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Second-Year Review of the NSF-DoD REU Site: HYPER

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Ali P. Gordon is the Associate Dean for Graduate Affairs in College of Engineering and Computer Science and a Professor in the Department of Mechanical and Aerospace Engineering at the University of Central Florida. As associate dean, his role is to maintain oversight of the college's graduate students and graduate programs. His leadership focuses on recruitment, retention, professional development, program assessment, and the introduction of new curricula/programs. Over the past four years, graduate student enrollment in engineering and computer science has increased 25% while at the same time becoming more selective. As a faculty member, his principal research activities focus on the development of microstructurally-informed, continuum-level models to predict behavior and durability of materials and structures subjected to complex conditions. To support these activities, he has accumulated funding from sources such as: NSF, ONR, ARO, AFRL, NASA, and numerous industrial partners. Ali is a four-time awardee of the Air Force's Summer Faculty Fellowship with on-going collaborations with colleagues at AFRL in Wright-Patterson, Ohio. He and his students have authored over 150 peer-reviewed technical articles and two have been recognized as best papers in American Society of Mechanical Engineers journals. He is a Fellow of ASME. Ali has taught 11 different courses and leads an engineering-based study abroad course in Brazil as well as the jointly-funded NSF-DoD REU site on Hypersonics (HYPER). Ali is well-known for engaging undergraduates in research, and he is UCF's 2019 Champion of Undergraduate Research inaugural awardee. At UCF and in the broader higher education community, Ali focuses his efforts on expanding the pipeline of graduate students qualified to pursue careers in academia. Just before joining UCF as an Assistant Professor, he earned a PhD in Mechanical Engineering from the Georgia Institute of Technology. His degree in Mathematics was attained from Morehouse College.

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Abstract

The challenges associated with achieving hypersonic flight, developing advanced propulsion systems, and designing reusable launch platforms are strongly interdisciplinary. Exposing undergraduate students to interdisciplinary research is recognized as a means to equip society's future engineers and scientists with the broad skillset necessary to contribute to these areas. The jointly funded NSF-DoD REU site Advanced Technologies for Hypersonic Propulsive, Energetic and Reusable Platforms (HYPER) unites multidisciplinary interests to study advanced structures and systems with application to hypersonics, space, propulsion, and energy. Over the course of two 10-week summer sessions (2019 and 2021), participants have gained hands-on training in contemporary challenges such as: (1) utilizing advanced manufacturing techniques for high-value components, (2) integrating in situ monitoring of stress-strain evolution, (3) developing novel methods for improved internal cooling and heat transfer effectiveness, (4) mitigating flutter through advanced rotor dynamic control, etc. Eleven research projects have been crafted to engage students in PhD-level topics. Many of these challenges rely on approaches that cut across disciplines and research techniques (e.g., experiments and computer simulation). The present reporting serves as a synopsis of challenges, advances, and lessons learned conducting the research thus far. The site HYPER has six core objectives that relate to: (1) preparing students for graduate school and/or research-oriented careers, (2) fostering technical skills in student participants, (3) improving participants' communication skills, (4) marketing to and recruiting a diverse group of participants, and more. Assessment of the program outcomes according to these objectives are reported here with data gathered after two years. Program outcomes were conducted with an external evaluator affiliated within the University of Central Florida's Program Evaluation and Educational Research Group (PEER). Results demonstrate a very effective site with strongly positive outcomes for all participants. Insights are provided so this research effort may be confirmed by other independent sites. It should be noted that the 2020 session was postponed out of an abundance of caution based on the uncertain and evolving conditions facilitated by the COVID-19 pandemic.

Keywords

Program assessment, interdisciplinary engineering

1. Introduction

Research Experiences for Undergraduate (REU) sites cultivate students' interest in research-oriented aspects of specific fields. In a similar manner, the NSF-DoD REU Site: Advanced Technologies for Hypersonic Propulsive, Energetic and Reusable Platforms (HYPER) fosters multidisciplinary interests to study advanced structures and systems with application to hypersonics, space, propulsion and energy. Participants gain hands on research training in contemporary challenges such as utilizing advanced manufacturing techniques for high-value components, integrating in site monitoring of stress-strain evolution, developing novel methods for improved internal cooling and heat transfer effectiveness, and mitigating flutter through advanced rotor dynamic control. Many of these challenges rely on approaches that cut across research techniques and disciplines. In many ways, HYPER is operated analogously to the research center which is home to the majority of HYPER faculty mentors named the Center for Advanced Turbomachinery and Energy Research (CATER).

Central Florida has a unique position in the world as a convergence for turbine, energy, and space technologies. With the presence of Siemens Energy, Pratt & Whitney, Mitsubishi Power Systems, Hanwha/Power Systems Manufacturing, Aerojet Rocketdyne, Florida Turbine Technologies, Chromalloy, Boeing, Lockheed Martin, Embraer, Kennedy Space Center in or near Central Florida, UCF's CATER has a unique opportunity and responsibility for taking the leadership in innovation and advanced technology development. This narrative overviews the site, the program objectives, and results gathered from an independent review.

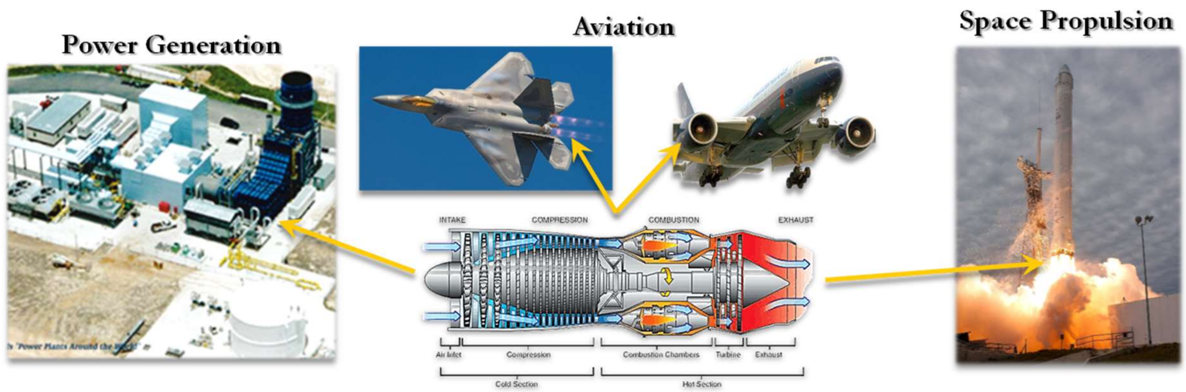

Figure 1: Research topics covered by HYPER and CATER.

2. Programmatic Overview and Recruiting

Most importantly, each HYPER REU student conducts research with one of eleven faculty mentors and a graduate student. The individual research projects available to the prospective students at the time of application are listed on the program's webpage (http://cater.cecs.ucf.edu/hyper):

- Continuum-Level Life Prediction of Materials under Combined Extreme Environments
- Damping of Anisotropic Composite Structures Under Extreme Multi-Axial Mechanical and Thermal Loads
- Evaluation of CFD Models for Solid-Propellant Rocket-Exhaust Modeling
- Atmospheric Entry, Descent and Landing (EDL) for Manned Mars Missions
- Non-Invasive Inspection of High-Temperature Coatings
- Transpiration Cooling for Turbine Blades as Enabled by Additive Manufacturing
- Additive Manufacturing of Ceramic Turbine Blades
- Fundamental Combustion Studies of Renewable Fuels for Hypersonic Propulsion and Rocket Engines
- Uncertainty Quantification and Massive Computing in Prognosis and Fleet Health Management
- Flame Diagnostics Using an Advanced 3D Tomographic Optical Technique
- 3D-Woven Polymer-Derived All-Oxide Ceramic Matrix Composites (CMCs)

Beyond the research, HYPER participants engage in a professional development series, industry tours, and computational software training. In addition, HYPER participants interact with the many other undergraduate students conducting summer research at UCF, both through other NSF REUs and UCF-initiated programs. This critical mass of activity enables successful workshops on graduate school preparation and research ethics, as well as social activities.

The program takes and national approach to recruiting. Online media, direct e-mails to engineering departments, social media, etc. are all used. The effort leads to a deep applicant pool and a highly selective evaluation process. The preferred criteria relate to GPA, major, research interests, and remaining time in the undergraduate program. In Year 1 of the program, 20% of the students met the preferred criteria. In the next cycle 80% met the criteria. HYPER's overall acceptance rate increases from 1.6% in Year 1 to 3.3% in Year 2.

3. Program Objectives

The HYPER REU Site has six core objectives: (1) technically prepare students for graduate school and/or research-oriented careers; (2) escalate students' abilities to simulate phenomena using multi- physics based finite element analysis; (3) improve participants' communication skills through repeated oral and written technical research reporting; (4) enhance participants' research skills and attitudes about contemporary and futuristic technologies for power generation, hypersonic flight and space propulsion; (5) present an REU site that is diverse in terms of student participation (e.g., prior research experience, age) and (6) provide high-quality mentoring to prepare the students in the program for research-related careers. Included in this research program is an independent annual assessment of the Site through pre- and post-experience surveys, study groups, and other assessment activities.

The site seeks to meet the six objectives by focusing the participant experience on next-generation transportation, energy, propulsion, etc. The collection of topics was inspired by the recent advances in potential transportation modes, increased propulsion efficiency, and the associated decreased travel cost [1, 2]. Recent research has identified the need for advanced platforms for transportation and electric power generation to support these business cases for [3, 4]. These technologies still exhibit significant performance gaps that limit their application; this projects seeks to produce the researchers who will create the transformative technologies that will bring about new transportation and energy systems [5,6,7]. Reusability and efficiency of propulsion systems in current-generation platforms have steadily improved, but transformative advances to turbomachinery and propulsion systems, materials, and manufacturing is vital to reduce both the costs and emissions associated with manufacture and operation [8]. Results from the 2019 and 2021 summer sessions indicate HYPER is accelerating progress and igniting excitement in the current generation of students to pursue research-oriented careers tackling these multidisciplinary research challenges [9, 10, 11].

4. Impact of COVID

The COVID pandemic significantly affected HYPER. In the 2020 summer, the University of Central Florida shifted to remote operation. Access to dormitories and laboratory spaces became more restricted as the summer progressed. The conditions did not facilitate the launching of a site which could meet its program objectives while maintaining health and safety. The summer 2020 site was consequently postponed by a year even though a cohort of students had applied. Summer 2020 applicants eligible to participate in the 2021 session were allowed to shift their applications to consideration in 2021.

Although COVID was on the decline at the outset of the summer 2021 session, many restrictions remained. Most notably social distancing was required in university laboratories. It was also expected that individuals would wear masks while on UCF's campus. Partners such as NASA KSC, Blue Origin, etc. were not open to site visits from non-essential groups. Most of the group activities during the summer were informal activities such as those shown in Figure 2. Professional development workshops organized by UCF's Office of Undergraduate Research were virtual instead of being offered in-person. The poster presentation was also transitioned to being fully virtual. The final group meeting was conducted in person. Each student summarized their research activities and fielded questions from other participants. Faculty and graduate mentors were also in attendance. Many students showed results that they expected would appear in either a conference or journal publication in the near future. As a part of the final week, the group met for dinner at a restaurant.

Finally, some HYPER research projects were conducted virtually. This meant that several students working on projects lacking a hands-on element were more than likely expected to conduct their research from a dormitory, library, or other location away from a conventional engineering laboratory space.

Figure 2: HYPER participants engaged in professional development and social activities: (a) ANSYS workshop training, (b) ngith-time bioluminescent kayak tour, (c) NASA Kennedy Space Center tour, (d) a ropes course, and (e) ice skating.

5. Assessment

Program assessment ultimately centers on the six core objectives. Program evaluation tools take the forms of pre- and post-program surveys of program participants, intermediate focus groups, and post-program mentor surveys.

6. Results

Data gathered from pre- and post-program surveys from both the 2019 and 2021 sessions are presented here. These results are shown in Figure 3. Based on a rating scale of 1 (low) to 5 (high), participants reported the largest pre- to post-experience jumps in "Research Self Efficacy" (from nearly 3.4/5 to almost 4.5/5), "Research Skills and Knowledge" (from about 3.4/5 to 4.3/5), and "Scientific Identity" (from 3.2/5 to 3.9/5). To Objective 2, participants significantly improved technical skills including with finite element analysis, improving from 50% to 90% on pre- and post-experience quizzes related to each participant's specific project. HYPER participants reported improved communication proficiency, from 3.4/5 to 4.1/5. Aerospace attitudes increased slightly throughout the research experience, with skills and attitudes about contemporary and futuristic technologies increasing from 2.97/5 to 3.86/5. Results from Year's 1 and Year 2 show consistency despite the impact of COVID. The independent assessment of HPER 2021 is expected in the February 2022 time frame. The manuscript will be updated with those results.

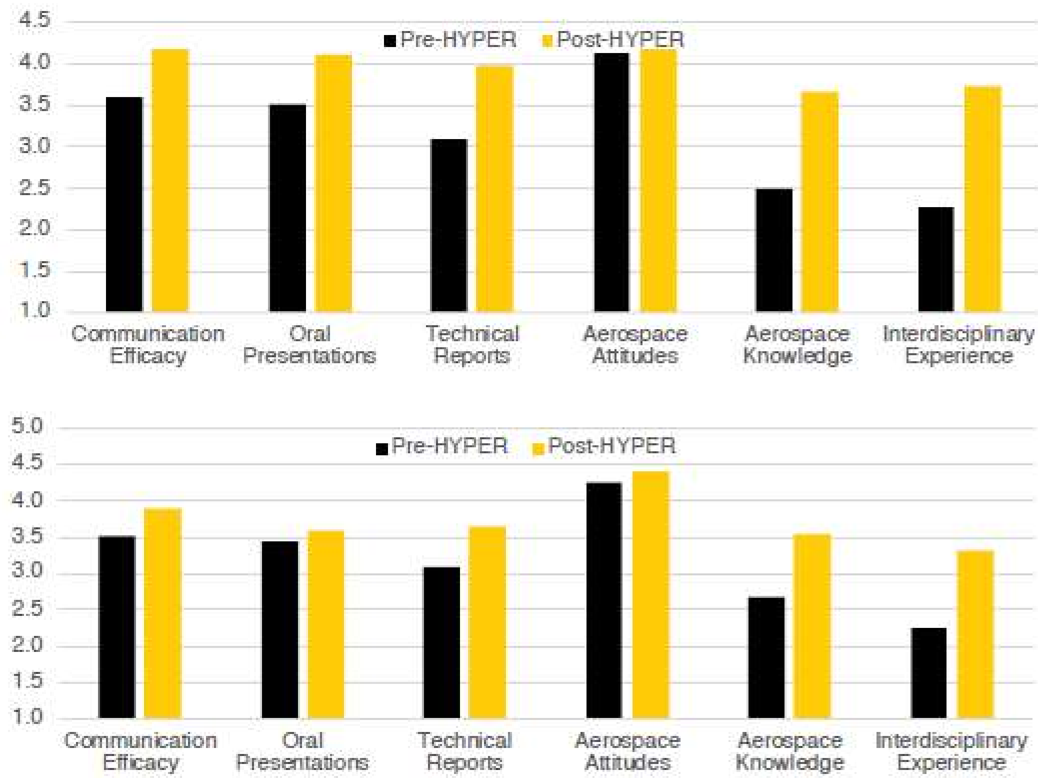

Figure 3: Self-reported skills and attitudes improved over the course of the (upper) 2019 and (lower) 2021 HYPER research experience.

7. Conclusions

Participants were presented with exciting research endeavors in which faculty mentors, as well as associated graduate students, offered multidisciplinary experiences rooted in areas of Aerospace and Mechanical Engineering. While students felt positive about their experiences, limitations by COVID posed as a barrier in allowing 2021 student participants to gain the full experience afforded to HYPER 2019 students. Students still demonstrated the ability not only to present research after short-term exposure, but also to apply newly learned software packages. Professional development was also valuable to the students. Areas that HYPER will be improved in the future relate to scaling. Firstly, resources outside of NSF and DoD will be identified to subsidize the participation of additional students. Many HYPER faculty work with large groups of research students (i.e., greater than 10 students). Several have expressed a desire to mentor multiple HYPER students were additional students available. HYPER students develop significant research momentum over the 10 weeks of the program. Despite some students being enrolled at institutions distance from UCF, several students continue to work with their HYPER mentors beyond the context of the summer program.

8. Acknowledgments

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