Orbital Express Autonomous Rendezvous and Capture Sensor System (ARCSS) Flight Test Results

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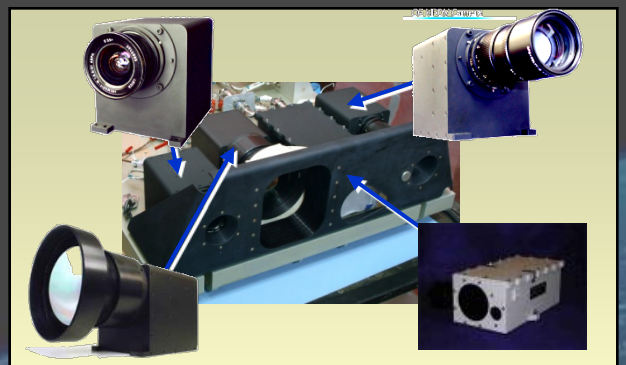
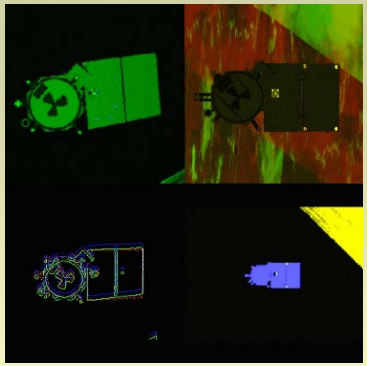
Orbital Express Autonomous Rendezvous and Capture (AR&C) Technologies Demonstrated



Space Qualified Rendezvous Sensors

- Enable Automated Rendezvous from >200 km to Capture



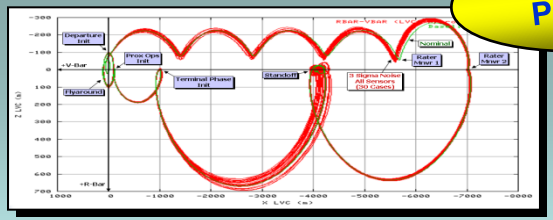
Vis-STAR

- Flight Sensor Software for Passive Client Attitude Determination

OESIL, SensorSIM

- HWIL Plus Realistic Scene Injection for Closed Loop Rendezvous Simulations

Focus of This Presentation

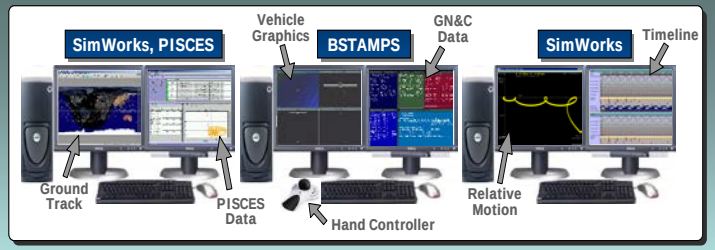


AutoGuide / AutoNav

- Guidance and Relative Navigation (G&RN) Software Enables Fully Automated Rendezvous and Capture

Sensor-GS

- Low Cost Sensor Cmd, Telemetry and Situational Awareness Ground Station



BSTAMPS+

- Mission Design, GN&C Software Development, Control Center, Telemetry/Graphics

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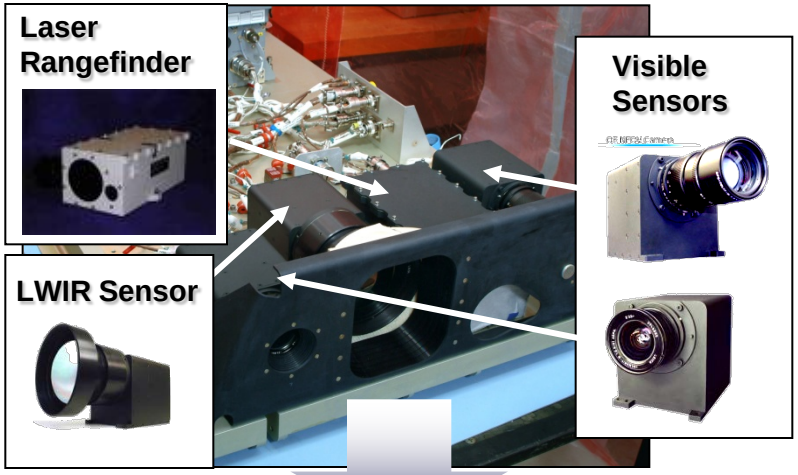
Autonomous Rndz & Capture Sensor System (ARCSS)

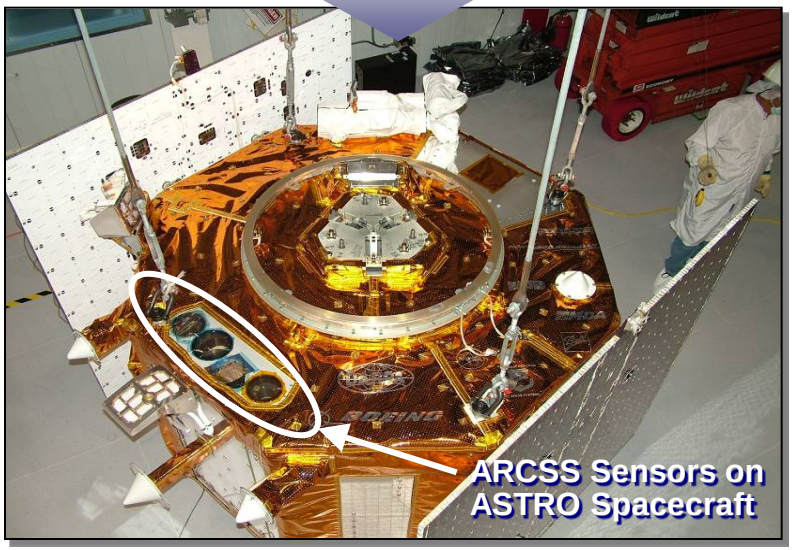
- **ARCSS features integrated visible & infrared sensors, laser rangefinder**

- **Highly capable system incorporates functional redundancy**
  - Long range small target acquisition and track
  - Active client ranging
  - Passive range and attitude determination using any or all sensors
  - LWIR and visible situational awareness imaging

- **Designed for non-cooperative targets**
  - Robust to failure (No GPS, crosslinks or targets on client required)

- **Status:**
  - ARCSS System 100% proven through successful mission operations – TRL 9

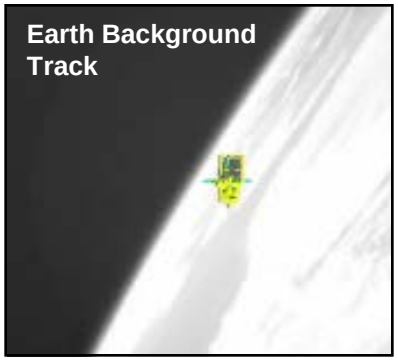


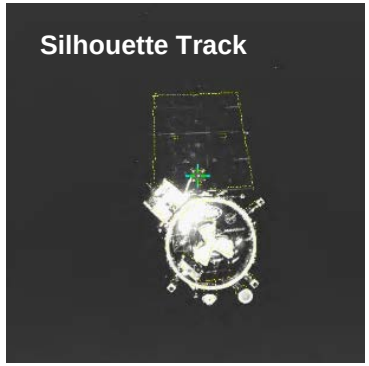


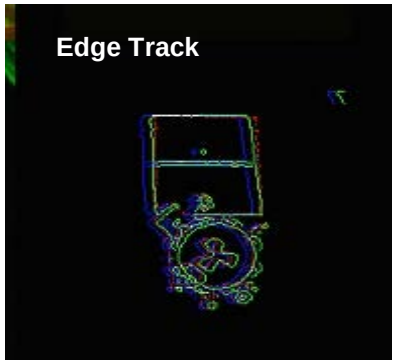
Vis-STAR*

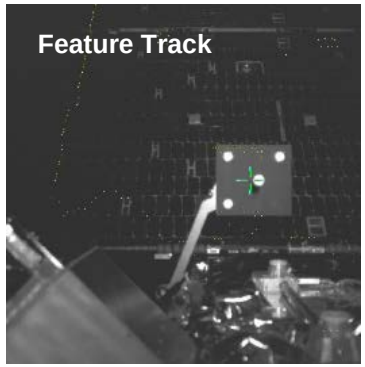
*Vision-based Software for Track, Attitude and Ranging

- **Vis-STAR provides the capability for passive relative range and attitude determination of a target, based on camera data only**
  - Boeing Patent issued Oct 2005
- **Real-time image correlation algorithm takes advantage of *a priori* client knowledge**
  - Enables relative navigation with respect to a completely passive client
- **Virtually identical software operates with all ARCSS imaging sensors**
  - Visible or IR sensor input
  - No additional hardware required
- **Highly scaleable**
  - Processing speed and accuracy adjustable with image library size
  - Range performance scalable with sensor FOV









All Vis-STAR Modes Successfully Checked Out On Orbit

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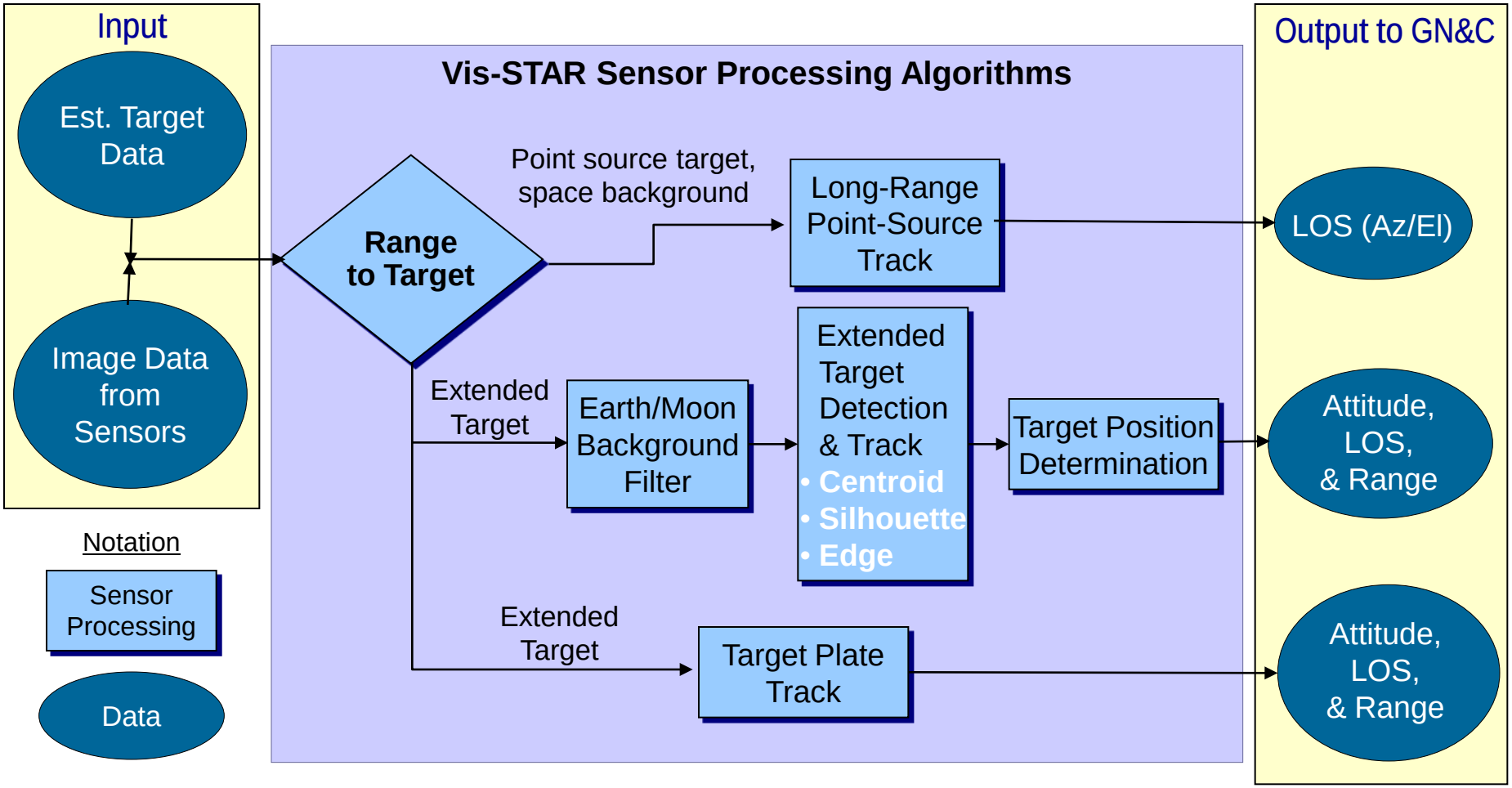
Sensor Software Functional Overview



Vis-STAR Algorithms Encompass All Operations From Long Range Track to Capture

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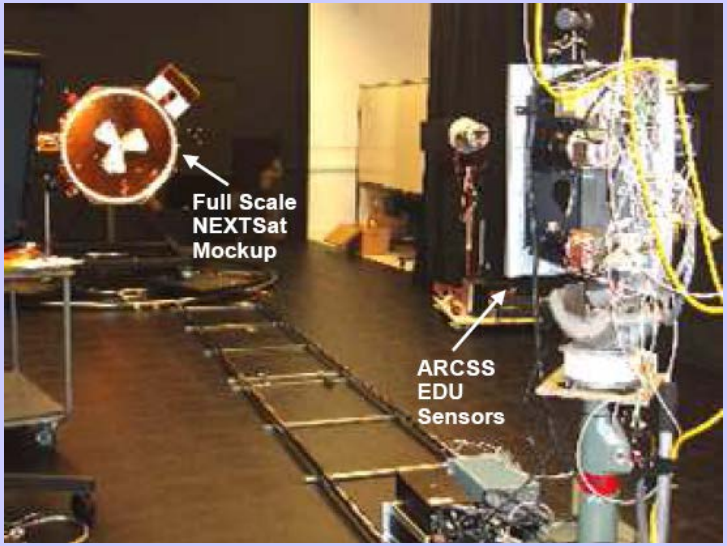
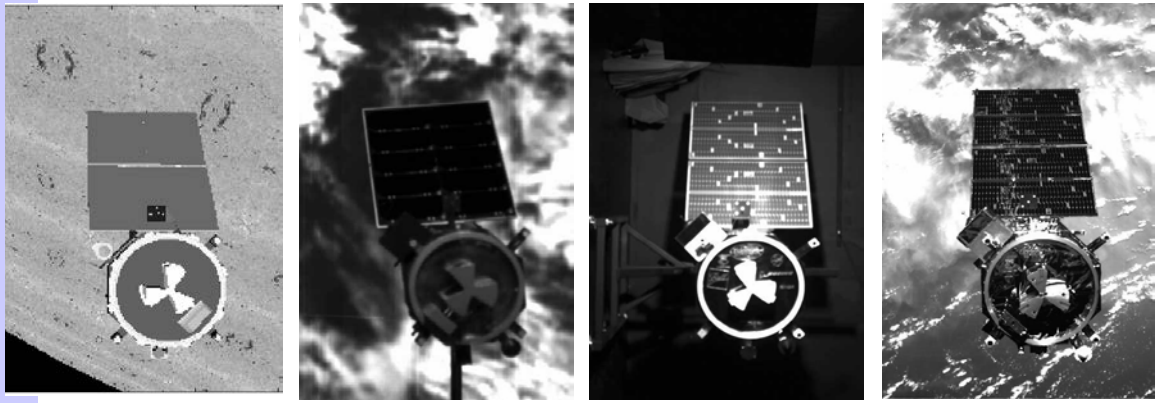
Lesson Learned – Test, Test, Test

- **A key to OE flight success:**
  - Extensive simulations
  - Subscale and full scale hardware in the loop testing with flight-like sensors
  - All done at varying ranges, target geometry, lighting conditions



HWIL Testing

Simulation | **1/8 Scale Model w/Plasma Screen** | **Full Scale Model** | **On-Orbit Image**



Earth Background Performance Testing

Simulation | **Full Scale Model** | **On-Orbit Image**

Target Plate Track Testing

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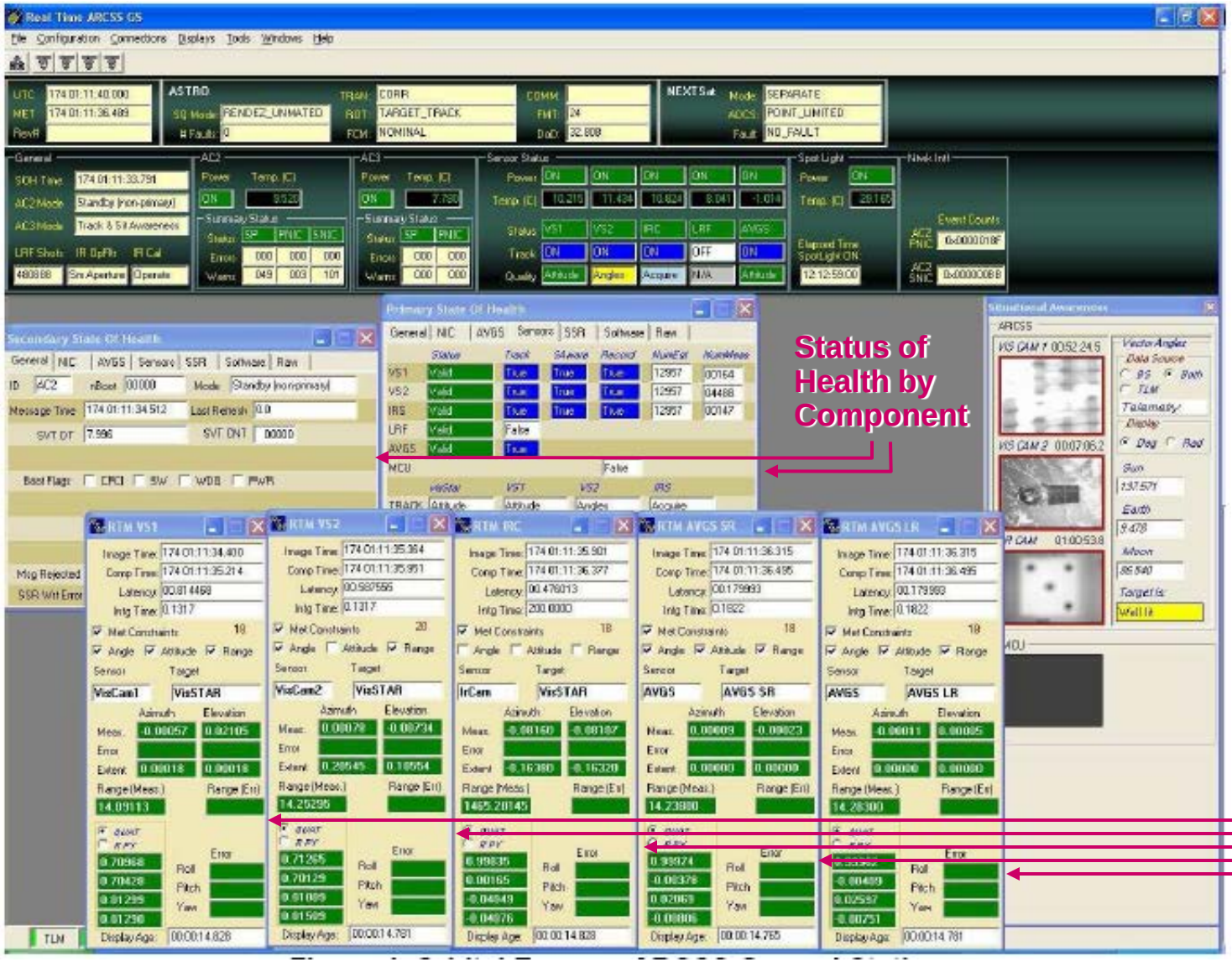
ARCSS Ground Station Provides Situational Awareness



ASTRO Spacecraft Status

Overall ARCSS Status of Health

Sensor Thumbnail Images

Real-time Sensor Performance Data

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IR Sensor Statistical Track Performance (Aggregate, All Scenarios)

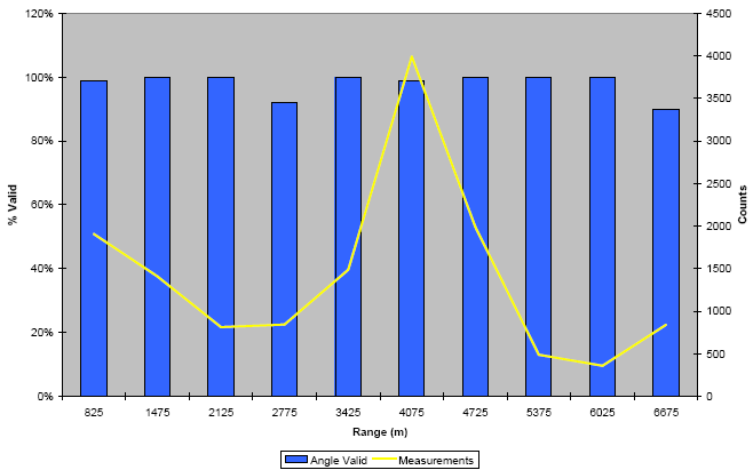


Figure 9g. Validity rates for IRC well lit from long range (0.5km-7km)

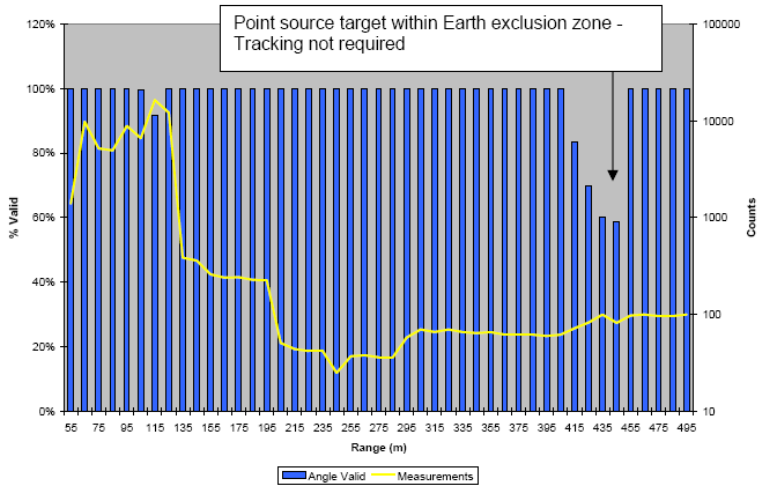


Figure 9i. Validity rates for IRC, target in shadow against a space background.

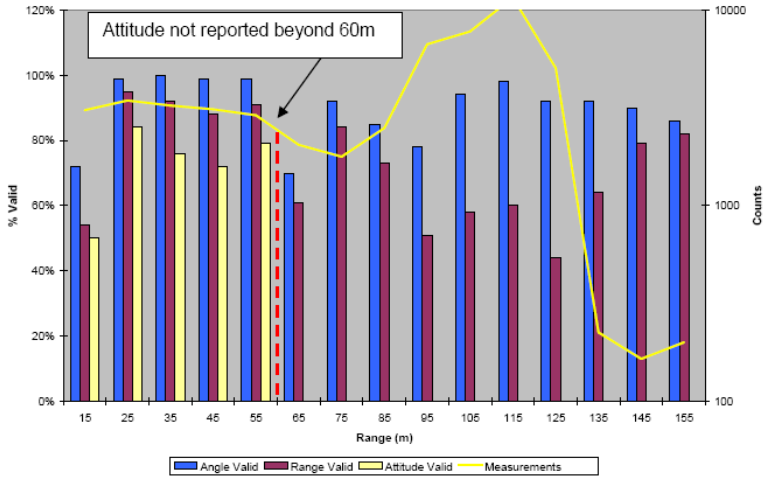


Figure 9c. Validity rates for IRC under good lighting conditions

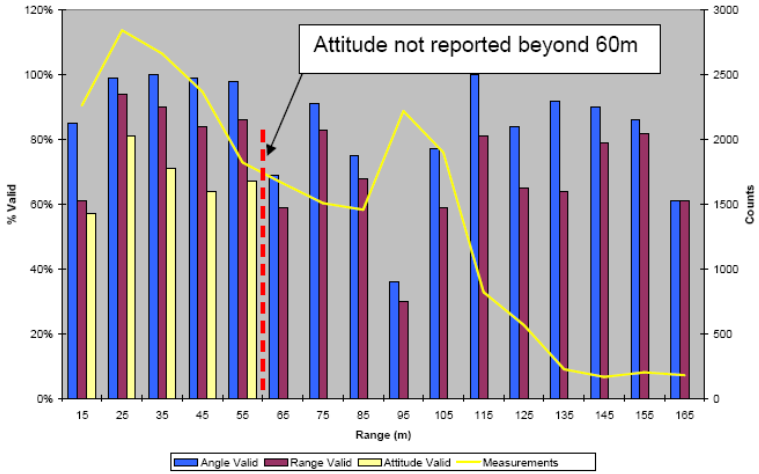


Figure 9f. Validity rates for IRC well lit but with Earth in the background

VS1, VS2 Statistical Track Performance (Aggregate, All Scenarios)

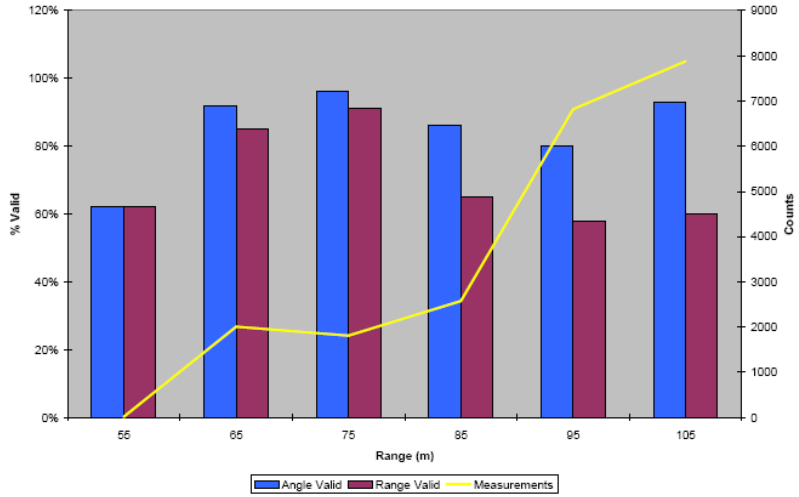


Figure 9d. Validity rates for VS1 under good lighting conditions

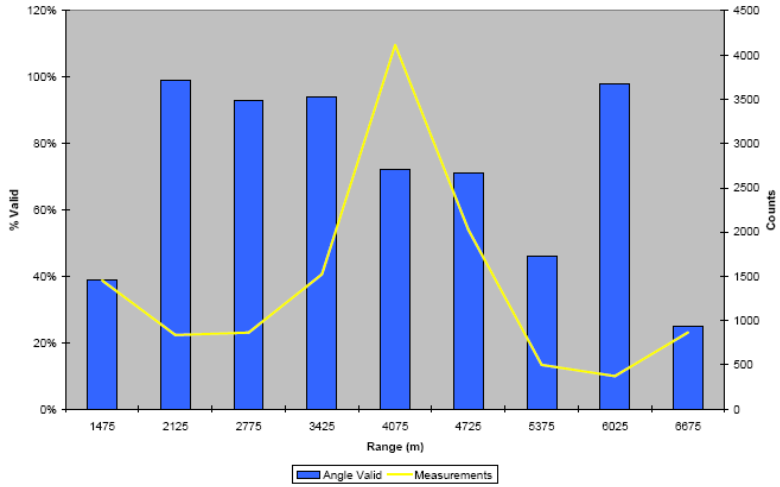


Figure 9h. Validity rates for VS1 well lit from long range (1.15km-7km)

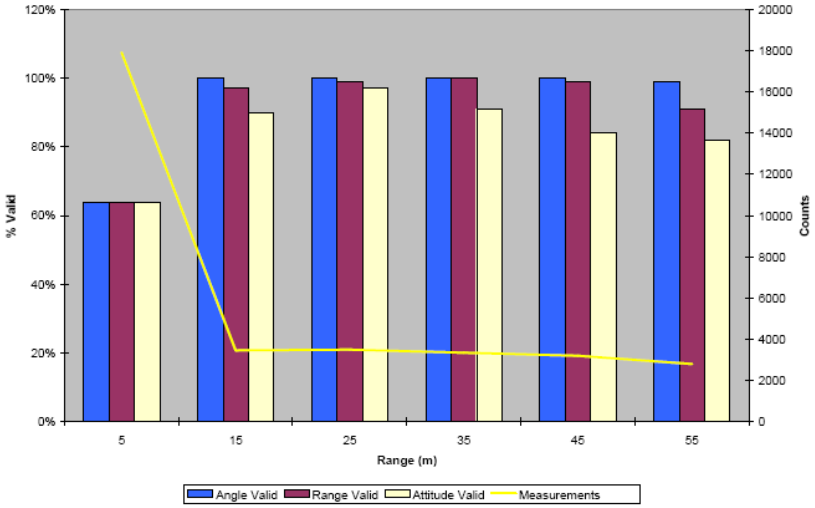


Figure 9a. Validity rates for VS2 under good lighting conditions

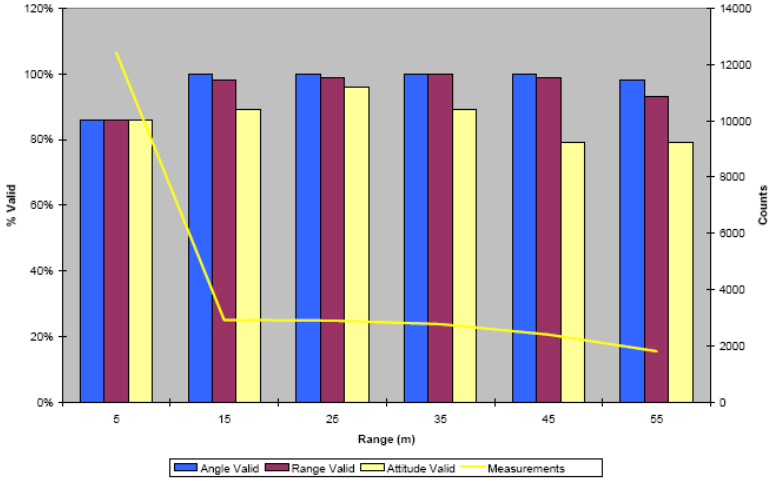
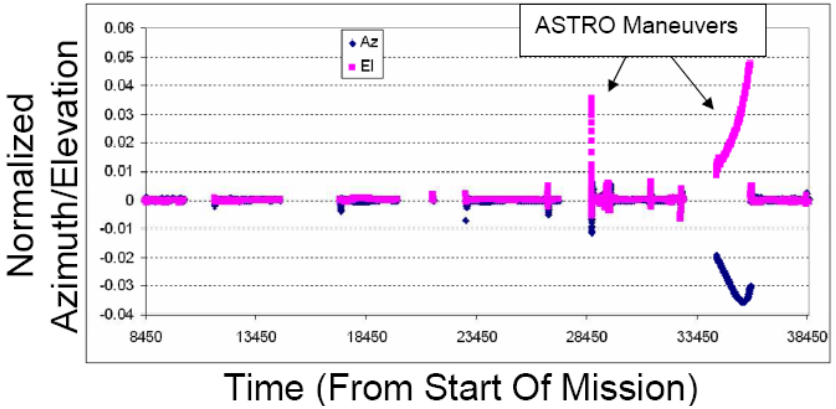


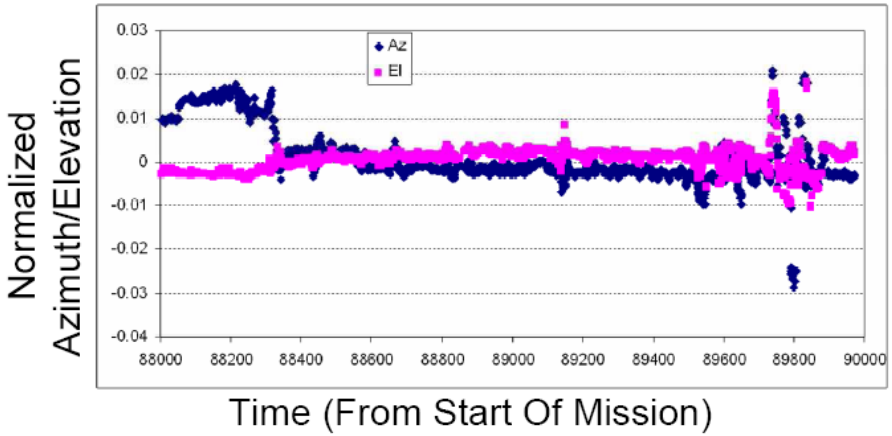
Figure 9e. Validity rates for VS2 well lit but with Earth in the background

Sample Track Performance - IR Sensor

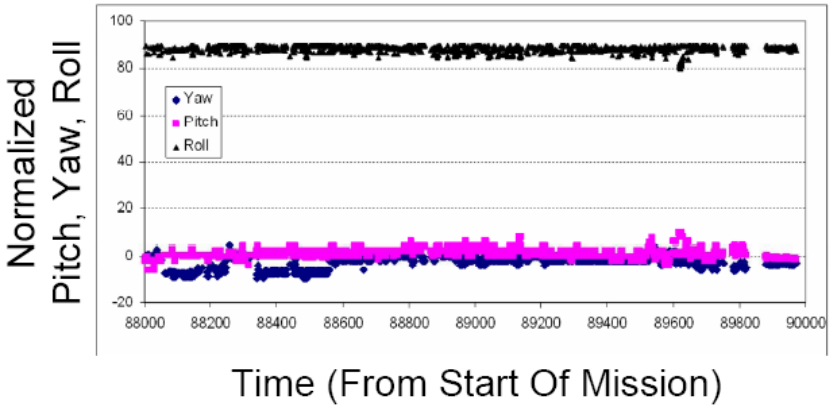
Scenario 7-1 Long Range Track (Bearing)



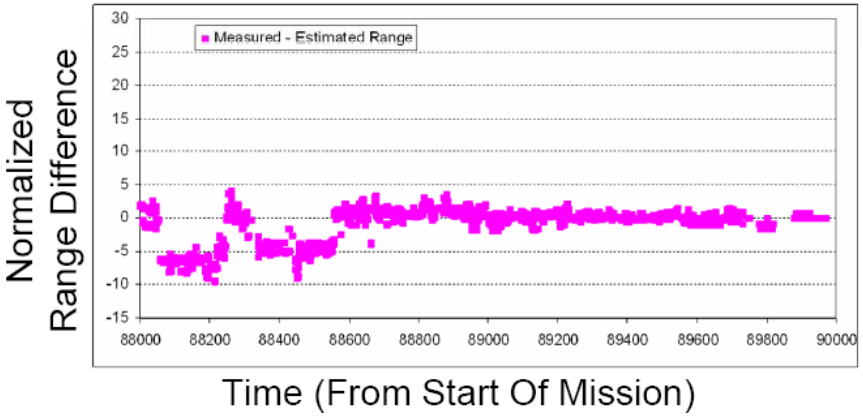
Scenario 8-2 Bearing Inside 60 m



Scenario 8-2 Attitude Inside 60 m

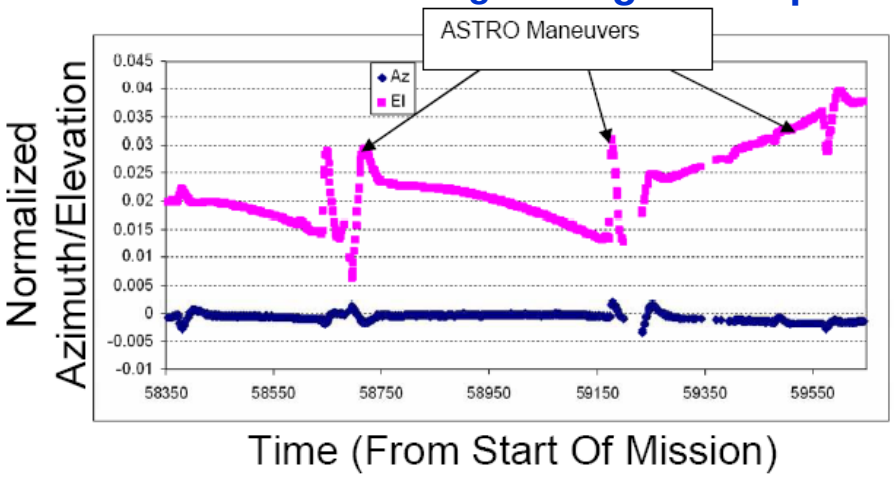


Scenario 8-2 Range Deviation Inside 60 m

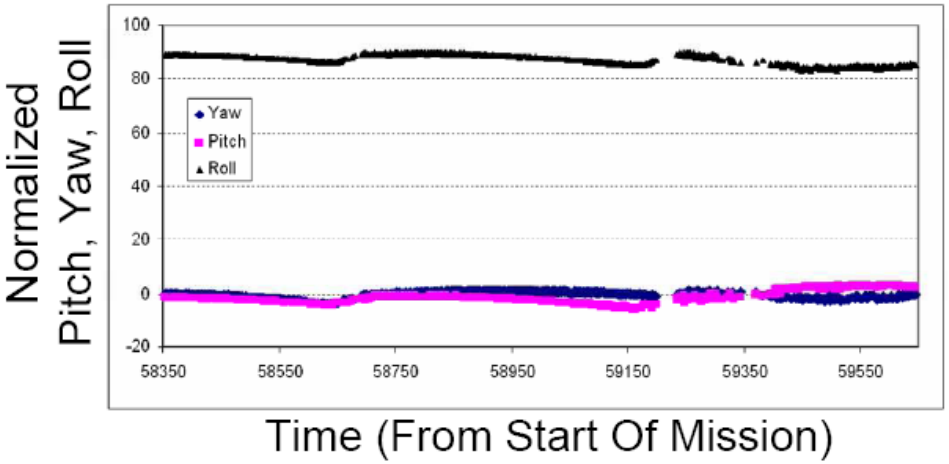


Sample Track Performance - Visible Sensor 1

Scenario 7-1 Bearing During Prox Ops



Scenario 7-1 Attitude During Prox Ops



Scenario 7-1 Range Deviation During Prox Ops

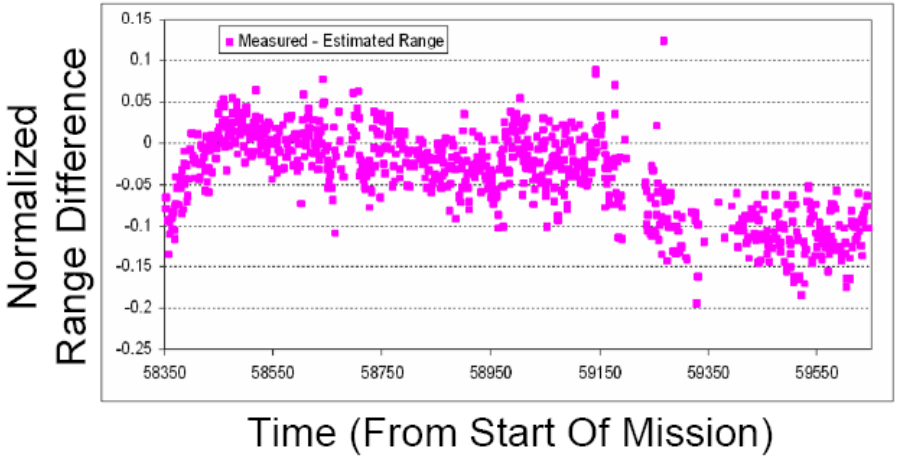
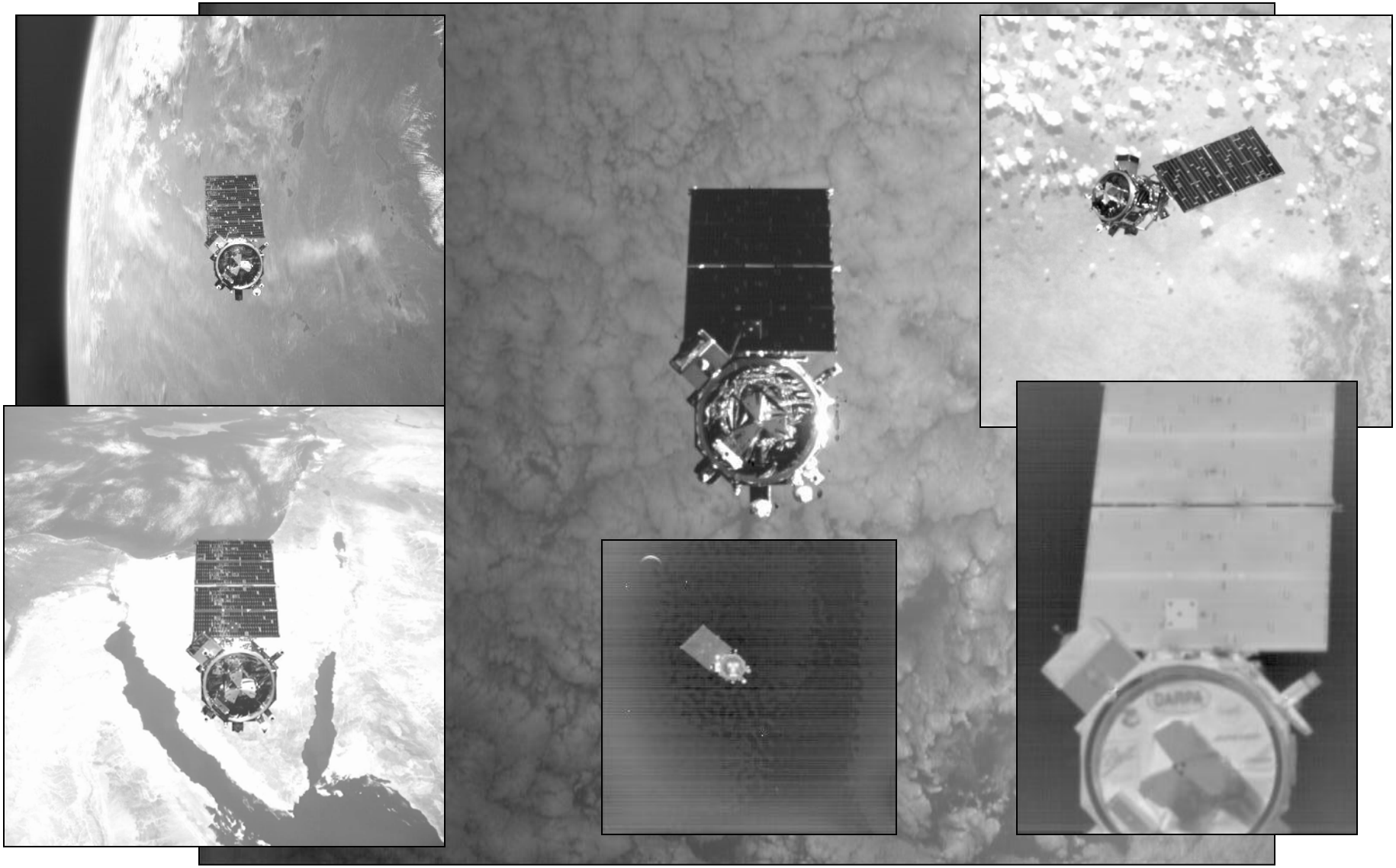
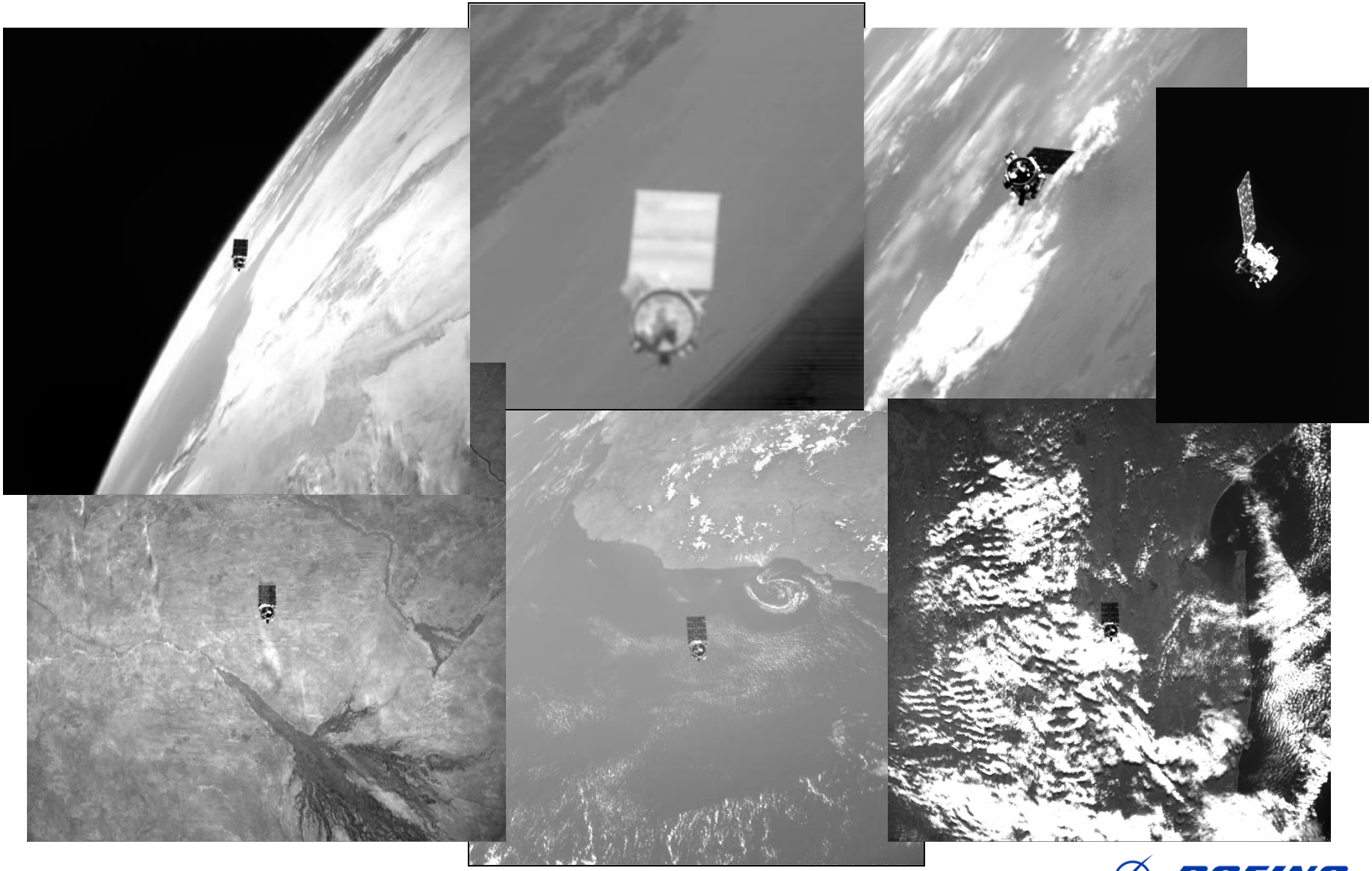


Figure 12. Scenario 7-1, VS1 Prox Ops Performance

OE Flight Imagery – Courtesy of ARCSS



OE Flight Imagery – Courtesy of ARCSS



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Scenario 8-2 Sensor View

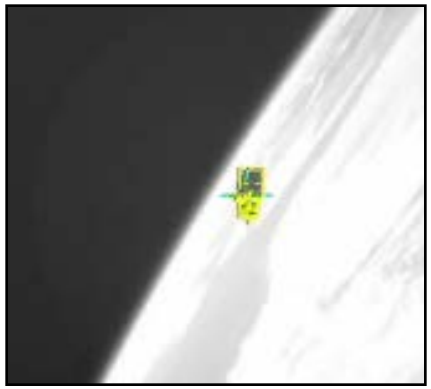
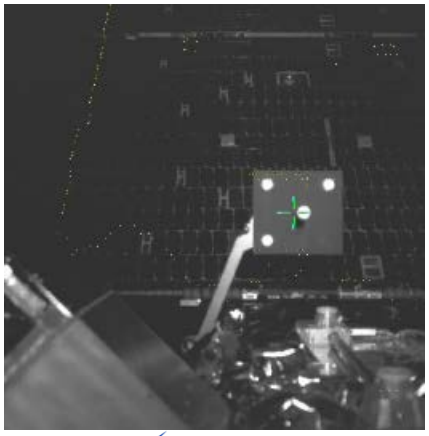
- Fully autonomous solar inertial separation
- Phasing to 7 km behind NEXTSat
- 4 km standoff for 6 hrs, 43 min.
- 100 m 3X orbital rate circular fly around
- Solar inertial approach to free flyer capture
- Total unmated duration: 1d 21h 54m 19s

(click to play movie)

ARCSS On Orbit Performance Was Outstanding

- **Long Range Track (Bearing)**
  - Visible track (daylight) to a range of > 500 km
  - LWIR track (day and night) to a range of > 7 km

- **Mid Range Track (Bearing and Range)**
  - Laser Rangefinder Active Ranging to >6 km
  - Visible and LWIR Passive Range determination to > 200 m
  - Space and Earth background



- **Prox Ops (Bearing, Range, Attitude)**
  - Visible and LWIR relative attitude determination to 60 m inside and outside approach corridor
    - Limited by on board software, greater ranges possible
  - Precision tracking of NEXTSat target plate feature to >10 m