TIGHTER - Tie Installer for Great Heights To Extend Research
International Space Station: EVA Zip Tie Installer

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Abstract

The International Space Station (ISS) was developed to advance science and humanity's understanding of microgravity. One required activity is the securing of cables, which is currently a strenuous task to complete during extravehicular activity (EVA). The team's design aims to allow astronauts to install zip ties around cables while in an EVA suit to reduce strain caused by current cable securing methods. The device proposed, TIGHTER, holds several zip ties which can be dispensed and installed as required with minimal effort required by the operator. TIGHTER can be actuated with very little force and does not require precise movements after initial placement. During EVA, this extra liberty of operation is beneficial due to the decreased dexterity caused by thick gloves and the inherent instability of being on a spacewalk.

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1. Introduction

The NASA Micro-g Next Challenges consist of competitions that require teams to accomplish the task or challenge at hand. Team P.A.R.T. (Poly Astronaut Resource Team) of Will Moffat, Truman Giesen, Ryan Ghosh, and Victor Rodriguez are participating in the EVA Zip-Tie Installer challenge. This challenge consists of being able to design and manufacture a device that can install a zip tie during an EVA in microgravity. In this report, the team expects to demonstrate its knowledge for the challenge at hand and to be able to showcase not only the objectives that NASA provided, but also the objectives and tasks that the team as a whole and individual members all aim to accomplish. In the background, the team discusses items and certain research that led to the preliminary concept. The project scope presents the desired deliverable for the project, and the objective section fully defines the problem and design specifications. In the project management section, the steps and procedure for the design process will be explained in further detail.

2. Background

2.1 Stakeholders and Needs

For this project, there was not much research done into the stakeholders because the team's stakeholders were clearly defined from the outset of the project. The stakeholders for this project are NASA, their astronauts, and their Neutral Buoyancy Laboratory (NBL) technicians. These stakeholders have been kept in mind as the project has developed, with the intent to create a design which will satisfy NASA's needs.

Research into NASA's needs involved a few main categories, including previous NASA Micro-g NExT Senior Projects, NASA's released parameters, and NASA's Information Sessions. Through this research, the team gathered and documented specific information regarding NASA's EVA Zip Tie Installer challenge and their proposal needs. This included base requirements, specifications, and assumptions for the project as well as an outline for the team's design proposal. Additionally, the team learned that the project requires an outreach program and has begun creating plans with Georgia Brown Elementary School based upon its research regarding NASA's learning and outreach objectives.

2.2 Existing Products/Solutions

Due to the nature of this project, there are few existing products or solutions regarding zip tie installation in space. However, team P.A.R.T. has done extensive research into similar solutions ranging from automatic zip tie guns to manually powered installers which utilize a variety of designs. These products have been verified via their patents, and the team's research into these products has allowed the team to become inspired with ideas of how to apply these concepts to a similar task in space.

One product that resembles the needs for NASA's Zip-Tie Installer is the Automatic cable tie gun: Autotool 2000 CPK by HellermannTyton. It features a very similar claw-like system that wraps around the object that it wants to install the zip-tie. Although this system requires electrical input to operate, the basic concept of it also uses a trigger mechanism such as that of a gun, as seen below in figure 1.1.

Figure 1.1 Autotool 2000 CPK by HellermannTyton.

Another product that demonstrates similar function and design is the Panduit which also contains the very common claw design. This product does not have the same tightening strength as the Autotool 2000 CPK by HellermannTyton, however, it is much lighter giving it the fluidness to be used over multiple without the operator getting fatigued.

Figure 1.2 Panduit PAT1.5M4.0 Automatic Cable Tie Tool Head

One product that is as similar as the other two or as similar as NASA’s specified zip-tie gun is a simple cable tie gun that only tightens and cuts the tie. The reason that product stood out was that it used a hand operated mechanism to tighten the tie. If you look closely you can also see a small metal piece with teeth notched into it that allows the gun to grab the tie and pull it tight. This ULINE cable tie gun, although it does not install zip-ties, gives a lot of avenues of inspiration towards other mechanisms that the gun must have in the challenge.

Figure 1.3 ULINE Stainless Steel Cable Tie Gun

2.3 Technical Solutions

In terms of technical solutions, the team still has much research to complete. The primary example of technical research which team P.A.R.T. has undergone is in NASA’s Zip Tie Cutter challenge from 2018. This is an example of a Micro-g NExT challenge which led to an official design by NASA, and the team has utilized NASA’s solutions in its brainstorming process for potential designs. Further technical solutions will be researched as the project continues, for the team wishes to fulfill NASA’s requirements with as much insight as possible.

3. Project Scope

The project involves designing, manufacturing, and testing a device for installing zip ties around objects that need to be secured. The zip tie installer must be usable in microgravity and while wearing a spacesuit. Figure 1 shows a boundary sketch that illustrates the scope of the project.

The zip tie installer must be able to install zip ties on objects of various sizes, and it must be easy enough to use with gloved hands during an extravehicular activity (EVA).

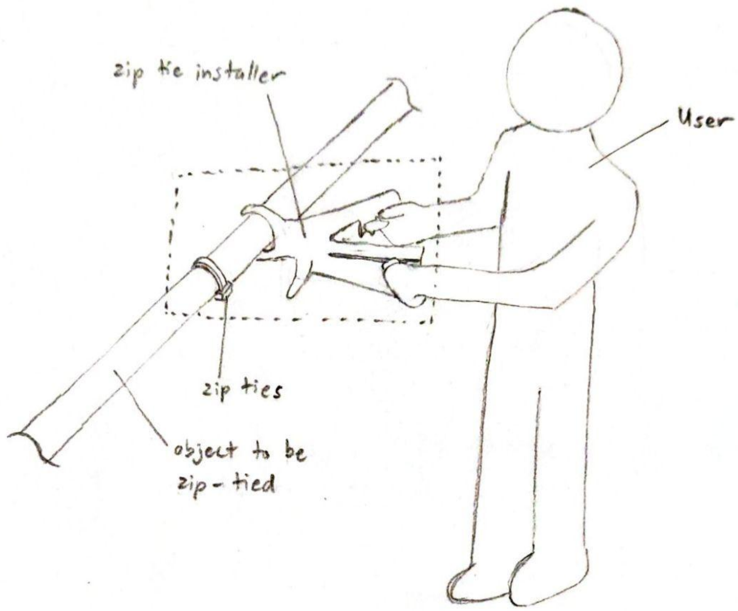

Figure 1: Boundary Sketch

In addition to the scope above, the team completed a Quality Function Decomposition process to break down the required functions to cover each part of the scope. In order to install zip ties, the device must fulfill multiple main functions: holding zip ties, preparing a zip tie, installing a zip tie, and facilitating use. Subfunctions necessary for holding zip ties include containing at least 10 zip ties, loading the next zip tie from the storage area, and allowing the zip ties to be reloaded when the storage area is empty. Subfunctions for preparing a zip tie include retrieving a zip tie from the storage area and moving the tie into place to be installed. Installing a zip tie involves wrapping the tie around the target object, forming a complete loop, and tightening the zip tie. Lastly, the subfunctions for facilitating use include preventing strain, protecting the user from pinch points and sharp edges, allowing easy ambidextrous operation, and allowing fluid to be drained from the device. The team will design and build a fully-functional prototype of the device to test at NASA's Neutral Buoyancy Laboratory (NBL), submit a plan for testing the device, and submit a plan for an outreach program.

4. Objectives

The objective of the NASA Micro-g Next EVA Zip-Tie Installer challenge is to design and manufacture a device that can install a zip tie during an EVA in microgravity. This device will be used to assist astronauts in routing cables and bundling items together, which is a common task during EVA on the International Space Station (ISS). While it may be proven useful inside of the ISS, the device's should be primarily designed to be functional on a spacewalk.

There are a few key assumptions to be addressed when considering the task at hand. The list of assumptions goes as follows:

- Objects to be zip-tied may be various shapes.
- Zip ties will range from 0.18” to 0.5” wide, and teams must select one size in this range. The team’s design does not have to accommodate for zip ties of different widths.
- Clipping the excess length off zip ties once installed is not required.
- The zip ties will be plastic.
- The device may have multiple parts capable of attaching and detaching.
- The device will be tested underwater at NASA’s Neutral Buoyancy Laboratory (NBL).
- The test subject will be weighed out to simulate microgravity.
- The astronaut is stabilized, has two free hands, and can react to stabilize themselves against small amounts of load.

In terms of requirements, NASA has provided a list of 15 design requirements and various material requirements. The design requirements are detailed in Table C-1 in Appendix C at the end of this report.

The material selection requirements for this challenge are largely based on NASA’s NBL Approved Materials list. The device will be tested underwater in the ~86 °F water at the NBL. Therefore, the materials the device is built out of for NBL testing can be non-flight-like but must adhere to the NBL Approved Materials list. The team is expected to detail its selected materials and provide rationale for any materials not included on the NBL Approved Materials list.

Team P.A.R.T.'s problem statement reads as follows: “NASA astronauts need a device to install zip ties in microgravity because the wire twist ties they are using currently take too long to install, and they cannot install zip ties by hand while wearing an EVA suit.” After defining the problem, the team moved on to Quality Function Decomposition (QFD). Throughout this process, each function of NASA’s proposed device was broken down into subcategories. Additionally, a House of Quality was created to explore the relations between each requirement and each requirement’s individual importance to the project. See Figure 2 in Appendix A for more details. The result of the QFD process is the team’s Engineering Specifications Table, which can be seen in Table 1 below.

Table 1: Engineering Specifications Table

Specification #	Specification Description	Requirement or Target (units)	Tolerance	Risk*	Compliance**
1	Diametric Range	0.5”-2”	N/A	H	T
2	Tightness	Unmoving After Installation	N/A	H	T
3	Storage Capacity	10 Zip Ties	N/A	L	A, I
4	Weight	4 lb	Min.	L	A, I
5	Process Steps	-	Min.	M	A, I
6	Volume	10” x 10” x 3”	Min.	M	A, I
7	Qualitative Test	-	N/A	L	T
8	Symmetric Design	-	N/A	M	A, I
9	No Power Source	-	N/A	L	A, I
10	Retained Liquid Test	Weight Before Submersion Equal to Weight After Submersion	Min.	L	T
11	Material Selection	-	N/A	L	S
12	Visuals and Labels	-	N/A	L	S, I
13	Concurrent Operations	-	Min.	M	I

Each of these specifications have been assessed in the House of Quality and in the team’s proposal document to NASA. The high risk specifications are the key items which the proposed design will be targeting. The team’s design will ensure that the diametric range is met, and that any installed zip ties remain tight and unmoving after installation has occurred.

5. Project Management

To ensure all work is completed in a timely manner, each team member has a specialization that guides how work is done. Truman, as the project manager, keeps track of deadlines and ensures that there is a plan to complete all work on time. Ryan, as the design lead, is in charge of the CAD and oversees any tasks related to the design, prototypes, or test models. Victor is in charge of outreach, and dictates all correspondence with a selected high school. Will is in charge of project scope and deliverables, and ensures that all of the team's work completes all of the requirements from design specifications to report requirements. Listed in Table 2 below is a timeline of the team's key milestones, which are also included in Appendix B, a Gantt chart detailing the team's plan to complete this project.

Table 2: Key Milestone Timeline

Milestone		**Date**	**Description**
[NASA]	Letter of Intent	10/13/22	A letter indicating interest in participation
[NASA]	Project Proposal	10/26/22	A report detailing plans to complete the challenge
[CP]	SOW	11/09/22	A report detailing the challenge details and scope
[CP]	PDR Presentation	11/15/22	A presentation showing design direction and concept
[NASA]	Project Plan	11/16/22	A report including a timeline detailing how the project will be completed over the next several months
[CP]	PDR Report	11/17/22	A report detailing what is covered in the presentation
[NASA]	Selected Projects Announced	12/22	Teams find out if they have been selected by NASA
[CP]	IDR	01/24/23	Interim Design Review
[CP]	CDR	02/14/23	Critical Design Review
[CP]	Project Expo	06/02/23	An exposition for all Senior Projects
[NASA]	Test Week	06/04/23	Selected teams test at the NBL
[CP]	FDR	06/09/23	Final Design Review

The tasks remaining before the PDR are to create a concept prototype, complete a design hazard checklist, and prepare the report and presentation. A lot of the content covered by a PDR was already completed within the Project Proposal Report, submitted to NASA on 10/26/22. A prototype model will be created from the detailed CAD model as demonstration of the concept and verification of design direction.

6. Conclusion

The overarching design challenge that the team was tasked with was being able to design and manufacture a device that can install a zip tie during an EVA in microgravity. This device is intended to be used on the International-Space Station replacing the current method of wire ties. Ultimately, the purpose of this document was to allow the team to demonstrate the insight and progress thus far of the zip-tie installer and to explain the direction the design will likely be taken. As discussed in the sections above, the team's CAD model demonstrates a gun-like trigger which is common amongst all other products that were researched and developed by other companies. Using this information, Team P.A.R.T. wants to achieve a working prototype to see whether or not the design is functionable or not. As of right now, the next big deliverable will be the PDR which can also be used for the NASA PDR.

7. References

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8. Appendices

A) QFD House of Quality
B) Gantt Chart
C) NASA Requirements

Appendix A: QFD House of Quality

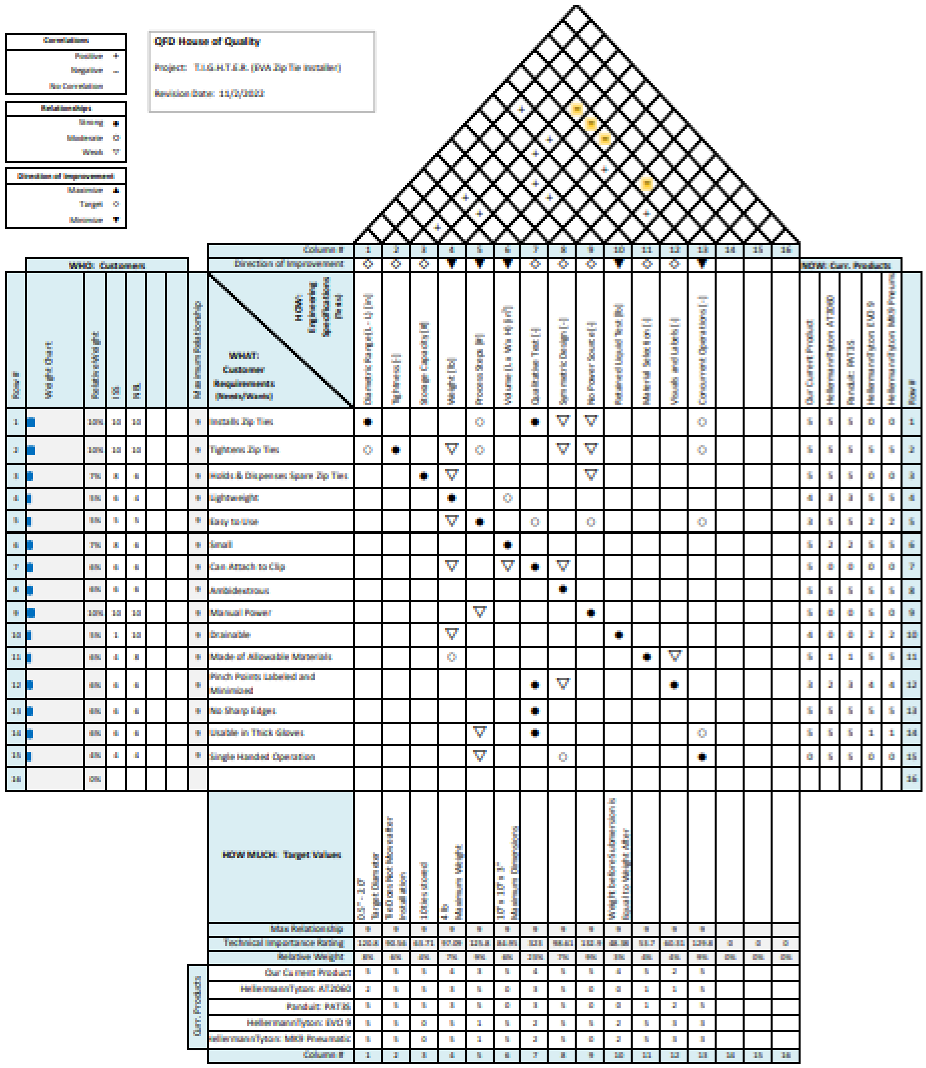
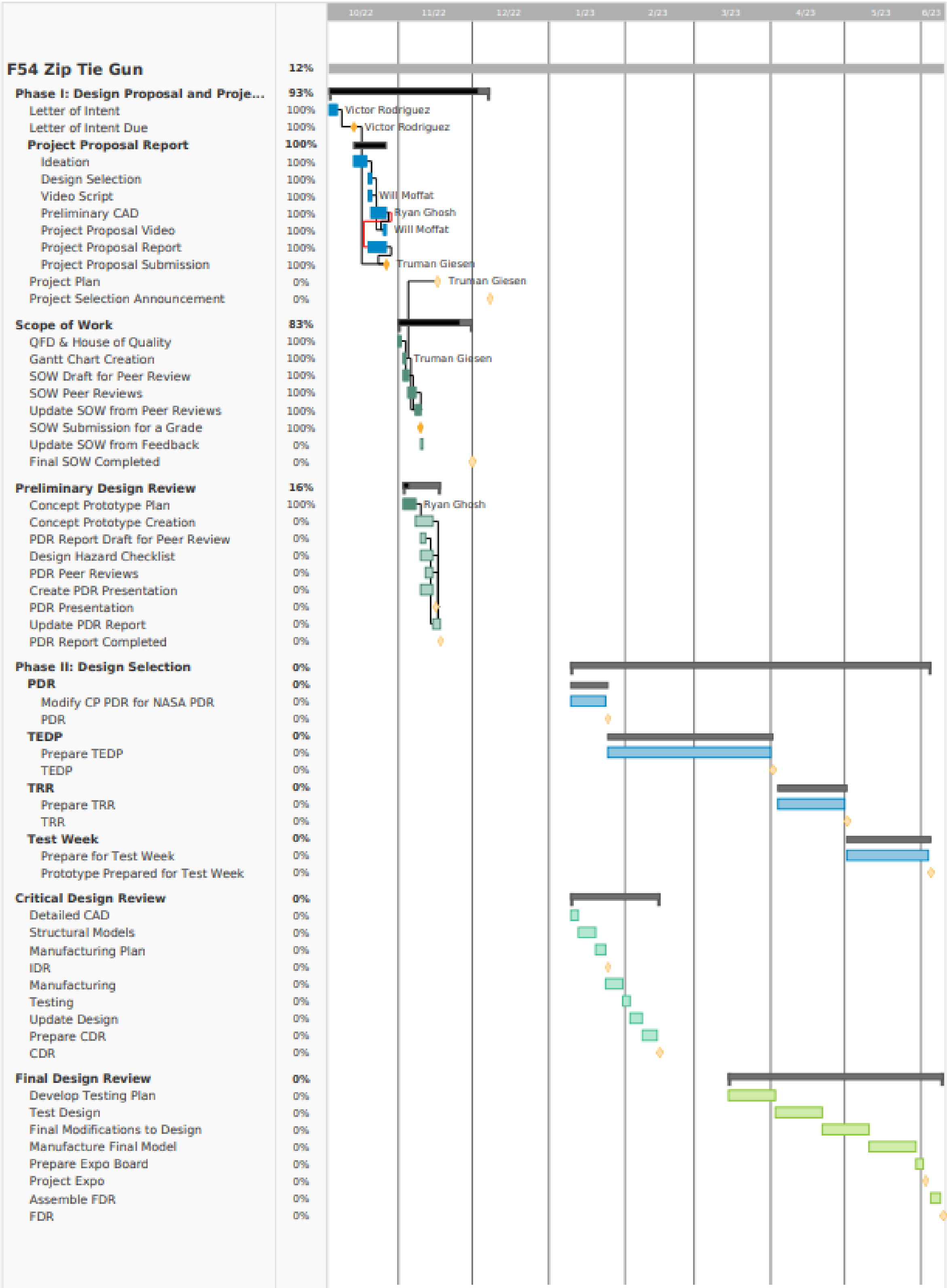


Figure 2: P.A.R.T. T.I.G.H.T.E.R Quality Function Decomposition House of Quality Chart

Appendix B: Gantt Chart



Appendix C: NASA Requirements

Table C-1: Provided List of Requirements from NASA

Requirement #	Description
1	The device shall be able to install and tighten a zip tie around an object ranging from 0.5” to 2” in diameter/width.
2	The device shall be able to hold and dispense 10 zip ties.
3	Teams must supply their own zip ties. For testing please supply minimum 10, maximum 20.
4	The device shall be able to pack into a 10” x 10” x 3” volume.
5	The total weight of all parts shall be less than 4 lbs.
6	The device shall only use manual power.
7	The device should be capable of one-handed operation, but two-handed operation is acceptable.
8	The device shall be ambidextrous.
9	The device and any removable components shall have a tether point 1” in diameter.
10	The proposed design shall specify all materials the provided hardware will be made from. The device shall be built for an underwater testing environment at the NBL and must be made from NBL Approved Materials. A waiver may be granted on a case-by-case basis.
11	The device shall be operable with EVA gloved hands (like heavy ski gloves).
12	There shall be no holes or openings which would allow or cause entrapment of fingers on the zip tie installer.
13	There shall be no sharp edges on the device. Functional sharp edges are acceptable but should be labeled and only exposed during operation.
14	Pinch points should be minimized and labeled.
15	Tools shall be designed with drain holes or geometry to allow the free flow of air and water as required to support submersion and removal to and from the NBL pool.