



**agi 2005**  
**USERS' CONFERENCE**  
OCTOBER 11-14, 2005 • WASHINGTON, D.C.  
**Delta Launch Vehicle Flight Data  
Collection & Display**  
Cheree Kiernan, Michael Taylor  
Boeing Delta Expendable Launch Vehicle Programs

AGI Pg 1 of 13 www.agiuc.com

---

---

---

---

---

---

---



---

---

---

### Overview

- Flight Data Collection
  - Pre-launch Analysis
    - Architecting a Telemetry Tracking Network
    - Flight Imagery Collection
  - Real-time Situational Awareness
    - Flight Visualization
    - Acquisition Assistance
  - Post-flight Assessment
    - Tracking Network Performance
    - Anomaly Resolution
- USAF Heavy Demo Scenario



Pg 2 of 23

---

---

---

---

---

---

---



---

---

---

### Application of STK within Delta Flight Operations

- Pre-launch Flight Data Collection Analysis
  - Flight telemetry coverage analysis
    - Deployable telemetry station siting
    - Solar conjunction analysis
    - Link margin analysis
    - Acquisition assistance message processing
  - Flight imagery assessment
- Real-time situational awareness
  - Use real-time or last known flight position and velocity to determine rise and set time at tracking stations
- Post-flight Analysis/Anomaly Resolution
  - Compare tracking network antenna pointing to flight trajectory



Pg 3 of 23

---

---

---

---

---

---

---



---

---

---

## Software in use

- STK:
  - STK PRO, AVO, Connect, Chains, Terrain modules
  - SLC-37 & Delta IV Heavy model (thank you Scott Cross!)
- Imagery
  - Terraserver for 1 meter resolution at CCAFS & VAFB
  - MODIS 250m imagery for Florida, Bahamas, California
  - Blue Marble 1 km global imagery
- Terrain
  - USGS GEM data for Vandenberg, SRTM data for California
  - SRTM DTED data for rest of planet
- Boeing STICS Lab Software
  - SPAM processor (telemetry front end, EU conversion)
  - grokc (graphical rendering of kinematics – c): Event Monitoring and Detection, conversion to earth fixed coordinates, TCP/IP connection to STK

Pg 4 of 23

---

---

---

---

---

---

---

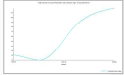
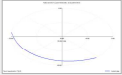
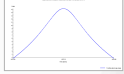
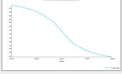
---

---

---


## Pre-Launch Analysis: Siting a Deployable Asset

- Short-notice need for deployable ground station
- STK supports immediate analysis of site feasibility (e.g. pass geometry, obscure, solar conjunctions)
- Prior to implementation of STK capability
  - A short-notice deployment made adjacent to a fixed site resulted in the deployable missing spacecraft sep
  - Obscurra analysis now reduces the probability of repeating this mistake

Solar Conjunction Analysis      Pass Geometry

Elevation Angles      Azimuth Angles



Pg 5 of 23

---

---

---

---

---

---

---




---

---

---

## Pre-Launch Analysis: Flight Imagery Aspect Angle


- Requirement for unobstructed imagery of particular mission events (e.g. liftoff, solid rocket motor separation, Max-Q, etc)
  - Finite supply of cameras
  - Multiple points of interest on the vehicle
- Camera site considerations
  - LV Attitude
  - LV Obstruction (e.g. Solid Rocket Motors, Common Booster Cores, Fixed Umbilical Tower etc)
  - Sun angle

Playalinda Beach DOAMS      Universal Camera Site 23

Cocoa Beach DOAMS

Example: Delta IV interstage (located near triangular blue Delta logo) during Heavy Demo transsonic flight



Pg 6 of 23

---

---

---

---

---

---

---



---

---

---

### Real-Time Situational Awareness

- GROK first used on Globalstar-3 (June 1999)
- Used GROK C code with modifications to send STK connect commands
  - Allows 5 years of experience in event detection & noise filtering
- Heavy Demo was first experience in using STK in a real time application, and just in time!
  - Off-nominal performance
- Use of STK to aid station acquisition, critical to flight data collection



Pg 7 of 23

---

---

---

---

---



---

---

---

### Connect Commands Employed

- Commands send every two seconds:
  - SetPosition
  - SetAttitude
  - Engine Gimbal Angles
- Commands sent upon event detection:
  - Solid motor ignition/burnout/jettison
  - Stage 1-2 separation (and stage 2-3 separation for Delta II)
  - Nozzle extension
  - Fairing Jettison
  - Engine burns
  - Spacecraft separation
- Manual commands available
  - Reassemble launch vehicle stack to pre-liftoff configuration
  - Set vehicle to on-orbit configuration
  - Jettison spacecraft



Pg 8 of 23

---

---

---

---

---


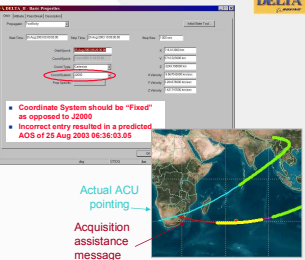
---

---

---

### Post-Flight Analysis: Station failure to acquire LV

- Typically hardware anomalies (e.g. cable wrap, antenna drive failure, etc) or operator error
- In the case of Delta II SIRTf, an acquisition assistance message was generated using a different coordinate system than the antenna control unit which led to a missed pass



Pg 9 of 23

---

---

---

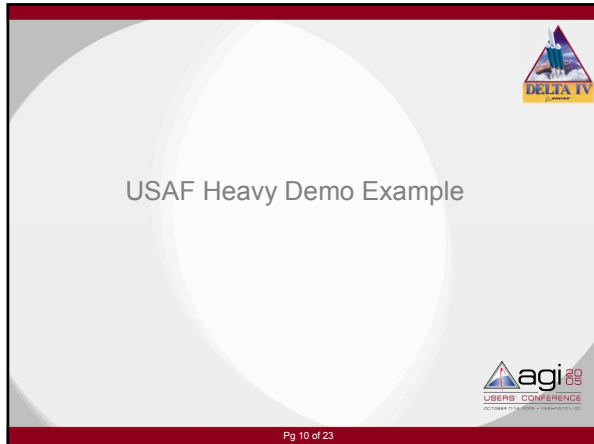
---

---

---

---

---



USA  
F  
A  
C  
E

DELTA IV

USA  
F  
A  
C  
E

agi 2005  
LIBERS' CONFERENCE  
OCTOBER 11-12, 2005 - HUNTINGTON BEACH, CA

Pg 10 of 23

---

---

---

---

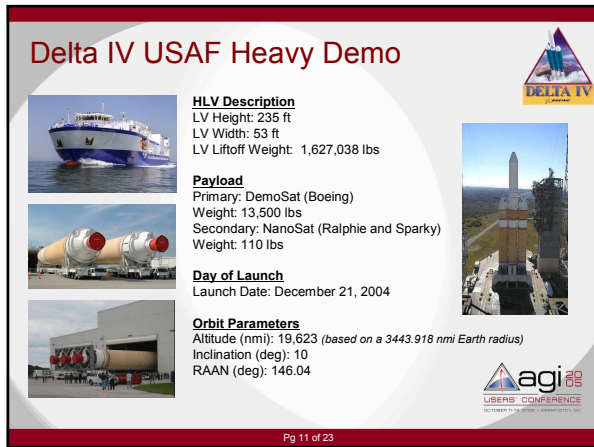
---

---

---

---

### Delta IV USAF Heavy Demo



DELTA IV

agi 2005  
LIBERS' CONFERENCE  
OCTOBER 11-12, 2005 - HUNTINGTON BEACH, CA

**HLV Description**  
LV Height: 235 ft  
LV Width: 53 ft  
LV Liftoff Weight: 1,627,038 lbs

**Payload**  
Primary: DemoSat (Boeing)  
Weight: 13,500 lbs  
Secondary: NanoSat (Ralphie and Sparky)  
Weight: 110 lbs

**Day of Launch**  
Launch Date: December 21, 2004

**Orbit Parameters**  
Altitude (nmi): 19,623 (based on a 3443.918 nmi Earth radius)  
Inclination (deg): 10  
RAAN (deg): 146.04

Pg 11 of 23

---

---

---

---

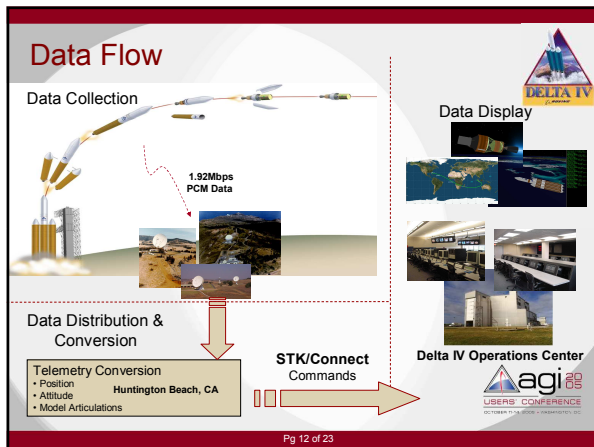
---

---

---

---

### Data Flow



DELTA IV

agi 2005  
LIBERS' CONFERENCE  
OCTOBER 11-12, 2005 - HUNTINGTON BEACH, CA

**Data Collection**

1.92Mbps PCM Data

**Data Display**

**Data Distribution & Conversion**

Telemetry Conversion  
• Position  
• Altitude  
• Model Articulations  
Huntington Beach, CA

STK/Connect  
Commands

Delta IV Operations Center

Pg 12 of 23

---

---

---

---

---

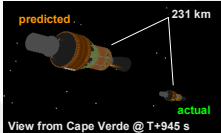
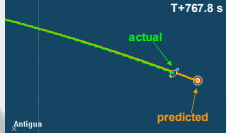
---

---

---

### Real Time Example: Heavy Demo - Ascent

- Pre-mature cutoff of all three Common Booster Core engines resulted in first stage velocity shortfall
- Second stage guidance attempted to make up performance, but vehicle not in expected location at first and second engine cutoffs
- STK provided real time situational awareness of present vehicle location & angles to all tracking stations



---

---

---

---

---

---

---

---



USERS' CONFERENCE

OCTOBER 11-14, 2005 • WASHINGTON, D.C.

Questions?

---

---

---

---

---

---

---

---