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

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Abstract

Over the decades of its existence, the NASA SLR network has provided excellent laser ranging data to ITRF as core-sites. In addition, these globally distributed stations have contributed significantly to altimetry, GNSS POD support, and extra-terrestrial transponder measurements. Obsolescence of hardware technologies is a continuing problem with its consequent engineering difficulty to maintain adequate spares required for a reliable and sustainable SLR network,. This has prompted an effort to replace, refurbish, and revamp the station engineering for continuity of operations, improved safety, and ranging accuracy required of core stations. This paper describes the context, challenges, and the technical effort currently in progress, in pursuit of these near term improvement goals.

Introduction

The current NASA SLR network consists of the MOBLAS 4-8, TLRS 3-4, and MLRS. The MOBLAS 4-8 started deployment for field operations in the late seventies, while the TLRS 3-4 started field operations in the late eighties. MLRS deployment dates back to the late 1960s. In the early years, MOBLAS and TLRS operated with greater mobility in different parts of the world and in some cases (TLRS) even performed short campaigns of 3 months. Eventually, with the changes in the geodynamic scope of SLR, these stations transitioned to become part of a fixed, but globally deployed network. Today, the NASA stations are distributed in North America, Hawaii, Tahiti, South Africa, and Australia, as shown in **Figure 1**. The strong southern hemisphere as well as North America through Hawaii coverage has become the hallmark of NASA SLR Network deployment and operations. Today, these stations support laser ranging to LEO, Lageos, HEO, and GEO satellites depending on the location and the intrinsic capability of the system. These globally distributed stations through their role as core stations have been making fundamental contributions to the ITRF, POD for altimetry, and support of extra-terrestrial transponder ranging activities like the LRO-LR.

Over the years and through the 1990s, NASA has improved some of the SLR technologies deployed in MOBLAS and TLRS to maintain a sustainable state of the art engineering and operational configuration for geodetic measurement. Subsequently, the pace of the required engineering changes slowed down due to the anticipated deployment of NASA's next generation millimeter accuracy SLR Network. Today, the MOBLAS and TLRS have certain obsolete technologies that are extremely hard to be sustained and any further deterioration may bring these stations to the brink of a shut down or long term down time.

As part of a NASA contract transition, an engineering plan was conceived, during the mid-2011 time frame, to make the network sustainable for a minimum period of 5 years by replacing obsolete technologies, some of which were deployed 35+ years ago. With the active participation of the international scientific community, NASA has planned a next generation Space Geodesy deployment Program. However, the need exists for the current operational network to continue to support the ITRF during the evolution and deployment of the Next generation NASA SLR stations. The current operational network should continue to support the Space geodesy measurement efforts, as long as it is necessary, by providing an operationally sustainable robust network at the desired level of data accuracy and reliability.

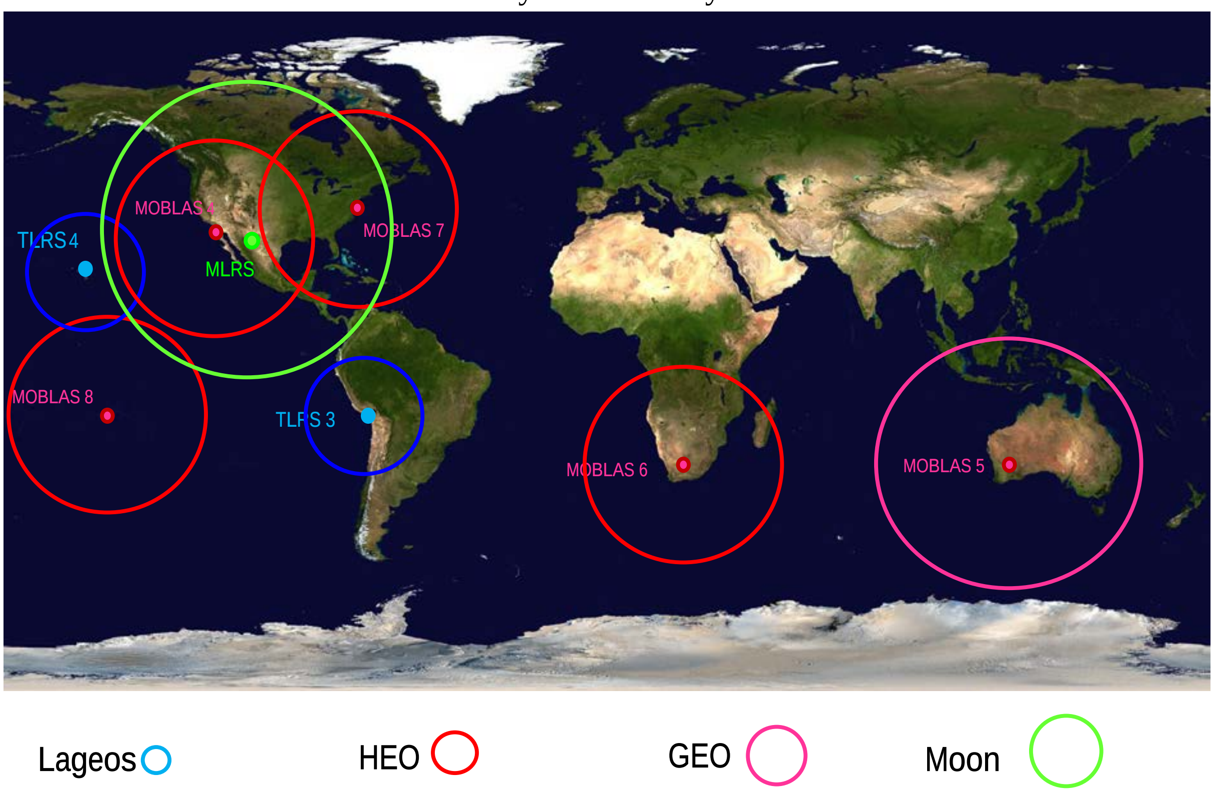

Figure 1: NASA SLR Network's global placement and the Upper bound of satellite coverage

State of the Network Engineering

As stated earlier, a detailed analysis of the Network engineering was conducted upon the contract transition from the NASA NENS to SCNS. This included the standard NASA risk analysis and classifying areas that need the highest level of attention for engineering changes. Each of the SLR subsystems was examined closely to assess the state of health, technology obsolescence, and the risk that it posed. From the risk analysis, it was inferred that the following areas need the highest level of attention amongst the MOBLAS subsystems, viz., Contraves Telescope Servo-controller, Radar, True Time (Symmetricom) Time and frequency standard, and the HP Time Interval Counter. Each of these major subsystems/ modules has been operating for the last 20-35 years, and in many cases well exceeding the device/ instrumentation projected life time. These hardware systems have performed extremely well over the years and have reached the end of life. In each of these cases, engineering sustainability is a significant problem further exacerbated by the globally distributed network topology.

As available working spares dwindled, original electronic components became unavailable, replacements had to be found and in some cases, design changes have to be made. The electronic components could not be replaced on the circuit board. Despite this precarious situation, particular attention was paid to ensure that all critical hardware used in the time of flight measurement and hence range measurement were calibrated and maintained as part of the standard operations procedure. The need for greater standardization in the network and better documented and controlled procedures were recognized as critical success factors for maintaining the ranging accuracy and reduced systematic biases.

State of the Network Data Performance

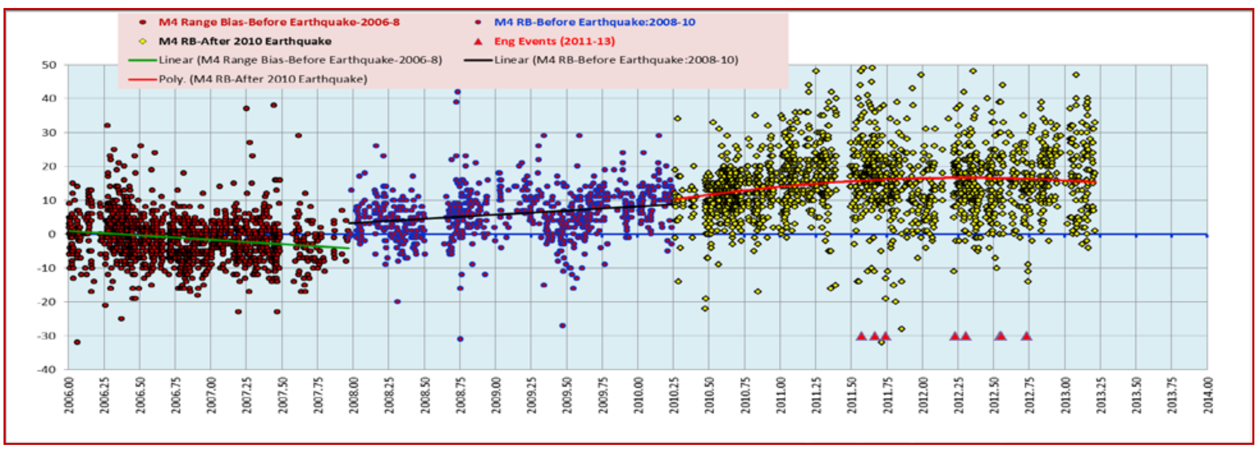

Figure 2: MOBLAS 4 Multi-year Range bias as seen from Quick look analysis

Individual SLR station Data Performance is another area of critical importance that was also studied and monitored on a quarterly basis. Sometimes, there are systematic signatures in the data for short term (quarterly) and long term (multi-year) analysis as shown in Figure 2. Special engineering effort was expended to understand the nature of the problem and its signature. In particular, the stability of observations over short and long time periods are examined by working closely with the analysis centers like JCET, Hitosubashi University, and CSR. Often, special engineering tests as well as hardware replacements are done in an effort to decouple the station engineering problem from that of any geophysical or site dependent seasonal effects or survey related issues. Figure 2 shows a MOBLAS 4 range bias observation as seen from the multi-year residual analysis. Biases of such data are trended for various periods and patterns in the data are examined for any instrument related or observation limited issues. This is particularly critical for core NASA SLR sites used in ITRF. Often, GPS data from the same site is also used to provide a comparison to further understand the geophysical signatures, if any, in an effort to constrain the problem. This continuing collaborative effort with the analysis community has proven to be extremely valuable for maintaining the operational data quality required of the NASA SLR network.

Engineering Analysis of the Major Subsystems

The Contraves servo-control system has been in operations for over 35 years in MOBLAS 4-8. This indeed is one of the hardest subsystems to sustain as no spare boards or original components exist. All of the printed circuit boards have been overworked from years of maintenance and the traces do lift off leaving no ability to solder parts other than using jumper cables. As a result, determinism that is needed for solving engineering problems does not exist leaving much to speculation and performance inconsistencies. All of these have an adverse effect on the cost and time taken for sustaining engineering as well as stability of performance.

The time interval unit (TIU), HP 5370B, is quite old and is in the class of 30 year old technologies. HP abandoned the product in the late nineties. Furthermore, the 10 Hz data capacity is compromised when tracking satellites with ranges greater than 40 milliseconds due to the instrument constraint of data settling prior to the GPIB based data acquisition. The TIU is restrictive for operating at 10Hz even for Lageos ranges and naturally for ranges above 100ms (thus applies to HEO and GEO satellites). Lageos can only be operated at 5Hz, HEO at 4Hz, and GEO at 2Hz, thus significantly compromising the 10Hz capability of the station. The age of the electronics as well as the significant loss of data due to instrument limitations makes it a candidate for immediate change.

Attention to Radar and hence the safety subsystem (LHRS) was particularly critical as the radar transceiver performance degraded due to usage and old age leading to significant increase in false alarm rates inhibiting laser operations with ensuing reduced data collection. The evolution of the radar engineering in the network also resulted in disparate electronics modules supporting the radar. To maintain the integrity as well as the reliability of the safety subsystem, it was mandatory that necessary refurbishment be done to safeguard the integrity of safe operations.

The slip rings (Azimuth, Elevation) used in the telescope mount, for transferring signals and voltages from the moving frame of the telescope to the static frame of the equipment rack, have been in operations over 20 years. These are subject to dust and debris while succumbing to the continuous wear and tear due to the frictional contacts used. Due to the encoder signals flowing through the AZ, EL sliprings, the telescope mount often glitches due to the conductance variability affecting the telescope pointing angles. In short, the ohmic measurements performed at different points along the track show a remarkable difference in value between the old and new slip rings.

The TLRS also has some of the above issues along with its own unique engineering/ technology problems. One key constraint is the Transmit-Receive Switch, which restricts the upper bound of all SLR operations to 5Hz. In addition, the motor casing assembly that encloses the servo-motor, tachometer, and the transducer for encoding has a slack in the current design, which results in the wobble of the mount. Unlike the MOBLAS or MLRS, with its radar based Laser Hazard Reduction System (LHRS), the TLRS radiation safety is managed using human observers for aircraft monitoring. This situation needs improvement as operators are expensive and the human lapse can cause potential problems.

Planned Engineering Changes and Implementation Approach

The general thrust of implementation has been cost-effectiveness coupled with seamless transition and minimum down time. In the case of the MOBLAS, the engineering changes were primarily focused on replacing the servo-controller and the time interval counter, while refurbishment was planned for the slip ring and the radar. Existing hardware from industry was chosen for all upgrades and refurbishments, while using the manpower allocated for sustaining the network carefully balanced between engineering upgrades and sustaining efforts. MOBLAS 7 is also a network engineering platform to support hardware or software testing prior to sending spares to the field stations. Therefore, it was particularly important to maintain a dual “switchable” configuration of the “old” and the new co-existing in MOBLAS 7.

As part of the cost-saving efforts for enabling engineering upgrades, all sustaining domestic and international travels were reduced drastically, compared to the historic spend profile, with a new strategy of “remote” sustainability. Adequate testing is completed *a priori* and then bench marked with MOBLAS 7 or laboratory equipment prior to dispatching to the field. This structured approach reduces the operational and data risk significantly while maintaining a highly cost-effective approach to achieving the necessary engineering changes.

The replacement hardware and software are planned to be deployed in the network through a seamless engineering to operations process without obstructing normal operations, while maintaining a very cost-effective approach backed with performance warranty. Cybioms manufactures hardware and software in the area of servo-controller and event timer, which is deployed with other international customers. The servo-control system capability includes sub-arcsec sidereal, GEO, and HEO tracking, while providing arcsec level tracking from LEO to Lageos. This capability will more than adequately support satellite laser ranging. The Event Timer, planned for network wide deployment, easily supports the 10 Hz capability of the NASA SLR network, while providing sub-millimeter range measurement. These changes, currently underway in MOBLAS 7, will be followed in other MOBLAS and TLRS, without obstructing the primary operations and with limited station downtime.

As part of the sustaining engineering effort, the Radar transceiver boards and other control electronics boards supporting the radar safety functions are being refurbished and streamlined to generate homogeneous operations and logistics support. Safety is paramount for SLR operations and now these upgrade efforts have been completed in 4 of the MOBLAS; the remaining MOBLAS 5 and MLRS will also be upgraded soon, thus completing the network wide safety enhancement. In the case of TLRS, we will also be actively seeking the use of ADSB receivers and cameras to enhance the safety posture at both TLRS 4 (Hawaii) and TLRS 3 (Arequipa).

In the case of the radar and slip ring refurbishment, we sought the help of commercial component suppliers along with internal engineering efforts to complete the refurbishment work. This refurbishment effort has vastly improved the station performance and reliability. The significant number of glitches in pointing that often stymied laser ranging in routine operations is no longer an issue. Radar false alarm rates also have fallen down dramatically, thus increasing the laser firing and data collection efficiencies. Replacement servo-hardware is now getting into MOBLAS 7 now to be followed by the Event Timer.

Observed / Anticipated Data Results

The projected data quantity increase because of the change to Event Timer is depicted in Figure 3 in RED. The ability to operate at 10Hz on all satellites by all NASA stations will significantly improve the tracking efficiencies and thus enhance both data quality and quantity. Furthermore, TLRS will also be able to reach up to the GNSS orbits at the 10Hz capability with the Event Timer and TR switch changes.

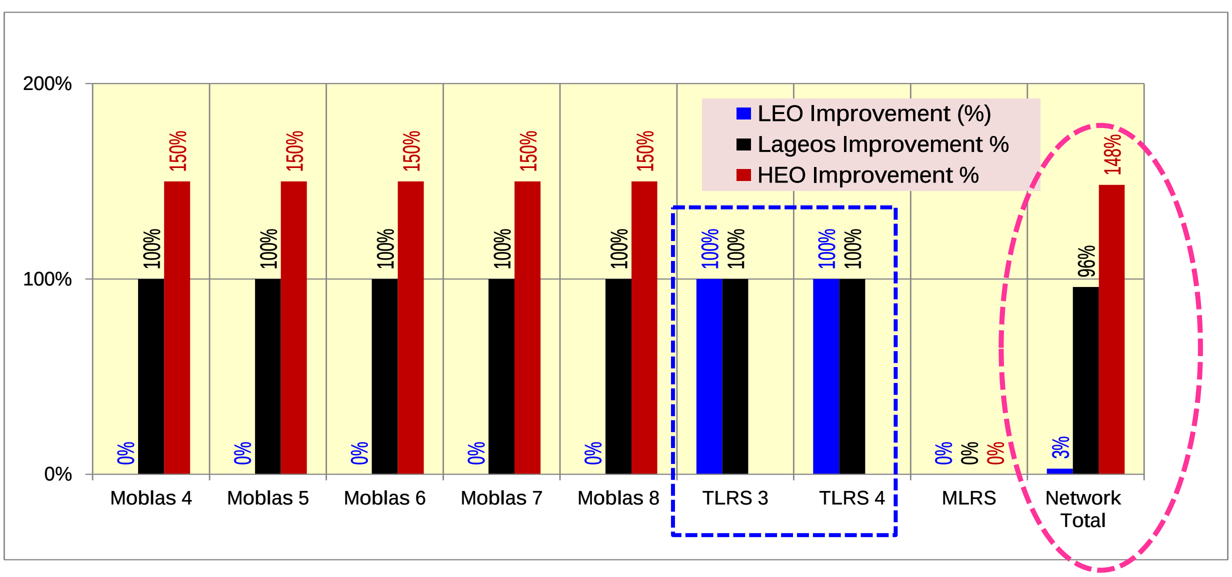

Figure 3: Projected increase in Data quantity from the change to the Event Timer

Conclusions

A cost-effective replacement and refurbishment strategy is executed in the NASA SLR Network for critical sub-systems that are on the verge of total failure so that the network can be sustained until the time of the NASA Next Generation SGP network's full-fledged operation. This change will be implemented in such a manner as to minimize the station down time by first realizing the transition in MOBLAS 7 to be followed by a replication strategy in other stations. We project the implementation of the new hardware (and software) to be completed by mid-2014, which will improve the system reliability, data quantity, and data quality.

Acknowledgement

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