

Automated Mirror Cover for Telescope Application

By

Rogelio Blanco, Miles Dehlin, Leland Doyle, Salazar Grey,
Katherine Hewey, and Paul Owen
Team 8

Needs Identification

Document

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Department of Mechanical Engineering
Northern Arizona University
Flagstaff, AZ 86011

Introduction

The NPOI (Navy Precision Optical Interferometer) located at the top of Anderson Mesa in Flagstaff, Arizona, is a United States Naval Observatory (USNO). This facility uses a series of expensive aluminum coated mirrors to reflect starlight down vacuum tubes, where the sunlight is then captured by sensors. The data is then analyzed by astronomers to produce a high resolution image of stars; in fact the NPOI gets such high resolution pictures, its main priority is discovering double stars or stars that rotate around each other.

The capstone's contact and client, James Clark, has been working at the NPOI since 1990. James Clark has become concerned about the potential safety risks associated with removing the mirror caps. The mirrors aluminum coating is only a few molecules thick, so the mirrors need to be covered when not in use or the coating can be damaged by moisture or debris. Currently the mirrors are covered with a Lexan glass cylinder with a nitrogen purge. The Lexan glass protects the mirrors from debris and the nitrogen purge maintains 10 psi of pressure that prevents moisture from condensing on the mirror. This requires NPOI employees to crawl into each telescope, remove the mirror cap, and crawl out at 4 a.m. with no lights, this process can be very dangerous particularly in winter and is a major safety concern with the addition of 2 new taller telescopes.

Needs Identification

After reviewing the initial project outline presentation put together by our client, our group arranged a meeting with the client at the location this project will be deployed. Although the project outline stated the problem and requirements for our deliverable, our group was unclear on the actual incipience for our project's creation. Questions that we were particularly interested in having answered were:

- What is the intended use of our device?
- Who are the people this project affects most directly?
- What were the motivating factors for our client to seek NAU capstone as a solution venue?
- What was the physical environment our device would operate in?
- Had our client already given thought to possible solutions?

While touring the facility grounds and being shown the physical locations of the project's environment, it became obvious to our group that the driving force for our project was the safety of the employees who interact with the current system. Although the automation of these mirror covers will eliminate unnecessary man hours; more importantly, the current system involves an unacceptable level of danger for the operators. Coupled with the possibility of damage to highly sensitive equipment that is put at risk with the current procedure, our needs statement is as follows:

“Needs Statement”-Potential for injury to employees of the Navy Precision Optical Interferometer is unacceptable.

Problem Statement

Goal Statement

A solution for removing and replacing essential mirror dust covers must be found while maintaining functionality of existing equipment, adding a minimum amount of mass to the system while incorporating autonomous/ semi-autonomous operation during power loss situations.

Objectives

The new cover must operate remotely, from outside of the equipment housing, keeping observers out of potential danger and protecting the equipment from accidental impacts. The mirror must be kept in a nitrogen environment in order to displace moisture. In order to do this, an orifice, 4 thousands of an inch in diameter must allow 10 psi of nitrogen to be injected through the mirror cover, purging atmospheric air. The nitrogen flow needs to automatically shut off when the cover is open. In addition, the equipment must maintain balance so that motor components are not exposed to excess stress during rotation. The new equipment should enhance the performance of the equipment that is in place and should in no way hinder the operations of the equipment.

Constraints

The cover must not block any light from the mirror's lens. The full range of motion of the siderostat must be maintained after installation of the automated cover. This includes a vertical tilt from -10 to 60 degrees and a horizontal pan of -60 to 60 degrees. The cover must be able to close in the event of a power failure.

Test Environment

Testing new designs at NPOI might jeopardize the equipment which is expensive and precise therefore a scale model of the housing will be constructed to provide a more appropriate test environment. The model will need to replicate the -10° to 60° range of motion of the siderostat to assure that our design does not hinder the movement of the mirror. The scale model will also assure that the mirror cover does not interfere with light collection while in the open position. The design is also required to operate between a temperature range of -20°F to 100°F. Critical components will be tested in an environment cooled by dry ice in order to replicate operational requirements. Large components will be tested during sufficiently cold nights. A comprehensive thermal analysis will supplement findings if negative 20 degrees is not reached. The design will be tested with the nitrogen purge operating to assure the design does not restrict the flow of the inert gas protecting the siderostat. NPOI will provide the compressed nitrogen for this test.

Recapitulation of Problem Statement

An automatic mirror cover is needed at NPOI and must operate without interfering with current equipment while maintaining a nitrogen purge.

Quality Function Diagram Development with House of Quality

Figure 1 is a Quality Function Diagram; this figure shows how qualitative requirements can be quantified into a list of product features.

		Engineering Requirements							
		Yield Strength	Young's Modulus	Moment of Inertia	Weight	Cost	Thermal Expansion	Dimensions	Power
Client Requirements	Durability	x	x			x			
	Inexpensive	x	x		x	x			
	Protect mirror from the elements	x						x	
	Maintain nitrogen purge							x	x
	Mitigate need for human interaction								x
	Low weight	x	x		x	x			
	Does not interfere with star light							x	
	Maintain range of swivel of siderostat							x	
	Withstand Extreme Temperatures (-20F TO 100F)						x		
Units	psi	psi	in ⁴	lb	\$	in/in *F	in	Volt	

Figure 1- Quality Function Diagram

Figure 2 is a House of Quality; this figure demonstrates the relationships between different product features.

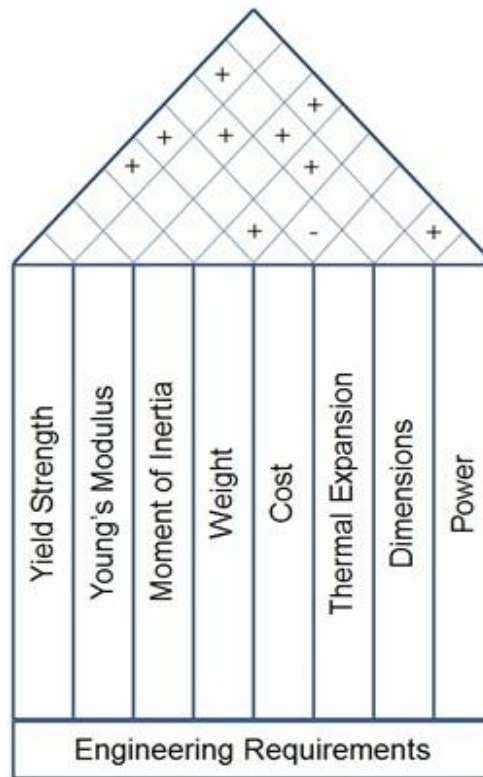
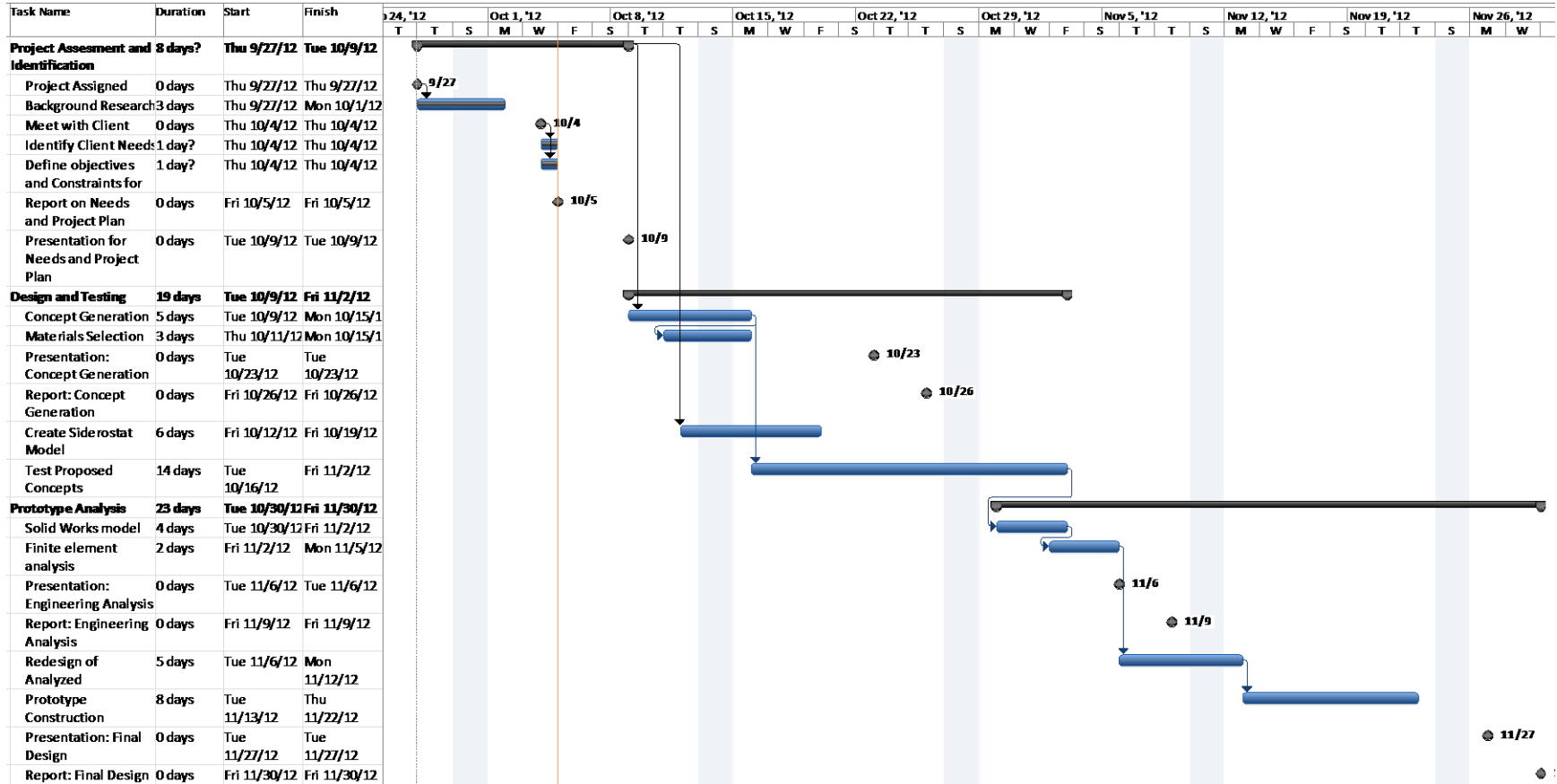


Figure 2-House of Quality, the + symbol represent a positive correlation, the – symbol represents a negative correlation.

Project Plan Gantt Chart



References

Navy Precision Optical Interferometer. "Automated Mirror Cover for Telescope Application." Navy Precision Optical Interferometer. Powerpoint. 5 Oct. 2012. <<https://bblearn.nau.edu/>>.

Navy Precision Optical Interferometer. Navy Precision Optical Interferometer, n.d. Web. 5 Oct. 2012. <<http://www.lowell.edu/npoi/index.php>>.