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# Leveraging the NASA T2U Program for Integrating Entrepreneurship Within Capstone Design

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Engineering capstone design programs offer a natural venue for introducing entrepreneurial concepts and promoting entrepreneurial spirit within engineering students. With this intent, the University of Idaho has integrated with the NASA Technology Transfer University (T2U) program to create two unique capstone projects using NASA-patented technologies. These projects enabled students to leverage the technologies to design and create a potential product for commercialization. In this context, students are required to conduct some basic customer discovery and value proposition development to create an idea for a commercial product. In addition, this approach enables collaboration with a parallel team of entrepreneurship students to create a formal value proposition and draft business plan. The integration initiative with T2U offers unique opportunities for capstone design students, but also enables longer term opportunities for acquiring subsequent startup funding via the NSF and NASA I-Corps™ programs.

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## Introduction

Engineering capstone design programs offer a natural venue for introducing entrepreneurial concepts, and many programs around the country have taken the initiative to integrate many of these concepts[1-4]. Furthermore, it is recognized that entrepreneurial skills will likely be considered highly valuable for future engineering leaders[1-4], even if those engineers do not become their own business leaders. As a result, it follows that introducing concepts of "entrepreneurial spirit"[4] to engineers can be a natural part of their development.

At the University of Idaho (U of I), the Interdisciplinary Capstone Design program involves teams of interdisciplinary students that conduct product development projects across a two-semester course sequence. Most of the projects are sponsored by external industry partners (or internal faculty) and often have singular clients with very targeted results for a specific functionality. As a result, in most cases, very little (if any) customer discovery is required to identify a potential commercial market for the product. Although these projects provide great educational experiences, they limit the ability for students to develop an "entrepreneurial spirit" via product development.

Meanwhile, the NASA Technology Transfer Program has implemented a Technology Transfer University (T2U) initiative to enable NASA-proven technologies to be utilized in university classrooms. NASA has hundreds of patented technologies that have potential for high societal impact but are not currently being utilized. The T2U program thus serves as a conduit for transfer of these technologies directly to universities to facilitate product development and commercialization opportunities. As a result, an opportunity exists to leverage the T2U program to engage capstone students in state-of-the-art innovation, while at the same time integrating both engineering (and entrepreneurship students) into the customer discovery and business planning processes.

The objective of this paper is to outline how we have integrated the T2U program into capstone design and highlight opportunities it has created for engineering capstone design students. This collaboration has been successfully piloted, with some lessons learned and future opportunities for ongoing development.

## Methodology

### NASA T2U innovations

The NASA T2U program has an extensive catalog of NASA-patented technologies available (many of them may be found online[5]) for review and selection. For our pilot program, the capstone instructors selected two separate technologies that aligned well with the research expertise of several of our resident faculty. Through informal discussions with NASA leaders of the T2U program, the U of I applied for and received a no-cost research license from NASA to pursue development of these two technologies. To enable licensing with NASA, it is recommended to start the process at least 6 months in advance. Funding for executing the capstone projects was generously provided via grant from the NASA Idaho

Space Grant Consortium (ISGC). For the projects, the resident faculty with strong interest in each respective technology served as the project clients.

The first technology selected includes the print-assisted photovoltaic assembly (PAPA) process for robotically automating the assembly of large-scale solar arrays (US patent 10,930,812). The second technology selected is the Prandtl-D flying wing[6], which is a novel aircraft design capable of improving flight efficiency by up to 12 percent (US patent 9,382,000). For each project, the student teams were charged with designing, building, and validating a representative prototype of the technology for a potential commercial application. Some initial guidance was provided by instructors for potential product ideas.

Communication with NASA throughout the application process and the project execution provided additional opportunities for capstone students. The director of the NASA T2U program helped navigate the licensing process, attended design reviews throughout the project, and attended our Annual Design EXPO at the conclusion of the projects. NASA engineers that contributed to the original patented technologies were available (virtually) to participate in capstone design reviews and provided consulting on an as-needed basis for the capstone teams.

### Entrepreneurship Integration

In parallel, teams of entrepreneurship students were identified to collaborate with the capstone teams during the 2nd semester of each capstone sequence. The learning outcomes for this collaboration were to develop the ability to a) identify a potential product (with the technology) and perform customer discovery, and b) develop a value proposition for the product and subsequent pitch competitions. The entrepreneurship students in an elective business course (from various disciplines, including engineering) initially met with the capstone teams to learn about the technologies and jointly brainstorm potential products and markets for the technology. In reality, after the initial meeting, the teams worked independently while the instructors coached the ongoing effort of customer discovery. Meanwhile, the capstone instructors delivered formal instruction for creating value propositions to all capstone teams.

The primary purposes for creating parallel teams with capstone students and entrepreneurship students are 1) promote collaboration and cross-pollination between the two disciplines, and 2) let engineering students focus on their assigned design, build, and validation activities instead of on creating business plans. In general, we do not want the capstone teams to feel that they need to execute the incremental entrepreneurship activities solely on their own.

## Results

The duration of the NASA ISGC grant spanned over two academic years, which enabled two sequential capstone design teams and sequential entrepreneurship teams to participate with each technology. As a result, a total of 36 undergraduate (UG) students (Table 1) were given the opportunity to work on development of the technology and the value proposition for a potential product. A graduate student mentor was available for each capstone team and served as a teaching assistant to help students with fabricating prototypes. Capstone teams for the 2nd year inherited the development of the prior team, but each team was empowered to identify and provide their own direction for how to develop a product and how to approach customer discovery for their potential product.

Table 1. Summary of students engaged in the NASA T2U technology capstone and entrepreneurship projects.

| Students | Technology Project | | Totals |
|---|---|---|---|
| | 1) Solar Cell Robotics | 2) Prandtl-D Wing | |
| **UG Engr.** (Capstone) | 6 | 5 | **11** |
| **UG Engr.** (2nd Capst.) | 5 | 6 | **11** |
| **Graduate Stud.** (TA) | 1 | 1 | **2** |
| **UG Entrepren.** (Yr. 1) | 3 | 4 | **7** |
| **UG Entrepren.** (Yr. 2) | 3 | 4 | **7** |
| **Totals** | **18** | **20** | **38** |

### Print-Assisted Photovoltaic Assembly (PAPA)

The objective of this sub-project is to design and demonstrate a repeatable and automated assembly process for compiling thin-film cells into larger photovoltaic arrays. Typical processes for assembling solar arrays on the market today are often manually accomplished and include multiple steps, which is time-consuming and prone to human error. To dramatically increase process efficiency, NASA developed the novel PAPA process that is robotically enabled to accomplish four tasks including 1) applying adhesive, 2) placing the cells, 3) printing the electronic connections between the cells, and 4) adding a protective cover.

Figure 1 illustrates a 3D rendering of the robot layout designed to accomplish the desired functionality. The capstone team successfully constructed a framework for mounting the robots, and a staging table for the substrates and workpieces. Next, the team designed and built multiple prototype iterations for end effectors for handling components, applying adhesive materials, and finalizing the assembly. Developing end effectors for consistently applying and printing fluid materials for conducting electrical current and adhering each panel was particularly challenging for the design team.

So far, most potential product ideas identified by the team(s) involve large-scale initiatives including solar

sails developed for spacecraft to facilitate traveling long distances (e.g., to Mars).

### Prandtl-D Flying Wing

The objective of this sub-project is to evaluate the improvement in aerodynamic performance of an unmanned aerial vehicle with a Prandtl-D wing design. The Prandtl-D wing has a proverse yaw due to the existence of induced thrust near the wingtips. Among several other benefits, the Prandtl-D wing is expected to reduce adverse yaw when correcting for aircraft roll, improve fuel efficiency, and enable a more simplified aircraft structure due to its inherent tailless design.

For this project, the capstone design team initially conducted simulation analysis of the wing design to verify expected performance. Next, the team developed a conceptual design for an unmanned aerial vehicle (UAV) with a wingspan of ~12 feet (Fig. 2). The size of this aircraft enabled the students to build a fully flyable proof-of-concept aircraft that would utilize the patented technology while fitting within their limited budget. Following thorough analytical efforts, the capstone team proceeded with construction of the UAV, which included complex shaping via balsa wood and carbon fiber reinforcement to maintain a lightweight design with adequate structural integrity. According to NASA, the UAV that was built and test flown by the students is the largest prototype of a Prandtl-D wing constructed to date. The prototype aircraft was featured in a booth at the I-90 Aerospace Corridor Conference in Coeur d'Alene, ID in June 2023.

## Discussion

### NASA T2U Program and Capstone Design

The NASA T2U program has served as a great resource for incorporating entrepreneurial learning outcomes within the capstone design sequence. These NASA-patented technologies provide the basis for students to design and create a solution to a real-world challenge at their own direction. This inherently promotes entrepreneurial thinking, as the students are required to create a product idea (using the technology) that could potentially have a commercial market, and then proceed with creating a proof-of-concept of this product.

Although the intellectual property for the initial technology is owned by NASA (via patent), the projects enable students to innovate and develop their own ideas using the technology. In fact, NASA is open to and interested in licensing such technologies to start-ups and established businesses for commercialization. As a result, any student(s) with an entrepreneurial spirit and a true desire to launch a new business could conceivably do so using the results from their capstone design experience. On numerous occasions, the T2U program director at NASA expressed that the approach described in this manuscript is an exemplar for how they envision the NASA T2U program to interface with universities.

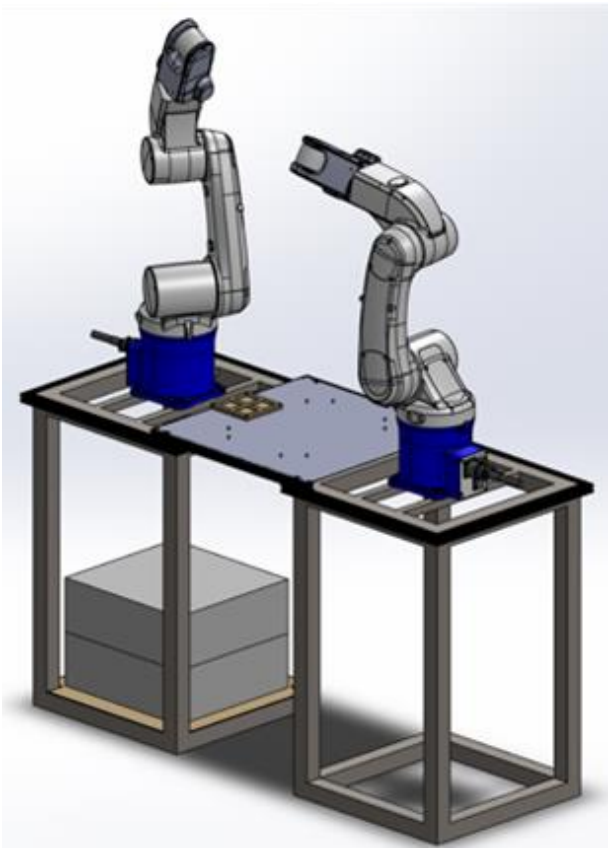

Figure 1. Dual robot rendering for accomplishing the PAPA process for assembling solar arrays.

Figure 2. Rendering of an unmanned aerial vehicle with ~12-foot wingspan designed for fabrication and flight.

## Entrepreneurship Integration

Identification of product ideas and potential markets was challenging for the engineering students. As a result, faculty engagement in the ideation process is required to help get the students on track without major delay in getting started with product development. However, a sense of ownership with the faculty (i.e., the client) is not perceived to be a bad thing, as this is likely highly beneficial for multi-year project continuity and other future opportunities for development. The business students also found it challenging to fully appreciate the novelty and commercial applicability of the technology. This naturally promoted some communication and cross-pollination between the two teams.

Each capstone team successfully identified product ideas and conducted some basic customer discovery, which naturally informed the articulation of the value proposition for their products. Assessment of the value proposition for each capstone project was conducted at every major milestone involving presentation of the project to an external audience (e.g., design reviews and final presentations). This process enabled students to tap into their "entrepreneurial spirit" more than traditional capstone projects which are often more linear in nature, resulting in compelling value propositions supporting possible business ventures. As a result, capstone instructors will evaluate adding more customer discovery instruction into future capstone design curriculum.

The entrepreneurship students were able to compete in multiple pitch competitions (with help from engineering students). Although they did not win any of the contests, participation in such events provides a valuable learning experience as it helps both teams to continually sharpen their value proposition, which subsequently informs their strategies for developing the product.

## Future Opportunities

The approach for integrating the NASA T2U program into capstone design was a pilot initiative to incorporate more entrepreneurial thinking into the capstone experience. While the initiative was highly successful, there is certainly room for continuous improvement. Most notably, the capstone engineering students would likely benefit from more targeted coaching and training on customer discovery, similar to the training offered via the NSF I-Corps™ program[7]. This training would be highly relevant for engineers in their future careers, and ideally assist the team with clear identification of a potential "beachhead" for commercialization. Such activity would likely help focus the subsequent product development. In addition, clear direction will facilitate stronger collaboration with the entrepreneurship students in value proposition and business plan development.

In any case, both the students and the faculty engaged in the project are well positioned to continue with product and business development beyond the conclusion of the capstone projects. Those involved in the projects would likely be highly competitive for participation in either the NSF I-Corps™ Regional or National training programs[7], or the NASA I-Corps™ program[8]. Each of these opportunities offer potential for between $3k - $50k in additional seed funding for participants that are genuinely interested in starting a business surrounding the NASA-patented technology.

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