Challenges in Lunar Landing Missions

For Prelims: Challenges in Lunar Landing Missions, **Russia's Luna-25**, **Soviet Union**, **India's Chandrayaan-3**, Lunar South Pole, International Lunar Research Station, **ISRO's Chandrayaan-2.**

For Mains: Challenges in Lunar Landing Missions.

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Why in News?

Recently, **Russia's Luna-25** crashed on the Moon's surface, ending its first mission to the lunar surface 47 years after the last landing by the **former** Soviet Union.

- This leaves **India's Chandrayaan-3** on course to become the first spacecraft to land **near the** Lunar South Pole.
- Russia's Luna-25 marked the resumption of lunar interest and plans to continue the Luna series.

What is the Luna-25 Mission?

- **About:**
  - The Luna 25 mission, originally named **Luna-Glob**, underwent over two decades of development before joining the historic Luna series initiated in 1976.
  - The mission aimed to **secure Russia's access to the Moon's surface** amid its significance in space exploration and geopolitical rivalry.
    - While Russia and China lead the **International Lunar Research Station (ILRS)**, the U.S. heads the Artemis Accords.
- **Failure:**
  - The Luna 25 spacecraft encountered a technical glitch, surpassing its **operational limits.**
  - The failure appears linked to an **attempt to shift its circular orbit to a lower pre-landing orbit.**
  - **Excessive thrust during this maneuver caused a trajectory deviation,** causing the craft to crash onto the Moon's surface.
    - Roscosmos lost communication during this critical event.
  - Due to the Russia-Ukraine war, Russia lost its privileges to **use satellite tracking systems operated by countries** in different parts of the world. Roscosmos could contact Luna 25, and receive signals from the spacecraft, only at three stations: two in **Russia and one in Russian-occupied Crimea.**
    - ISRO, unlike Russia, is receiving help from **National Aeronautics and Space Administration (NASA)** and the European Space Agency (ESA) to track **Chandrayaan 3 around the moon.**

What are the Complexities in Successful Lunar Landing?

- **Complexity of Lunar Descent:**

    - Lunar landings involve a **challenging descent from lunar orbit to the Moon's surface**, often referred to as the **"15 minutes of terror."**
    - The complexity arises from the **need to precisely control the spacecraft's speed, trajectory, and altitude** during this crucial phase.
- **Historical Perspective:**
    - Despite more than 20 successful landings, including six with human crew, the **technology remains imperfect.**
        - Most successful lunar landings occurred within a **decade between 1966 and 1976**, with three Chinese landings in the past decade as exceptions.
        - Lunar landing technology during the 1960s and 1970s was far from perfected, with a 50% success rate among 42 attempts.
    - Contemporary lunar missions deploy safer, cost-efficient, and fuel-efficient technologies **but require testing and validation.**
- **Complex Propulsion:**
    - Lunar landing involves **a sequence of controlled maneuvers,** from deceleration to final touchdown. Precise propulsion systems must be employed to manage speed and altitude accurately.
- **Thermal Challenges:**
    - Extreme temperature variations on the Moon, from scorching heat to freezing cold, pose challenges for spacecraft systems. Thermal protection and insulation are critical to prevent equipment malfunctions.

What are the Recent Failures and Successes in Lunar Landing Attempts?

- **Failure:**
    - Missions from **India, Israel, Japan, and Russia** all faced challenges during the landing process, resulting in crashes on the Moon's surface.
        - **ISRO's Chandrayaan-2:** Malfunctions **prevented the desired speed levels from being achieved.**
        - **Beresheet (Israel), Hakuto-R (Japan):** Different kinds of malfunctions disrupted landing plans.
- **Successes:**
    - China's Chang'e-3, Chang'e-4, and Chang'e-5 missions achieved successful lunar landings.

Way Forward

- India's Chandrayaan-3 exemplifies the importance of learning from failures. After the Chandrayaan-2 setback.
- While recent failures underscore the **complexity of soft-landing on the Moon,** they also reflect the determination of space agencies **to push boundaries and advance the field of lunar exploration.**
- The lessons learned from these attempts **will contribute to the development of more reliable and successful lunar landing** technologies in the future.