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MORAL: Alt-Azimuth one meter class mount for SLR

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Abstract. *MORAL, MOunt Robotic ALt-azimuth , is a project led by N.P.C. New Production Concept S.r.l. in collaboration with the University of Rome "La Sapienza". The system is a 1 m class telescope mount conceived to offer an high quality and affordable solution for space debris monitoring having its strength in fast and precise pointing and tracking capabilities. A distance between plates of approximately 1350 mm permits to host 1 m class telescopes up to 1000 Kg weight.*
MORAL is a suitable solution for SLR thanks to the presence of a hollow structure and through hole shafts on both axes that permit the identification of multiple light paths to project laser (Coudè path configuration option).
Innovative technologies has been exploited to determine the motion units and sensors configuration to be compliant with the design drives. In parallel an important reasearch has been conducted in order to define an innovative methodology in manufacturing procedure in order to obtain the required level of accuracy on each part to be assembled.
MORAL is based on the use of first quality commercial components and manufactured parts: the result is a flexible solution with high level of modularity that permit easy customization as well as handling and inspection of each component without the need of a full disassembly of the mount: this constitutes an important feature also considering applications in harsh accessible locations.
The first prototype has been assembled within facilities of NPC and is currently undergoing testing phase.

Introduction

MORAL (MOunt Robotic ALt-azimuth) is an Alt-az mount for 1m class telescopes designed to update the state of the art introducing innovative technologies and offering a new approach in terms of performances and accessibility.
The project is led by Spacemind division of the company N.P.C. New Production Concept S.r.l. based in Italy, through a cooperation with the University of Rome "La Sapienza". Drives of the project have been defined in order to satisfy the performances required for observation of fast objects in LEO, in particular space debris, subject where Spacemind team has long time experience starting from nanosatellite systems dedicated to spacedebris removal and mitigation and also ground based equipement. MORAL mount shall therefore satisfy high performances in terms of velocity and pointing accuracy, in order to be compliant with most of ground based applications such as optical survey and laser ranging studies.
Besides the technical innovation it is important to undestand the new approach that has been at the basis of MORAL design. In fact, the first important thing to understand about this product is that MORAL is a standalone mount thought to be "universal" and compatible with different types of telescopes from different suppliers that fit in the large available clearance area (Figure 1) .

The idea is to offer a top quality platform that can be exploited by different users permitting to associate different optics with desired features. This is crucial especially in case of requirements update or application needs, permitting to install different optics for different purposes.

Figure 1. *MORAL mount in N.P.C. facilities*

To satisfy this requirement it is important to achieve a level of performances that covers all possible astronomical applications, introducing then strong technical innovations: with respect to state-of-the-art mounts MORAL exploits innovative technologies borrowed from different industrial fields of excellence.
The level of innovation permits to reach top level performances that increase the range of applications obtainable with a single mount.
As well as the technologies applied, also the design methodology is new: MORAL has been designed exploiting aerospace methods and instruments. This permitted the introduction of several improvements in the structural design which result fundamental for the quality of the measures and results obtained during operations.
In order to offer a platform that can be versatile it has been necessary to achieve a new conception of large telescope mount that can be accessible and manageable in spite of dimensions.
MORAL is thought to offer the possibility of being easily handled , as well as the possibility of being installed in many adverse environments also given the easy portability. The maintenance of the system is designed to be carried out on site without the need for removal of the entire machine. These features constitute an upgrade of the standard conception of large telescope mount that is usually fixed and designed for a specific installation.
The first prototype has been assembled and will be tested within NPC facilities and is expected to be fully operational by the end of April 2016.

Layout and design philosophy

The drive of MORAL project has been the design a multipurpose system suitable for several demanding applications in terms of pointing and tracking accuracy and high rates and accelerations on both axes.The entire design phase of the product has been carried out with a particular focus on requirements for optical observations of very fast LEO objects (e.g. space debris) and satellite laser ranging applications. A list of design drives is provided below:

- Lightweight structures
- Maximum load: 10000 N
- Contribution of electro-mechanical to overall pointing accuracy ≤ ± 1 arcsec
- 30°/s slew rate
- 360° free rotation in azimuth axis
- High torque (scalable upon requirements)
- Hollow shafts on both axes for laser applications
- Large clearance for installation of large instruments

The accurate determination of rotation axes is achieved thanks to precision bearing units and optimized mechanical design, while motion is performed by means of two servo drives controlled by a main motion controller connected to the workstation. Two high resolution absolute angle encoders permit to read the position and slew rate of the two axes. Moral can mount telescopes up to 1000 kg and 1,35 m in diameter. Through the use of slip ring technology, both axes permit 360° free rotation avoiding the problem of meridian crossing. The electrical cabinet is separated from the mount in order to offer a flexible installation according to the needs and it is designed to work at low level of voltage (230VAC) in order to be exploited also in environments with minimal resources. The complete assembly and main dimensions are provided in Figure 2, while a list of main parts is presented in Table.1.

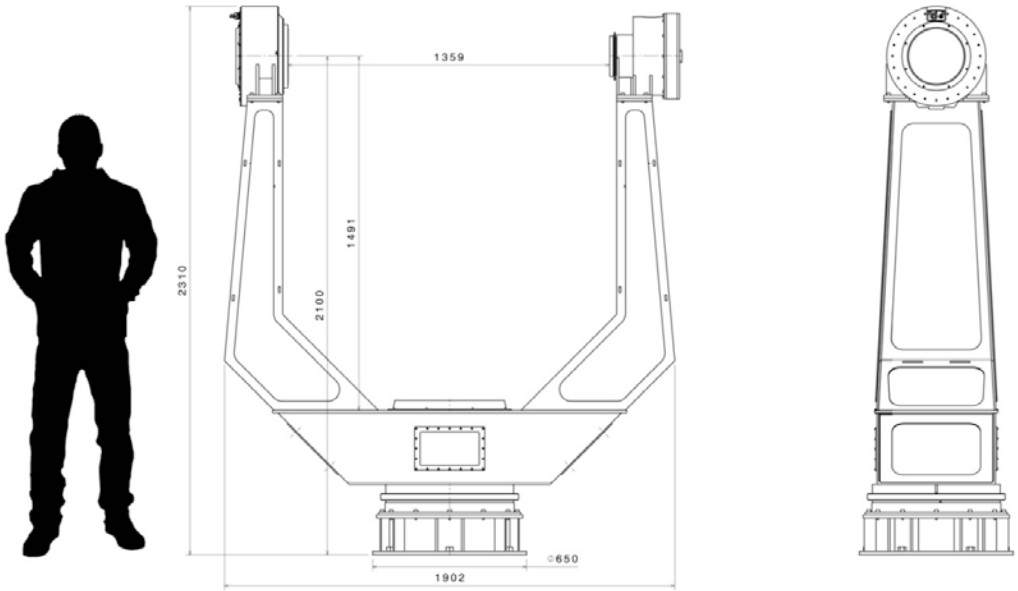

Figure 2. *MORAL main dimensions*

Table 1. MORAL main layout

Mount	Electrical cabinet	Interfaces
- Azimuth group - Elevation Motor group - Elevation Brake group - Fork	- Power Supply management unit - Controlling Joystick - Motion Control Chain - Controlling Sw and Interface	- Controlling Sw - GUI - ASCOM compatible driver - Custom available communication & pwr lines directly to EL axis

Performances

MORAL exploits direct drive motors thus eliminating transmission hardware between the motor and telecope axes. The high torque available ensures the achievement of target accelerations, for a whole range of loads. Values of maxima slew rate and accelerations are settable scaling the gains of the motors.
The system has been designed applying aerospace derived methods for structural design and optimization in order to achieve high stiffness and a lightweight structure.
As for static dimensioning a reference load of 10000 N has been considered: limited displacements and margins of safety for all loading conditions have been ensured.
First resonant frequency has resulted to be above 20 Hz considering a telescope mass of 500 kg connected to the for top plate (15 hz if considering a mass of 1000 kg).
Dimensional and geometrical tolerances havee been deeply investigated to minimize the contribution of mechanical error to final pointing accuracy.
Hollow shafts and a tubular structure along with the presence of lightening holes on the fork give maximum flexibility to perform different operations and make it suitable for a Coudè path installation.

- Multiple light paths can be identified
- The fork can be easily adapted to support additional instruments by adding custom intermediate brackets for specific application;

In nominal conditions telescope center of gravity should be placed on the Alt axis since an off-axis applied load produces an elastic rotation of bearing center: the selection of high precision, high stiffness bearing units ensures the correct positioning of axes also in case of load misalignment.
Bearing units are characterized by very low breakaway torque without “stick slip” effect ensuring the possibility of positioning micro corrections.
Concerning encoders MORAL mounts two high resolution absolute encoders that measure mount angular motion with an accuracy of ±1 arcsec.
MORAL interface has been designed to perform basic pointing and tracking operations using all ASCOM compliant commercial astrometric softwares thanks to an ASCOM base driver; moreover a GUI has been developed that allows the setting of configuration parameters (acceleration, maximum speed etc.) and the direct sending of commands to the controller. The system also presents a controlling pad that allows the direct contol of both axes (and the setting of slew rate).
Finally MORAL offers a TCP server socket: through an open communication protocol other software from any PC in the network can connect and send direct command to the mount. In fact the controller allows TCP/IP communication for remote control.
Target position of the two axes can be refreshed at a maximum frequency of 200 Hz. A resume of main features is presented in Table 2:

Table 2. MORAL mechanical features resume

		Symbol	Unit	Value
Mechanical Data	Material	s355 Steel with antirust treatment		
	Weight	W	Kg	ca 750
	Height		mm	2310
	Fork Aperture		mm	1902
	Distance between Plates	DBP	mm	1359
	Nominal Load	NLd	N	5000
	Maximum Load	MLd	N	10000
	First Frequency mode (@NLd)		Hz	23
	Protection	Protective sealing		
	Treatment	Rust protective painting		
Operational Performances	Power Supply	Vsup	VAC	230
	Maximum Torque Az (peak)	TAZ	Nm	658
	Maximum Torque El (peak)	TEL	Nm	493
	Current Peak per motor	Ip	Amp	17.5
	Operative velocity	OSR	Deg/sec	settable
	Maximum operative velocity	MSR	Deg/sec	30
	Maximum acceleration	-	Deg/sec^2	settable
	Rotation angle on azimuth	Free rotation (Uninterrupted passage through meridian)		
	Rotation angle on elevation	0 – 180° (Free rotation if required)		
	Pointing accuracy	PA	Arcsec	<2
	Minimum Alt axis braking time	tbr	millisecond	<100
	Minimum time to MSR Azimuth	tAz	millisecond	732
	Minimum time to MSR Altitude	tAlt	millisecond	714
Operational Data	Controller	Real time 2ax synchronous control		
	Software and Interface	- ASCOM Platform Driver - GUI - Controlling PAD - TCP Server socket for open comm. protocol		
	Electrical line	- Fixed power and signal lines 2A @ 24V - Custom power and signal lines (standard is 4 x 250VDC/VAC – 10A, 2 USB 1.0/2.0)		
	Operative Temperature	Top	°C	-30°÷40°
	Storage Temperature	Tst	°C	-40°÷60°

Conclusion

MORAL is an innovative telescope mount that presents outstanding features in parallel with a renovated concept of accessibility that makes it versatile and able to be exploited for multiple applications. Through an experienced process of design and control on manufacturing (Figure 3) it has been possible to reach the highest level of quality. Moreover, designs dedicated to coudè path installation have been performed in order to fulfill requirements of satellite laser ranging (Figure 4).

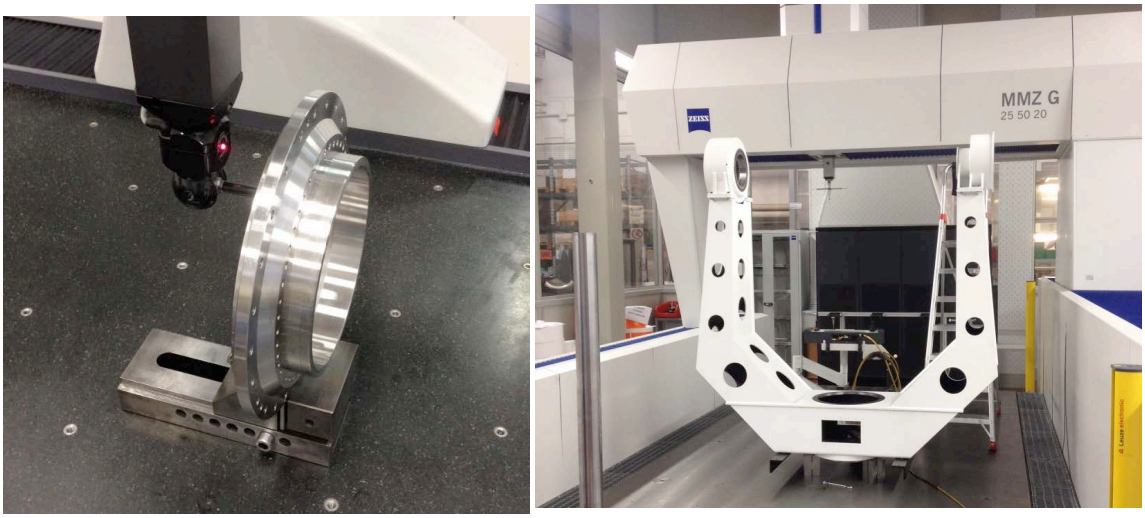

Figure 3. Components quality measures

Figure 4. Coudè Path configuration

References

Rastelli, Naldi, Valdatta, Bellini; *"Design and first prototype of an alt-az mount for 1 m class telescope for space debris tracking"*, 66th International Astronautical Congress 2015, Jerusalem, Israel, IAC-15,A6,IP,31,x30646

Locarini, Bellini, Naldi, Valdatta, Rastelli, Fullum; *"Design and first prototype of an alt-az mount for 1 m class telescope for space debris tracking",* 65th International Astronautical Congress 2014, Toronto, Canada, IAC-14-A6,7,7,x25436