Team B7
NAU Psyche Sampling Team

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Subject: Engineering Requirements & Testing Procedures Edits

The Psyche Sampling Team has been tasked with creating a sampling device that is capable of operation on the surface of the Psyche asteroid. Psyche is an asteroid that is the first of it's kind to be explored that is hypothesized to be composed of an iron-nickel metal. This project is working towards creating a successful sampling system that is capable of drilling and collecting samples under the environmental conditions of the asteroid. It is important to note that the Psyche surface has not yet been explored, therefore the true composition and topography of this asteroid is still fully unknown. As a result of this, the team will be testing on multiple different surfaces, provided by their team client. This will be changing the scope of the project to focus testing primarily on the drilling capability of the team's designed system on materials of different Brinell hardness. Further, the team's customer requirements for this semester have narrowed. The team has worked with the client to cut down the customer requirements to the system being reliable, durable, safe, inexpensive, able to function on different surfaces, have sample caching capabilities, and be stable under orbital rotation. This change allowed the team to not need to focus on the system's ability to utilize minimum power, compact samples, operate under low gravity & operate in extreme temperatures. Due to the limited budget that the Psyche Sampling Team has, acquiring space grade materials would be too expensive for the scope of this project. This change also influenced a removal of related engineering requirements. This has further narrowed the engineering requirements down to weight, hardness, cost and force, as explained below. While the team will still be testing all re-evaluated engineering requirements, the main focus will be to create a system that can drill through the hardest material that will be tested. The team does not have the full, finalized list of testing surfaces yet, but does know that the hardest material will be a ⅛ inch thick sheet of steel. Therefore, the scope and testing of this project has changed for the team to focus primarily on the drilling subsystem and its efficiency.

1 Customer Requirements (CRs)

In the previous semester the team met and discussed the customer requirements with their client, Dr. Bowman. All the customer requirements follow the project demands that were originally provided. In the previous semester the team gathered eleven customer requirements, but in this semester the team decided to drop four less relevant customer requirements after meeting again with Dr. Bowman. The four customer requirements that the team decided to eliminate included the systems ability to operate under minimal gravity, utilize minimal power, create compact sample caching and operate under cold temperatures. All the changes in the customer requirements occured because the client decided they are no longer within the scope of the final product that she wants the team to create. Now the team has seven customer requirements and will then use them to create quantifiable engineering requirements. All of the finalized customer requirements and their weights can be seen below in Table 1.

Table 1: CRs and their weights

Customer Requirements	Weights
Reliable	12
Durable	8
Safe	10
Inexpensive	12
Functions on different surfaces	15
Sample caching	10
Stable under orbital rotation	5

2 Engineering Requirements (ERs)

From the customer requirements (CRs), the team developed engineering requirements (ERs) to have values that the team can test and measure against. Originally, the team had six ERs: weight, hardness, storage, cost, velocity, and lifespan. Currently, the team will be primarily focusing on weight, hardness, cost, and force instead of velocity. The team decided to focus on these specific ERs after talking with the client.

2.1 ER #1: Weight

Weight is a factor that is related to the customer requirements: durability, inexpensiveness, safety, and sample caching. Weight can be controlled by minimizing the amount of material in the project, as well as selecting components whose density is lower. This project takes place on an asteroid with minimal gravity, so weight is not a big concern for the group. However, the team will focus on the weight to ensure that the system is not too big and/or heavy.

2.1.1 ER #1: Weight under 20 kg - Target = 18 kg

The target weight value was decided on by taking into consideration the weight of the new parts and assemblies. The target value is also created with the unknown knowledge of the final design and all of its parts. The target value has been increased to what seems to be a reasonable and realistic value that the device could be built with. The weight target has been increased from last semester as the team is focusing more on the physical drilling aspect of the design, rather than its real-world feasibility.

2.1.2 ER #1: Weight under 20 kg - Tolerance = +/- 2 kg

The tolerance for the weight target was chosen to be +/- two kilograms in order to provide a realistic target weight for the model. As the final weight is unknown and the team is focusing on the drilling aspect of the design, the tolerance for the weight is made larger to allow for a functional drill design.

2.2 ER #2: Hardness

Hardness has a strong relationship with the CR reliability, durability, and functions on different surfaces. The hardness can be controlled by choosing a material that can penetrate multiple surfaces while remaining rigid and sharp. The team has been looking into diamond drill and coring bits to achieve this requirement. Hardness is an important ER because if the bit breaks, the entire system will fail rendering the project useless.

2.2.1 ER #2: Hardness up to 150 HB - Target = 150

The hardness target is set to a Brinell Hardness value of 150 to anticipate the conditions the design may function under. The surface of Psyche is currently unknown and the asteroid is theorized to be made mostly of iron nickel alloy. The drill will in theory only be required to drill material up to a brinell hardness of 150.

2.2.2 ER #2: Hardness up to 150 HB - Tolerance = +/- 50

The tolerance for hardness is large due to the unknown surface of Psyche. A large tolerance allows the team to design a drill capable of drilling materials harder than what is expected, helping to ensure the success of the design.

2.3 ER #3: Cost

Cost is directly tied to inexpensiveness. As a team, we are not allowed to go over the budget simply because the team cannot afford to go over. The cost is defined by the amount the team was given at the beginning of Fall 2019.

2.3.1 ER #3: Cost under $1,000 - Target = $800

The cost is set at 1000 dollars as this is what is supplied to the team by the client. The budget has not changed since last semester and will remain the limit for the project. The target value is set to be 800 dollars in order to allow for a contingency budget to be set aside for emergency and last minute purchases.

2.3.2 ER #3: Cost under $1,000 - Tolerance = +/- $200

The tolerance for the cost is set to be 200 dollars to allow for unexpected purchases. As the design is being manufactured, not all parts are finalised and the functionality of the design is yet unknown. A higher tolerance will allow for money to be set aside for any necessary purchases.

2.4 ER #4 Force (changed from velocity)

Last semester, the group originally had velocity as the ER. The team changed it to force because the force the drill creates against the surface must be smaller than the force the electromagnetic creates. Force would be directly tied with stability and functionality on different surfaces. This is a better requirement than velocity because velocity can be computed from the drill.

2.4.1 ER #3: Force less than 5 N - Target = 4.8 N

The target force was calculated to be around five newtons. This would be the maximum force that drill will be allowed to apply to the surface. The target force is set to be 4.8 Newtons in order to decrease the required force of the magnetic base.

2.4.2 ER #3: Force less than 5 N - Tolerance = +/- 0.2 N

The tolerance has been set to 0.2 Newtons in order to ensure the magnetic base will have enough force to hold the device on the surface. The tolerance is smaller for this engineering requirement as the magnetic base is designed to apply a specific force to the surface. If the drill appies too much force, there will not be time to redesign the magnetic base.

3 Testing Procedures (TPs)

The testing procedures used are to meet each customer requirement and engineering requirement that was created by the NASA Psyche Sampling Team.The engineering requirements are taken from the House of Quality. The engineering requirements to be met from the ERs are force, hardness, cost, and weight. The most important tests will be focused on the material hardness that the drill is able to sample from and the force analysis. The cost and weight requirements are easily tested with simple testing that is described in the below sections, along with all other testing procedures that are to be carried out.

3.1 Testing Procedure 1: Drilling Test

The drill testing is one of the most important tests. The team will be testing the drilling bit and mechanism on material provided by the client to represent what is thought to be the makeup of Psyche. This test is to prove the system created is fully functional and does what the system is meant to do. This test meets the customer requirements of sample caching and collection of unknown material. The team is to test this system once the full system is created and functional. This testing will not have to be in the testing period, preferably the testing will be done before this period.

3.1.1 Testing Procedure 1: Objective

The objective of this test is to test the drilling and sampling system. This will give data on whether the materials used for the drill and the mechanism for collecting the samples are sufficient and will work for what is needed. The main function of the drill test is to make sure the material selection for the drill is adequate to drill into the assumed material of the asteroid. The next subsystem that will be tested is the collection system, this is to test it is functionality of the collection system and reliability of the system as the designed system will need to collect multiple samples. This testing procedure will meet the engineering requirement of hardness.

3.1.2 Testing Procedure 1: Resources Required

The resources used are provided to the team by ASU. The system will be tested on the six different materials, potentially from lava rock to steel, these will be created by the NASA/ASU team and shipped to the NAU team for pick up. These six materials will replicate the material makeup of what is thought to be on the asteroid. The hardest of the materials will for sure be a ⅛ inch thick sheet of steel. These tests will be carried out at Northern Arizona University's machine shop. This test will be done after the drilling mechanism is complete.

3.1.3 Testing Procedure 1: Schedule

This test is expected to be carried out while creating the drilling system, and will be on the first test that needs to be passed. The full system is not required for this test and only the drilling mechanism needs to be completed. The team expects to have this test completed in early March, shown in the Gantt chart. This test is the highest priority of the team as it is the primary function of the system being created. From the Gantt chart this test will be carried out on the 9th of March. The team must complete the drilling mechanism, the testing surfaces, and preferably the electronic system to control the drilling system.

3.2 Testing Procedure 2: Weight

Weight is an important factor as it will need to under the maximum load the rover can carry and move around. This test is to meet the engineering requirement of weight, and will be conducted by simply weighing the whole system. This test will be completed after the final design is produced.

3.2.1 Testing Procedure 2: Objective

The objective of this test is to create a system that can be easily moved by a rover that will deploy the sampling system, it cannot be too heavy for the rover to move and not too light do that it will have no gravitational effects. The target ER value is 20 kg and is determined to be the desired weight.

3.2.2 Testing Procedure 2: Resources Required

The resources required for this test is a scale, if the system is too large for an in home scale then an industrial scale will be needed. These types of scales are easily found in many rentable testing facilities.

3.2.3 Testing Procedure 2: Schedule

This test is expected to be done when the final design is produced, the full system is required for this test. This will be done by the end of March after the entire project is completed, from the Gantt chart this will take place on March 23rd.

3.3 Testing Procedure 3: Cost

This engineering requirement does not require any tests, the project is expected to cost the team $1,000. The budget given to the team is $1000 and the system is expected to be under this by the client's suggestions. This test will be conducted the whole year and will require each team member to keep track of all spending using the budget.

3.4 Testing Procedure 4: Force

Force testing refers to the engineering requirement of the system overcoming the centrifugal forces that it will not fly off the surface, due to the asteroid and the drill itself. This test will be done mathematically first then tested using multiple magnets. This test will need to be done after the drill and design are created so it may test the project will everything active.

3.4.1 Testing Procedure 2: Objective

The objective of this test is to make sure the magnet used to keep the sampling system on the surface will suffice. This will be affected by the rapid spinning, low gravity of the asteroid, and the upward force from the drill into the surface. The objective is to confirm the magnet used for stability meets what is required.

3.4.2 Testing Procedure 2: Resources Required

Calculations must be done to determine the force acting on the full system. This will be done by using the rotating velocity and gravity of Psyche. After the force is determined a magnet must be made that is strong enough to overcome the forces acting on it. This can be tested using a force gauge. The team will be able to pull the force gauge to the desired amount to test if the magnet will detach or not. If the magnet does not hold at the desired force this will be considered a failure.

3.4.3 Testing Procedure 2: Schedule

This test will be done once the magnet is fully created. From there the team will be able to constantly test and perfect the magnet. This testing will begin once the magnet is completed. The team will plan for early March, however the team has created some leniency in the schedule and the latest this will need to be tested is March the 3rd.

4 Conclusion

In conclusion, although some requirements and testing procedures have changed, the team has developed a plan to ensure that all needs of the client are met and that the system's building & testing schedule will still be on track for success. With these updates finalized, the team will be able to focus on the main drilling function of the system and create a system that can correctly retrieve samples from the Psyche asteroid.

5 Disclaimer

This work was created in partial fulfillment of Northern Arizona University's Capstone Course "ME 486C". The work is a result of the Psyche Student Collaborations component of NASA's Psyche Mission (https://psyche.asu.edu). "Psyche: A Journey to a Metal World" [Contract number NNM16AA09C] is part of the NASA Discovery Program mission to solar system targets. Trade names and trademarks of ASU and NASA are used in this work for identification only. Their usage does not constitute an official endorsement, either expressed or implied, by Arizona State University or National Aeronautics and Space Administration. The content is solely the responsibility of the authors and does not necessarily represent the official views of ASU or NASA.