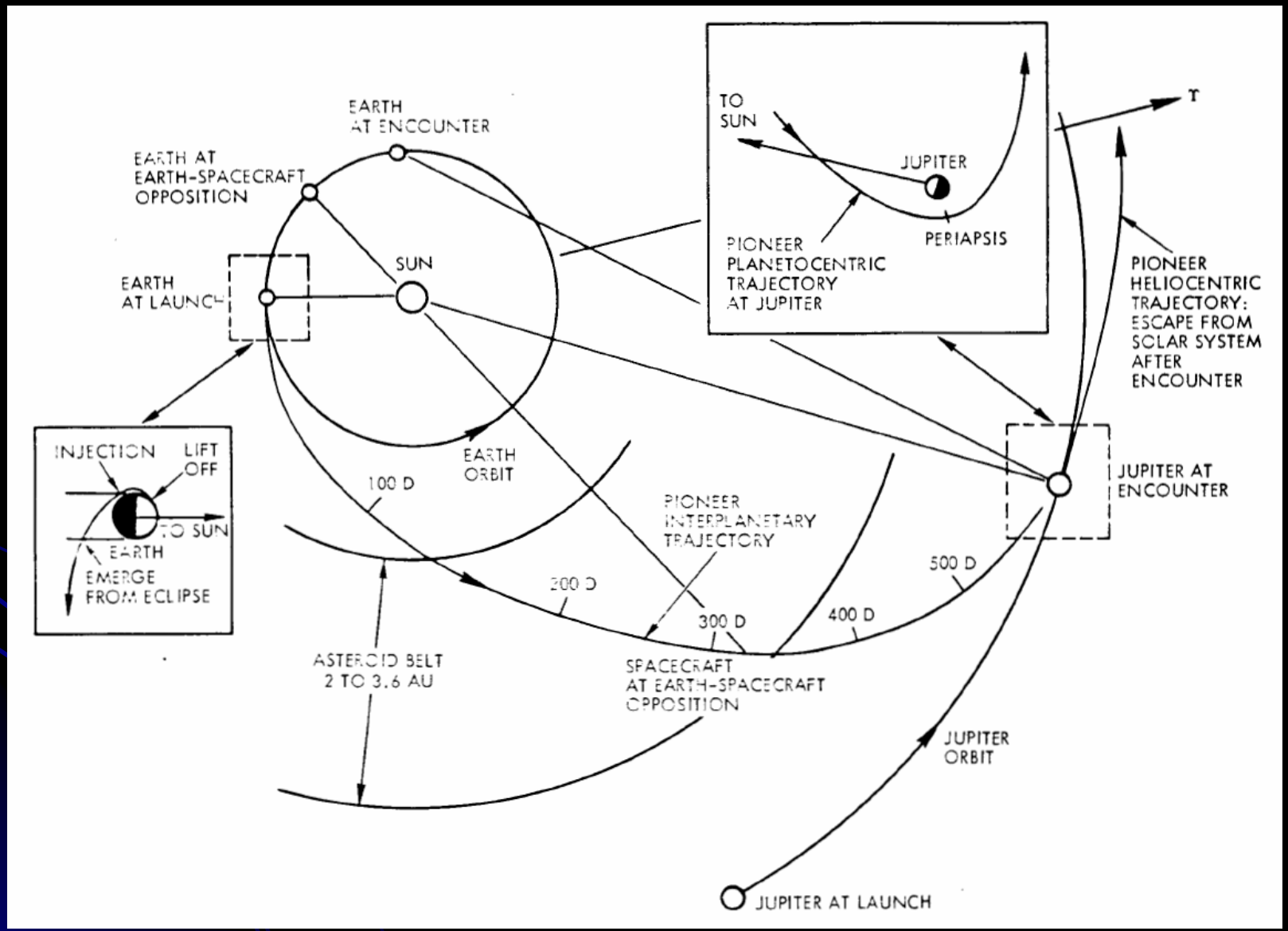
Pioneer 10/11

Spacecraft and subsystems

Overview

- Primary mission
  - Exploration beyond Mars orbit
  - Exploring the asteroid belt
  - Flyby observations of Jupiter
  - 600-900 days primary mission duration
- Initial mass: ~250 kg
- Spin-stabilized: 4.8 rpm (nominal)
- Powered by RTGs

Nominal Mission



Mission Phases

- Launch vehicle: Atlas/Centaur
  - Pioneer-10 launch: March 3, 1972
  - Pioneer-11 launch: April 6, 1973
- Powered flight: 13 minutes 44 seconds
- Post Injection: despin, booms, orientation
- Flight
- Encounter
- Post-encounter

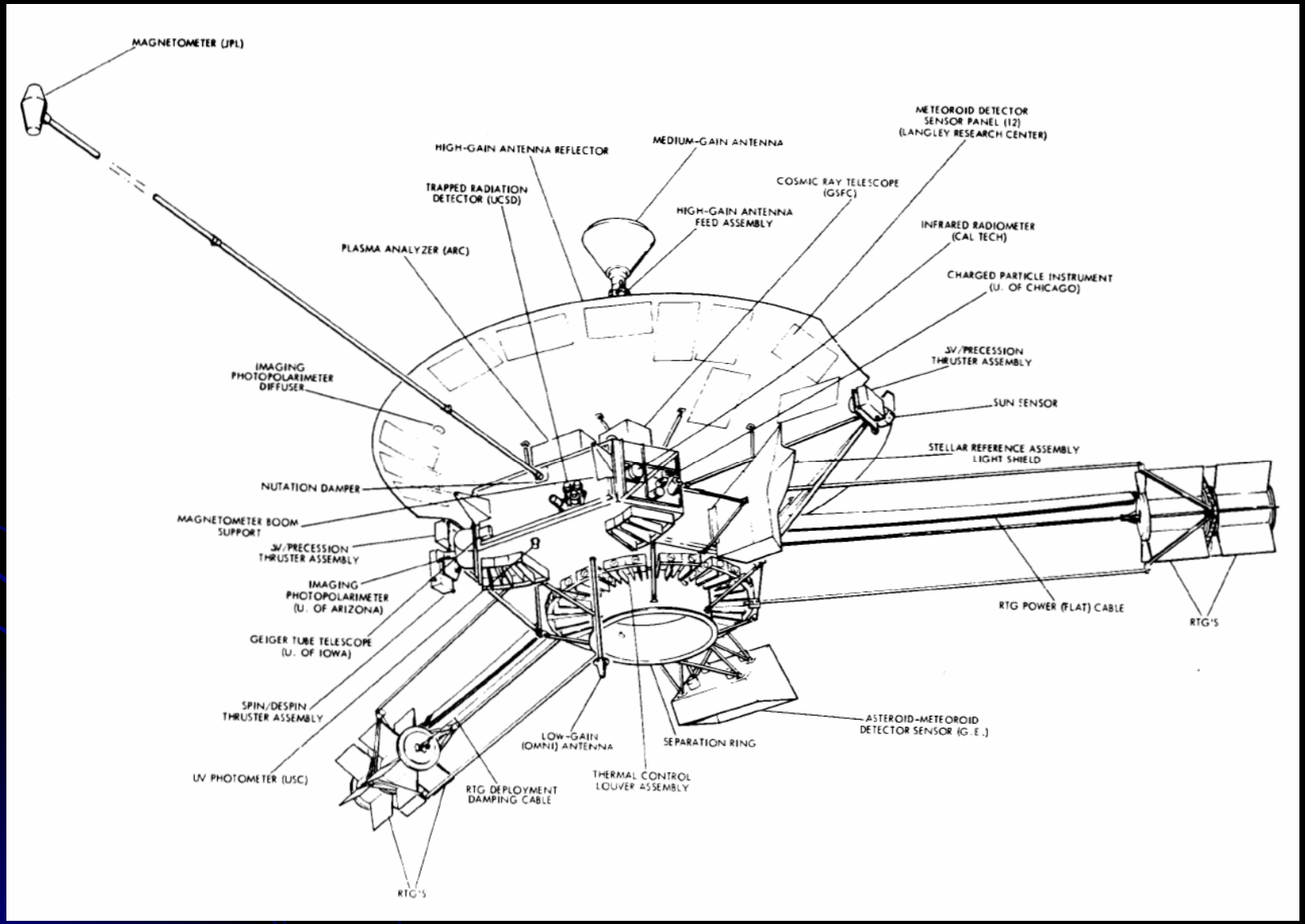
Operating Modes

- Initial Operations
  - Spacecraft spin rate
  - Orientation
  - Calibration of precession thrusters
- CONSCAN
- Midcourse Maneuvers
- Trim Maneuvers

Physical Description

- HGA: 3-meter reflector
- Equipment compartment behind HGA
  - Temperature control
  - Micrometeoroid protection
- Six one-lb hydrazine thrusters
  - Four parallel to spin axis
  - Two tangential, for spin rate control
- Three appendages: RTGs, magnetometer

Physical Description



Capabilities and Limitations

- Communications
  - HGA effective power: 70 dBm
  - Beamwidth: ~3.3° (~3.5° uplink)
- Propulsion
  - Propellant: ~27 kg
  - Despin capability: ~58 rpm
  - Spin control: ~ 14 rpm
  - Precession: 1250°
  - Δv: 200 m/s

Capabilities and Limitations

- Power
  - 4 RTGs @ 39.2W each at launch
  - ~35W at Jupiter encounter
  - Main bus: 28VDC @1%
  - Battery (load sharing): 9x5Ah AgCa
- Data
  - Downlink bit rates: 16 - 2048 bps
  - 49152 bits on-board storage
  - Timing and control
  - Commanding

Science Instruments

1. JPL Helium Vector Magnetometer
2. ARC Plasma Analyzer
3. U/Chicago Charged Particle Experiment
4. U/Iowa Geiger Tube Telescope
5. GSFC Cosmic Ray Telescope
6. UCSD Trapped Radiation Detector
7. UCS Ultraviolet Photometer
8. U/Arizona Imaging Photopolarimeter
9. CIT Jovian Infrared Radiometer
10. GE Asteroid/Meteoroid Detector
11. LaRC Meteoroid Detector
12. Flux-Gate Magnetometer (Pioneer-11 only)

Mechanical Design

- Internal Configuration
  - Hexagonal equipment section
  - Rectangular experiments section
- External Configuration
  - Instrument detectors
  - Booms
  - Mechanisms: Wobble damper, deployment dampers, feed movement, cutters, latches
- Mass properties
  - Deployment in XZ plane
  - Principal axis remains parallel to centerline
  - Expending propellant introduces rotation in XZ plane

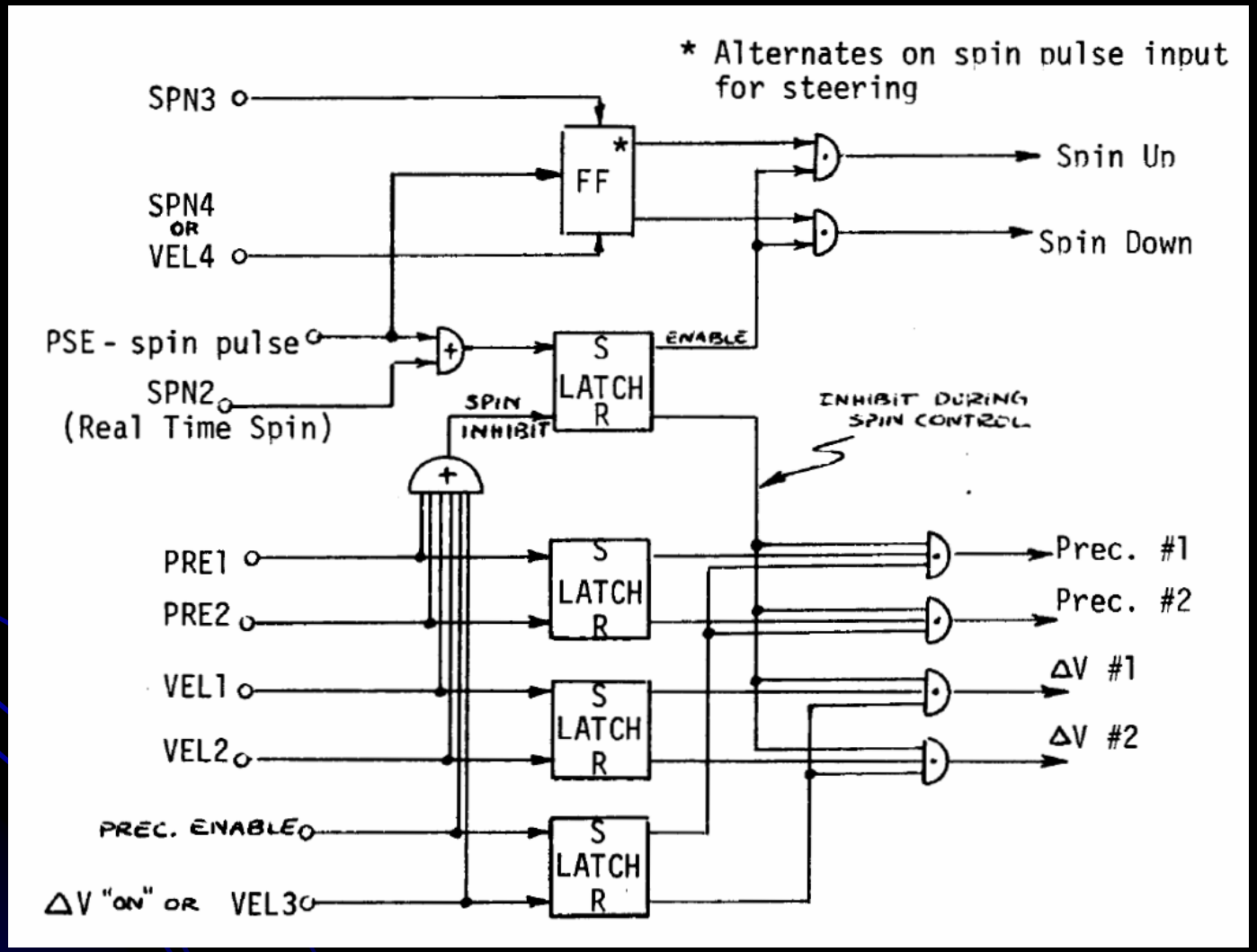
Thermal Control Subsystem

- Insulated equipment compartment
- Aft mounted louver system
  - Bimetallic springs
  - Louver angle (0-90°) for T=40-90°F
- Exterior radiometric properties documented
  - General description
  - Solar absorptance (0.21 for HGA +Z)
  - Emittance (HGA +Z: 0.85, HGA –Z: 0.04)

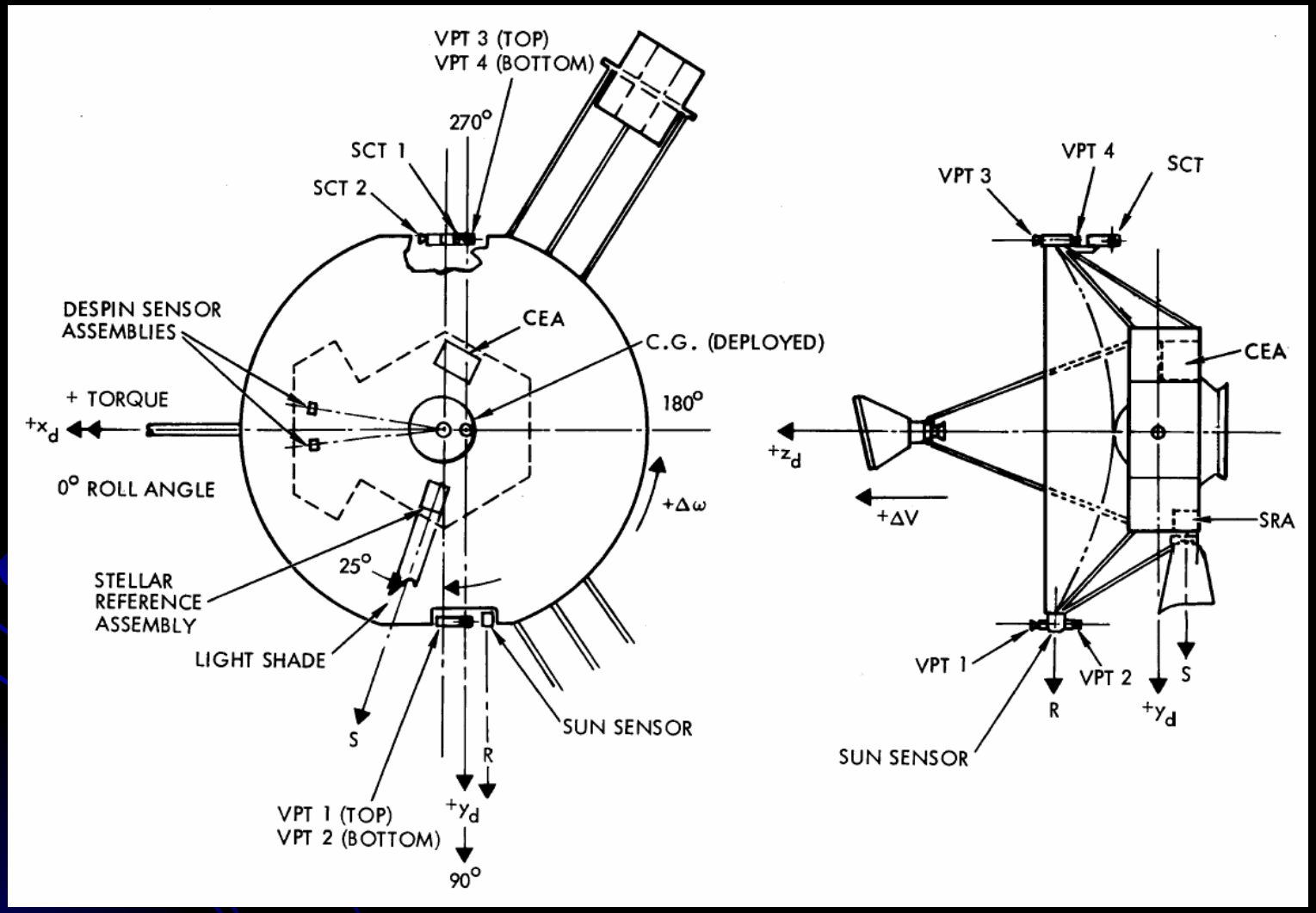
Attitude Control Subsystem (ACS)

- Control electronics (Program Storage and Execution – PSE subassembly)
- Sun sensor provides sun pulses, also serves as redundant roll reference
- Stellar reference (primary roll reference) also serves as precession reference
- Despin sensor assembly (redundant, used only during despin operation)
- Functions: Despin, Spin control, CONSCAN, Δv control, Roll reference, ACS telemetry

"TTL era" electronics



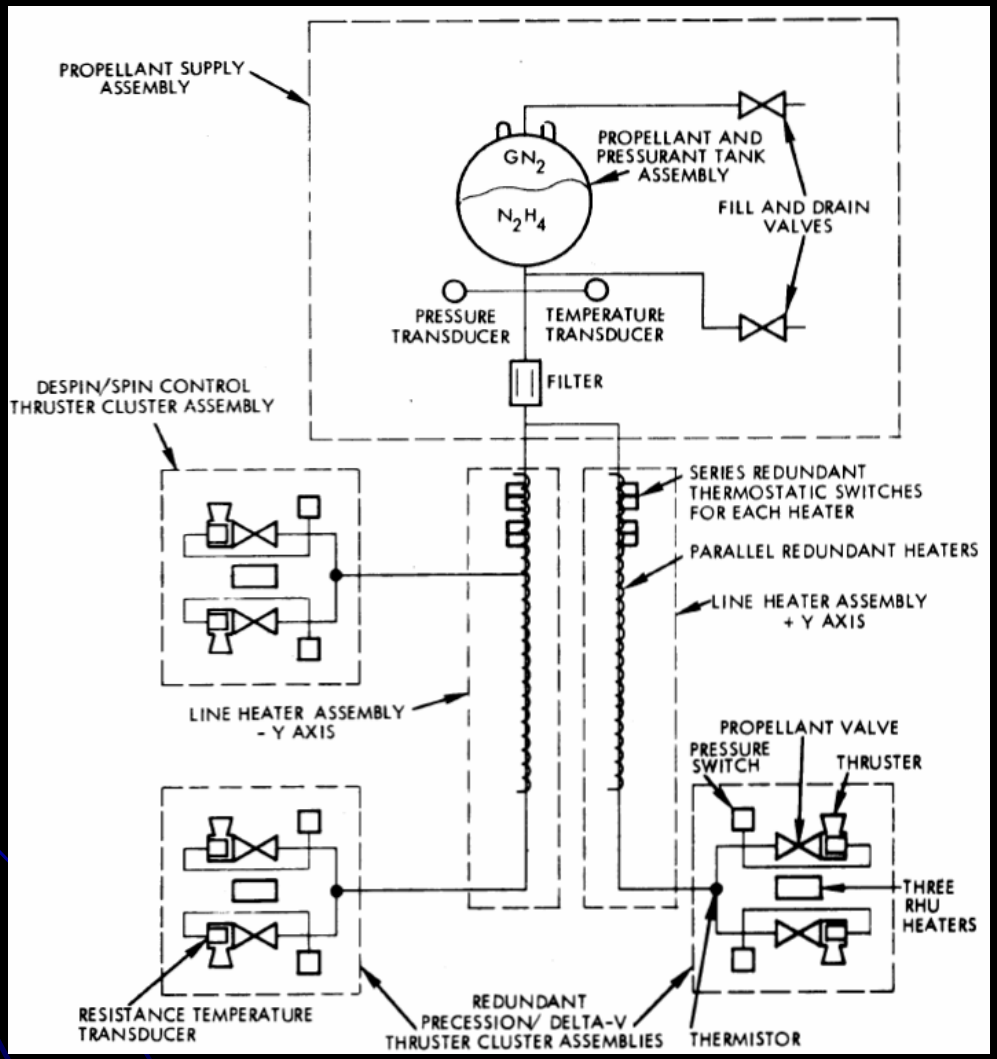
ACS & Propulsion



Propulsion Subsystem

- Three Thruster Cluster Assemblies
  - Velocity Precession Thrusters (VPT)
    - VPT1&3 face the +Z direction
    - VPT2&4 face the –Z direction
  - Spin Control Thrusters (SCT)
  - Each contains three RHUs
- Propellant Supply Assembly (PSA)
  - Propellant tank (~38 l); elastic diaphragm
    - N_2 expellant
    - N_2H_4 monopropellant
  - Pressure and temperature transducers in outlet line
- Two Line Heater Assemblies (LHA)

Propulsion Subsystem



Data Handling Subsystem

- Digital Telemetry Unit (DTU)
  - ~ 800 integrated circuits
  - 10 science formats (5 used)
  - 4 engineering formats
  - 18 combinations
  - 3 modes (realtime, store, readout)
  - Clock outputs
- Data Storage Unit (DSU)
  - 49152 bits (ferrite core!)

Communications Subsystem

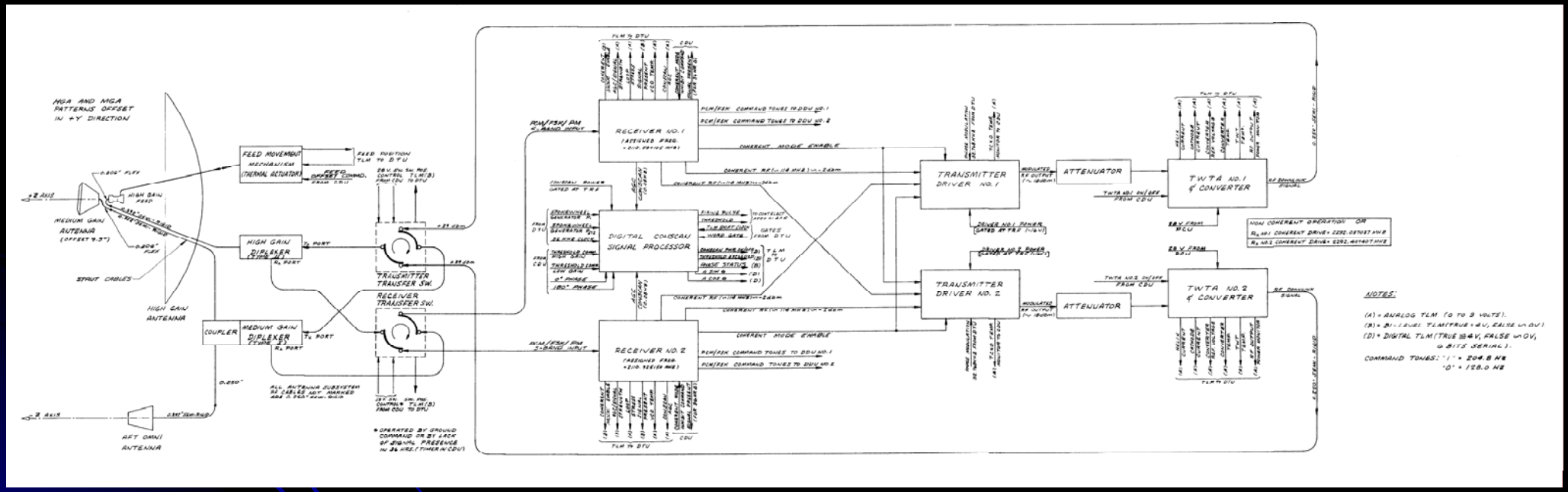
- Functions
  - Noncoherent one-way transmission
  - Phase-coherent (240/221) retransmission
  - Receive/demodulate DSS signal
  - Modulate/transmit to DSS
  - Generate CONSCAN error signal
- Frequency: 2.1/2.2 GHz (uplink/downlink)
- Radiated power: 70 dBm (HGA)

Communications Subsystem

- Components
  - High-gain antenna (HGA)
  - Medium-gain antenna (offset from HGA)
  - Low-gain omnidirectional antenna (-Z)
  - Two receivers, switchable between HGA and MGA/LGA
  - Two TWT transmitters, switchable
  - Feed movement mechanism (CONSCAN)
- HGA 3dB bandwidth: 3.5°/3.3° (up/downlink)
- Receiver threshold: –149dBm (last: –131.7dBm)

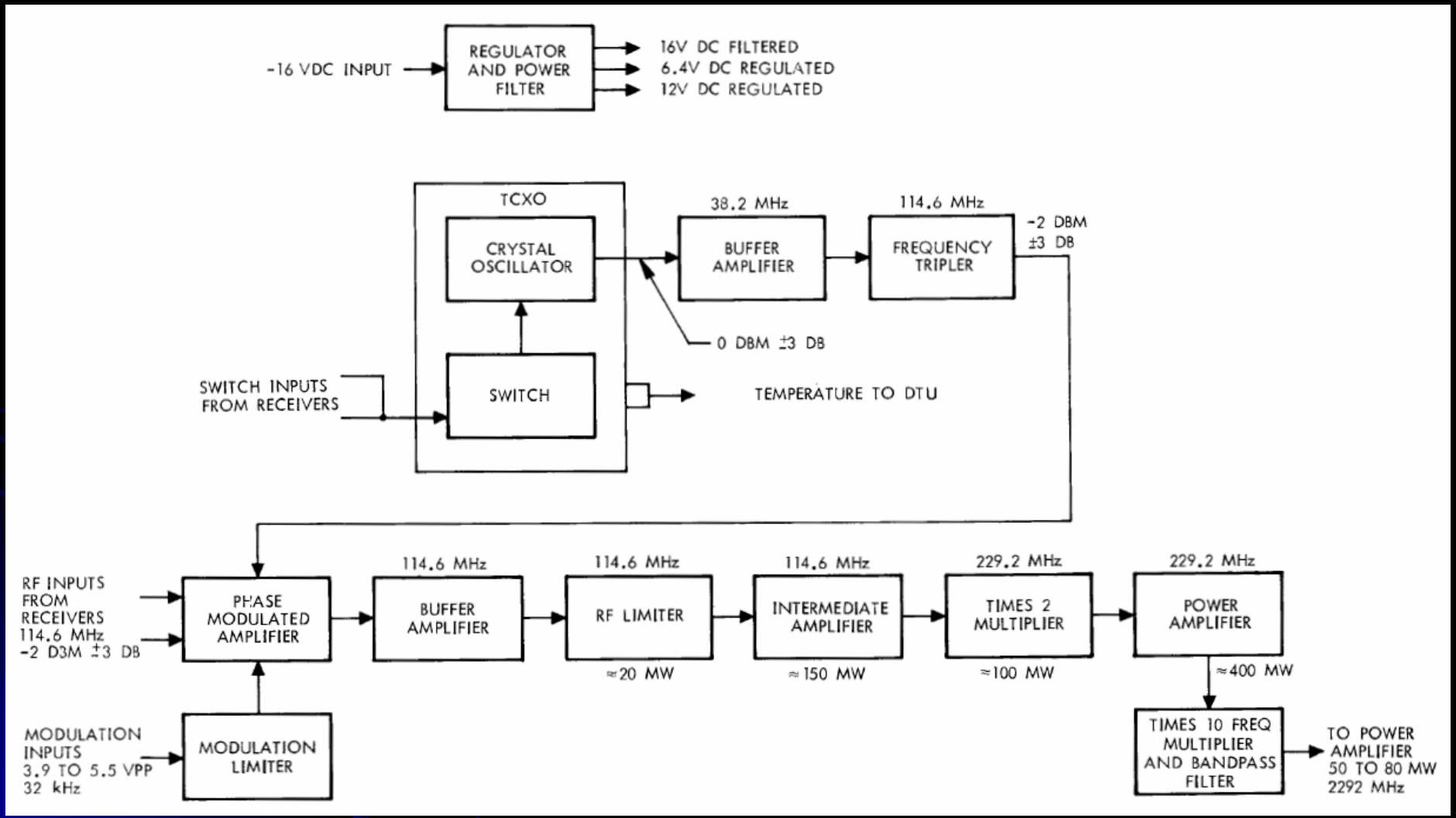
Communications Subsystem

Block Diagram



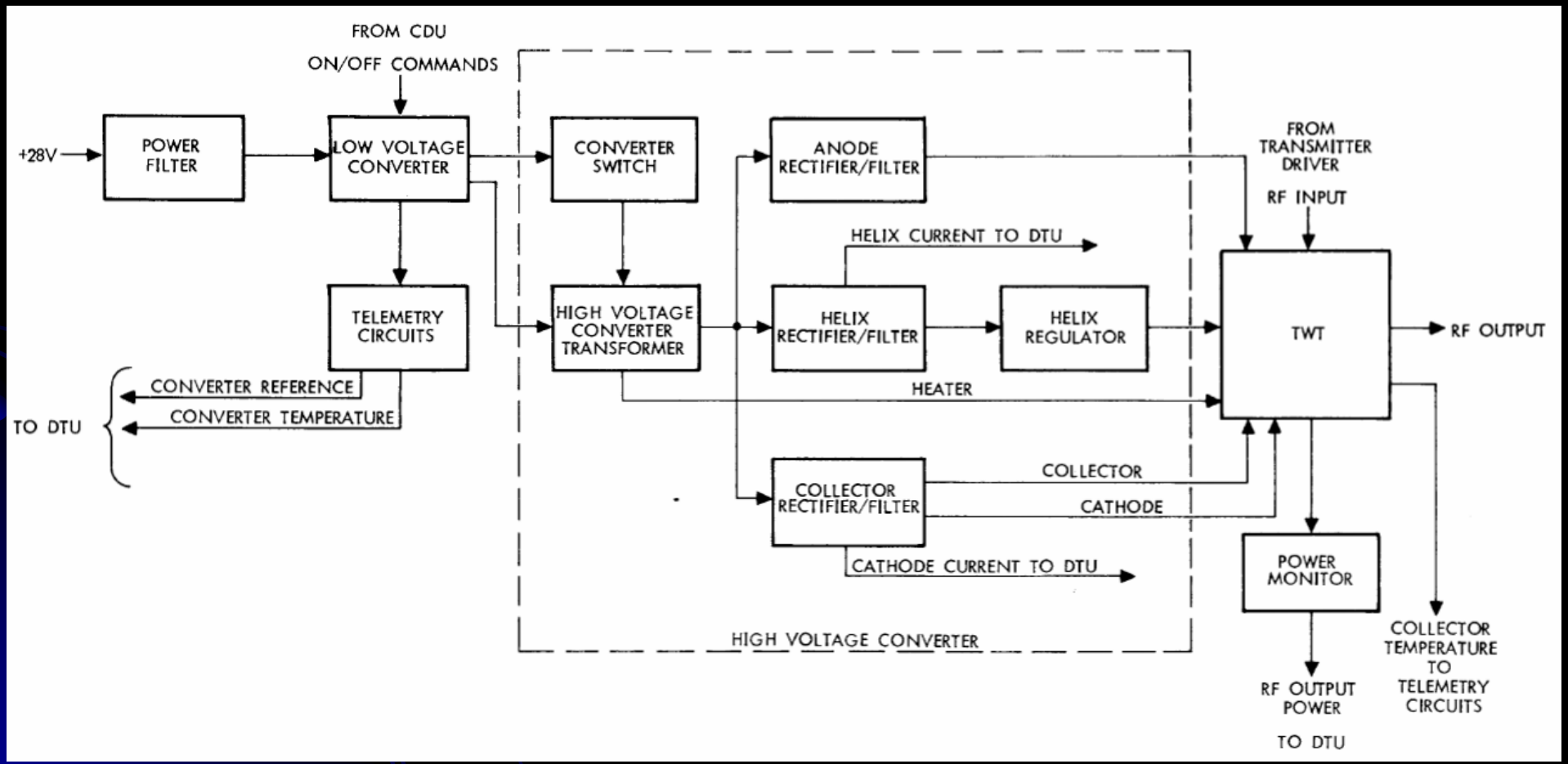
Communications Subsystem

Transmitter Block Diagram



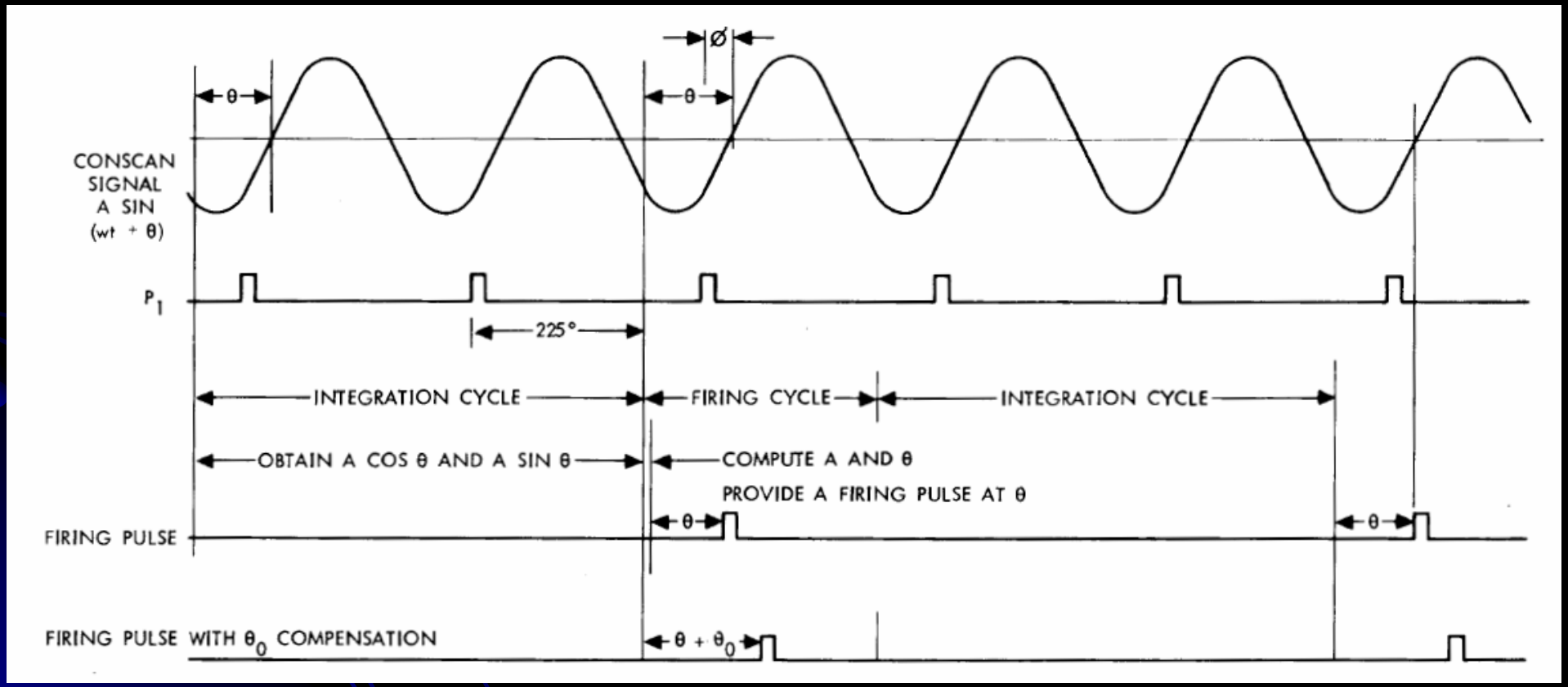
Communications Subsystem

TWT Amplifier Block Diagram

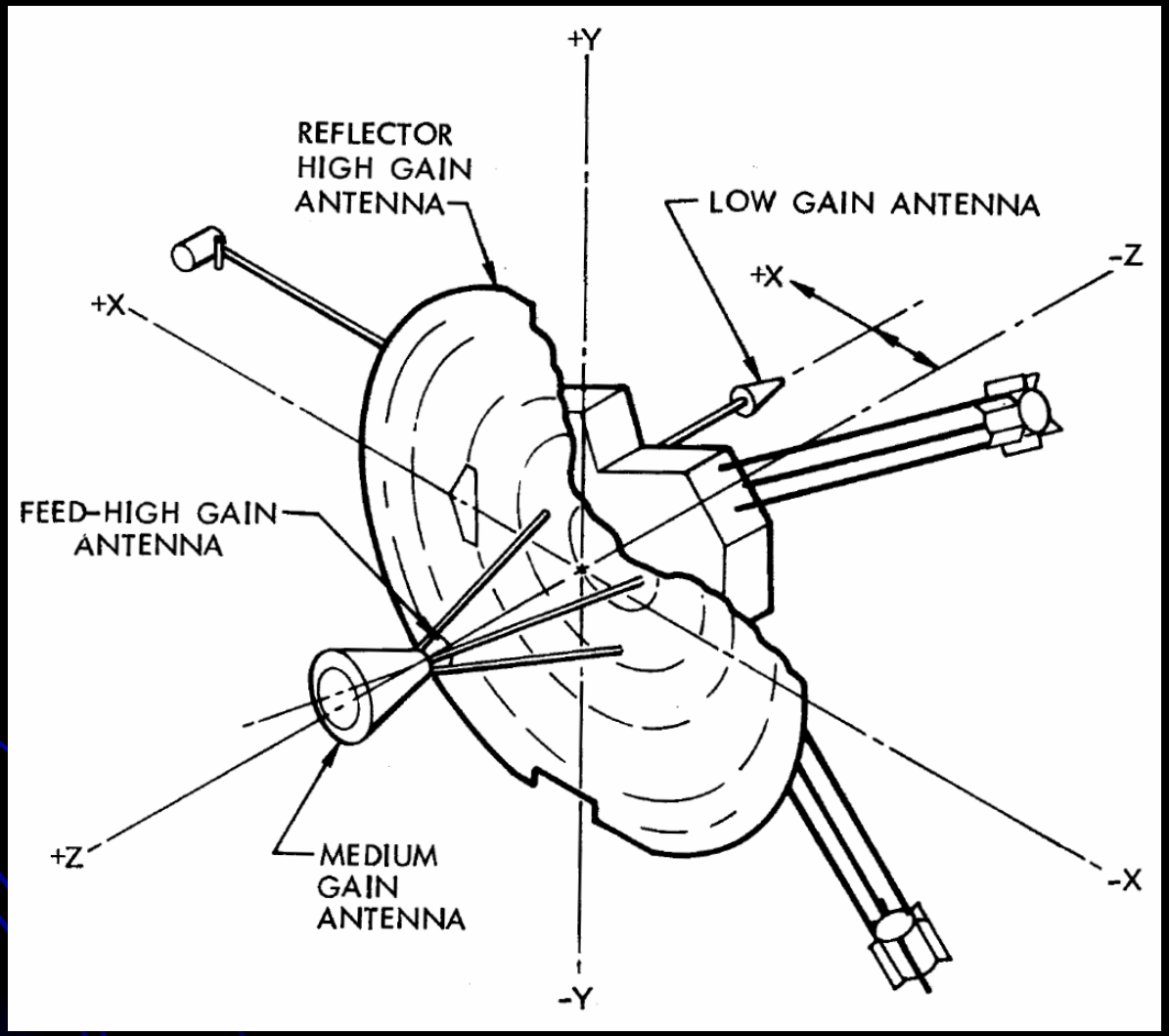


Communications Subsystem

CONSCAN Timing Diagram



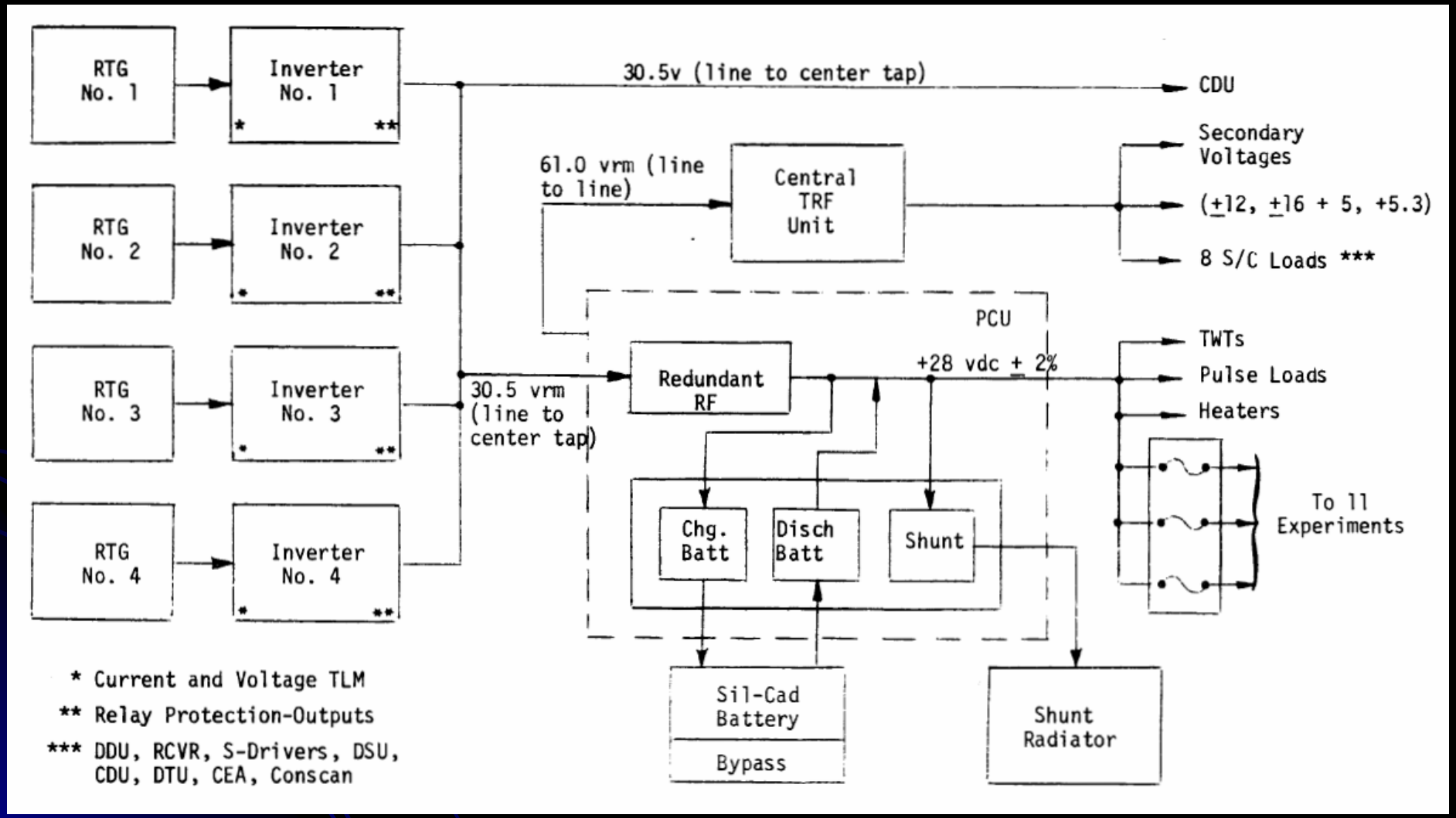
Antenna Subsystem



Electrical Power Subsystem

- Inverter Assemblies
  - process low-voltage RTG output
- Power Control Units
  - rectify AC onto regulated DC bus
- Battery
- Central Transformer Rectifier Filter
- Shunt Radiator

Electrical Power Subsystem



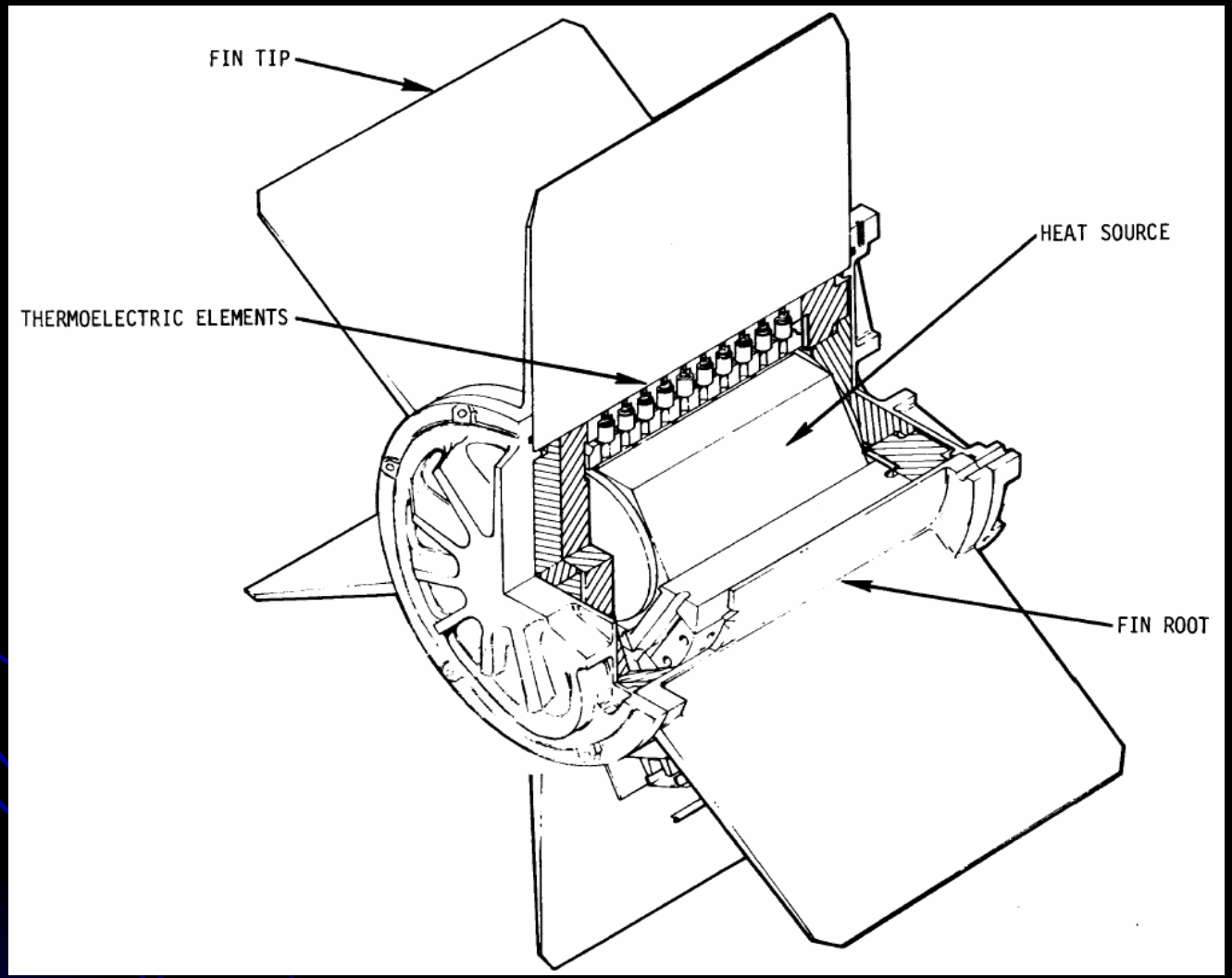
Electrical Power Subsystem

- RTG Power at Acceptance: 175W
- Inverter Output Voltage: 61.0 V_{rms} ± 3%
- PCU Output Voltage: 28VDC ± 1%
- Shunt Power Capability: 118.5W (max)
- Battery Capacity: 5Ah, 40Wh
- Battery Discharge: 10A (1A @ 28VDC)

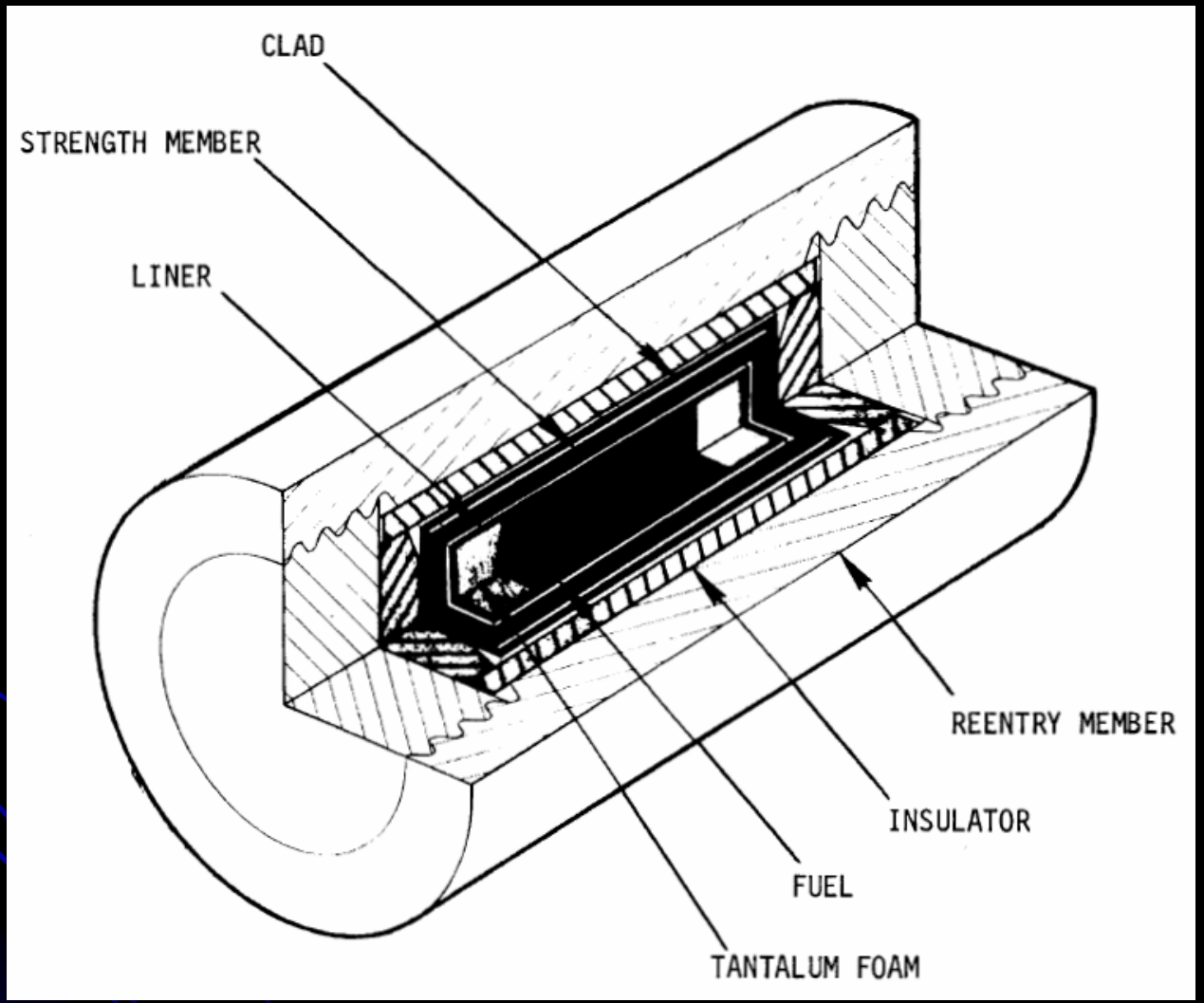
RTGs and RHUs

- SNAP-19 Radioisotope Thermal Generator
- RTGs designated 1-o (4), 1-i (3), 2-o (2), 2-i (1)
- ^{238}Pu decay (~87 year half life)
- RTG Telemetry:
  - Voltage (4.2 VDC nominal)
  - Current (~10A at launch)
  - Root fin temperature (~180°C at launch)
  - Hot junction temperature (~500°C at launch)
- 11×1W Radioisotope Heater Units (RHUs)
  - 3 each at thruster cluster assemblies
  - 1 at magnetometer
  - 1 at Sun sensor

SNAP-19 RTG



1W Radioisotope Heater Unit



After 30 Years

- One instrument (GTT) still operating (power-down command sent last track, but never confirmed)
- Bus voltage ~ 26VDC
- Transmitter XCO failed (probably due to cold)
- Transmitter still operating in coherent mode
- Many temperature readings “off the scale” or outside calibrated ranges
- Propellant lines frozen (no maneuvers possible)