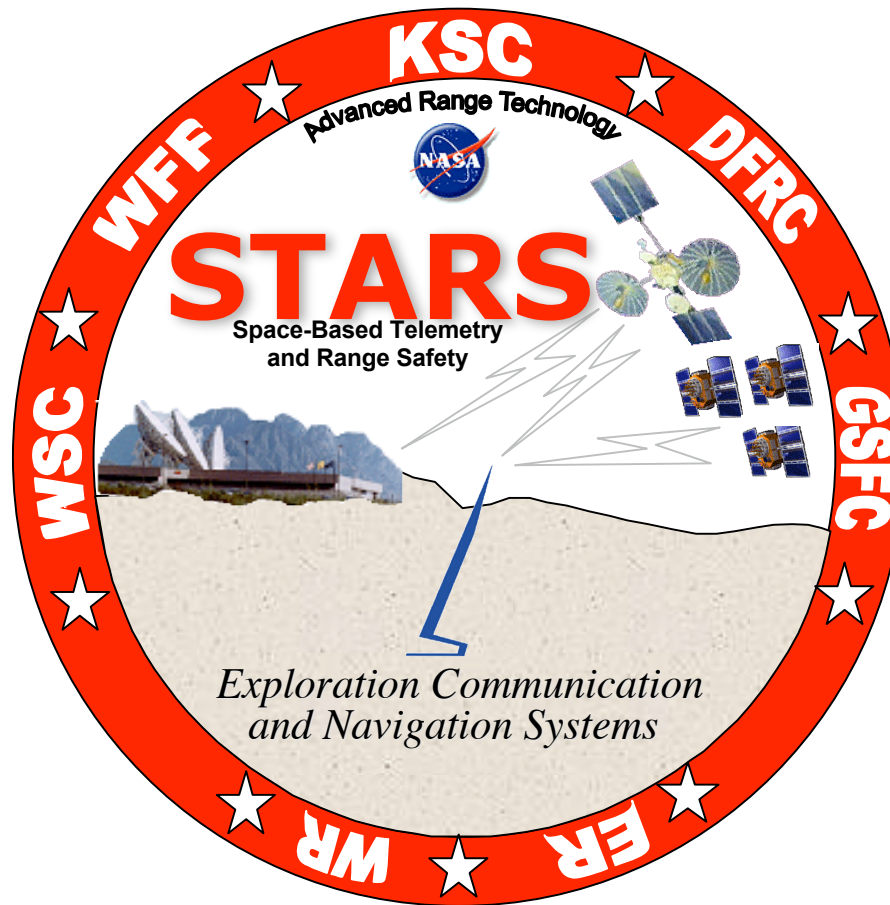# Space Based Range
Demonstration and Certification (SBRDC)

**Robert Sakahara, STARS Dryden Flight Research Center
(DFRC) Project Manager
October 25, 2005**

SBR Goal:

Reduce the cost of operating and maintaining range systems supporting space launch vehicles while increasing range responsiveness

SBR Strategic Objective:

Demonstrate space based range technologies to provide more responsive, robust, and economical tracking and communication systems

- Responsive
    - Reduce launch turn-around times
    - Reduce launch delays and scrubs due to range instrumentation problems
    - Support multiple vehicles simultaneously
- Robust
    - Increase vehicle telemetry data rates
    - Increase launch trajectories
    - Launch from any spaceport in the world
- Economical
    - Reduce range operations and maintenance (O&M) costs by $50M per year by eliminating ground based down-range infrastructure

SBR Project Objectives
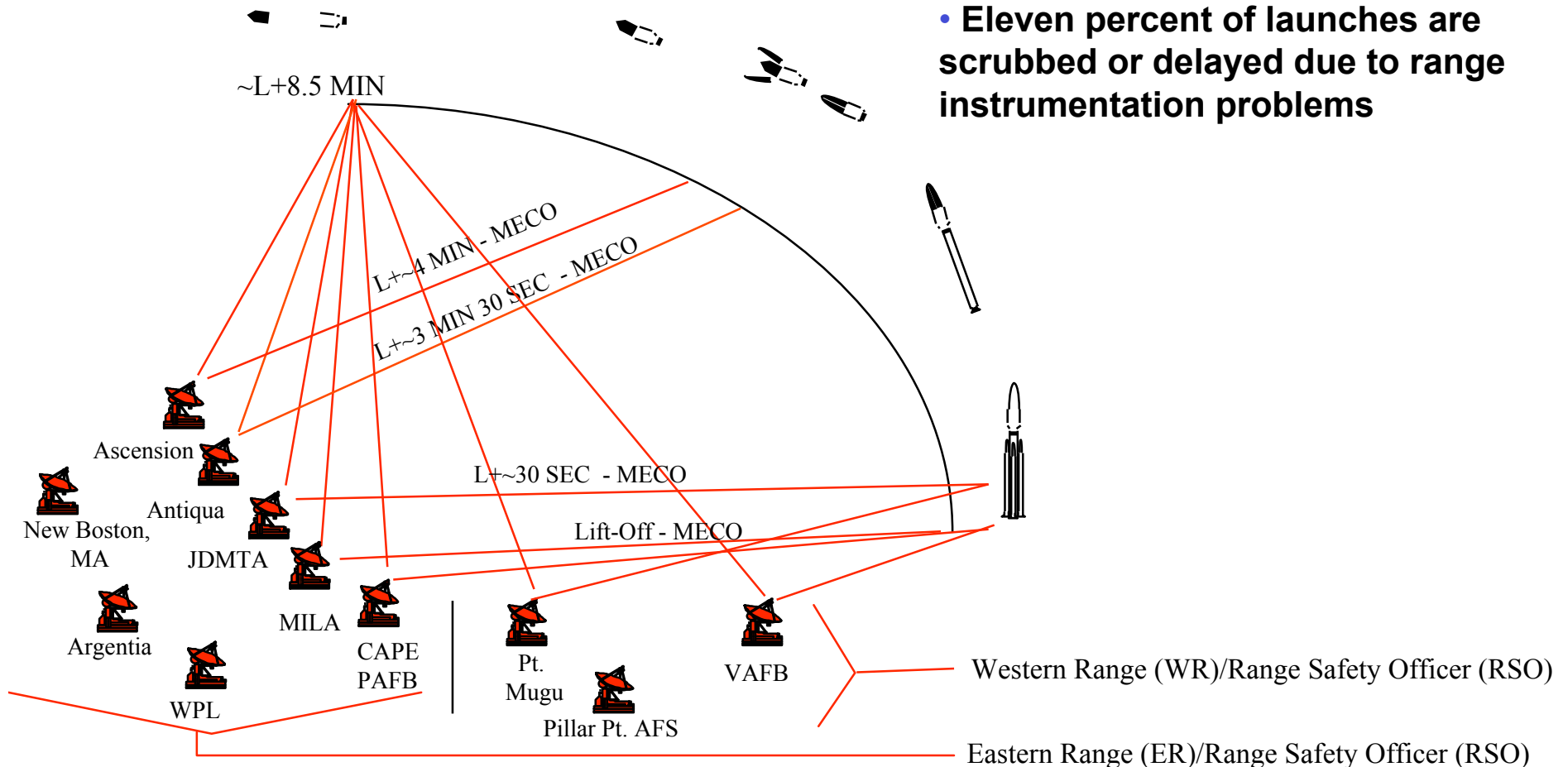
SBR Technology Development:

Develop, utilize, test, and demonstrate state-of-the-art technologies for Range Safety and Range User Systems.

- Range Safety System (Flight Termination, Vehicle Tracking, Key Flight Telemetry Data)
    - Support simultaneous forward links
    - Meet intent of range safety requirements

- Range User System (Video, Voice, Vehicle Data)
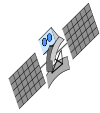   - Maximize high data rate capabilities

Today's United States Range

• **A complex ground based infrastructure consisting of:**
- Radars
- High power UHF transmitters
- Telemetry receive stations

• **Very costly to operate and maintain**

• **Eleven percent of launches are scrubbed or delayed due to range instrumentation problems**

~L+8.5 MIN

L+~4 MIN - MECO

L+~3 MIN 30 SEC - MECO

L+~30 SEC - MECO

Lift-Off - MECO

Ascension

Antiqua

New Boston, MA

JDMTA

Argentia

MILA

WPL

CAPE PAFB

Pt. Mugu

Pillar Pt. AFS

VAFB

Western Range (WR)/Range Safety Officer (RSO)

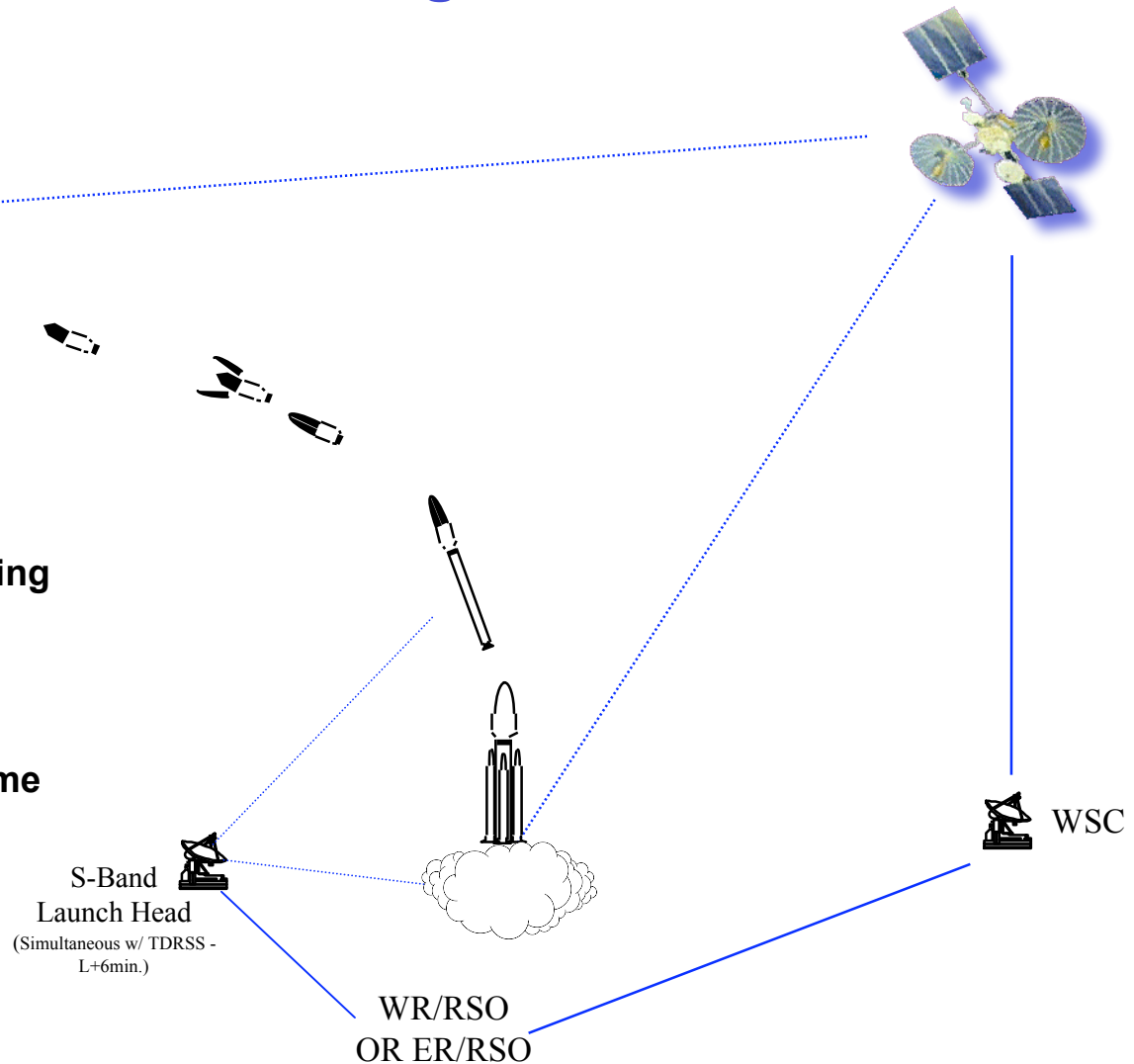Eastern Range (ER)/Range Safety Officer (RSO)

Future Range

GPS

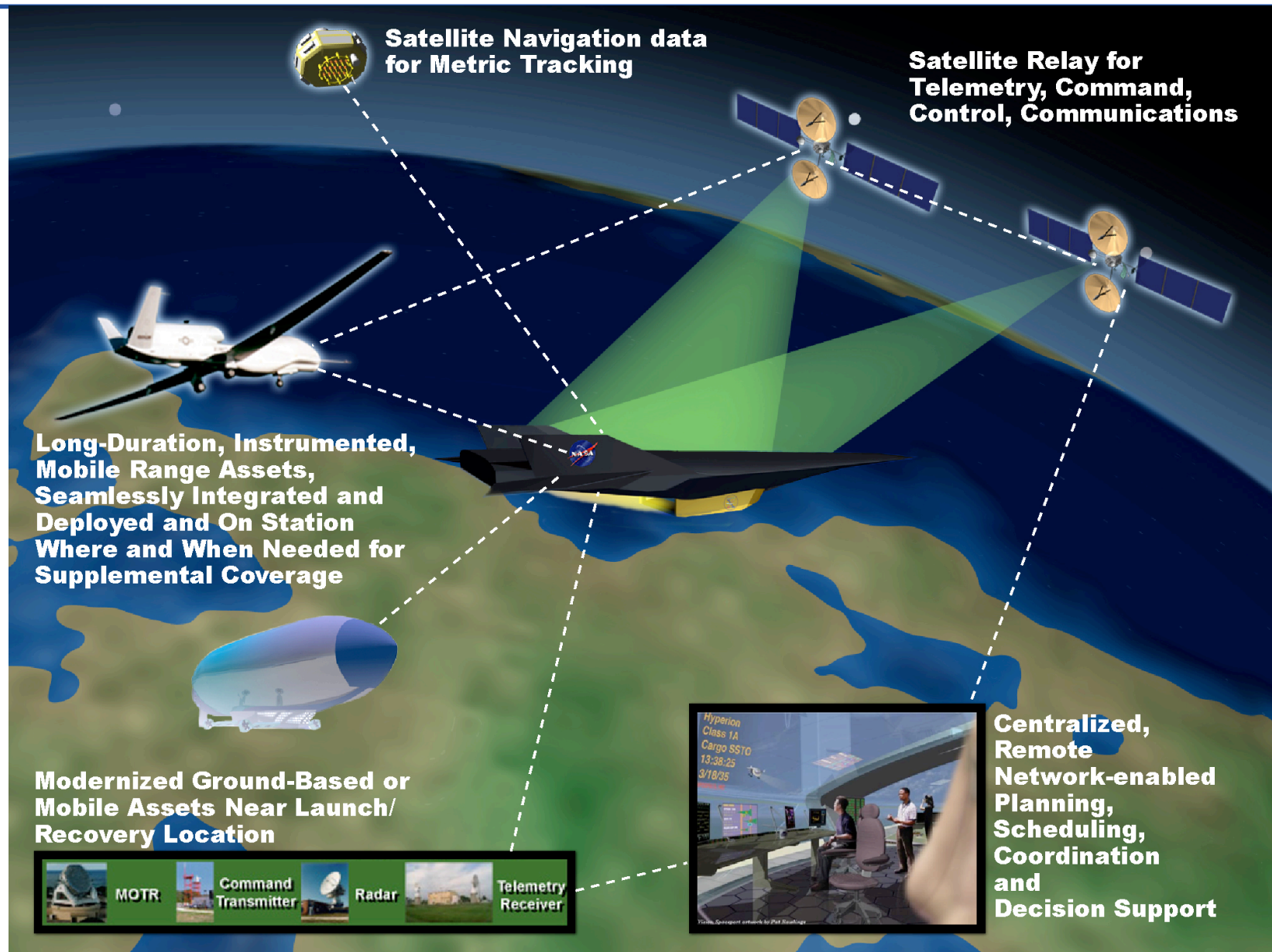~L+8.5 MIN

- **Space based range using:**
  - **Communication satellites for command and telemetry relay**
  - **GPS satellites for vehicle tracking**
- **Reduce O&M costs**
  - **~$50M per year**
- **Increase flexibility**
  - **Reduced launch turn around time**
  - **Support multiple vehicles simultaneously**
  - **Launch from Spaceport anywhere in the World**

S-Band
Launch Head
(Simultaneous w/ TDRSS -
L+6min.)

WSC

WR/RSO
OR ER/RSO

Another Vision for the Future Range

Satellite Navigation data for Metric Tracking

Satellite Relay for Telemetry, Command, Control, Communications

Long-Duration, Instrumented, Mobile Range Assets, Seamlessly Integrated and Deployed and On Station Where and When Needed for Supplemental Coverage

Modernized Ground-Based or Mobile Assets Near Launch/ Recovery Location

MOTR   Command Transmitter   Radar   Telemetry Receiver

Hyperion
Class 1A
Cargo SSTO
13:38:25
3/18/35

Centralized, Remote Network-enabled Planning, Scheduling, Coordination and Decision Support

STARS Project Goals

- ◆ **STARS will utilize existing space-based platforms to provide reliable communications for flight termination commands, telemetry, and vehicle tracking for Range Safety and Range Users**
  - Tracking and Data Relay Satellite System (TDRSS) for command/data relay
  - Global Positioning System (GPS) for metric tracking

- ◆ **STARS will develop and utilize state of the art technologies that can be applied to Launch Vehicles:**
  - Multi-channel transceivers (TDRS/GPS)
  - Antennas (Ka/Ku-band phased array)
  - Data formatting (Error-correction, Encryption, Standard Protocols, Compression)

- ◆ **STARS will conduct a series of incremental proof of concept flight demonstrations to increase the Test Readiness Level (TRL)**

- ◆ **STARS team members will participate in the development of requirements for space based range full scale development**

- ◆ **STARS team members will support the United States Air Force (USAF) in the certification of the Range Safety System and the Range User System on the Operational Space-lift Ranges (i.e. ER and WR)**
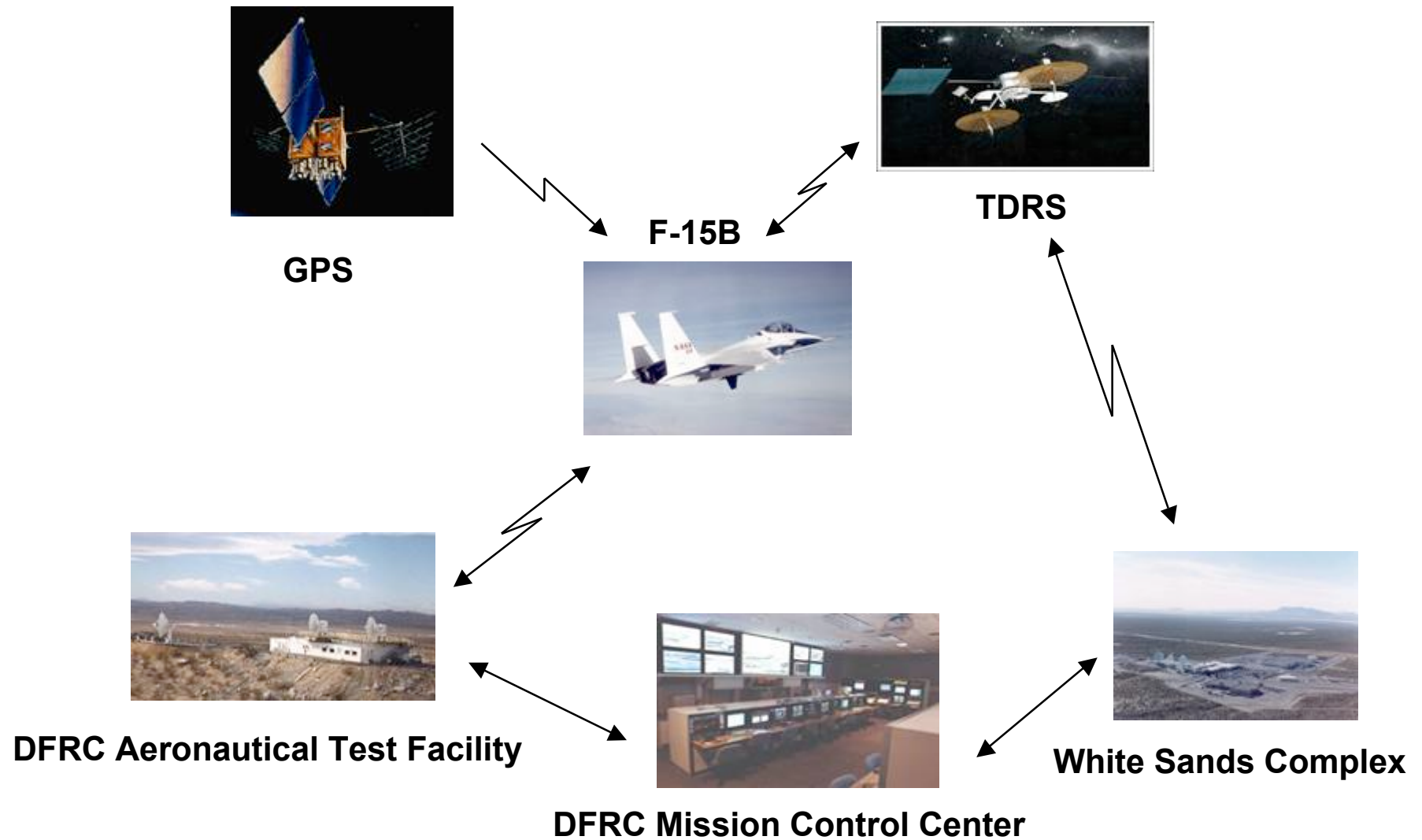
STARS Content

- ♦ **STARS has four flight demonstrations planned**
  - • **Flight Demo 1 – Completed successfully June 2003**
    - – Proof of concept using F-15B as test vehicle
    - – Range Safety (RS) System
      - • Developed Low Power Transceiver (LPT) with basic flight termination receiver capabilities and low-rate return link
      - • Developed Command & Data Handler (C&DH) for command decoding and telemetry formatting
      - • Utilized commercial off-the-shelf (COTS) Ashtech Z-12 GPS receiver
      - • Utilized Omni patch antennas (combined S-band/L-band receive antennas on top and bottom of the F-15B and S-band transmit antennas located on the top and bottom of the F-15B)
    - – Range User (RU) System
      - • Utilized COTS hardware transmitting up to 500 kbps data rate
      - • Utilized Omni patch antennas (S-band transmit antennas only located on top and bottom of the F-15B)
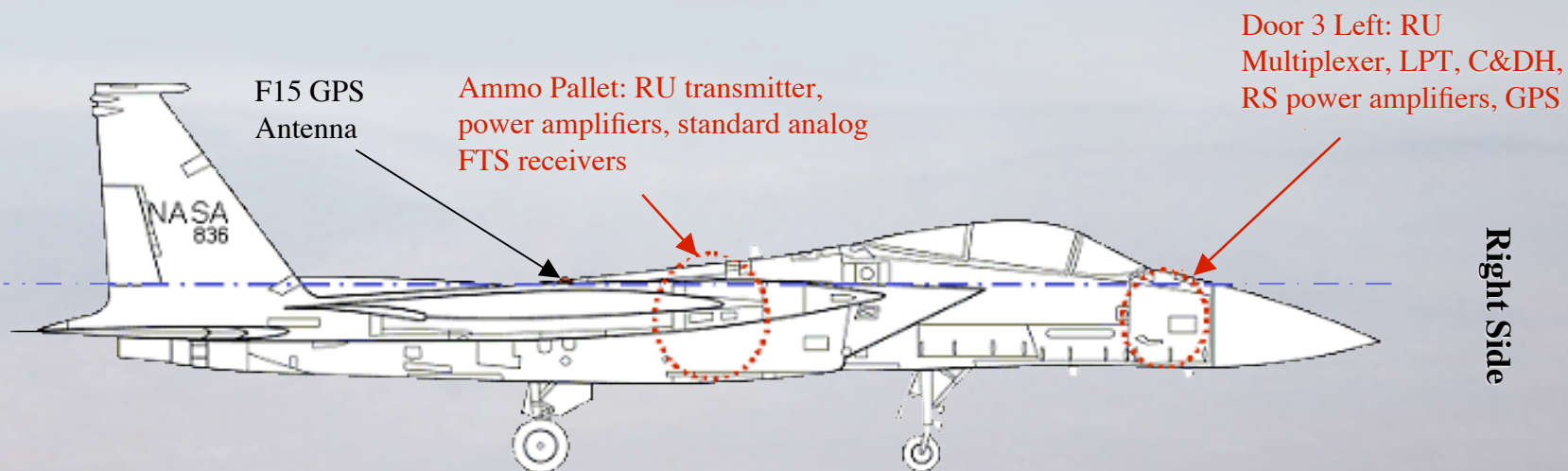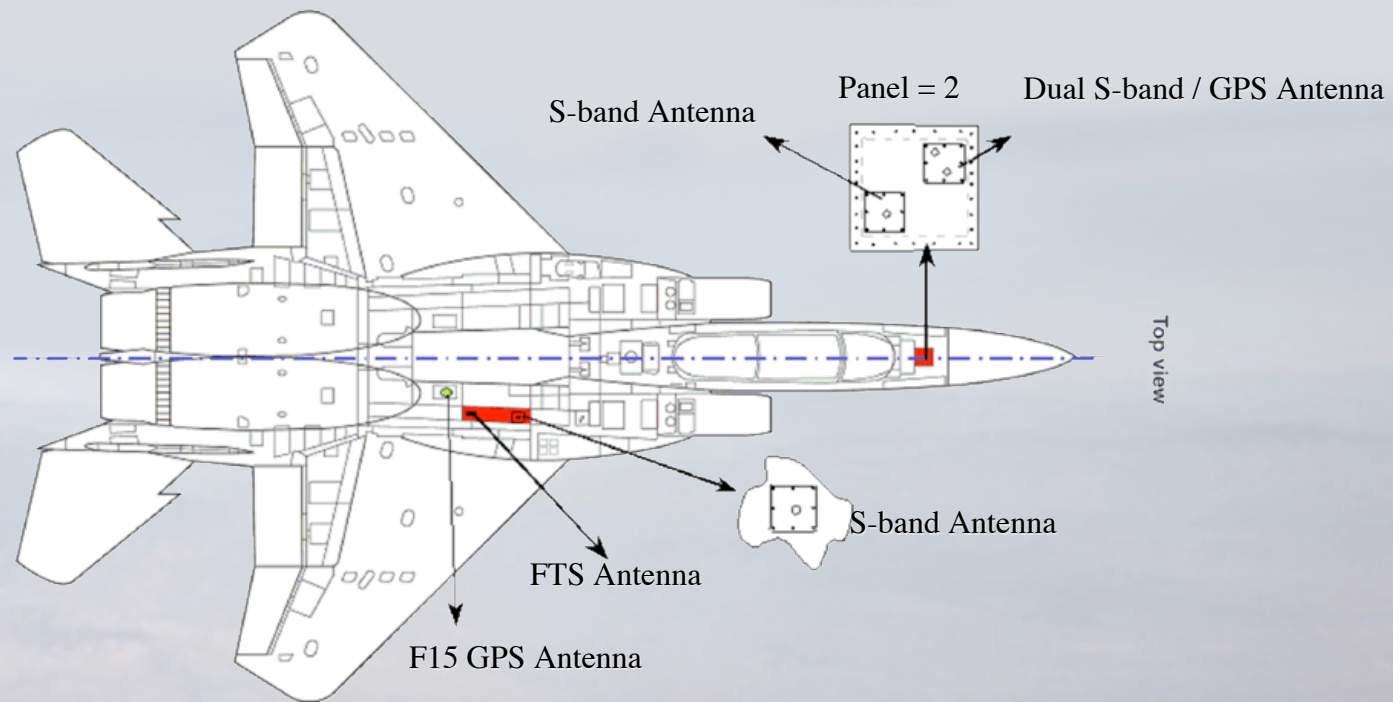
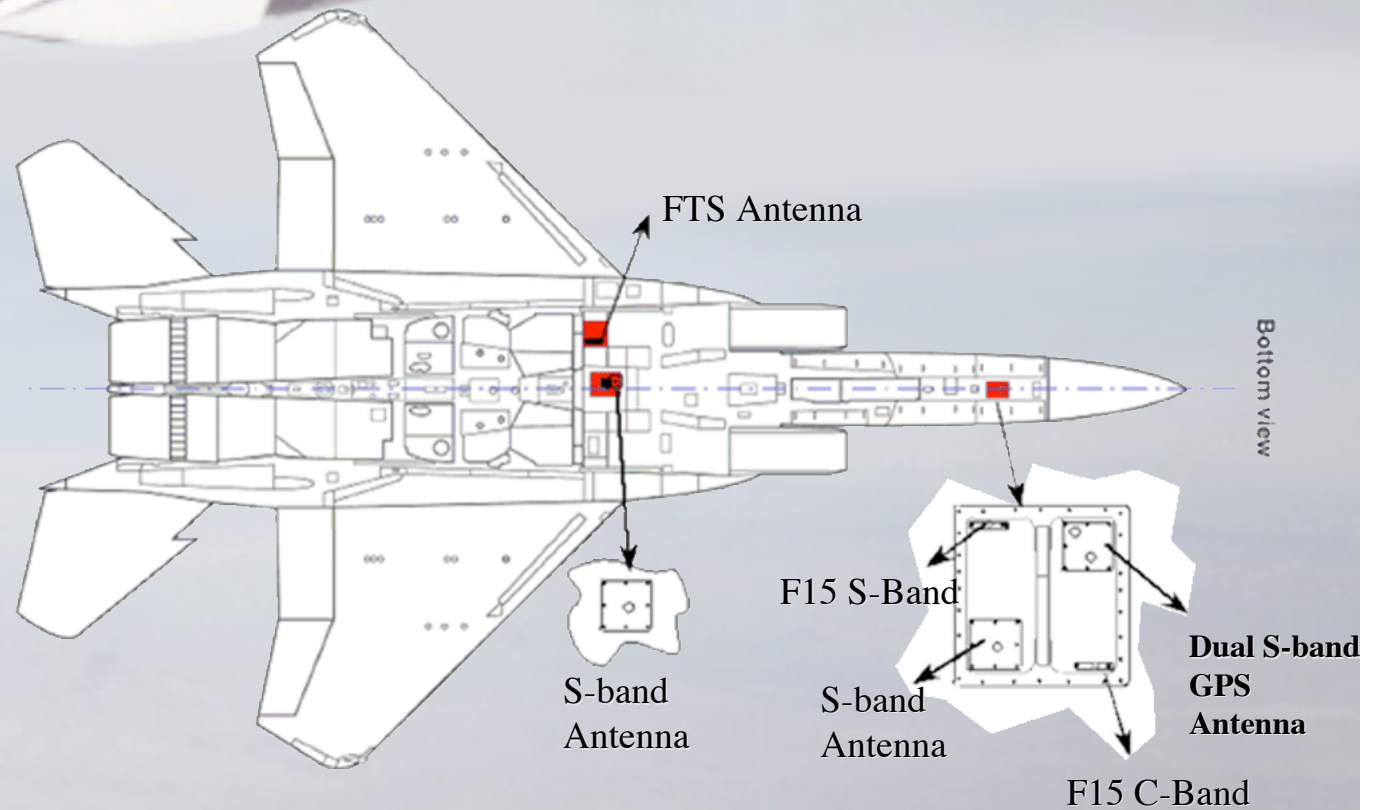STARS Configuration
Flight Demonstrations 1 & 2

GPS

TDRS

F-15B

DFRC Aeronautical Test Facility

DFRC Mission Control Center

White Sands Complex

Hardware Locations

F-15B

F15 GPS Antenna

Ammo Pallet: RU transmitter, power amplifiers, standard analog FTS receivers

Door 3 Left: RU Multiplexer, LPT, C&DH, RS power amplifiers, GPS

Right Side

Antenna Locations

♦ **F-15B – Top View**

Panel = 2   Dual S-band / GPS Antenna

S-band Antenna

Top view

FTS Antenna

S-band Antenna

F15 GPS Antenna

Antenna Locations

♦ **F-15B – Bottom View**

NASA
836

FTS Antenna

S-band
Antenna

F15 S-Band

S-band
Antenna

Dual S-band
GPS
Antenna

F15 C-Band

Bottom view

Spaceport And Range Technologies
STARS Objectives and Results

FD1 Test Objectives and Results:

◆ Range Safety (RS)

- Verify link margin, acquisition/reacquisition, signal lock, Bit Error Rate (BER), and simultaneous forward links (satellite and launch head)
- Receive and process FTS commands (100% of all FTS commands were successfully initiated: over 300 Arm and Terminate commands were sent during the flight tests)
- Receive and process GPS metric tracking data
- Transmit tracking, telemetry, and status data from a high dynamic vehicle to DFRC via WSC (Data was also transmitted to Kennedy Space Center (KSC) and Wallops Flight Facility (WFF) in near real-time for monitoring)
- Process and display the RS return link data

➢ The objectives were satisfied, although the RS return link margin was less than predicted due to interferometer effects and surface wave interference
- Interferometer effects and surface wave interference will be corrected for FD2

◆ Range User (RU)

- Verify link margin, acquisition/reacquisition, and signal lock
- Transmit RU data (video, voice, and telemetry) from a high dynamic vehicle to DFRC via WSC
- Process and display the RU return link data

➢ The objectives were satisfied, achieving higher link margin than predicted

Spaceport And Range Technologies
STARS FD2 Objectives

FD2 Test Objectives

♦ **Similar to FD1 with modified flight hardware**

♦ **Range Safety System**
- Integrate the LPT, C&DH, and GPS receiver into single unit
- Characterize latency, implement encryption on the forward link, implement Reed-Solomon encoding on both forward and return links
- Verify link margin, acquisition/reacquisition, latency, signal lock, BER
- Verify ability to send commands to transceiver and respond with flight termination action, measure the Signal to Noise ratio, test with 2 TDRS simultaneously, verify vehicle location (GPS with inertial navigation system (INS))

♦ **Range User System**
- Develop Ku-band transmitter and Phased Array Antenna supporting 5 Mbps data rates
- Integrate hardware on test aircraft with GPS/INS controller
- Verify link margin, latency, acquisition/reacquisition performance, BER in dynamic environment, compression system performance, antenna capabilities & performance, antenna flight control interface and control algorithms performance

♦ **Schedule: 8 Test Flights on NASA F-15B, July 06**

♦ **Status**
- All Range Safety and Range User hardware for Flight Demo 2 has been designed, developed and acceptance tested.
- STARS RU hardware is currently in the integration and test phase prior to aircraft installation
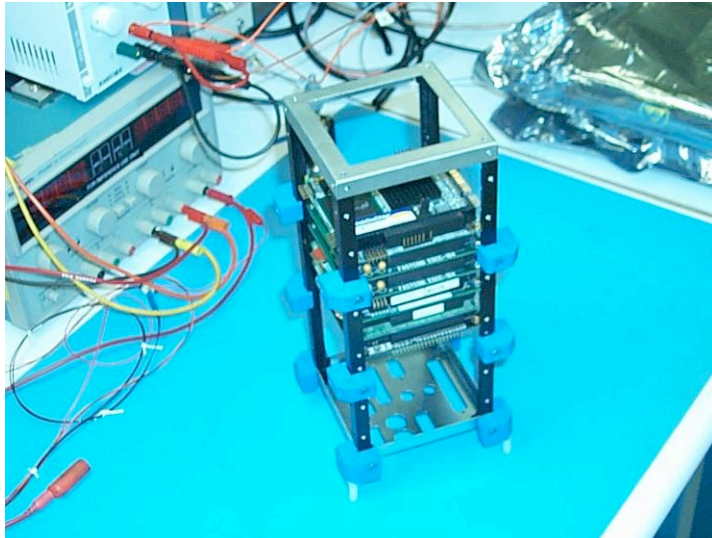- Additional testing will occur after aircraft installation prior to flight testing
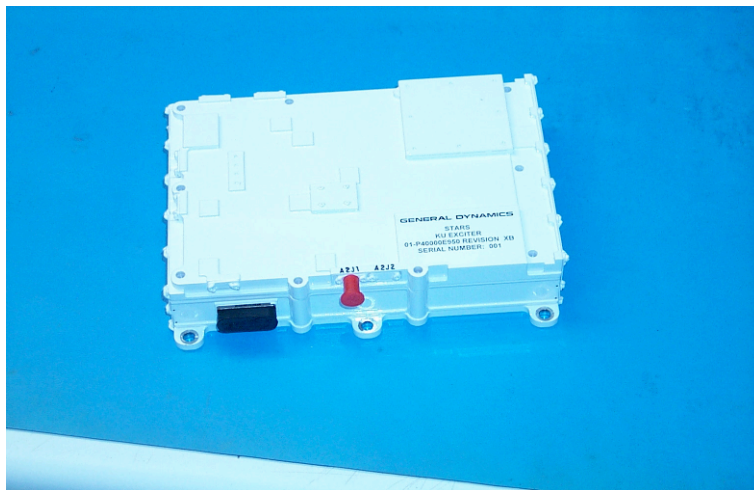
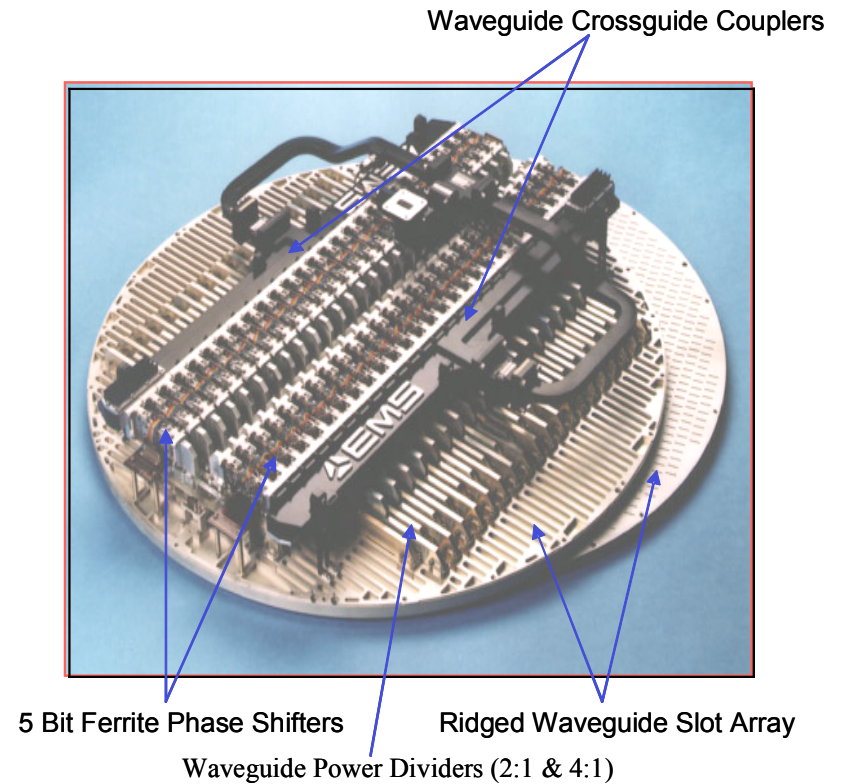# Range Safety Hardware

Range Safety Unit

Range User Hardware

IP Formatter

Ku-band Transmitter

Waveguide Crossguide Couplers

5 Bit Ferrite Phase Shifters   Ridged Waveguide Slot Array

Waveguide Power Dividers (2:1 & 4:1)

Ku-band Phased Array Antenna

Past/Future Flight Demo Plans

- **Global Flyer support – FY05 (Flight Demo 1a)**
  - STARS was asked to provide hardware to the Global Flyer program to provide continuous video during the 67 hour global flight
  - STARS Flight Demo #2 RS hardware was delivered January 13, 2005
  - Flight was successfully completed March 3, 2005
  - STARS system exceeded performance expectations. Eb/No's were greater than 10dB for most of the flight.

- **Flight Demo 3 – 2007**
  - Develop smaller, lighter version of the RSU for the Range Safety system
    - Use low cost transmitter (LCT) 2 developed in-house at NASA Wallops and port C&DH functionality into digital signal processor on LCT2
    - RSU dimensions would be roughly 5"x5"x6" (with internal high power amplifier)
    - RSU weight would be roughly 3 lbs
  - Perform flight test on a hypersonic vehicle over the horizon
    - Sounding rocket is baselined, however, possible opportunity on expendable launch vehicle (ELV)

- **Flight Demo 4 – 2008**
  - Develop Ka-band transmitter and phased array antenna for Range User system
  - Re-fly RSU design from Flight Demo 3 with enhancements
  - Perform flight test

QUESTIONS

♦ ???