Upgraded Servo-control system for Matera 1.5 meter telescope

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Abstract

An upgraded state of the art servo-control system, to replace the original Contraves Telescope control system for the ASI MLRO telescope, was completed by Cybioms Corporation with support from e-GEOS in March 2016..This system uses state of the art digital electronics, servo-control hardware, and control software to perform SLR (from LEO to GEO) and LLR. The command is performed by the existing MLRO HP-RT machine writing the real-time commands to its IEEE 488 GPIB ports supporting the AZ and EL axes at a rate of 10Hz and receiving the observed data at the same rate for the GUI needs of station operations. A separate servo-control computer receives the GPIB commands to drive the new servo-electronics in real-time. The tracking system currently provides the capability to point, acquire, and track satellites that has high orbit accuracy with a laser beam divergence of a few arcseconds, better than the previous controller. Data rate is improved above all for Lageos and HEO satellites. Results are highlighted in the poster.

MLRO: Scope of Applications

1. Laser ranging of ILRS and other Satellite
   1. LEO
   2. Lageos
   3. HEO
   4. GEO
2. Lunar laser Ranging
   1. Apollo 11
   2. Apollo 14
   3. Apollo 15
3. Other Astronomical / Optical /Electro-optical Experiments

MLRO: System Upgrade Requirements

1. Implement a switchable servo-configuration from the prior configuration to the new configuration
2. Ensure that the SW and HW has the capability to handle large range of angular velocities (0.1-6000 mdeg/sec) encountered in tracking LEO to LLR;
3. Receive real-time commands from the Controller and act upon it every frame of 100ms;
4. Send data back to the real-time controller upon request to support the GUI operations; these commands are variable and are not repeated every frame.
5. Support handheld operations for any manual activities;
6. Support 1 arcsec laser beam divergence operations;
7. Perform all prior MLRO operations to meet or exceed performance;

MLRO: Prior Telescope Servo-Configuration

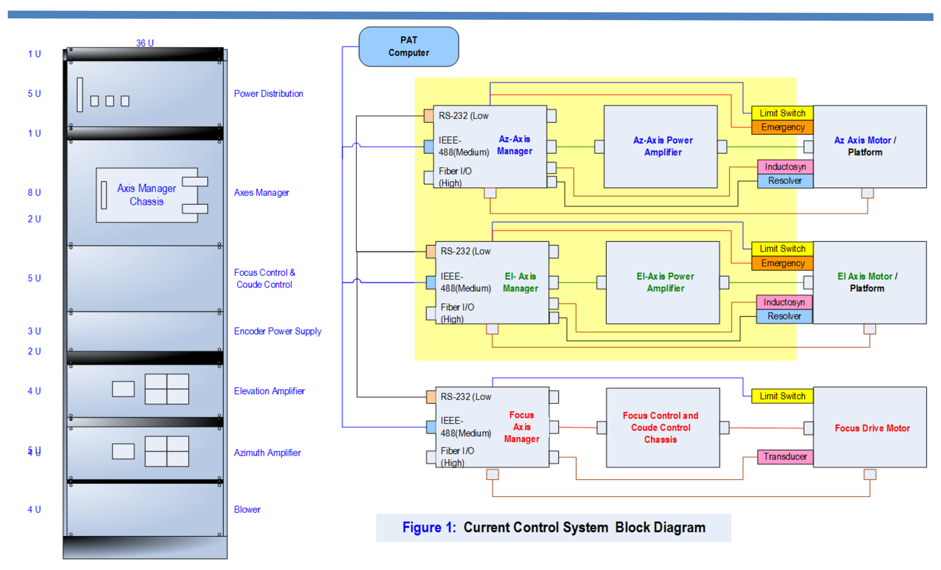
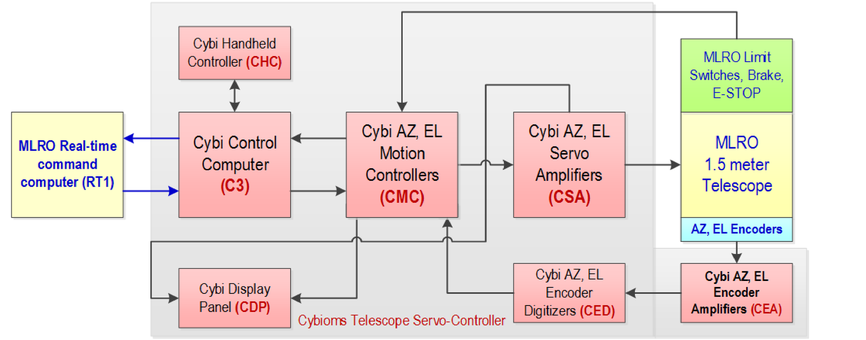


Figure 1: Current Control System Block Diagram

MLRO: New Configuration



1. Modern state of the art modular servo-controller is incorporated to address the needs of MLRO; shaded region shows the new controller.
2. The system uses: (1) the MLRO real-time computer and its GPIB, (2) telescope interfaces such as Limit switches, E-STOP, (3) encoders like the Inductosyn and resolver, as well as the (4) LAN to complete the seamless integration with the overall system;

MLRO: Telescope Servo-Controller

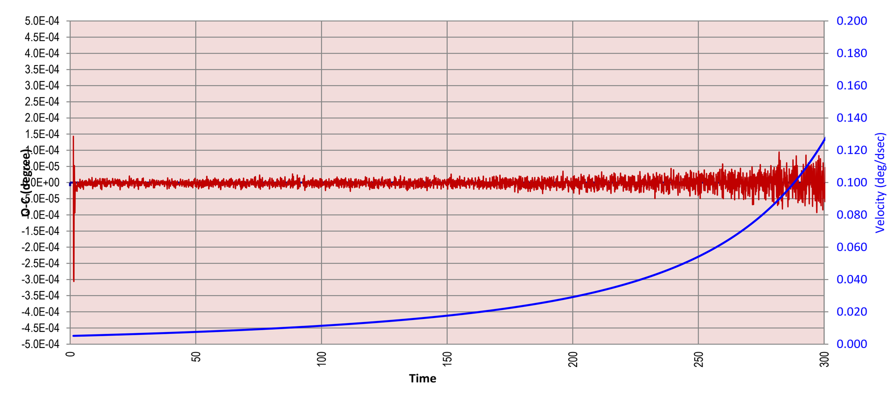
MLRO: HW/SW issues encountered

1. Servo Technology: Manufactured during 1996-98; servo electronics became obsolete;
2. Digital Interface: IEEE 488 migrated to higher versions; absence of product level support even from a reputed US manufacturer like the National Instruments; GPIB incompatibility between the old and new implementations;
3. Real-time HP computers (HP-RT): HP dropped support 20 years ago; increasing the scope of a task is extremely difficult;
4. Insufficient bandwidth: low bandwidth (10Mbps) TCP/IP to interconnect the various computers;
5. Real-time SW: Customized software uniquely matched the 4 HP-RT machines with the Contraves servo system and the existing SLR tasks; utilization efficiency of the CPU was very high (>90%); SW tasks consumed significant CPU time, thus inhibiting the addition of other features or causing interruptions;

MLRO: Lessons learned

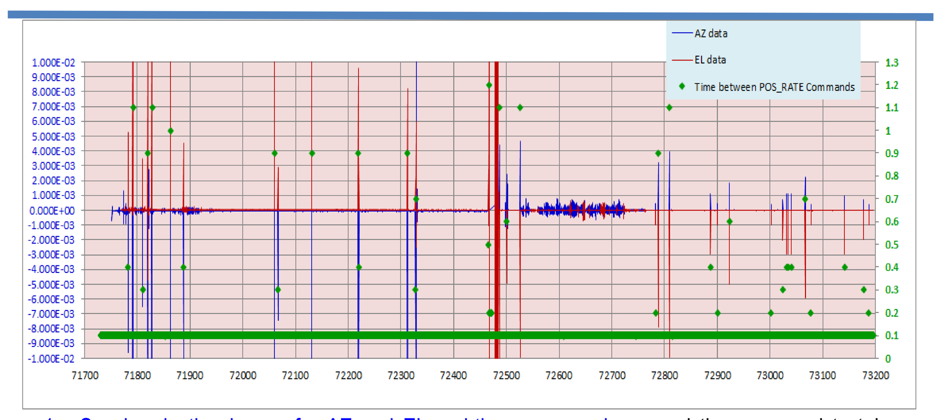
1. Any upgrade strategy, is largely guided by the technical and operational constraints of the existing system unless it is a very simple part or module; this is particularly true of SW
2. Even in a world of modular SW, the aftershocks of SW changes, in a HW-SW based configuration, are often felt in many areas for a long time;
3. Even when direct knowledge of a system exists, the issues are often more complex and intertwined than what is seen from the periphery;
4. Upgrades are often oversimplified.
5. It is always a collaborative team effort with the customer and their support staff to make it happen;

MLRO: Tracking Simulation



1. Each Division is 5E-5 degree → 0.18 arcsec;
2. 1 sigma for tracking at low angular rates <100 mdeg/sec) is <20 milliarcsecs, limited primarily by the encoder hardware

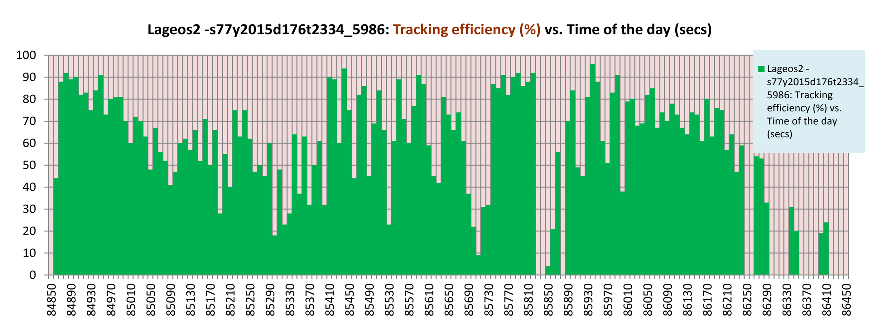
MLRO: Real-time tracking issues to overcome



1. Synchronization issues for AZ and EL real-time commands caused the command to take more than the expected 100ms update rate or failed to deliver the command until much later (see the secondary axis and the green dots) causing command latencies across the GPIB interface and perturbing the AZ, EL pointing and losing the track;
2. Code had to be optimized just right for reducing the above latencies.

MLRO: Early issues for Satellite Tracking

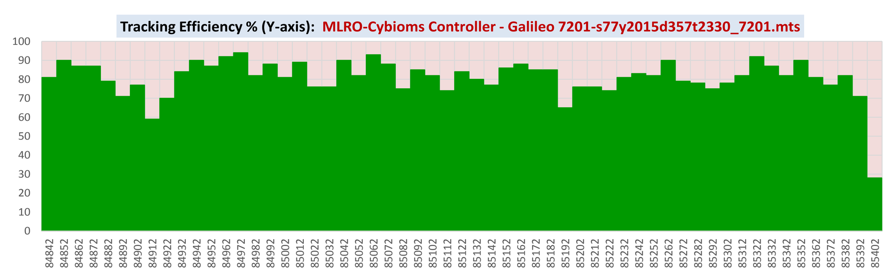
Missing data due to real-time command synchronization issues



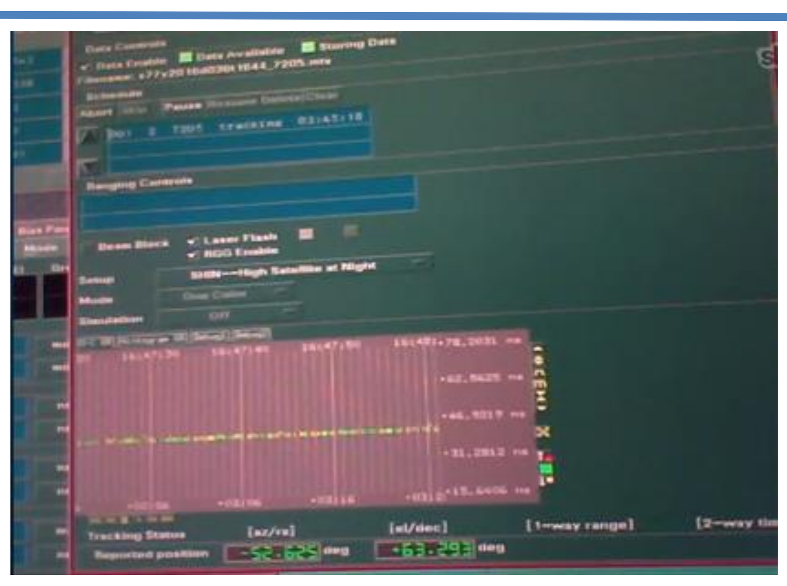
1. Missing commands manifested as "Gaps" OR reduced RX rates causing loss of data;
2. These problems were solved subsequently to achieve consistent tracking;

MLRO: Improved Tracking Efficiency (%)

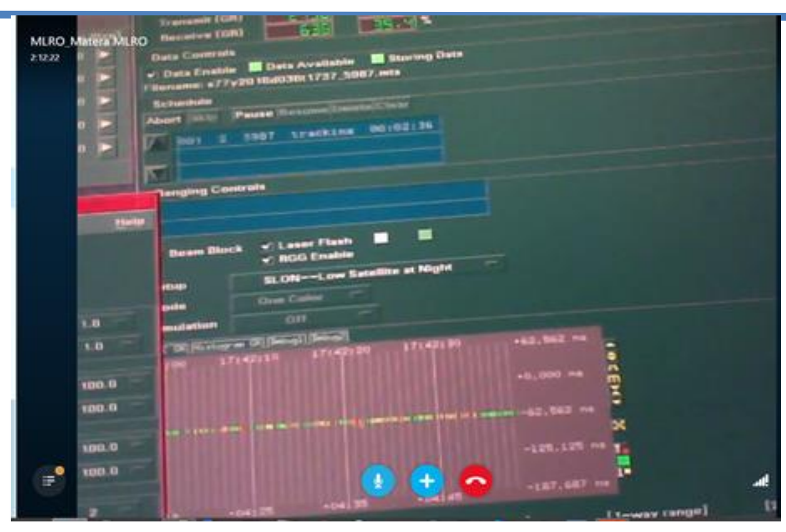
1. System tracking capability for Galileo 7201;
2. each horizontal division is 10 seconds
3. Laser fires at 10Hz and in a 10 second time bin, we have 100 laser fires;
4. Number of data points in each RX bin represents the % of tracking efficiency;
5. Tracking efficiency >90% achieved for laser BD = 1arcsec on Galileo



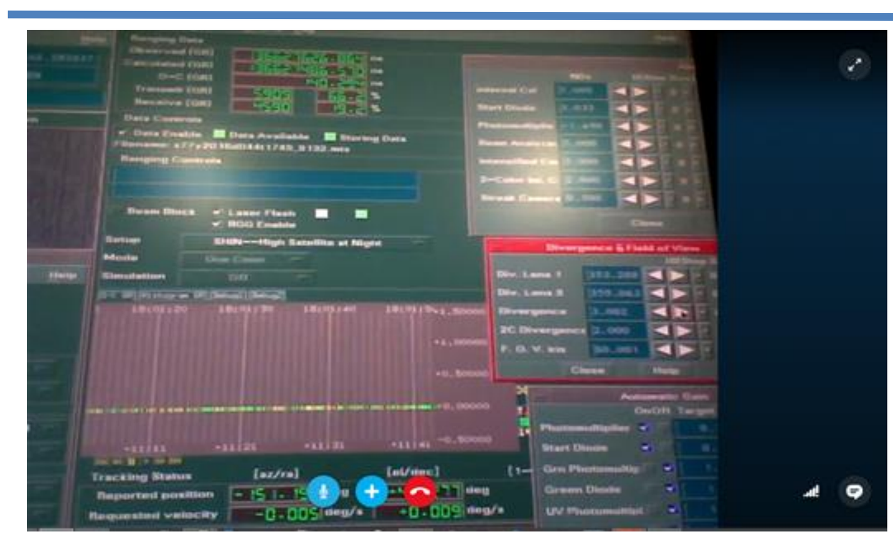
MLRO: Galileo Tracking



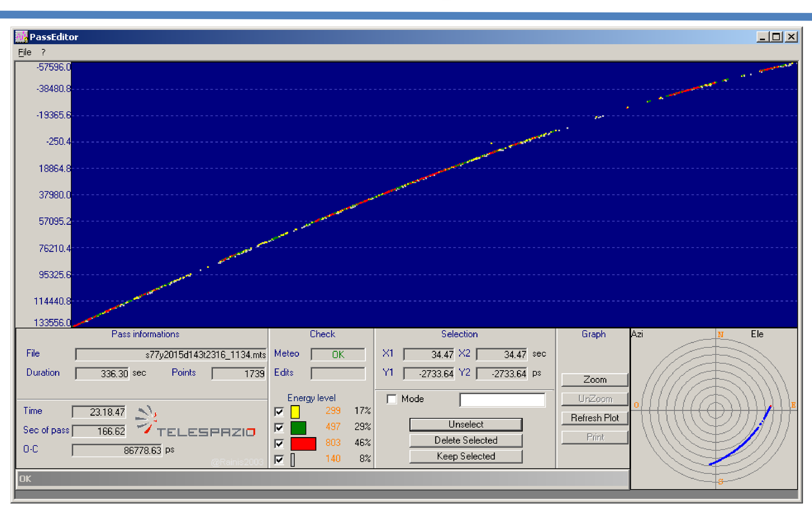
MLRO: Lares Tracking



MLRO: Glonass Tracking



MLRO: Tracking Starlette



Summary

1. Tracking resolution (0.05 arcsec) and RMS jitter (as low as 10-20 milliarcsec) were obtained, which is better than the previous controller;
2. 1 arcsec laser BD was exploited without any loss of data for tracking HEO satellites, which points to the stable tracking capability of the HW& SW;
3. Lageos tracking was successfully tried with 2 arcsec, even though there is NO link related need for that orbit for a 1.5 meter system;
4. A quickly switchable (<15 minutes) configuration with the prior controller was established to support dual modes;
5. Minimal OR no changes were made to the existing GUI allowing ease of every day operations;
6. Secure remote connections from USA to the MLRO network supported most of the SW developmental testing and tracking, which helped enormously;
7. The technical and operational support provided by the MLRO team was superb and Cybioms extends its gratitude to such a fine team.