Ground Segment

Space System Design, MAE 342, Princeton University

Robert Stengel

- Launch Ranges/Spaceports
- Range Safety
- Ground Stations
- Flight Dynamics
- Ground Data System
- Flight Operations System

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http://www.princeton.edu/~stengel/MAE342.html

Launch Ranges

- Site for launching and landing spacecraft
- Typically along a coastline
  - Available launch azimuths for desired orbit inclinations (polar, sun-synchronous, equatorial, …)
  - Advantageous use of Earth's rotation (near equator)
  - Need for safe lower-stage impact zones down-range
- Distance from heavily populated areas
- Infrastructure for
  - Vehicle/spacecraft assembly
  - Pre-flight testing
  - Component transport and storage
  - Launch pads
  - Assurance of ground and flight safety
  - Launch control and handoff
  - Tracking, communications, data processing Down-range facilities

List of launch sites
https://en.wikipedia.org/wiki/Spaceport

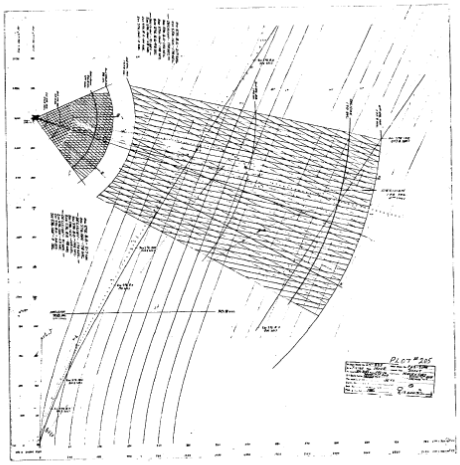
Launch Operations

Range Safety

FPS-16

Wallops Control Center, c. 1960

Radar Plot

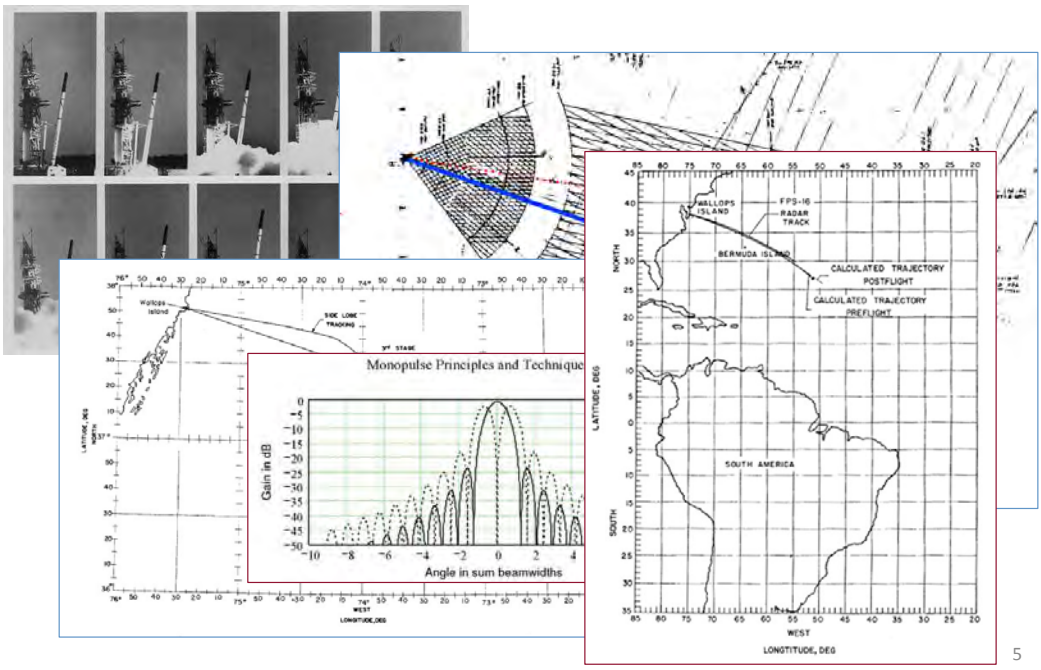


(a) RCA AN/FPS-16 radar.

Figure 50.- Copies of radar plot boards for ST-1 flight test.

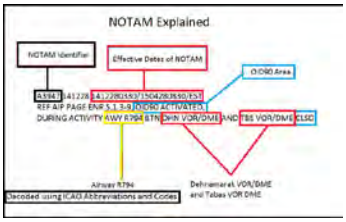
Scout ST-1

July 1, 1960



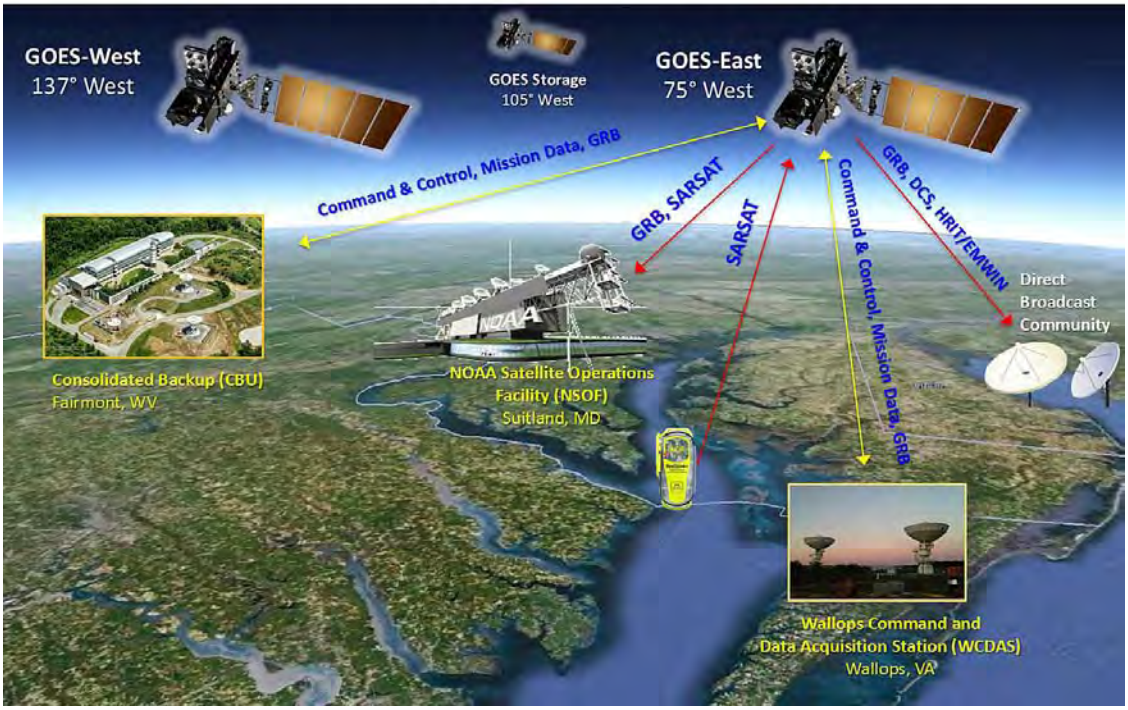
Range Safety

- **Range surveillance**
  - **Restricted airspace**
    - **Prohibited airspace**
    - **NOTAMs (Temporary flight restrictions)**
  - **Surface vessel monitoring**
- **Meteorological information**
  - **Apollo 12 lightning strike during launch**
- **Monitoring hazardous materials**

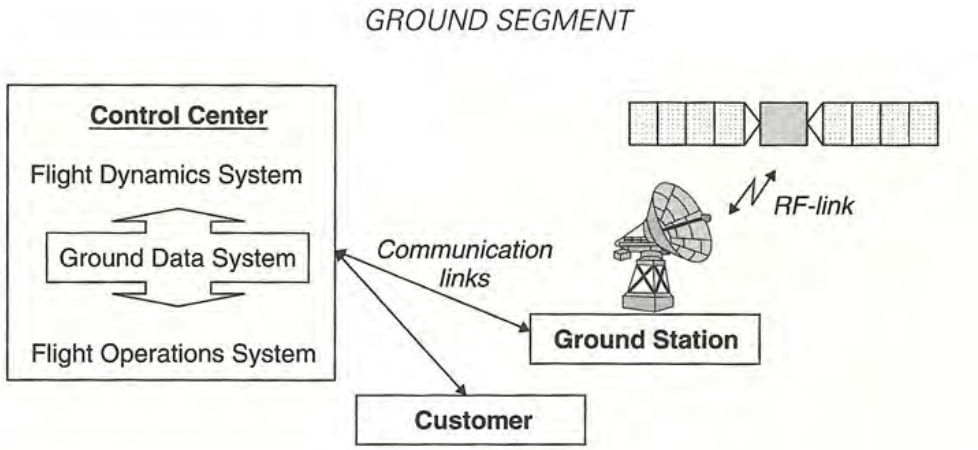


Space and Ground Segments for Spacecraft Operation

GOES-R System Architecture



Ground Segment Basics



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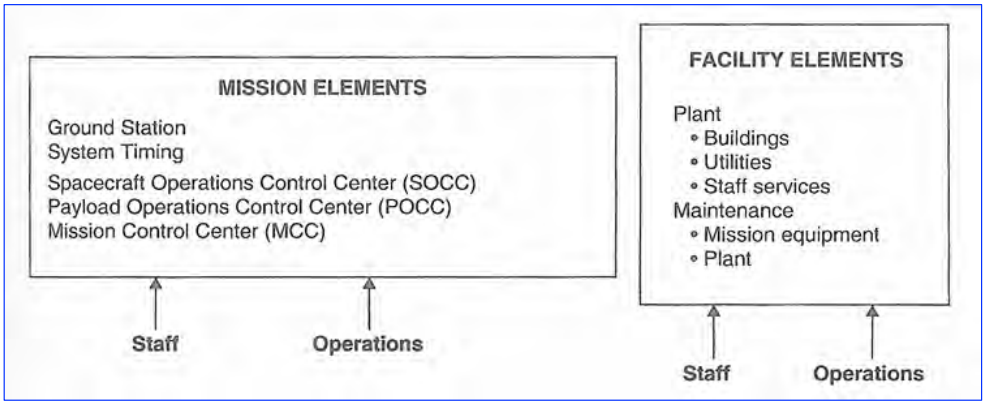
Ground Segment Basics



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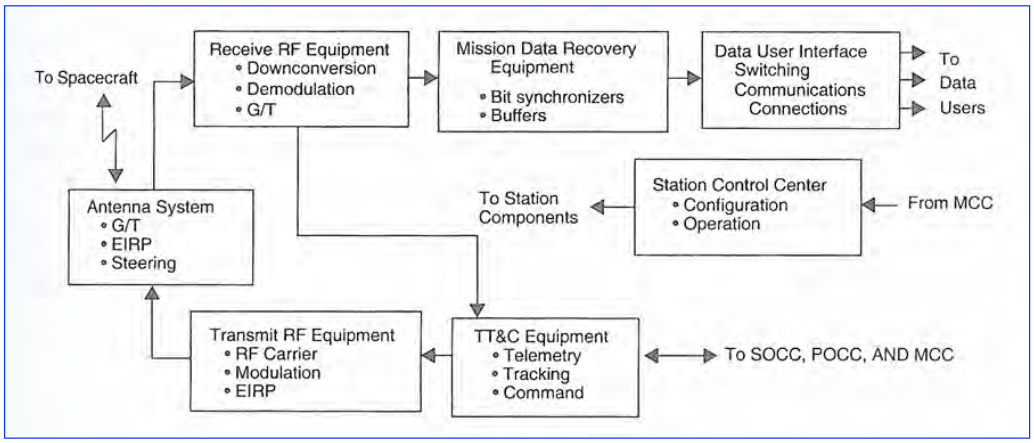
Ground Segment Basics



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Ground Station Location and Antennas

- **Coverage of celestial sphere**
- **Access to low-elevation tracking and communications line-of-sight**
- **Low radio-frequency (RF) interference from surrounding area**
- **Stable geology, satisfactory weather**
- **Adequate, reliable power source**

Tracking and Communication

- Low frequencies for
  - Launch and early-orbit phase, launch vehicle and spacecraft
- High frequencies for payload
- Frequency allocations by international agencies

- Antenna control
  - Pointing and tracking
  - Modes: program-, auto-, step-tracking
- Satellite transponders for ranging and range rate
- Uplink/downlink frequency shifts to avoid interference

Band	Downlink, GHz	Uplink, GHz
S, deep-space	2.29-2.3	2.11-2.12
S	2.2-2.29	2.025-2.11
C	3.4-4.2	5.925-6.425
X	7.25-7.75, 8.4-8.5	7.9-8.4,7.145-7.235
Ku	10.7-12.75	13.75-14.5
Ka	17.7-21.2,25.5 -27.5	27.5-31

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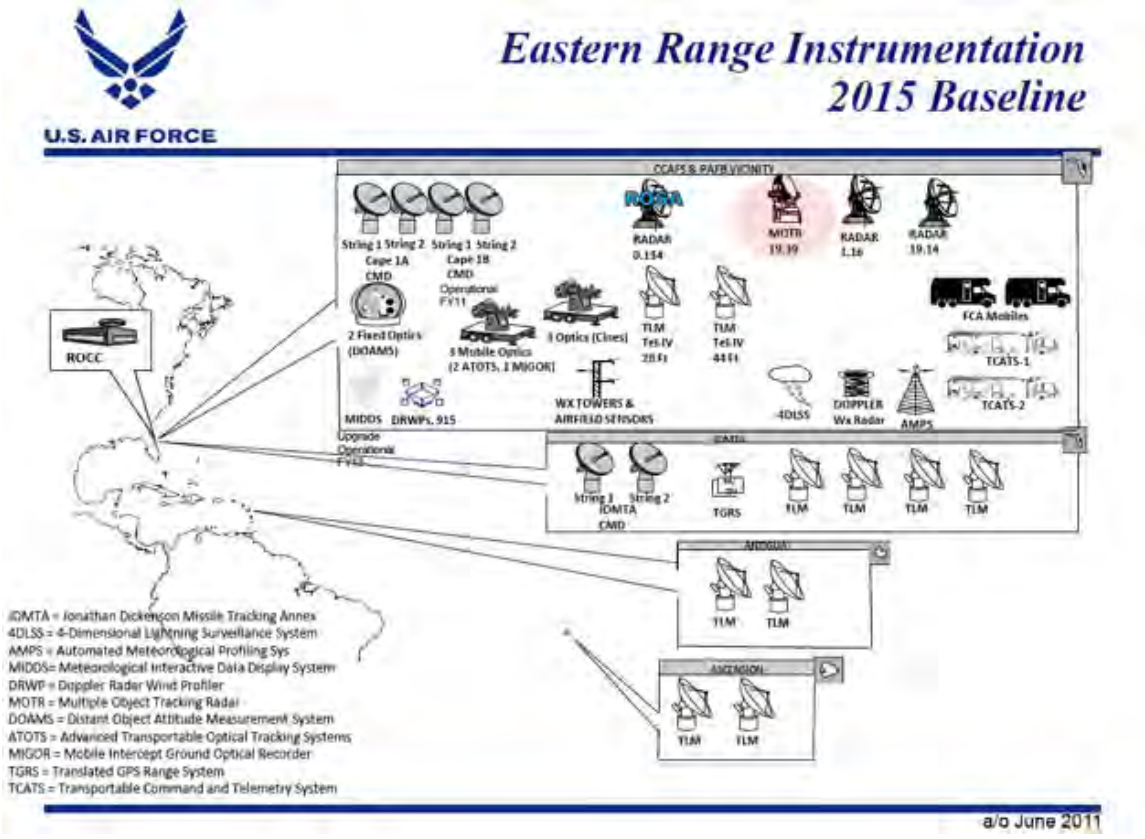
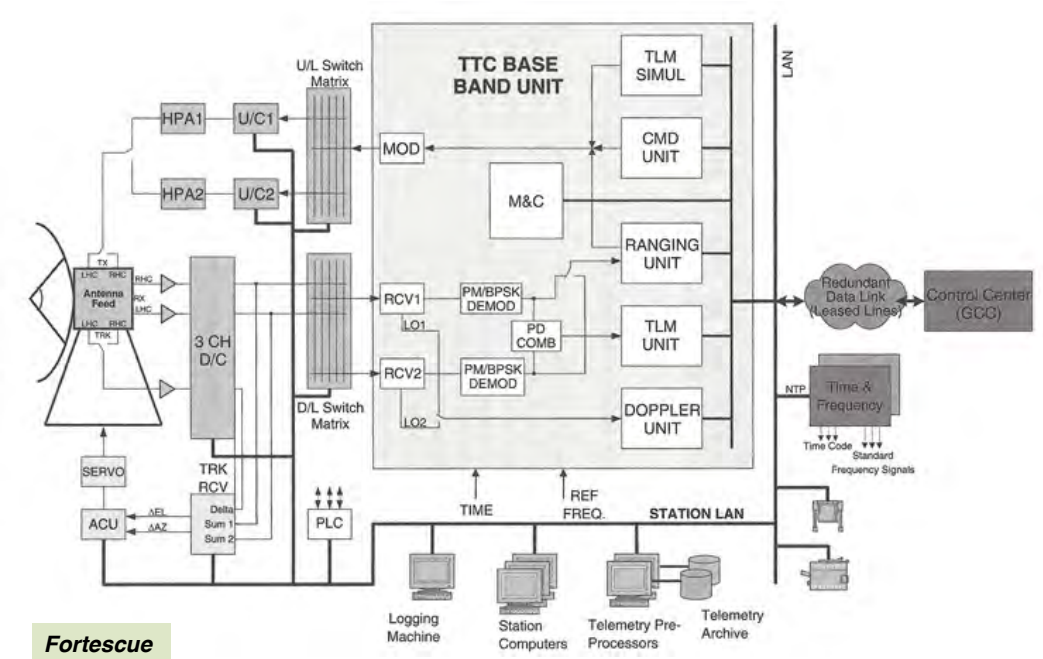


Ground Station Block Diagram



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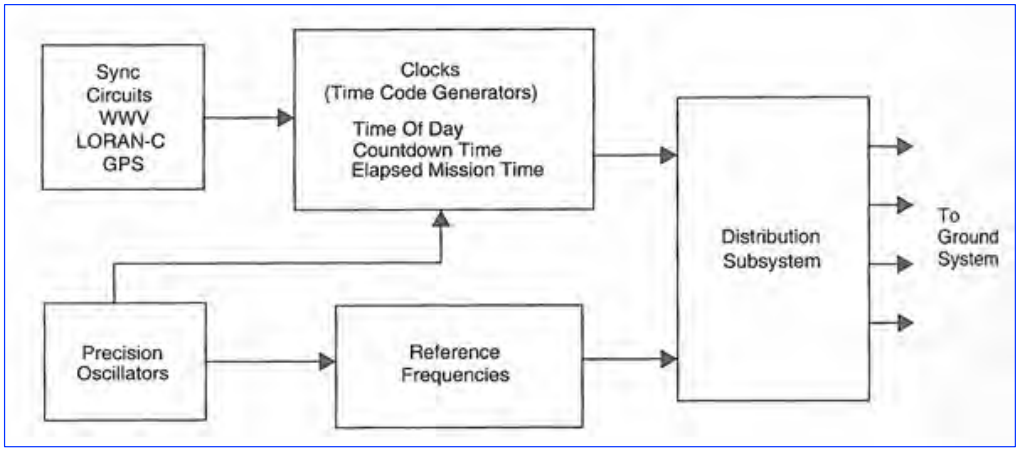
System Timing



NIST Primary Time Standard, Boulder, Co

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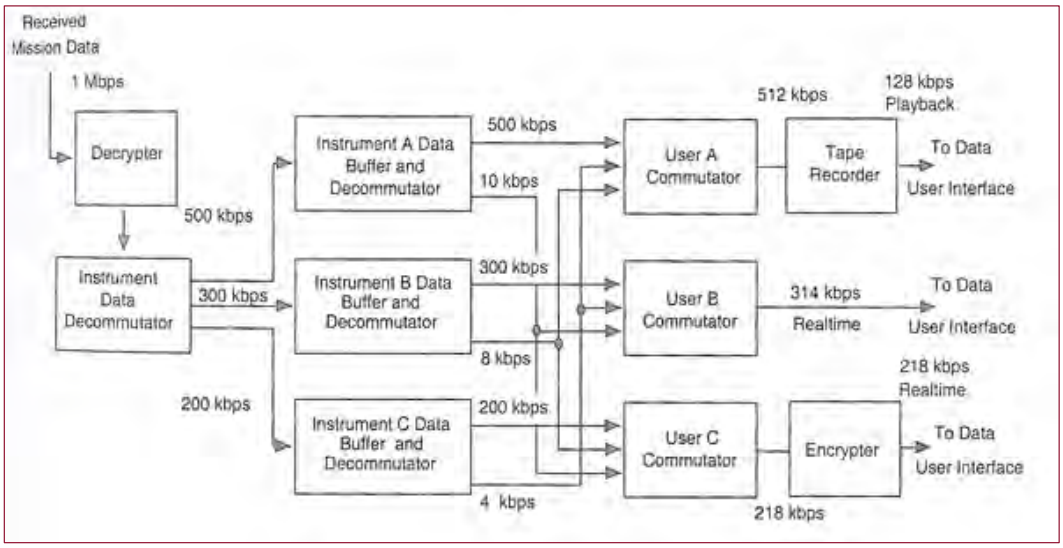
Data Handling



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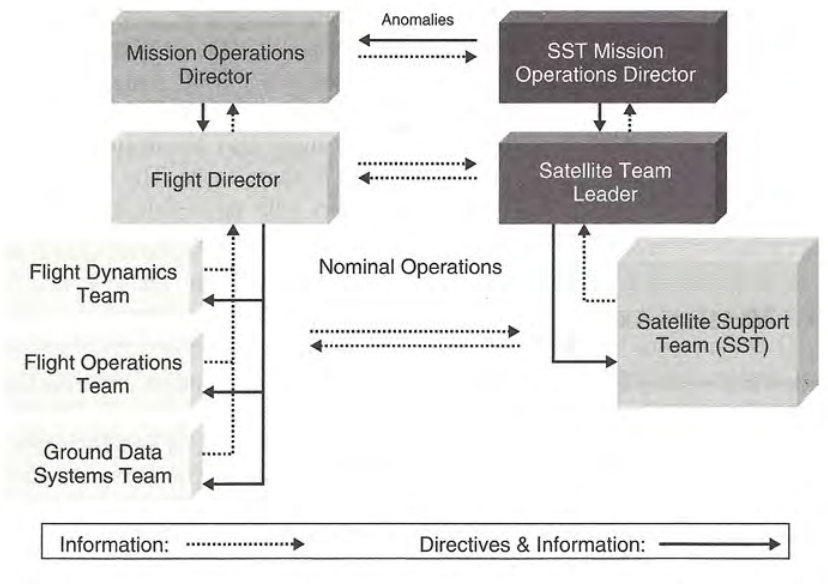
In-Orbit Testing

- **Telemetry, data communications testing**
- **Payload checkout**
- **Calibrations**
- **Adjacent satellite interference**
- **Acceptance tests**

Ground Control Teams



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Flight Dynamics Mission Analysis

- Identification of suitable ground sttion network
- Launch window determination
- Orbit maneuver planning
- Final orbit acquisition and station-keeping
- Sequence of orbit-related events
- Ground station ephemeris (antenna-pointing)
- Command and telemetry files
- Interface documents

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Orbit and Attitude Determination

Orbit Type	Measurement Type	Position Error, m
LEO	Angle Data	< 100
	Processed GPS Data	< 10
	Raw GPS Data (single frequency)	< 2
	Raw GPS Data (dual frequency)	< 0.01
GTO/GEO	Angle, Range, Range-Rate Data	x,y: < 100 z: < 400

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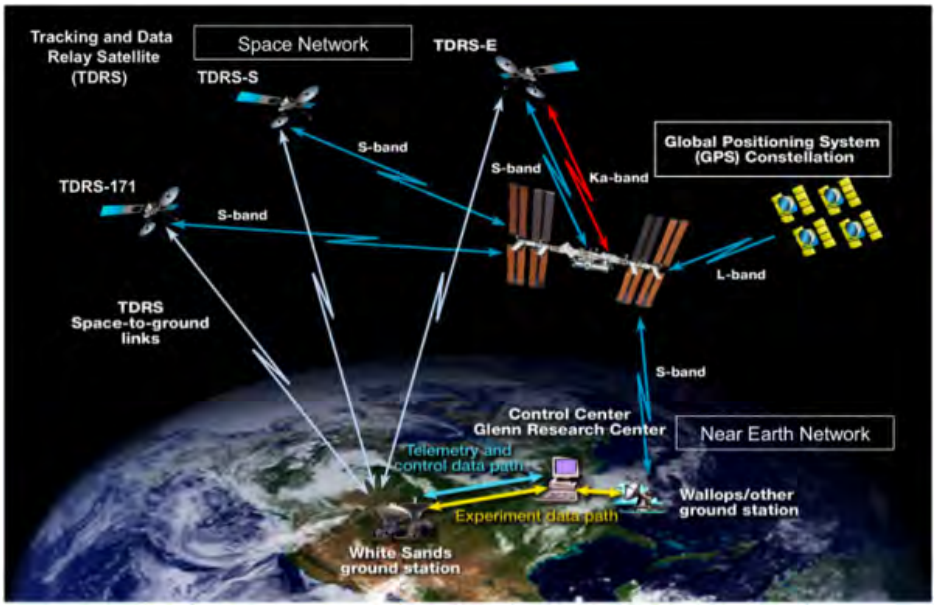
Communications Links and Flight Readiness



Tracking and Data Relay Satellite System

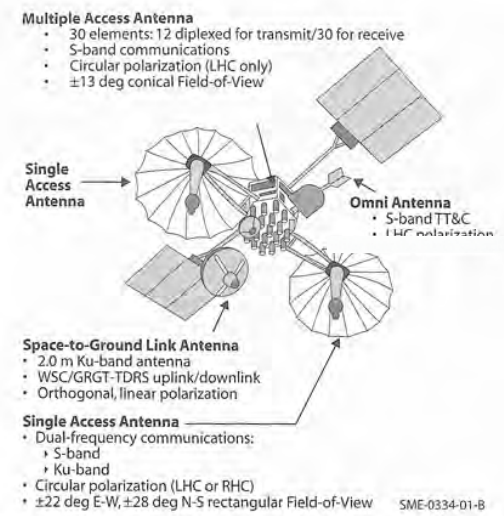


Fig. 28-8. First Generation TDRS Capabilities.

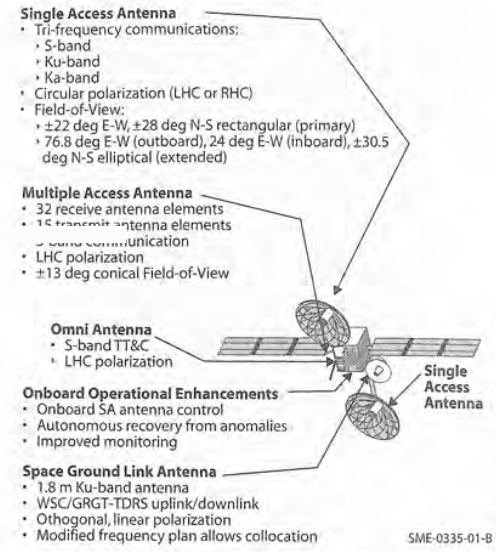


Fig. 28-9. Second Generation TDRS Capabilities.

Wertz, Everett, &Puschell

Flight Operations Monitoring and Control

- Raw data extraction
- Translation to engineering values
- Validity & verification of telemetry and commands
- Out-of-limit status, alarms
- Derived parameters

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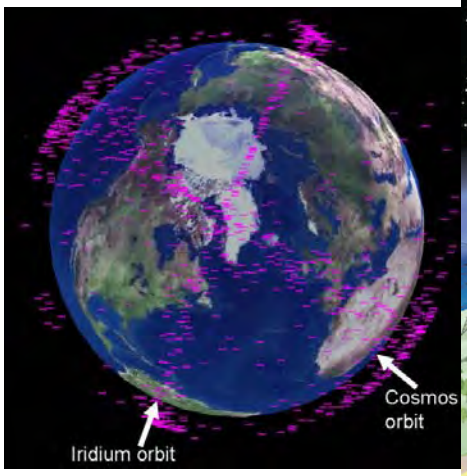
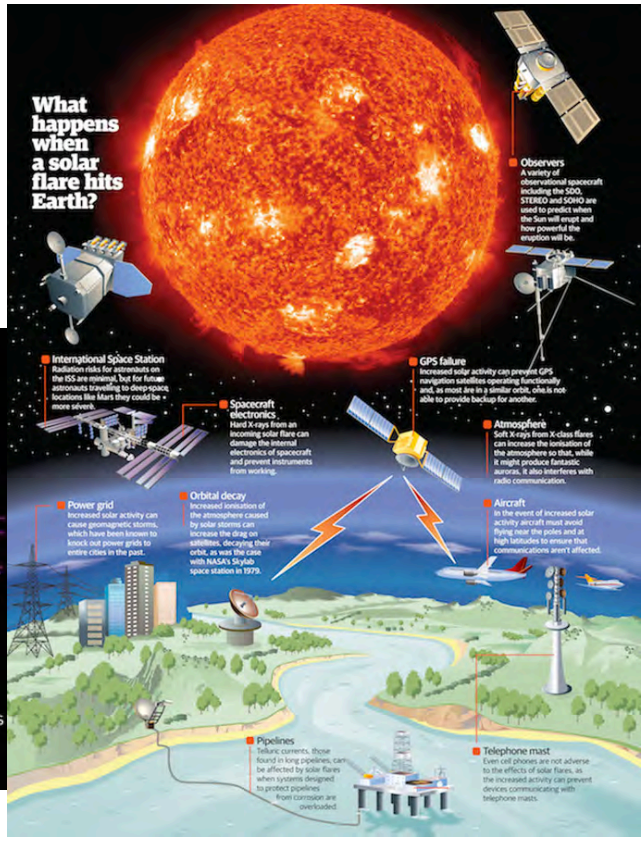
Flight Operations Monitoring and Control

- Collision avoidance
- Space weather





Next Time: Electromagnetic Compatibility

Supplemental Material

Ground Station