Results of the TLRS-4/Moblas-7 Intercomparison Test

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Near Earth Networks Services

Introduction

- Summary of TLRS-4 Operational Readiness Review completed September 2006
  - TLRS-4 Pre-Upgrade Status
  - Major Hardware and Software Repairs/Upgrades
  - System Operations Verification Tests (SOVT)
  - System Validation
    - Pre-Intercomparison
    - Intercomparison Results

TLRS-4 Pre-Upgrade Status

- TLRS-4 system was maintained by HTSI in a care taker status at GGAO under NASA SLR mission contract for the previous 10 years

- System used for spare parts for NASA SLR Network and as a test bed
  - Hardware removed from system to support the NASA SLR Network
  - Software missing
  - Other
    - TLRS-4 required 6 years of hardware and software upgrades

Major Hardware and Software Repairs/Upgrades

- Every major and minor subsystem upgraded/repaired

  – Laser Subsystem

  – Telescope/Optics Subsystem

  – Transmit/Receive Subsystem

  – Computer Subsystem

  – Console Subsystem

  – Timing Subsystem

  – Facility Subsystem

  – Safety Subsystem

  – Software Subsystem

System Operations Verification Tests (SOVT)

- System Operations Verification Tests (SOVT) are performed subsequent to each relocation and prior to any laser system beginning operational support.

- SOVT document NSLR-05-0002 details all System Tests for Operational Verification.

  – System Operations Verification Tests Performed (Communications, Timing, Mount Level and Dome Control, Tracking Computer, Processing Computer, Data Measurement, Laser, Safety Interlock, Telescope Pointing, Star Calibration, Ground Tracking, Controller Computer Operations)

- SOVT Completion report generated on July 15th, 2005, all SOVT results were nominal

System Validation

- The NASA SLR program validates newly built, or newly upgraded SLR systems with an Intercomparison Technique.
  - Designed to directly compare an upgraded SLR system to an established SLR tracking system (Moblas-7 at GGAO currently operates as the Global Standard SLR system)
  - Characterizes and verifies the operational performance and laser ranging capabilities of the upgraded system
- System Validation occurs in two phases
  - Pre-Intercomparison
  - Intercomparison

Pre-Intercomparison

- The Pre-Intercomparison phase ensures that all prerequisites for the Intercomparison phase are completed.

- The following are the prerequisites for Intercomparison:

    – First Order Geodetic Survey

    – TLRS-4 / Moblas-7 Simultaneous Ground tests

    – TLRS-4 / Moblas-7 Simultaneous Satellite Tracking

    – Comparison of Meteorological Sensors

   – Comparison of Station Timing

    – Configuration freeze

Intercomparison

- The configuration of both Moblas-7 and TLRS-4 were frozen on August 1, 2005.

- TLRS-4 / Moblas-7 Simultaneous Satellite Tracking Requirements
  - Minimum of 15 simultaneous Lageos-1 or Lageos-2 passes
  - Minimum of 20 low orbital simultaneous satellite passes
  - Data analyzed using Polyquick and Geodyn software.
    - Range and Range-rate Dependencies
    - Azimuth / Elevation Dependencies
    - Energy Dependencies
    - Long Term Mean Range Bias Stabilities
    - System Delay Range Biases
    - Diurnal effects
    - Sky Coverage
    - Orbital Comparison
    - Independent Data Analysis (Peter Dunn, Raytheon)
  - TLRS-4 / Moblas-7 Simultaneous Ground Tests

- All simultaneous data taken from August 1st, 2005 through September 6th, 2005 were included in the Intercomparison analysis.
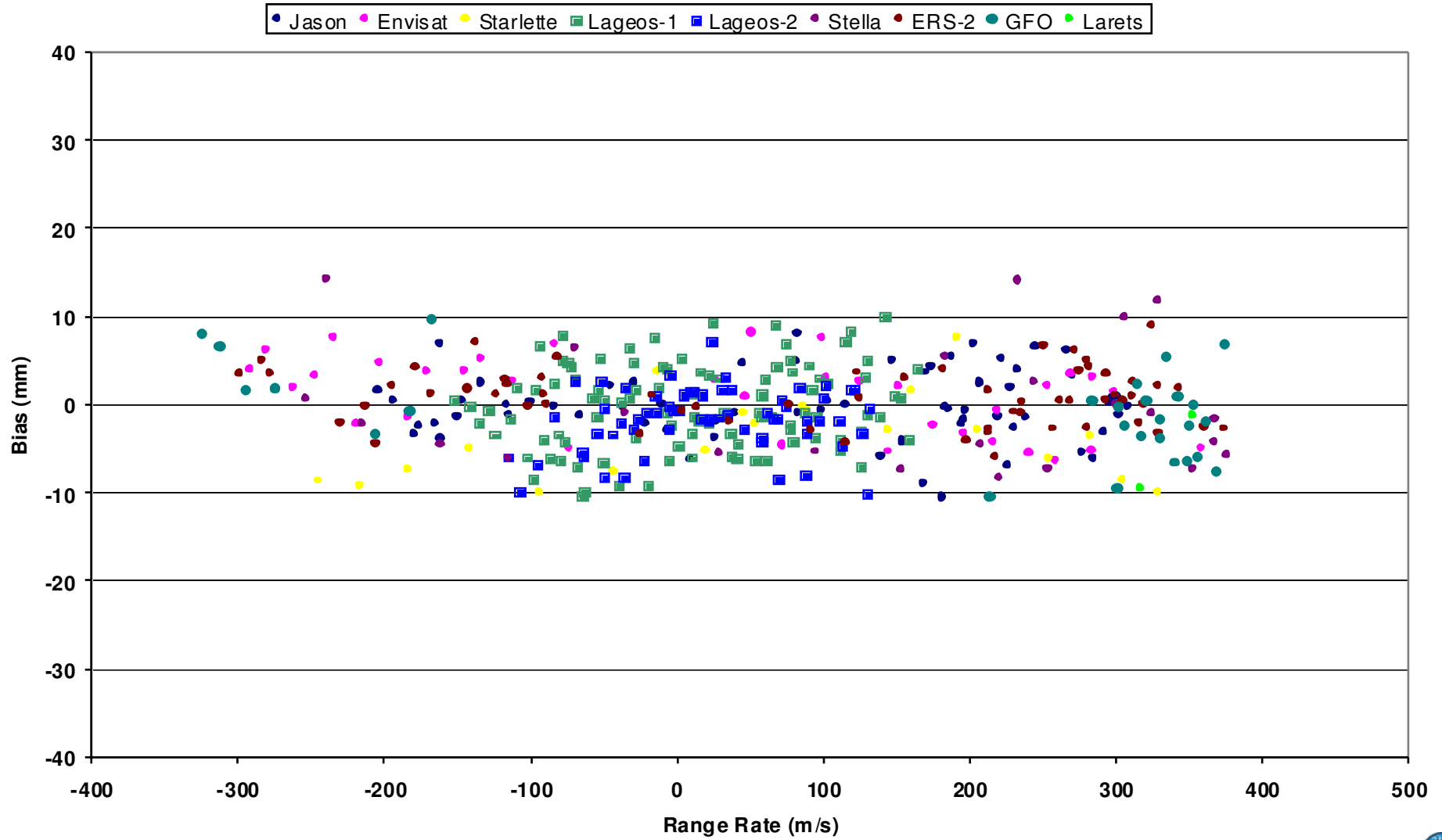
8

Simultaneous Data Analysis

TLRS-4 Mean Bias from Moblas-7 vs. Range
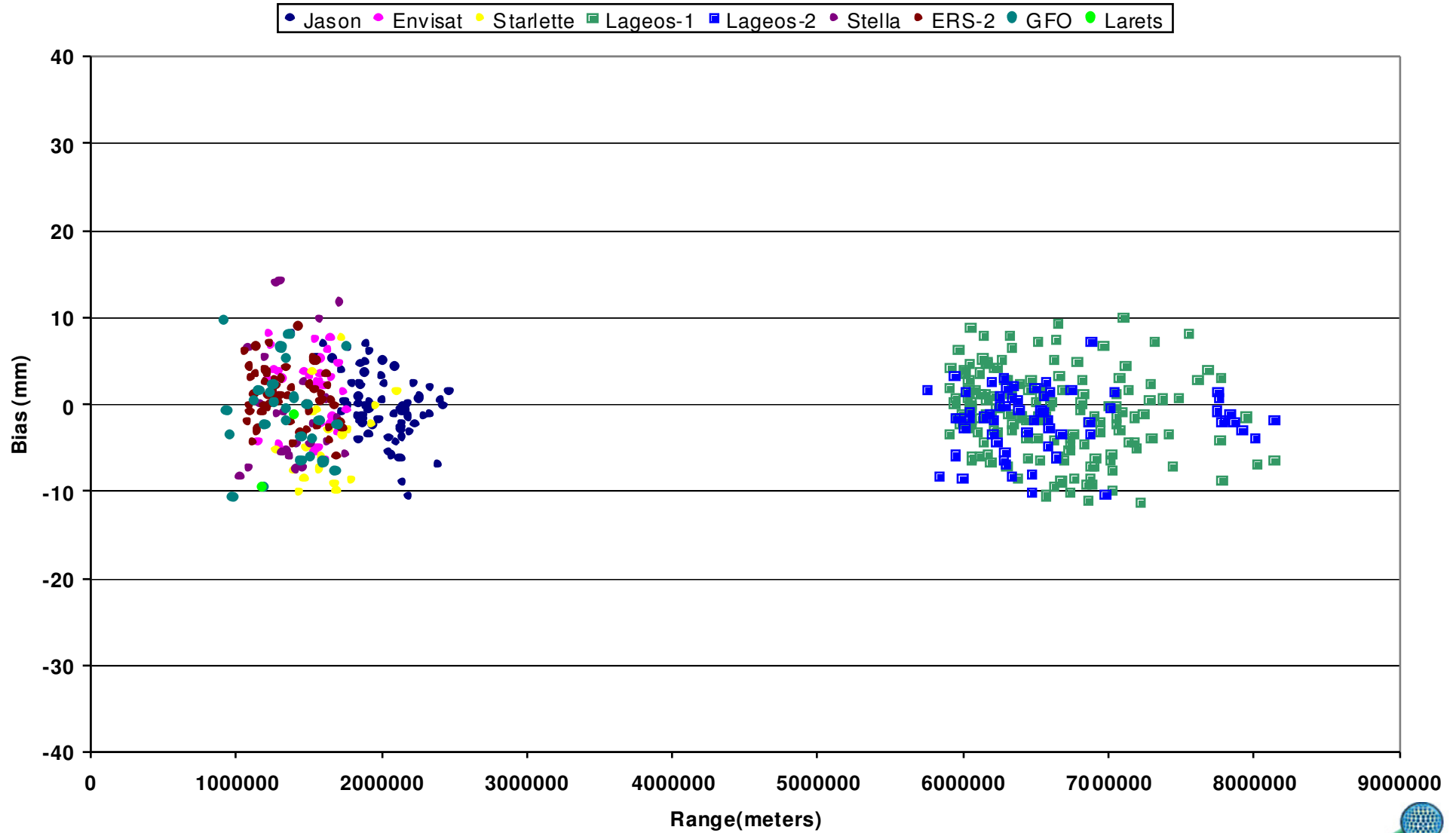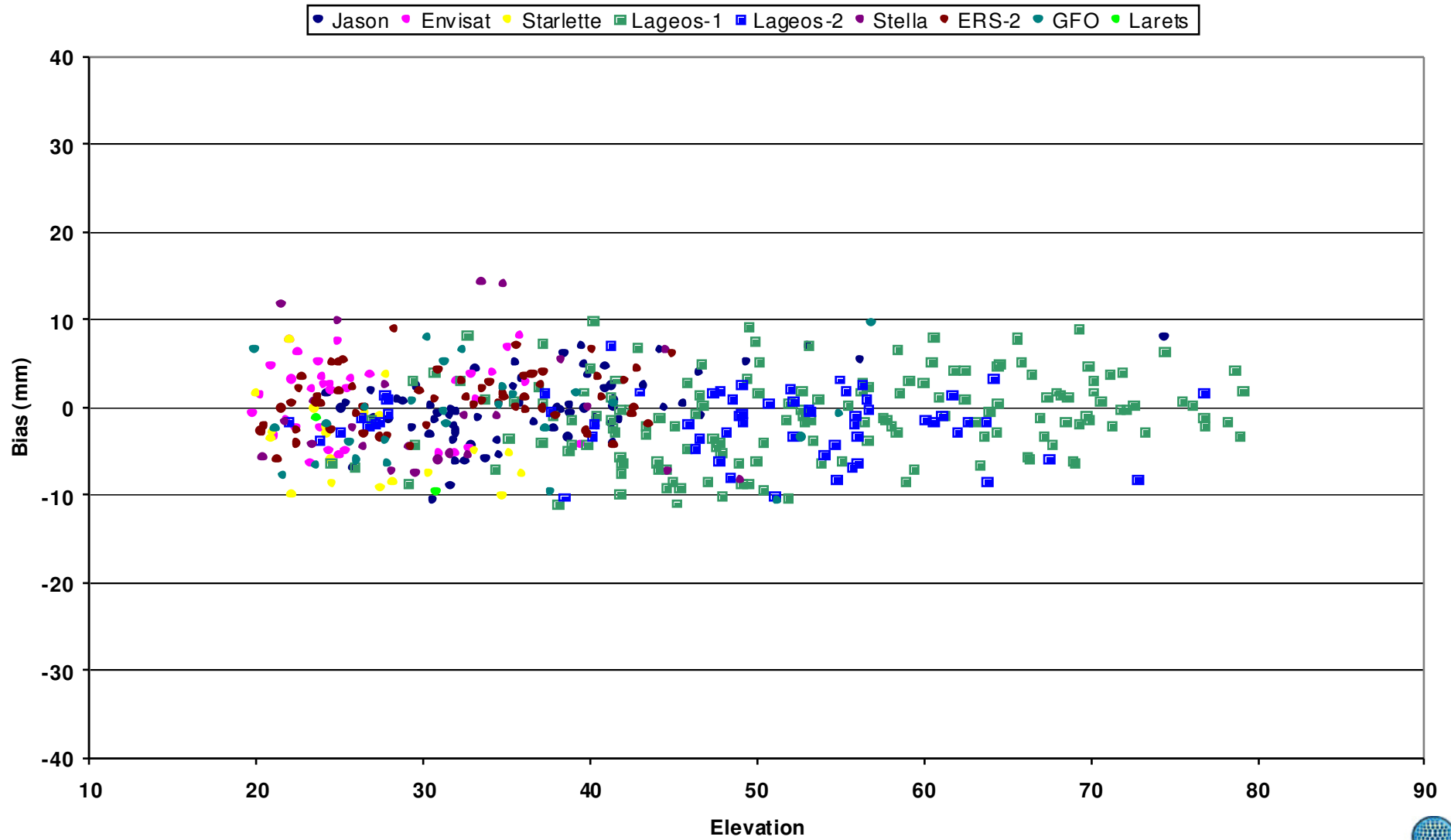
Simultaneous Data Analysis

TLRS-4 Bin Bias from Moblas-7 vs. Range Rate
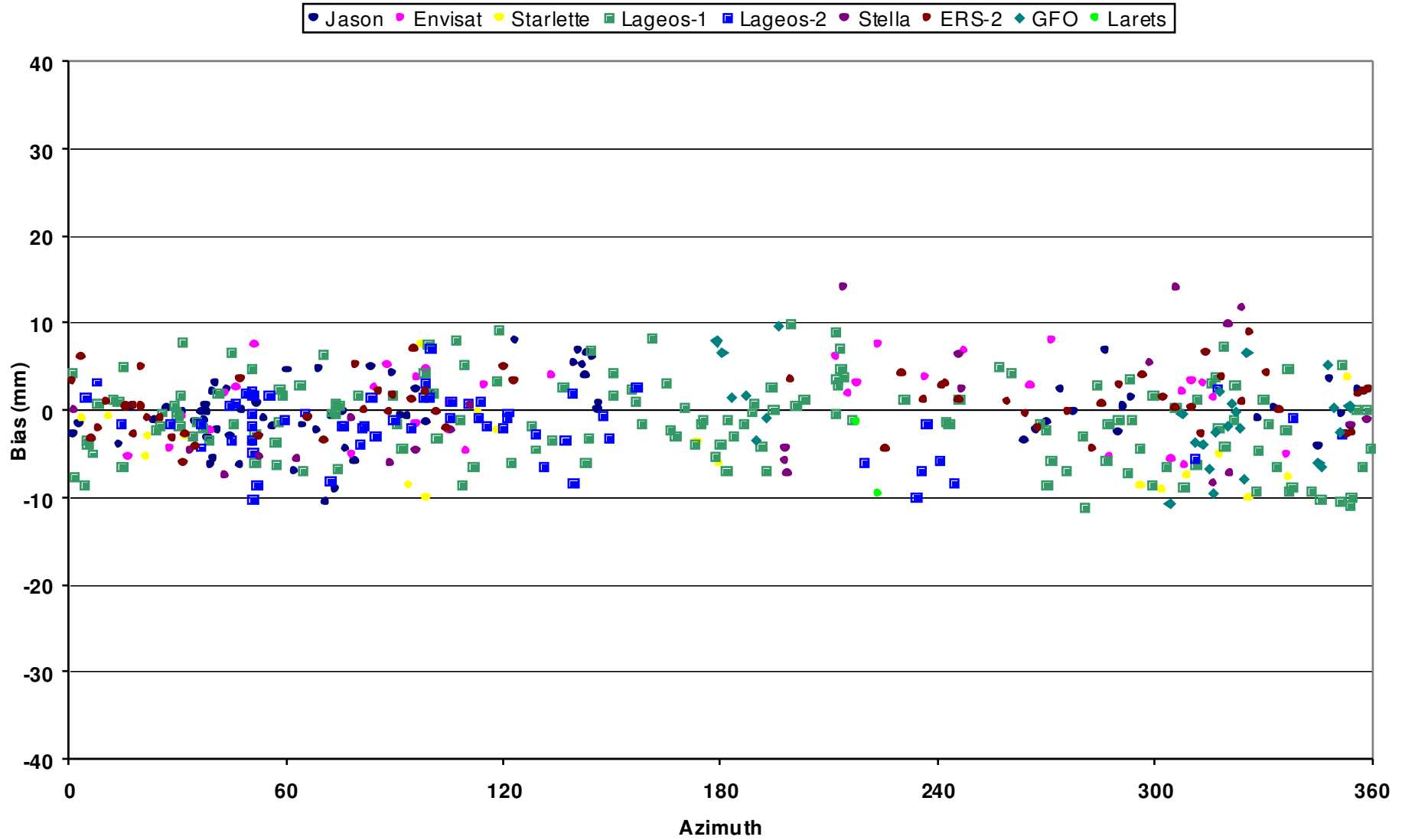
Simultaneous Data Analysis

TLRS-4 Bin Bias from Moblas-7 vs. Elevation
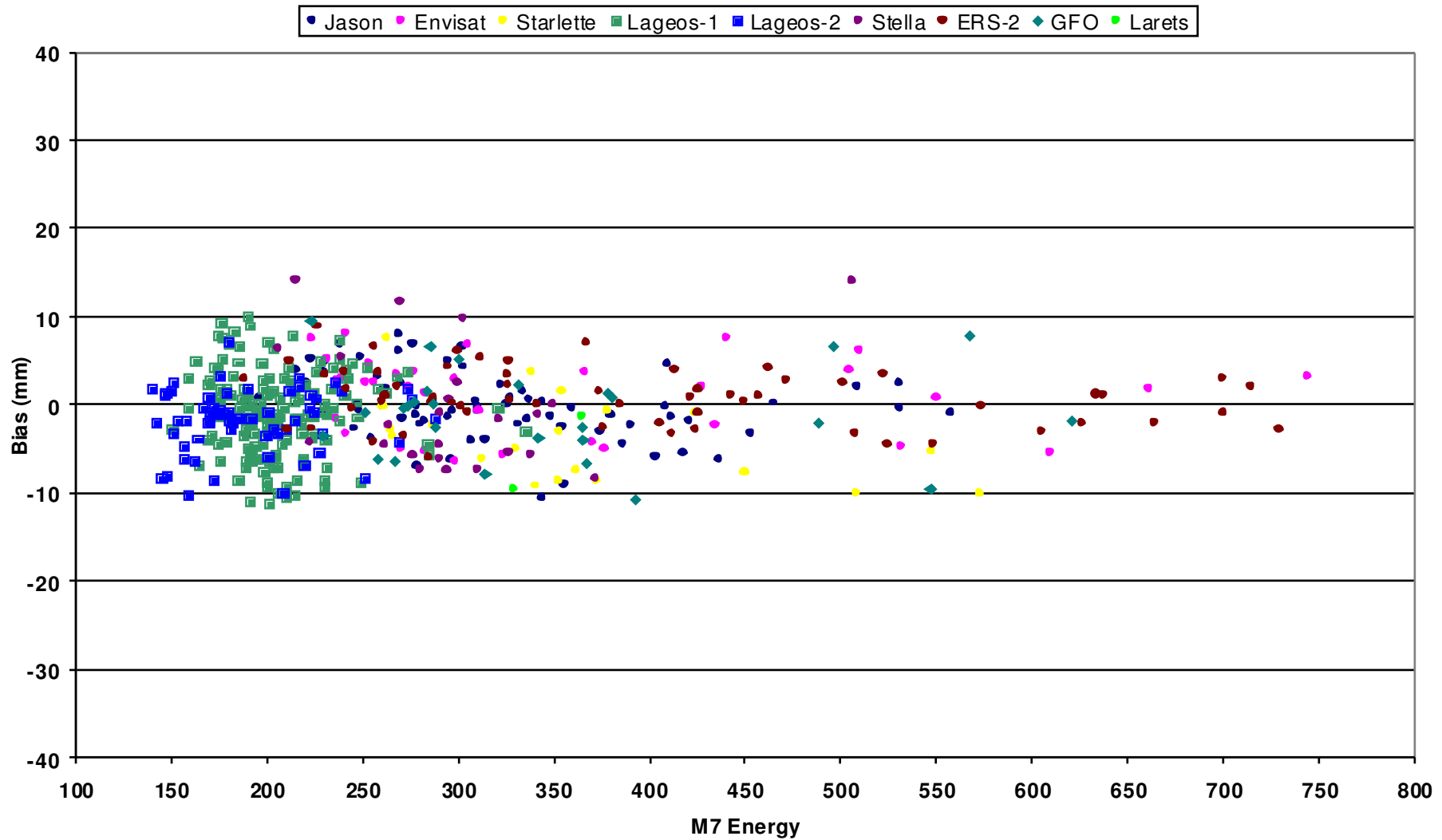
Simultaneous Data Analysis

TLRS-4 Bin Bias from Moblas-7 vs. Azimuth
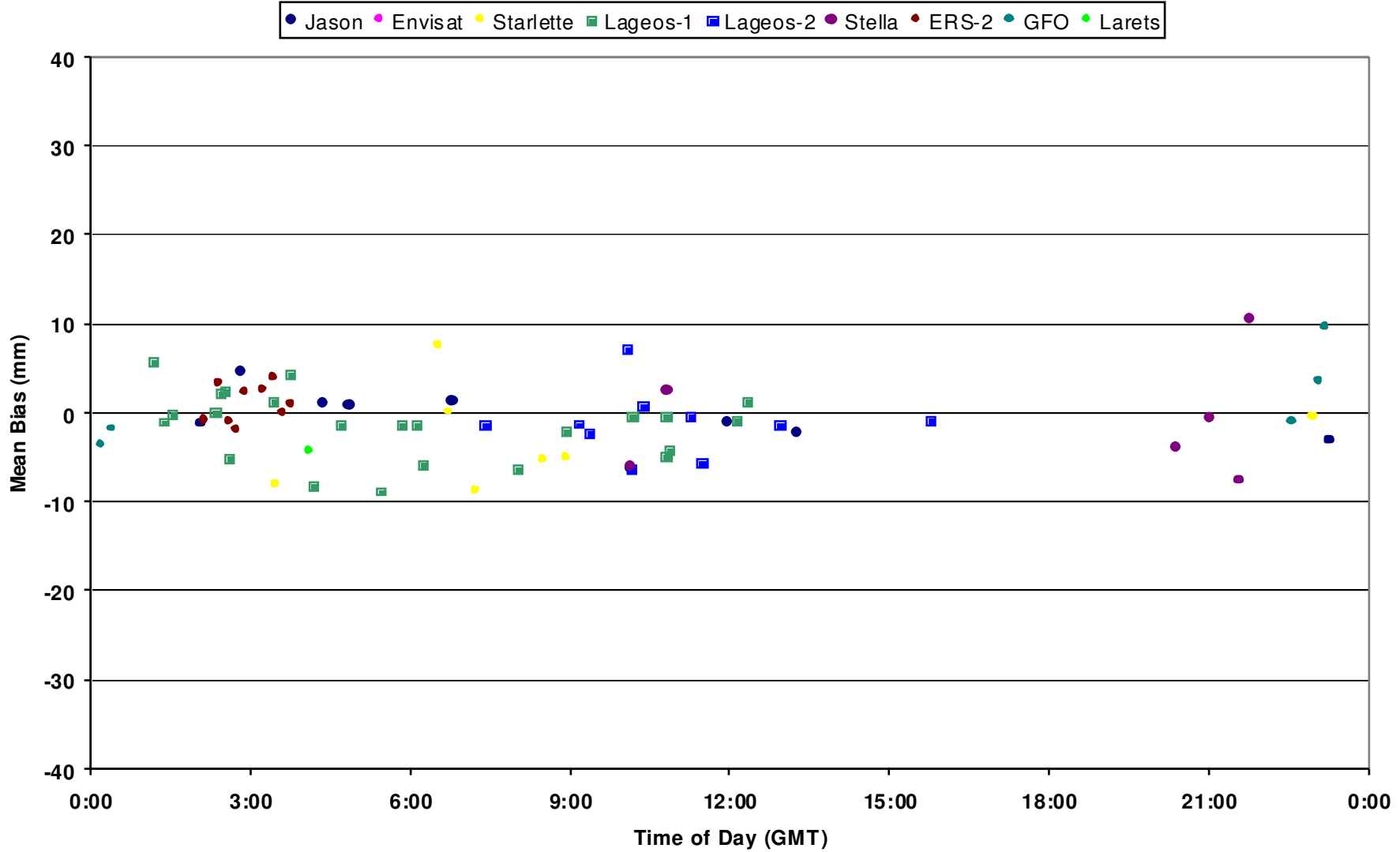
Simultaneous Data Analysis

TLRS-4 Mean Bias from Moblas-7 vs. M7 Energy

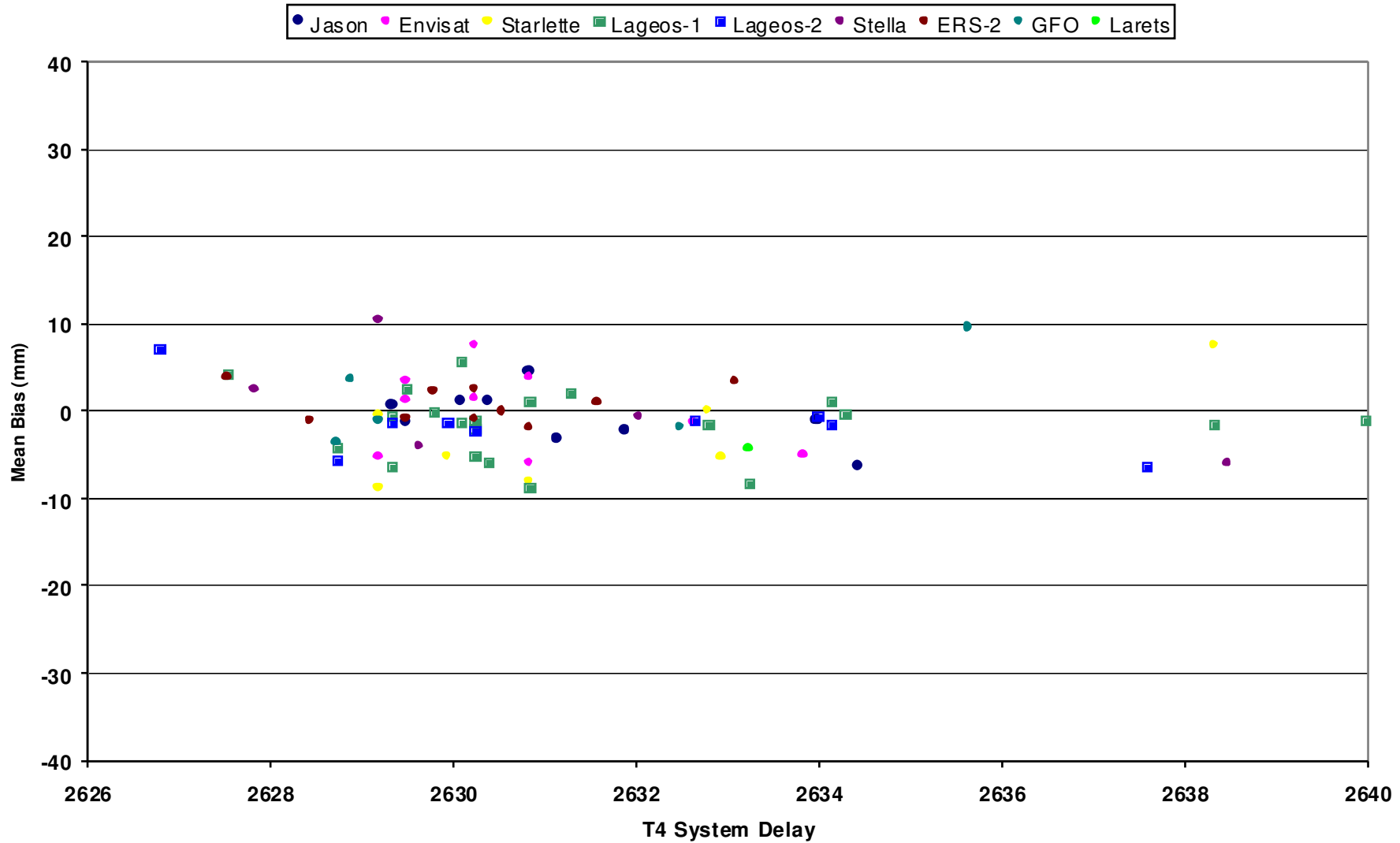# Simultaneous Data Analysis

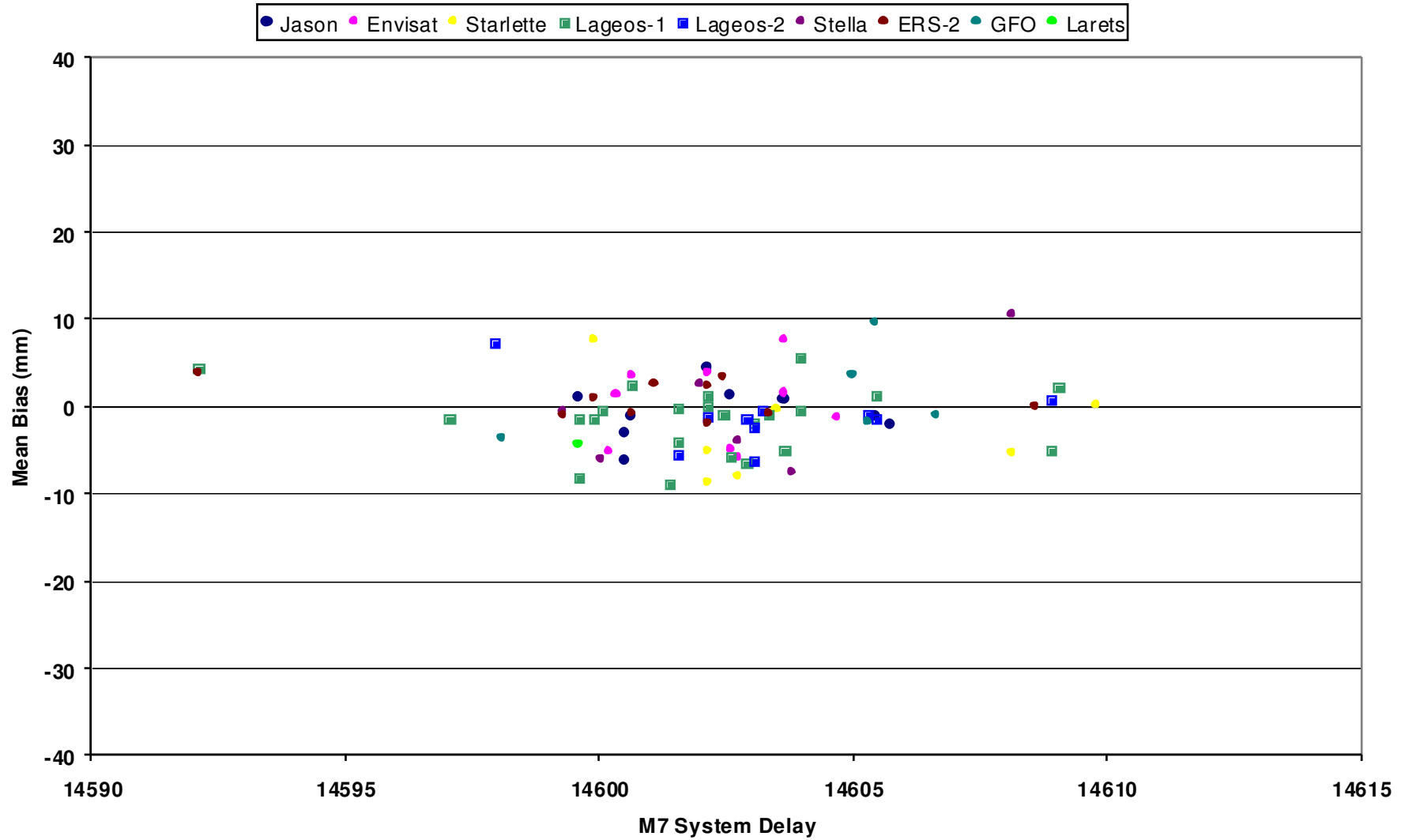**TLRS-4 Mean Pass Bias from Moblas-7 vs Time of Day**

Simultaneous Data Analysis

TLRS-4 Mean Pass Bias from Moblas-7 vs T4 System Delay
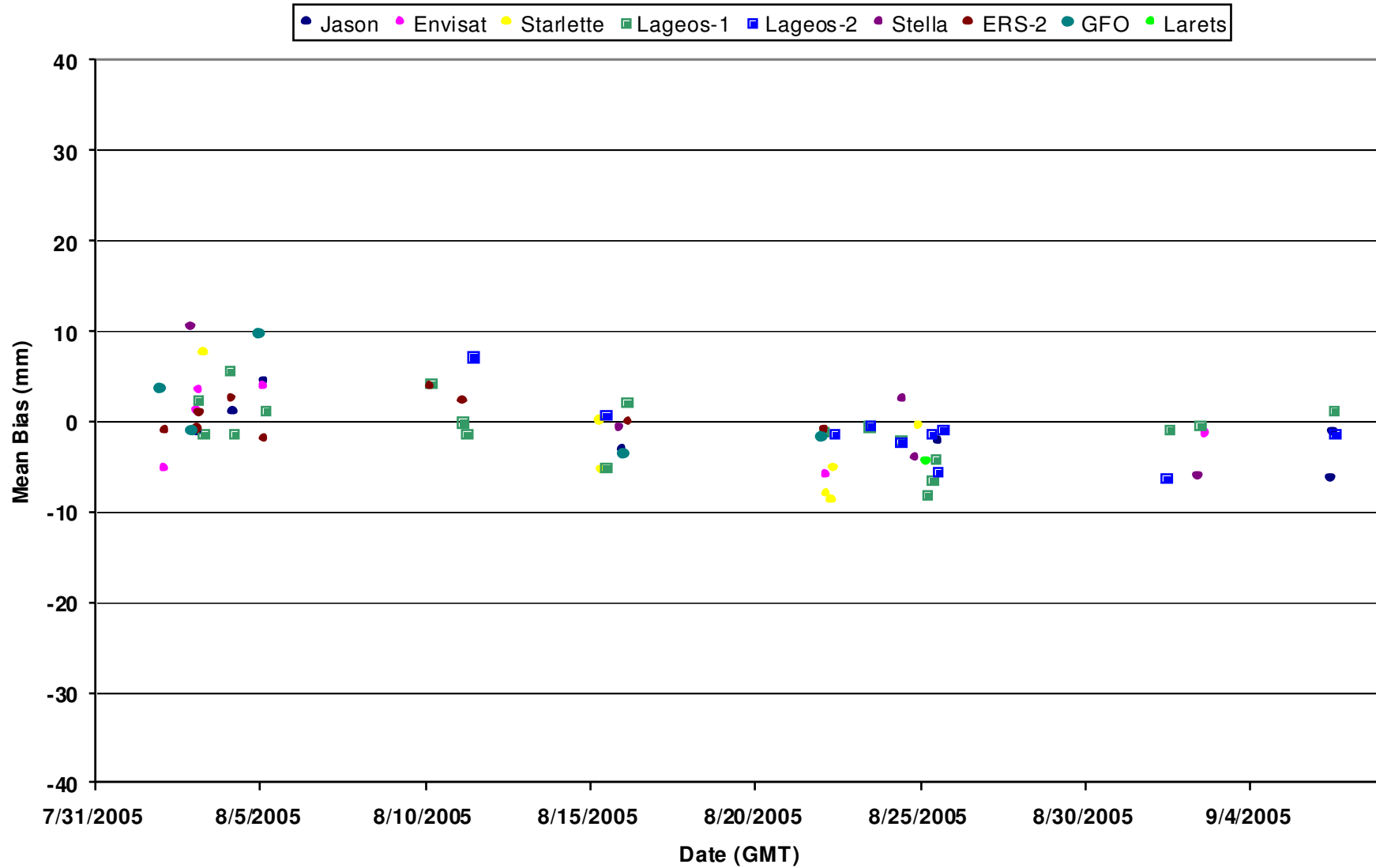
Simultaneous Data Analysis

TLRS-4 Mean Pass Bias from Moblas-7 vs M7 System Delay

Simultaneous Data Analysis
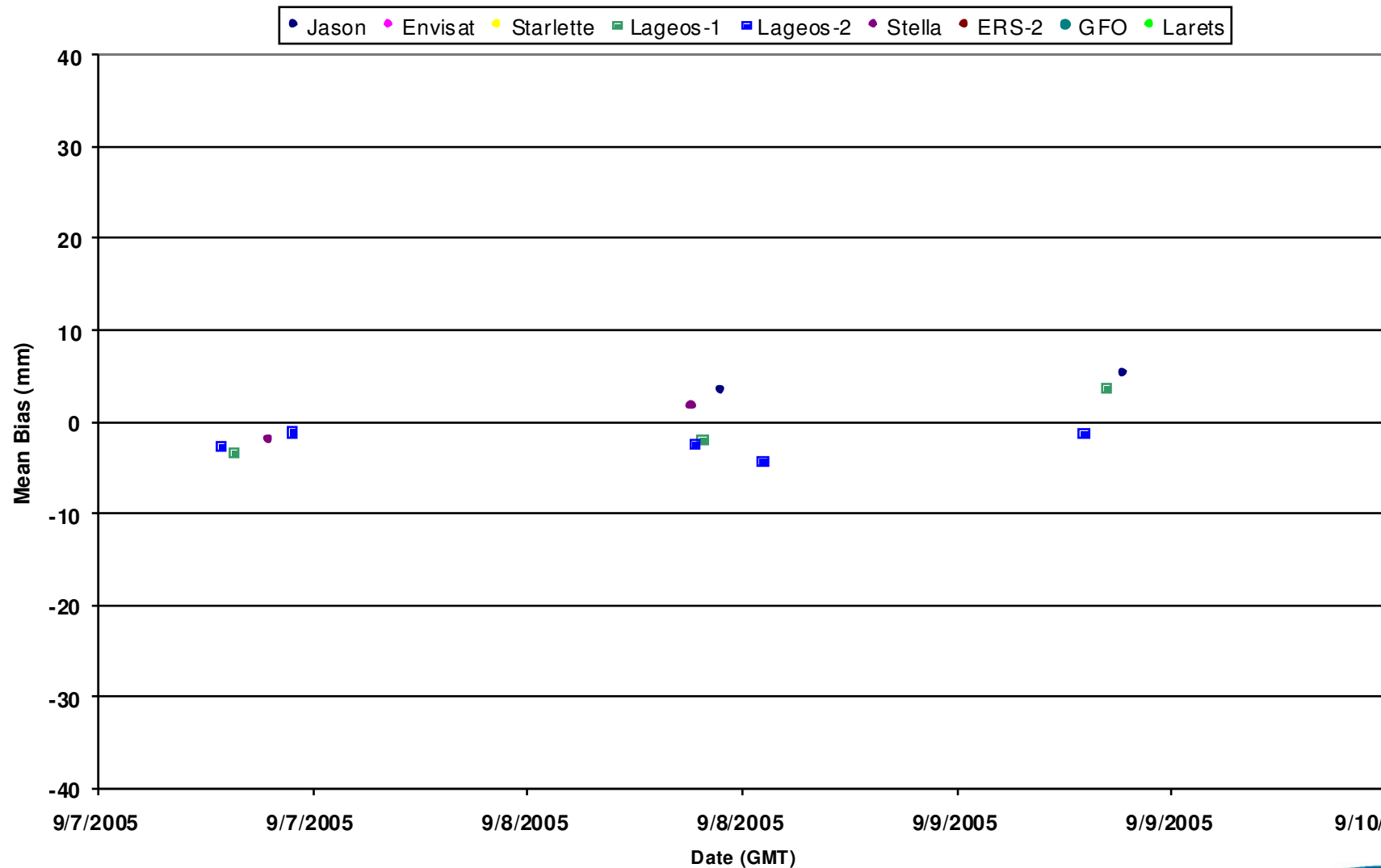
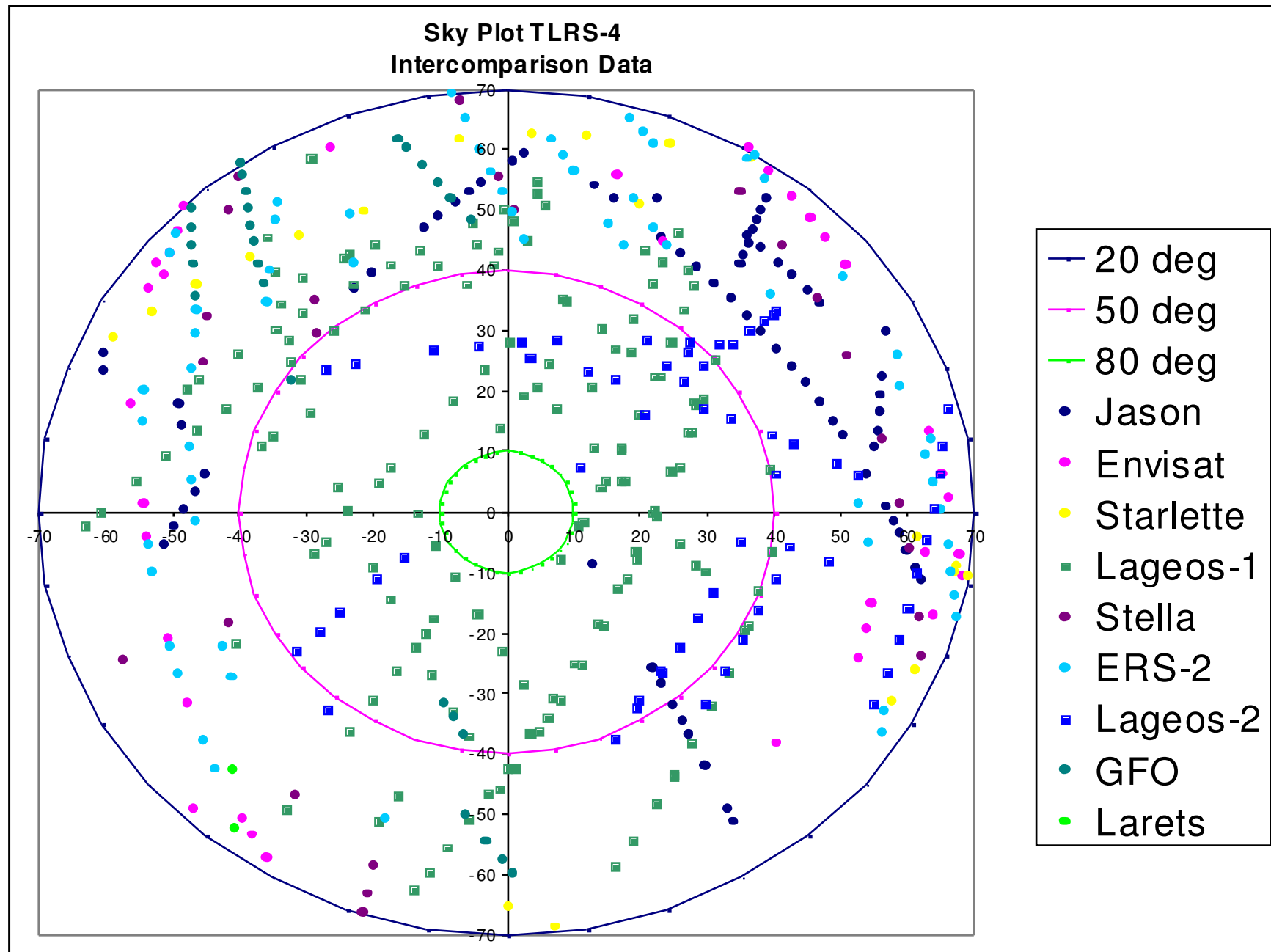**TLRS-4 Mean Pass Bias from Moblas-7 vs Date**

Simultaneous Data Analysis
(Post-Intercomparison/New Descriminator)

TLRS-4 Mean Pass Bias from Moblas-7 vs Date

Simultaneous Data Analysis

Sky Plot TLRS-4
Intercomparison Data

Intercomparison Result's Summary

Intercomparison				
TOPIC	**TLRS-4**	**Moblas-7**	**TLRS-4 Results**	**Moblas-7 Results**
Minimum Simultaneous Passes				
Lageos-1 & Lageos-2	15	15	29	29
LEO's	20	20	123	123
Fullrate Data RMS				
Calibration	< 7 mm	< 7 mm	5.44 mm	5.49 mm
Calibration Shift	< 10 mm	< 10 mm	0.31 mm	0.71 mm
Lageos-1 & Lageos-2	< 15 mm	< 15 mm	11.25 mm	9.17 mm
LEO's	< 12 - 30 mm	< 12 - 30 mm	16.11 mm	11.21 mm
Ground Test Delay Variations				
Stability Test	< 8 mm	< 8 mm	2.55 mm	1.73 mm
Extended MINICO	< 8 mm	< 8 mm	2.95 mm	2.13 mm
Intercomparison Bias				
TLRS-4 Mean Pass Bias from Moblas-7	+ 15 mm		**1.07 mm**	
Lageos-1 & Lageos-2	+ 15 mm		**0.91 mm**	
LEO's	± 15 mm		**1.67 mm**	

Conclusion

- Repairs and Upgrades Required to all Major Subsystems
  - Telescope / Gimbal
  - Laser
  - Data Measurement System
  - Precision Timing
  - Processing, Controller & Administration computers – software and hardware
  - Communications
  - Radar
  - Facilities – instrumentation van and support trailer
  - Spare Parts
  - Safety
  - Code 250 – New GPR 1850.2A compliance
- Results
  - Completed task within 6 months, according to schedule, on time
  - TLRS-4 / Moblas-7 mean system bias 1.07 millimeters far exceeding requirement
- System Is Operational