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Engineering Changes to The NASA SLR Network to Overcome Obsoleteness, Improve Performance and Reliability

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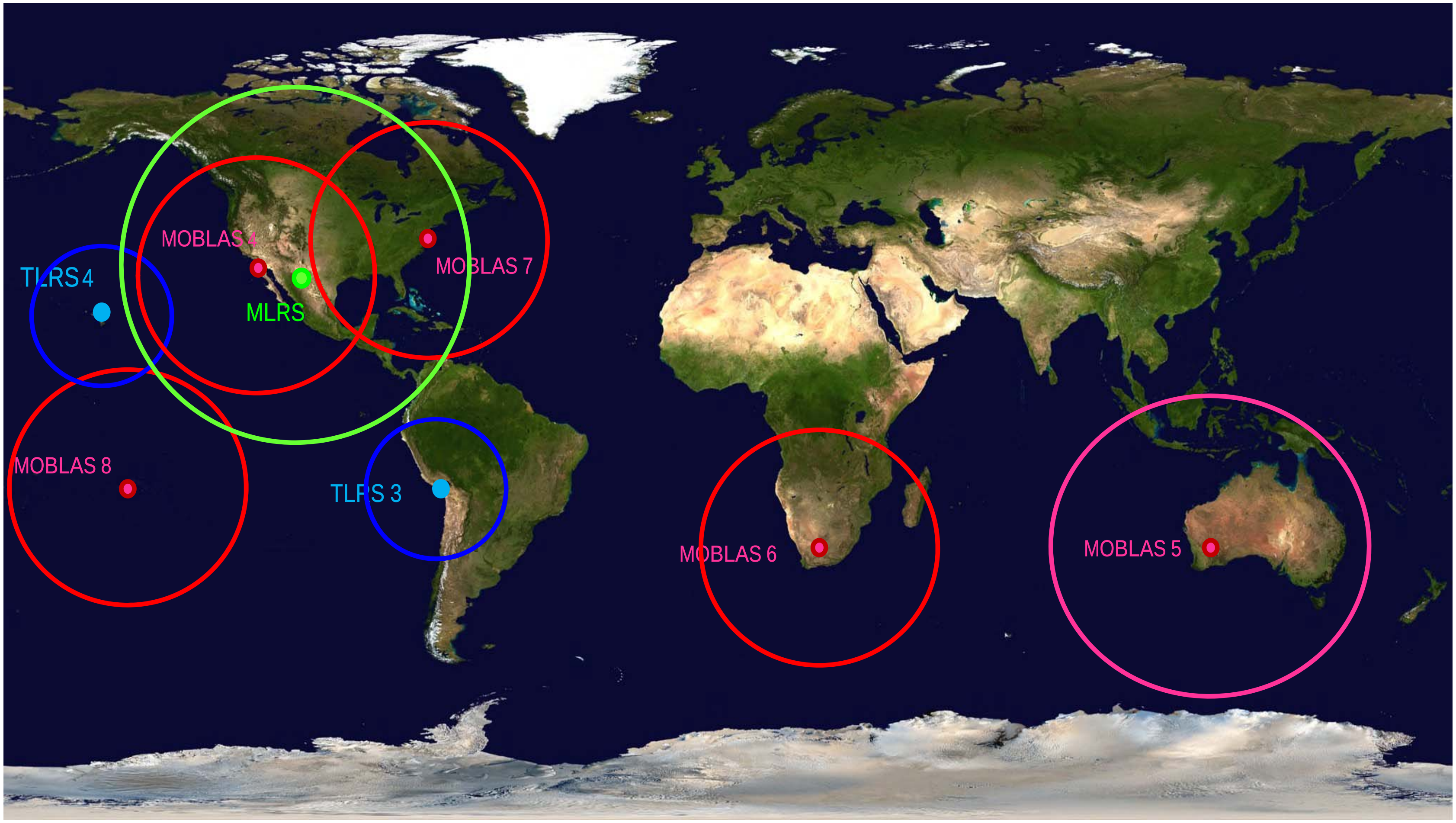
NASA SLR – Network of 8 Stations, 3 Types

1. Moblas 4 – Monument Peak, CA, USA
2. Moblas 5 – Yarragadee, Australia
3. Moblas 6 – Harteebeesthoek, South Africa
4. Moblas 7 – Greenbelt, MD, USA
5. Moblas 8 – Tahiti, French Polynesia

1. TLRS 3 – Arequipa, Peru
2. TLRS 4 – Haleakala, Maui, USA

1. MLRS – Fort Davis, TX, USA

NASA SLR – Site locations + Current Upper bound of Ranging

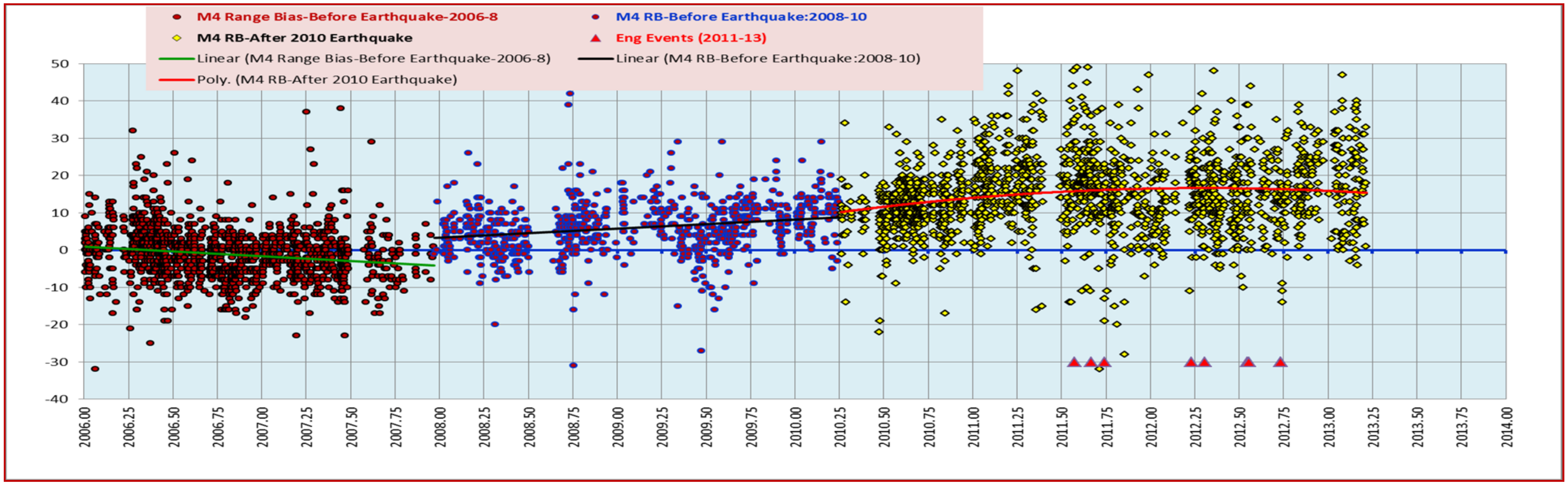


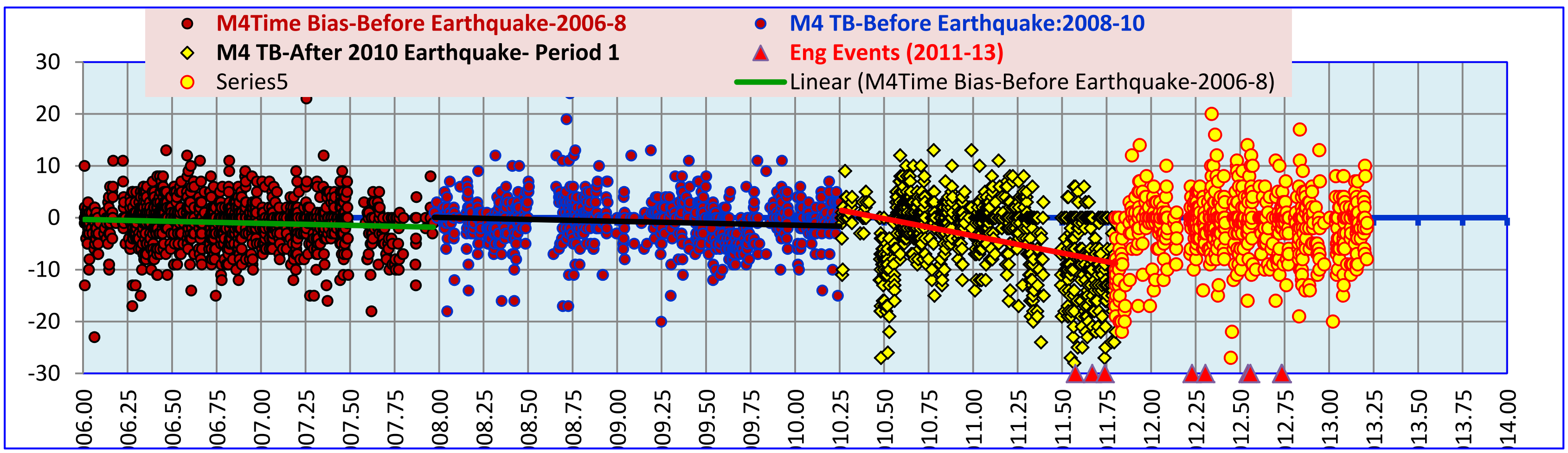
Lageos | HEO | GEO | Moon

NASA SLR – Network (Eng, Data) Analysis

- Scope Engineering Sustainability Issues
  1. Degree of Obsoleteness;
  2. Complexity of changing hardware, software (including remote locations);
  3. System Down-time;
  4. Cost of Material and Labor;
  5. HW, SW Standardization;
  6. Timing of technology / subsystem changes;
- Understand/ Establish Station Data Performance (in particular Range Bias)
  1. Work with Analysts to understand Range Bias of each NASA station;
  2. Establish what is station unique vs. outside of the station;
- Understanding the Risk Profile
  1. Completed NASA Risk chart;
  2. Near Term Objective: Lower Network (Operations + Performance) Risks

M4 - Multi year RB, TB Trends Analysis





NASA SLR – Engineering Overview

- MLRS built in 1960s; Moblas 4-8 built in the late 1970s; TLRS built in the mid 1980s;
- Over the years through the 1990s, significant Improvements were made to the various subsystems to maintain the best SLR performance;
- Only modest improvements/ replacements were performed since then, which has placed the network in a precarious position for maintainability/ sustainability;
- There are subsystems that were maintained over the years with great difficulty and now have come to the point of extreme difficulty to sustain;
- Modern/newer systems have a much shorter lifecycle than the older hardware (and hence software) and is often forgotten in the budgeting and planning process;

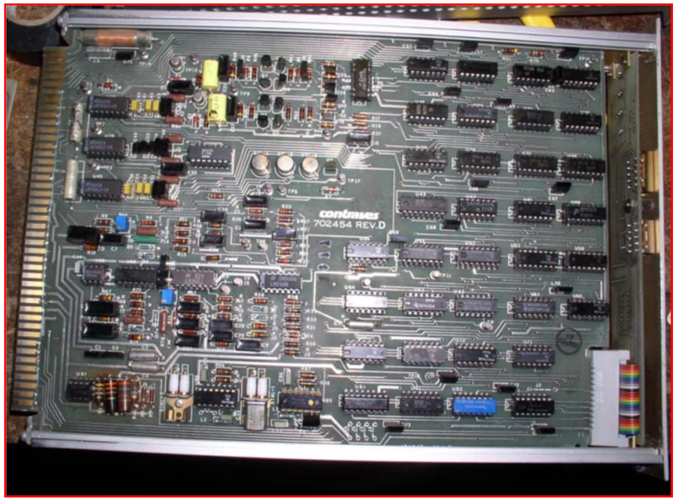
NASA SLR – Intrinsic Weakness/Risk Assessment

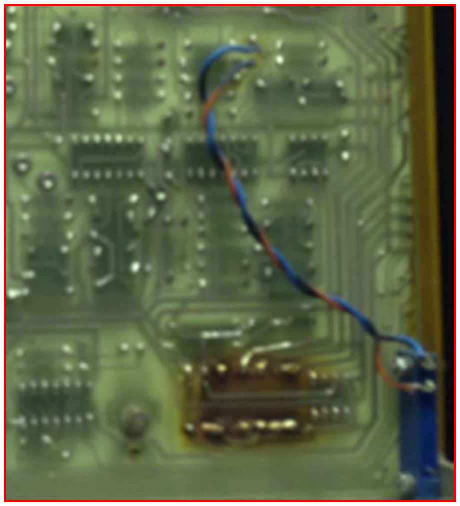
- Major areas of concern/ deficiencies
  - Servo-control & servo-Drive system
  - Slip ring assembly
  - Time of Flight Measurement
  - Time and Frequency
  - Miscellaneous electronics
  - Real-time Controller (see also MLRS poster paper)
  - Safety (see also poster paper)
- Minor areas of concern/ deficiencies
  - Laser and its subassemblies
  - Detectors

NASA SLR : OLD Servo-control systems

- Moblas Telescope servo-control system
  - Contraves MPACS, 22 bit resolution system, 1970s Vintage
  - Performed very well over the years
  - No change in technology since the 1970s (due to cost, complexity, downtime)
  - NO replacement PCBs available for the Electronics;
  - Considerable time, cost, (and travel) for caring for this old electronics
  - Previous efforts to change this either did not work / scrubbed for funding reasons
- TLRS Telescope servo-control system
  - Mostly an in-house developed servo-control system, 1980s vintage;
  - similar problems as that of Moblas

NASA SLR: OLD Servo-control – Moblas MPACS





Modular Precision Angular Control System

NASA SLR: NEW Servo-control

- Servo Control system
  - Cybi Servo-Controller;
  - 24+ bit resolution;
  - Sub-arcsec RMS at sidereal rates; arcsec at higher rates;
  - High Quality Surface Mount Electronics to support Inductosyn, Resolver Encoders;
  - Modular maintenance strategy;
- Applicability
  - Moblas or TLRS or any other telescope;
  - <u>2 Moblas to be upgraded initially; M7 to be followed by TBD;</u>

NASA SLR – OLD Servo-Drives

- Telescope AZ, EL servo-drives
  - Contraves, 1970s Vintage;
  - High average power linear amplifiers;
  - NO replacement PCBs available;
  - Recently found high power transistors capable of replacements of the old ones after significant amount of trials;
  - circuit changes needed to rectify the new characteristics;
  - still interface board level reliability and availability issues remain;

NASA SLR – SERVO DRIVES: OLD vs. NEW

Contraves Linear Amplifier

OLD UNIT

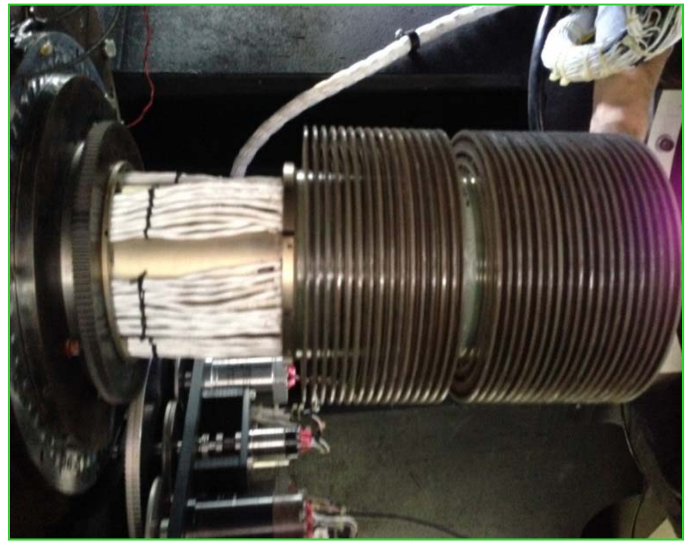
Cybioms Linear Amplifier

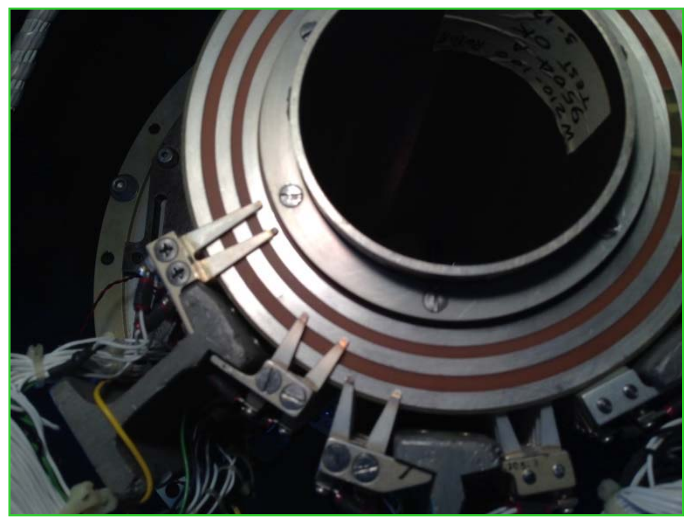
NEW UNIT

NASA SLR – OLD Slip Ring

- Slip ring, AZ & EL;
  - Manufacturer: Wendon, 1970s vintage;
  - AZ, EL slip rings transfer signals from a moving frame to a static frame and vice versa; 210 circuits, of which only 70 are used;
  - Brush blocks in contact with a platen provide the ohmic contact:
  - wear and tear leads to large ohmic differences and causes signal glitch /drop;
  - Telescope pointing problems as a result
  - High BW signals transmitted via hanging cables that move with the moving frame;

NASA SLR – Old vs. New Slip ring





M7 modification completed;

Most of the glitches seen before are gone;

NASA SLR – OLD Time of Flight (via Time Interval)

- Time Interval Counter;
  - Manufacturer: Hewlett Packard HP 5370 of 1980s vintage;
  - 20 ps resolution; ~20ps single shot RMS;
  - For Lageos 2 lab measurement, a stack of 5 specially selected, optically calibrated, and optimized TIUs provided sub-mm stability and accuracy (short measurements);
  - Data transfer time: >50ms restricts Lageos to 5 Hz, HEO to 4 Hz and GEO to 2Hz;
  - Performs well, but Obsolete

NASA SLR – Time of Flight via Event Timer

- NEW Event Timer
  - Manufacturer: Cybioms
  - 1 ps resolution; ~2 ps single shot RMS;
  - Initial Deployment in M7 concurrently with HP5370;
  - Proven performance based migration to Station Operations;
  - Deployment in MOBLAS & TLRS: 1-6 months

NASA SLR – OLD Time and Frequency Standards

– XL-DC GPS disciplined Rb:: Timing & Frequency Outputs

- manufactured by True Time (now Symmetricom),
- Performs well, but Obsolete - No longer manufactured by Symmetricom

– TCG: Timing Outputs ONLY

- manufactured by Trak Systems
- Generation of timing signals from 10 MHz by alternate approaches required;
- 4 Hz, 5 Hz, 10Hz, and 20 Hz needed for station firing, interrupts, gates;

– Distribution Amplifier: Frequency Outputs ONLY

- Can be consolidation into the clock;
- Old and Obsolete

NASA SLR – Old T&F standards

XL-DC GPS disciplined Rb

Time Code Generator

Distribution Amplifier

NASA SLR – New T&F standards

– Xli GPS disciplined Rb: Timing & Frequency Outputs

- manufactured by Symmetricom,
- Better than 30ns RMS accuracy to UTC;
- Better than 10^{-12} frequency accuracy;
- Consolidation of additional timing functions into Xli;
- 10Hz, and 20 Hz needed for station firing, interrupts;
- Preliminary maser comparison performed in the SLR lab

NASA SLR - Radar Modifications

- Refurbished + modified the network radar to a standard configuration;
- Added several new tests to strengthen the system testing and validation
- New tests to monitor radar false alarm;
- Maintaining reduced modes of operation
- Effort to enhance the safety awareness and reliability;

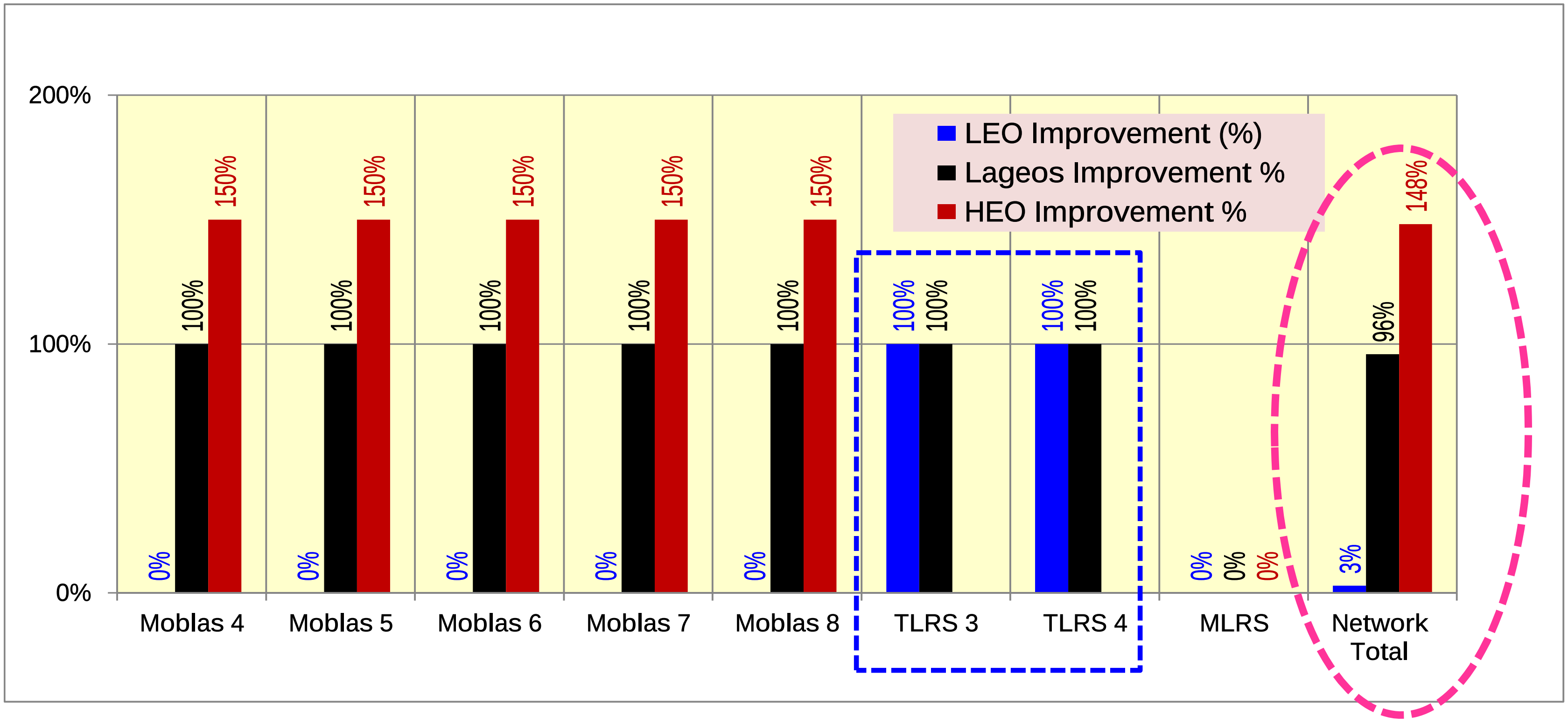
NASA SLR - TLRS Modifications

- Remove the mount wobble with a Cybioms enhanced motor casing assembly design; T4 replacement completed; T3 to be completed;
- Replace the mount operator with a combination of Camera + ADS-B RECEIVER for aircraft monitoring;
- Replace the rotating Obsolete TR switch with a static one, which will also improve PRF from 5 Hz to 10Hz for all satellites;
- Replace TIU with Event Timer;

NASA SLR – MLRS Modifications

- Laser Modifications; lab work completed for a 150 mJ (532nm) laser
- Radar Refurbishment;
- Laser and Radar changes to happen simultaneously;
- High sensitivity Optical camera;
- Real-time Controller (Randy Ricklefs has completed this already; see poster paper in this conference)

NASA SLR- Projected improvements to Data Quantity/Quality



- With the ET deployment, the network as a whole will transition to 10 Hz Operation on ALL satellites; Laser can be optimized best for the 10Hz operation;
- This will improve the Data Quantity in the NPT as well as the Data Quality of the Normal point;
- Quality of the NPT (Precision and Range Bias) will be further enhanced by the use of the ET;

NASA SLR: Modifications & Improvements Summary

1. Network sustainability → Increase station availability to perform SLR
2. Enhanced reliability and stability → Continuous flow of Data;
3. Improved Data Performance – Data Quality (Precision & Accuracy) and Quantity
4. Reduced cost of operation → Reduced Sustaining engineering, Logistics, Travel