Ground Segment

MAE 4160, 4161, 5160

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Today’s topics:

- Functions and requirements
- Ground segment options/ alternatives
- Coupling between ground segment and space segment
- An extended digression on Apollo

Functions of the ground segment

- Maintain communication links with spacecraft and payload
  - Receive telemetry and science data from spacecraft
  - Send commands to spacecraft
- Process and store telemetry data
  - Monitor spacecraft health
  - Determine spacecraft attitude
- Track spacecraft orbital position
- Interface between spacecraft and data users
  - Process, store, and distribute mission commands and data

Main components of the ground segment

- Antennas
- Radio equipment
  - Receiver electronics
  - Cables, racks, etc.
- Control centers
  - Payload ops (POCC)
  - Spacecraft ops (SOCC)
  - Mission (MCC)
- Data servers
  - Servers
  - User interfaces
  - Software
- Others: administrative, etc.

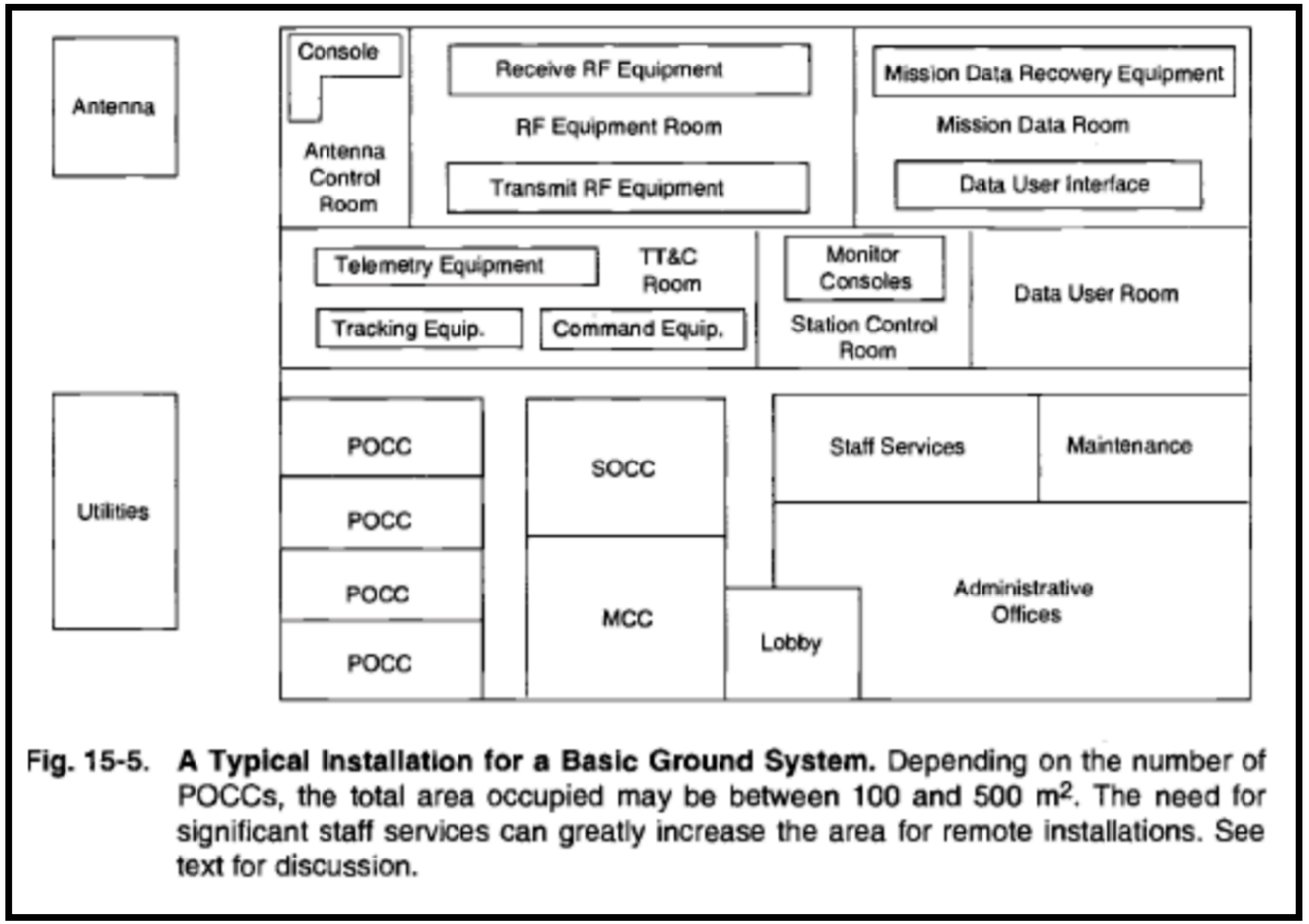


Fig. 15-5. **A Typical Installation for a Basic Ground System.** Depending on the number of POCCs, the total area occupied may be between 100 and 500 m^2. The need for significant staff services can greatly increase the area for remote installations. See text for discussion.

Physical layout of a typical ground system

Ground segment design variables

- Number and location of facilities
  - Latitude/longitude
- Number and type of antennas and electronics
  - Frequency, diameter, steering/elevation angles, EIRP, G/T ratio, modulations and coding schemes
- Assignment of SOCC/POCC/MCC’s to facilities
- Main trade-offs
  - Reuse existing facilities vs. develop new ones
  - Ground vs. on-board function allocation
  - Centralized vs. distributed allocation of control centers to facilities

Couplings between ground and space segments

- Communications architecture
  - Trade-off between $EIRP_{sat}$ and G/T_{ground}
  - Trade-off between data rate and contact time (number of ground stations)
- On-board vs. ground mission functions
  - Data processing
  - Orbit control

Ground system figures of merit

- **Availability**: % time ground stations are available (off-time primarily due to maintenance, but potentially also due to other factors like cloudiness or precipitation)
- **Data rates**: data rates which can be supported for some distance
- **Coverage**: e.g. total contact time, percentage of all LEO orbits covered
- **Latency/response** time: total time from image request to image at MCC
- **Number of simultaneous contacts**: through multiple antennas, multiple beams per antenna, or multiplexing (time, frequency, codes)
- **Reliability**: related to probability of failure
- **Security**: avoid adversaries reading, adding, changing, removing data, jamming communications, etc.
- **Survivability**: avoid being detected, avoid being hit by a weapon, ability to withstand the hit, ability to restore capabilities quickly when hit

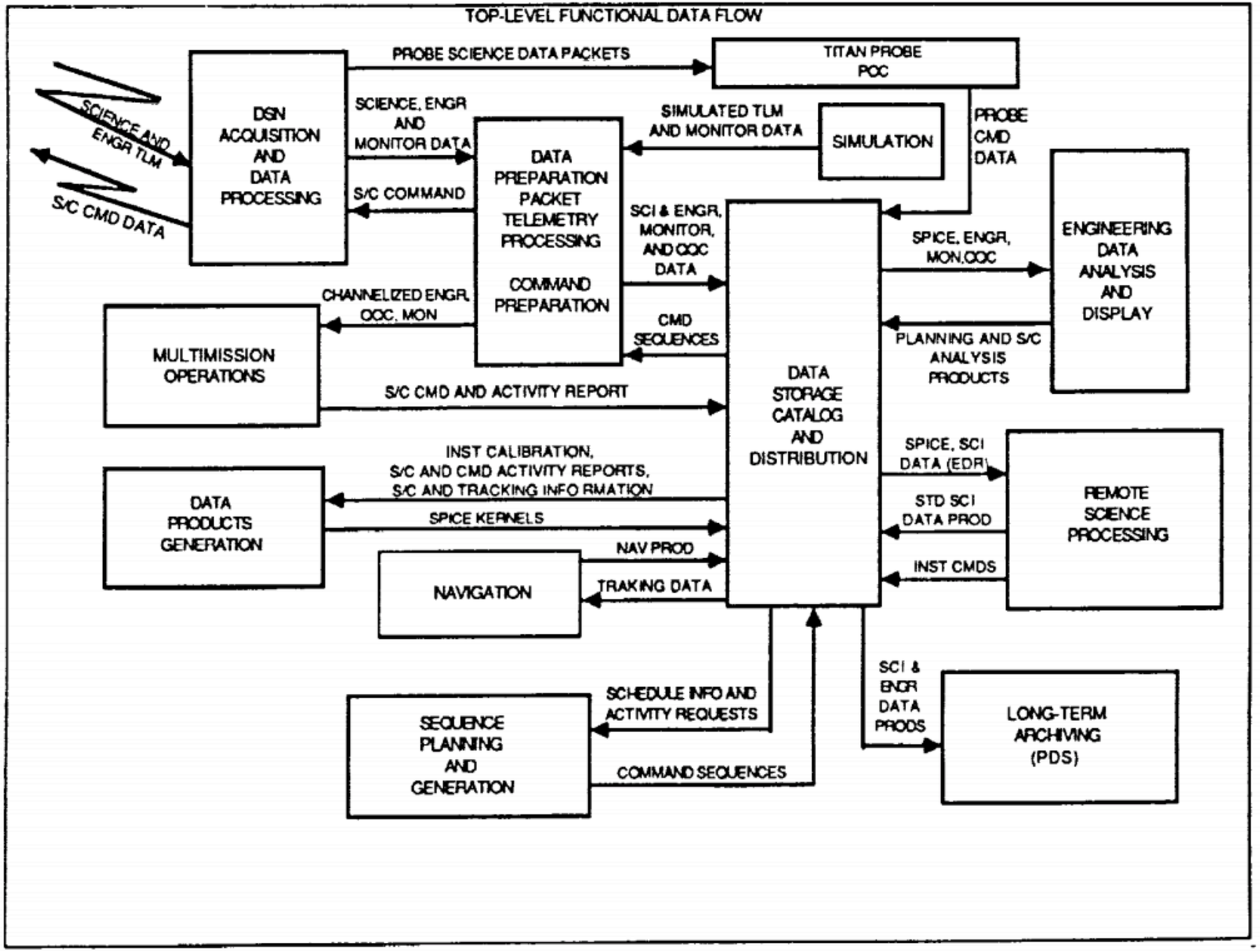


Figure 10.2: *Top level functional data flow*

Ground station service providers

- **NASA**
  - Deep Space Network (Goldstone, Madrid, Canberra)
  - Space Network (TDRSS, White Sands, Guam)
  - Near Earth Network (14 locations around the world, some commercial)
- **NOAA (weather, oceanography)**
  - NOAA Satellite Operations Facility (Maryland)
  - NOAA Command and Acquisition Stations (Alaska)
- **USGS (Landsat)**
  - Earth Resources Observation Systems (South Dakota)
- **DOD**
  - Air Force Satellite Control Network (8 locations)
  - GPS ground segment (16 locations)
  - National Reconnaissance Operations Center (5+ locations)

Capabilities of various service providers . . .

The Deep Space Network

Making humanity's longest-distance calls.

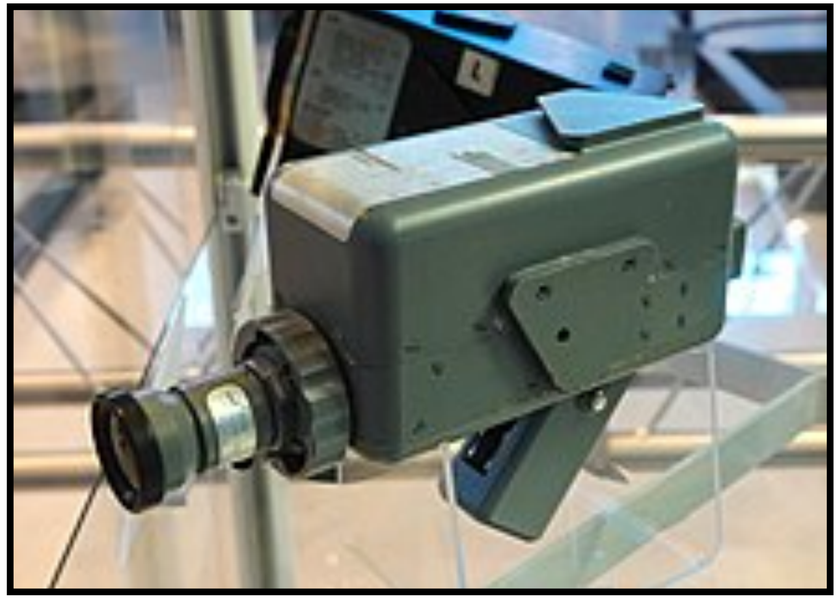
- Composed of three complexes
  - Goldstone Deep Space Communications Complex (outside Barstow, CA)
  - Madrid Deep Space Communications Complex (guess where??)
  - Canberra Deep Space Communications Complex (40 km southwest of Canberra, Australia)
- S-band, X-band, Ka-band services
- Multiple 34m, 70m dishes per center
- G/T: 40 to 60 dB/K depending on type
- EIRP: 99 dBW to 116 dBW depending on type (up to ~100kW!)
- Data rates: up to 10Mbps or 150Mbps for Ka-band
- BPSK, QPSK modulations with Reed-solomon, turbocodes, and convolutional codes

70m dish at Goldstone

The Deep Space Network

Making humanity’s longest-distance calls.

- Collaborated with the Manned Space Flight Network (MSFN) to track the Apollo capsules
- A wing was constructed at each DSN facility to be staffed by manned spaceflight people. This allowed the DSN to be quickly switched from supporting deep-space missions to Apollo and back again
- The high-gain DSN antennas were required to support television broadcast from the Moon.



Apollo television camera

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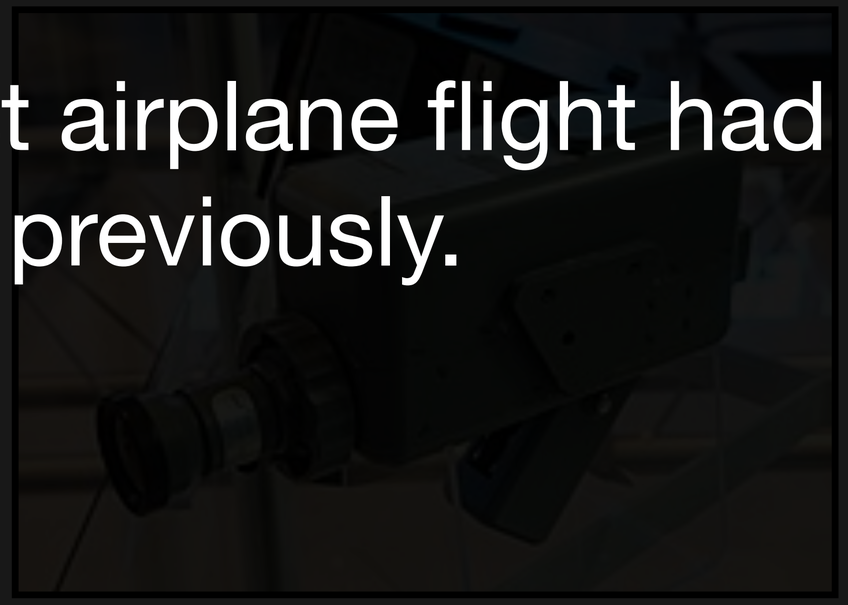
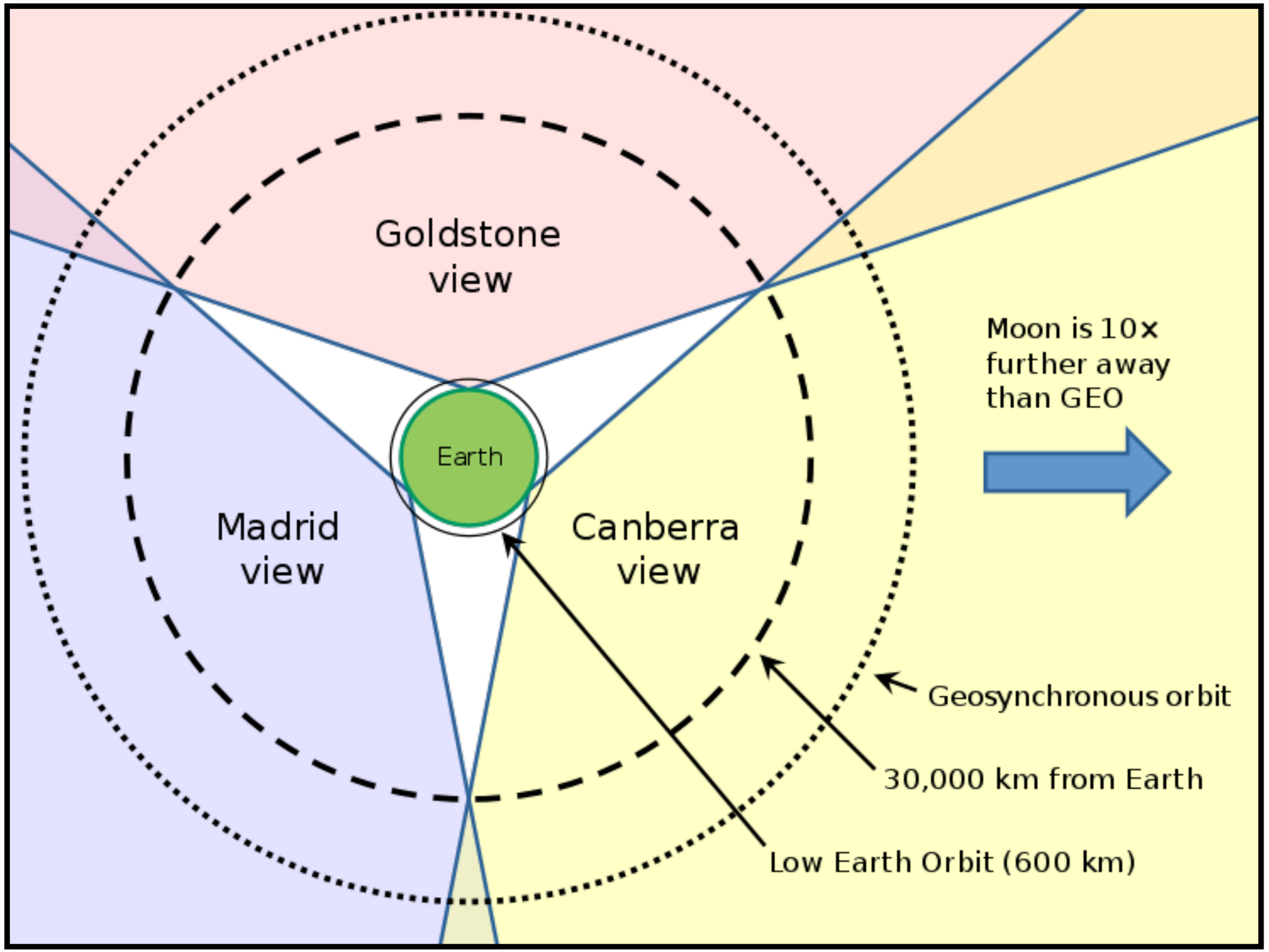
Imagine watching this live. The first airplane flight had taken place only 66 years previously.



Apollo television camera

Why can’t we use the DSN to continuously track low-Earth spacecraft?



DSN fields of view

The Near-Earth Network

The Near-Earth Network

- Network of ground stations located around the world that provide communication/tracking services to missions operating in the near-Earth region.
- Persistent operation
- S-Band, X-Band, Ka-Band
- Communications for sub-orbital flights, LEO, MEO, GEO, HEO, and Lunar/Lagrange orbits
- Communications through launch, early orbit, operations, and disposal
- Services including data transport, command/telemetry, and navigation

Space Network

A NASA program that combines **space and ground** elements to support spacecraft communications in Earth vicinity.

Facilities include:

- Geosynchronous Tracking and Data Relay Satellites (TDRS)
- Supporting ground terminal systems
- Bilateration Ranging and Transponder System
- Merritt Island Launch Annex
- Network Control Center Data System

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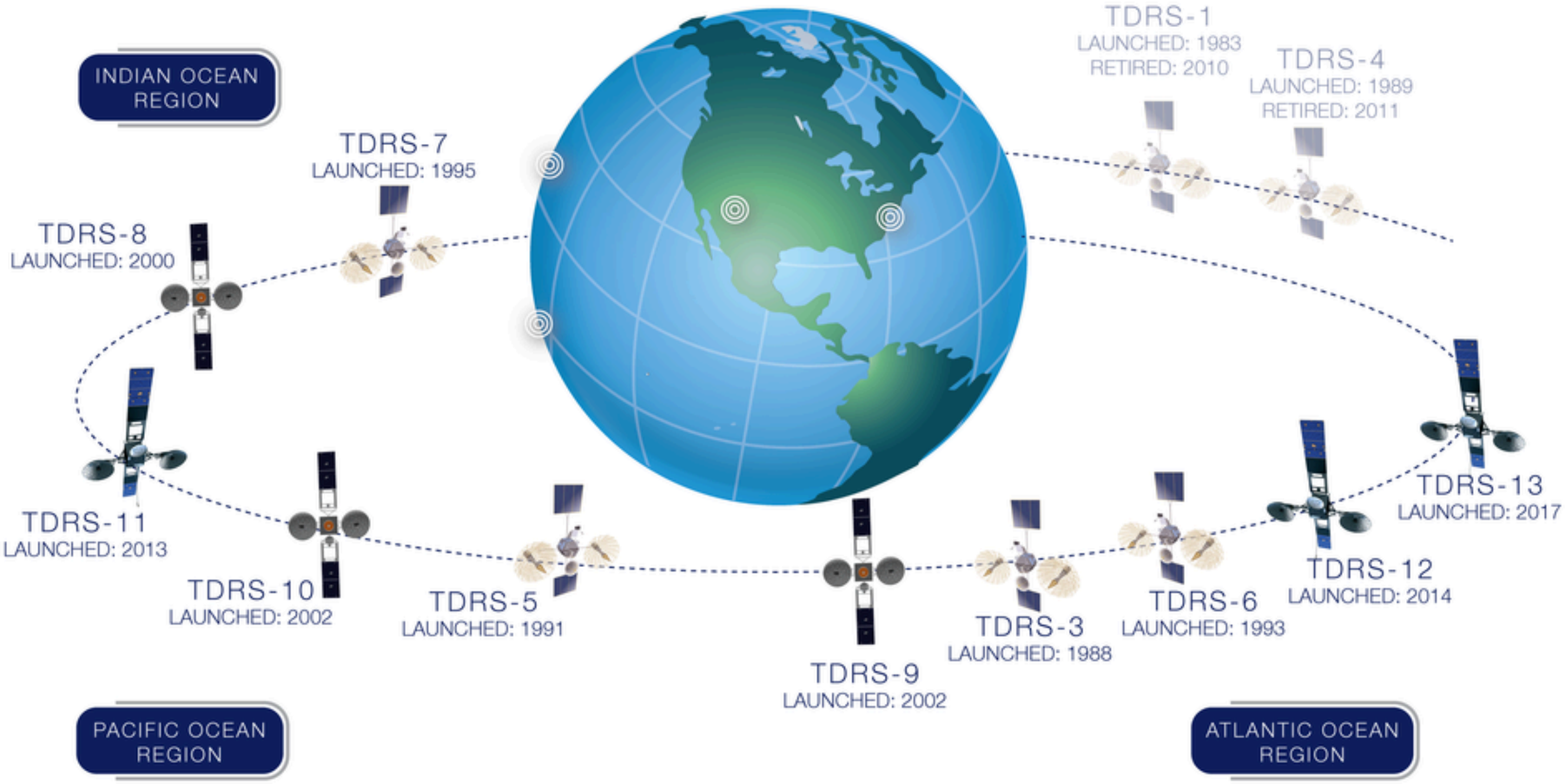
TDRS

- A network of geosynchronous satellites for persistent communication from ground to satellites, balloons, aircraft, the international space station, and remote base stations on Earth
- Designed to replace global network of ground stations that supported NASA crewed/robotic missions

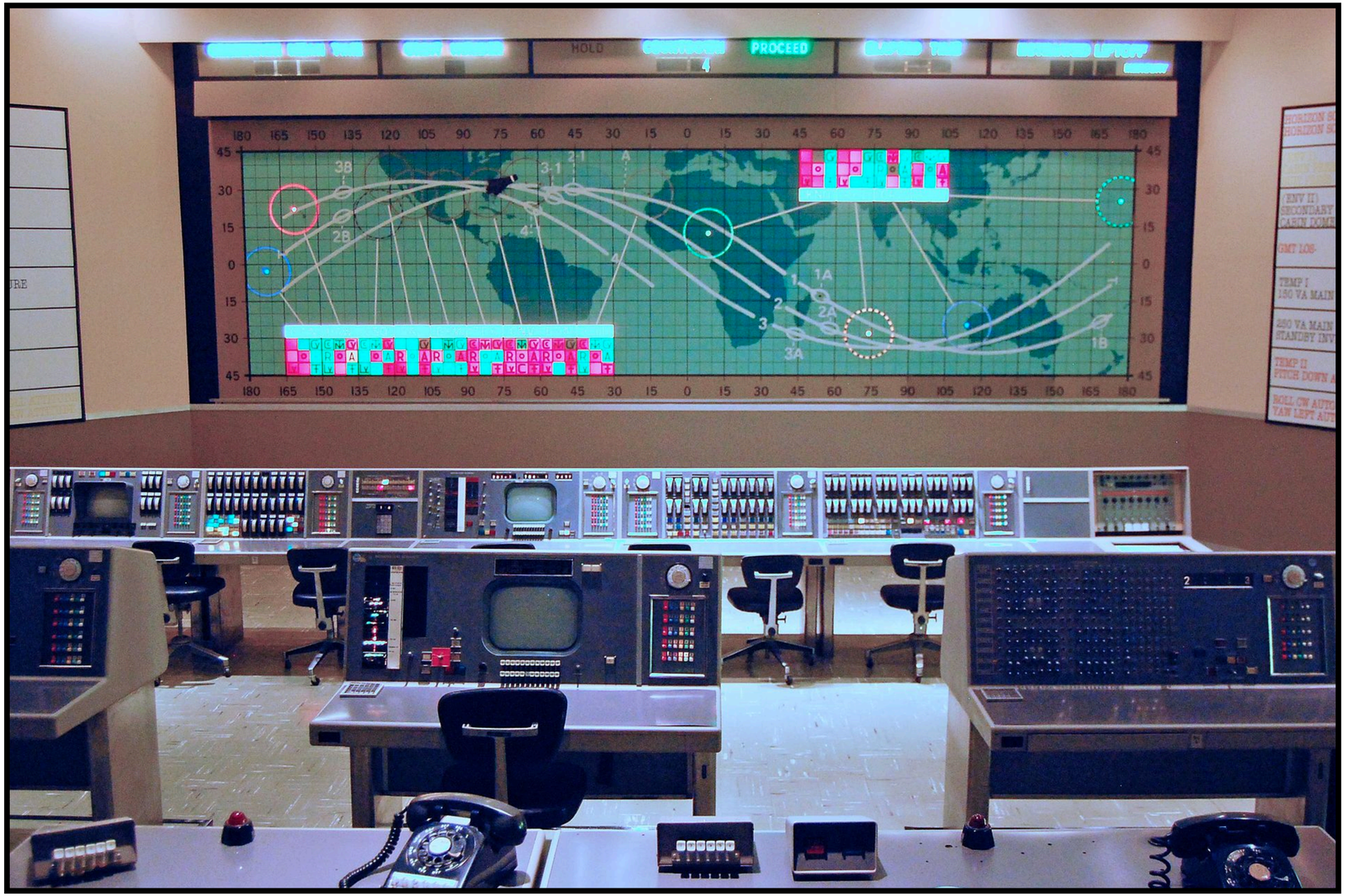


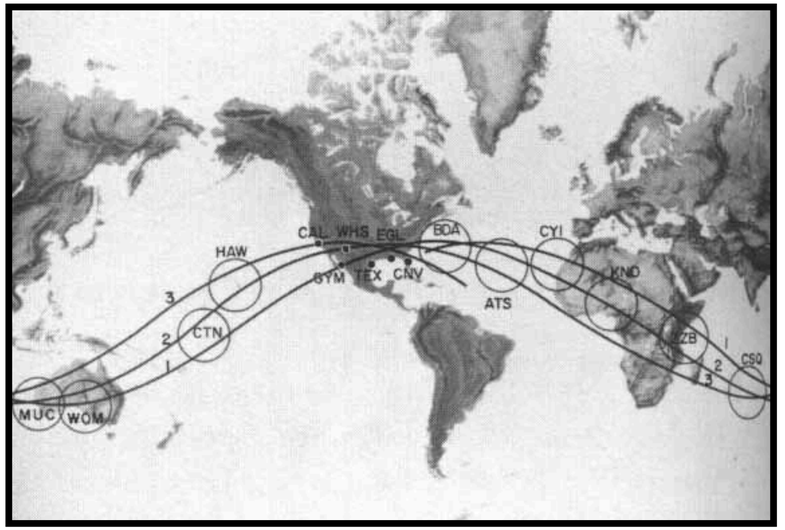
Air Force Satellite Control Network (AFSCN)

- Operated by U.S. Space Force's Space Operation Command
- Provides support for the operation, control, and maintenance of a variety of DoD satellites
- Provides tracking data to help maintain a catalog of space objects
- Consists of control centers and tracking stations around the world. Satellite Operation Centers are manned at all times and are responsible for command/control of their assigned systems
- Originally activated to support CORONA

Manned Spaceflight Network

- “Misfin” — a set of tracking stations built to support Mercury, Gemini, Apollo, and Skylab





Mission control

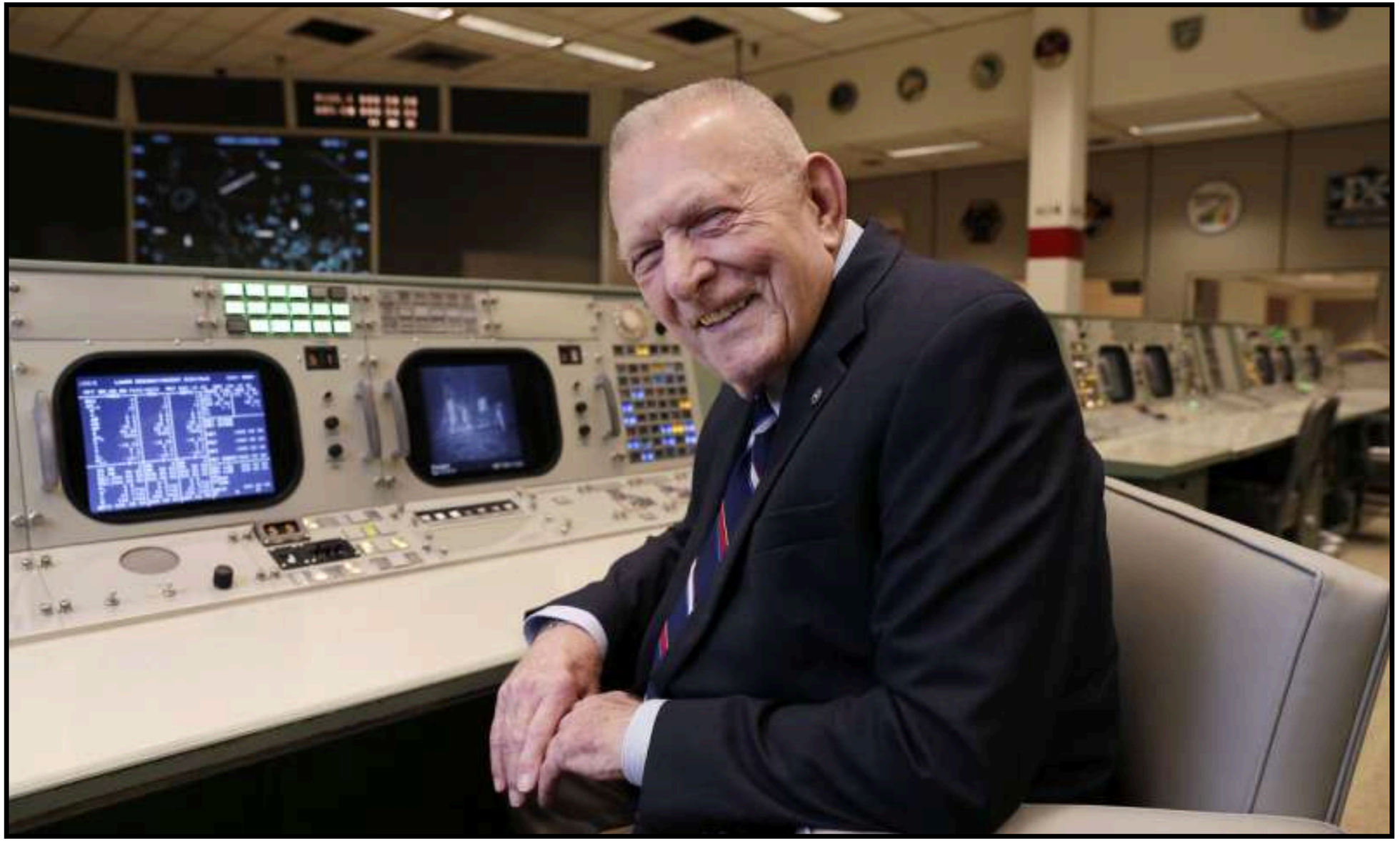
JPL mission control

SpaceX mission control

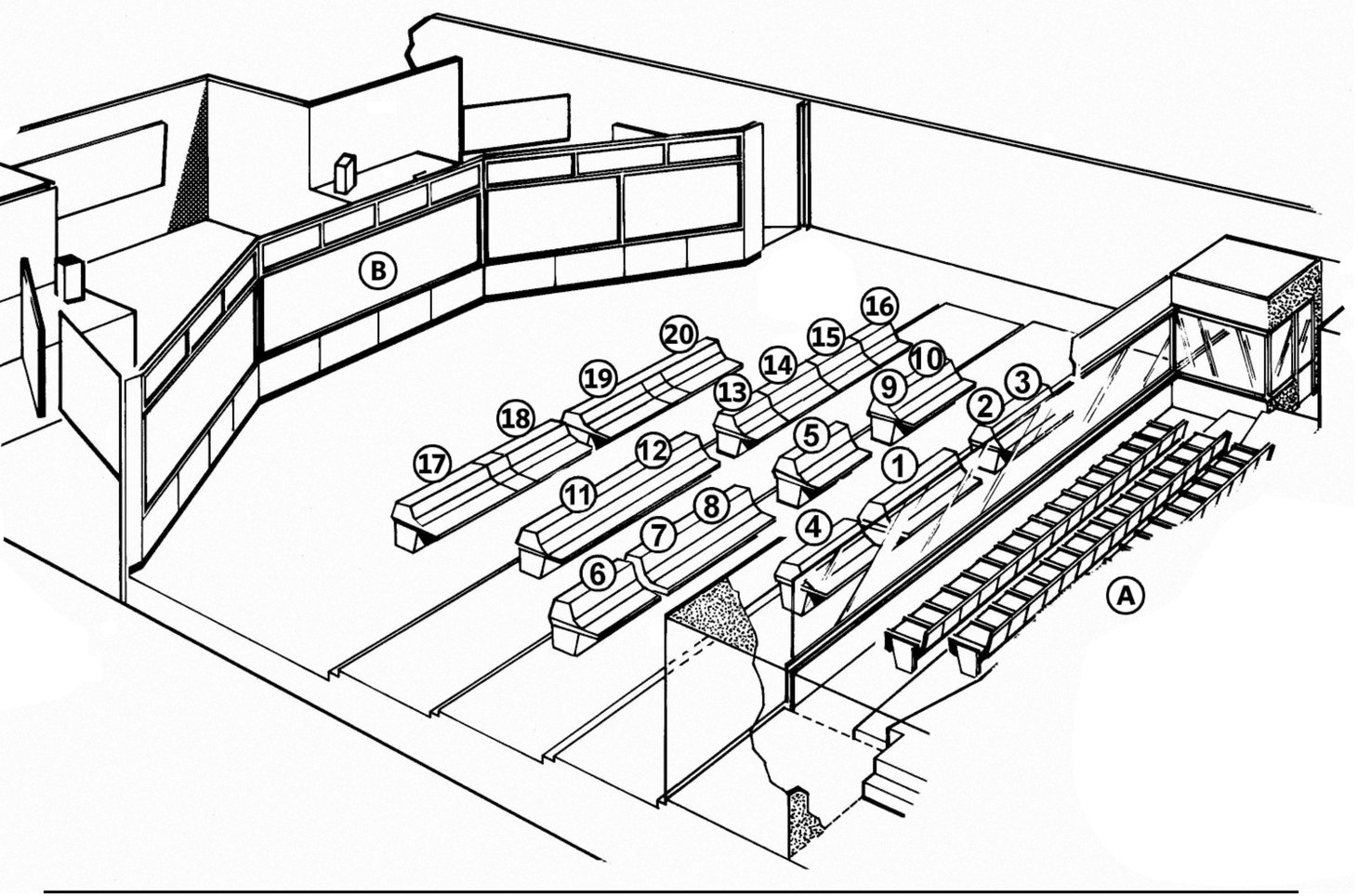
Apollo mission control

Apollo 8?

Apollo mission control



Closer view of console



Apollo seating arrangements

B: Display and projection area

Fourth row, "The Trench"
17: BOOSTER – Booster Systems Engineer
18: RETRO – Retrofire Officer
19: FDO – Flight Dynamics Officer
20: GUIDO – Guidance Officer

Third row:
11: SURGEON – Life Systems Officer/Flight Surgeon
12: CAPCOM – Capsule Communicator
13: EECOM – Electrical, Environmental, and Communications
14: GNC – Guidance, Navigation, and Control
15: TELMU – Telemetry, Electrical, and EVA Mobility Unit (LM EECOM)
16: CONTROL – LM Guidance & Navigation

Second row:
6: INCO – Instrumentation and Communications Officer
7: O&P – Operations and Procedures
8: AFLIGHT – Assistant Flight Director
5: FLIGHT – Flight Director
9: FAO – Flight Activities Officer
10: NETWORK – Network Controller

First row:
4: PAO – Public Affairs Office
1: DFO – Director of Flight Operations
2: HQ – NASA headquarters (Mission Operations Directorate)
3: DOD – Department of Defense

A: Glass fronted viewing room seating 74 authorized visitors

An aside on mission control rooms, and human spaceflight in general. Do not forget that there are **people in the loop**. People have attention spans, attention limitations, and workload limitations.

We can listen to (and understand) the mission control chatter as Eagle descends to the Sea of Tranquility.

https://www.firstmenonthemoon.com/

“The greatest speech never told.”