Planning Systems for Pioneer Mission Control

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Introduction

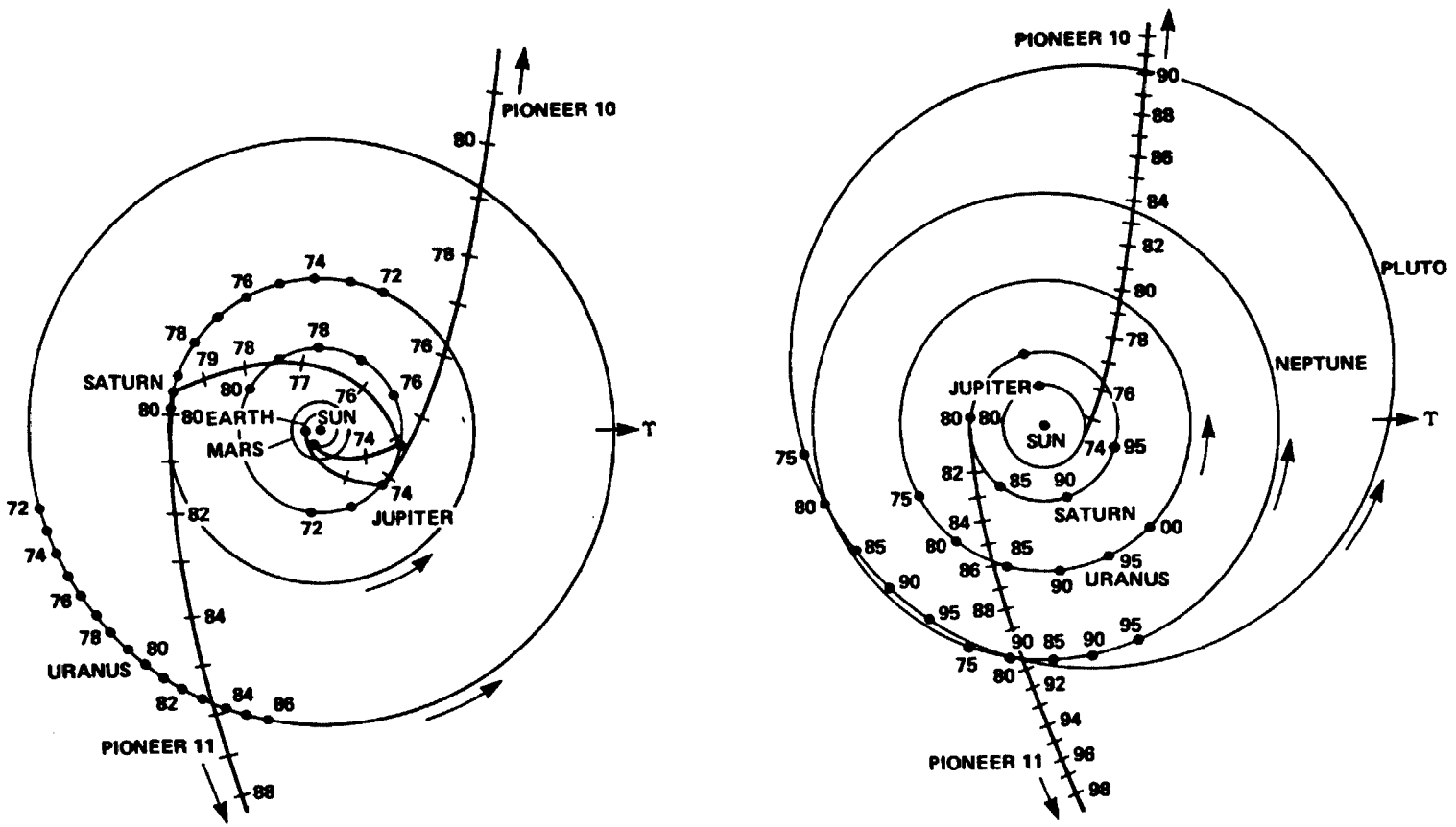
Description of Pioneer Missions
Pioneer Flight Operations
Planning Procedures
Operation of Spacecraft Past Original Design Scope
Pioneer Venus Orbiter Expert System
Planning Future Long-term Missions

Description of Pioneer 10/11 Mission

Flight Profile
- Launch
  - Pioneer 10 3/2/72
  - Pioneer 11 4/5/73
- Firsts
  - Through asteroid belt
  - Jupiter: Pioneer 10: 12/72; Pioneer 11: 12/74
  - Saturn: Pioneer 11: 9/79
  - Exit solar system Pioneer 10: 6/83 (hyperbolic escape ~2.5 AU/yr)

Science Objectives
- 11 instruments (8 still operating) + radio science
- Planetary Environment at Jupiter, Saturn
- Interplanetary Environment

Pioneer 10/11 Trajectories



Pioneer 10/11 Spacecraft

Built by TRW

570 lb (260 kg)

9 ft diameter High Gain Antenna (HGA) dish x 4 ft tall

Attitude control
- Spin stabilized - spin axis is HGA axis
- Sun/Star sensors for roll reference
- Hydrazine propellant / thrusters

Power
- 4 RTG's 160 W BOL

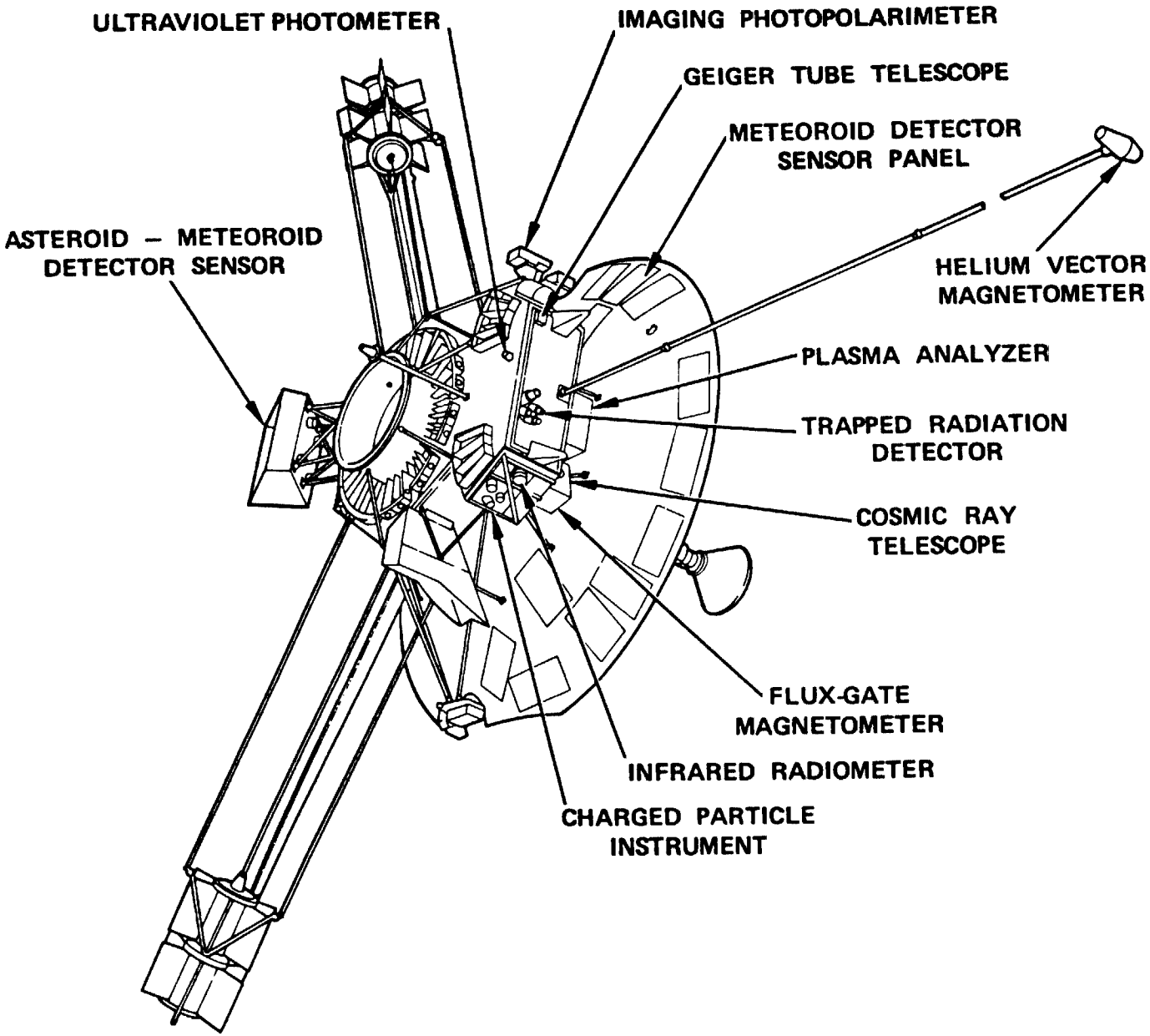
Communications
- 8 W transmitter [RTLT = 9 hrs; 14.5 hrs]
- SBand - 1° pointing
- Main feed offset for attitude determination
- Medium gain backup antenna

Command
- 22 sec/command uplink rate
- Storage for 5 commands and time delays

Telemetry
- Telemetry rate @ Jupiter = 1024 bps; @Saturn = 512 bps; currently 16 bps (minimum)
- 4 Science formats, 4 Engineering formats
- Real-time operations only (storage of only 49kbits)

Safety features
- Timer to switch receivers if no uplink in 36 hours
- Undervoltage trip
- Redundancy and cross strapping

Pioneer 10/11 Spacecraft

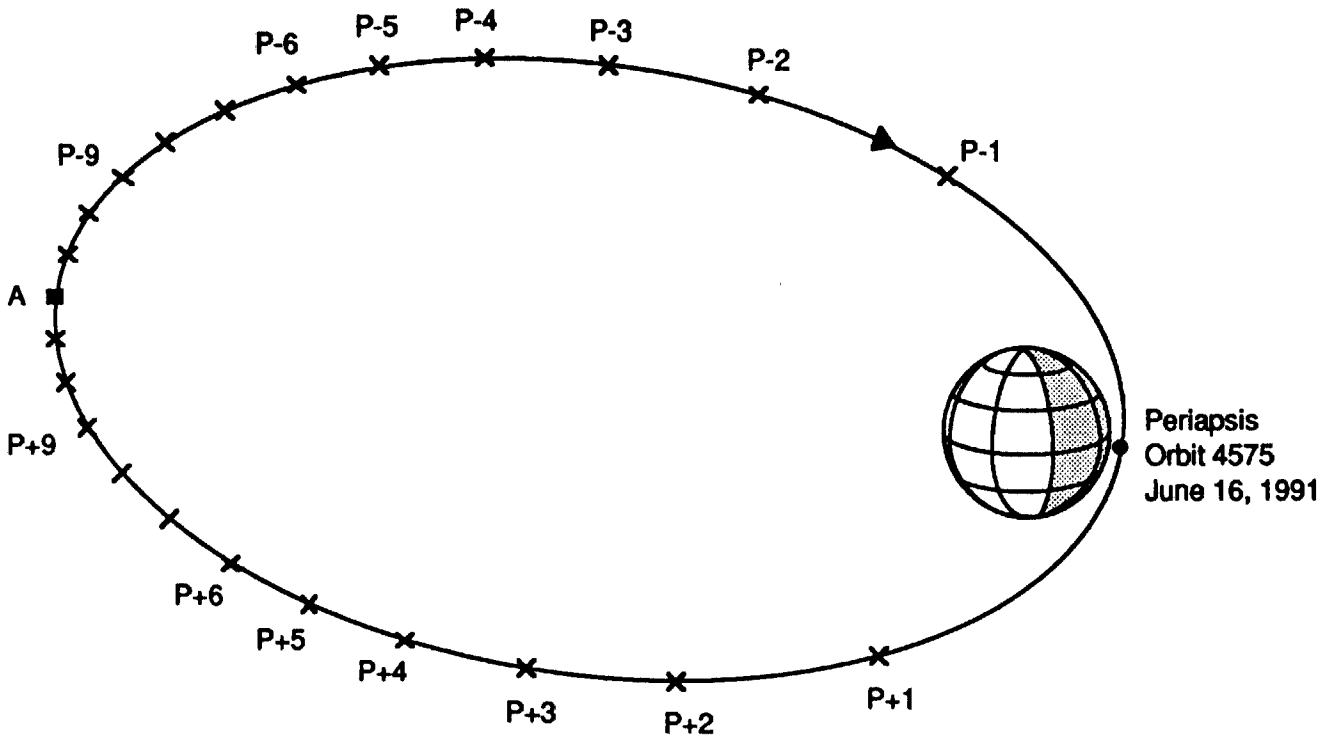


Description of Pioneer Venus Mission

Flight Profile
- Launch 5/20/78, Arrival 12/4/78
- Orbit about Venus
  - Elliptical orbit with 24 hr period
  - 105° inclination
  - Latitude of periapsis near Equator
  - Periapsis skimming atmosphere
- Changing geometry of Earth and Venus
  - RTLT ranges from 5 to 25 minutes
  - Synodic period = 584 days
- Changes of orbit with time
  - Altitude of periapsis up to ~1800 km, then back to 150
  - Latitude of periapsis down from 18°N to 10°S

Science Objectives
- 12 science instruments (10 still operating)
- Venus Atmospheric data
- Solar wind data

Pioneer Venus Orbit 4575



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DENOTES DARK SIDE

PVO Spacecraft

Built by Hughes Aircraft Company

590 kg (225 kg propellant for orbit insertion)

2.5 m diameter

Attitude Control
- spin stabilized
- sun/star sensor for roll information
- hydrazine propellant / thrusters
- solar panels perpendicular to sun
- attitude position measured using sun/star sensors

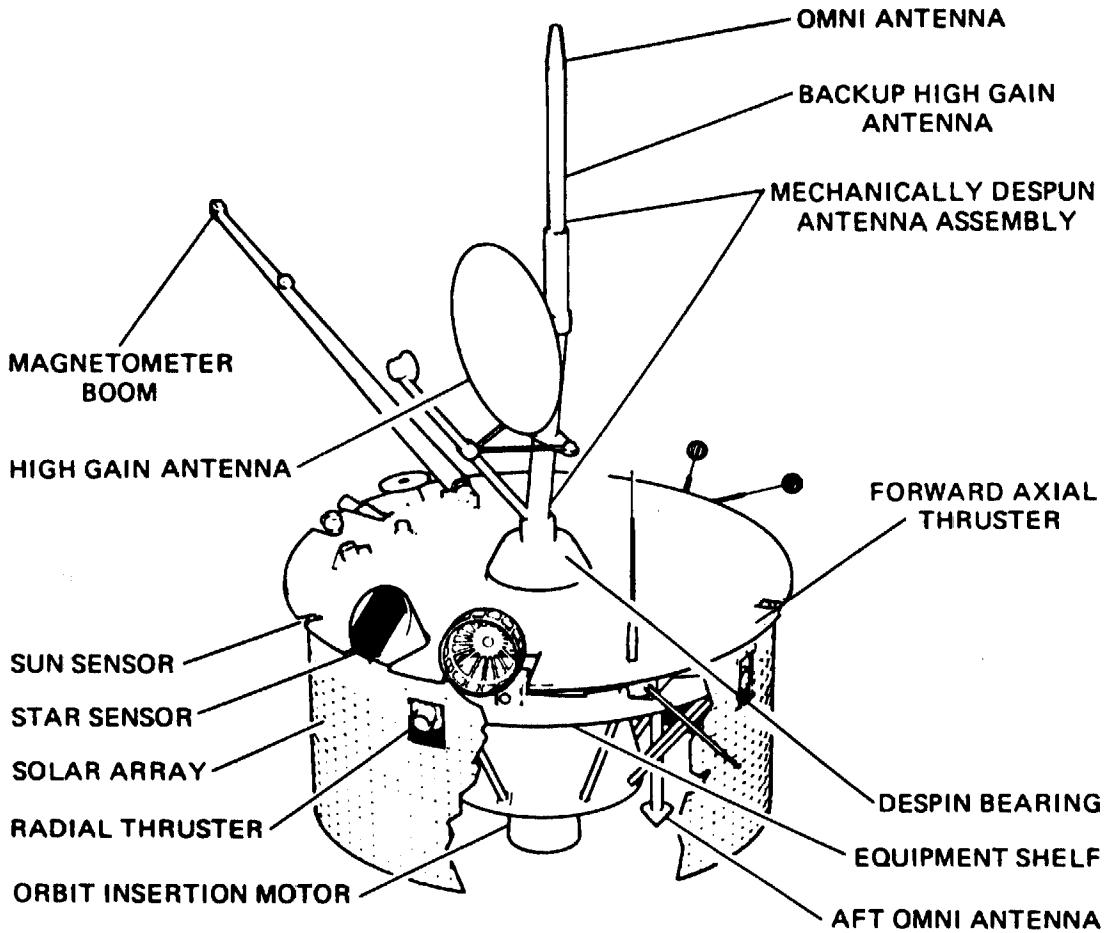
Communications
- Despun HGA (1.09 m diameter)
- 10/20 W transmitter
- S-Band (3° pointing) (Xband for science)
- Backup HGA, omni's

Command
- 12 sec/command uplink rate
- SCL -256 commands or time delays (8 commands/s execution rate)

Data
- Telemetry rates 8 bps to 4096 bps
- DSU (524Kbits(x2))
- 8 science formats; 5 engineering formats

"Safety" features
- Timer to switch receivers if no commands in 36 hours
- Undervoltage/Overload trip
- Redundancy and cross strapping

Pioneer Venus Orbiter



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Flight operations

- Staffing / Organization
  - Project Operations and Management at Ames Research Center (ARC)
    - NASA (6)
    - BFEC (42)
  - Operational Support at Jet Propulsion Laboratory (JPL)
    - DSN Scheduling
    - Orbit Determination
    - DSN Operations
      - Pointing Predicts
      - Frequency Predicts
- ARC Functions
  - Commanding
  - Telemetry monitoring
  - Data processing and archiving
  - Software and hardware maintenance
  - Engineering Analysis
    - Power balancing
    - Communications maintenance
    - Maneuvers - trajectory/orbit corrections, reorientations, spin trims
    - Eclipses/Occultations
    - PVO Comet Observations

Planning Procedures

No spacecraft simulation

Real-time operations
- Pioneer 10/11 - no data or command storage
  - Continual downlink
  - Procedures scheduled when round-trip tracking is available
- Pioneer Venus Orbiter
  - Commands files prepared for each 24 hour orbit
  - SCL used for periapsis commands and power balancing during tracking gaps
  - Data storage limited - periapsis priority
- Responsive to last minute changes
- Vulnerable to DSN problems

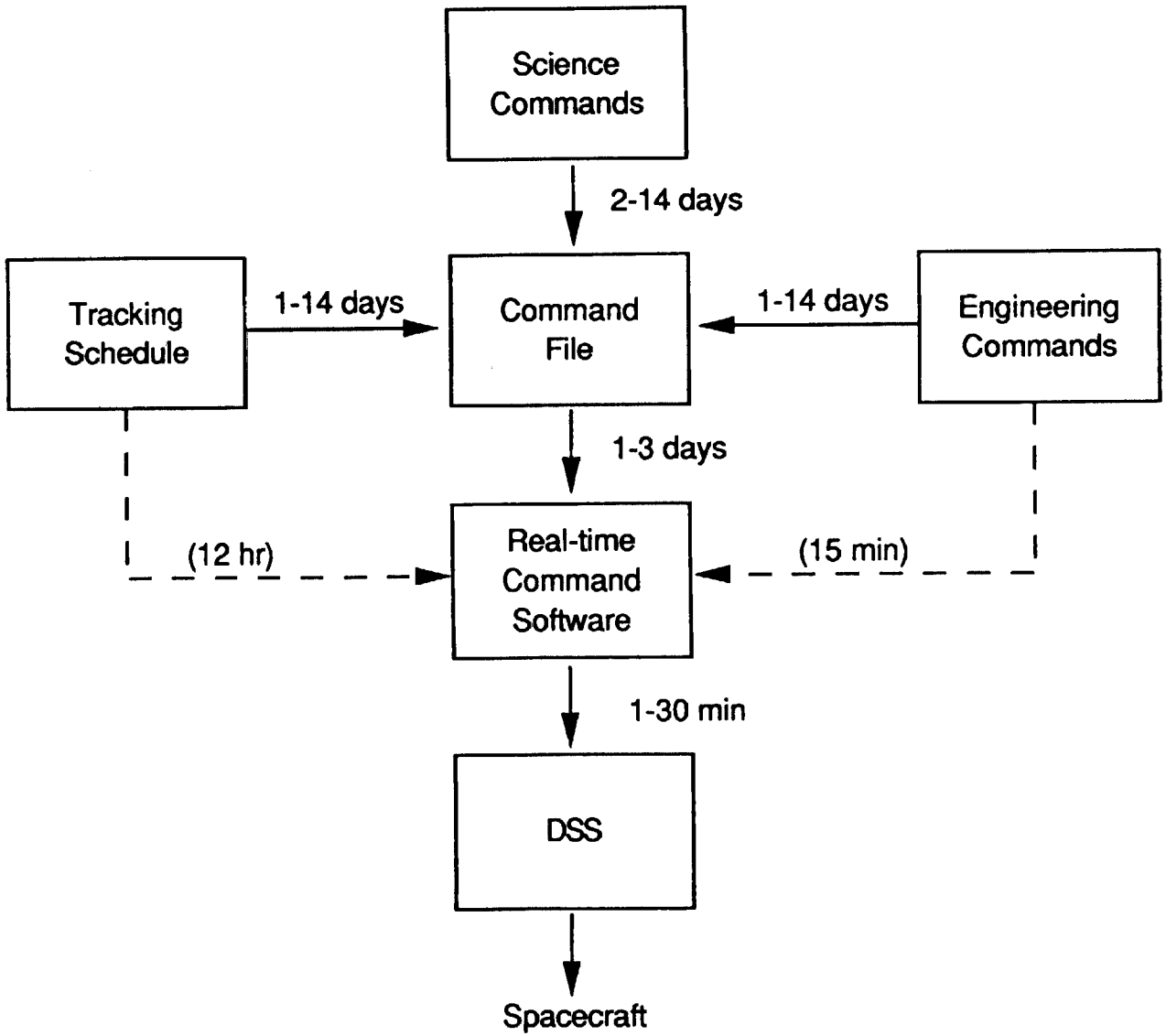
Command file generation
- Existing command files modified as necessary
- New procedures developed referencing spacecraft manuals

Error checking
- Checked by hand by other engineers
- Hexes checked as valid by command system
- Passwords required to command critical functions

Depend on individuals with project experience

Depend on spacecraft simplicity and redundancy

Pioneer Venus Orbit Planning



Operation of Spacecraft past nominal mission

- Change in spacecraft operation with time
  - Power degradations
  - Hardware failures
    - Redundant systems
    - Pioneer 11 antenna switch
    - Pioneer 10 star sensor
    - Pioneer 11 spin down thruster
    - Instrument failures
  - Operation outside original mission envelope
    - Pioneer 10 sun sensor
    - Extensive use of battery on Pioneer Venus Orbiter
- Changes to DSN
  - Mark IV interface changes
  - 64 m -> 70 m DSS; new DSN receivers
  - Loss of 26 m DSS
  - Dual tracking with Magellan
- ARC operational changes
  - Hardware changes
    - Improved computers
  - Software changes
    - Command checking
    - Collecting engineering data for transfer to VAX
    - PC to verify real-time data
    - Engineering analysis programs as required

Examples of major operational changes

Pioneer 10 loss of roll reference
- Sun sensor out of range; star sensor failed at Jupiter
- Use IPP to measure star angle 1/wk
- IPP data processed off line by engineers
- Attitude determination data must be reprocessed
- Precession maneuvers — time to fire pulses timed to arrive at correct roll angle

Pioneer 11 attitude determination
- Loss of receiver on HGA; failure of antenna switch
- Range too great to use medium gain antenna for attitude determination
- Developing procedures for IPP, downlink AGC

Pioneer Venus Halley observations
- Fortuitous viewing of Halley by Venus in 1986
- UltraViolet Spectrometer (UVS) instrument fixed cone angle about spin axis
- Reorientation maneuvers required every day to keep comet in UVS FOV

PVO Expert System

Developed by ARC/Information Sciences Office

Addressed normal operational planning for PVO only

VAX 8600 / VMS / OPS5

Design goal -- collect and organize all inputs to PVO orbit command file program

Problems

- Couldn't keep up with changing environment - rules changed too fast
- Interface problems between Operations personnel and programming staff
  - Required "high-level" rather than "low-level" man-hours
  - Programmers often worked without Project input
  - Not "user-friendly" or robust in preliminary stages
- Never developed to the point of making real decisions, only made deterministic calculations
- Scaled down to "uninteresting" problem; never became user-driven

Planning future, long-term missions

Documentation!!
- Spacecraft manual
- Operations record
- Engineering data archiving
- With future complex missions, on-line data base driven by expert system will be required

Maintaining knowledgeable staff

Planning systems
- Evolutionary system required
  - Impossible to anticipate future operating scenarios
  - Allows upgrade to new systems as available
- Expert system decision-making software must become a "tool" for the operations personnel

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