Controlling design for Nasmyth focus concept for 2.1 m telescope of the OAN-SPM

Diseño del control para el concepto del foco Nasmyth para el telescopio de 2,1 m del OAN-SPM

Isaac Porras-Navarro[1], Joel H. Castro-Chacón[2], Joel Herrera-Vázquez[3], Juan Manuel Nuñez[3], Mauricio Reyes-Ruiz[3]

Porras-Navarro, I, Castro-Chacón, J.H, Herrera-Vázquez, J, Nuñez, J.M, Reyes-Ruiz, M. Controlling design for Nasmyth focus concept for 2.1 m telescope of the OAN-SPM. Tecnología en marcha. Edición especial Movilidad Estudiantil 7. Abril, 2020. Pág.65-75.

https://doi.org/10.18845/tm.v33i6.5168

1 Ingeniero. Instituto Tecnológico de Costa Rica, Mecatrónica, Costa Rica. Correo electrónico: isaacpona@gmail.com
https://orcid.org/0000-0002-9413-125X

2 CONACYT - Instituto de Astronomía, Universidad Nacional Autónoma de México, Ensenada, B.C., México.
https://orcid.org/0000-0002-2583-076X

3 Instituto de Astronomía, Universidad Nacional Autónoma de México, Ensenada, B.C., México.

Keywords

Nasmyth focus; 2.1 m telescope; tertiary mirror; OAN-SPM; 3D printing prototype.

Abstract

Telescopes has been the eyes that humans have used to discover the universe; observational astronomy had pinned out the development on technology and engineering. The Instrumentation Department of the OAN-SPM is looking for updating the main general purpose telescope. This telescope had supported investigations in many study fields, but since its construction still operating in Cassegrain configuration. The operation of Nasmyth focus is an option that will introduce the telescope to another steps on investigations. In this work we show the design of the controlling, for the first concept, that allows Nasmyth focus to operate on 2.1 m telescope of the OAN-SPM. Develop of testing for validating the controlling design and the characterization of the prototype are shown below.

Palabras clave

Foco Nasmyth; telescopio de 2.1 m; espejo terciario; OAN-SPM; prototipo impreso 3D.

Resumen

Los telescopios han sido los ojos que los humanos han usado para descubrir el universo; La astronomía observacional ha fijado un desarrollo impulsivo en la tecnología y la ingeniería. El Departamento de Instrumentación de OAN-SPM está buscando actualizar el principal telescopio de propósito general. Este telescopio había ayudado en investigaciones en muchos campos de estudio, pero desde su construcción funciona con la configuración tipo Cassegrain. La operación del foco Nasmyth es una opción que introducirá el telescopio a otros pasos en las investigaciones. En el presente trabajo mostramos el diseño del control para el primer concepto que permite que el foco Nasmyth funcione en un telescopio de 2.1 m de OAN-SPM. El desarrollo de pruebas para la validación del diseño del control y la caracterización del prototipo se muestran a continuación.

Introduction

The National Astronomical Observatory in Sierra de San Pedro Mártir (OAN-SPM) has several telescopes for general use, where the most important, because of its size, instruments and research the 2.1 m telescope (figure 1). This telescope is in operation since 1979 and since then his configuration is Ritchey-Chrétien (Cassegrain focus) [1].

Figure 1. 2.1 m telescope of OAN-SPM.

The implementation of another focus on the 2.1 m telescope, the Nasmyth focus, is proposed by OAN-SPM experts; since the structure allows its implementation. So far there is only the first concept of the mechanical design that is why it is necessary to develop a control design to validate the whole system working.

In the following pages here is an approach for the controlling. Besides there is the explanation about how the control was validated and the prototype construction using 3D printing technology.

Methodology

Because the mechanical design was given, the project is focused on designing the control and verify whether satisfy all the requirements. The steps followed to design are shown below:

A. Requirements involved within the controlling part and its movements.
B. The mechanical design was doing by the experts on OAN-SPM that is why it was necessary the get it and understand every part of it.
C. The controlling were did it to meet all the requirements and for taking care the tertiary mirror.
D. When the mechanical design was understood and all mechanical parts gotten, the prototype was fabricated by using a 3D printer.
E. Finally, the design was tested by some probes like checking the movements and the response of the control.

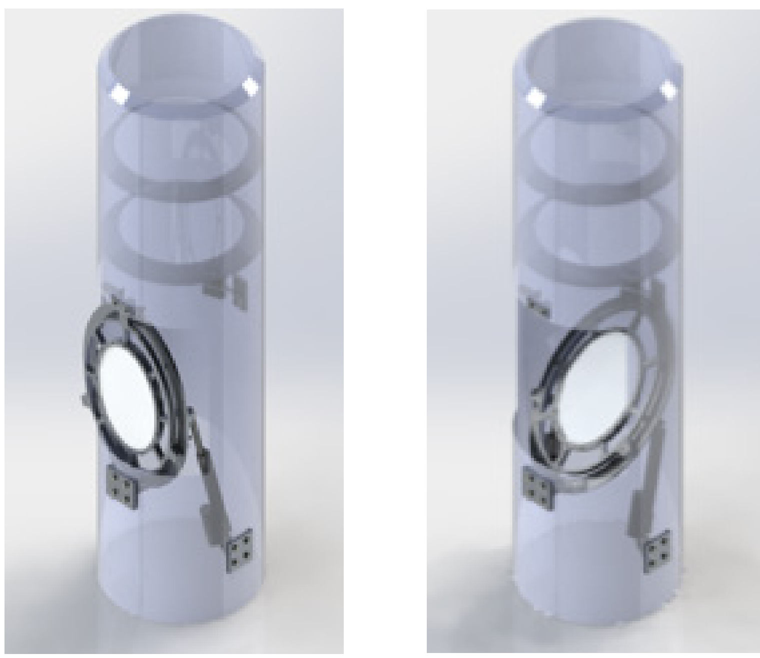
Requirements

The requirements for the controlling were given by the experts of OAN-SPM. Those are part of more requirements that the tertiary mirror system has to meet to be implement on 2.1 m telescope. The requirements are show below:

- The coupling has to be automatically take operation off when the actual configuration (Cassegrain Focus) is needed.
- Repeatability in the movement from positions off-on and on-off will be less than 20 arcseconds for an object seen by a camera and f/7.5 focus.
- The third mirror will be in stand by position when the Nasmyth is not working.
- The prototype can be made on the Instituto de Astronomía in Ensenada, and the materials purchase is not difficult.

Mechanical design

The mechanical design was given by the experts of OAN-SPM. They designed this part within the requirements that allow the implementation of the Nasmyth focus. In order to understand the control system and the testing procedures, the mechanical design is explained below.



a- Tertiary mirror turned off. b- Tertiary mirror turned on.

Figure 2. Tertiary mirror coupling on primary baffle.

In figure 2-a the coupling of the tertiary mirror and the baffle coupled to the primary mirror are presented. In this figure, the focus is outside the operation, hence the Cassegrain focus is working. On the other hand, in figure 2-b the tertiary mirror is in operation position with its necessary inclination for reflecting the light from the optical axis of the telescope to the Nasmyth focus.

There are elements that will allow to pivot the structure that supports the tertiary mirror and be able to enter and exit the Nasmyth focus operation, those elements work~~s~~ like a hinge. The actuators that allow~~s~~ the Nasmyth focus to start operation are two electric pistons with position sensors [2], see figure 2.

In addition, there is a metal ring that supports the tertiary mirror and will allow it to move and tilt as need it. Experts on OAN-SPM proposed that the system has to have a calibration to prevent movements during the operation and ~~to~~ setup, this subsystem is called "fine tuning system".

Another important element of the mechanical is the fixation subsystem. It prevents movements like vibrations and do not let the tertiary mirror leave the actual position until the fixation pin frees the system. There are two segments in this subsystem, one is used to fasten the tertiary mirror system when the Cassegrain focus is in operation, and the second segment is located to fix the tertiary mirror for the operation of the Nasmyth focus.

Aluminium 1060 is the proposed material for the mechanical elements.

Control design

The control is divided into two areas, hardware and software. As for the hardware, it is suggested to use the Beaglebone Black [3] as a microcontroller of the whole system, because it has the capacity of interconnection with the quadrature encoders from the operating system, it has enough inputs and outputs for controlling the complete system and experts of the OAN-SPM have comprehensive experience in its implementation. The use of the Pololu VNH5019 driver [4] is suggested for each motor.

In terms of software, it is designed not only for the Nasmyth focus to come into operation and for the tertiary mirror to be adjusted with greater precision, but also for the integrity of the entire system to be safeguarded The control software was coded in Python and the algorithm is shown in Appendix 1 as flow diagrams.

For the main sequence, if both end sensors (ES), located when the Nasmyth focus is in operation~~s~~ (ES_on) and when is not (ES_off), are activated at the same time there is an abnormal situation, so it is required that the tertiary mirror system must be checked. Otherwise, if both ES are not activated when the main sequence is running is an abnormal situation, but in this case it could be because a failure when the system was turning on/off, so if the telescope operator know about this state, he could let the system continuing turning on/off because it not represent a danger for the telescope and its equipment. But the control will display an error for be check it next.

The algorithms to turning on and off the Nasmyth focus by the tertiary mirror system are showing on Appendix 1. In both cases, the position sensors of both electric pistons are sensing constantly for checking the correct operation of the pistons. If an abnormally movement is detected the system will stop immediately.

The correct way to control the fine turning system is pointed out on Appendix 1. As an example, if the fine turning is not properly calibrated the control system will do it by itself, that will keep the system under correct parameters for movements. Next, when the system is calibrated it is allowed to move one of the three motors. If the movement proposed by the user is out of the range of normal operation, the control system will prevent any movement of the motors and a message will show to guard the system integrity.

Testing

To verify that the control design would work as expected, a 3D printed prototype was built with ABS plastic as figure 3 shows, which was subjected to several tests to verify its correct operation and compliance with the requirements.

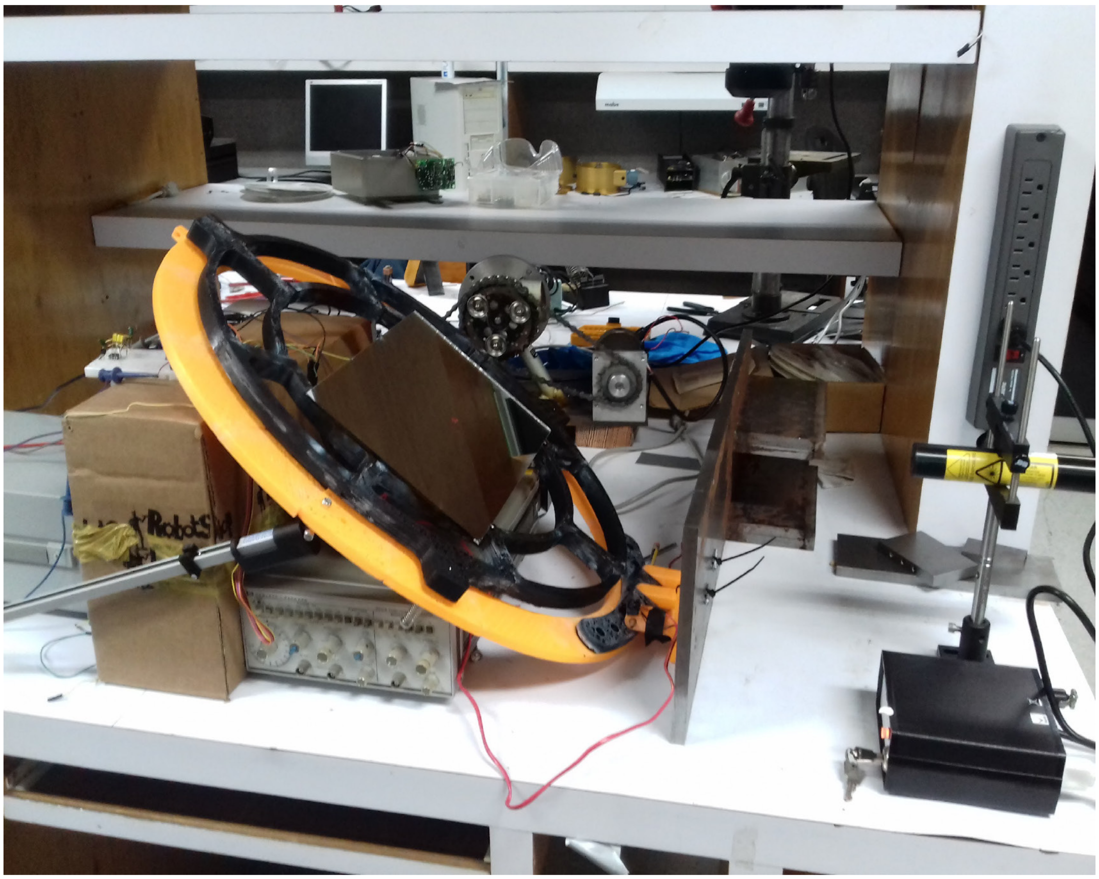


Figure 3. 3D printed prototype of tertiary mirror coupling.

The software made in Python that ran in the Beaglebone Black to verify the readings of the signals coming from sensors. The used actuators were pistons allowing the movement, two solenoids operate the subsystem of fixation; a spring next to a screw and a motor perform the fine turning.

The complete system (prototype and software running) was exposed to several situations for checking the behaviour of it. In all the times the system response as predicted the control design.

A repeatability test was also performed for the entry and exit from operation, where the system was tested by series of movements and thus obtain its deviation. By means of a mirror the light that comes from a laser was reflected and projected on a millimeter paper. Later an analysis was made to obtain the position of the reflected light.

Table 1 shows the iterations and the position in the Cartesian plane for each iteration. By the plate scale [5] of the telescope it is possible to convert the distance values to angular separations, so by doing this procedure and calculating the value of the standard deviation for repeatability, the value of 26.78 arcseconds was obtained for the x axis and 42.05 arcseconds for y axis, for a radial standard deviation of 49.85 arcseconds. Although it is high error that the prototype has, it is not the same error that the design would have due to changes in the assembly and in the materials, so the value obtained is projected by means of the Young's modulus of each material for the designed coupling.

Table 1. Position of reflected light for every turned on/off of tertiary mirror.

Iteration	x [mm]	y [mm]
1	8.9571	13.4429
2	10.9620	11.1416
3	12.0229	8.1204
4	11.3440	9.4156
5	10.9112	10.6610
6	10.3505	11.6078
7	10.9278	10.8465
8	10.1531	11.3636
9	8.5832	14.5525
10	7.8982	15.9244
11	7.0534	16.8737
12	5.7245	17.4664

For aluminum 1060 the Young's modulus is 69 GPa [6] and for ABS it is 2 GPa [6]. Aluminum has the Young module 34.5 times greater than ABS plastic, so an approximation of the value of the standard deviation for the design of the coupling is 34.5 times smaller than that of the prototype printed in 3D, this will give result 1.22 arcseconds radial standard deviation in the repeatability of the OAN-SPM experts proposed design.

The time that tertiary mirror coupling takes to start or to be off operation is around 50 s.

Results analysis

The prototype was made as similar as the mechanical design and it was enough to do the testing.

All the subsystems worked as expected on the testing. The fixation subsystem hold on and extend its pins when the tertiary mirror powering on or off was need it. The pivoting subsystem worked as expected, stopping the system if some position sensor do not move as expected (e.g. piston do not move), and move to tertiary mirror from off to on or on to off position when is needed it. On the other hand, the fine tuning subsystem works fine too, moving the motors the steps need it and correcting the angle of the tertiary mirror as the user need it either.

Verifying with the value of the requirement, the system is within the accepted value since it indicates that the repeatability must be less than 20 arcseconds and within the testing and approximation the repeatability is around 1.22 arcseconds.

The time that takes turning on or off the tertiary mirror is acceptable according to OAN-SPM experts.

The prototype could be built on Instituto de Astronomía in Ensenada within the materials and tools provided by OAN-SPM staff. And the 3D plastic printing works as expected for the testing.

Conclusion

- A control design for the Nasmyth focus coupling was proposed.
- A prototype for testing was made by ABS plastic 3D printing.
- The proposed control design that meets the requirements established by the OAN instrumentalists was validated.
- The software and hardware of the control system show the proper operation of the tertiary mirror, and when the prototype is replaced, this control system is reliable enough to be implemented with the real mirror in the 2.1m telescope in the OAN-SPM.

References

[1] "Telescopio de 2.1metros", *Astrossp.unam.mx*. [Online]. Available: http://www.astrossp.unam.mx/~sectec/web/telescopios/2mt.html. [Accessed: 14- May- 2018].

[2] "Pololu - Glideforce LACT12P-12V-20 Light-Duty Linear Actuator with Feedback: 50kgf, 12" Stroke (11.8" Usable), 0.57"/s, 12V", *Pololu.com*. [Online]. Available: https://www.pololu.com/product/2313. [Accessed: 02- Jun- 2018].

[3] "beagleboard/beaglebone-black", *GitHub*. [Online]. Available: https://github.com/beagleboard/beaglebone-black/wiki/System-Reference-Manual. [Accessed: 28- May- 2018].

[4] "Pololu - VNH5019 Motor Driver Carrier", *Pololu.com*. [Online]. Available: https://www.pololu.com/product/1451. [Accessed: 02- Jun- 2018].

[5] "Manuales y reportes. Departamento de Instrumentacion", *Astrosen.unam.mx*. [Online]. Available: http://www.astrosen.unam.mx/Ens/Instrumentacion/frame_manuales.htm. [Accessed: 20- Jul- 2018].

[6] *Solidworks 2016*. Dassault Systèmes, 2016.

Appendix 1

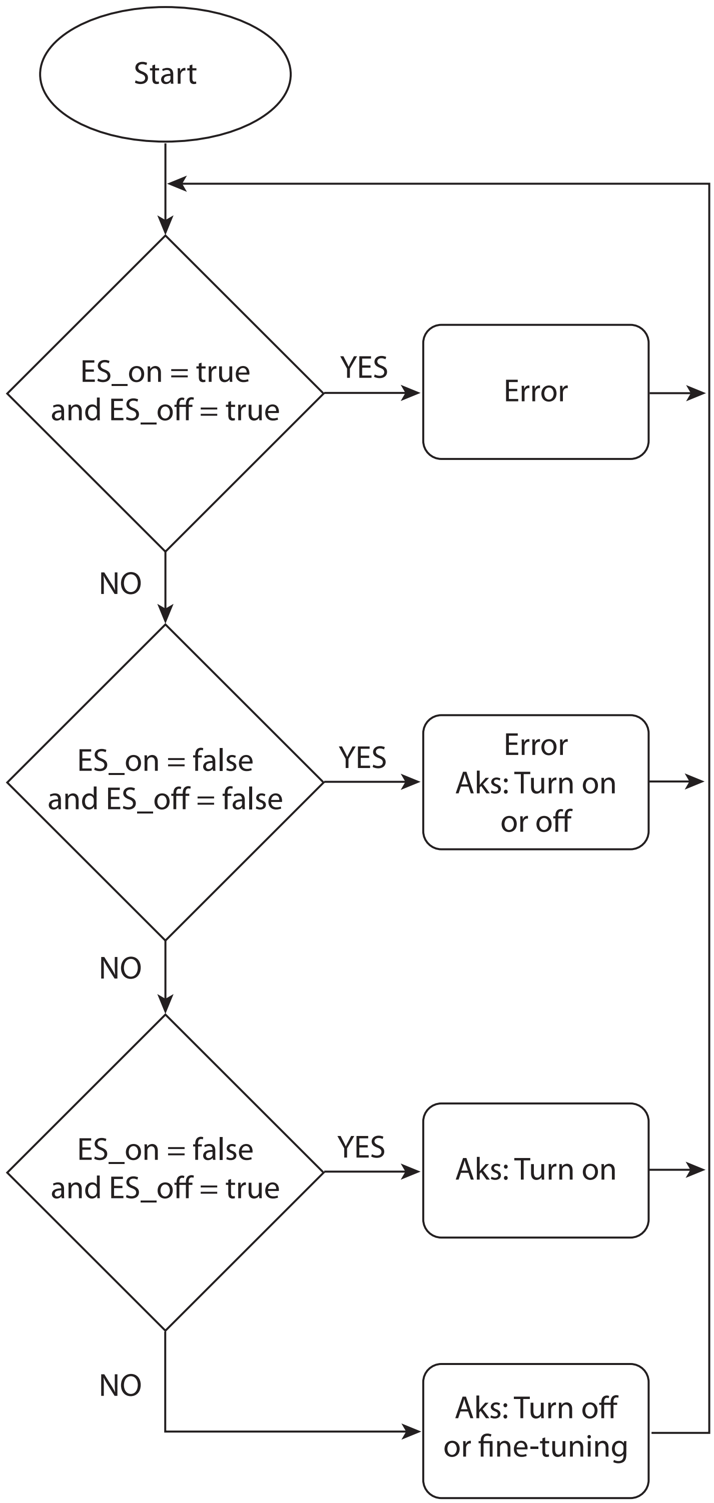


Figure 4. Main sequence.

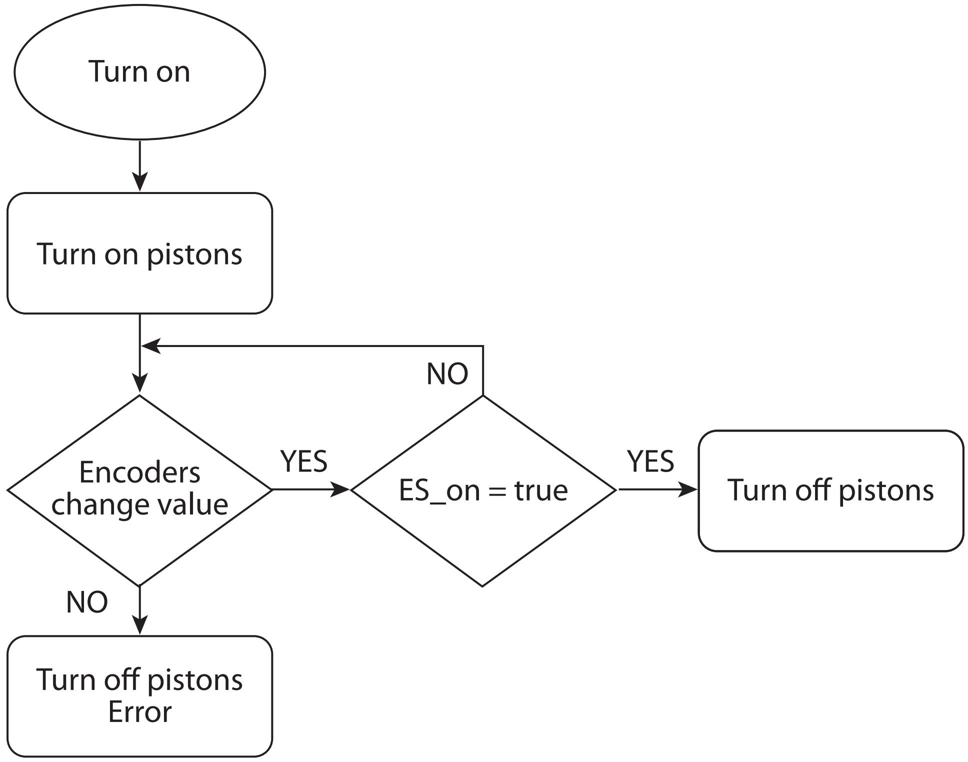


Figure 5. Turn tertiary mirror on sequence.

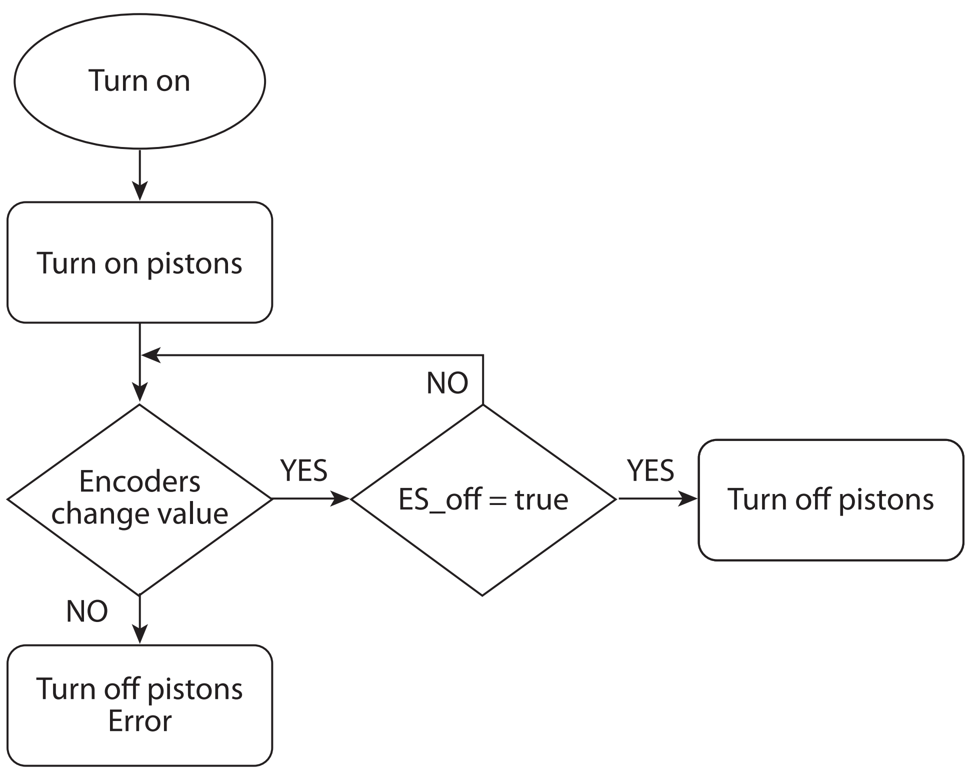


Figure 6. Turn tertiary mirror off sequence.

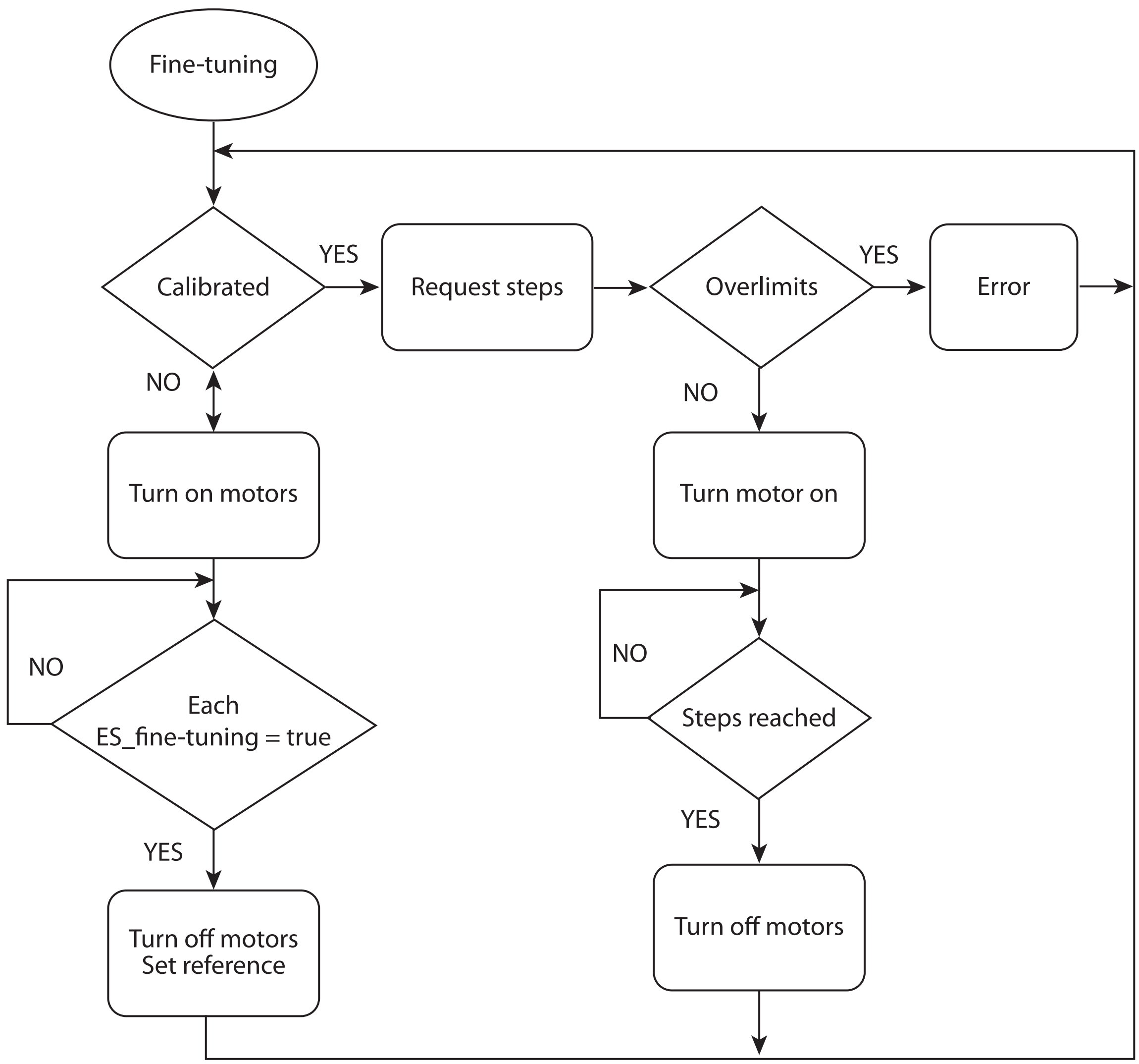


Figure 7. Fine-tuning tertiary mirror sequence.