Q1. in case of hypersonic missiles what guidance technologies are employed to ensure precision at hypersonic speeds?

Ans1.

| **Technology** | **Role** | **Strength** | **Challenge** |
| --- | --- | --- | --- |
| INS | Base navigation | Self-contained | Drift over time |
| GPS/Satellite Nav | Mid-course correction | High accuracy | Susceptible to jamming & plasma blackout |
| TERCOM | Mid-course navigation | Terrain-based, jam-resistant | Needs accurate terrain data |
| DSMAC | Terminal targeting | Very precise | Needs clear imagery |
| Radar/IR Seeker | Terminal homing | Autonomous targeting | Sensitive to countermeasures |
| Data Link | Mid-course updates | Real-time intel | Hard at hypersonic speeds |
| AI/Autonomy | Entire flight | Fast decision-making | Complex, still evolving |
| Glide Algorithms | Flight control | Evasive, agile | Requires real-time updates |

Q2. how does the missile handle real time course correction or target tracking during flight.

Ans2. 1. Flight Control Surfaces & Thrust Vectoring -> Hypersonic missiles (especially glide vehicles and air-breathing types) have **aerodynamic control surfaces** (e.g., fins, canards) or **thrust vectoring** mechanisms to alter trajectory.

2. Onboard AI/Autonomy & Sensor Fusion -> Inertial sensors (gyros/accelerometers), Radar or infrared seekers, Satellite navigation, Environmental sensors (e.g., altimeters, pressure sensors)

3. Mid-Course Guidance Updates (When Possible)-> Data Links -> If communication is possible (before plasma blackout or in low-atmosphere cruise), the missile can receive: New target coordinates, Navigation corrections

Q3. are there any unique challenges in navigation a hypersonic missile compared to subsonic or supersonic systems

Ans3. **Plasma Blackout** At hypersonic speeds, a plasma sheath forms around the missile due to intense air compression and heat. This blocks GPS and communication signals.

**Extreme Heat and Structural Stress :** Surface temperatures can exceed **2,000°C**, which can degrade or disrupt sensitive navigation sensors (e.g., radar domes, antennas).

**Navigation Without GPS :** Because of signal loss or jamming, hypersonic missiles must rely more on inertial navigation, terrain mapping, and internal sensors, which can drift over time without correction.

Q4. what measures are in place to protect the missile from electronic warfare or intercept attempts

Ans4. Hypersonic missiles counter electronic warfare with **INS(Inertial Navigation Systems)-based navigation**, **AI-driven autonomy**, and **encrypted, jam-resistant communications**. To evade intercepts, they rely on **extreme speed**, **unpredictable high-G maneuvers**, and **stealthy designs**. Their electronics are **hardened** against jamming, EMPs, and sensor disruption, ensuring mission reliability even in contested environments.

Q5. are there plans to integrate artificial intelligence or autonomous features into the hypersonic missile system

Ans 5. Yes, **Autonomous navigation** using AI-driven control systems is in use, especially to manage flight during **GPS denial or plasma blackout**.

Q6. Nucleared-powered spacecraft promise faster and more efficient travel revolutionizing deep-space reconnaissance- how far this is achievable by india.

**Ans6.** having successfully tested radioisotope heating units on Chandrayaan-3 and developing 100-watt RTGs (Radioisotope Thermoelectric Generator). Collaborative efforts between ISRO and BARC are exploring nuclear thermal propulsion for faster interplanetary travel. While full-scale nuclear-powered missions are still years away**,**

Q7.