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Gaganyaan Parachutes

Mains: *GS III – Science and Technology*

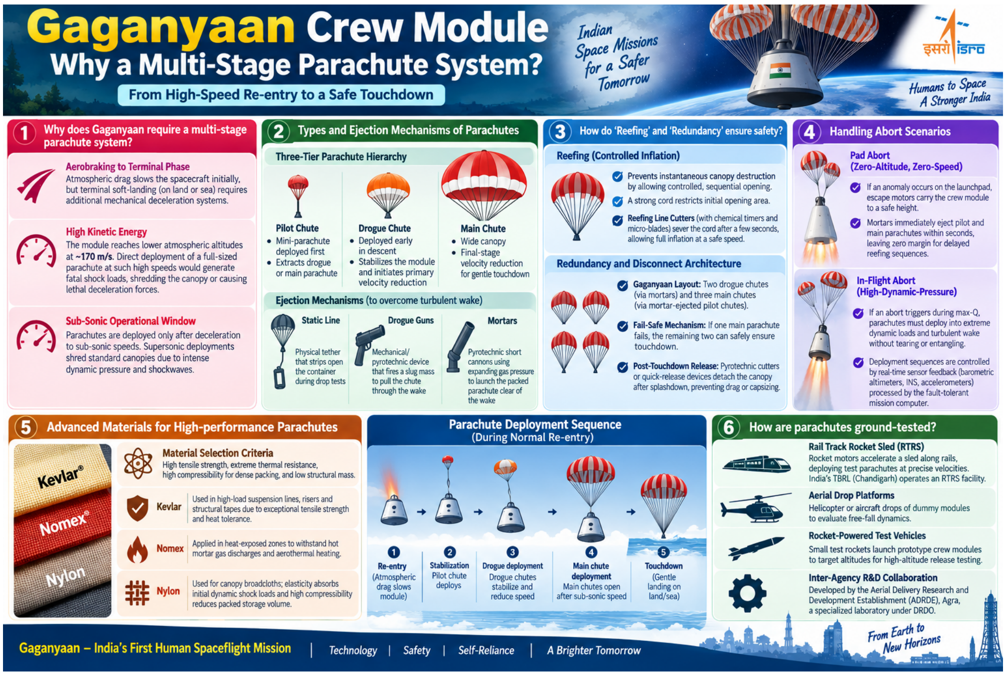
Why does the Gaganyaan Crew Module require a multi-stage parachute system for re-entry?

- **Aerobraking To Terminal Phase –** Spacecraft re-entering Earth's atmosphere rely primarily on atmospheric drag for initial high-speed decelerations.
- However, terminal phase soft-landing (on land or sea) requires additional mechanical deceleration systems.
- **High Kinetic Energy –** The returning Gaganyaan module reaches lower atmospheric altitudes at velocities of 170 m/s.
- Direct deployment of a full-sized main parachute at these speeds would generate fatal opening shock levels, shredding the canopy fabric or subjecting astronauts to lethal deceleration forces.
- **Sub-Sonic Operational Window –** Parachute deployment occurs after the module decelerates to sub-sonic speeds.
- Supersonic deployments shred standard canopies due to intense dynamic pressure and shockwave interaction.

What are the primary types and ejection mechanisms of parachutes used in aerospace recovery?

- **Three-Tier Parachute Hierarchy –**
    - **Pilot Chute –** A mini-parachute deployed first to extract larger drogue or main parachutes.
    - **Drogue Chute –** Deployed early in descent to stabilize the module and initiate primary velocity reduction.
    - **Main Chute –** Features a wide canopy designed for final-stage velocity reduction to ensure gentle touchdown conditions.
- **Overcoming Turbulent Wake Energy –** The blunt crew module creates a turbulent wake at its rear.
- Ejection mechanisms must impart sufficient energy to launch the parachutes past this wake into the free-stream air –

   - **Static Line –** A physical tether anchored to an aircraft that strips open the container during drop tests.
   - **Drogue Guns –** Mechanical/pyrotechnic devices that fire a slug mass at high velocity to pull the chute through the wake.
   - **Mortars –** Pyrotechnic short cannons that use expanding gas pressure from controlled explosions to launch the packed parachute clear of the wake.



How do 'Reefing' and 'Redundancy' ensure safety during atmospheric descent?

- **Reefing (Controlled Inflation) –**
- Prevents instantaneous canopy destruction by allowing the parachute mouth to open in controlled, sequential steps analogous to opening an umbrella gradually in strong winds.
- A strong cord runs around the canopy skirt to restrict initial opening area.
- Integrated *Reefing Line Cutters* (containing chemical timers and micro-blades) sever the cord after a few seconds, allowing the canopy to fully bloom once speed drops to a safe threshold.
- **Redundancy and Disconnect Architecture –**
- **Gaganyaan System Layout –** Equipped with two drogue chutes (deployed via mortars) and three main chutes (deployed by mortar-ejected pilot chutes).
- **Fail-Safe Mechanism –** If one main parachute fails completely, the remaining two independent parachute chains can safely achieve a touchdown.

- **Post-Touchdown Release –** Immediate activation of pyrotechnic cutters or mechanical quick-release devices detaches the canopy upon splashdown, preventing winds from dragging or capsizing the module.

How do parachute deployment systems handle abort scenarios like Pad Abort and In-Flight Abort?

- **Pad Abort Scenario (Zero-Altitude, Zero-Speed) –** If an anomaly occurs on the launchpad, escape motors carry the crew module to a safe height where mortars must immediately eject the pilot and main parachutes within seconds, leaving zero margin for delayed reefing sequences.
- **In-Flight High-Dynamic-Pressure Abort –** If an abort triggers during max-Q (maximum dynamic pressure), the extraction parachutes must deploy into extreme aerodynamic loads and turbulent wake without tearing or entangling with jettisoned rocket stages.
- **System Interfacing with the Flight Computer –** Deployment sequences are controlled by real-time sensor feedback (barometric altimeters, INS, and accelerometers) processed by the fault-tolerant mission computer, automatically overriding default timelines if descent rates exceed safety thresholds.

What advanced materials are utilized to withstand high dynamic and thermal loads?

- **Material Selection Criteria –** Demands high tensile strength, extreme thermal resistance, high compressibility for dense packing, and low structural mass.
- **Kevlar –** Deployed in high-load suspension lines, risers, and structural reinforcement tapes due to its exceptional tensile strength and heat tolerance.
- **Nomex –** Applied in heat-exposed zones to withstand hot mortar gas discharges and aerothermal friction heating.
- **Nylon –** Utilized for canopy broadcloths because its elasticity absorbs initial dynamic shock loads during inflation, and its high compressibility reduces packed storage volume.

How are aerospace parachutes ground-tested before spaceflight?

- **Rail Track Rocket Sled (RTRS) –** Ground facility where rocket motors accelerate a sled along rails, deploying test parachutes at precise velocities. India's Terminal Ballistic Research Lab (TBRL) in Chandigarh

operates an RTRS facility.
- **Aerial Drop Platforms –** Helicopter or aircraft drops of dummy modules to evaluate free-fall dynamics.
- **Rocket-Powered Test Vehicles –** Small test rockets launch prototype crew modules to target operational altitudes for high-altitude release testing.
- **Inter-Agency R&D Collaboration –** Developed by the Aerial Delivery Research and Development Establishment (ADRDE) in Agra, a specialized laboratory under DRDO.

Reference

[The Hindu | Gaganyaan Parachutes]