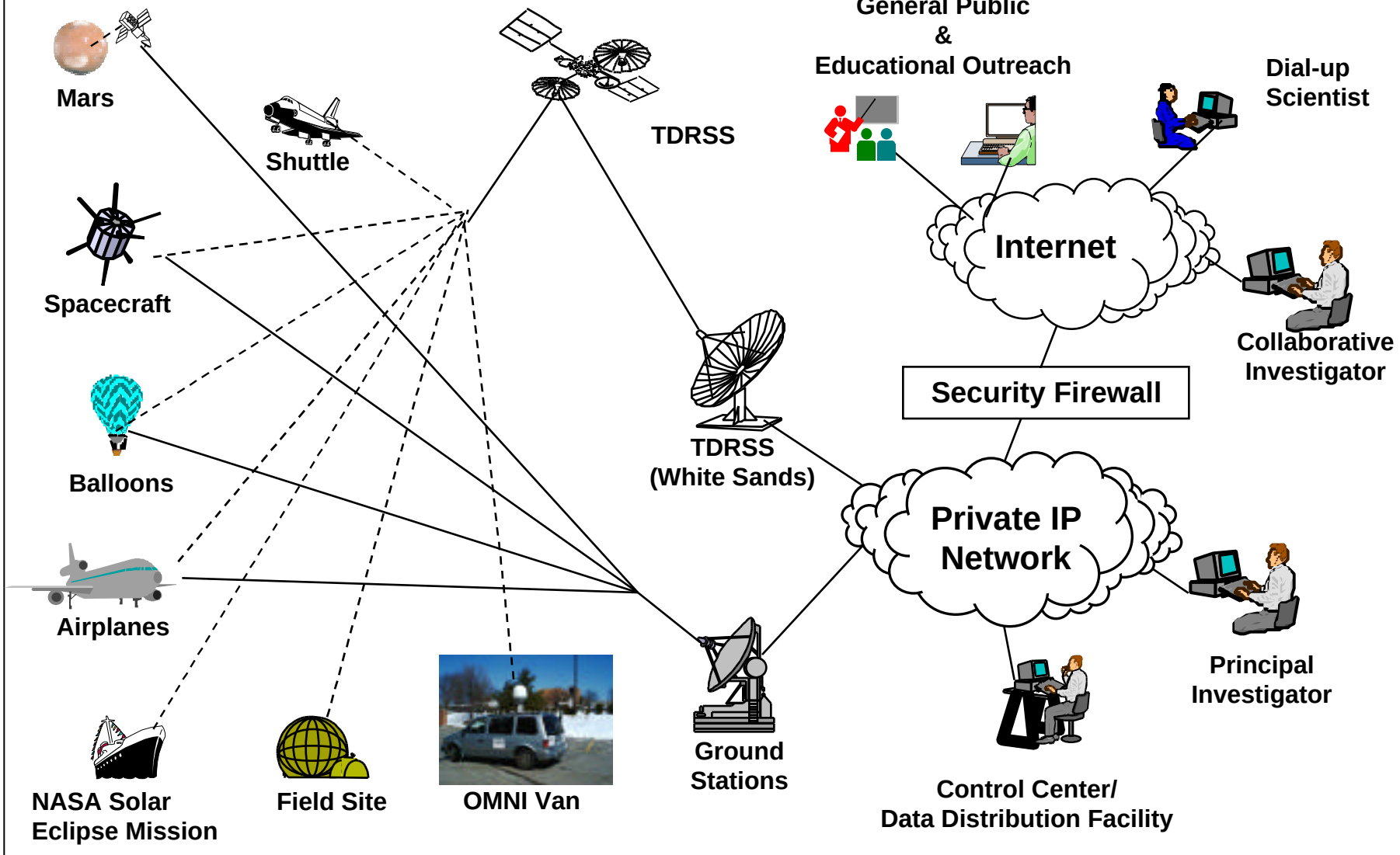
Operating Missions as Nodes on the Internet (OMNI)

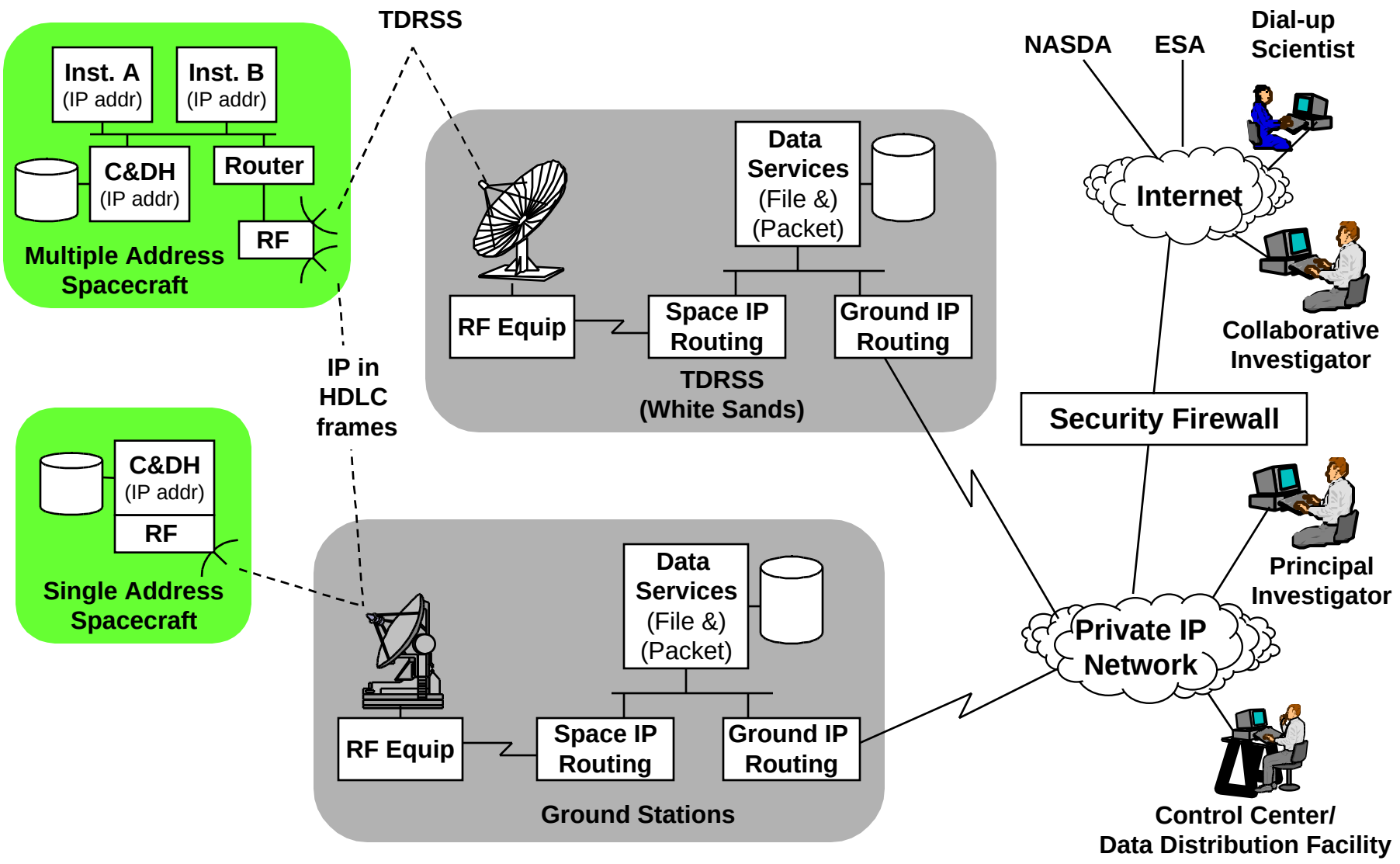
Summary of Recent UoSAT-12 IP Testing

July 26, 2000

Space Internet Communication Concept



Space Internet Implementation



OMNI Goals

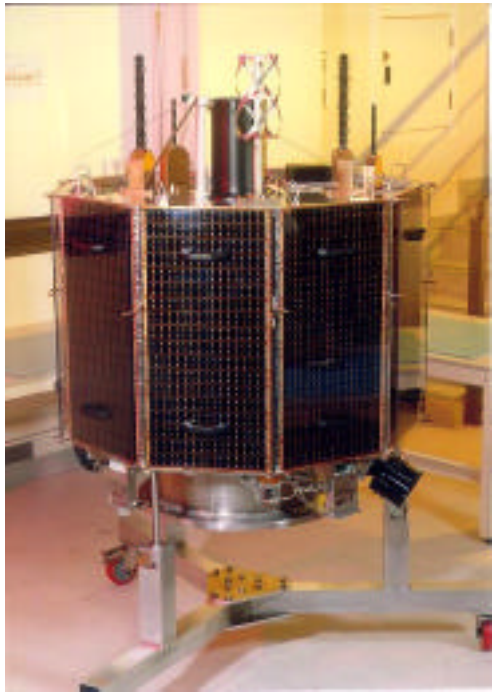
- **Demonstrate feasibility & benefits of Internet Protocols (IP) for future space missions**
- **Develop repository of expertise in end-to-end engineering of missions using IP communications**
- **Provide institutional resource for end-to-end testing of hardware/software solutions for IP missions**

OMNI Major Milestones

- **Feb-Apr 1999 - Demonstrations of IP communication through TDRSS to mobile spacecraft simulator (OMNI van)**
- **Aug 1999 - Solar eclipse mission in Black Sea - eclipse images and telemetry webcast via TDRSS to thousands of viewers**
- **Nov 1999 - JSC Inspection Day '99 - Supported Technology Showcase by providing live audio/video/telemetry from mobile OMNI van to the SOMO Technology Booth in the lobby of "mission control" in Houston.**

OMNI Major Milestones (cont.)

- **Nov 1999 - Identified opportunity to use UoSAT-12 spacecraft for IP to spacecraft demonstrations**
- **Feb 2000 - Contract in place for flight software and spacecraft time**
- **Apr 2000 - Successful initial tests with spacecraft**
- **May - Sept 2000 -**
  - Incorporate protocols required for operational support
  - Demonstrations to HQ, scientists, etc.
  - Consult with missions interested in using IP
- **Future - More demonstrations and enhancements**



UoSAT-12 IP-in-Space Testing

- **Key team members**
  - System Integration and Testing (CSC)
    - Keith Hogie, Dr. Ron Parise, Ed Criscuolo, Jim, Langston, Thinh Le
  - Flight software (VyTek)
    - Harold Price, Skip Hansen
  - Spacecraft/Ground Station (Surrey Satellite Technology Ltd., SSTL)
    - Jeff Ward, Chris Jackson
  - Test Plan
    - Larry Frank (APL)
  - Civil servants
    - Jim Rash, Freemon Johnson, Semion Kizhner

UoSAT-12 IP-in-Space Testing

- **Accomplished so far**
  - First IP node in space using only standard Internet protocols
    - IP connectivity via standard Ping
  - First spacecraft clock synchronization with ground time standard using only standard Internet protocols
    - Standard network time protocol (NTP)
  - Reliable Data File Up/Download using FTP
- **Significance of first results**
  - Fact: IP works in space
  - Cheap, simple solution to on-board clock synchronization problem
  - Effective reliable transport of data using COTS protocols

UoSAT-12 IP Test Overview

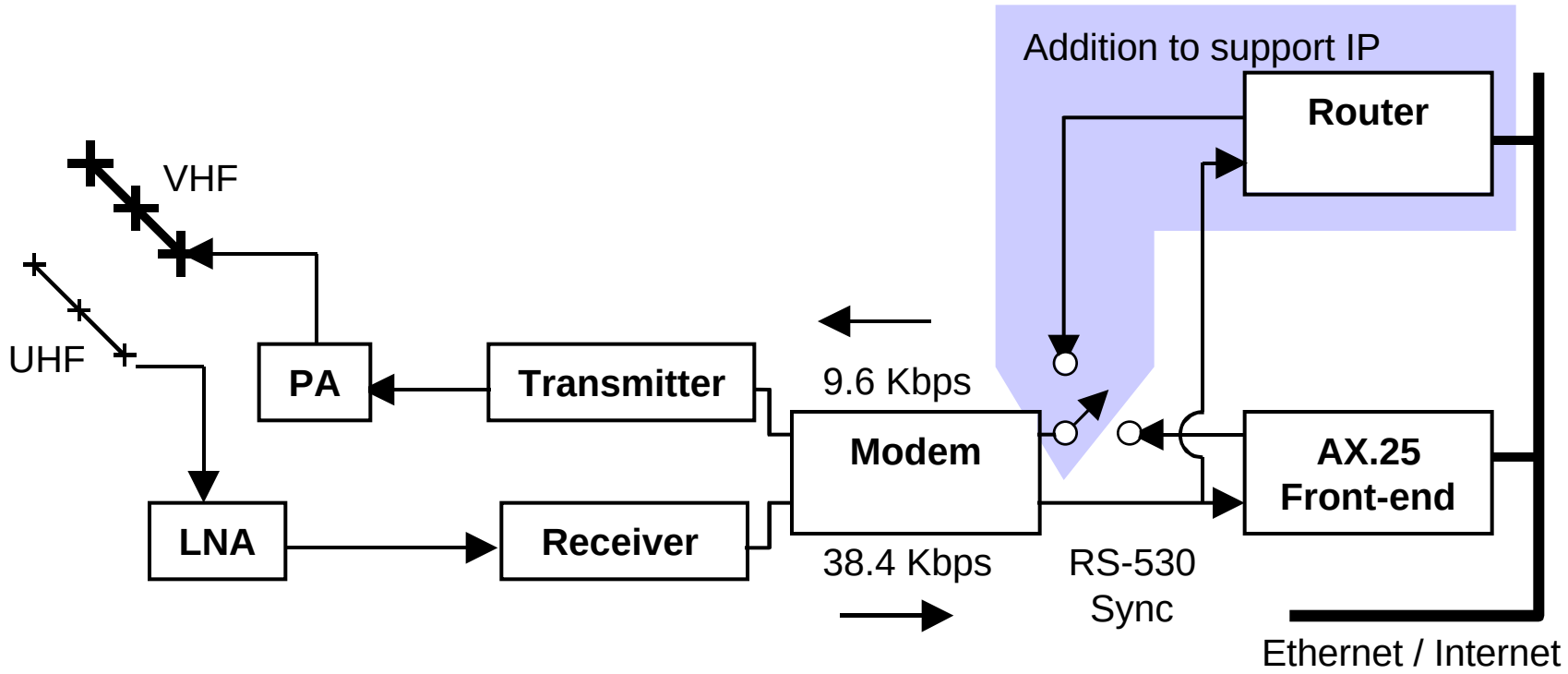
- **UoSAT-12 and Surrey Ground Station Preparation**
- **Initial Tests (Phase I & II)**
  - Basic network connectivity (PING)
  - Spacecraft clock synchronization (NTP)
  - File transfer/link utilization (FTP)
- **Distribute Test Results**
- **Phase III and Beyond**
  - Real-time engineering data
  - Multicast data delivery
  - Unidirectional operations
    - Blind commanding
    - File transfer
  - Automatic store-and-forward (SMTP)
  - Multiple ground stations (Mobile IP)
  - Security (VPNs on ground and space links)

UoSAT-12 & Surrey Ground Station

- **UoSAT-12 Flight Software (VyTek)**
  - SpaceCraft Operating Systen (SCOS) developed by VyTek
  - Added FreeBSD 4.4 IP stack to SCOS
    - Basic stack supports PING and IP timestamp option
  - Ported NTP client and FTP server to SCOS
  - Tested with Cisco router and SCOS simulator system in Pittsburgh

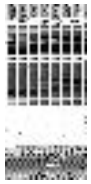
- **Surrey Ground Station (SSTL)**
  - Installed Cisco provided router with RS-530 interface at SSTL
  - Some problems connecting router to SSTL simulator,
  - Simulator tests skipped, went straight to spacecraft tests
  - Interfaced router to clock/data from SSTL transceiver
  - Verified router receiving HDLC frames
  - Uploaded new SCOS modules to secondary CPU onboard UoSAT

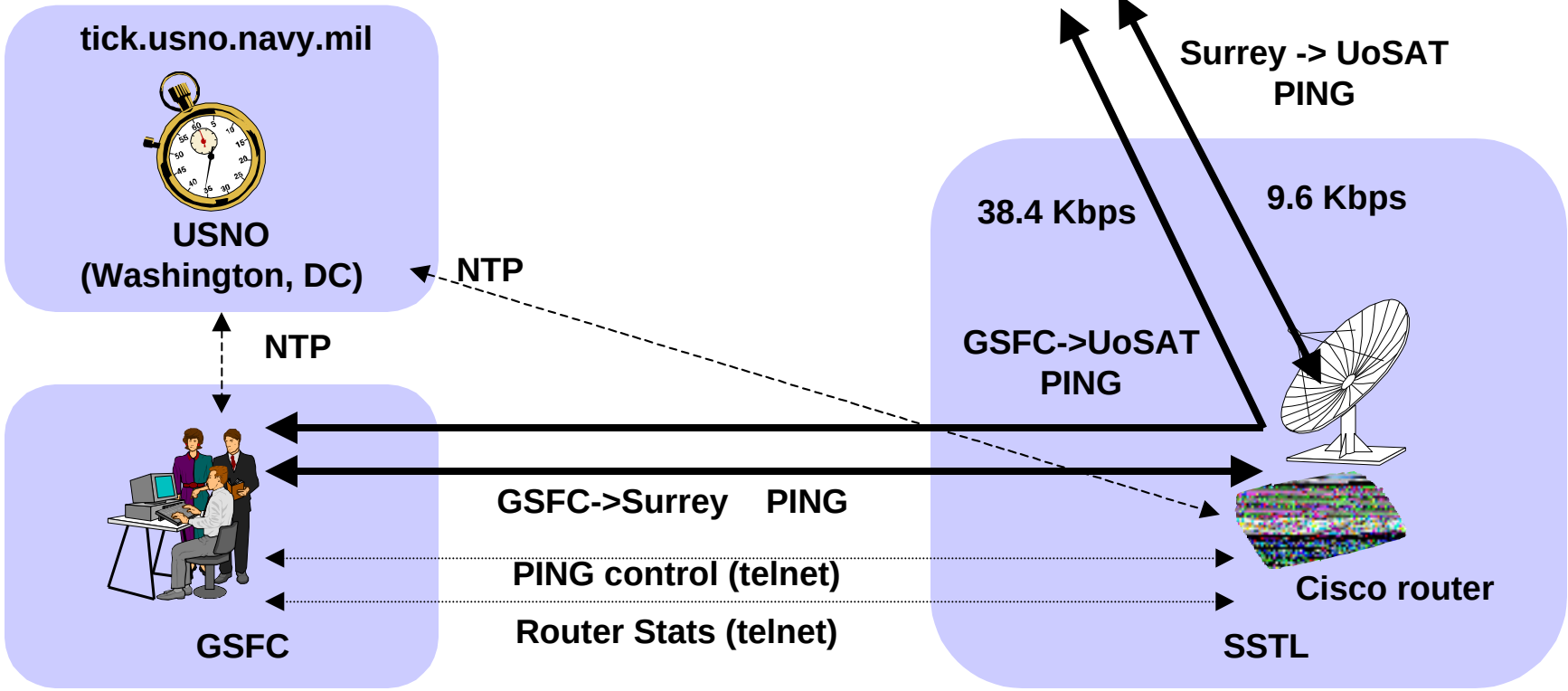
Surrey Ground Station Modifications



Network Connectivity Configuration

- Continual PING from router to UoSAT-12
- GSFC to Surrey router PINGs (10 sec.)
- GSFC to UoSAT-12 PINGs (10 sec.)
- Router monitoring from GSFC



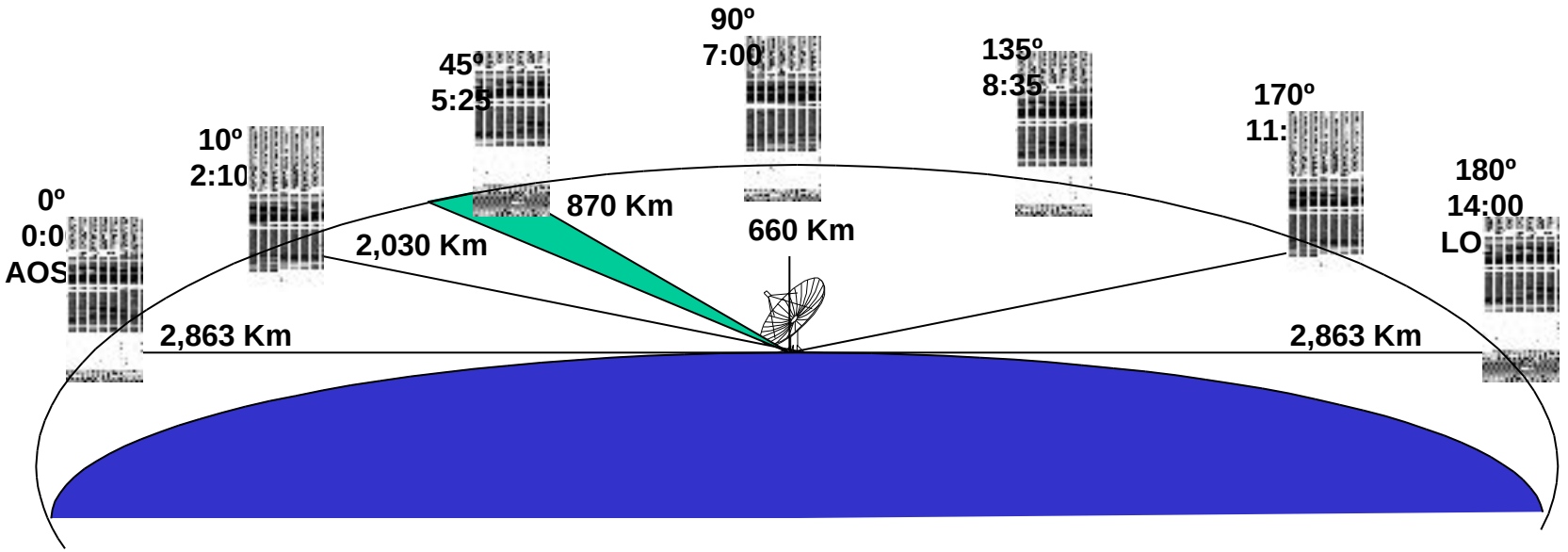


UoSAT-12 Pass Characteristics

- **Propagation delays are a function of data rate and distance**

Pkt. Size \ Rate	9.6	38.4
64 byte (ms.)	53	13
1280 byte (ms.)	1,067	267

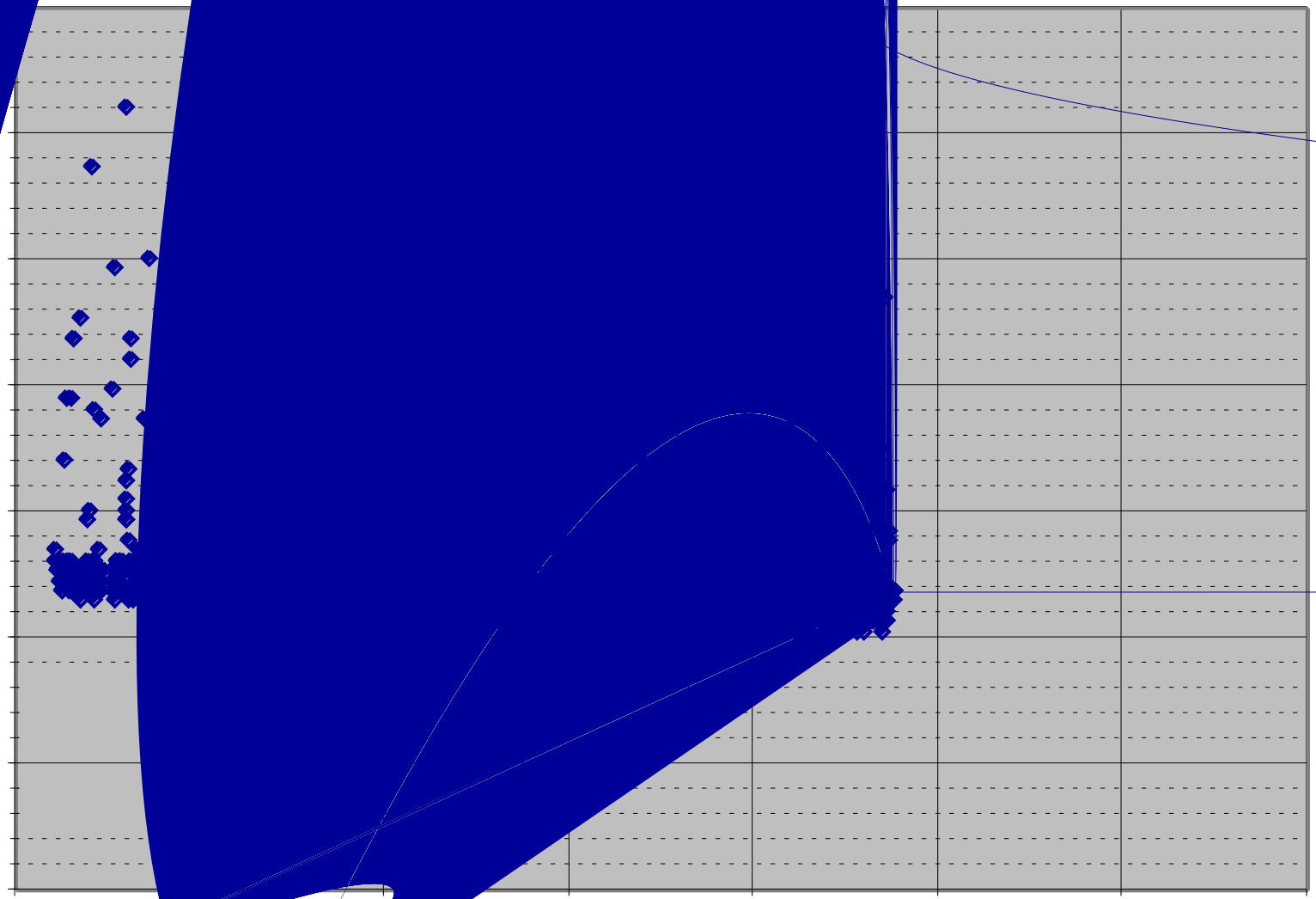
Data Path \ Elevation	0º	10º	45º	90º
One-way delay (ms.)	10	7	3	2
64B packet round-trip (ms.)	86	80	72	70
1280B packet round-trip (ms.)	1,354	1,348	1,340	1,338



Network Connectivity

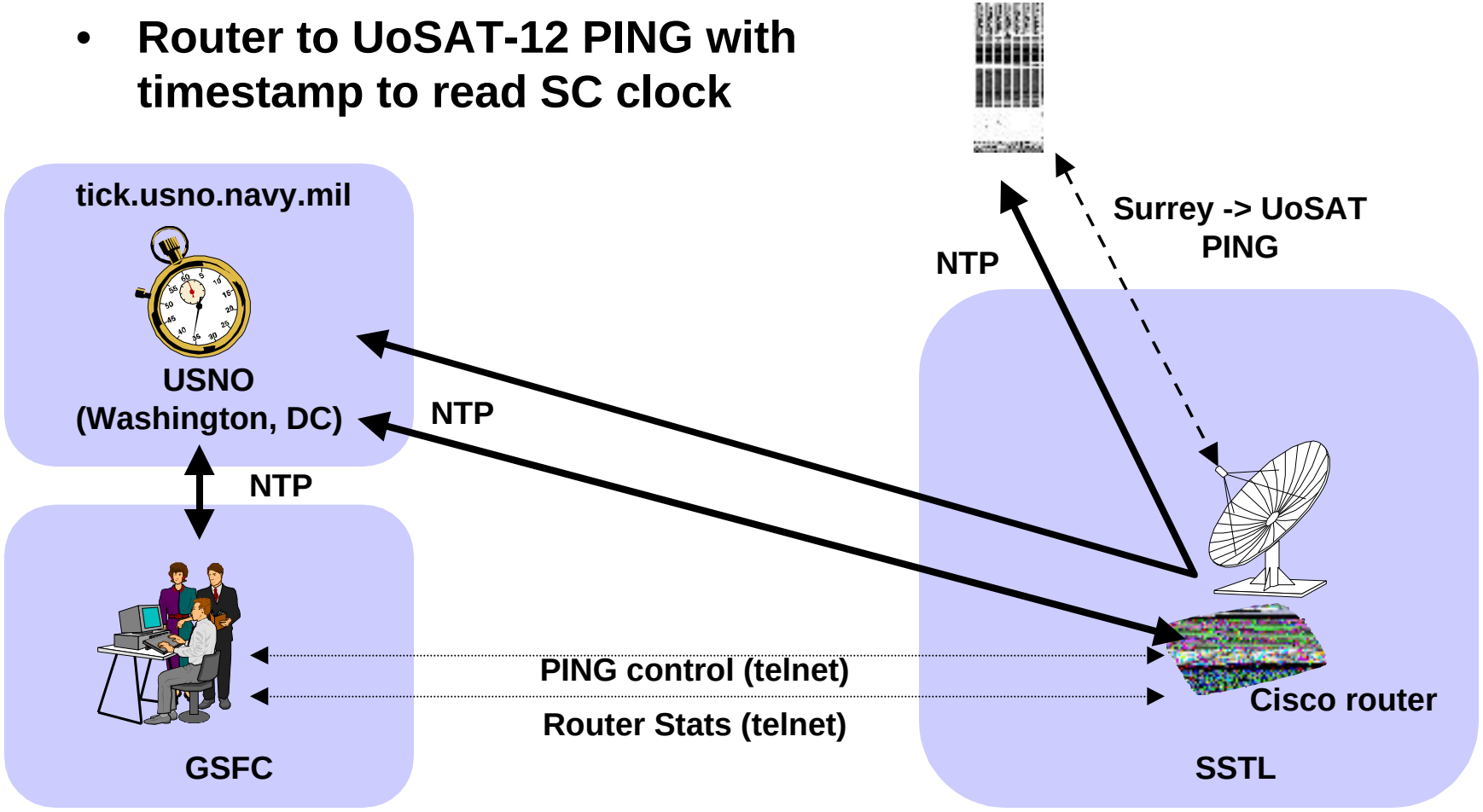
- **PING Tests**
  - Verify HDLC/Frame Relay framing functionality
  - Demonstrate end-to-end network connectivity
  - Measure propagation delay from AOS to LOS
  - Simple link availability from AOS to LOS
- **Data collected**
  - Continual PINGs from Surrey to UoSAT-12
    - Detailed characterization of delay/connectivity from AOS-LOS
    - 3349 successful PINGs - 181 no response
    - Average of 4.17 successful PINGs per second
  - 10 second PINGs from GSFC to UoSAT-12
    - End-to-end connectivity
    - 22 hops from GSFC to UoSAT-12
  - Surrey router stats
    - Serial link data transfers and errors

P 10, 2000



Clock Sync Configuration

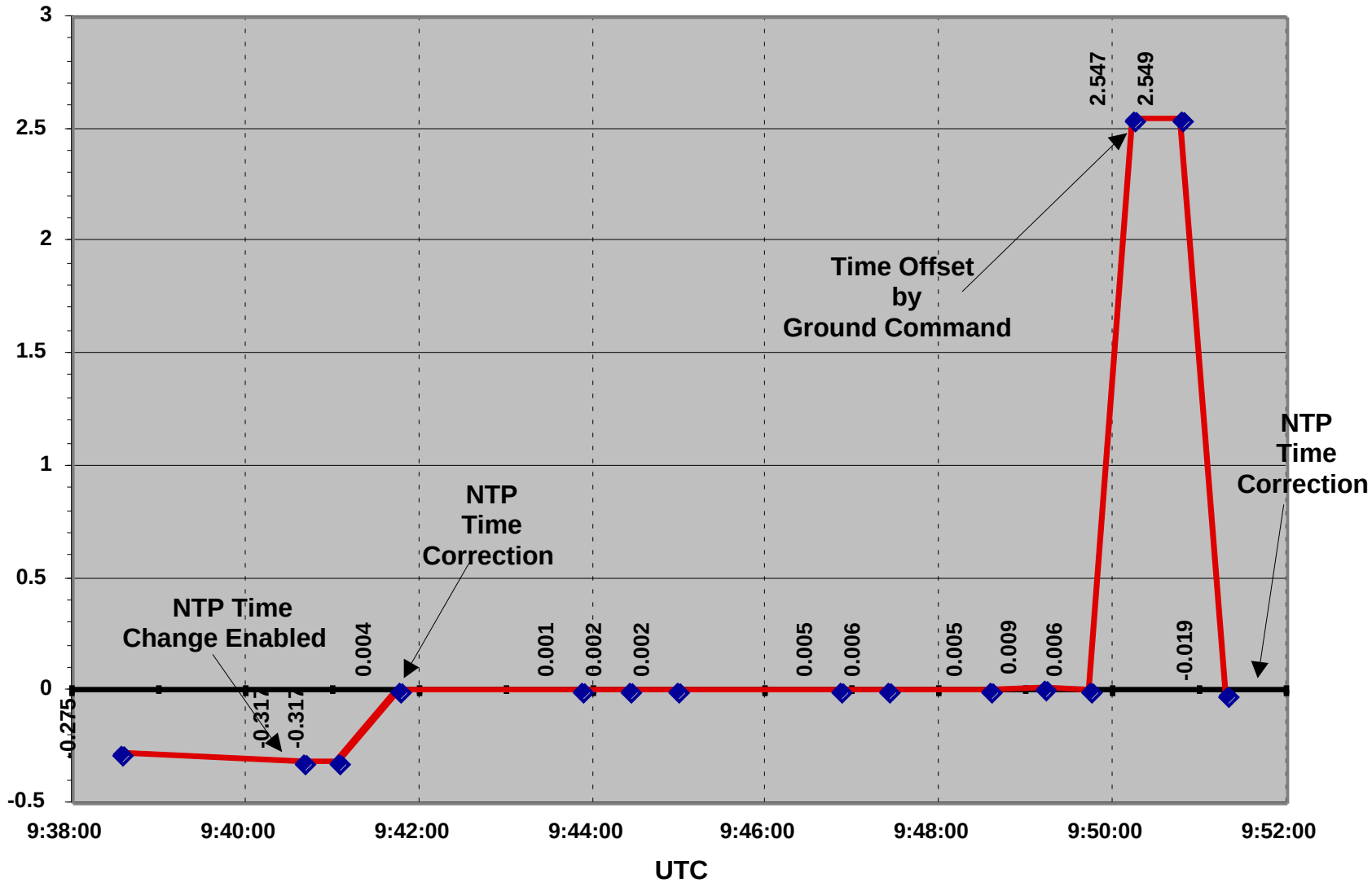
- NTP on UoSAT-12 to sync SC clock
- Router to UoSAT-12 PING with timestamp to read SC clock



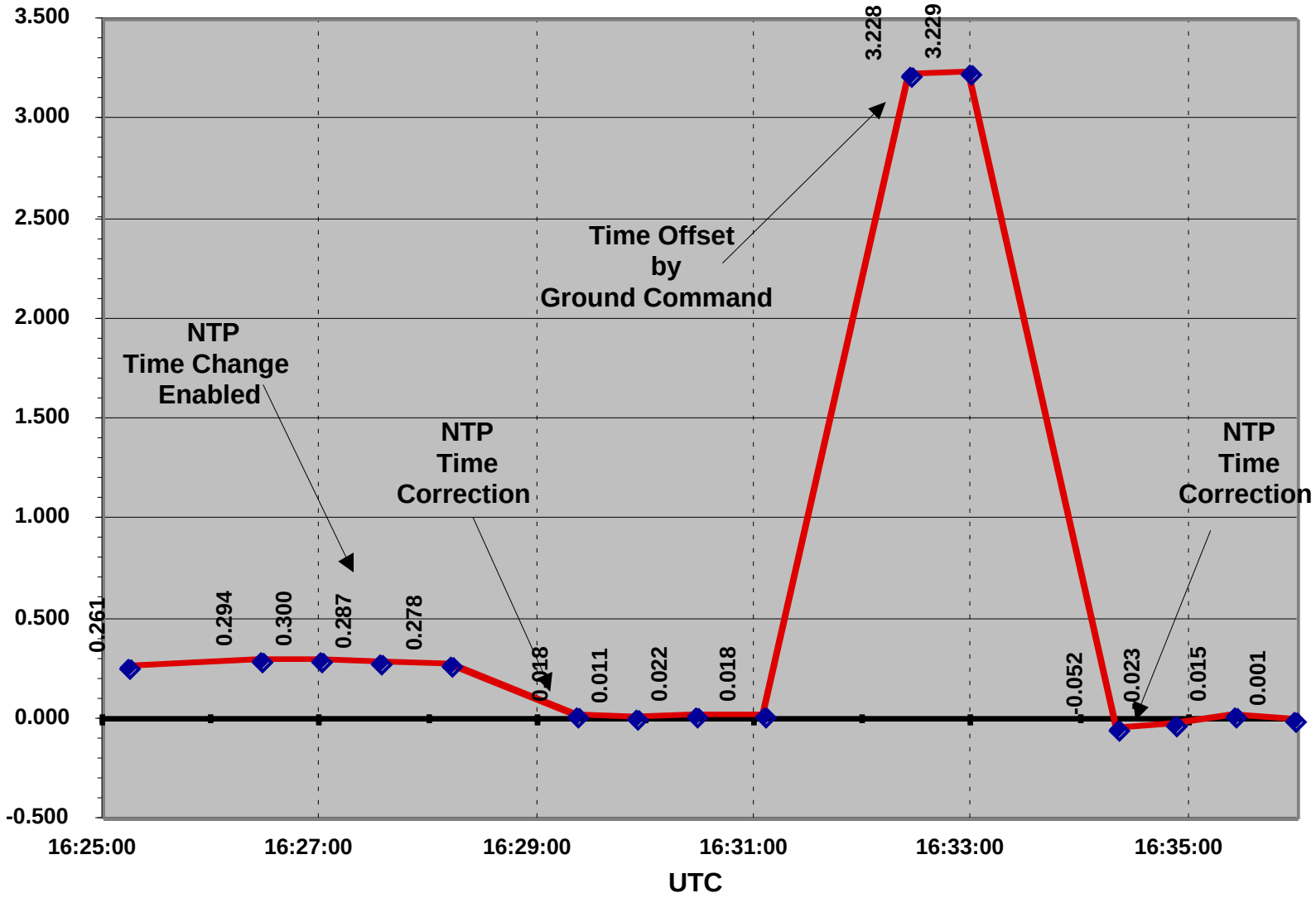
Clock Sync

- **NTP Test Configuration**
  - Install NTP client on UoSAT-12
  - Sync Surrey router with USNO NTP server
  - Surrey router has too little memory to support NTP server so aim spacecraft directly at USNO timeserver
- **NTP Tests**
  - Use PING with timestamp to read and compare SC clock
  - Monitor NTP setting spacecraft clock in SCOS UDP telemetrypackets
  - Manually offset spacecraft clock and watch resync
- **NTP Results**
  - NTP successfully corrected clock 4 times over 2 passes
  - NTP corrections within limits of UoSAT-12 10 ms. clock ticks

NTP Test 1 - 09:38 - Apr. 14, 2000

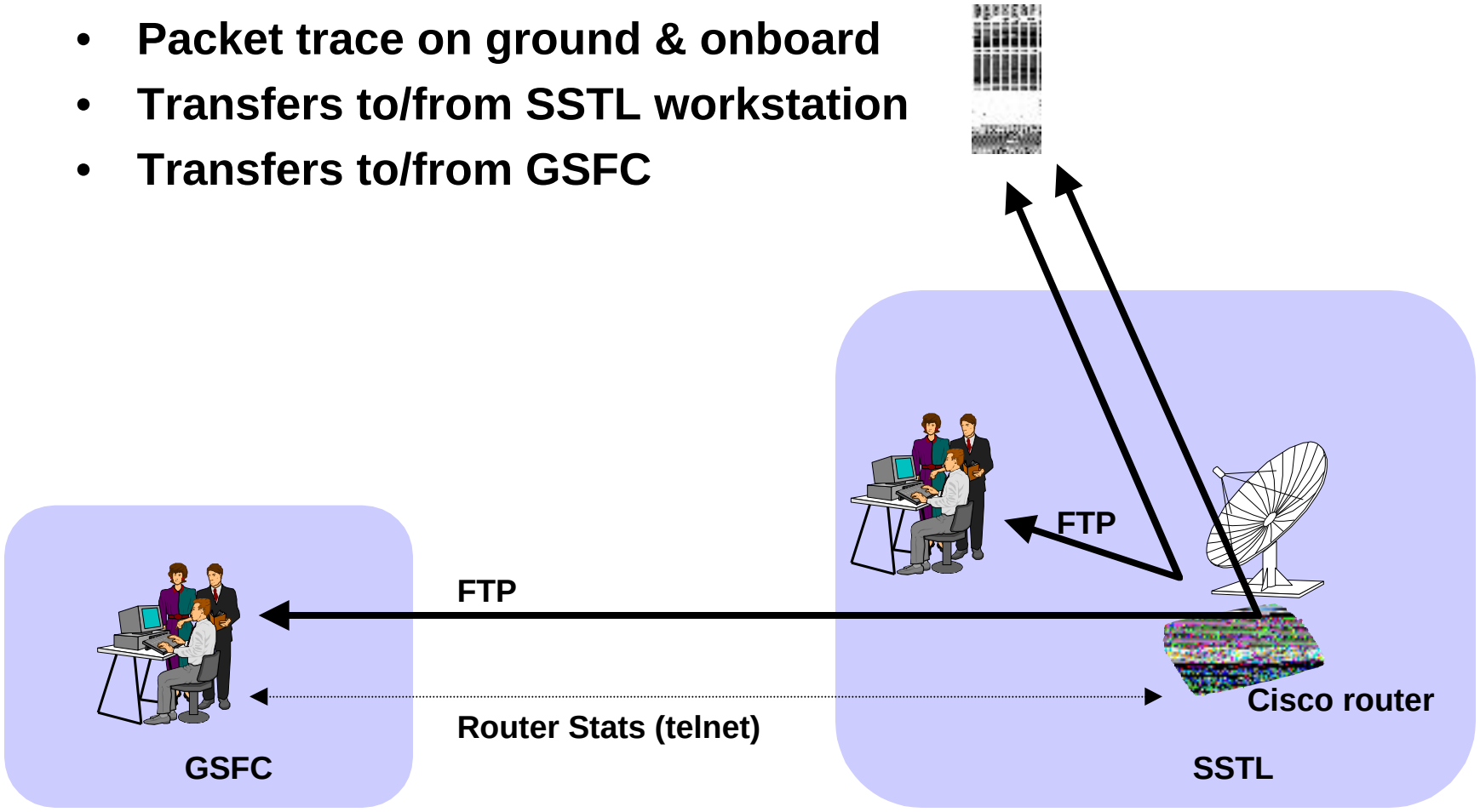


NTP Test 2 - 16:25 - Apr. 14, 2000



FTP Configuration

- FTP server on UoSAT-12
- Packet trace on ground & onboard
- Transfers to/from SSTL workstation
- Transfers to/from GSFC



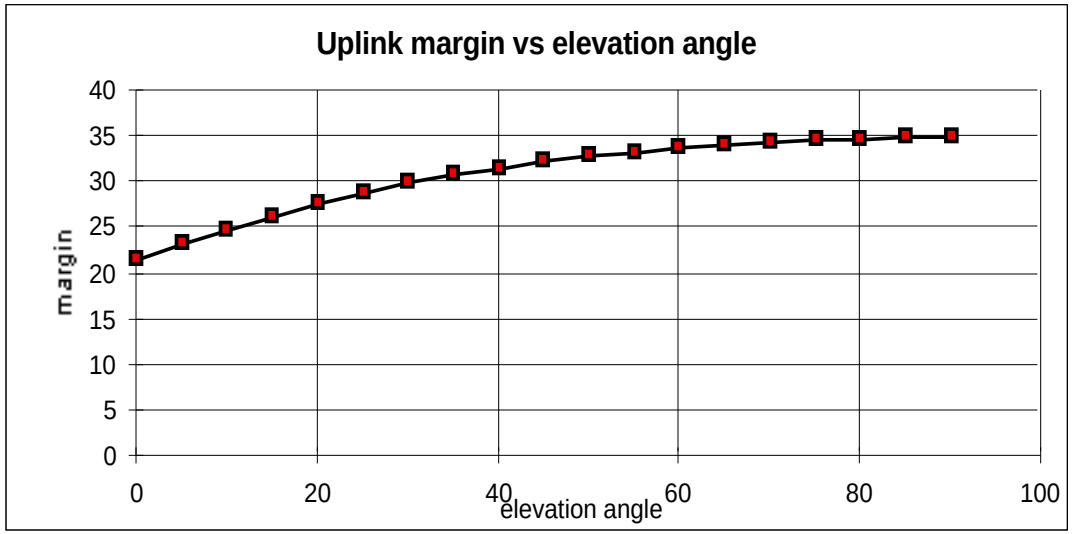
UoSAT-12 Data Transfer Characteristics

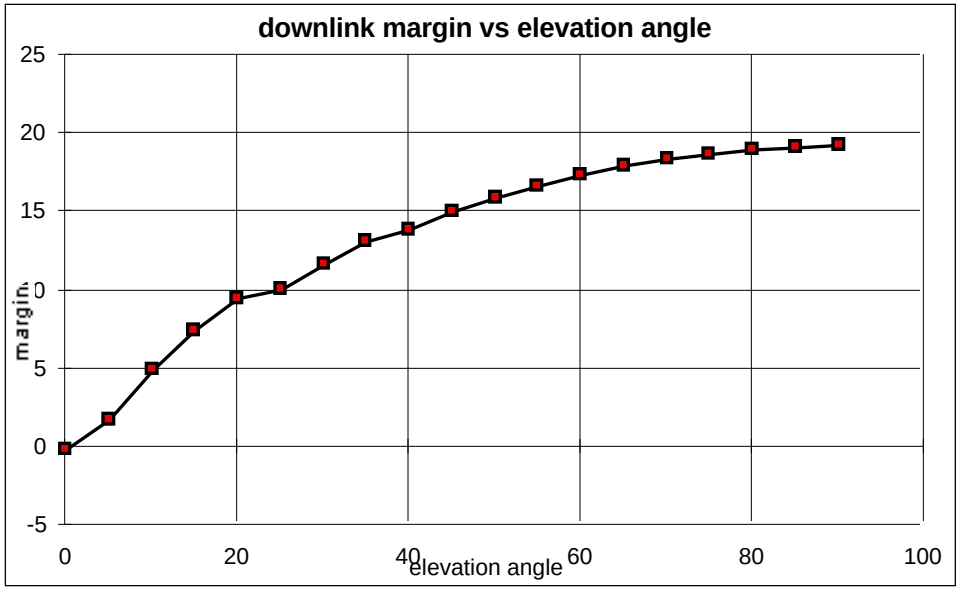
- **Data Rates**
  - Uplink - 9.6 Kbps Downlink - 38.4 Kbps
- **Data Volume / Time**
  - Data transfer volumes selected to provide 1 minute or less transfers

Bits	Bytes	9.6 Kbps	38.4 Kbps
100 K	12.5 K	10.4 sec.	2.6 sec.
1 M	125 K	104 sec.	26 sec.
10 M	1.25 M	17:20	4:20
30 M	3.75 M	52:00	13:00

UoSAT-12 Link Margins

- **Link margins computed at 0 margin = Eb/No of 12 dB 10e-5 BER**



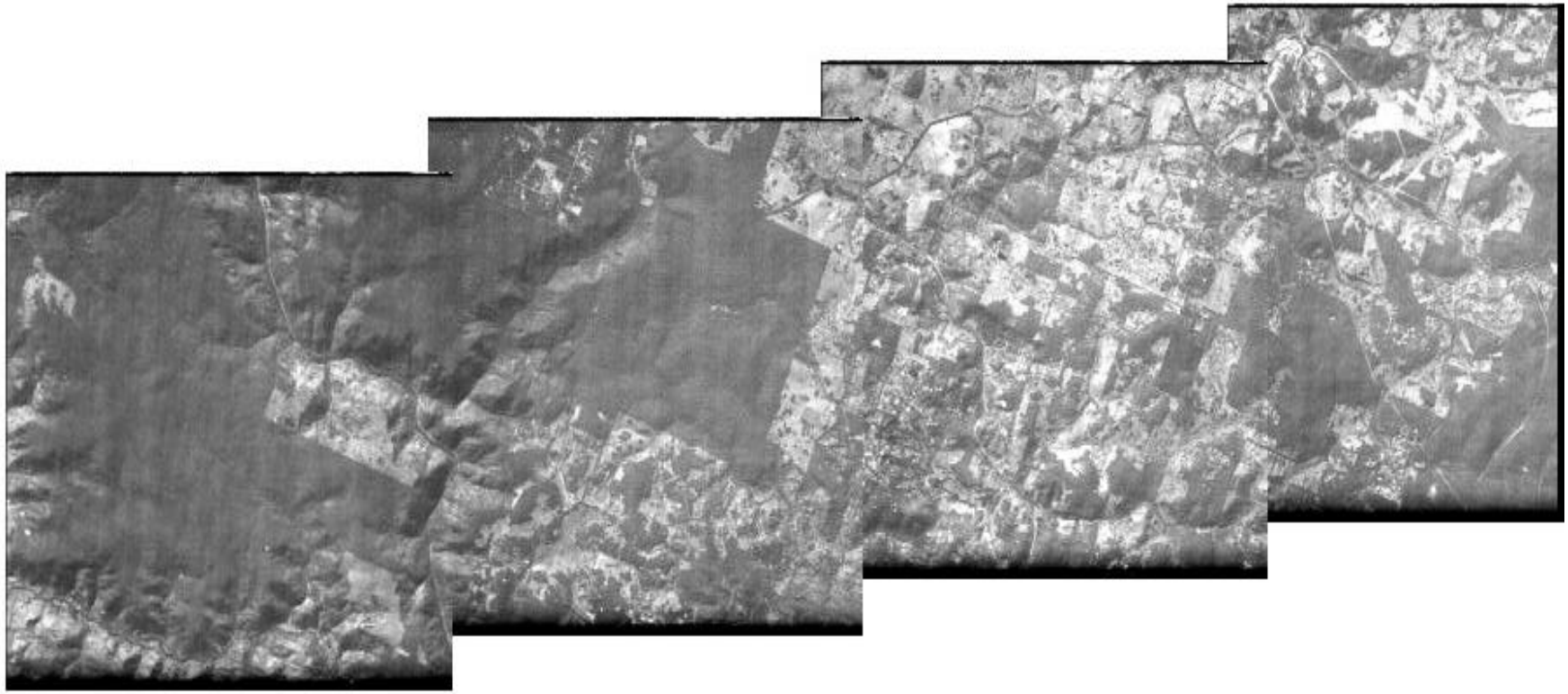


FTP Testing

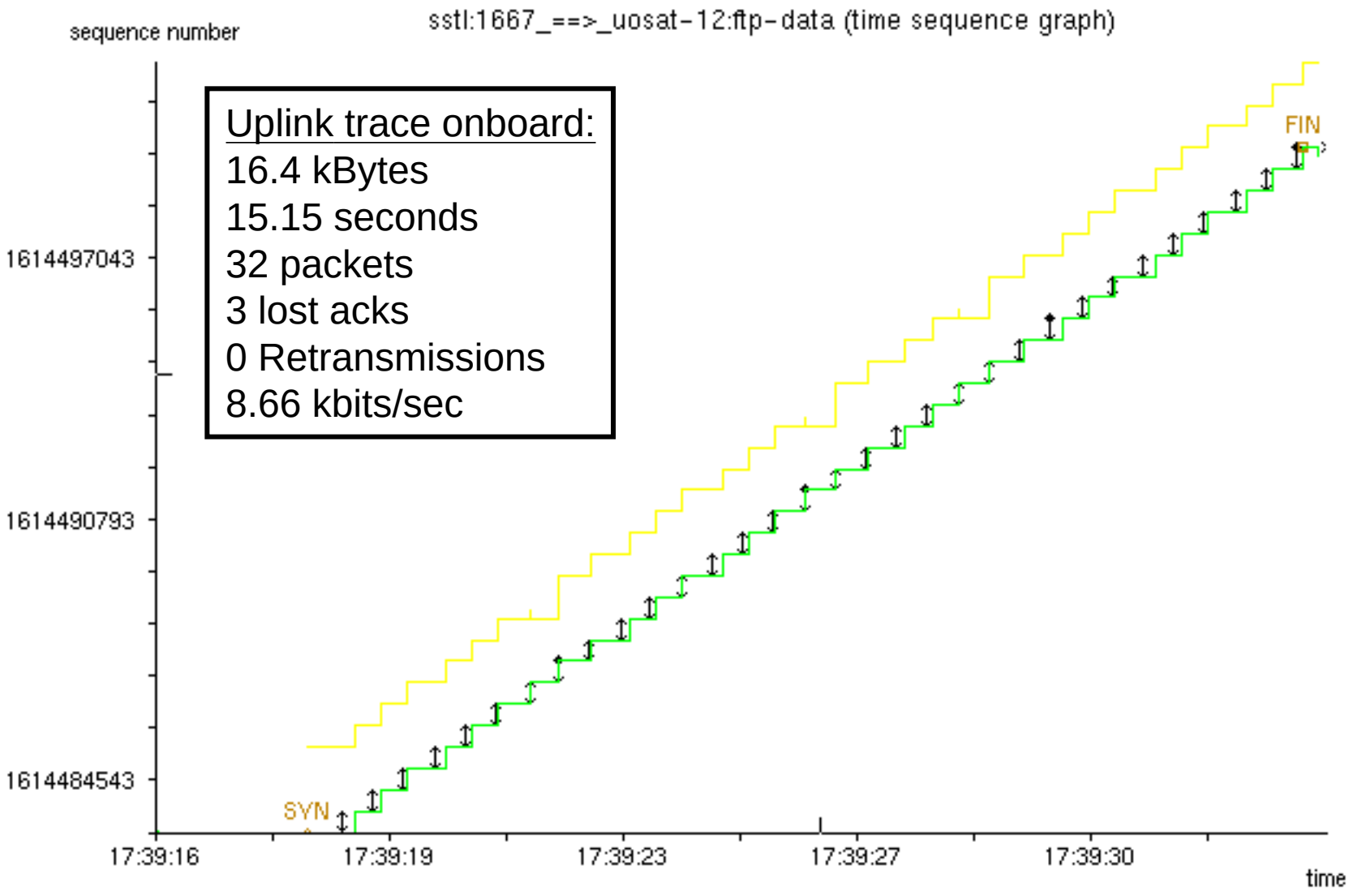
- **FTP Test Configuration**
  - Install FTP client on UoSAT-12
  - Install packet trace software on UoSAT-12
  - Install packet trace software on SSTL workstation
- **FTP Tests**
  - Functional: Uplink and Downlink from GSFC
  - Uplinks from SSTL with packet traces
  - Downlinks from SSTL with packet traces
- **FTP Results**
  - Successful data file and image transfers up and down
  - Uplink: 16.4 kBytes, 8.66 kbits/sec, 90.2% bw util. (with 0 retr.)
  - Downlink: 227 kBytes, 30.4 kbits/sec, 79.2% bw util. (with 9 retr)
  - FTP theoretical maximum bandwidth utilization is 91.6%

FTP Test 3 - June 7, 2000

Downloaded 4-Image Mosaic of Perth, Australia

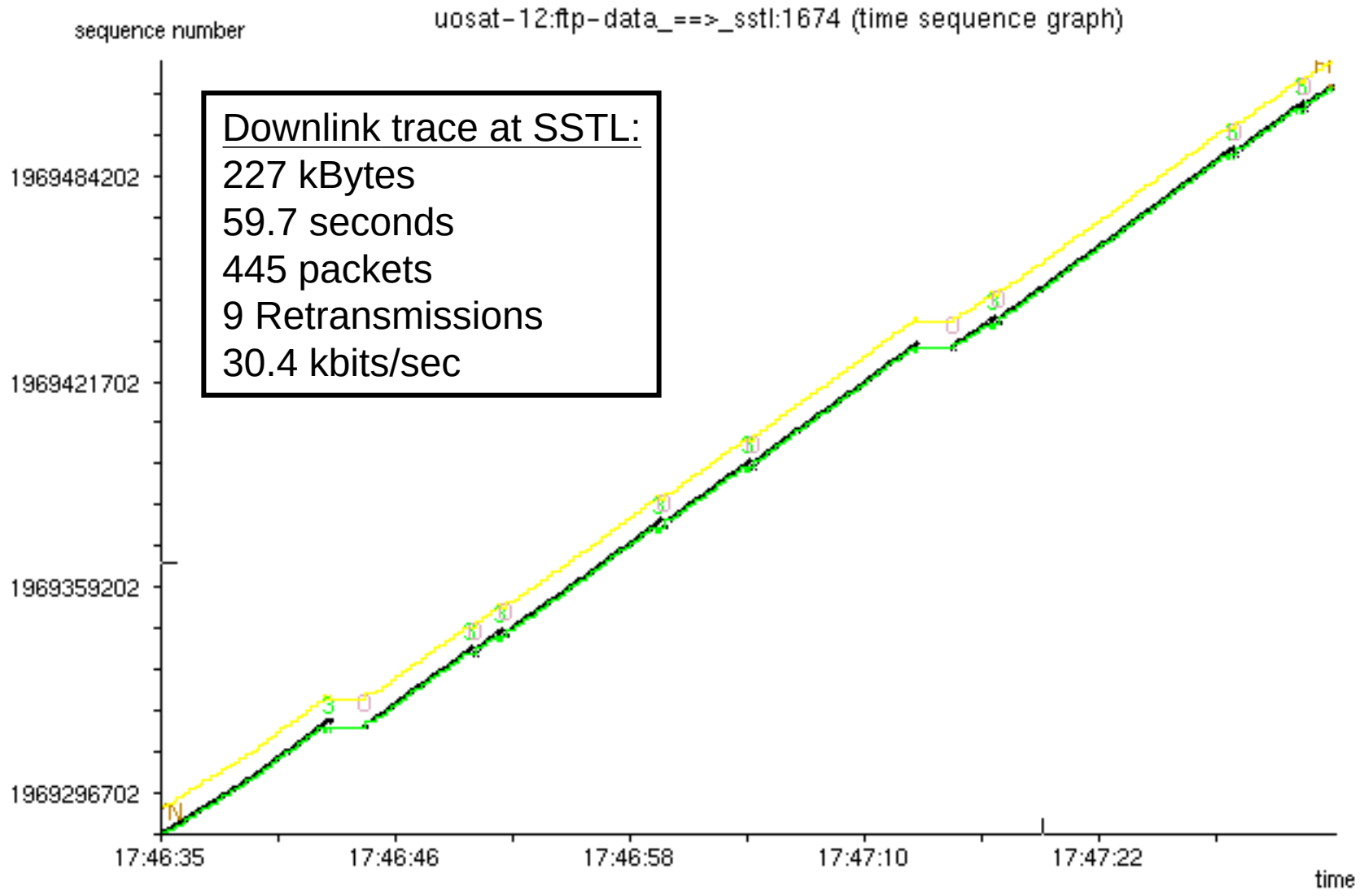


FTP Test 7 - July 5, 2000



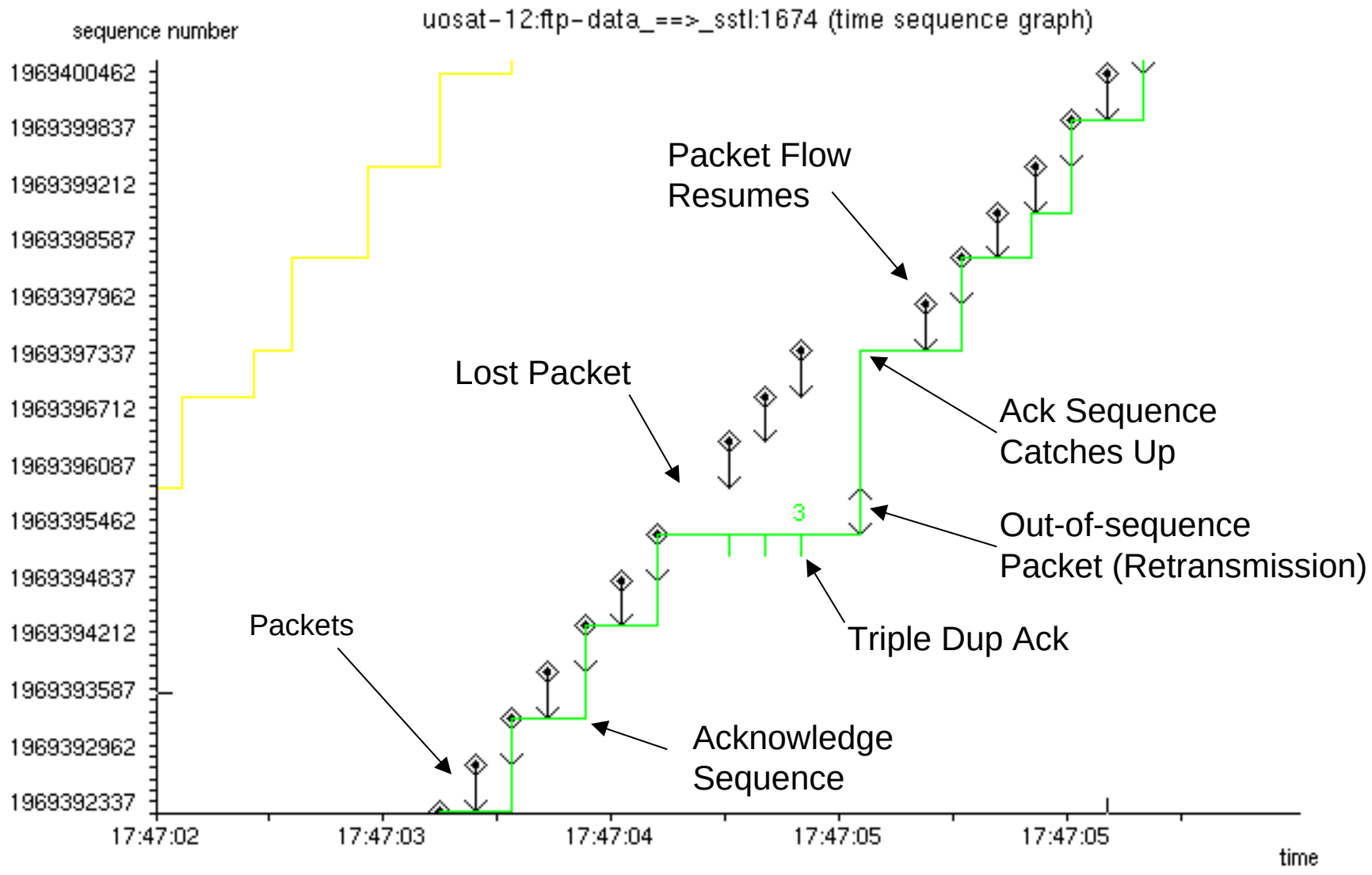
Uplink trace onboard:
16.4 kBytes
15.15 seconds
32 packets
3 lost acks
0 Retransmissions
8.66 kbits/sec

FTP Test 7 - July 5, 2000

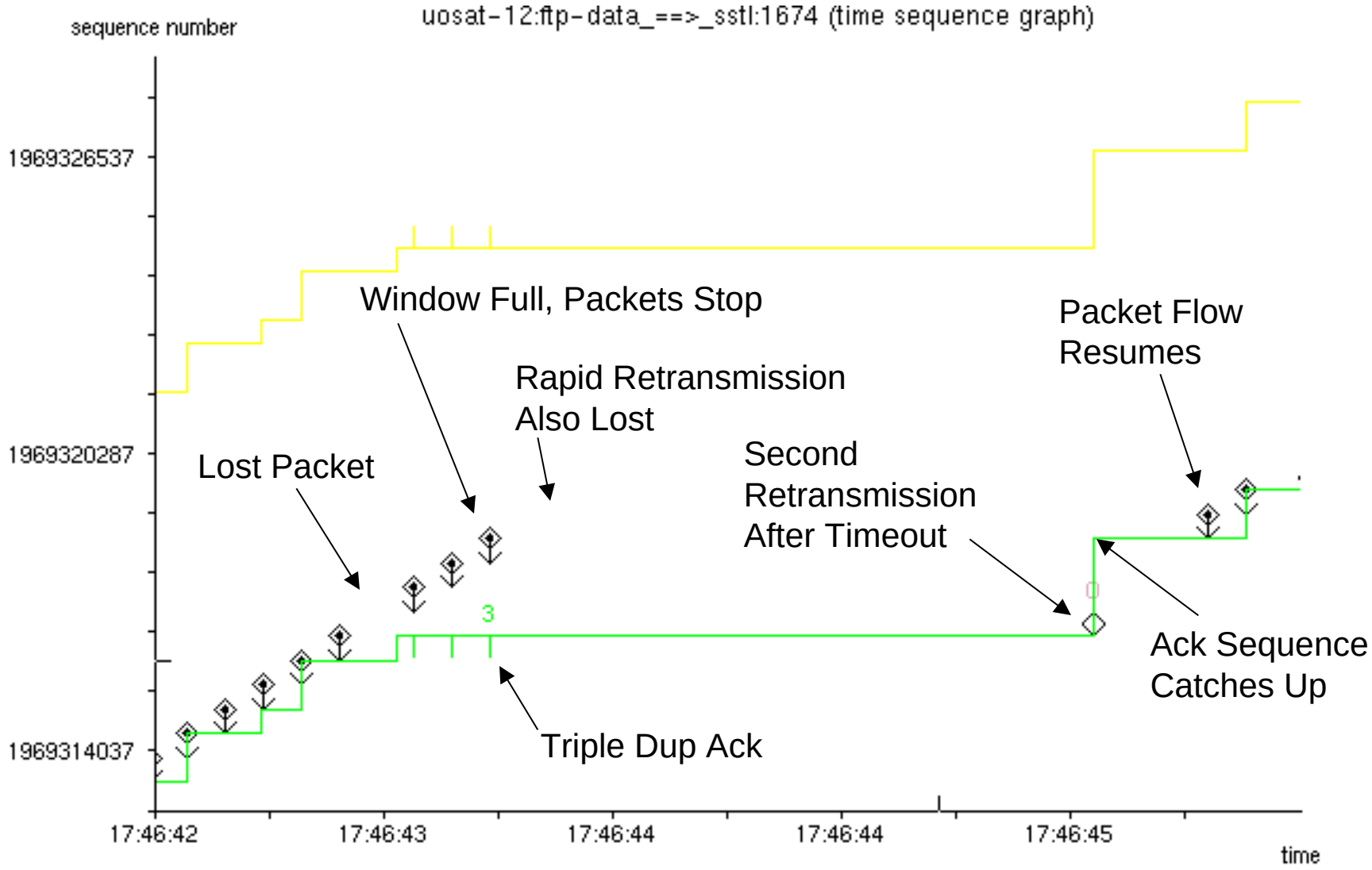


Downlink trace at SSTL:
227 kBytes
59.7 seconds
445 packets
9 Retransmissions
30.4 kbits/sec

FTP Rapid Retransmit



FTP: Retransmit Timeout



Future OMNI / UoSAT-12 IP Experiments

- Real-time data delivery (UDP)
- Reliable commanding (TCP) and blind commanding (UDP)
- File transport using HTTP
- Multicast real-time data delivery (UDP/IP multicast)
- Extremely asymmetric bandwidth “reliable” file transfer (MFTP, CFDP, etc.)
- Automated file store and forward (SMTP)
- Automatic routing at multiple ground stations (Mobile IP)
- Network security (VPN at ground sites and spacecraft)