PERFORMANCE IMPROVEMENTS OF TRACKING STATION AT SAN FERNANDO

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ABSTRACT

The proliferation of space debris jeopardizes the continuity of space missions and poses a serious challenge to any orbital activity. Therefore, space agencies from all over the world combine their efforts to minimize their effects and to mitigate its accumulation.

The Spanish Royal Observatory of the Navy (ROA) in San Fernando has a laser station able to perform telemetry on space objects. In order to contribute to tracking space debris ROA is carrying out a series of improvements in the station. These are aimed at optimizing the precision of its observations on smaller, passive objects.

This work aims to present a realistic solution that redesigns the guidance system to optimize the results of telemetry observations, resulting in a station hardware capable of state-of-the-art SST tracking.

This simple and proven solution is presented as an example of a feasible way to improve considerably the performance of SST observatories.

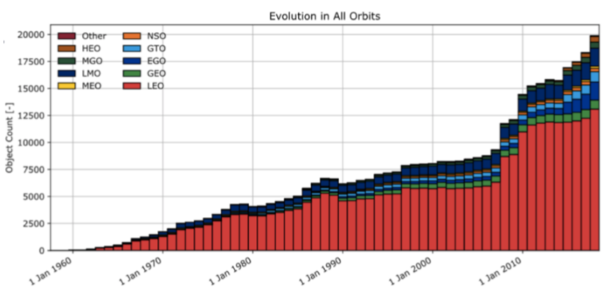

Figure 1. Evolution of Objects in Orbit (ESA Annual Space Environment Report 2018)

1 INTRODUCTION

The number of objects in orbit around Earth has been growing in the last decades. This growth has been more rapid since 2008 than before, posing a challenge to present space activity and future missions. Low Earth Orbit (LEO) is the region where more objects have been detected (see Fig. 1), the destination of an increasing number of satellites as well as the pathway to space for every mission.

Some observatories participating in SST programs (i.e. ILRS) have in the past years improved their capabilities and performances to support this risk mitigation needs.

2 THE ROA TRACKING STATION AT PRESENT

The laser tracking station is installed on an altazimuth mount, inside the dome of the main Royal Institute & Observatory of the Navy (ROA) building. This is originally a Satellite Laser Ranging (SLR) Station. Altazimuth setups are robust and are well suited for the tracking of space debris, since the relative motion of debris is much greater than the speed due to the rotation of Earth. The mount serves as support for the laser emitting components and for the optical receiving components that detect incoming photons, without the impact on performance of a Coude focus. It carries a total payload of about 100kg. The receiving subsystem is a 600 mm f/12 Cassegrain telescope. The station has been updated recently with a 3rd generation laser equipment, improving its LEO space debris tracking capabilities [1].

At present each of the rotations is enabled by a servomotor and controlled by an incremental encoder with a resolution of 1000 pulses/turn. A 200-tooth gear is used, as well as a coupling mechanism. This would provide a pointing resolution of 6.48 arcsec by pulse in each of the two rotations (see equation 1).

$$Resolution_{\text{design}} = \frac{360°}{200 \times 1000} = 6.48 \text{ arcsec / pulse} \qquad (1)$$

However, the actual resolution after 40 years of operation is found to be about 13-15 arcsec.

Wear on the screw and cogwheel has decreased pointing

Proc. 1st NEO and Debris Detection Conference, Darmstadt, Germany, 22-24 January 2019, published by the ESA Space Safety Programme Office
Ed. T. Flohrer, R. Jehn, F. Schmitz (http://neo-sst-conference.sdo.esoc.esa.int, January 2019)

performance. This leads to lags in response that the control system overcorrects, resulting in tracking errors.

3 PROPOSED IMPROVEMENT

The proposed solution includes modernizing the mount-telescope pointing system, focusing first on the mount mechanical setup and control system. It is an up to date yet proven solution for the motion of each axis. Similar solutions have been applied by AVS throughout the years in machine tooling and other science fields.

This solution employs high torque direct drive motors. These are installed alongside high precision absolute digital encoders, and they are all mounted directly on the axis. This eliminates any unwanted play or reading delays. An example of these components assembly from the machine tooling industry is shown on Fig. 2.

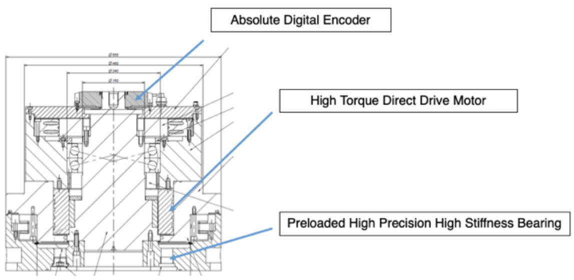

Figure 2. Direct Drive, Encoder & Bearing Application Example

Some of the advantages of these motors are the lack of vibrations or friction losses, lower maintenance and accurate lower speed motions while still capable of reaching high speeds. Reaching high speed of rotation is necessary in the case of LEO tracking. Direct drive technology has been chosen in other recent station upgrades. The selected bearings combine radial rollers and axial needles, for a repeatable, high precision rotation.

There are thru axle commercial components, to leave the optical path free of obstacles (See Fig. 3).

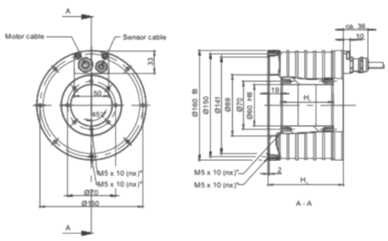

Figure 3. IDAM Drive with thru hole

A system of screw and crown gear will be used for the rotations, to ensure that there is no play between components. An example of this application by AVS can be seen in Fig. 4 for a satellite positioning system for a Ground Support System for the Indian Space Research Organization (ISRO). The crown is over 1m diameter in this case and operates under very demanding specifications.

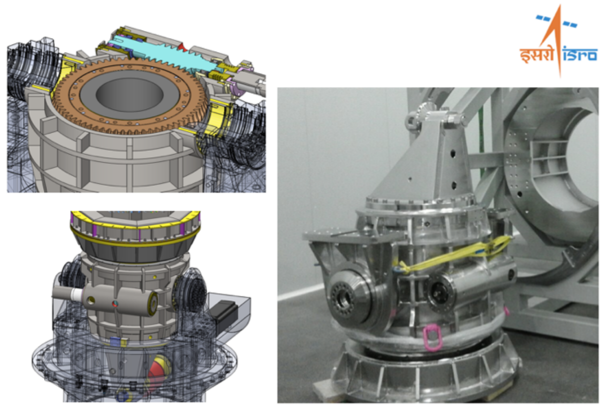

Figure 4. Satellite Positioning System

The proposal includes an improvement of the control system, set in three phases. The first phase applies to the motor motion control, the second applies to the main control system, and the third is the user interface.

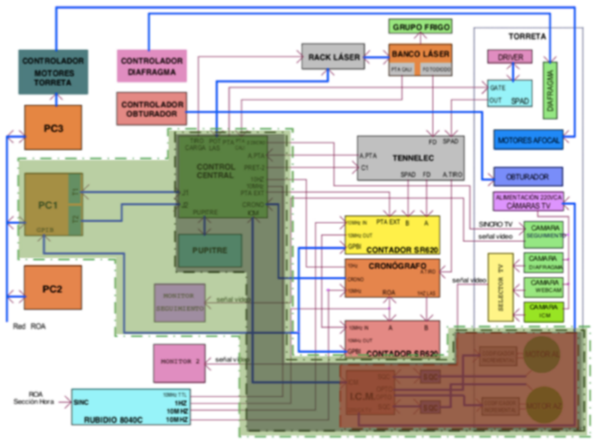

Figure 5. Areas of Improvement of Control System

The first phase (shown in red in Fig. 5) includes an update of the Motor Control Interface and the encoders. This enables closing the control loop in the power phase, allowing more precise rotations and eliminating over-corrections. It would also simplify operations by removing the need to carry out homing procedures, since the encoders are absolute.

The second phase would entail using a PLC and an EtherCAT network, to enable real time processing and recording of parameters and ease future software updates.

Real-time processing opens the possibility of automatically updating the tracking of orbits if the object is not following the expected path. Reliable recording of elevation and azimuth with precise timing opens up possibilities for orbit computations, since it provides key data to improve models [2]. This second phase is shown as a black dotted line on Fig. 5.

Using direct drive motors, the pointing error is defined by the limitations of the encoders and the rigidity of the mount. The encoders have a specified resolution of ±1.11 arcsec in each axis, giving a combined error of ±1.21 arcsec, for a maximum of 2.42 arcsec. This is equal to 8.7 millidegrees, achieving state of the art pointing performance.

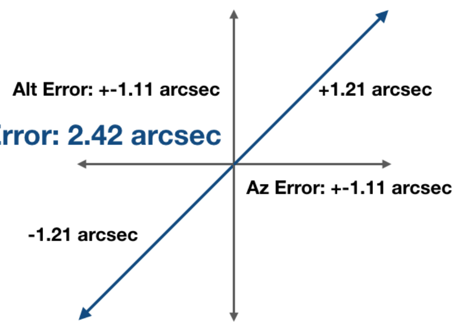

Figure 6. Pointing error of the resultant system

Tab. 1 shows the offset suffered in the pointing depending on the resolution achieved by the tracking system, and the orbit height. In particular, the row in red shows the present status, whereas the row in green shows the proposed performance.

Table 1. Error at Different LEO heights – Actual versus Proposed

		Distance to Object (km)									
	Resolution (arcsec)	200	400	600	800	1000	1200	1400	1600	1800	2000
Error (m)	0,50	0,48	0,97	1,45	1,94	2,42	2,91	3,39	3,88	4,36	4,85
	1,00	0,97	1,94	2,91	3,88	4,85	5,82	6,79	7,76	8,73	9,70
	1,50	1,45	2,91	4,36	5,82	7,27	8,73	10,18	11,64	13,09	14,54
	2,00	1,94	3,88	5,82	7,76	9,70	11,64	13,57	15,51	17,45	19,39
	2,50	2,42	4,85	7,27	9,70	12,12	14,54	16,97	19,39	21,82	24,24
	3,00	2,91	5,82	8,73	11,64	14,54	17,45	20,36	23,27	26,18	29,09
	3,50	3,39	6,79	10,18	13,57	16,97	20,36	23,76	27,15	30,54	33,94
	4,00	3,88	7,76	11,64	15,51	19,39	23,27	27,15	31,03	34,91	38,79
	4,50	4,36	8,73	13,09	17,45	21,82	26,18	30,54	34,91	39,27	43,63
	5,00	4,85	9,70	14,54	19,39	24,24	29,09	33,94	38,79	43,63	48,48
	5,50	5,33	10,67	16,00	21,33	26,66	32,00	37,33	42,66	48,00	53,33
	6,00	5,82	11,64	17,45	23,27	29,09	34,91	40,72	46,54	52,36	58,18
	6,50	6,30	12,61	18,91	25,21	31,51	37,82	44,12	50,42	56,72	63,03
	15,00	14,54	29,09	43,63	58,18	72,72	87,27	101,81	116,36	130,90	145,44

These improvements can be utilised on future technologies as well, such as Laser Momentum Transfer, which will require precise, reliable and easily controlled pointing, even for larger telescopes.

4 SUMMARY

The proposed improvements would enable the station to decrease the pointing error from about 15 arcsec to 2.42 arcsec (8.7 millidegrees) using commercial components. Further accuracy improvement is feasible using a custom system.

The solution described would also decrease maintenance by removing gears and friction, while streamlining operations by removing homing needs.

Furthermore, the control subsystem upgrade would also enable real time orbit tracking updates and recording of object azimuth and elevation to improve tracking models. Future software upgrades can be implemented easier with this control subsystem upgrade.

5 REFERENCES

1. Catalán, M. et al (2019). *San Fernando Laser Station Updates and New Improvements*. Proc. ESA NEO and Debris Detection Conference, Darmstadt, Germany

2. Bamann, C., Hugentobler, U. (2017). *Accurate Orbit Determination of Space Debris with Laser Tracking*. Proc. 7th European Conference on Space Debris, Darmstadt, Germany