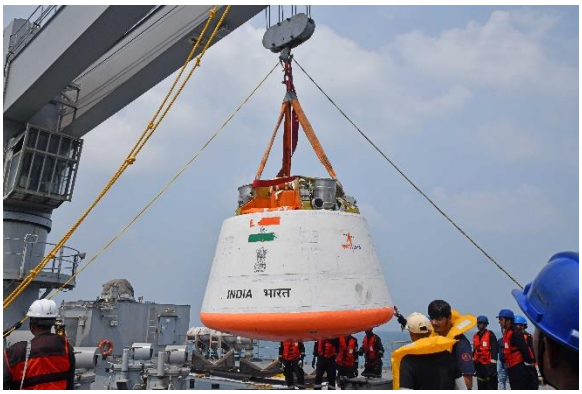

Figure 3. Crew module retrieval after splash down. (Gaganyaan TV-D1 Gallery, n.d.)

On 13th February 2014, Hindustan Aeronautics Limited handed over the first boilerplate prototype of the Crew Module structural assembly to ISRO for the Crew Module Atmospheric Re-entry Experiment (CARE). ISRO's Vikram Sarabhai Space Centre

equipped the Crew Module with life support, navigation, guidance, and control systems. An uncrewed test launch of the vehicle aboard the GSLV Mark III X1 took place on 18th December 2014. During this experimental sub-orbital flight, the crew module separated from the rocket at an altitude of 126 km. Onboard motors controlled and reduced the module's speed until it reached an altitude of 80 km, where thrusters were shut off, allowing atmospheric drag to further slow the capsule.

The module's heat shield was designed to withstand temperatures exceeding 1,600 °C. Parachutes deployed at 15 km to slow the module for a splashdown in the Bay of Bengal near the Andaman and Nicobar Islands. This flight tested the orbital injection, separation, and re-entry procedures and systems of the Crew Capsule. Additionally, the flight evaluated the capsule separation, heat shields, aerobraking systems, parachute deployment, retro-firing, splashdown, flotation systems, and recovery procedures from the Bay of Bengal. In-flight launch, abort, and parachute tests were expected to be conducted by the end of 2019.

IV. BHARATIYA ANTARIKSHA STATION

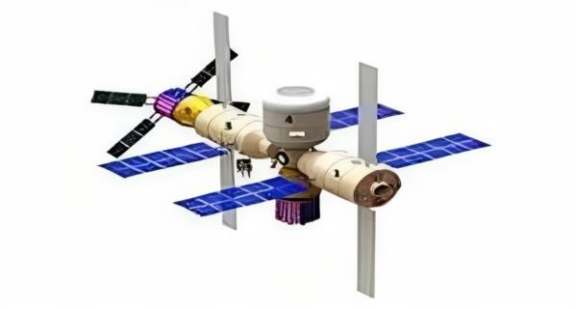

Figure 4. Bharatiya Antariksha Station. (*Bharatiya Antariksha Station — Post Images*, n.d.)

India plans to deploy a space station as a follow-up program of the Gaganyaan mission. On 13th June 2019, ISRO Chief K. Sivan announced the plan, saying that India's space station will be deployed in 5–7 years after completion of Gaganyaan project. He also said that India will not join the International Space Station program. The space station would be capable of harbouring a crew for 15–20 days at a time. It is expected to be placed in a Low Earth Orbit of 400 km altitude and be capable of harbouring three humans. Final approval is expected to be given to the program by the Indian government only after the completion of the Gaganyaan mission.

The Bharatiya Antariksha Station will have a basic design including a crew command module, a habitat module, a propulsion module and docking ports. The entire capsule is estimated to have a mass of around 25 tonnes, which will be increased in the future depending on the expansion of the station. The establishment of the Bharatiya Antariksha Station is poised to enhance India's presence in space research and exploration significantly as it will provide a unique platform for conducting scientific experiments in microgravity and foster advancements in space technology, potentially leading to economic activities based on lunar resources 2047.

According to ISRO Chairman S Somanath, the Indian Space Station is in the final stages of design as of February 2024. After the first part of the project is launched successfully in 2028, humans may be sent to the station. The electronics for the station will be produced at the U R Rao Satellite Centre (URSC) in Bengaluru, while Vikram Sarabhai Space Centre (VSSC) will help in hardware development.

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