

Satellite History and TT&C

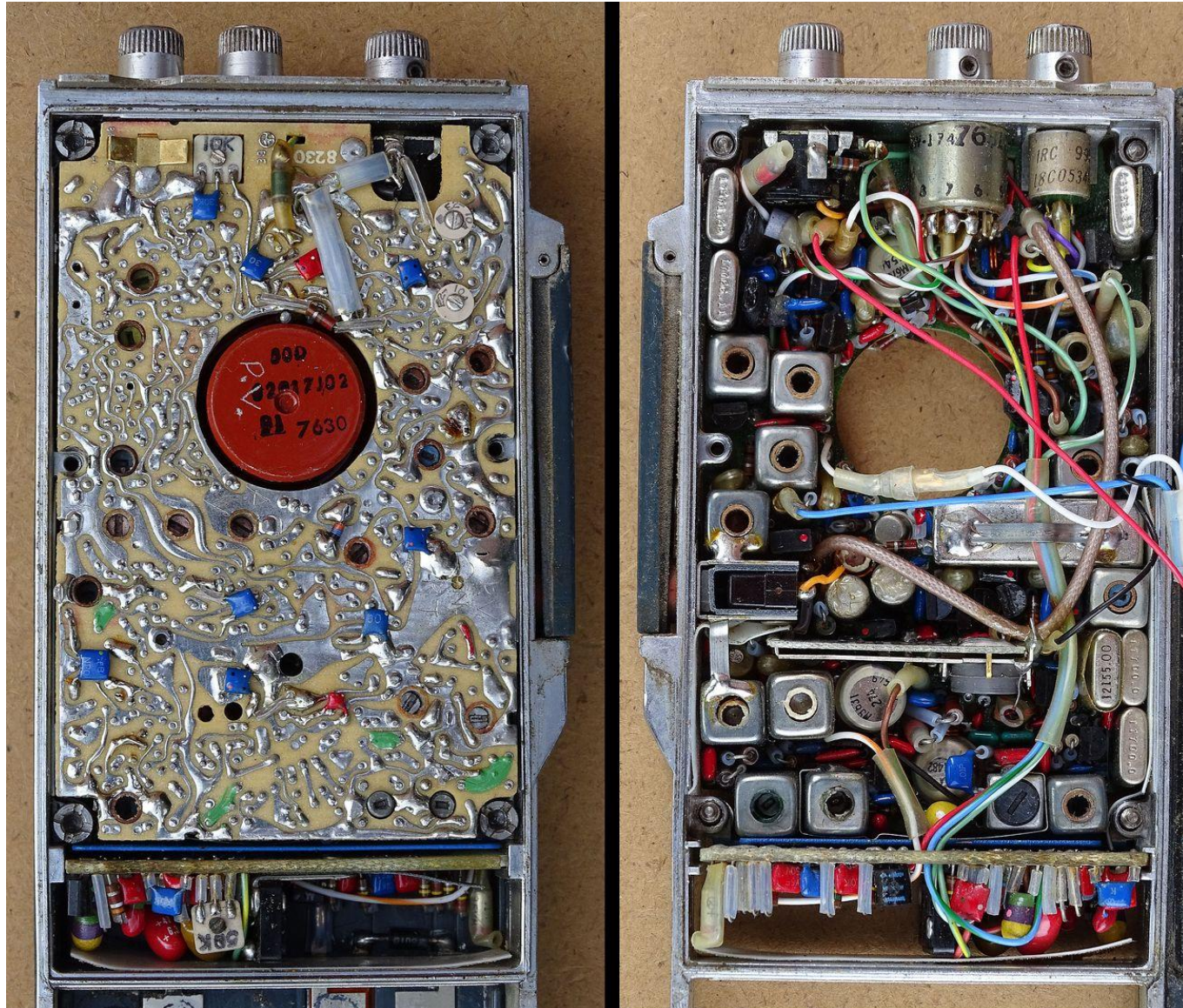
By Phil Cohen WA6BUZ

- Brief Introduction & Bio
- Stations, Lots of Stations
- A Brief History of Early Satellites
- Examples of Geosynchronous Satellites
- Simplified Ground Station
- Satellite Attitude Control and Ranging
- Equipment Examples
- Recovery Missions

Motorola C&E



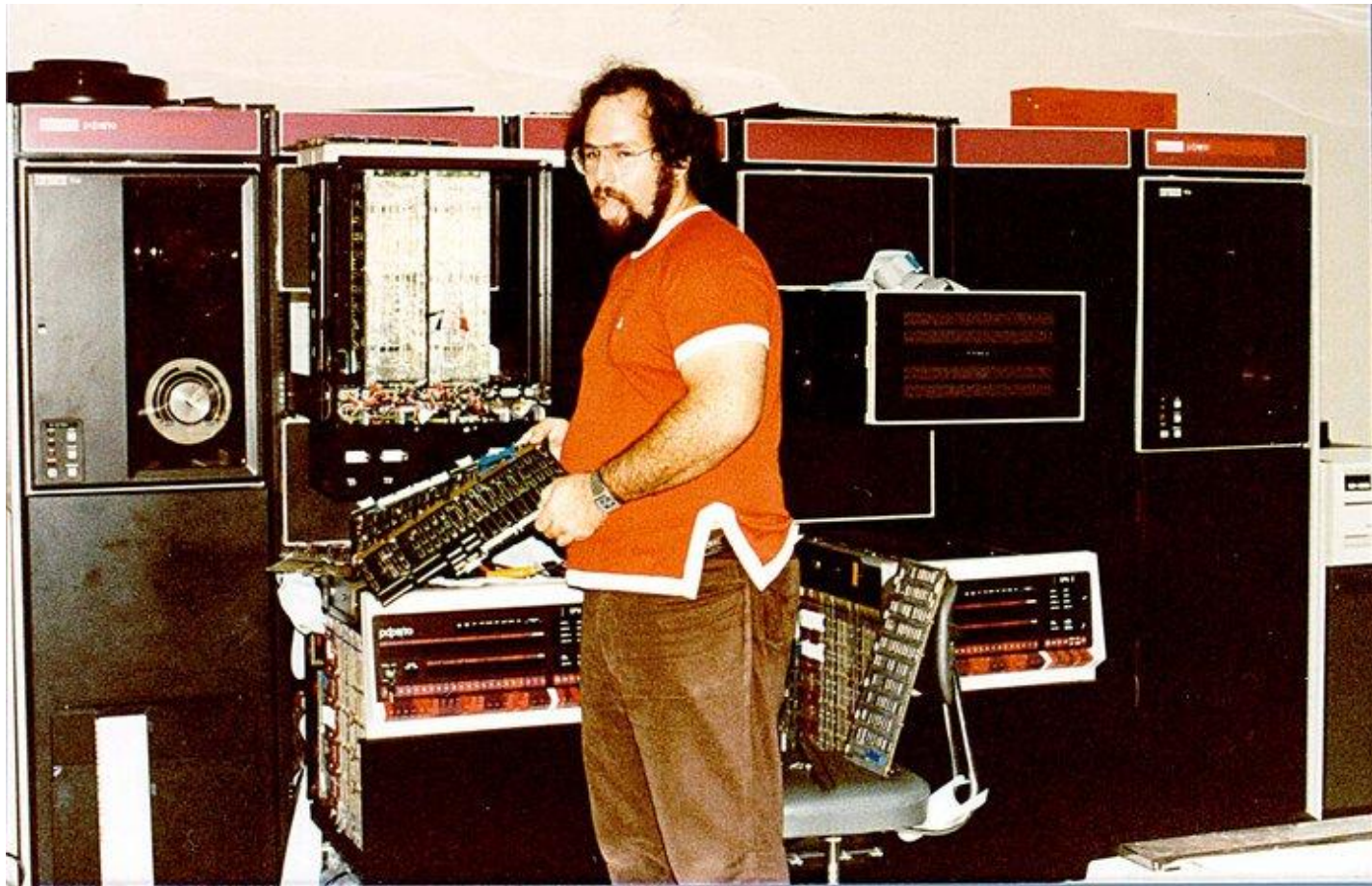
Motorola HT220



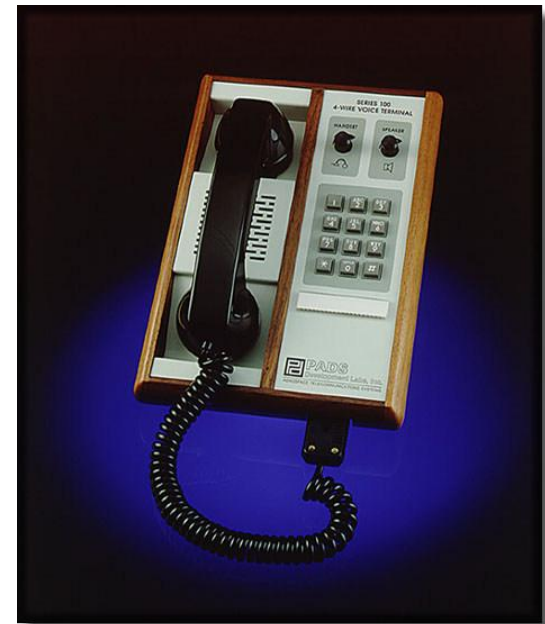
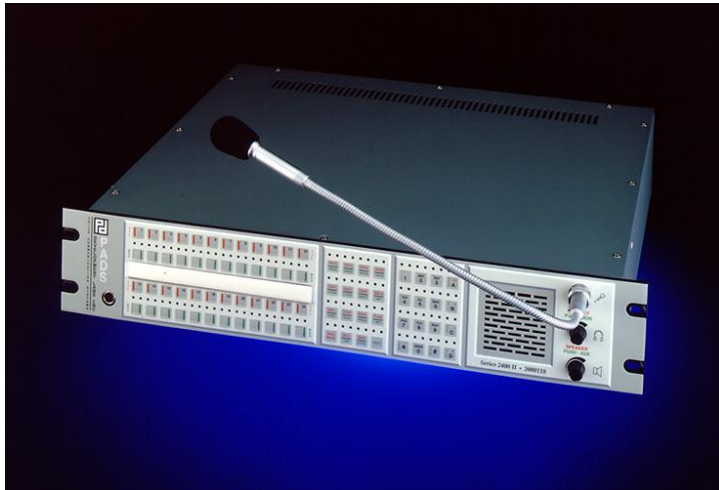
Motorola Mountaintop



Hughes Aircraft Co. Satellite Ground Equipment Lab



PADS Development Labs



Early Passive Satellites 1960-63



Westford Dipole Needles And Needle Dispenser

Project West Ford (also known as **Westford Needles**) was a test carried out by MIT in 1961 and 1963 to create an artificial ionosphere above the Earth.
480,000,000 copper dipole antennas!



Early Passive Satellites 1960



Echo 1 Balloon and Launcher



Echo Satellite and Station



Early Active Satellites



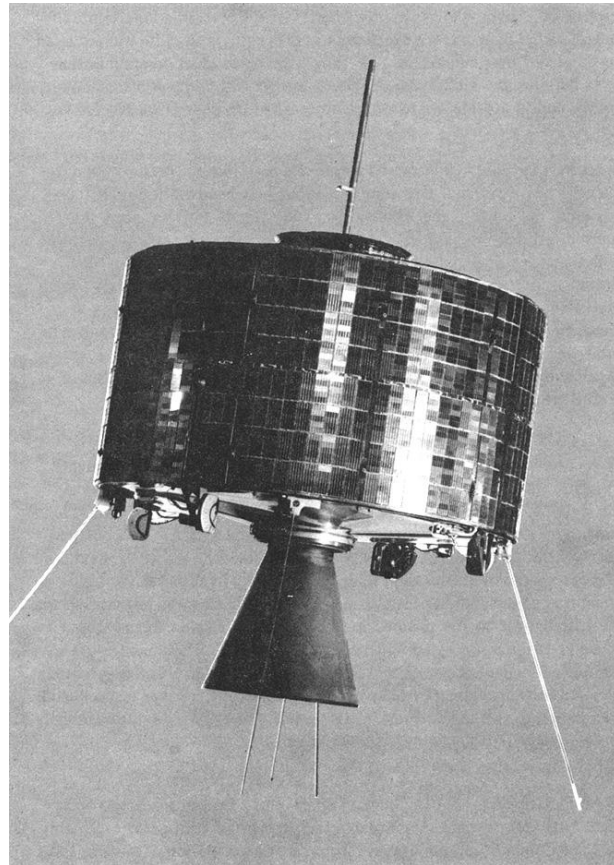
Courier 1 1960
First Active Repeater Satellite



Telstar 1 1962

Geosynchronous Satellites

- Syncom 1 – 1961



Hughes HS-333 Satellite

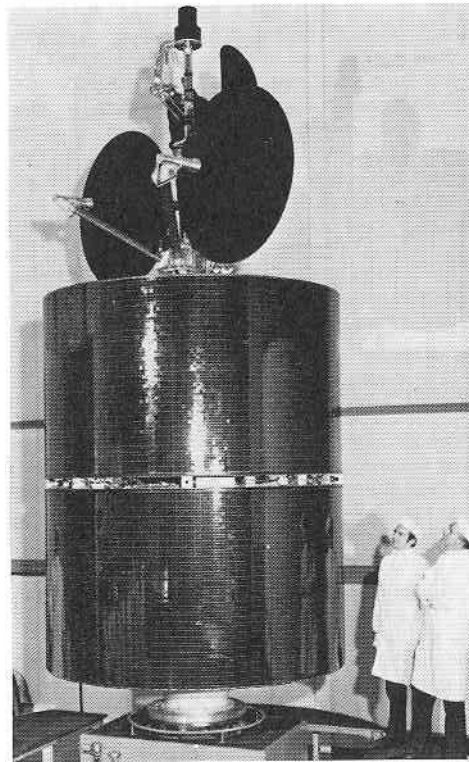


Westar – Anik A – Palapa

Getting Bigger

- Intelsat IV

Left Intelsat 4 (F4) *Right* Intelsat 4A



And Bigger

- TACSAT

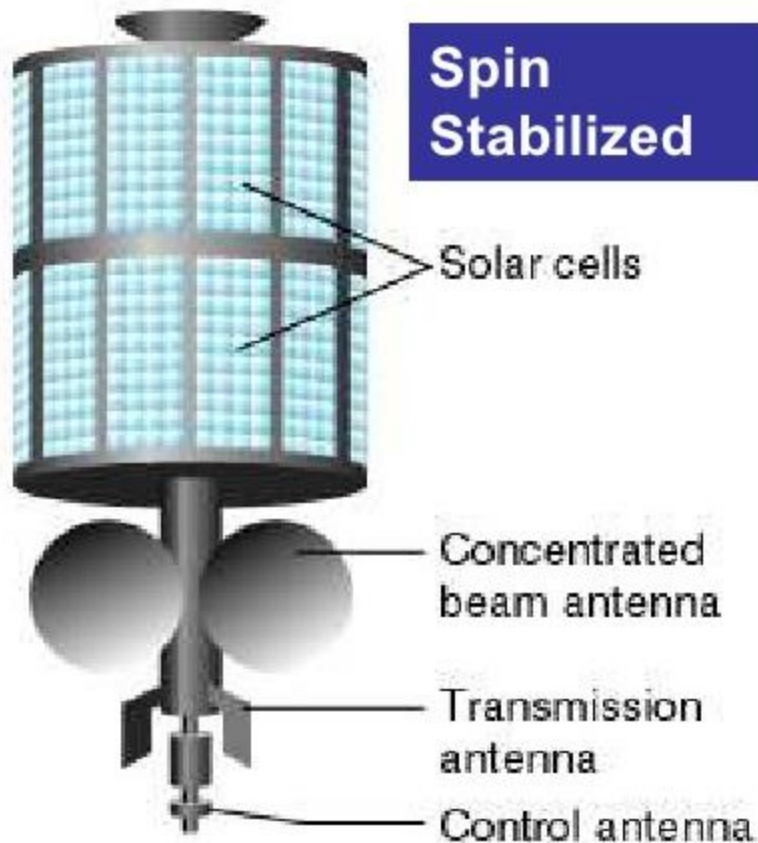


And Really Big!

- Intelsat VI

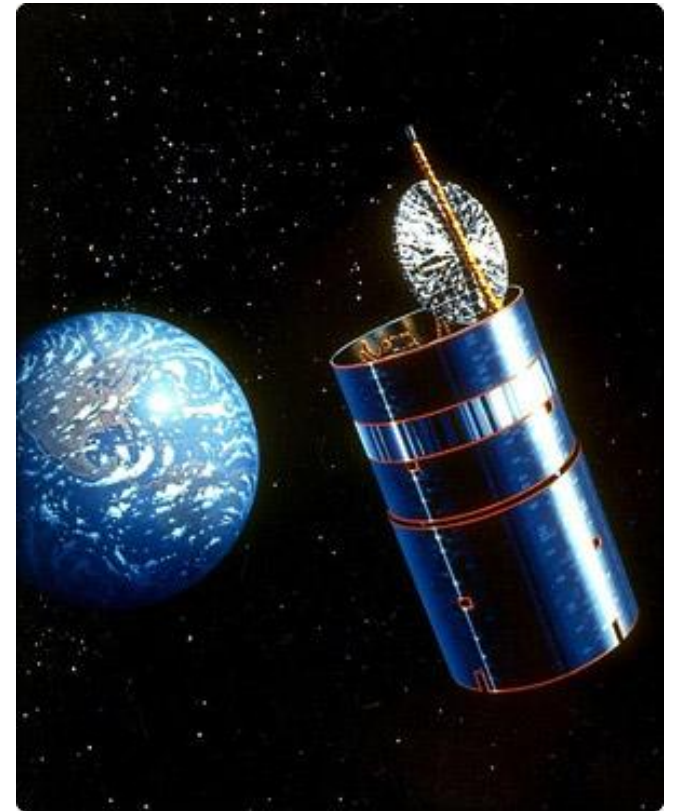
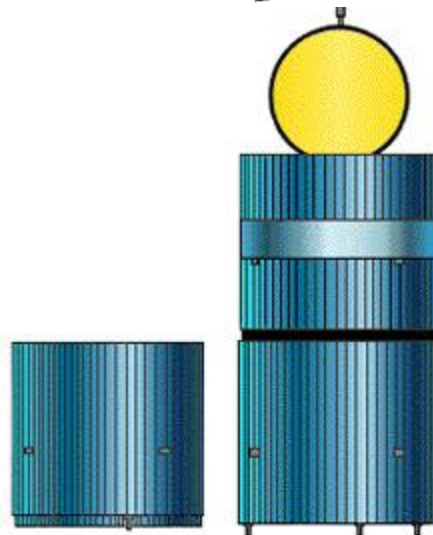
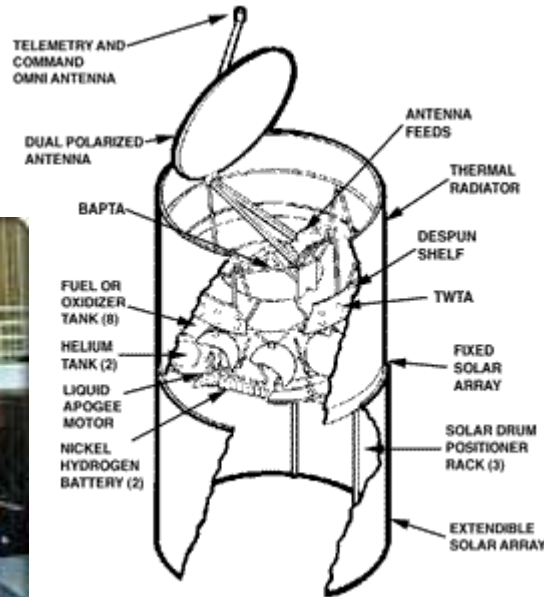


Spin Stabilized



- ❑ **Satellite Body is Spin Stabilized (60-100 RPM)**
- ❑ **Gyroscopic stability**
- ❑ **Spins to minimize thermal effects**
- ❑ **1/2 the solar cells face the sun at one time**
- ❑ **More efficient for smaller satellites**
- ❑ **Antenna must de-spin -**

Spinning & Despun Sections

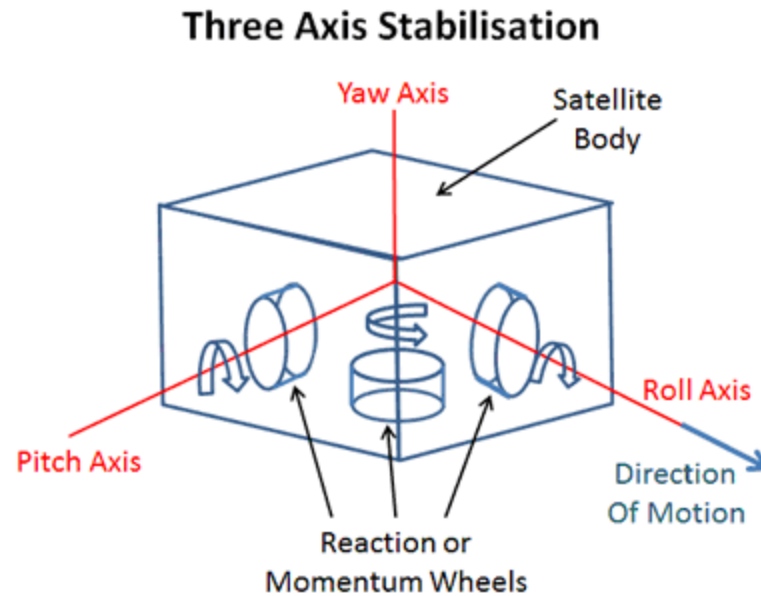


And Wings!

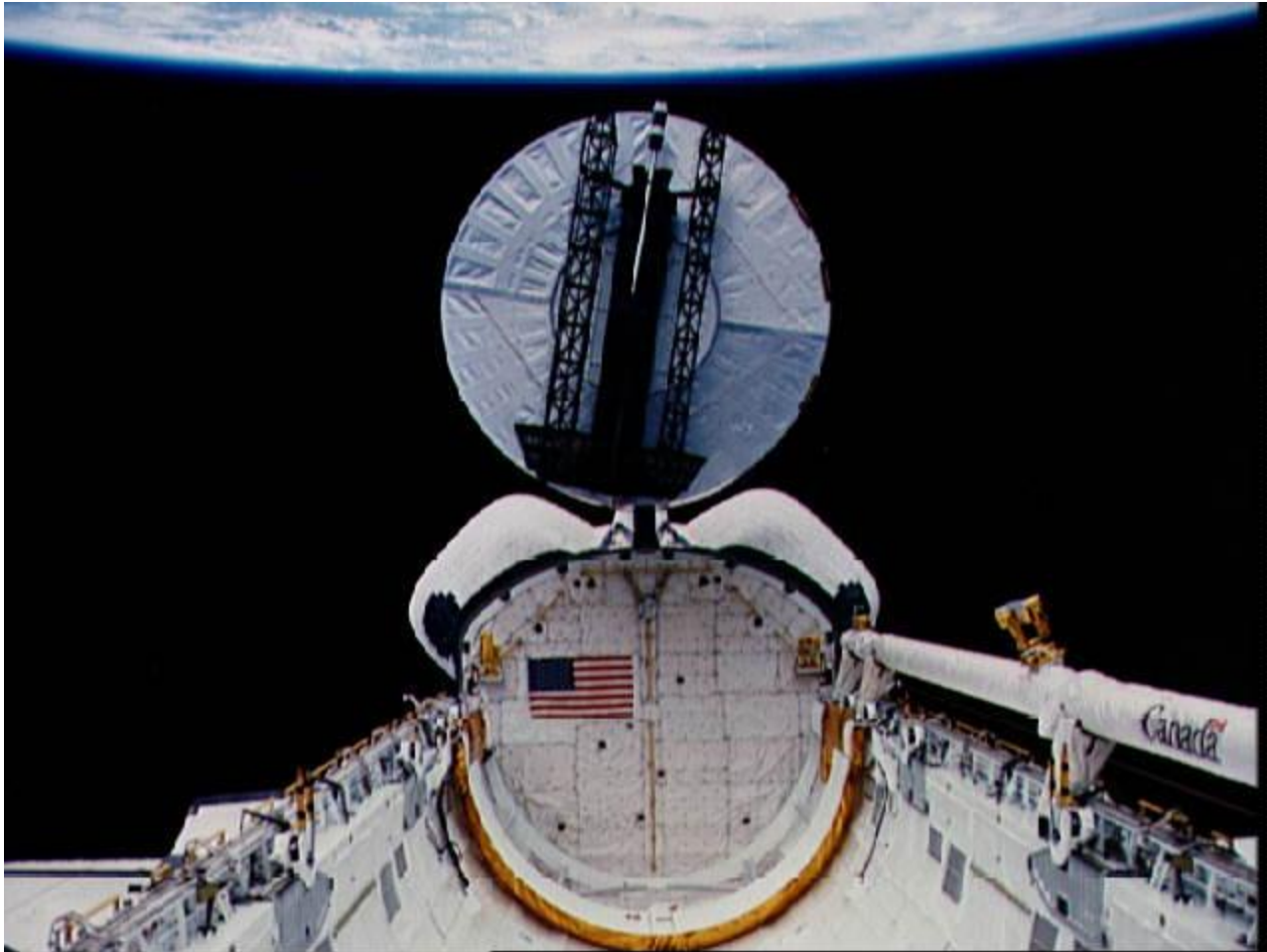
- PanAmSat V



3 Axis Stabilized

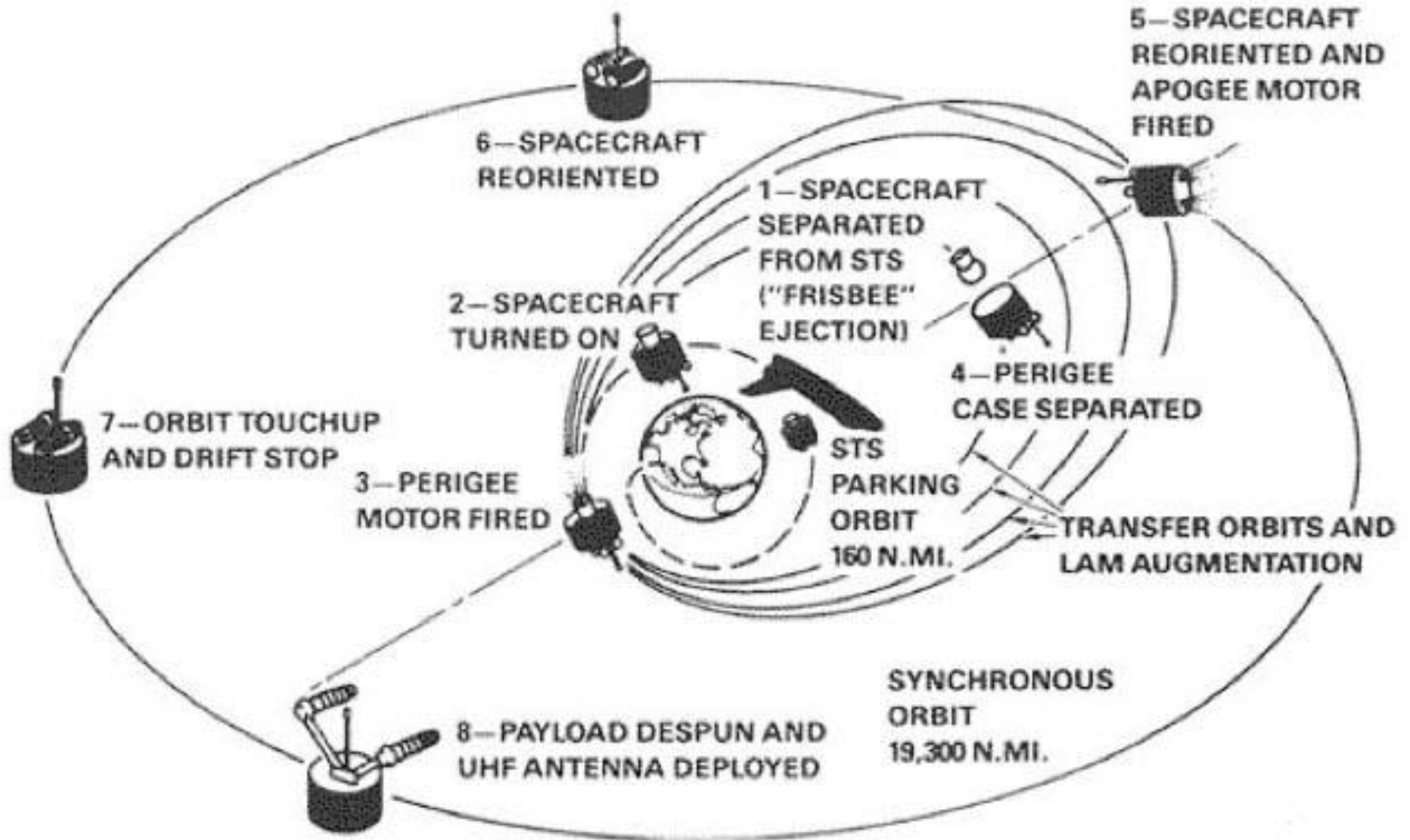


Leasat Deployment



Giant Frisbee

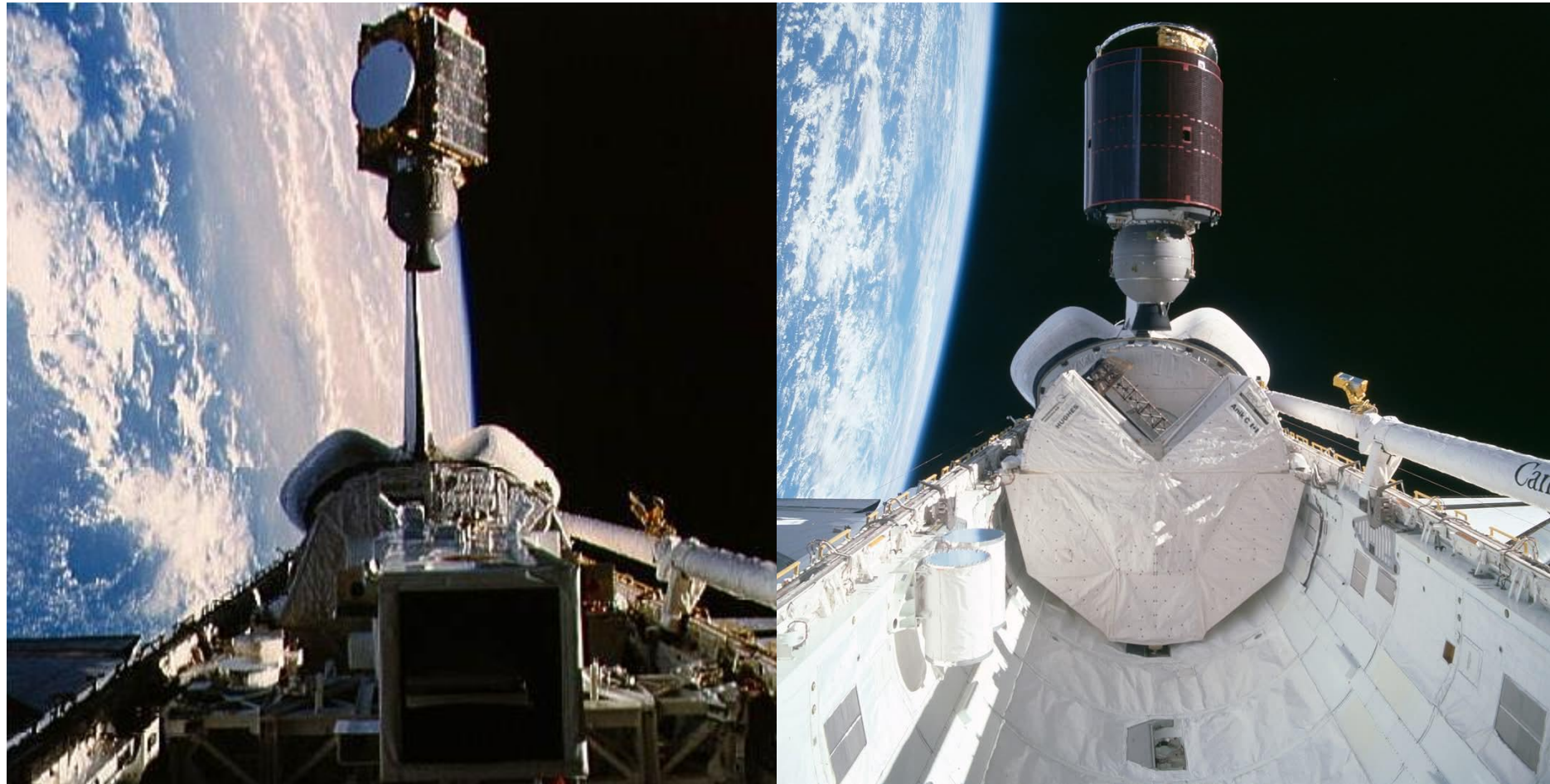
Leasat Launch From Shuttle



Leasat On Station



Spinning Satellite Deployment



What's Behind That Dish?



Cibinong Indonesia



Fillmore, California



Ft. Stanley, Hong Kong



Jatilahur, Indonesia



Telesat Canada



Guaratiba, Brazil



Daan Mogot, Indonesia



Fucino, Italy



Full Motion Antenna Types



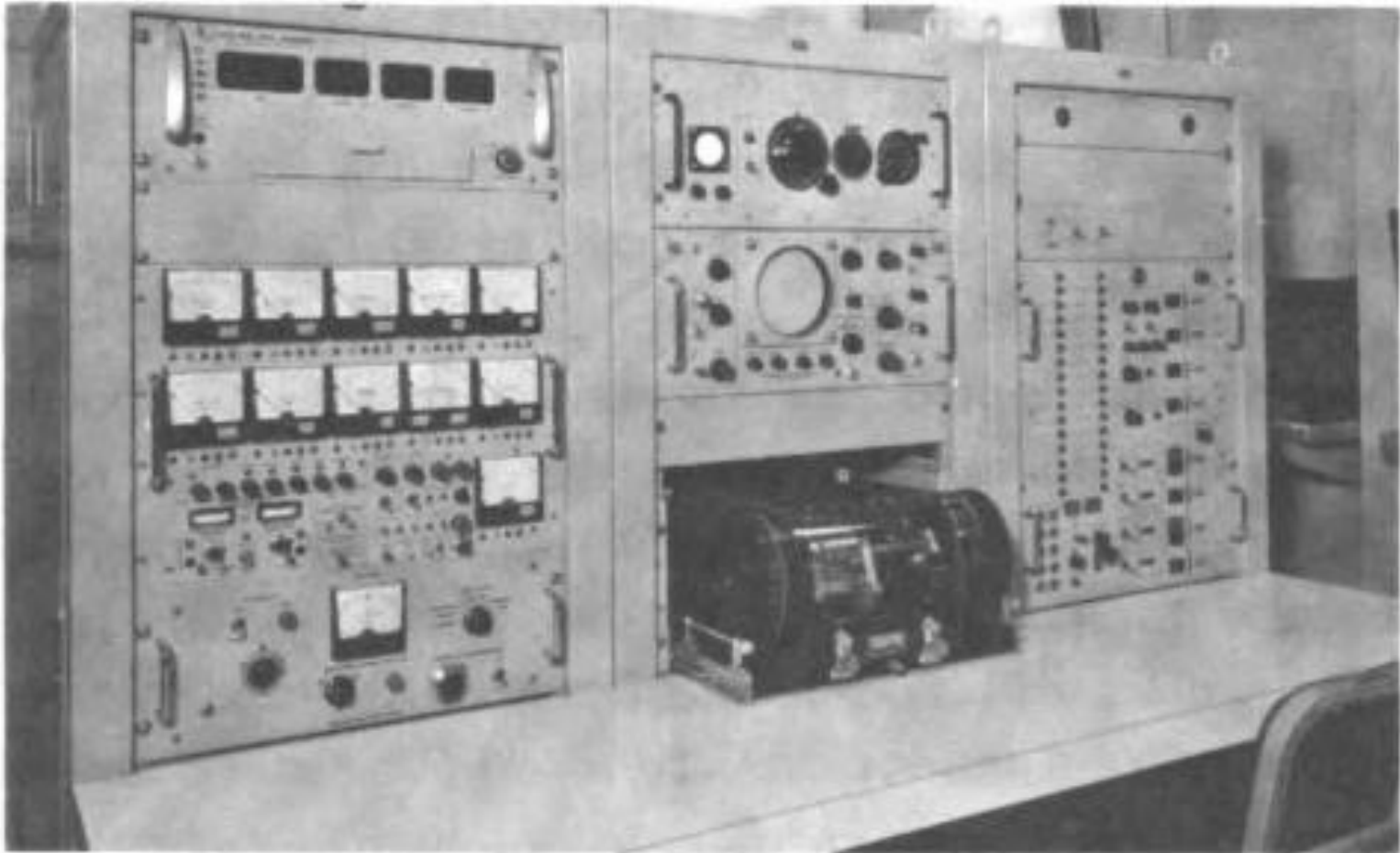
X-Y Type



Az – El Type

An Inside Look at TT&C

- **Original Syncom Command & Telemetry 1961**



SYNCOM telemetry and command system control console.

Daan Mogot 1992

- Palapa C Command and Control



Daan Mogot RF Racks



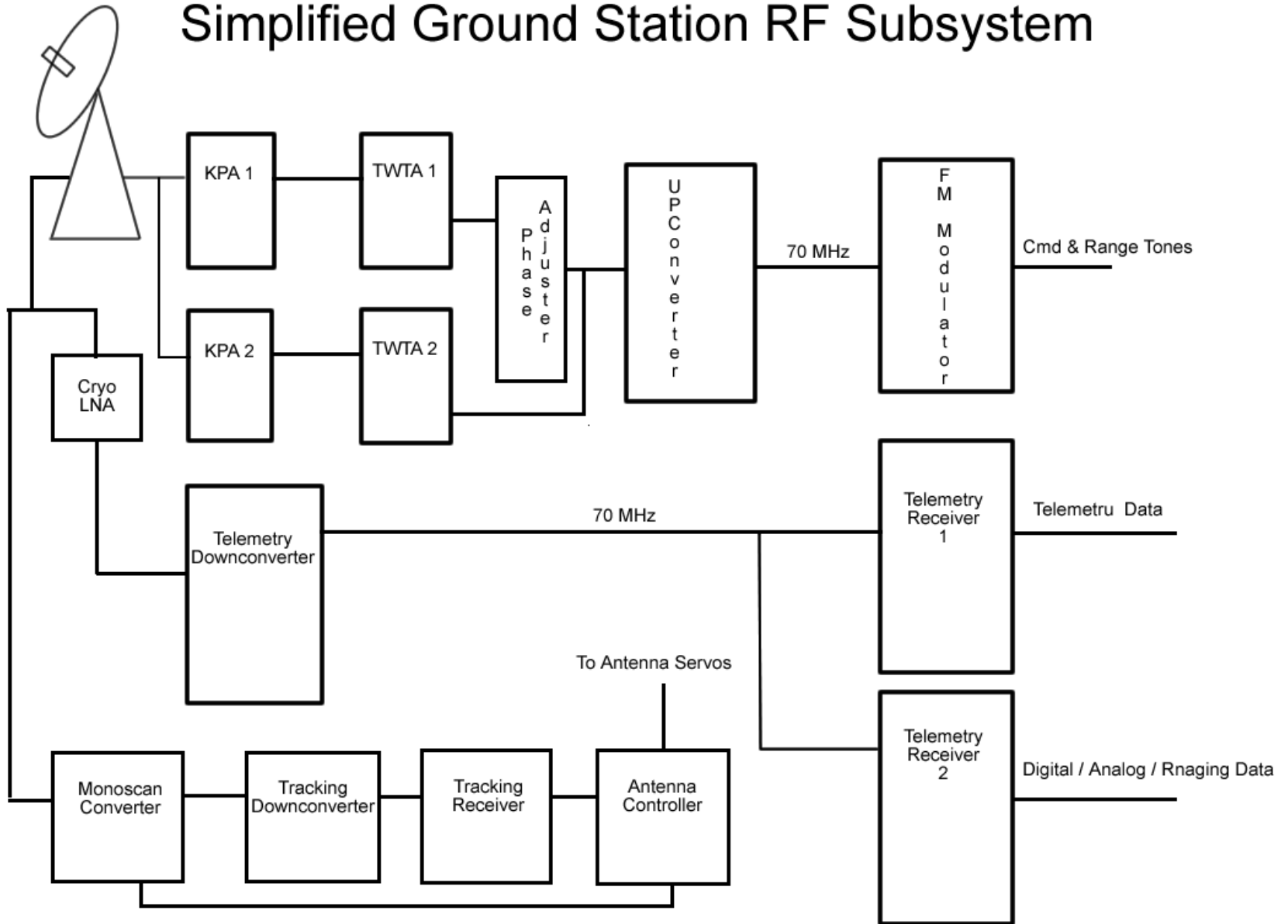
Ft. Stanley RF Racks



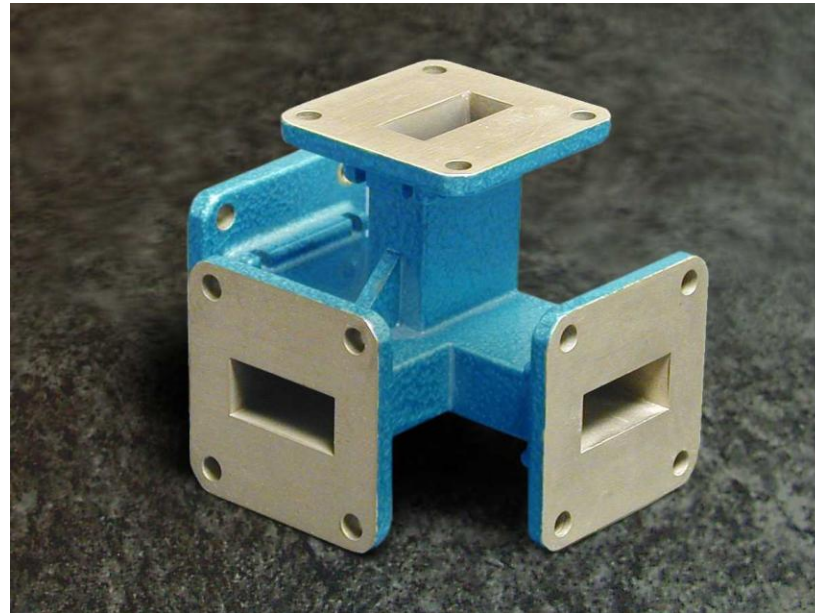
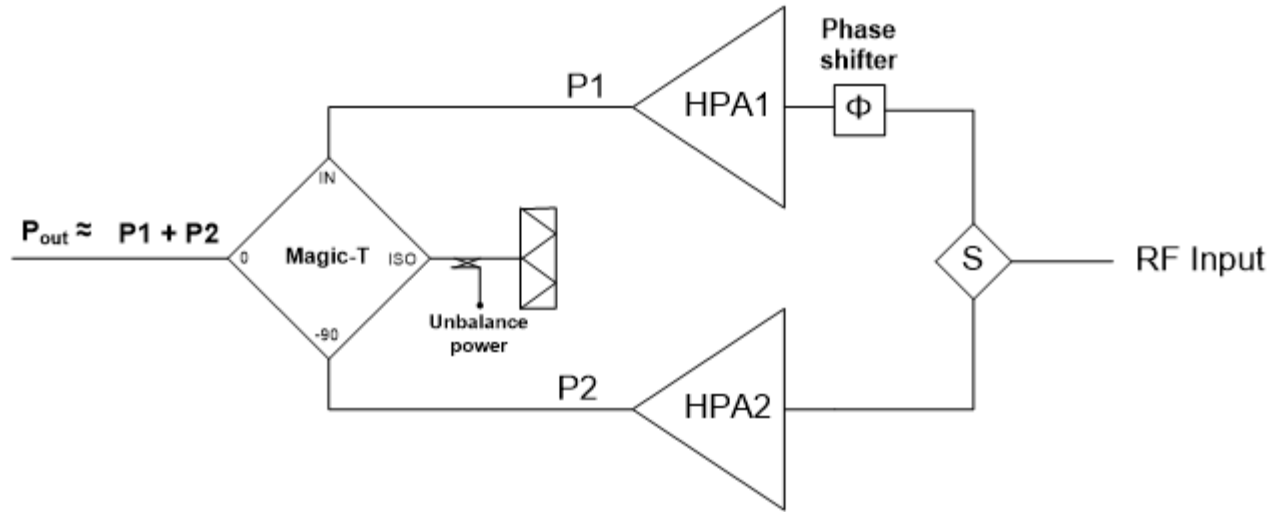
Ft. Stanley RF Switching



Simplified Ground Station RF Subsystem



Phase Combined Uplinks



FM Data Detector



Synchronous Command Gen



1KBS NRZ M PCM Data

Voltages

Attitude Data

Temperature

Antenna Pointing Data

CS Switch Settings

Despun Rate

Command Verification

Battery Pressure

Code	Code Waveforms	Code Definitions
Value	1 0 1 1 0 0 0 1 1 0 1 0	
NRZ-L		1: is 'high' 0: is 'low'
NRZ-M		1: is a change 0: is no change
NRZ-S		1: is no change 0: is a change
Bio-L		1: 'high' to 'low' 0: 'low' to 'high'
Bio-M		1: no change at start of period 0: change at start of period
Bio-S		1: change at start of period 0: no change at start of period

PCM Decom & Frame Synch



Range Tone Processor



Satellite 4 Tone Ranging

Range Tone Frequencies

Minor Tones:	54.25 Hz	5,529,953.92 meters (3436 miles)	1536 meter accuracy
	434 Hz	691,144.24 meters (4294 miles)	192 meter accuracy
	3472 Hz	86,405.53 meters (54 Miles)	24 meter accuracy
Major Tone:	27777 Hz	10800 meters (6.7 miles)	3 meter accuracy

Starts with a range estimate, how many cycles or what part of a cycle of each frequency at a given time and projected forward by the estimated speed of the spacecraft.

Each of the minor tones is sent, from lowest to highest and the phase of that tone is measured, the initial distance is calculated based on the first tone, and how many cycles of the next tone. The second tone is then measured to give a finer distance, etc. This process is called initial ambiguity check.

The final range is then calculated by measuring the Major tone and tracking the phase measurements across a given time period 20 measurements are made per second at a given rate and the range and speed is calculated, at the time of ranging the antenna azimuth and elevation information (.001 degree increment) are also attached to the phase angle measurement which will be used to compute the orbit of the spacecraft.

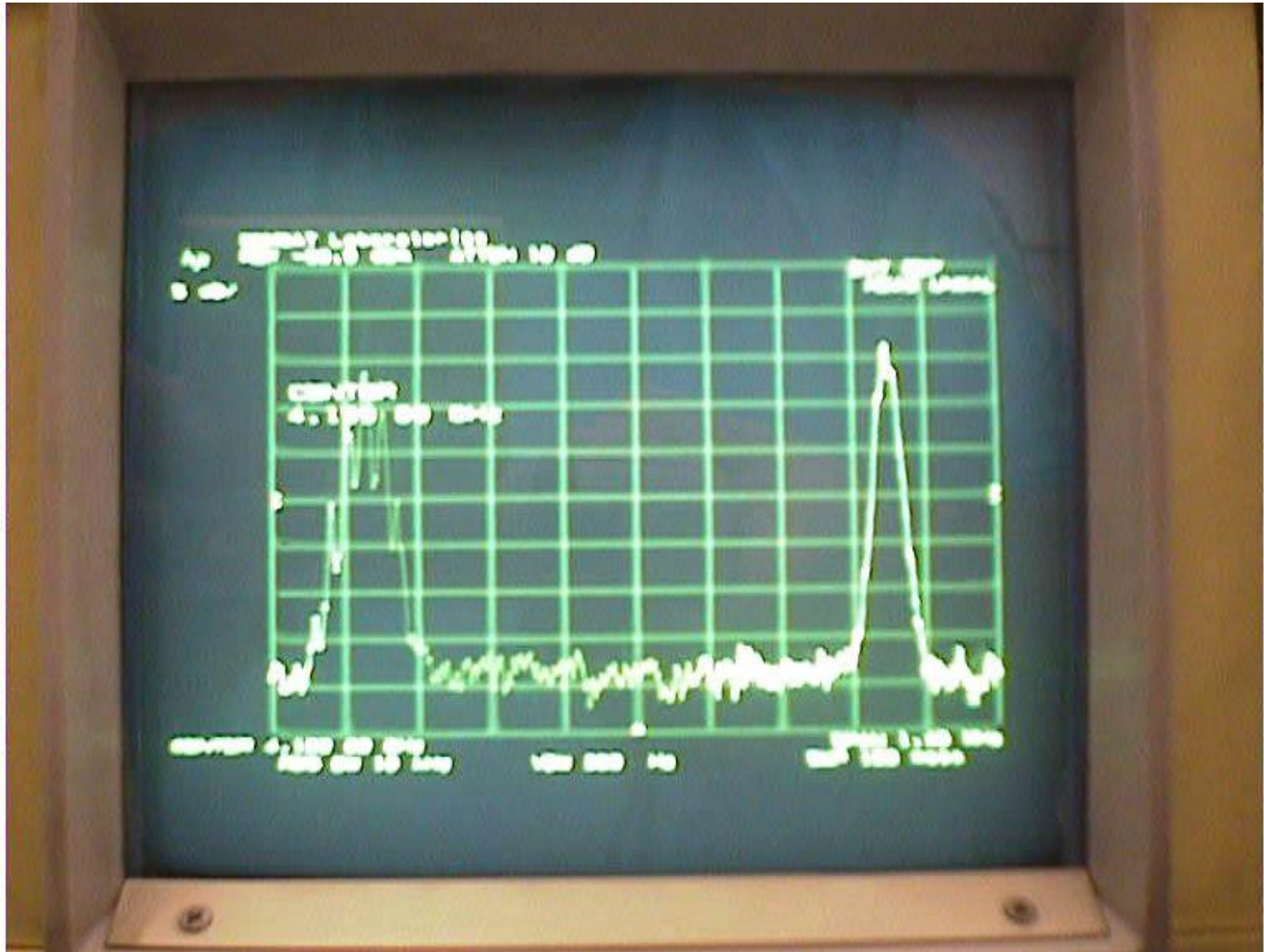
After 5 minutes or so of collecting ranging data the tones are stepped through downward in frequency this time and based on the range and range rate the minor tones are tested to see if their phase angle is within the margin of error. This is called final ambiguity check. If this is successful, the ranging data is passed on to the orbital estimator program.

The accuracy of this method of ranging is approximately 3 meters at a distance of 22,300 miles or more. We used this system to range to the spacecraft as it approached the moon at a distance of over 180,000 miles, numerous cycles of the lowest tone. The ranging estimator was not written for this great distance so I ended up writing a program for my HP calculator to figure out the estimated range and phase angles and manually entering them into the computer ranging program.

Telemetry & Tracking Receiver

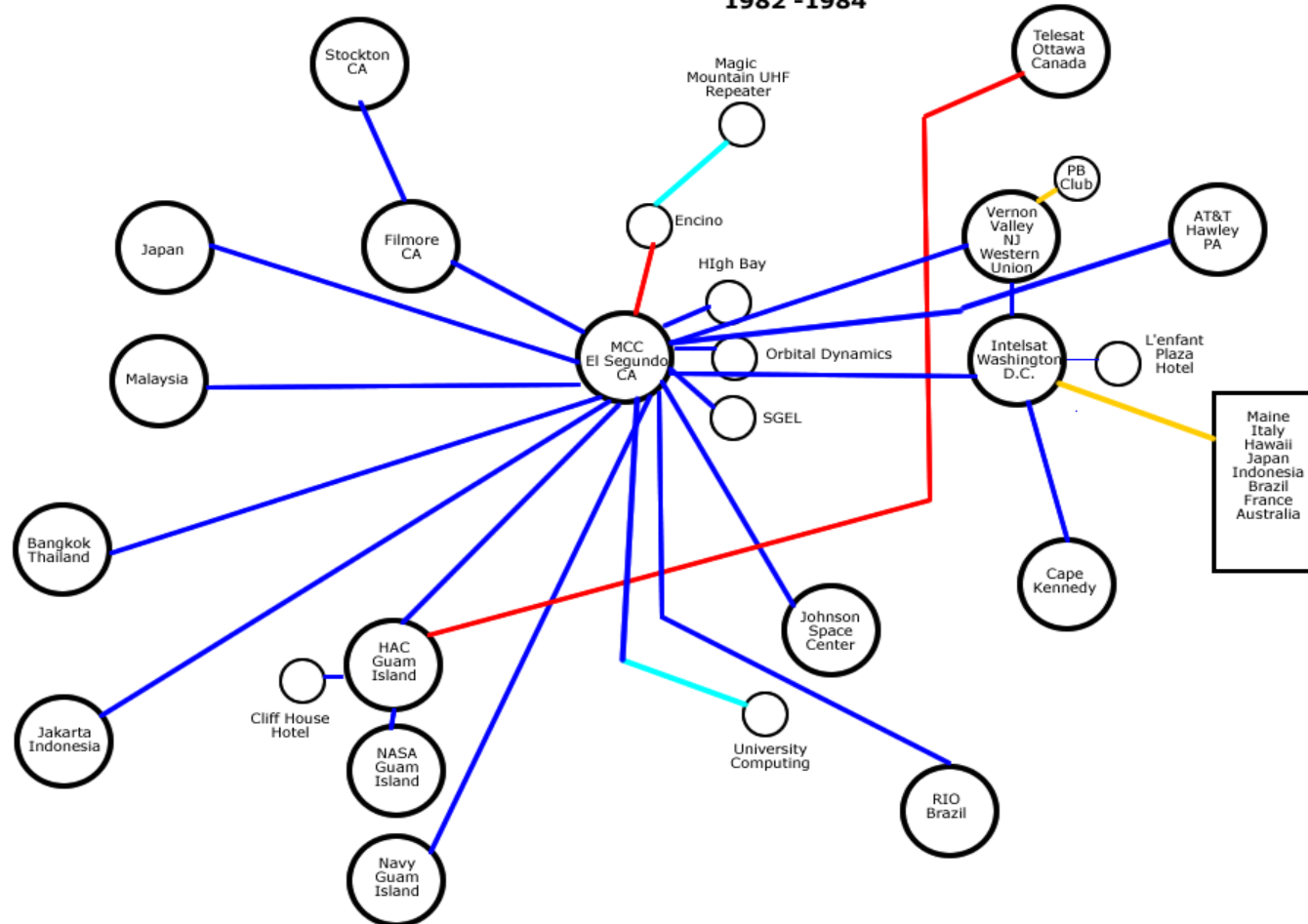


Satellite Telemetry Beacons



Launch Operation Network Pre-Internet

WAGBUZ International Launch Network
1982 - 1984



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Westar 6 Palapa B Rescue



HS-376 Recovery



Used Satellites For Sale



For Sale Cheap!



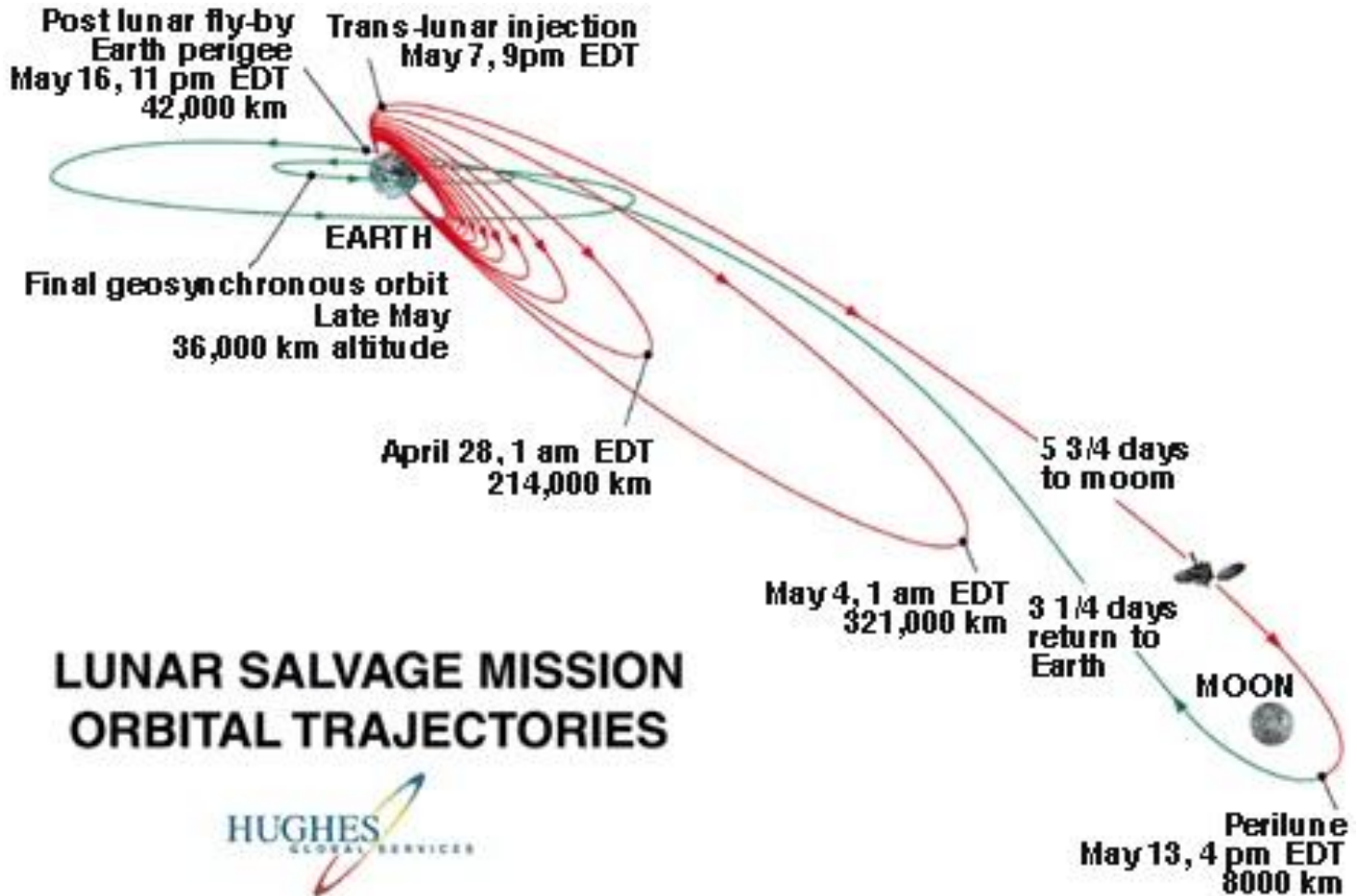
Ready for Ebay



Proton Rocket



Lunar Fly By Recovery



Lunar Fly By Asiasat 3



The Night of the Fly By



Fun Times on the way to work



So I Flew Home



Greeted by my Employees

