Evaluating Fastener Durability and Cleanliness in cryogenic vacuum environments: A Comprehensive Testing Approach

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INTRODUCTION

Numerous astronomical phenomena including high-redshift galaxies emit radiation detectable in the infra-red (IR). This poses significant challenges to astronomers hoping to research them as IR detectors will pick up any heat source in addition to the astronomical target, making the development of specialized instrumentation for this research necessary. The Gemini Infra-Red Multi-Object Spectrograph (GIRMOS) is designed for use with the Gemini-North telescope in Hawaii and will have the capability to observe these targets in Infra-Red and at very high resolution.

Problem: The cryogenic and vacuum conditions necessary for high-resolution imaging can lead to hardware challenges including seizing and cold-welding of fasteners making repairs and modifications very difficult.
To mitigate this issue, tests will be performed on different fastener combinations to determine which are best for this application.

REQUIREMENTS

The fastener combinations were decided through discussions with the project engineers based on existing industry standards and characteristics of the project. The fasteners to use in the project will be selected based on how well they meet the basic requirements described in Table 1.

Table 1: Fastener Requirements

Requirement	Rationale
R1: The fasteners shall not seize or cold-weld due to vacuum or low temperatures (70 K).	As the spectrograph will be kept at cryogenic temperatures to ensure that the amount of heat interference is small, it is critical that the selected fastener combinations not cold weld when at cryogenic temperatures. This will allow for modifications to be made to the spectrograph should alterations ever be needed.
R2: The fasteners shall not create debris during installation or removal.	Due to the sensitive nature of the optics in place in the GIRMOS project, it is imperative that no debris should be created by the fasteners.

The fastener types to test are described in Table 2 below.

Table 2: Fastener Type Combinations

Fasteners	Nuts	Threaded Inserts	Straight Tapped

• Primed
  • A286
  • 316
• Un-primed
  • A286
  • 316
	• Locking
	  • A286
	  • 18-8
	• Not Locking
	  • A286
	  • 18-8
		• Locking
		  • Plain
		  • Dry-Lubricated
		  • Nitronic 60
		• Not Locking
		  • Plain
		  • Dry-Lubricated
		  • Nitronic 60
			• 6061 T6 Al
			  • Plain
			  • Greased
			• 302
			  • Plain
			  • Greased

TEST PROCEDURE

To determine which fasteners meet the requirements, they must undergo a series of tests. The test stages are described below:

1. **Installation**
   a. All fasteners are to be installed using a torque wrench in a clean environment where any debris would be easily visible.
2. **Vacuum**
   a. The plates are to be placed in vacuum for 1 hour after which, the breakaway torque will be measured and recorded.
3. **Cryogenic**
   a. The plates will be placed in a cryo-chamber at 70K for 2 hours, after which, the breakaway torque will once again be recorded.
4. **De-installation**
   a. When removing the fasteners, any visible debris should be recorded along with any visible damage that can be seen on the plate or the fasteners.

TEST DESIGN

These plates were designed to allow for as many fastener combinations as possible to be tested simultaneously whilst being constrained to fit in the test chamber with spacing allowing for the fasteners to not interfere with one another. The CAD and engineering drawing for each plate can be seen in Figure 1.

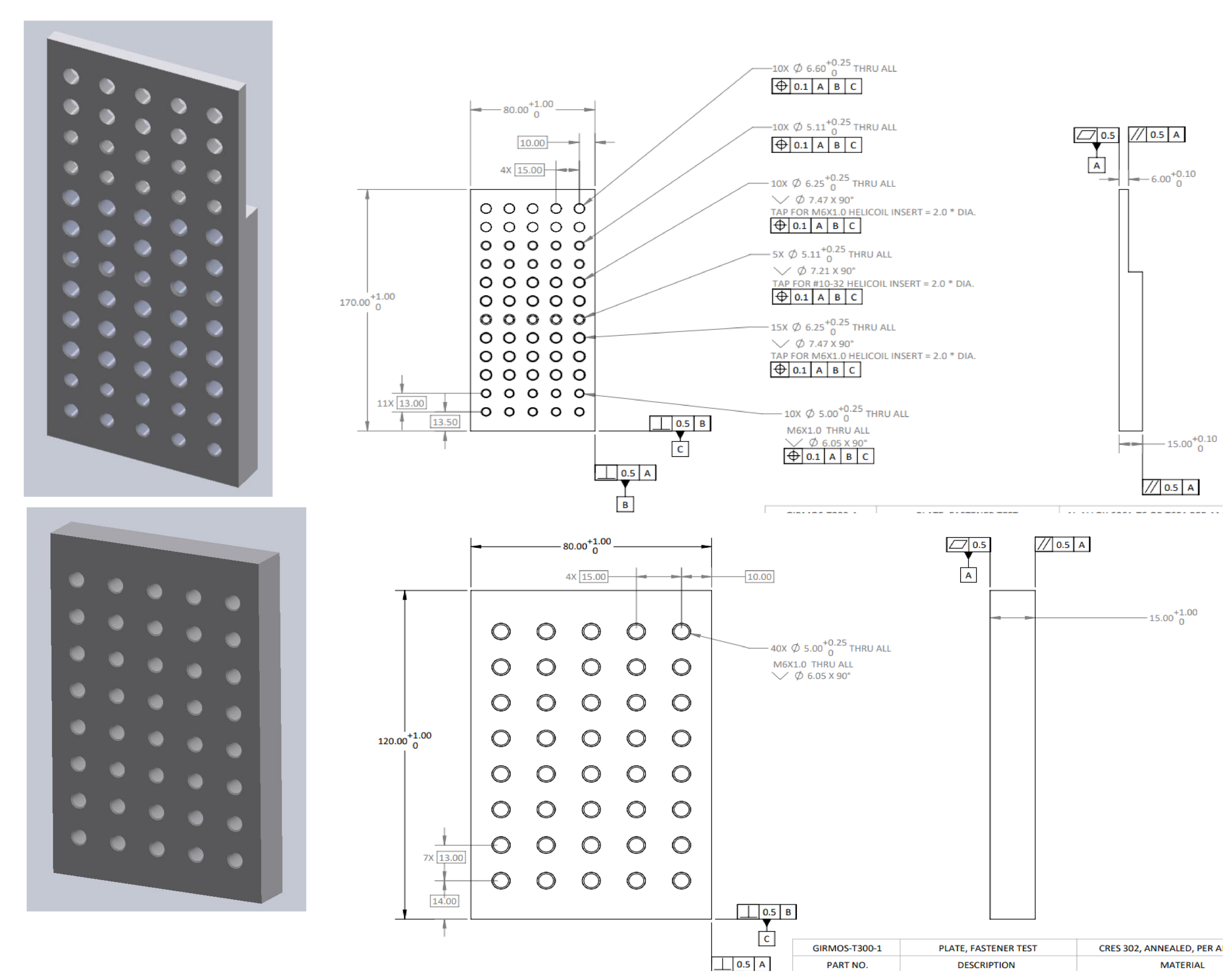

Figure 1: CAD drawing and engineering drawing of both the aluminum and stainless steel plates to be used in testing.

RESULTS

The plates were manufactured in the physics shop at the University of Toronto. The finished plates can be seen in Figure 2.

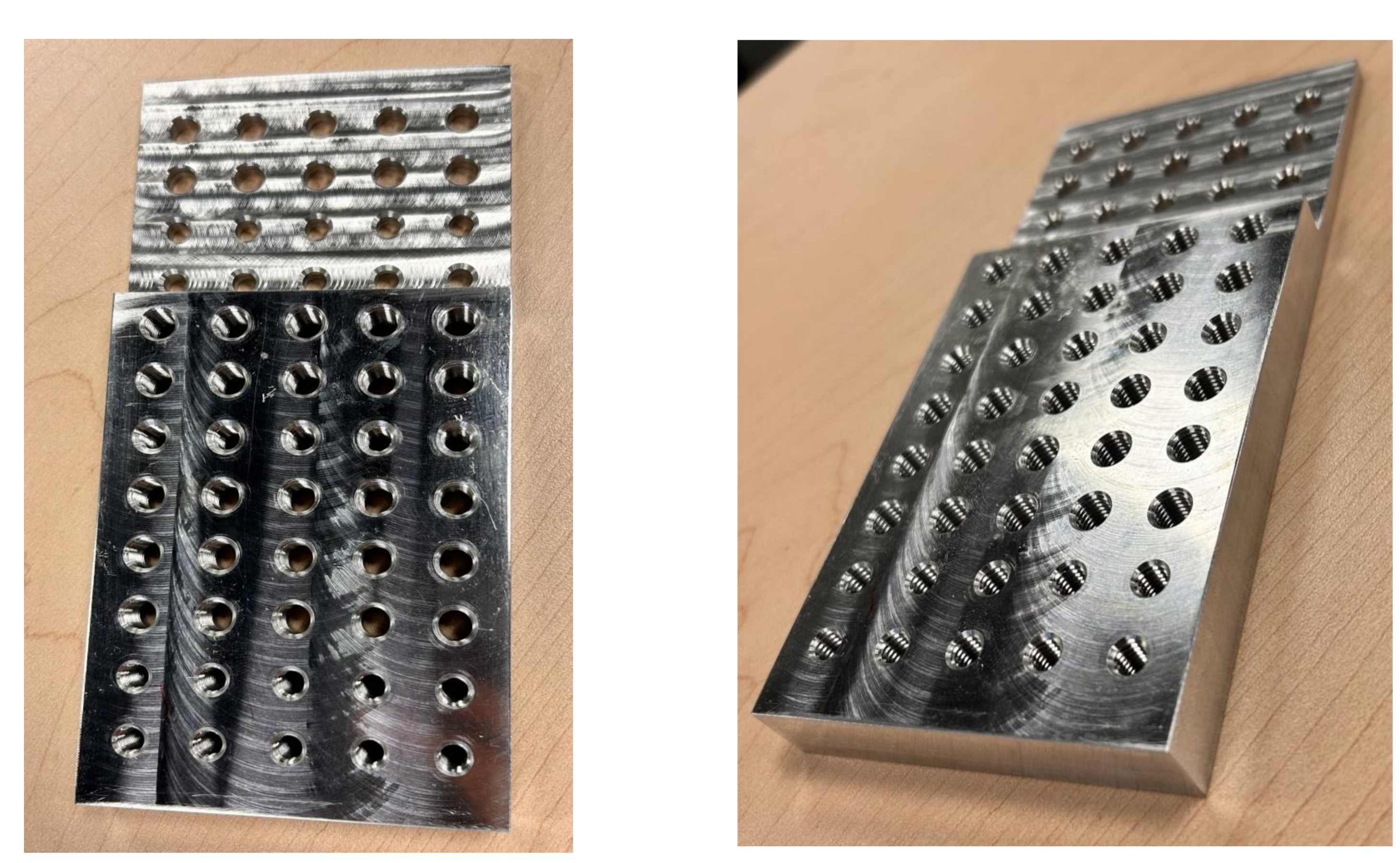

Figure 2: Test plate top and side view.

DISCUSSION

The plates were finished in the shop on August 14th. In the coming weeks, the fastener combinations will be tested using the testing process detailed above. Should multiple fasteners pass the tests, meaning that they neither cold-welded nor produced any debris, the recommended fastener combination will be the one that maintains its strength the best throughout testing. Other factors that may be considered are the cost of the fasteners, the ease of use, and the availability of different sizes. These tests will provide valuable insights into the best fastener choices for the project leading to more robust and longer-lasting projects. Additionally, the results could be used to advise fastener choice decisions in future projects.

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