Semi Cryogenic Technology for Gaganyaan: RSTV – In Depth

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Context:

India's strategic partner Russia has offered its **Semi Cryogenic engine technology** and critical components for the Gaganyaan project.

Gaganyaan:

- In 2018, India's **first manned space mission** was announced by Prime Minister Narendra Modi in his Independence Day speech.
- **Gaganyaan** will be the Indian crewed orbital spacecraft intended to be the basis of Indian Human Space Flight Program.
- With Gaganyaan, India will become only the **4th country after Russia, the USA and China** to send humans to space.
- It will be ISRO's next big project after the anticipated soft landing of **Chandrayaan 2** on the lunar
- The target is to launch it before the **75 year celebration** of India's independence.
- Before the manned mission scheduled for **December 2021**, two unmanned tests will be carried out in December 2020 and July 2021.
- ISRO's indigenous mission will be assisted by few other countries in selecting and training astronauts.
- According to ISRO, a budget of **Rs 10,000 Cr.** has been set aside for putting the infrastructure in place.
- It is described as a national mission than an ISRO mission.

The Spacecraft:

- The spacecraft will take 3 Indian astronauts, who will be known as 'vyomnauts' (in Sanskrit 'vyom' means space.
- It will circle the earth for 7 days from a distance of 300-400 km.
- It will be launched by India's biggest rocket **GSLV Mk 3 from Sriharikotta**.
- The **7 ton spacecraft** will orbit the earth at an **altitude of 400km for up to 7 days**.
- ISRO has developed most of the critical technology needed for the mission.
- Its **service module** will be powered by **two liquid propellant engines**.
- It will have **life support and environmental control systems**.
- It will be smaller than the current Russian and Chinese ones or **NASA's Apollo** or the planned **Orion**
- But it will be slightly larger than the U.S **Gemini**
- ISRO Telemetry Tracking and Command Centre in Peenya will monitor it round the clock.

Crew Module:

- **The crew module** is a **twin walled sealed structure** that recreates earth like conditions.
- It will be equipped with **Emergency Mission Abort and Emergency Escape System**.
- The **crew escape system** is an emergency system to help the crew pull away from the launch vehicle when the mission has to be aborted. It can be done at the 1st and 2nd stage of the rocket.
- Crew escape system ensures that the crew module gets advance warning if anything goes wrong with the rocket.

- It pulls the crew module away to a safe distance and can be landed either on sea or on land with parachutes.

Development of the Project:

- Preliminary studies and technological development started **in 2006** itself under the generic name **'orbital vehicle'**.
- The plan was to design a simple capsule similar to the **Mercury class spacecraft** with an endurance of about 1 week in space.
- It was initially designed to carry 2 astronauts and to land on water upon re-entry.
- The design was finalised in
- A full-fledged training facility will be set up at Bangalore for training the astronauts.

Russian Support for Gaganyaan:

- Russia has offered **Semi Cryogenic engine technology** and **critical components** for the human space capsule. Agreements will be signed soon in this regards.
- ISRO Chairman K Sivan revealed that the technology will be transferred under the '**Make in India**' programme so that the engines can be made in India.
- The two countries have already signed a deal for the training program of astronauts.
- Based on an agreement between ISRO and **Glavcosmos**, a subsidiary of Russia's state run space corporation **Roscosmos**, four Indians will be trained at the **Yuri Gagarin Cosmonauts Centre.**
- The Russian agency will select, test and qualify the trainees in collaboration with the state run **Institute of Medical and Biological Problems**, Russia.
- India is also negotiating with Russia for the supply of **space suits, crew seats and windows**.
- Recently, **National Security Advisor** Ajit Doval and Roscosmos Director General discussed matters related to **Rocket Aerodynamic Test, Piloted Vehicle and Crew Rescue System** for the Indian mission.
- Upcoming top level meetings at the **Eastern Economic Forum in Vladivostok**, Russia, may include further discussions on piloted flight, satellite navigation and engine technology.

Russia's Role in India's Space Program:

- Russia is one of the **world leader in space technology** and one among the few countries, such as France, Germany, Israel, U.S.A etc. who have assisted substantially in India's space program.
- Cooperation in space program remains **one of the main pillars in the strategic partnership** between India and Russia.
- It has emerged as a key area in the high technology sector.
- **ISRO and Soviet Academy of Sciences** signed a contract to launch India's first national satellite, **Aryabhata-1 in 1975.**
- USSR provided satellite launch facility and consultation on design and construction while India undertook the production of the satellite.
- In 1979 and 1981, the partnership continued for the launch of **Bhaskara 1 and 2**
- **Rakesh Sharma**, the first Indian to travel to space was carried by the Russian space vehicle **Soyuz T-11**.
- In 1988 and 1991, **Soviet Vostok rocket** launched India's imaging satellites in spite of the fact that India had developed its own satellite launch vehicle in 1987.
- By the early 1990s, India became self-reliant in delivering its satellites into orbits through the **Polar Satellite Launch Vehicle** (PSLV).
- In 1992, India signed an agreement with Russia for transfer of engine technology for the launching of **geostationary satellites**.
- But, the **US** had concerns over triggering an **arms race** in the region and violation of **Missile Technology Control Regime (MTCR).**

- In 1994, the deal was renegotiated but with **no transfer of technology**.
- Instead 7 Russian made engines were transferred from Russia to India to be used in **GSLV Mk 1 launcher.**
- India's entire cryogenic program got delayed because of the issue.

Post USSR Partnership:

- After the dissolution of the USSR, **Russia continued** the USSR policy of assisting India in the space domain.
- In 2004, New Delhi and Moscow signed 2 agreements:
- The **Inter-Governmental Umbrella Agreement for Cooperation In Outer Space For Peaceful Purposes** and
- **The Inter Space Agency Agreement for GLONASS** (Global Navigation Satellite System, the Russian version of GPS).
- But, both the agreements couldn't be materialised.
- In 2011, agreement was reached to grant **Inter Military Preferential Access** for positioning data under GLONASS.
- The two countries also negotiated cooperative measures under GLONASS and **Chandrayaan 2**

Russian Cryogenic Technology:

- Russia had transferred **Cryogenic technology** also to India.
- Original Russian technology was not much useful for ISRO but, India **reverse engineered** and improved it.
- Patterned on Russian engines, India successfully tested its cryogenic technology in GSLV Mk 2 in 2014.
- In **2015**, ISRO and Roscosmos signed a MoU for expanding cooperation on space exploration and use of outer space for peaceful purposes.

Cooperation in Recent Years:

- In the **2016 BRICS summit** at Goa, India and Russia reaffirmed the commitment to pursue the immense potential for cooperation in outer space to advance **socially useful applications and scientific knowledge.**
- In his recent visit to India, Russian President Vladimir Putin signed an agreement on joint activities in the **human space flight program**.
- The importance of mutually beneficial cooperation in outer space and enhancing the cooperation on exploration and use of outer space for peaceful purposes were also emphasised.
- Dialogues are under way for the setting up of ground stations in each other's land to enhance the accuracy of **satellite navigation systems**.
- Russia will set up one **at Bengaluru** and India's **NAVIC station** will be set up at **Moscow**.

Cryogenic Technology:

- Rocket engines need **enormous thrust** to escape Earth's gravitational pull.
- **Hydrogen and Oxygen** that produce a good thrust are found in **gaseous form** on earth.
- However, sending huge tanks of gas in a rocket is an impossible task.
- In **Cryogenic engines**, fuel, oxidiser or both are stored as **liquefied gases at very low temperatures (-253^{O}C)** to maintain the liquid state.
- These are usually prepared for the **upper stages or the last stage**.
- Cryogenic fuels such as liquid hydrogen are used because ordinary fuel can't be used in space due to an **absence of environment that support combustion**.

• *Parameters*	*Cryogenic Technology*	*Semi Cryogenic Technology*
Fuel used	Liquid **hydrogen**	Refined **kerosene**
Oxidiser used	Liquid **oxygen**	Liquid **oxygen**
Temperature required by Fuel	Very low **(-253^{O}C)**	**Normal**
Heaviness of Fuel	Comparatively heavier	**Lighter**
Space required	Comparatively more	**Lesser**
Advantages	a) Easier to **transport**. b) More **density** and hence **more thrust** can be produced in **smaller burning time**. c) More thrust makes it possible to **carry more weight** and take that weight into a **higher orbit.**	a) Can carry **more weight to a higher altitude**. b) Despite being a lighter fuel kerosene combined with oxygen gives a **higher thrust**. c) **More propellant** can be carried in the fuel compartment as Kerosene **needs lesser space** d) **Payload can be increased** since the weight of fuel will come down by around **500kg**. e) Engine is **more powerful, environmentally friendly and cost effective**. f) Under **deep throttle**, we can go from **27% to 105%** and work with **much higher operability.**
Status in India	Used in **Vikas engine** of **GSLV** (With 3 stages; solid, liquid and cryogenic respectively).	**SCE 200** is being developed.

Semi Cryogenic Engine 200 (SCE 200):

- Semi Cryogenic technology is very important for India's space program to move to the next level. With Russia's assistance India might be able to achieve it faster.
- ISRO plans to commission a **Semi Cryogenic Engine 200 (SCE 200).**
- **In 2009**, the project was approved at a sanctioned cost of **1798 Cr**.
- It is being developed by the **Liquid Propulsion Systems Centre**.
- It uses **liquid oxygen and RP1 kerosene** in an **oxidiser rich staged combustion cycle**.
- 200 denotes the **power (200 tons).**
- However, the throttle can go from **60% to 105% only**.
- The initial target of 2014 was postponed and now ISRO is **planning to flight test** the engine in
- Its purpose is to power the **Unified Launch Vehicle (ULV), the Reusable Launch Vehicle (RLV) and the future GSLV Mk 3 rockets**.

Challenges in a Manned Mission:

- Satellites launched by ISRO are meant to remain in space even after their life is over. Even the **Chandrayaan and Mangalyaan are not meant to return to earth.**
- But, a manned spacecraft need to return with the astronauts inside it.
- For a spacecraft to re-enter atmosphere, it needs to withstand **very high temperature** created **by friction**, and hence special parameters are required.
- Astronauts need **special physical and mental training.**
- **Re-entry** needs to be carried out at a **very precise speed and angle.**

- **Recovery** of the module after it lands in land or water need to be done promptly.

Crew Module Atmospheric Re-entry Experiment:

- In **2014,** ISRO successfully tested an experimental crew module that came back to earth from an **altitude of 126km in space**.
- It re-entered the atmosphere at a **height of 80km and landed in the sea** near the Andaman and Nicobar islands.

Challenges for astronauts:

- The astronauts will have to adapt to the change in **gravitational field.**
- The change in gravity affects **hand-eye and head-eye coordination**.
- Bones may lose minerals adding to the risk of **osteoporosis** related fractures.
- **Lack of exercise and improper diet** make them lose muscle strength and cause develop vision problems.
- Travelling in the rocket involves change of **0 to 29000 km/Hr. speed in less than 30 minutes**.
- Despite the many inbuilt safety features, **rockets may disintegrate** in the launch phase itself.
- The systems **can't be tested in actual operating environments**.
- Once they are in space, astronauts will receive over **10 times more radiation** than what people are subjected to on earth.
- It can cause **cancer, nervous system damage** and trigger nausea, vomiting, and anorexia and fatigue.
- Without pressure, human **blood heats up**.
- Despite the training, **behavioural issues** may crop up due to isolation leading to **depression, fatigue, sleep disorders and psychiatric disorders**.
- Space vehicles needs an atmosphere like earth and adequate **supply of oxygen** along with **comfortable temperature and humidity levels.**

Conclusion:

The assistance from Russia will help India in realising faster, the dream of taking humans to space.