

FINAL PRODUCT BREAKDOWN

TEAM: 20F11 NAU Psyche Exploration Robot

Due Date: April 23, 2021

Provide several pics of the completed system here:

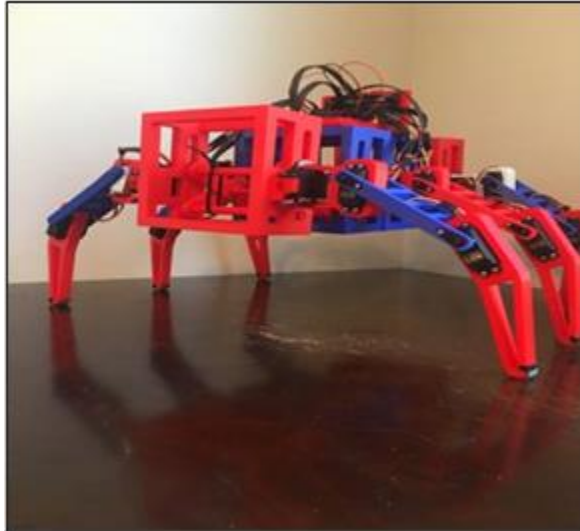


Figure I. Angled View of Small-Scale Model standing in "tpose" position

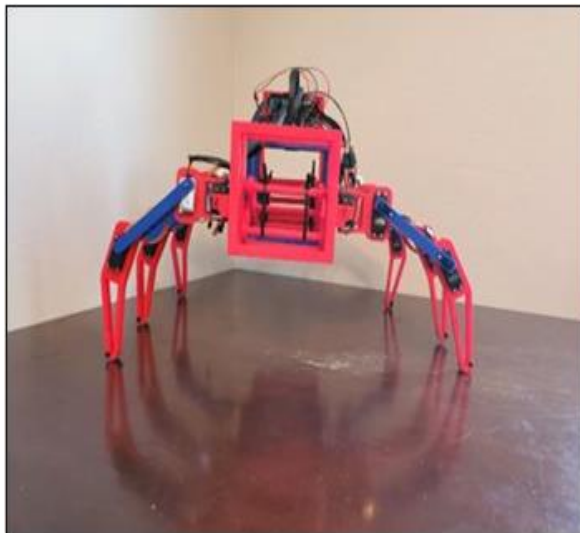


Figure II. Front View of Small-Scale Model standing in "tpose" position

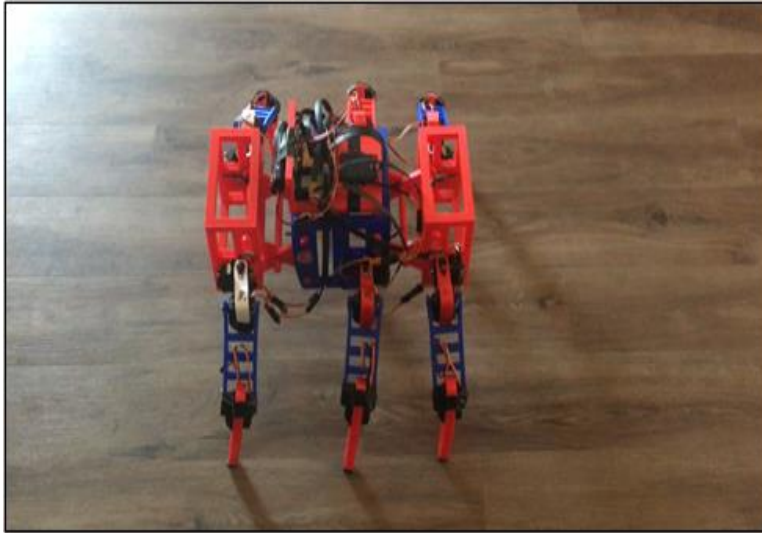


Figure III. Image of Small-Scale Model walking on laminate surface



Figure IV. Image of Small-Scale Model walking on gravel



Figure V. Image of Small-Scale Model walking on sand



Figure VI. Side View of Full-Scale Leg Model



Figure VII. Close-up View of Full-Scale Leg Model claw

The following are the Action Items each person completed between Hardware Review 2 and the completion of the final product:

Team Member: Isaac Anderson


Action Item	Date Completed	Result/Proof of Completion
Finish programming walking sequence for the small-scale model.	4/3/21	Finished working through the angles at which the servos rotate, trial and error. Found the angles that provide the most stability to the model, allowing it to run through the walking sequence. Videos of the small-scale model walking are available in the final presentation (show videos).
Finish testing the small-scale model walking on various surfaces.	4/4/21	The small-scale model was tested on laminate, gravel, sand, concrete, and asphalt. The gravel simulated potential debris ridden areas that could be present on the asteroid. The sand represented finer debris which could also be present on the asteroid. The laminate simulated potentially slick surfaces which could be present on the asteroid.
Finish operations portion on the operation and assembly manual for the small-scale model.	4/13/21	Discussed the primary operations of the small-scale model. Discussed the purpose of the walking program, and how it controls the servos. Also discussed how to operate the model (uploading the program to the Arduino and then running it.)
Finish assembly portion of the operation and assembly manual for the small-scale model.	4/15/21	Provided instructions on how to assemble the small-scale model, given the various pieces. Provided pictures with each step, to ensure the user has little to no difficulty in assembling the model.
Working on Final CAD Package and BOM	4/16-4/22	Developed drawings for each part of the small-scale model. Developed drawing for the full assembly of the model, included BOM of each part made within SW on the model. Turned each drawing into a pdf, just need to combine into one document and order them based on the BOM of the assembly. Will also include the BOM that incorporates prices and hardware not designed within SW.
Working on Final Report	4/19-4/23	Currently have finished the concept generation portion, requirements portion, and benchmarking portion of the report.


Team Member: John Dynda

Action Item	Date Completed	Result/Proof of Completion
Finished the code for the Small-Scale Rover to walk	04/03/2021	Edited the angles for the servos to perfect the walking sequence (Specifically to move the servos either a bit more or less). Proof is in the final presentation where videos are displayed of the rover walking.
Finished the testing portion of the Small-Scale Rover.	04/04/2021	Tested the small-scale model with Isaac on laminate flooring, gravel, and dirt/sandy materials. Also tested on concrete and asphalt, but only have good videos of the laminate, gravel and sand.
Completed the operations and assembly manual for the small-scale rover.	04/16/2021	Completed my portion of the assembly manual as well as editing the operations portion of the manual. Specifically, the electrical components portion and editing the entire document to ensure it had proper formatting and grammar...


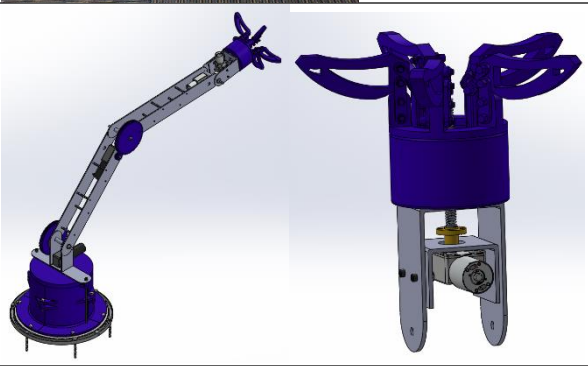
Team Member: Eric "Sean" Sullivan

Action Item	Date Completed	Result/Proof of Completion
Meet with leg group to assemble	03/27/2021	Attached and adjusted the upper arm segment
Meet with leg group to assemble	03/28/2021	Drilled bracket holes to mount motor to lower section of upper arm segment.
Meet with leg group to assemble	03/29/2021	Attached, adjusted and tested the lower arm segment. Drilled the motor mount for the wrist joint.

Print 3d Claw parts	03/30/2021	
Meet with leg group to assemble	03/31/2021	Created first bracket to attach the claw motor and secured the claw in place.
Meet with leg group to assemble	04/01/2021	Issues with bracket. Claw slips off shaft.
Meet with leg group to assemble	04/02/2021	Redesign claw motor bracket
Bend wrist bracket	04/03/2021	Gain access to metal break in Rm119. Thank you Perry.
Reprint 3D claw parts at 100% infill		Reprinted linkages at 100% for claw assembly.

Meet with leg group to assemble	04/04/2021	
Wire the motors	04/06/2021	Testing performed to pick up and move object.

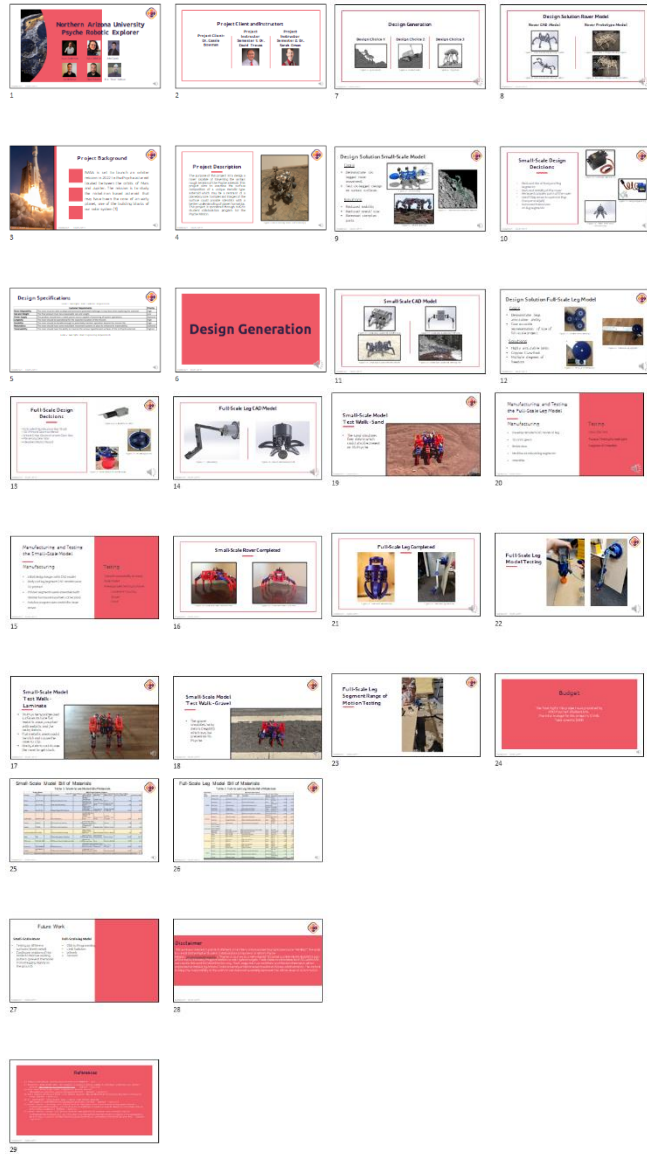
Team Member: Kate Collette

Action Item	Date Completed	Result/Proof of Completion
Meet with leg group to assemble leg (28 hrs)	3/27/21-4/4/21	
Resized CAD files (0.5 hrs)	3/28/21	

<p>Met with team to detail budget (1 hr)</p>	<p>3/30/21</p>	<table border="1"> <thead> <tr> <th></th> <th>A</th> <th>B</th> <th>C</th> <th>D</th> <th>E</th> <th>F</th> </tr> </thead> <tbody> <tr> <td>1</td> <td colspan="6">Purchase Log</td> </tr> <tr> <td>2</td> <td colspan="6">Use any purchase purchase link in this spreadsheet</td> </tr> <tr> <td>3</td> <td colspan="6">Include URL link if possible please</td> </tr> <tr> <td>4</td> <td>Item</td> <td>Price</td> <td>Unit</td> <td>Qty</td> <td></td> <td></td> </tr> <tr> <td>5</td> <td>7-DCI OR Topo Cable: Wisp-Wire Tube Flaw & 90 Fused Speed of 1/8inch ID Pulswire/2 1 Cable Wisp Wire Tube Heat Shrink Tubing</td> <td>21.96</td> <td>pdf receipt in team</td> <td>John</td> <td></td> <td></td> </tr> <tr> <td>6</td> <td>Swimming Motor: Servo Motor: 900005 RC Servo 20kg Metal Gear Corro-KA RC Robot Arm Helicopter Airplane Remote Control (H7CS)</td> <td>26.71</td> <td>pdf receipt in team</td> <td>John</td> <td></td> <td></td> </tr> <tr> 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<p>Worked on wiring motor controller for full-scale model (1.5 hrs)</p>	<p>5/6/21</p>																																																																																																																																																																																							

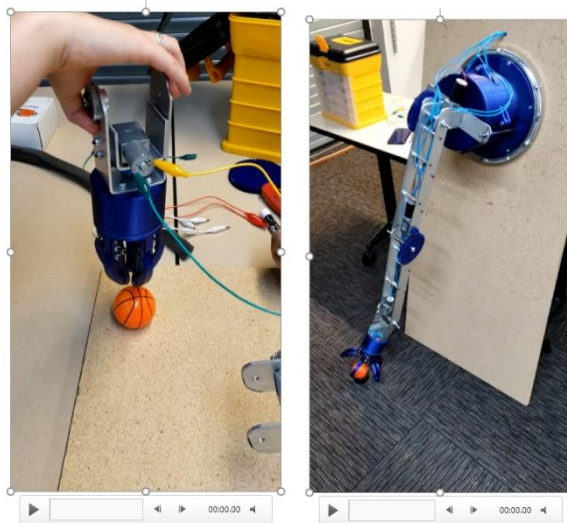
Worked on final presentation for UGRADs (3.5 hrs)

5/7/21



Edited video for UGRADs (1 hr)

5/8/21



3.0 ASSEMBLY

3.1 Base

3.1.1 Plywood Support

- To assemble the Plywood Support, you will need:
 - 1 Plywood Support
 - 1 1/2" Plywood
 - 1 1/2" Plywood

Step 1: Use a saw to cut a piece of plywood to fit around the motor and wiring with a 1/2" gap.

3.1.2 Motor Mount

To assemble the Motor Mount, you will need:

- 1 Motor Mount
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood

Step 1: Begin by gluing the Plywood support to the motor mount and wiring with a 1/2" gap. The motor will be used to drive the blades, so you will need to ensure it is secure.

Step 2: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.

Step 3: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.

Step 4: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.

Step 5: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.



Figure 5: Motor mount assembly

Operations Manual

Page 11

3.1.3 Base Case Box

To assemble the Base Case Box, you will need:

- 1 Base Case Box
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood

Step 1: Begin by gluing the plywood support to the motor mount and wiring with a 1/2" gap. The motor will be used to drive the blades, so you will need to ensure it is secure.

Step 2: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.

Step 3: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.



Figure 6: Base case box assembly

3.1.4 Primary Gear System

To assemble the Primary Gear System, you will need:

- 1 Primary Gear System
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood

Step 1: Begin by gluing the plywood support to the motor mount and wiring with a 1/2" gap. The motor will be used to drive the blades, so you will need to ensure it is secure.

Step 2: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.

Step 3: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.



Figure 7: Primary gear system

Operations Manual

Page 12

3.2 Leg

3.2.1 Shoulder Joint

To assemble the Shoulder Joint, you will need:

- 1 Shoulder Joint
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood

Step 1: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.

Step 2: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.



Figure 8: Leg assembly

3.2.2 Segment 1

To assemble Segment 1, you will need:

- 1 Segment 1
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood

Step 1: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.

Step 2: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.



Figure 9: Shoulder joint assembly

Operations Manual

Page 17

3.2.3 Segment 2

To assemble Segment 2, you will need:

- 1 Segment 2
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood

Step 1: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.

Step 2: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.



Figure 10: Segment 2 assembly

Operations Manual

Page 18

3.3 Motor Bracket

To assemble the Motor Bracket, you will need:

- 1 Motor Bracket
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood

Step 1: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.

Step 2: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.



Figure 11: Motor bracket assembly

3.3.3 Wheel Segment

To assemble the Wheel Segment, you will need:

- 1 Wheel Segment
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood

Step 1: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.

Step 2: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.



Figure 12: Wheel segment assembly

Operations Manual

Page 21

3.3.4 Wheel Segment

To assemble the Wheel Segment, you will need:

- 1 Wheel Segment
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood
- 1 1/2" Plywood

Step 1: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.

Step 2: Place the motor on the plywood support and glue it in place. The motor should be centered on the plywood support.



Figure 13: Wheel segment assembly

Operations Manual

Page 22

Edited draft of final poster
(1 hr)

5/20/21

NAU
NORTHERN ARIZONA UNIVERSITY
Mechanical Engineering

Psyche Robotic Explorer

Isaac Anderson, Kate Collette, John Dyrda, Jacob Sasse, Chad Schafer, Eric "Sean" Sullivan
Department of Mechanical Engineering, Northern Arizona University

Abstract

The aim of this project was to design and prototype a robotic explorer capable of traversing the hypothesized surfaces of the 16 Psyche asteroid. The proposed rover will house various scientific instruments for measuring the surface conditions on the asteroid. The scope of this project includes construction of both a small-scale rover to demonstrate mobility over various surfaces as well as a full-scale model of one leg of the rover to demonstrate leg actuation and claw grip. These prototypes were then validated through a combination of computational and experimental analysis.

Background

The current NASA Psyche Mission is an orbiter mission and will not land on 16 Psyche. It is set to launch in 2022 and arrive at the asteroid in 2026. 16 Psyche is a unique metallic type asteroid which may be the remnants of a planetary core. This mission could help us to further understand planet formation. However, after learning about Psyche from orbit, there may be scientists and engineers interested in proposing a subsequent mission to land on the asteroid. At this time, scientists hypothesize that 16 Psyche could be comprised of surfaces such as flat metallic, flat metallic with metal and/or rocky debris, rough/high-relief metallic and/or rocky terrain, and high-relief metallic crater walls¹. The robotic explorer must be able to traverse each of these hypothesized surfaces. The low gravity on 16 Psyche as well as its distance from the sun could cause further challenges for the explorer.

Project Goals

- Design a rover concept that can traverse the hypothesized surfaces that might be found on 16 Psyche.
- Prototype a small-scale model and full-scale leg model to validate the full-scale design.
- Test the models on different surfaces for maneuverability as well as ability to manipulate objects around the rover.

Design and Testing

The design of the full-scale leg model is based around the concept of "redundancy of method of movement". This concept was created by the team to deal with issues of mechanical or software malfunction after the robotic explorer has been deployed. Since repairing the rover on the asteroid is not possible the system can implement many different methods of movement. Wheels are used to quickly move the rover across flat terrain with few obstructions. The walking movement is designed to traverse debris stream areas as well as to climb in and out of shallow craters. In the event of a major leg malfunction the explorer can also "inchworm" along the ground using a pair of scissor-like extenders which extend and contract to allow the rover to inch across the surface. Finally, there is climbing mode which makes use of the rover's midbody hinge to arch back as well as the inchworm feature to extend up a high relief cliff face and then retract, bringing up the lower segments. Using the claw foot mechanism, designed to use micro-spike grippers, the rover can secure its limbs to the walls of the crater to assist in climbing.



The small-scale model was designed to demonstrate insect-like movement of the rover as well as maneuverability through different substrates that would simulate hypothesized surfaces found on 16 Psyche. This rover was tested on a surface that had a low coefficient of friction ($\mu = 0.1$) to see how it would handle smooth metallic surfaces. Sand was used to test a loosely packed regolith which may be found on the asteroid, and color rocks were used to simulate debris stream surfaces.

The large-scale leg model was designed to illustrate the size of the full-scale rover as well as demonstrate the leg's agility and actuation abilities. This model was tested by picking up small objects analogous to small boulders or possible samples the rover might need to manipulate on the asteroid.

Results

The small-scale model was able to traverse several substrates effectively. Despite the slow movement through the loose debris the rover was still able to move through the substrates.



The testing procedure for the full-scale leg included picking up objects placed in the leg's path and moving them. This type of testing can indirectly demonstrate the movement of walking, which also relies on precise placement of the claw and rotation of the leg joint.



References

¹ Hypothesized Surface: Psyche Explorer - NAU, Arizona State University, Jan 1, 2021. Accessed on April 20, 2021. <https://www.nau.edu/mechanical-engineering/psychex-robotics/psychex-robotics/>

Acknowledgements

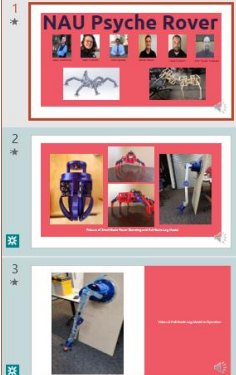

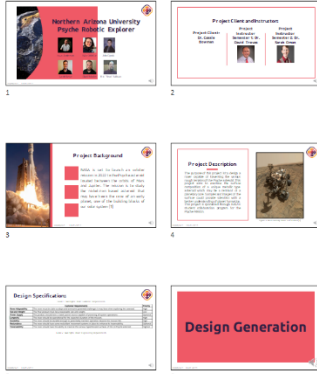
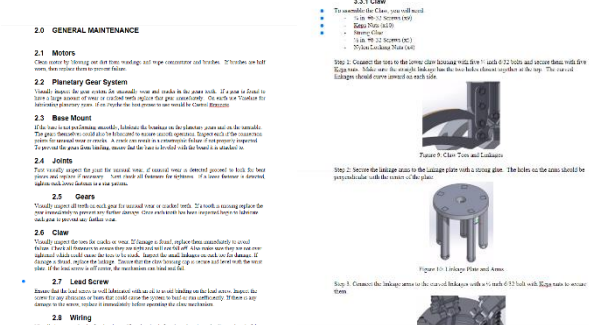
Supporters: Dr. David Trevas (Professor), Dr. Sarah Chua (Professor) & Cassie Breenan (Client Contact/Co-ordinator)
Northern Arizona University, Department of Mechanical Engineering, Chandler Phase 1

Disclaimer



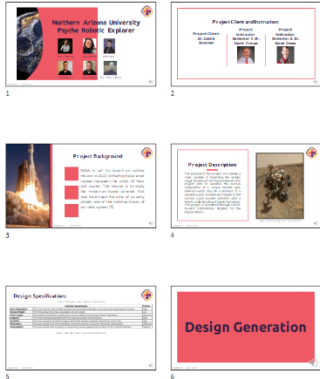
This work was created in partial fulfillment of Northern Arizona University's Graduate Course "ME6600". The work is a result of the creative process of individuals concerned with the design of a robotic explorer. The work is not intended to be a "final report" (as such) and should not be used for any other purpose without the express written consent of the author(s). The work is not intended to be a "final report" (as such) and should not be used for any other purpose without the express written consent of the author(s). The work is not intended to be a "final report" (as such) and should not be used for any other purpose without the express written consent of the author(s).

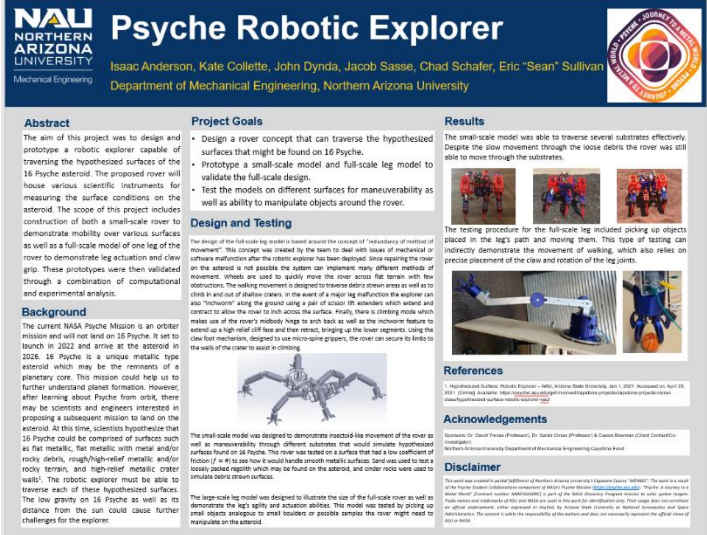
Team Member: Jacob Sasse

Action Item	Date Completed	Result/Proof of Completion
Worked with leg team to assemble the prototype.	3/27/21-4/4/21	
Redesigned parts of the claw to allow for easier 3d printing.	3/28/21	

<p>Worked on presentation for client.</p>	<p>5/4/21</p>	
<p>Worked with leg team on wiring and programing the model.</p>	<p>5/6/21</p>	
<p>Worked with team on the final UGRADS presentation.</p>	<p>5/7/21</p>	
<p>Worked on UGRADS Presentation voice recordings.</p>	<p>5/8/21</p>	<p>Recorded the sections regarding the design generation and the wooden prototype the team built at the beginning of the semester.</p>
<p>Worked on operations and assembly manual.</p>	<p>5/11/21-5/16/21</p>	

Team Member: Chad Schafer

Action Item	Date Completed	Result/Proof of Completion
Worked on assembly of the full-scale leg model	3-27-4-21	
Worked on wiring with team	5-6-21	
Worked on UGRADS prestation	5-7-21	
Worked on operations Manual	5-11-5-26	<p>2.0 GENERAL MAINTENANCE</p> <p>2.1 Motors Check motor wiring for any loose wiring, add tape connections and tighten. If trouble see ball bearings for motor bearing removal.</p> <p>2.2 Primary Gear System Visually inspect the gear system for wear and make in the gear teeth. If gear is found to have a large amount of wear or visible teeth signs that gear should be replaced. The gear is finished by lubricating gear teeth with grease. If the gear is found to be worn or damaged, it should be replaced. The gear is finished by lubricating gear teeth with grease. If the gear is found to be worn or damaged, it should be replaced.</p> <p>2.3 Base Mount Check the base mount for any cracks or damage. Lubricate the base mount with grease. The gear is finished by lubricating gear teeth with grease. If the gear is found to be worn or damaged, it should be replaced. The gear is finished by lubricating gear teeth with grease. If the gear is found to be worn or damaged, it should be replaced.</p> <p>2.4 Joints Test visually inspect the joint for any cracks or damage. If a crack is found, the joint should be replaced. The joint is finished by lubricating joint with grease. If the joint is found to be worn or damaged, it should be replaced.</p> <p>2.5 Gears Visually inspect all gears in the gear system for wear and make in the gear teeth. If gear is found to have a large amount of wear or visible teeth signs that gear should be replaced. The gear is finished by lubricating gear teeth with grease. If the gear is found to be worn or damaged, it should be replaced.</p> <p>2.6 Claw Visually inspect the claw for any cracks or damage. Lubricate the claw with grease. The claw is finished by lubricating claw with grease. If the claw is found to be worn or damaged, it should be replaced. The claw is finished by lubricating claw with grease. If the claw is found to be worn or damaged, it should be replaced.</p> <p>2.7 Lead Screw Check the lead screw for any cracks or damage. Lubricate the lead screw with grease. The lead screw is finished by lubricating lead screw with grease. If the lead screw is found to be worn or damaged, it should be replaced. The lead screw is finished by lubricating lead screw with grease. If the lead screw is found to be worn or damaged, it should be replaced.</p> <p>2.8 Wiring Visually inspect all wiring in the system for any loose wiring, add tape connections and tighten. If trouble see ball bearings for motor bearing removal.</p>
Completed voice over UGRADS prestation	5-8-21	Explained each slide by recording

Worked on final report	4-20-21	Updated the final report with all the team's progress.
Read over final poster	5-20-21	 <p>NAU NORTHERN ARIZONA UNIVERSITY Mechanical Engineering</p> <h2>Psyche Robotic Explorer</h2> <p>Isaac Anderson, Kale Collette, John Dynda, Jacob Sasse, Chad Schafer, Eric "Sean" Sullivan Department of Mechanical Engineering, Northern Arizona University</p> <p>Abstract The aim of this project was to design and prototype a robotic explorer capable of traversing the hypothesized surfaces of the 16 Psyche asteroid. The proposed rover will house various scientific instruments for measuring the surface conditions on the asteroid. The scope of this project includes construction of both a small-scale rover to demonstrate mobility over various surfaces as well as a full-scale model of one leg of the rover to demonstrate leg actuation and claw grip. These prototypes were then validated through a combination of computational and experimental analysis.</p> <p>Background The current NASA Psyche Mission is an orbiter mission and will not land on 16 Psyche. It is set to launch in 2022 and arrive at the asteroid in 2026. 16 Psyche is a unique metallic-type asteroid which may be the remnants of a planetary core. This mission could help us to further understand planet formation. However, after learning about Psyche from orbit, there may be scientists and engineers interested in proposing a subsequent mission to land on the asteroid. At this time, scientists hypothesize that 16 Psyche could be comprised of surfaces such as flat metallic, flat metallic with metal and/or rocky inlays, rough/high-relief metallic and/or rocky terrain, and high-relief metallic crater walls. The robotic explorer must be able to traverse each of these hypothesized surfaces. The low gravity on 16 Psyche as well as its distance from the sun could cause further challenges for the explorer.</p> <p>Project Goals</p> <ul style="list-style-type: none"> • Design a rover concept that can traverse the hypothesized surfaces that might be found on 16 Psyche. • Prototype a small-scale model and full-scale leg model to validate the full-scale design. • Test the models on different surfaces for maneuverability as well as ability to manipulate objects around the rover. <p>Design and Testing The design of the full-scale leg model is based around the concept of "refraction of motion of movement". This concept was created by the team to deal with issues of mechanical or software malfunction after the robotic explorer has been deployed. Since repairing the rover on the asteroid is not possible the system can implement many different methods of movement. Wheels are used to quickly move the rover across flat terrain with low obstructions. The walking movement is designed to traverse debris or uneven terrain as well as climb in and out of shallow craters. In the event of a major leg malfunction the explorer can also "inchworm" along the ground using a pair of silicon lift actuators which extend and contract to allow the rover to inch across the surface. Finally, there is a climbing mode which makes use of the rover's midbody hinge to inch back as well as the inchworm feature to extend on a high-relief cliff face and then reeled, bringing up the lower segments. Using the claw foot mechanism, designed to use micro-grip grippers, the rover can secure to limbs to the walls of the crater to assist in climbing.</p> <p>Results The small-scale model was able to traverse several substrates effectively. Despite the slow movement through the loose debris the rover was still able to move through the substrates.</p> <p>The testing procedure for the full-scale leg included picking up objects placed in the leg's path and moving them. This type of testing can indirectly demonstrate the movement of walking, which also relies on precise placement of the claw and rotation of the leg joints.</p> <p>References 1. "Exploring Psyche: Psyche Robotic Explorer - NAU, Arizona State University, Jan. 1, 2021. Accessed on April 20, 2021." (https://www.mech.nyu.edu/~isaacanderson/psyche-robotic-explorer/)</p> <p>Acknowledgements Sponsors: Dr. Jacob Pezdek (Professor), Dr. Sarah Grimes (Professor), & Cassin Bowman (Client Contact/Co-Investigator) Northern Arizona University Department of Mechanical Engineering Graduate Student</p> <p>Disclaimer This work was created as a part of the Department of Mechanical Engineering's Graduate Course "M6500". The work is a result of the Psyche Robotic Explorer's development of small-scale models and full-scale leg model. There is no warranty or liability for the work. The work is a result of the graduate student's independent work and is not endorsed by the Department of Mechanical Engineering. 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