Apollo Lunar Module Guidance and Navigation: Lessons for LSAM

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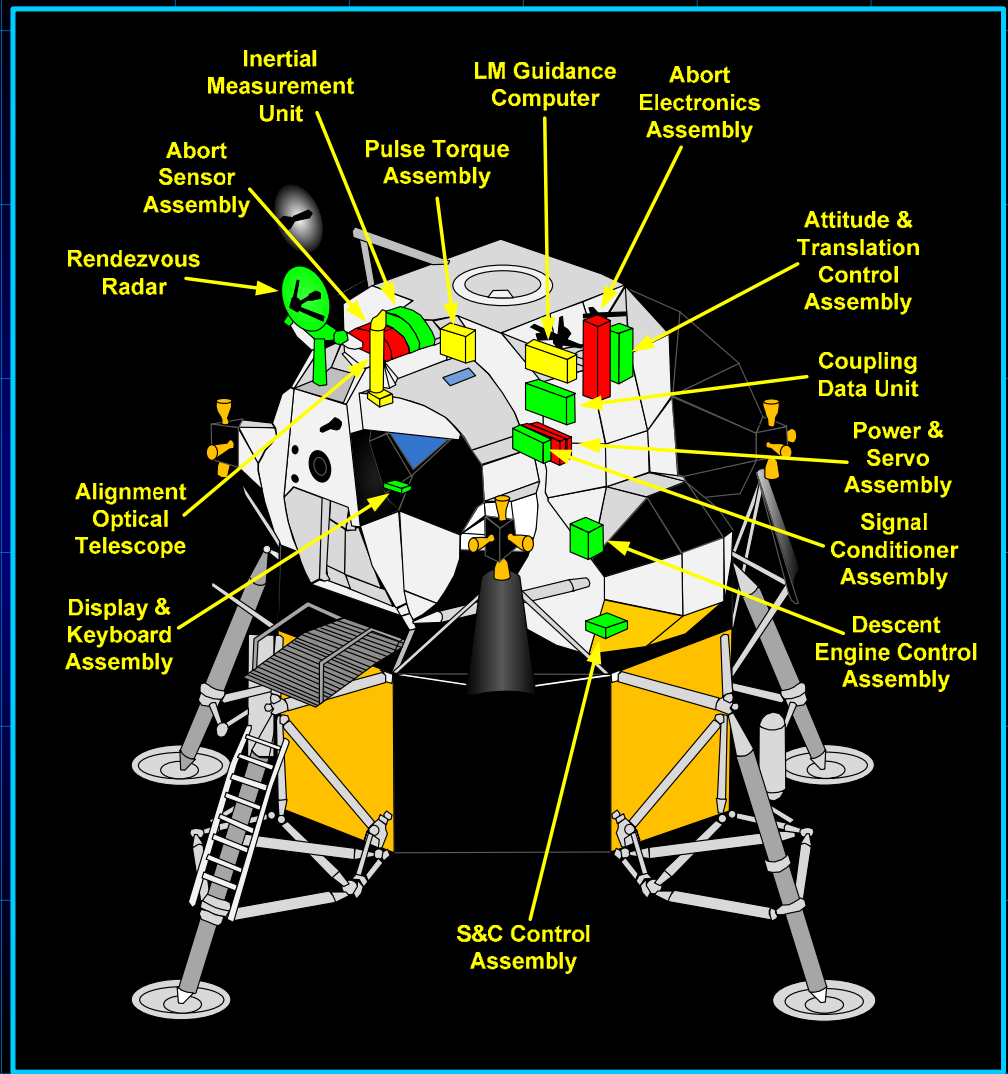
Lunar Model GN&C Avionics

- GNC architects were Milton Trageser & Richard Battin of Draper Laboratory and Robert G. Chilton of NASA Langley.
- Lunar surface transponders were considered as a navigation aid.
- Abort Sensor Assembly (ASA) was a strapdown IMU.
- ASA used a Kalman filter for rendezvous navigation updates.

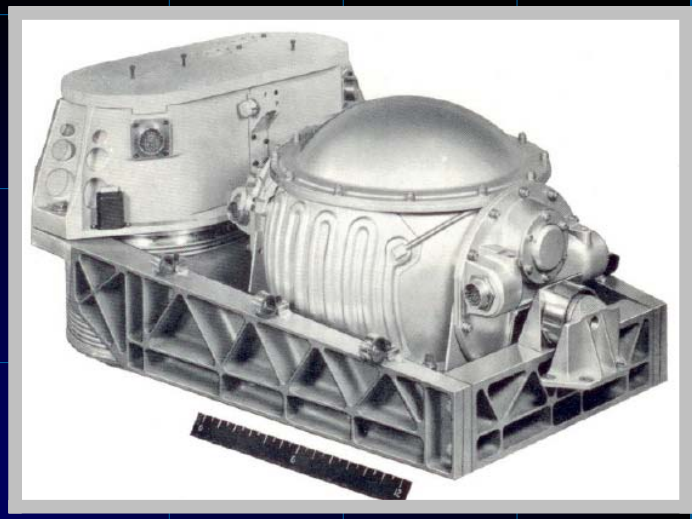


Contractor Roles

- Prime contractor, Lunar Module – Grumman Aerospace Corporation (now Northrop-Grumman)
- Primary Navigation, Guidance, & Control System (PNGCS) – Charles Stark Draper Laboratory
- Abort Guidance System (AGS) – Hamilton Standard and TRW (now Northrop-Grumman)
- Apollo Guidance Computer – Raytheon
- Rendezvous radar – RCA (now GE)
- Landing Radar – Teledyne Ryan (now Northrop-Grumman)
- Alignment Optical Telescope - Kollsman
- Consulting – Bellcom, Analytical Mechanics Associates.

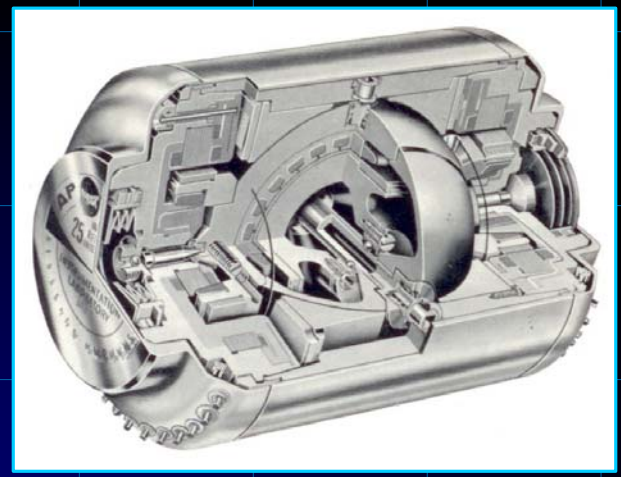
Navigation Base and PGNCS IMU

- IMU derived from Polaris missile program:
  - Strapdown still in laboratory stage, but used for the Abort Guidance System
  - Fourth gimbal removed to save weight
- Same IMU used for Command Module as well.
- Atmospheric entry was driving flight phase for accuracy.
- The system was over-designed for accuracy so as to benefit from the higher reliability of more precise instruments.
- Alignment Optical Telescope & IMU precisely aligned to nav base.



PGNCS IMU Instruments

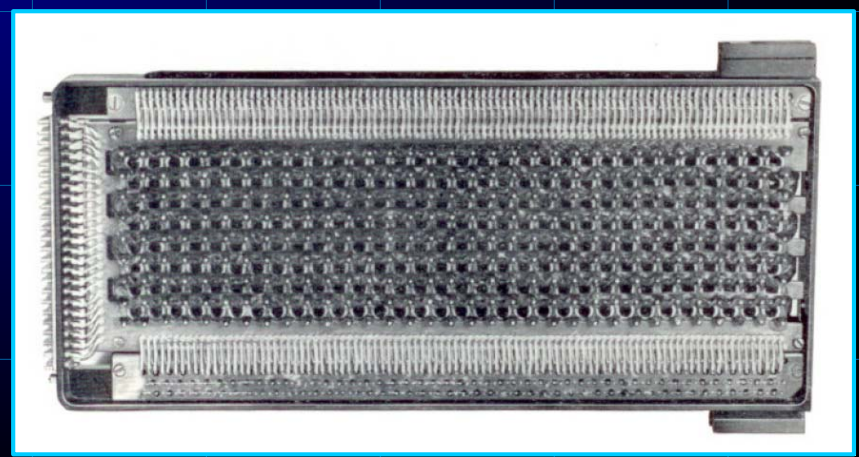
- Gyros – 3 Apollo II Inertial Reference Integrating Gyros (IRIG)
  - Floated
  - Pulse-rebalanced
  - Ducosyn suspension



- Accelerometers – 3 Model D, size 16 Pulsed-Integrating Pendulous Accelerometers

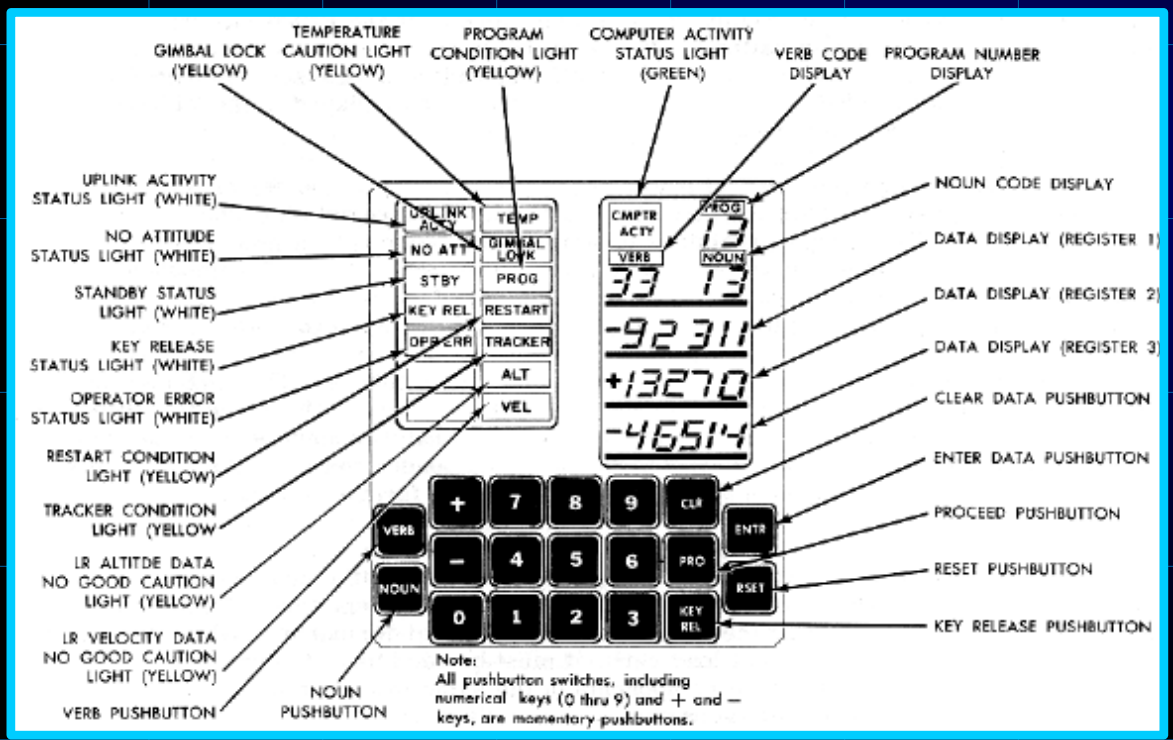
Apollo Guidance Computer (AGC)

- Processor characteristics:
  - 36,864 words “core-rope” ROM
  - 2048 words eraseable memory
  - Data word 16 bits (including parity)
    - *Signed ones-complement*
  - Instruction word:
    - *3 code bits*
    - *12 address bits*
- Program was hard-wired using a special weaving machine.
- CPU used integrated circuit technology



Display & Keyboard (DSKY)

- Primary interface of astronaut with the AGC.
- Each key press causes an interrupt to the processor.
- DSKY uses 100 commands (verbs) with objects (nouns).



- A DSKY simulator can be downloaded from http://www.ibiblio.org/apollo/