

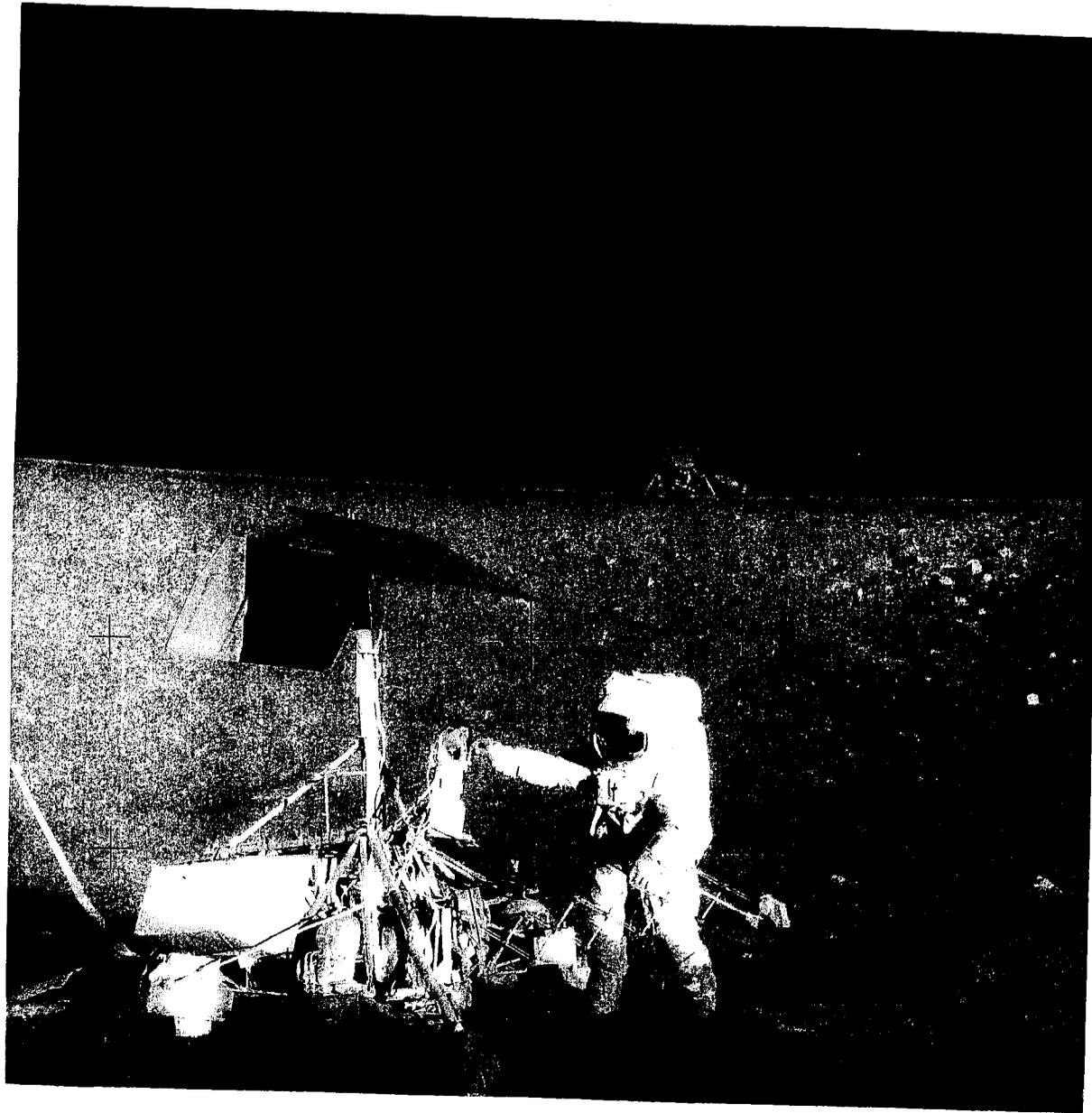
# Cislunar Navigation

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- Nav. To/from/on equat. near side is a solved problem
  - Surveyor, Apollo, Luna, Lunokhod
- Whole Moon now well mapped
  - Lunar Orbiter, Clementine, Lunar Prospector
- **However**, more advanced navcom now needed:
  - New mission requirements
  - New technologies both on and off Earth
- Our purpose here is to define and advocate actions



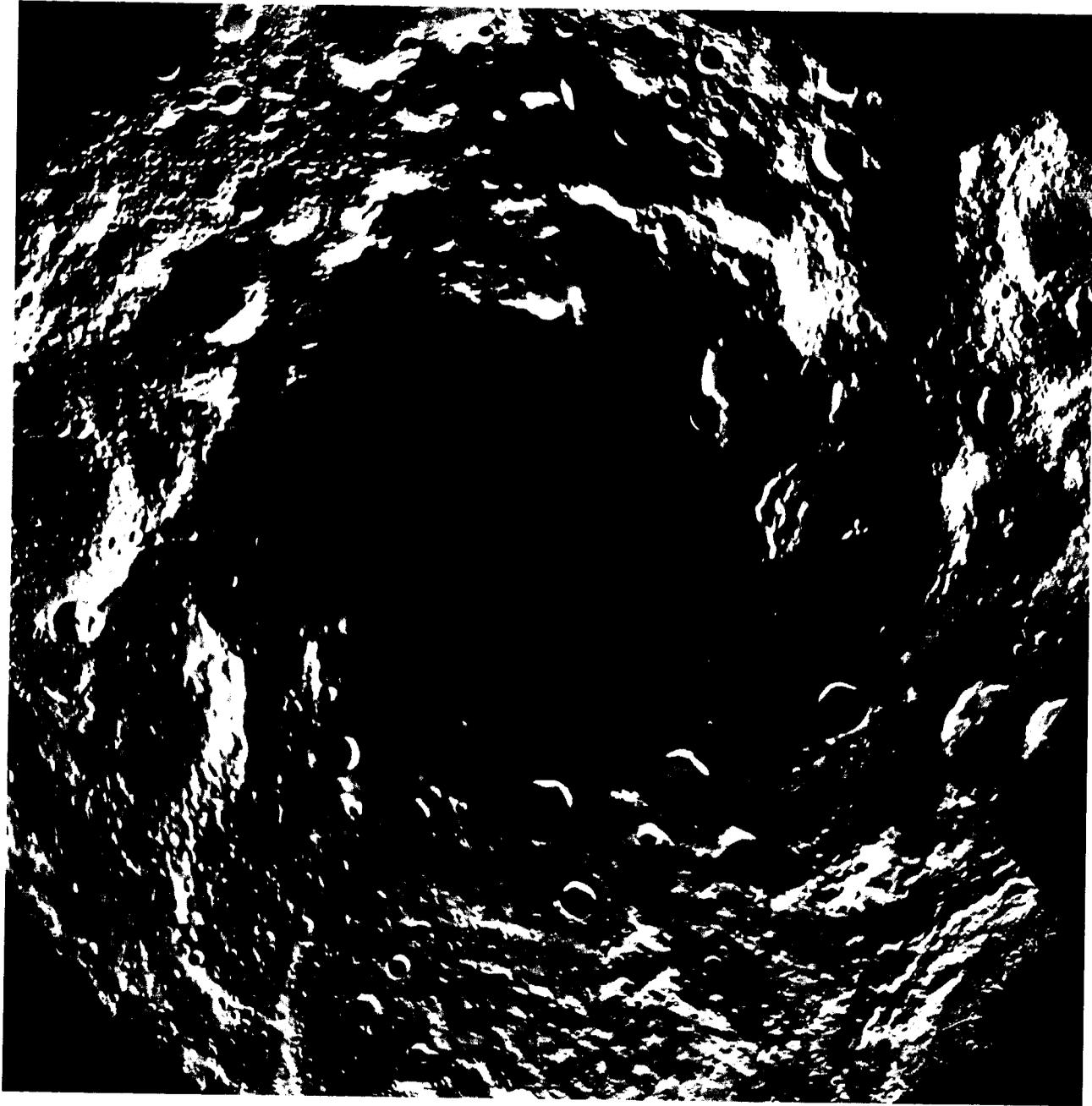
**Apollo 12 Lands Near and Visits Surveyor 3**

# **New Technologies, New Requirements**

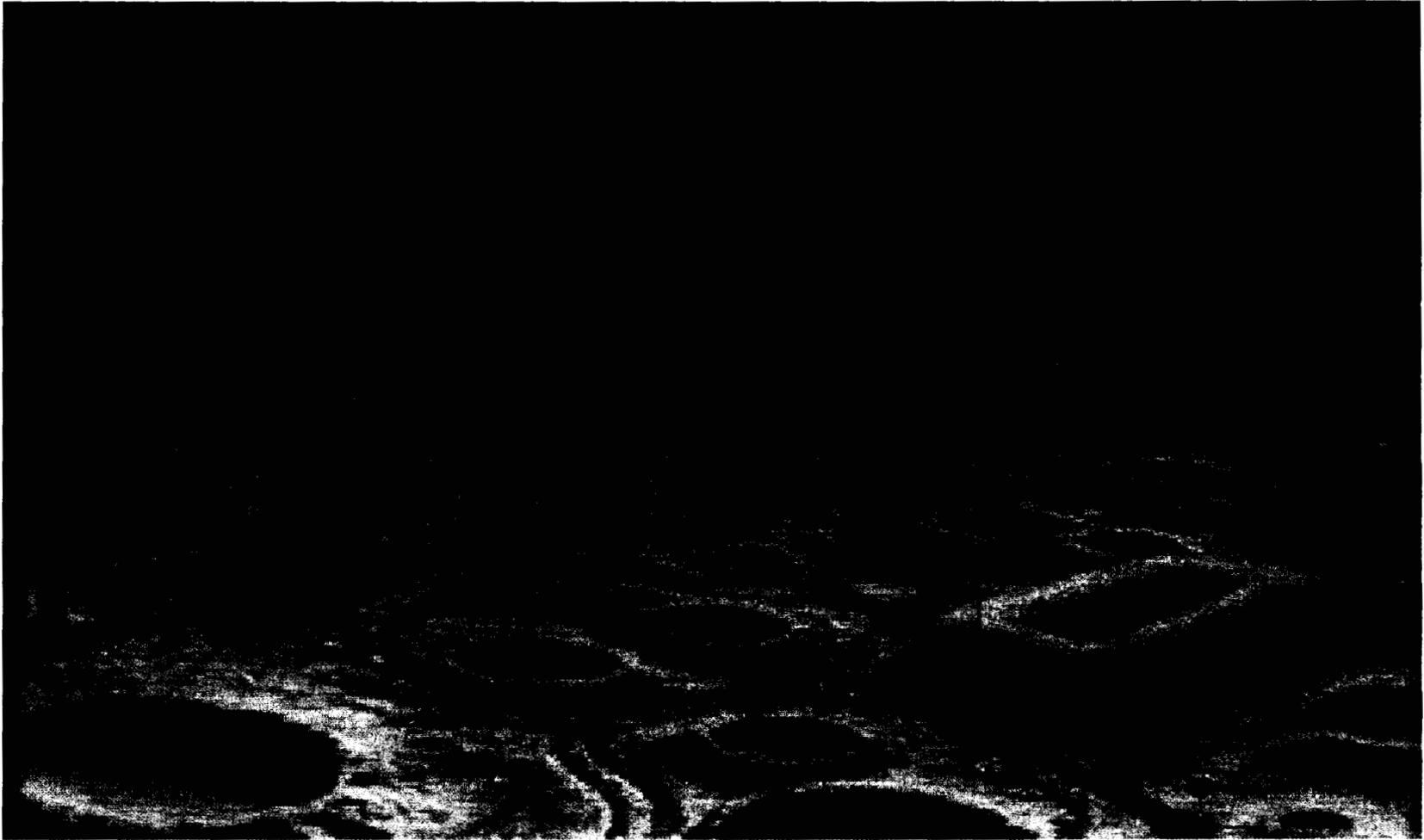
- Deep Space Net moving up in frequency
- Spacecraft autonomy coming
- Low-thrust propulsion, non-ballistic trajectories
- Invariant-manifold transfers, libration point orbits
- Aerobraking on return to Earth
- Departure from and/or return to ISS
- Operation beyond lunar limb (polar, far side)
- Formation flying, interferometry
- Synthetic-aperture and ground-penetrating radars

# Navigation and Communication Options

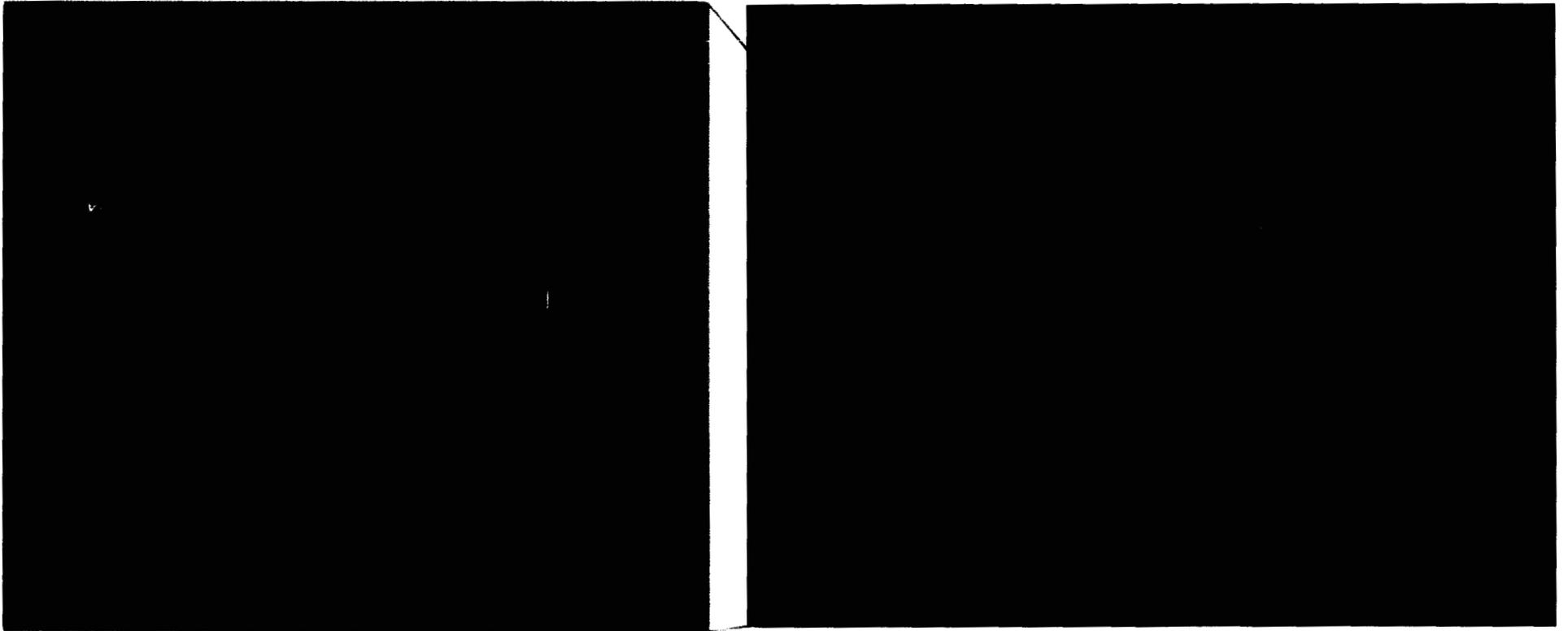
- Relay beyond line-of-sight
  - Roving into cold polar dark regions
    - Ice detection
    - Cryogenic astronomical instruments
  - Far-side installations
    - Earth radio noise shield, optical relay
- Libration point delivery & halo orbit maintenance
- On-board and on-Earth autonomy
  - Benefit from previous Mars work



**Lunar South Pole / Aitken Basin**



**Conceptual Lunar Far-Side Astronomical Observatory**



## **Low Energy Portals & Tunnels Generated by Lagrange Points**

**(Portals = Halo Orbits; Tunnels = Invariant Manifolds)**

## **Near-term Actions**

- Include navcom options evaluation in current mission studies
- Develop low-energy transfer orbit handbooks
- Select a subset of above options, insert into existing technology programs
- Make program and system architecture analyses
- Based on all above, fly navcom demos using micro-spacecraft as auxiliary payloads
- With demo results in hand, emplace an international navcom infrastructure in cislunar space

## **Policy Implications**

- A cislunar navcom infrastructure should serve multiple missions
- Its capabilities can be modest at first, achievable with micro-spacecraft launched as auxiliary payloads
- Its design and installation should evolve in step with programs and missions
- It should be created and maintained as an international, shared resource
- To move toward this goal, the early, low-cost phases should be international too. ISU can lead

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