Spring 2023

JPL Robotic Avionics & Sensor Kit (RASK)

John Helzer
University of Nebraska-Lincoln

Leadership
John Helzer
9 May 2023

There's a saying that "too many cooks will spoil the broth", which is intended to mean that too many leaders on a team will cause chaos and unproductiveness. However, as anybody who has either seen The Great British Baking Show or been on a team full of successful leaders knows, there is no such thing as too many cooks, even for a simple food like broth. Leadership is not about position or responsibility, and great leaders are able to adapt to different roles and function well in any position on a team.

One of the skills that great leaders have is versatility. The responsibilities of a team leader are very different from those of a team member, but a great leader is able to be successful in either role. Team leaders are typically responsible for the organization, planning, and communication of a project. For example, the team leader of our senior capstone project set up a weekly update document to send to our sponsor, monitored our budget and schedule to ensure we were staying on track, and served as the primary point of contact for communications with our team sponsor, faculty advisor, and class professor. While ultimately every team member is responsible for the project's organization, having one person dedicated to project management ensured that responsibility wouldn't get deflected or diffused among the team.

In addition to project management, team leaders also have to lead the team members to success. It is very important here to distinguish between leadership and management. A *project* can be managed, but *people* must be led. Management of a project involves focusing on the details, making sure objectives are met and the project follows an organized path. Leadership of people means ensuring everyone is involved and contributing to the project and giving people the tools they need to be successful (meet objectives). The key for a great leader is understanding what type of leadership works best for every team member. Some people need to be "managed" and given lots of direction, but others work best with a hands-off approach. In order for a project to be successful, the team leader must enable the team members to be successful.

The last responsibility of a team leader is to work as a team member, but almost a "team member plus". This means that while a team leader has individual duties, they are also responsible for the success of the entire project. In addition to project management and leadership, a leader must also pick up any extra work that needs to be done for the project to succeed. This is why many managers in industry work more hours than their employees.

The most important responsibility of a team member in creating a successful project is to embrace the team leader's leadership. Sometimes bad leaders get uncomfortable as a team member and

push to be in charge. Good leaders, however, respect their leader and help them be successful. In addition, the role of a successful team member is to pull their weight and make sure there is no slack for the leader to pick up.

A great leader can function as a leader or a team member, but the role that they make the most impact in depends on their individual strengths & interests and the needs of the team & project. For example, if a team is comprised of motivated and skilled self starters that don't need much direction or a project is simple and doesn't require much planning, a leader may find their time best spent working as a member of the team instead of providing leadership that is not needed. On the other hand, if a project is complex or a team needs lots of direction, having a strong leader may be more impactful.

The impactfulness of a leader also depends on their comfort and experience level with the roles of team member and leader. Sometimes in industry, for example, a manager might oversee team members on an interdisciplinary project despite the manager not having experience with all the disciplines. In this case, the manager would be much more impactful as a leader than as a team member. The same is true if a leader lacks experience as a leader- while gaining leadership experience would be beneficial overall, they would have much more impact as a team member instead of an inexperienced leader.

I had the opportunity to experience being a leader for one semester and a team member for the second semester in our senior capstone project. While I was comfortable with both roles, I felt more productive as a team member than a leader. This was for several reasons. First, everyone in our group is motivated and doesn't require much leadership. This meant that my main work as a leader was just project management and communication, such as with our project sponsor and our senior design professor, Dr. Palik. Secondly, project management is not one of my strengths. I have experience leading my peers in other groups, such as my Aerospace subteam, but I'm much better at breaking down work into necessary tasks than I am at delegating it or assigning the project to a timeline. Luckily for our group, our second semester team leader Kasey is much better at schedules and timing a project. Therefore, I was more productive when I spent less of my time on my weak areas. Finally, I had more time to do work when I was a team member, so I was more productive overall. I was able to construct most of the CAD for the updated lens cover mechanism second semester, whereas first semester, I only had time to make a few simple prototypes. In a different situation where the project required less management or our team members needed more direction, my work as a leader might have been more productive. However, with this particular project my skills were most productive as a team member.

This senior design project has taught me about both sides of leadership: being a leader and being a team member. Through undertaking both roles, I've learned how to lead a successful team and how to allow a team to be led by someone else, so I'm not just one of "too many cooks". This versatility will allow me to be a great leader so that no matter what role I assume on a team, I will be able to contribute to its success.

UNIVERSITY OF NEBRASKA-LINCOLN
DEPARTMENT OF MECHANICAL & MATERIALS ENGINEERING

SENIOR DESIGN II
POST-MORTEM REPORT

JPL Robotic Avionics & Sensor Kit (RASK)

Team 24: John Helzer, John Cerny, Jack Doan, Kasey Moomau, and Idreis Bari

Author: John Helzer

Sponsor: NASA JPL

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Executive summary

As part of NASA Artemis program, NASA plans on testing cold-operable robotics arms in the pursuit of knowledge. The Cold Operable Lunar Deployable Arm (COLDArm) will improve the utility of robotic operations for lunar landers. The objective is to have a robotic manipulator that can work in the extremely low temperatures in space, where temperatures can go as low as -280°F (-173 °C). Our senior design group was approved to help with this project. The section we are working on is the RASK camera box, used for 3D mapping, autonomy, lunar surface imaging, and other general operations. Our goal is to improve the lunar surface imaging capabilities of the RASK by updating the housing, lighting, and lens cover mechanisms to support addition of updated cameras, as well as vibrational tests.

The redesign of the camera box imaging, illumination, and lens covering design was designed in SolidWorks and 3D printed. Preliminary testing was done at UNL to ensure that adequate lumens and functionally. In addition the prototype will be shipped to JPL and further testing will be done.

Budget

Category	Total	Estimated cost	Spent
JPL/NASA NE	$1,600.00	$900.00	$1,430.00
Electrical components		$200.00	$200.00
Hardware		$400.00	$900.00
Shipping		$0.00	$30.00
Test Supplies		$300.00	$300.00
	Under budget by $170		

Final budget

Our final budget is shown above. We were under budget by $170. We spent more on hardware than we had planned as we iterated through prototypes. However we still completed our prototype and testing without exceeding our project's spending limit.

Our budget is similar to our initial budget (shown below), but with some very notable changes. First, our original budget included $1600 from JPL as well as $7000 from a separate NASA NE space grant. We had estimated costs of $7620, so we were predicted to be under budget by $980. However, we found out for undisclosed reasons that the $7000 from NASA NE space grant was no longer available, so our budget dropped to $1600. Secondly, our original

budget included $4500 for students to travel to JPL to test the final design in-person. However, changes in student availability and the removal of the $7000 space grant funding prevented this.

By removing student travel and spending less on overall supplies, we successfully stayed under budget. We also conservatively planned to spend only $900 of our $1600 budget, so we had enough margin for error that even with spending $530 more than expected, we were under budget.

Budget

JPL / NASA Nebraska Space Grant

$1600

NASA Nebraska Space Grant

$7000

Total

$8600

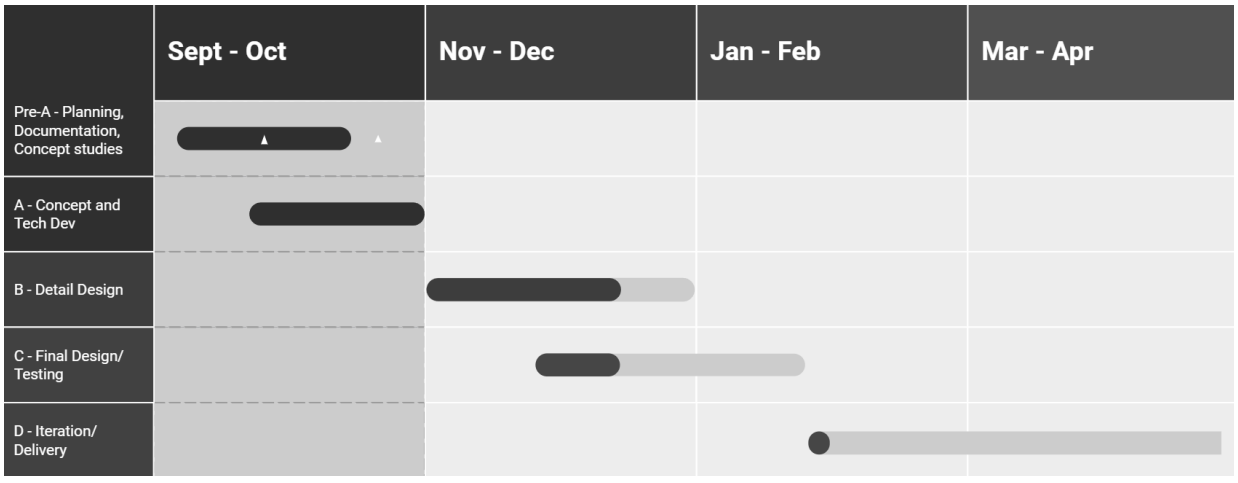
Spent

$0

Category	Total	Estimated cost	Spent	Available
JPL/NASA NE	1600		0	
4 NIS memberships		720		
KM/NASA NE	7000		0	7000
Supplies	3600		0	3600
3D printing filament		200		
Aluminum		200		
Optical Lunar Simulant		400		
Hardware		400		
Electrical components		600		
Test rig components		600		
Operating Expens	1600		0	1600
Thermal chamber time				
Machining				
Domestic Travel	1800		0	1800
5 people to JPL		4500		
Totals	8600	7620	0	8600

Original budget

Timeline



Final timeline

Our final timeline is shown above. We did not update our timeline after the first semester. While the basic project phases remain the same, some of the original tasks changed.

Using NASA's Systems Engineering Handbook, we developed a resilient plan for completing the project. Working ahead of schedule meant we had the flexibility to adapt to unforeseen circumstances, such as needing extra time to verify our safety protocols with EHS and having no assigned workspace at UNL without sacrificing our client's objectives in the process. Some of the challenges to keeping our project on schedule were:

1. Delays in shipping electronic components
2. Lack of availability from team members due to busy semester
3. Inability to test at UNL due to EHS safety protocols and lack of space

We ultimately mitigated these problems by building in enough spare time to ensure that our project could be completed in a timely manner.

Recap of previous post mortem report

The post mortem report I wrote last semester for Mech 446 began by discussing the project overview, such as the budget, timeline, and overall health of the project. At that point, our budget was healthy (we had spent 0$), and our timeline was a bit behind, but still on track.

The report then covered project improvement ideas. The areas of improvement were identified as sponsor communication about constraints and sponsor feedback on our designs. We had issues early in the project with our sponsors not giving us the design constraints, or at least not until after we had made design changes. We also struggled because our sponsors didn't give us timely design feedback on our concepts. For example, we had made a full CAD model of a lid design that used a motor instead of springs before the sponsor told us it wasn't feasible.

The next area covered in the old post mortem report was design improvements. The two changes suggested were updating the lens cover design (to fix the sponsor's issues with the roller concept) and to shift the lenses backward to allow for better fastening of the camera holder to the main box.

The final area of improvement covered in the post mortem report was project team interaction. The main problem identified in our project-team interaction was that each team member mainly worked on one specific subsystem, so team members didn't have a comprehensive analysis of the entire project. I thought that this could be fixed in two ways: team members working on multiple subsystems and multiple people working on each subsystem.

After identifying areas of project improvement, the post mortem report included an action plan. The action items were:

1. **Pressing sponsor for more design requirements and feedback**
2. **Shifting lenses back**
3. **Updating lens cover**
4. **Members working on multiple subsystems, more people working on each subsystem**

Of these action items, 1 and 3 were implemented, while 2 and 4 were not. We implemented "pressing sponsor for more design requirements and feedback" by following up in emails if our questions weren't answered. Additionally, our second semester team leader Kasey was very good at persistently pressing JPL to answer questions in the weekly meetings. This was successful; we received feedback on our designs and made a prototype without having to rework it due to updated requirements. Action item 3, updating the lens cover, was implemented by changing the CAD and ensuring the design fit into the "do not exceed" volume specified by JPL.

Action items 2 and 4 were not implemented. Action item 2, "shifting lenses back", was ignored because the updated CAD for the camera box was modified to fit the connections on the main box without shrinking or moving back. Additionally, the updated design for the lens cover mechanism and LED tray removed the need for a different camera location. Action item 4, "members working on multiple subsystems, and more people working on each subsystem" was also not implemented. Most of this was due to time; early in the semester we struggled to find time to coordinate meetings with the group. However, we solved the problem of members being unfamiliar with all the subsystems by initiating weekly group meetings to work on the project and posting regular updates in our Discord project group. This ensured that all members, even if not intimately familiar with the details of each system, had a working knowledge of all the facets of the project.

Project Evaluation

Overall, the senior capstone project was successful. Our original deliverables were:

- Deliver drawing package
- Deliver report on design process (supported by a PDR and CDR)
- Deliver illumination testing
- Deliver thermal and vibrational analysis
- Report on work to NASA NE, present at Nebraska Academy of Sciences
- Stay on schedule and budget

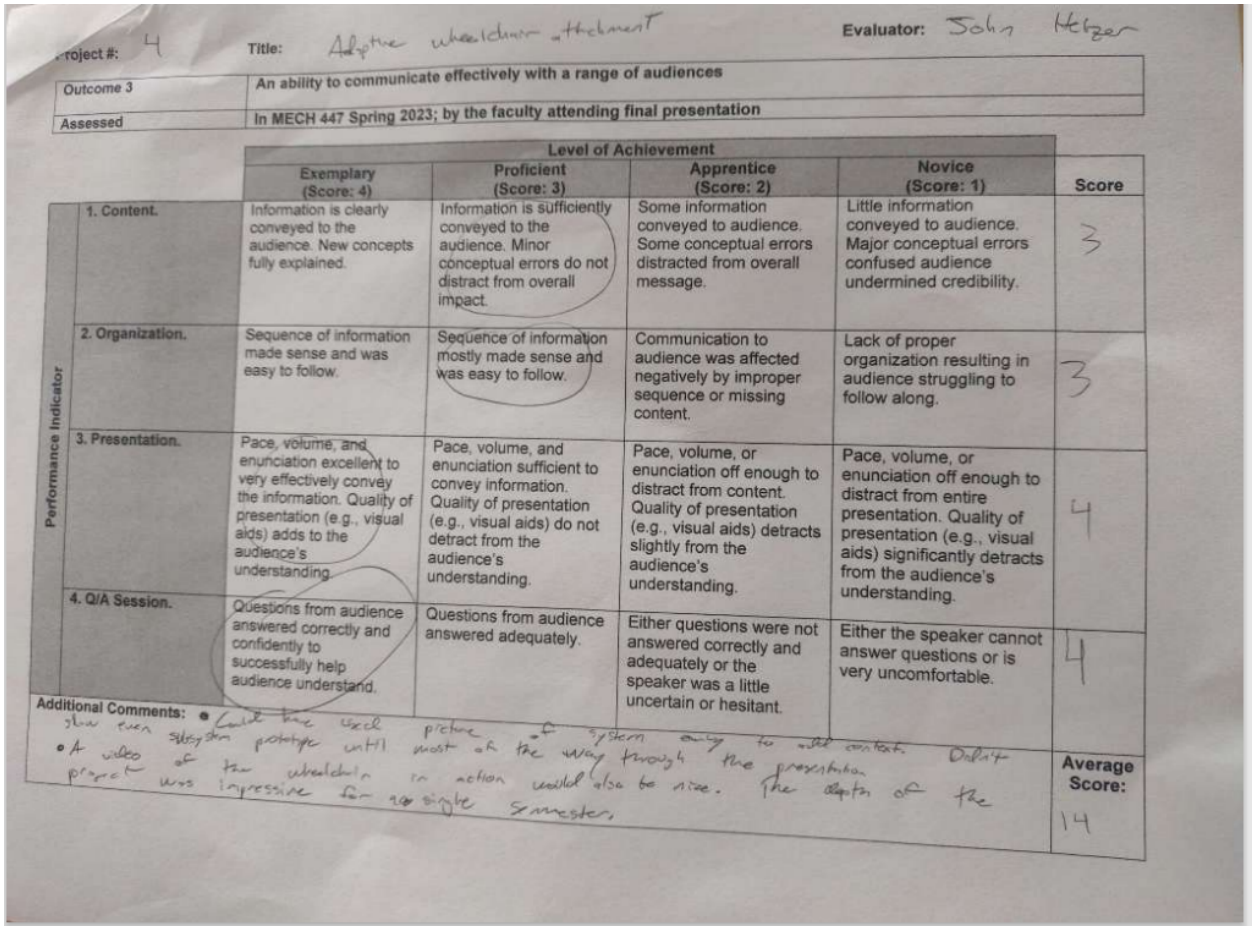
According to these deliverables, our project was a success. We actually delivered CAD models to our sponsor instead of drawings, because the raw CAD files were more useful to them. We also evaluated our project through a PDR (not a CDR, because of time), and we delivered illumination testing results. We conducted vibrational analysis on the final design at a range of frequencies that realistically predicted launch and landing loads. Thermal analysis was discarded as a deliverable after our sponsor informed us that the camera flashes were only for fractions of a second, so heat generated would be negligible. We virtually presented a poster at Nebraska Academy of Sciences. Finally, we stayed on schedule and budget. Our successes were mainly due to proper project management, individual leadership and motivation, and communication between team members that allowed feedback on designs and ensured the whole team was on the same page.

Despite our overall success, the project could have been improved in several ways. First, we could have incorporated weekly work meetings earlier. After evaluating our performance after the first semester, we decided that we should communicate more throughout the team so everyone was better informed about all facets of the project. We initially started the second semester by just planning to meet after our weekly sponsor meetings. However, we didn't have dedicated team work meetings until about a third of the way through the second semester, when we realized that people tended to be busy before and after the sponsor meetings. Starting formal team meetings earlier could have increased the amount of work we did in the second semester.

Secondly, we could have more actively searched for the voice of the customer. Although we definitely improved this second semester, our progress first semester was delayed by mixed information and having to rework designs that turned out to conflict with customer requirements. A stronger approach to seeking constraints and design feedback early would have optimized our time and made the project more successful.

The final improvement that would have increased the success of this project comes from outside the team. Senior design currently only counts for 2 credit hours, which means that in theory, students spend less time weekly on senior design than typical 3 credit hour classes. However, senior design requires more time than most 3 credit hour classes, so dedicating it as a 3 or 4 credit hour class would increase the amount of relative time students have in their schedule. Instead of taking 15 credit hours with 13 credit hours apart from senior design, students would take 15 credit hours with only 11 or 12 credit hours apart from senior design. Additionally, and I want to be very careful how my tone comes off here, senior design projects should be funded. As much as this is a great learning opportunity, and it definitely is, we are doing work that produces profit for companies, so we should be monetarily compensated. Otherwise, our labor is being stolen. If we received personal compensation for senior design projects, we could dedicate more time to our project instead of working other jobs to pay our expenses.

I really enjoyed this class and project. My involvement in Aerospace Club and this JPL project has spoiled me with opportunities, but I am conscious of how unique it is for undergraduate students to work on projects that will one day touch the stars and change humanity's future.



Project #: 4 Title: Adaptive wheelchair attachment Evaluator: John Helzer

Outcome 3	An ability to communicate effectively with a range of audiences
Assessed	In MECH 447 Spring 2023; by the faculty attending final presentation

Performance Indicator	Level of Achievement: Exemplary (Score: 4)	Proficient (Score: 3)	Apprentice (Score: 2)	Novice (Score: 1)	Score
1. Content.	Information is clearly conveyed to the audience. New concepts fully explained.	Information is sufficiently conveyed to the audience. Minor conceptual errors do not distract from overall impact.	Some information conveyed to audience. Some conceptual errors distracted from overall message.	Little information conveyed to audience. Major conceptual errors confused audience undermined credibility.	3
2. Organization.	Sequence of information made sense and was easy to follow.	Sequence of information mostly made sense and was easy to follow.	Communication to audience was affected negatively by improper sequence or missing content.	Lack of proper organization resulting in audience struggling to follow along.	3
3. Presentation.	Pace, volume, and enunciation excellent to very effectively convey the information. Quality of presentation (e.g., visual aids) adds to the audience's understanding.	Pace, volume, and enunciation sufficient to convey information. Quality of presentation (e.g., visual aids) do not detract from the audience's understanding.	Pace, volume, or enunciation off enough to distract from content. Quality of presentation (e.g., visual aids) detracts slightly from the audience's understanding.	Pace, volume, or enunciation off enough to distract from entire presentation. Quality of presentation (e.g., visual aids) significantly detracts from the audience's understanding.	4
4. Q/A Session.	Questions from audience answered correctly and confidently to successfully help audience understand.	Questions from audience answered adequately.	Either questions were not answered correctly and adequately or the speaker was a little uncertain or hesitant.	Either the speaker cannot answer questions or is very uncomfortable.	4

Additional Comments:
- Could have used picture of system early to set context. Didn't show even subsystem prototype until most of the way through the presentation.
- A video of the wheelchair in action would also be nice. The adaptation of the project was impressive for a single semester.

Average Score: 14

Team 4: adaptive wheelchair attachment

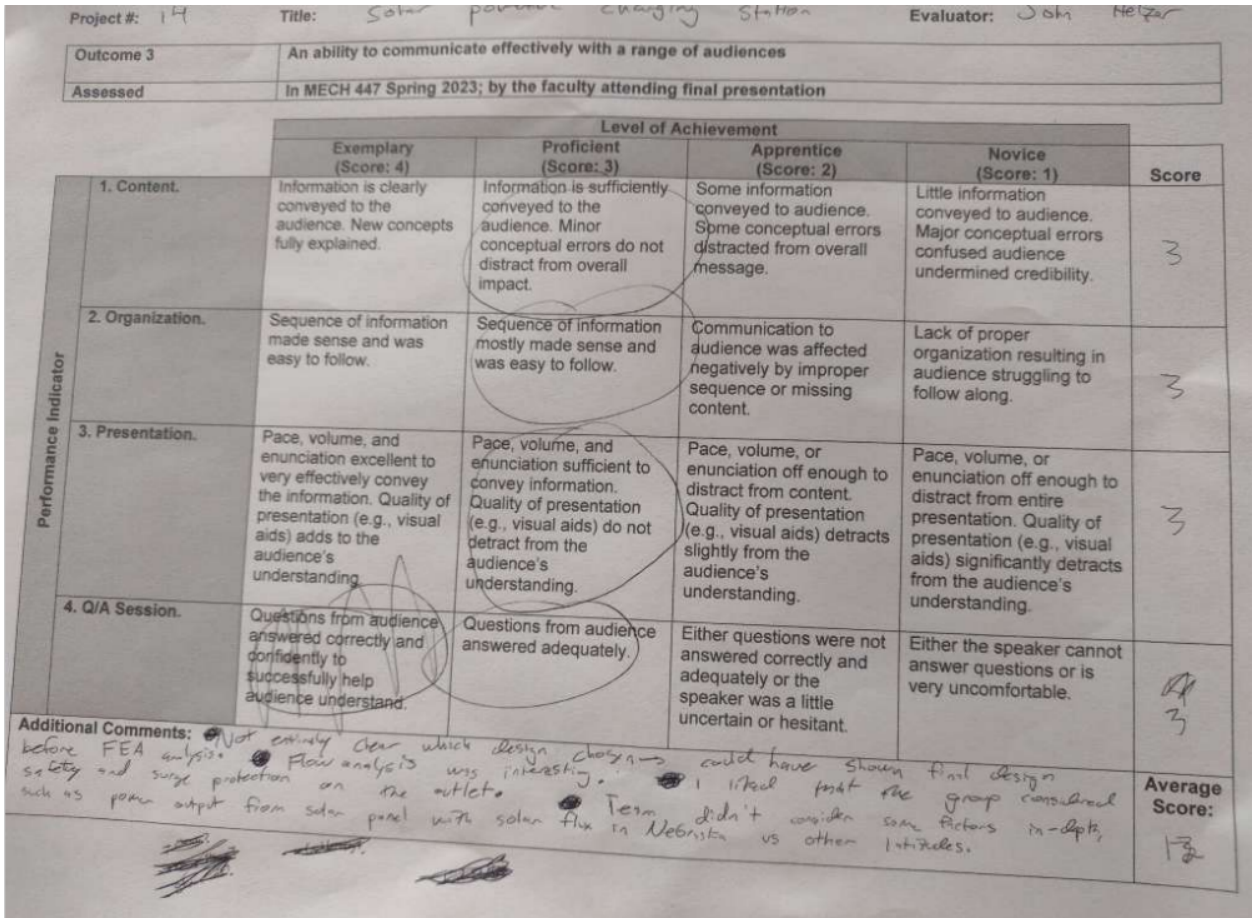
1. Content
    a. The team's overall content was very good. They covered all systems and had obviously put a lot of work into the project, something that was even more impressive since they only had 5 months to work on it. The reason I scored them a 3 instead of a 4 was that they didn't include pictures of the system until almost the end of the presentation. The pictures they did have were just of the subsystem, not of the entire design. Pictures or CAD models early in the presentation would help the audience understand the design better.
2. Organization
    a. The organization of the presentation was overall good. They included all the necessary elements of a final presentation and it was easy to follow the flow of the project. One improvement would be to discuss the electronics after discussing the layout and mechanical workings of the device; that way, the audience would have a better idea of what the electronics' function was.
3. Presentation
    a. The presentation of the team was very smooth. All team members were obviously comfortable with the information and experienced at public speaking.

They referenced slides when discussing them and overall had a very compelling presentation.

4. Q/A session
    a. The team answered all questions well and obviously were comfortable with the project.

Other comments:

- Overall this team was really good! They could have added more pictures/videos of the project in the presentation, but I'm impressed by how much they accomplished in a single semester.



Project #: 14 Title: Solar powered charging station Evaluator: Josh Helzer

Outcome 3	An ability to communicate effectively with a range of audiences
Assessed	In MECH 447 Spring 2023; by the faculty attending final presentation

Performance Indicator	Level of Achievement: Exemplary (Score: 4)	Proficient (Score: 3)	Apprentice (Score: 2)	Novice (Score: 1)	Score
1. Content.	Information is clearly conveyed to the audience. New concepts fully explained.	Information is sufficiently conveyed to the audience. Minor conceptual errors do not distract from overall impact.	Some information conveyed to audience. Some conceptual errors distracted from overall message.	Little information conveyed to audience. Major conceptual errors confused audience undermined credibility.	3
2. Organization.	Sequence of information made sense and was easy to follow.	Sequence of information mostly made sense and was easy to follow.	Communication to audience was affected negatively by improper sequence or missing content.	Lack of proper organization resulting in audience struggling to follow along.	3
3. Presentation.	Pace, volume, and enunciation excellent to very effectively convey the information. Quality of presentation (e.g., visual aids) adds to the audience's understanding.	Pace, volume, and enunciation sufficient to convey information. Quality of presentation (e.g., visual aids) do not detract from the audience's understanding.	Pace, volume, or enunciation off enough to distract from content. Quality of presentation (e.g., visual aids) detracts slightly from the audience's understanding.	Pace, volume, or enunciation off enough to distract from entire presentation. Quality of presentation (e.g., visual aids) significantly detracts from the audience's understanding.	3
4. Q/A Session.	Questions from audience answered correctly and confidently to successfully help audience understand.	Questions from audience answered adequately.	Either questions were not answered correctly and adequately or the speaker was a little uncertain or hesitant.	Either the speaker cannot answer questions or is very uncomfortable.	4 3

Additional Comments: Not entirely clear which design choices could have shown final design before FEA analysis. Flow analysis was interesting. I liked that the group considered safety and surge protection on the outlets. Team didn't consider some factors in-depth, such as power output from solar panel with solar flux in Nebraska vs other latitudes.

Average Score: 3

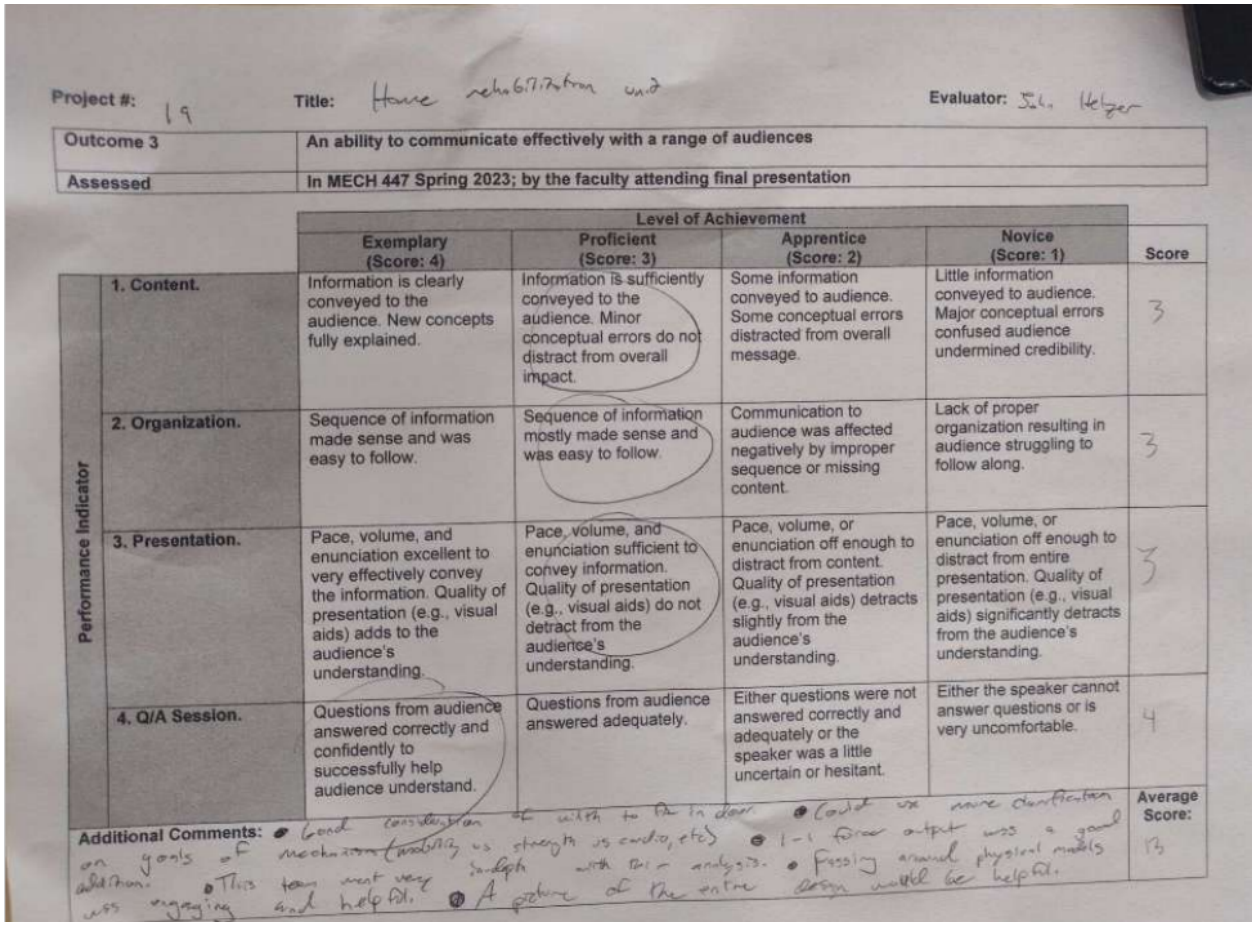
Team 14: solar powered charging station

1. Content
    a. This team included all the necessary information, but it was obvious that they failed to conduct some necessary analysis. While they did consider outdoor safety for the solar powered station, like surge protection and GFCI protected outlets, they also didn't analyze thermal effects or the potential for the station to tip in the wind. On the other hand, the analysis they did conduct seemed accurate and had adequate factors of safety.

2. Organization
    a. The organization of this project was adequate. The team had all the necessary elements, but could have included pictures or CAD models of the final design before the FEA analysis to make it clear to the audience which design was picked. The sequence of information was followable, but the final design wasn't shown until the end of the presentation.
3. Presentation
    a. The team's presentation wasn't perfect, but it wasn't distracting. Team members could work on public speaking skills like not using filler words (um, uh, etc) and practicing smoother explanations. Overall though, the presentation was adequate.
4. Q/A session
    a. The team answered questions adequately, but were not entirely confident with the project. There was one occasion where one team member started explaining an answer, then another team member jumped in with a different explanation. They also didn't seem comfortable talking about the derivation of the solar panel angle.

Other comments:

- I liked the flow analysis- it was interesting to see the effects of drag on the solar panel. Overall, the team did an ok job, it just would have been nice to see more in-depth analysis.



Project #: 19 Title: Home rehabilitation unit Evaluator: Jil. Helzer

Outcome 3	An ability to communicate effectively with a range of audiences
Assessed	In MECH 447 Spring 2023; by the faculty attending final presentation

Performance Indicator	Level of Achievement: Exemplary (Score: 4)	Proficient (Score: 3)	Apprentice (Score: 2)	Novice (Score: 1)	Score
1. Content.	Information is clearly conveyed to the audience. New concepts fully explained.	Information is sufficiently conveyed to the audience. Minor conceptual errors do not distract from overall impact.	Some information conveyed to audience. Some conceptual errors distracted from overall message.	Little information conveyed to audience. Major conceptual errors confused audience undermined credibility.	3
2. Organization.	Sequence of information made sense and was easy to follow.	Sequence of information mostly made sense and was easy to follow.	Communication to audience was affected negatively by improper sequence or missing content.	Lack of proper organization resulting in audience struggling to follow along.	3
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4. Q/A Session.	Questions from audience answered correctly and confidently to successfully help audience understand.	Questions from audience answered adequately.	Either questions were not answered correctly and adequately or the speaker was a little uncertain or hesitant.	Either the speaker cannot answer questions or is very uncomfortable.	4
					Average Score: 13

Additional Comments: • Good consideration of with to fit in door • Could use more clarification on goals of mechanism (mobility vs strength vs cardio, etc) • 1-1 force output was a good addition. • This team went very in-depth with their analysis. • Passing around physical models was engaging and helpful. • A picture of the entire design would be helpful.

Team 19: Home rehabilitation unit

1. Content
    a. The content was very in-depth and the team obviously considered many factors in their design. For instance, they imposed a constraint of the system being less than 36 inches wide to fit inside standard house doors, and they used a 1-1 force output from the trainer to the client. It seemed like they conducted plenty of testing as well; the 3d models they used were the result of repeated iteration. The reason I gave a 3 instead of a 4 on this section was that the team did not include a picture of the entire system in their presentation.
2. Organization
    a. As with other teams (even my own team, looking back), this team could have included a picture or CAD model of the design early in the presentation so the audience had a mental picture of the concept. Other than that, though, their presentation was well organized and easy to follow.
3. Presentation
    a. The team seemed fairly confident in their content and presentation. There were a few times where they stumbled or didn't talk very clearly, which is why I gave them a 3 instead of a 4. However, for the most part the presentation was very

good. The use of props (plastic pieces they 3D printed as part of their prototype) was engaging and allowed us to see hands-on examples of their design.

4. Q/A session

   The team seemed very comfortable answering questions and explained their choices well.

Other comments:

- I liked the video at the end where they demonstrated use of their bike with actual people!

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Project Description

As part of NASA Artemis program, NASA plans on testing cold-operable robotics arms. The Cold Operable Lunar Deployable Arm (COLDArm) will improve the utility of robotics for lunar landers. The objective is to have a robotic manipulator that can work in the extremely low temperatures in space, where temperatures can go as low as -280°F (-173 °C). Our senior design group was approved to help with this project. The section we are working on is the RASK camera box, used for 3D mapping. Autonomy, lunar surface imaging, and other general operations. Our goal is to improve the lunar surface imaging capabilities of the RASK by updating the housing, lighting, and lens cover mechanisms to support addition of updated cameras, as well as thermal and vibrational tests.

Deliverables: we will deliver a drawing package, a report on the design process (supported by a PDR and CDR with our sponsor), the illumination testing, and the thermal and vibration analysis (if conducted) to our sponsor. We will also report on our work to NASA Nebraska as outlined in our grants, and may present at the Nebraska Academy of Sciences, if required or so advised. We will present updates on our work weekly to our sponsor, and biweekly to our class. We will give 4 formal update presentations to our class at midterms and finals of MECH 446 and 447. Finally, we will stay on schedule and under budget.

Budget

Budget

JPL / NASA Nebraska Space Grant

$1600

NASA Nebraska Space Grant

$7000

Total

$8600

Spent

$0

Category	Total	Estimated cost	Spent	Available
JPL/NASA NE	1600		0	
4 NIS memberships		720		
KM/NASA NE	7000		0	7000
Supplies	3600		0	3600
3D printing filament		200		
Aluminum		200		
Optical Lunar Simulant		400		
Hardware		400		
Electrical components		600		
Test rig components		600		
Operating Expens	1600		0	1600
Thermal chamber time				
Machining				
Domestic Travel	1800		0	1800
5 people to JPL		4500		
Totals	8600	7620	0	8600

Timeline (Google Sheets version here)

Phase	TASK TITLE	TASK OWNER	START DATE	DUE DATE	DURATION
O	**Documentation**		**9/26/22**	**9/30/22**	**1 wk**
	Generate initial problem statement, scope, constraints and deliverables	KM			0
	Generate GANTT chart	JC			0
	Generate Preliminary Test Plan	KM			0
	Generate Preliminary Budget	KM			0
	Generate Risk Mitigation Plan	KM			0
	Generate Work Breakdown Structure	KM			0
Pre A	**Concept Studies**		**10/3/22**	**10/14/22**	**2 wk**
	Functional Decomposition - 6 facets				2
	Identify Research Questions				0
	Identify Initial Constraints				0
	Identify Risks and propose Mitigation Strategies				0
	Verify outer limits of scope				0
	Brainstorm ideas (min 5/member)				3
	Morphological Analysis				3
	Determine contractor or campus location for vibe testing.				10
	Determine availability of thermal chamber on campus.				10

A	**Concept and Tech Dev**	**10/17/22**	**10/28/22**
	Research Questions Answered		
	Technical Risk concepts refined as necessary		
	Constraints refined as necessary		
	Trade Parameters identified, necessary studies complete		
	Scope reduced as necessary		
	Final design concept identified (Decision matrix)		
	Preliminary test plan complete for each facet		
	Demonstrate viability (engineering models and breadboards)		
	LEDs: constant current PSU is operational and illumination breadboards are in progress		
	PDR 11/2 with Ryan		
	Midterm Presentation 10/24/22		
	Initial Cost estimate and component BOM complete		
B	**Prelim Design and Tech Completion**	**10/29/22**	**11/18/22**
	Concept mechanical CAD complete for printing, incl. Case, lens cover, illumination face		
	Lunar test simulant identified, test setup verified against known system		
	Illumination Circuit/circuit design works on bench		
	11/11 Preliminary Drawing Package and review?		
	Fit testing (nonfunctional 3d printed prototyping)		
	All Prototypes Complete		
	Tolerancing Complete		
	Detail Drawings Complete		
	CDR 11/18 with Ryan? Space out more/later?		

C	**Final Design and Fabrication**	**11/19/22**	**12/16/22**
	Machining if necessary		
	Further testing and refining of each facet as required.		
	12/8 Presentation for class/sponsor		
	12/9 Design phase final report submitted for class, sponsor		
	Complete illumination testing and verification		
D	**Vibe / Thermal Testing**	**12/17/22**	**1/27/23**
	Conduct Vibe Testing		
	Conduct Thermal Testing		
	Complete Testing Reports		
D.2	**Iteration/Rework**	**1/28/23**	**3/3/23**
	Iterrate on the design as needed		
D.3	**Delivery**	**3/4/23**	**5/15/23**
	Final Design Prototype		

Our timeline began with documentation and concept studies- basically all the “pre-work” needed to understand the project. This included preliminary design work like design concepts, morphological analysis, and decision matrices. One of the most important steps was analysis of the interfaces between different systems, which provided constraints for each subsystem. Once the concepts were brainstormed and evaluated through decision matrices, we started the actual CAD work. We were supposed to have our PDR with completed CAD by November 2nd, but we decided to push it back so we would have more complete designs. Our CAD was completed by the time of our PDR, November 23rd. The next steps are to 3d print preliminary designs, conduct testing, and fabricate our final design.

Based on the budget and timeline, our project is in good health. We have not exceeded our budget; actually, we have spent $0 dollars. If budget becomes an issue, an easily removable expense is the travel for 5 people to go to JPL. While we are slightly behind our timeline, the timeline was constructed very early and included us finishing our project by March 4th. This means that even though we are slightly behind, we still have plenty of time to complete the project.

Project Improvement

The two areas in the project that could be improved to increase the effectiveness of the team are receiving more design constraints from our sponsor, NASA JPL, and receiving more feedback on our designs. Most of this project has felt like our team making designs based on limited information, then only receiving detailed feedback at our design review. For example, we didn't receive the "do not exceed" dimensions for our camera box until after our PDR, at which point we had been designing the CAD for several months. We also brought up our new lens cover design at weekly meetings, but had it largely ignored; when we discussed it at our PDR, our sponsor explained that it wasn't feasible. Our team can help our project be more effective over the remainder of the time by pressing our sponsor more for requirements and being more insistent on feedback in our weekly meetings.

Design Improvement

The two design changes to improve our final design are a) updating the current lens cover and b) shifting the lenses back. The lens cover needs to be updated because at our PDR, we found out that the lens cover design we were using was not compatible with our sponsor's requirements. Instead of using our roller design, we need to use an updated hinge design. The hinge will be simpler to implement, physically and electronically, and will be simple to test. It is feasible to implement this change because it is just an updated version of the lens cover JPL already used and tested before. The second change, shifting the lens covers back, will fix some of our issues with screw holes on the camera lens holder attached to the camera box. Since we received the "do not exceed" volume from JPL after our PDR, we have discovered that we cannot shift the camera lenses forward to add space for more fastening holes. Both the updated lens cover and shifted camera lenses are feasible and will improve our project's design.

Project Team Interaction

Overall, our team has worked well together. However, the effectiveness of the team could be improved by changing the way we allocate work. Our first approach was to divide the work into subsystems and have each person responsible for a subsystem (a "subsystem lead"). Everyone else would help with all the subsystems as well. However, this has led to each person only working on the subsystem they're responsible for. This isn't inefficient, as all the necessary work has still gotten done, but it has limited team members' in-depth knowledge of other subsystems. There are two main changes that would fix this problem: a) team members working on multiple subsystems and b) more people working on each subsystem. Implementing these two solutions (which would be easy, as it's just a matter of dividing up tasks) would enable more complete knowledge of the project while still maintaining the efficiency of each subsystem.

Action plan for MECH 447

Changes to implement:

1. **Pressing sponsor more for design requirements and feedback**
    a. Goals and measures of success:
    This goal is hard to quantify, because we don't know how much information they have until we find out later that it was being withheld from us. However, we can note how many of the questions we bring to the weekly meetings are answered as a measure of success. We can also ensure we receive feedback (a clear yes or no on the feasibility of each subsystem) at least one week before our next design review.
2. **Shifting lenses back**
    a. Goals: complete CAD of lenses and camera covers by 24 December 2022 at the latest
    b. Measures of success: CAD of lenses and camera cover complete, fits with existing cameras and camera boxes, ready for JPL to review
3. **Updating lens cover**
    a. Goals: complete CAD of new lens cover by 1 January 2023 at the latest
    b. Measures of success: CAD of new lens cover complete, fits with lenses and camera holders, ready to submit to JPL for review
4. **Members working on multiple subsystems, more people working on each subsystem**
    a. Goals: each member works on at least one more subsystem than they currently are, each subsystem has at least 2 people working on it (including the lead)
    b. Measures of success: contributions to each subsystem, contributions from each person measured

Project #: 9 **Title:** **Remote Control Ultrasound** **Evaluator: John Helzer**

Outcome 3	**An ability to communicate effectively with a range of audiences**
Assessed	**Final Presentation MECH 446 – Senior Design Capstone Project**

		Level of Achievement				
		Exemplary (Score: 4)	**Proficient (Score: 3)**	**Apprentice (Score: 2)**	**Novice (Score: 1)**	**Score**
Performance Indicator	**1. Content.**	Information is clearly conveyed to the audience. New concepts fully explained.	Information is sufficiently conveyed to the audience. Minor conceptual errors do not distract from overall impact.	Some information conveyed to audience. Some conceptual errors distracted from overall message.	Little information conveyed to audience. Major conceptual errors confused audience undermined credibility.	**4**
	2. Organization.	Sequence of information made sense and was easy to follow.	Sequence of information mostly made sense and was easy to follow.	Communication to audience was affected negatively by improper sequence or missing content.	Lack of proper organization resulting in audience struggling to follow along.	**4**
	3. Presentation.	Pace, volume, and enunciation excellent to very effectively convey the information. Quality of presentation (e.g., visual aids) adds to the audience's understanding.	Pace, volume, and enunciation sufficient to convey information. Quality of presentation (e.g., visual aids) do not detract from the audience's understanding.	Pace, volume, or enunciation off enough to distract from content. Quality of presentation (e.g., visual aids) detracts slightly from the audience's understanding.	Pace, volume, or enunciation off enough to distract from entire presentation. Quality of presentation (e.g., visual aids) significantly detracts from the audience's understanding.	**4**
	4. Q/A Session.	Questions from audience answered correctly and confidently to successfully help audience understand.	Questions from audience answered adequately.	Either questions were not answered correctly and adequately or the speaker was a little uncertain or hesitant.	Either the speaker cannot answer questions or is very uncomfortable.	**4**
Additional Comments:						**Average Score: 4**

I really liked this project, from both a technical and presentational standpoint. They started off the presentation by giving us a broad background about the use of ultrasound and examples that we could understand. Even on the more technical aspects, like FEA and electronics, they had plenty of pictures and diagrams to aid understanding. Their presentation was well organized; it defined the problem statement and scope first, then explained the design. Everyone speaking seemed knowledgeable about the information and comfortable presenting it to us. They also answered questions well. Overall, I can't think of ways they can improve because their presentation worked perfectly.

Project #: 22 **Title:** B36 Crew Passover Tunnel Replica **Evaluator:** John Helzer

Outcome 3	**An ability to communicate effectively with a range of audiences**
Assessed	**Final Presentation MECH 446 – Senior Design Capstone Project**

		Level of Achievement				
		Exemplary (Score: 4)	**Proficient (Score: 3)**	**Apprentice (Score: 2)**	**Novice (Score: 1)**	**Score**
Performance Indicator	**1. Content.**	Information is clearly conveyed to the audience. New concepts fully explained.	Information is sufficiently conveyed to the audience. Minor conceptual errors do not distract from overall impact.	Some information conveyed to audience. Some conceptual errors distracted from overall message.	Little information conveyed to audience. Major conceptual errors confused audience undermined credibility.	**3**
	2. Organization.	Sequence of information made sense and was easy to follow.	Sequence of information mostly made sense and was easy to follow.	Communication to audience was affected negatively by improper sequence or missing content.	Lack of proper organization resulting in audience struggling to follow along.	**4**
	3. Presentation.	Pace, volume, and enunciation excellent to very effectively convey the information. Quality of presentation (e.g., visual aids) adds to the audience's understanding.	Pace, volume, and enunciation sufficient to convey information. Quality of presentation (e.g., visual aids) do not detract from the audience's understanding.	Pace, volume, or enunciation off enough to distract from content. Quality of presentation (e.g., visual aids) detracts slightly from the audience's understanding.	Pace, volume, or enunciation off enough to distract from entire presentation. Quality of presentation (e.g., visual aids) significantly detracts from the audience's understanding.	**3**
	4. Q/A Session.	Questions from audience answered correctly and confidently to successfully help audience understand.	Questions from audience answered adequately.	Either questions were not answered correctly and adequately or the speaker was a little uncertain or hesitant.	Either the speaker cannot answer questions or is very uncomfortable.	**4**
Additional Comments:						**Average Score: 3.5**

Overall, this presentation was pretty good. Their process seemed solid, and they included all the necessary elements. However, they could have explained the background and problem statement more. I was unsure exactly what they were trying to design until later in the presentation. One thing that would have helped with this, and helped with the presentation in general, was more pictures and diagrams. Their technical information seemed sound, especially the use of an mdf "spine" to enhance rigidity. Finally, although this is not entirely the team's fault, it seems like there has been a lack of communication between the team and their sponsors. The sponsors asked conceptual questions about the team's design at the final presentation that indicated few meetings. However, the team presented well and answered all questions.

Project #: 5 **Title:** DuoGlide 360 **Evaluator: John Helzer**

Outcome 3	**An ability to communicate effectively with a range of audiences**
Assessed	**Final Presentation MECH 446 – Senior Design Capstone Project**

		Level of Achievement				
		Exemplary (Score: 4)	**Proficient (Score: 3)**	**Apprentice (Score: 2)**	**Novice (Score: 1)**	**Score**
Performance Indicator	**1. Content.**	Information is clearly conveyed to the audience. New concepts fully explained.	Information is sufficiently conveyed to the audience. Minor conceptual errors do not distract from overall impact.	Some information conveyed to audience. Some conceptual errors distracted from overall message.	Little information conveyed to audience. Major conceptual errors confused audience undermined credibility.	**4**
	2. Organization.	Sequence of information made sense and was easy to follow.	Sequence of information mostly made sense and was easy to follow.	Communication to audience was affected negatively by improper sequence or missing content.	Lack of proper organization resulting in audience struggling to follow along.	**4**
	3. Presentation.	Pace, volume, and enunciation excellent to very effectively convey the information. Quality of presentation (e.g., visual aids) adds to the audience's understanding.	Pace, volume, and enunciation sufficient to convey information. Quality of presentation (e.g., visual aids) do not detract from the audience's understanding.	Pace, volume, or enunciation off enough to distract from content. Quality of presentation (e.g., visual aids) detracts slightly from the audience's understanding.	Pace, volume, or enunciation off enough to distract from entire presentation. Quality of presentation (e.g., visual aids) significantly detracts from the audience's understanding.	**4**
	4. Q/A Session.	Questions from audience answered correctly and confidently to successfully help audience understand.	Questions from audience answered adequately.	Either questions were not answered correctly and adequately or the speaker was a little uncertain or hesitant.	Either the speaker cannot answer questions or is very uncomfortable.	**4**
Additional Comments:						**Average Score: 4**

This team was extremely detailed in their presentation, especially when discussing their design logic and subsystems. I felt like I understood the logic they used to break down each part, and they illustrated the relationships between each part that caused constraints well. While a picture of the full CAD would have been nice at the beginning, the CAD models and pictures of each part later helped illustrate what they were talking about. Their organization and content were solid, and they presented well. All questions from the audience were answered in detail.