Overview of NASA Glenn Aero/Mobile Communications Demonstrations

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The Glenn Research Center at Lewis Field (GRC) has been involved with several other NASA field centers on various networking and RF communications demonstrations and experiments since 1998. These collaborative experiments investigated communications technologies new to aviation, such as wideband Ku satcom, L-band narrowband satcom, and IP (Internet Protocol), using commercial off-the-shelf (COTS) components These technologies can be used to distribute weather and hazard data, air traffic management and airline fleet management information, and passenger cabin Internet service.

Terminal Development
The first step was to construct a terminal capable of utilizing a prototype phased-array Ku-band satcom Transmit/Receive antenna system and a packet VHF line-of-site communications system.

The phased-array antenna system required an aircraft attitude and position data for pointing calculations. Extra integration was required when the terminal was not used in a modern aircraft. A laser ring gyro, external GPS, an onboard computer and custom software provided the required data for the antenna system. In addition, the onboard computer provided logging of some terminal state information.

The initial terminal used a Sun workstation as a IPv4 router. A commercial router replaced the Sun workstation during a subsequent terminal upgrade.

A complementary fixed station was also constructed.

Aero/mobile Communications Van Ground Tests
Once the terminal was constructed, its electronics and antennas were integrated into a large van. The van was used to simulate an aircraft in flight. Although the motion of the van is certainly nothing like that of an aircraft, the van still provided a mobile platform and helped us work out many problems we would encounter on an actual aircraft at a small fraction of the cost of flying.

We were able to demonstrate successful satellite and VHF data connections while in motion.

AeroSAPIENT
This collaborative effort with NASA Dryden Flight research Center (DFRC) demonstrated in-flight networking and communications demonstrations using Ku-band broadband satellite communications to a DC8 aircraft. Several network applications were demonstrated such as Internet Web browsing/serving, e-mail, telnet, FTP, voice-over IP, remote buffered network bus air to ground connectivity and the transmission of DC-8 digital such as air data, system data and live video.

This campaign was completed successfully and mobile terminal was returned to the van.

LaRC 757
For this program, we provided a connection to the Internet via Ku satcom. Through this connection, we were to support the WinComm program experiments and other experimenters. One application was to transfer turbulence measurement data from the airplane to the ground.

This was the first installation of the terminal on a modern aircraft, and the first use of a commercial router in the terminal.

Mobile Router Experiments
The mobile terminal was upgraded to support mobile IPv4 networks. This eliminated the static routes used to switch between the data links. Also, the L-band satcom link and 802.11b link were added to van. Several experiments were carried out to demonstrate the operation of four data links to the van to support IPv4 applications.

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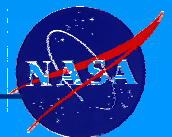
Why Aero/Mobile Demonstrations?

- Requirement to demonstrate emerging and current communication technologies that distribute IP-based services to a mobile platform such as an aircraft or a van.

- Various NASA projects have aviation communication concerns that could be explored with a mobile platform:

  - Advanced Communications for Air Traffic Management (AC/ATM)

  - Aeronautical Satellite Assisted Process for Information Exchange through Network Technologies (Aero-SAPIENT)

  - Aviation Weather Information (AWIN)

  - Weather Information Communications (WINCOMM)

  - Advanced Air Transportation Technologies (AATT)
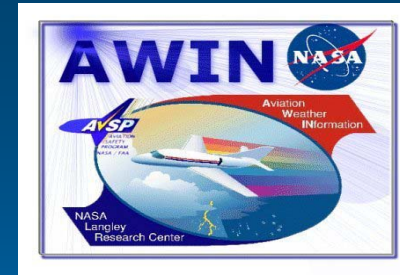
AC/ATM

Aero-SAPIENT
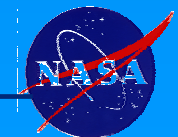
How did our group go about it?

- Developed a flexible system supporting multiple communication links to an aircraft or ground vehicle that be used as an aviation communication testbed.

- Used COTS hardware, custom software/hardware, IP protocols for mobile and aircraft demonstrations.

- Installed the communication system into GRC's Aero/Mobile van, DFRC's DC8 and LaRC's B757 to support various projects such as AATT, AeroSAPIENT and AC/ATM.

- Used CPDLC, HTTP, ftp, iperf, ttcp, system logging capabilities and other applications to demonstrate the system.
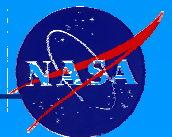
Who was involved?

Information Technology Program
- Ames Research Center (ARC)
- Dryden Flight Research Center (DFRC)
- Creare - Ring Buffer Network Bus

Aviation Safety Program
- Langley Research Center (LaRC)
- Rockwell Collins - Weather/Turbulence

Airspace Systems Program
- Ames Research Center (ARC)
- Boeing - Ku-band Phase Array Antenna
- CNS, Inc - CPDLC
- Dubbs and Severino, Inc - Digital Aviator/Multifunction Display

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AC/ATM
- Free Flight Concepts

WINCOMM
- Access to weather information.

AeroSAPIENT
- Broadband network connectivity.
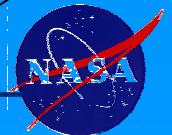
GRC Aero/Mobile Van System Overview
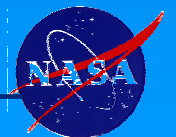
GRC Aero/Mobile Van

- Mobile platform started with a single Ku-band satellite link with three more links added over 2002-2003 for ATN and IPv4 connectivity.

  – Ku-band geosynchronous satellite link with a ~2 Mb/s QPSK downlink and a 256 kb/s Spread Spectrum uplink to GRC's Ku fixed station

  – L-band MDSS satellite link to an offsite fixed link providing IP connectivity back to GRC.

  – VHF 19.2 kb/s link to GRC's fixed station.

  – 802.11B (2 -11 Mb/s) connectivity up to 4 bridge points around the GRC campus.

- System is reconfigurable for new capabilities such as:

  – communication links, networking hardware, applications, aviation ...

- Initial test platform before system upload to an aircraft.

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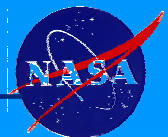
Mobile Multilink Demonstration Progression

GRC van's support for multiple communication paths :

- Select between VHF and Ku-band mobile communication paths using static routes on the van's Cisco 3640 router for IPv4 connectivity. (2001-2002)

- Select between VHF and Ku-band mobile communication paths using a weighted routing table on the van's Cisco 3640 router for IPv4 connectivity. (2002-2003)

- Select VHF, Ku-band, L-band and 802.11B mobile communication paths using Mobile IPv4 RFC3344 with NEMO(Networks in Motion) to support a fixed IP subnet using a Cisco 3640 router. (2003-2004)

- Select VHF, Ku-band, L-band and 802.11B mobile communication paths using current IETF draft Mobile IPv6 NEMO using a Cisco 3745. (January 2004-Present)

*NOTE:* Most experiments were conducted while under motion around the GRC campus and northeast Ohio.
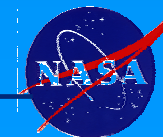
What can be demonstrated in the van?

- Ability to record mobile system state information from various devices to a file with microsecond resolution timestamps.
    - The logging system suite is called NASA GRC AATT Logging System(NGALS).
    - NGALS files can be used to correlate network and other system events.
    - NGALS files include attitude, position, router, modem status and other data points.
- Any aviation communication system requiring attitude and position data on an ARINC429 data bus.
    - ARINC429 data is created by combining ring-laser gyroscope data with Global Positioning System(GPS) data on a SUN computer. The combined data is written out a Ballard ARINC429 PCI card for communication system use.
    - Steerable antenna systems require this attitude and position information .
- Any software that can run under Solaris2.x, Windows2000 and OSX on the various van computer platforms.
- Any IPv4 or IPv6 based hardware.
- An opportunity to test aeronautical communication systems without the expense or logistical burden of flight testing

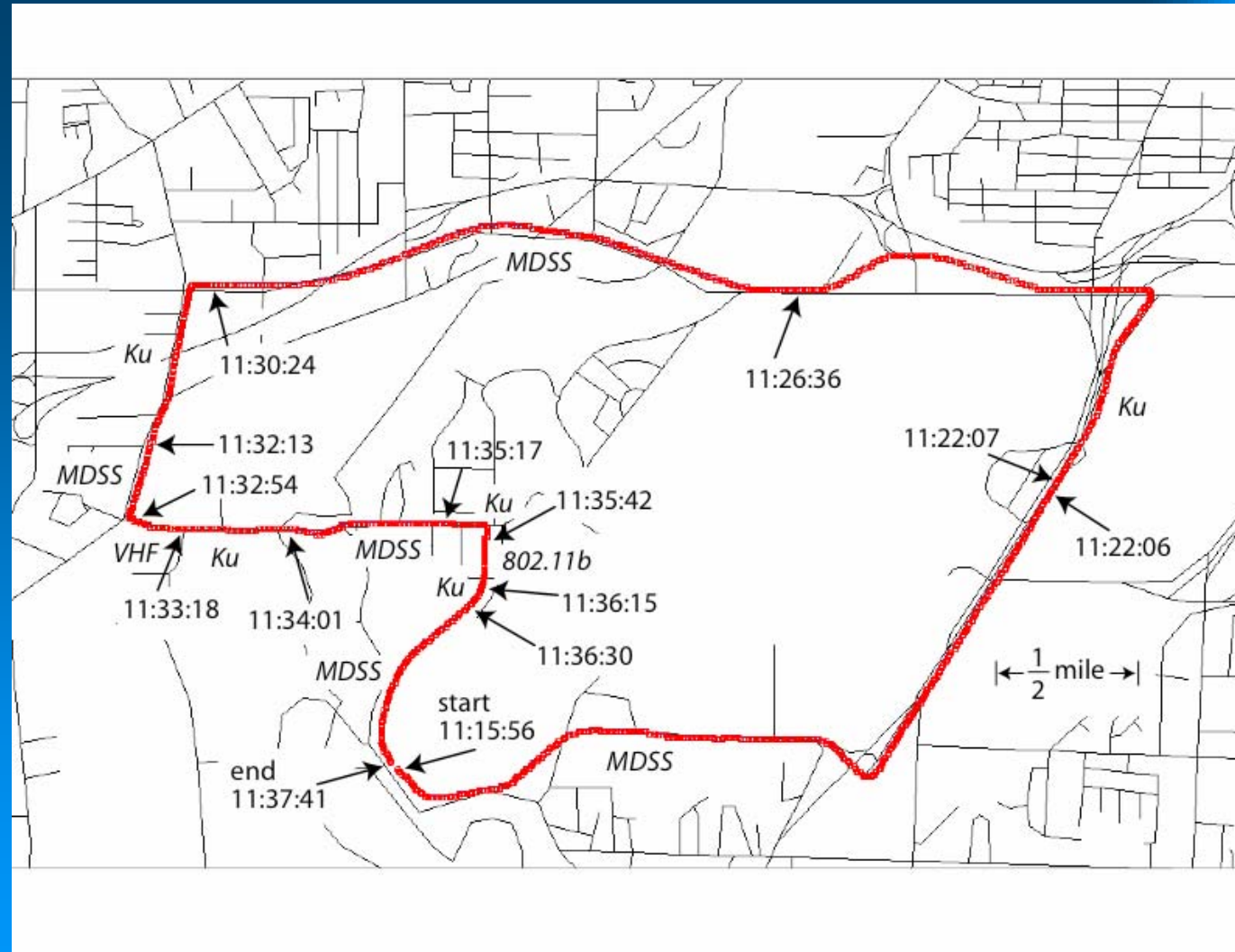GRC **GLENN RESEARCH CENTER**

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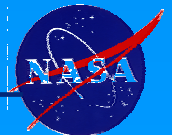
Mobile Platform Multi Link Switchover

- Map of platform link switchovers while driving north of the GRC campus on March 2nd, 2004.

- The map is a 20 minute subset of a 70 minute test.

- Link priority:
  - 802.11B(High)
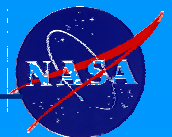 - MDSS
  - Ku-band
  - VHF(Low)
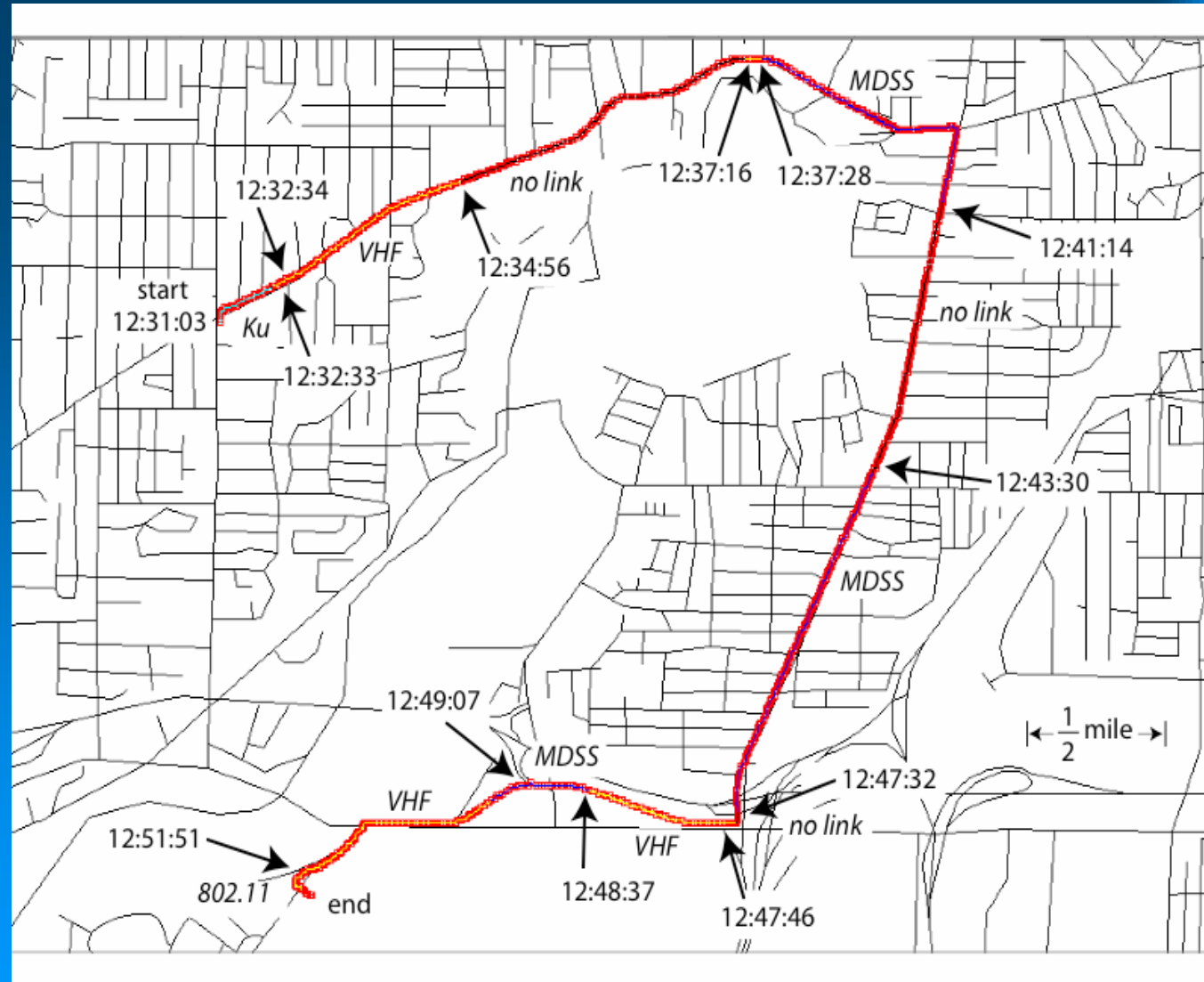
Mobile Platform Multi Link Switchover

- Map of platform link switchovers while driving outside the GRC campus on March 2nd, 2004.

- The map is a complete run.

- Link priority:
  - 802.11B(High)
  - MDSS
  - Ku-band
  - VHF(Low)

Mobile Platform Uplink Demonstrations

- AXIS2100 web camera uploads a low resolution jpeg picture to a ground ftp server every minute.

- This demonstrates IP-based telemetry from the mobile platform to a fixed server.
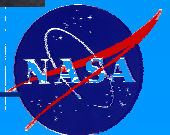
GRC Aero/Mobile Van
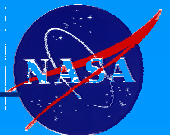
GRC Aero/Mobile Van

Aviation demonstrations using one bi-directional Ku-band link
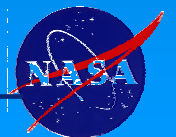
NASA DFRC's DC8 for AeroSAPIENT

DC8 flights near Tinkers AFB in Oklahoma (11/28/2000 through 12/11/2000)

- Provided GRC and DSFC IP connectivity for the AeroSAPIENT project.

- Achieved 256 kb/s transmit from, and 2.1 Mb/s receive, between NASA DC-8 and GRC, DFRC, and ARC using the Ku-band phase array.

- Used a SUN computer as a IP router to support various simultaneous applications (intra/internet) on the link.

  - VoIP (voice), FTP (file transfer), TTCP (capacity test tool), E-mail, HTTP (web browsing, weather access, web server provided DC-8 Digital Air Data System), CPDLC (ATN app), Sun Forum (duplex video, white boards, text) and SSH (secured remote access) used by GRC.

  - Ring Buffered Network Bus (Java middleware, cache management, stream proxy services) and Authentication (PKI) used by DFRC.

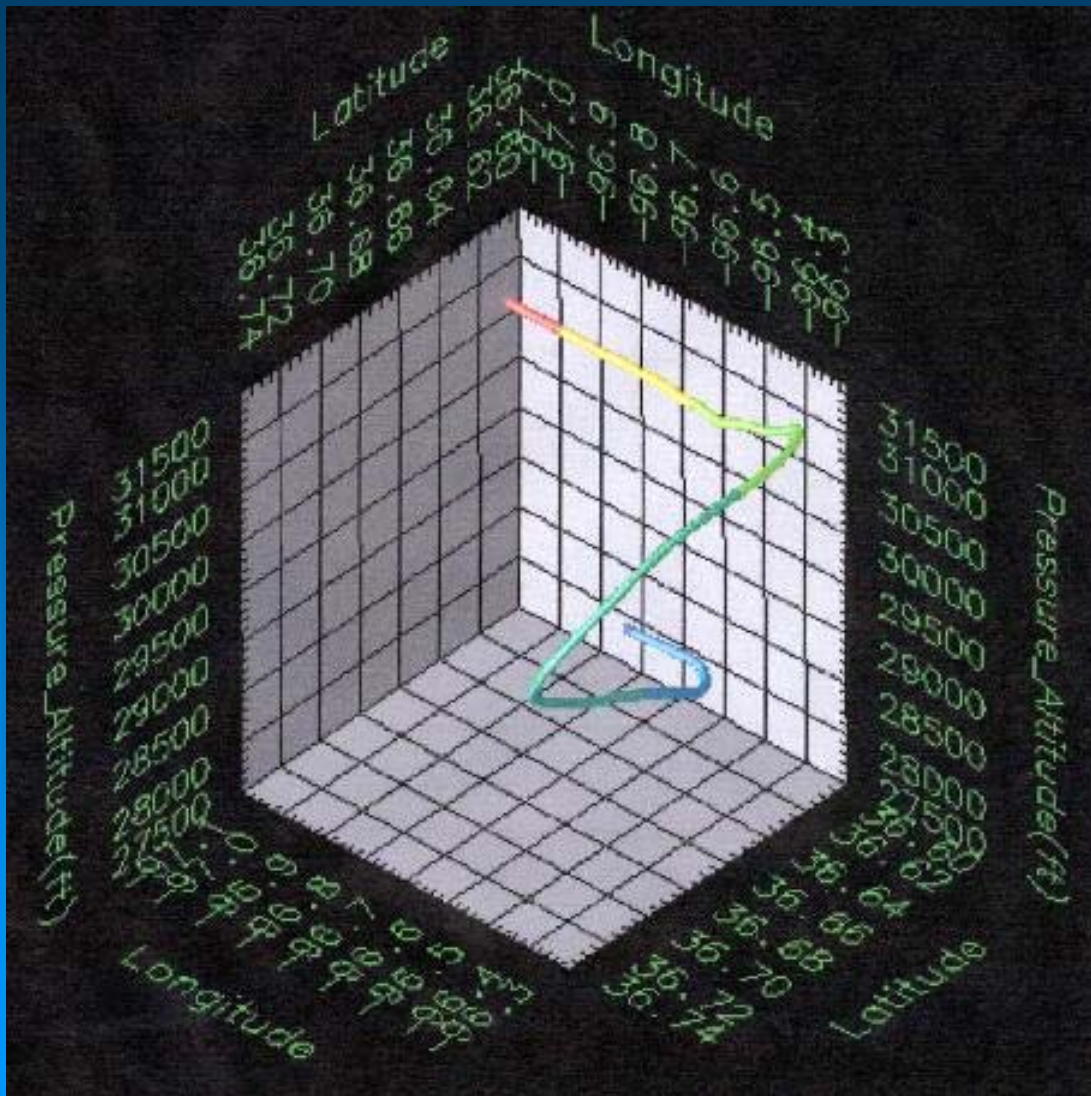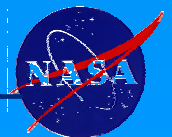- Sustained connectivity except in extreme conditions due to INS refresh issues.
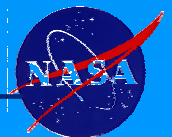
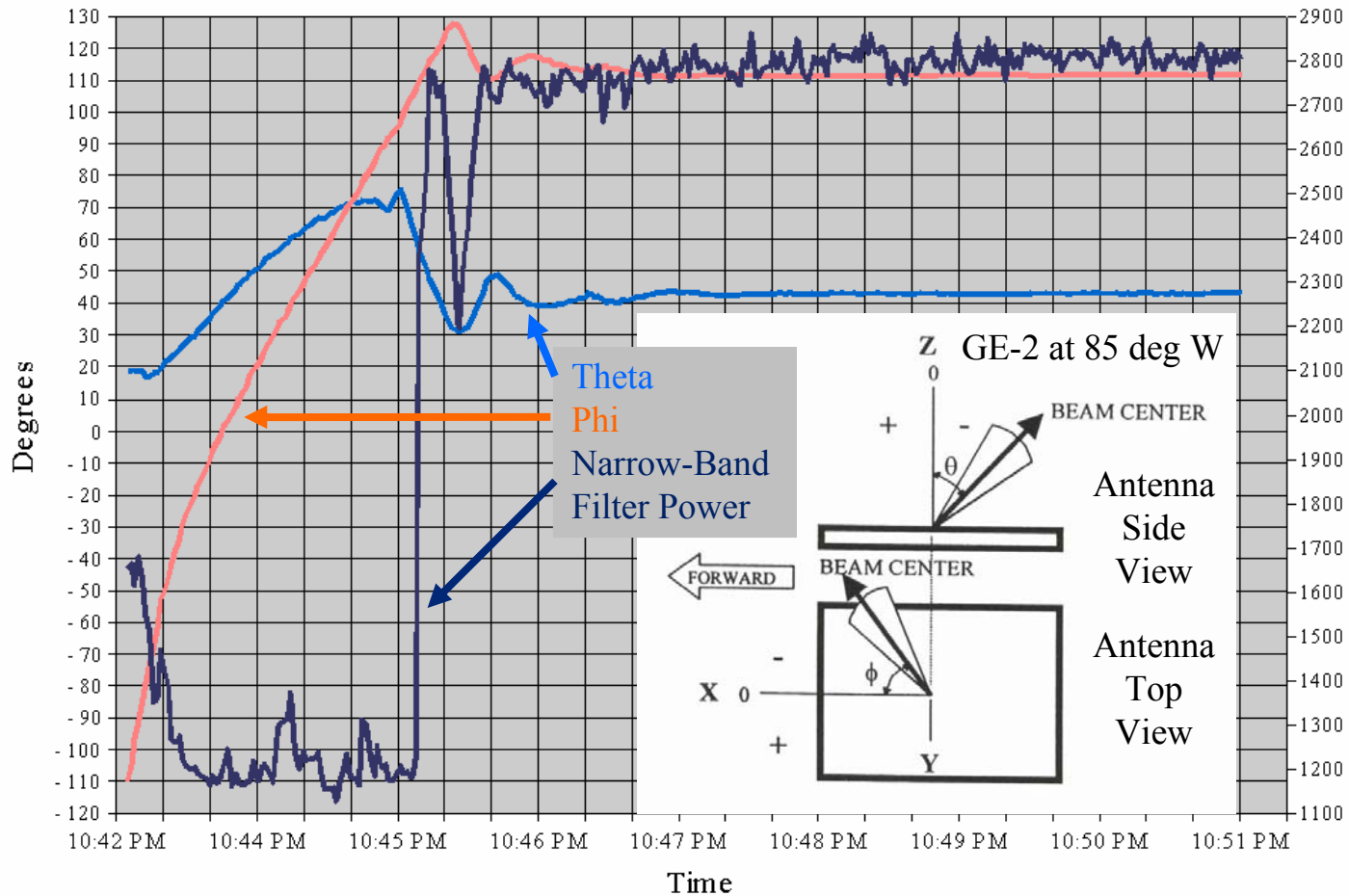# Severe Flight Profile

Dec 8, 2000

Red = 10:50pm

Blue = 10:40pm

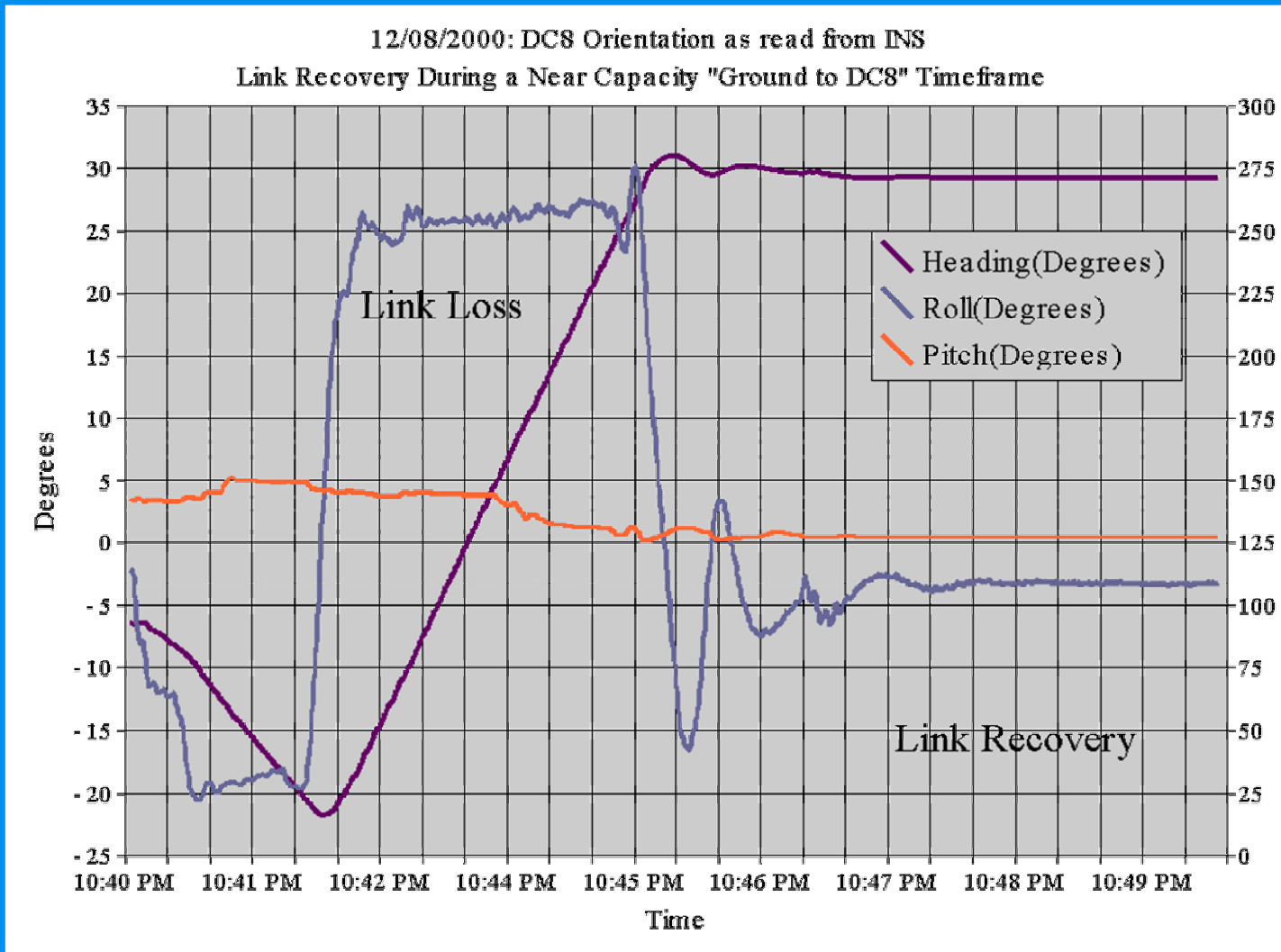# Antenna Performance

December 8, 2000: Boeing Antenna Statistics
Antenna Elevation/Azimuth and Narrow Band Power

Link Recovery

12/08/2000: DC8 Orientation as read from INS
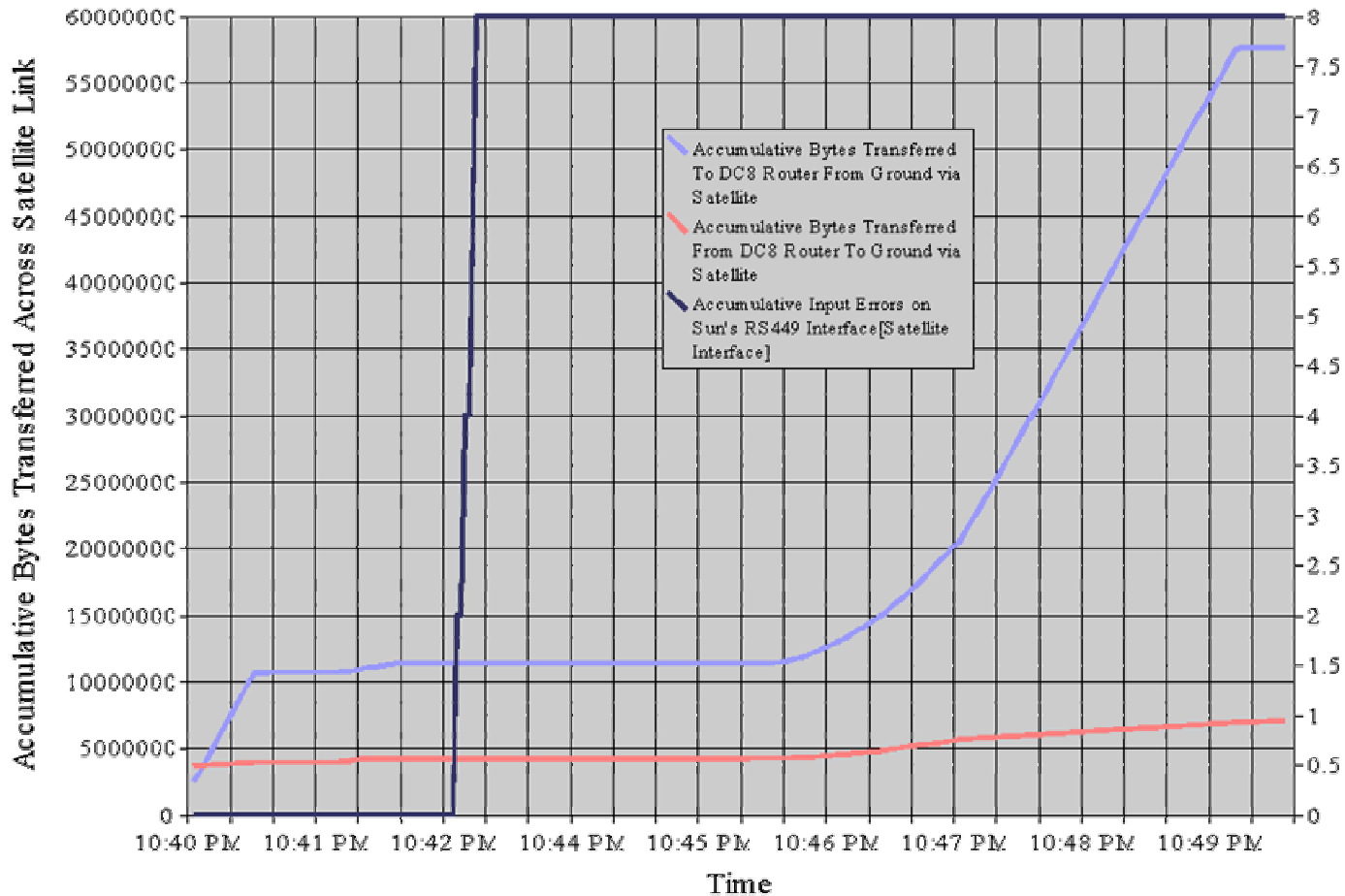Link Recovery During a Near Capacity "Ground to DC8" Timeframe

Network Recovery

12/08/2000: DC8 Airborne Router Satellite Link Utilization
Link Recovery During a Near Capacity "Ground to DC8" Timeframe

NASA LaRC's B757 for AWIN/WinComm

B757 flights near Hampton, Virginia (April 2002)

- Supported LaRC and GRC mission IP connectivity for WINCOMM, AWIN and AC/ATM projects.

- Used a Cisco 3640 IP router on the aircraft to route between the aircraft and the fixed station.

- Achieved 256 kb/s transmit from, and 2.1 Mb/s receive, between NASA B757 and GRC using the Ku-band phase array.
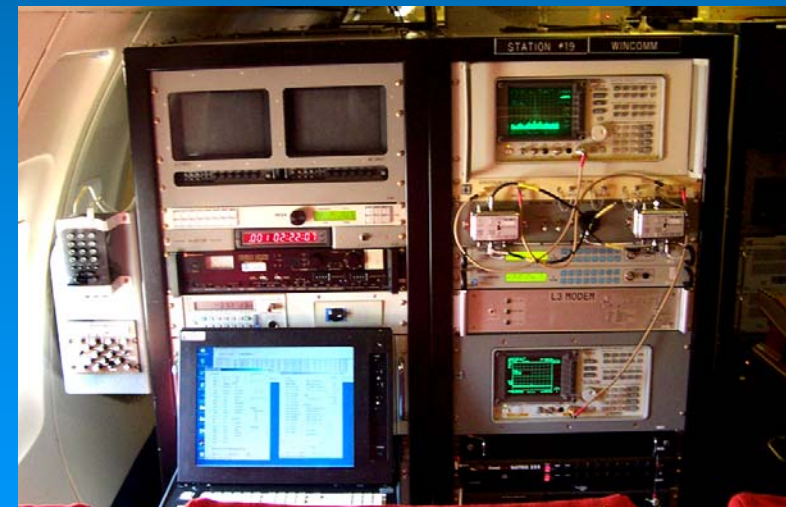
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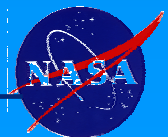
What is coming up?

- Integrate the van into a Test Bed for IPv6 for Aeronautical Communications and Services research using NEMO mobile IPv6.

  Partners:
  - Eurocontrol
  - CNS, Inc
  - Cisco Systems, Inc

- Research how mobile platforms can interconnect to current and future ATC and aviation systems.