BOARD # 239: Fifth-Year Review of the NSF-DoD REU Site: HYPER

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Jeffrey L. Kauffman is an Associate Professor and Associate Chair of the Department of Mechanical and Aerospace Engineering (MAE). He earned PhD and MS degrees in Aerospace Engineering at Penn State and a BS degree in Engineering and Applied Science with an Aeronautics concentration at Caltech. Prof. Kauffman conducts broad research in the areas of structural dynamics and adaptive structures, with particular emphasis on multifunctional and energy-efficient structures for vibration reduction, structural morphing, and energy harvesting. Ongoing projects range from developing high-bandwidth, high-authority actuators for vibration testing in jet engines to taking inspiration from how mosquitos eject drops from their wings before flight to discover new ways of decontaminating surfaces. His current research is funded by the Office of Naval Research, NSF, DoD, NASA, and several industry partners. Prof. Kauffman enjoys teaching a variety of courses in the MAE Department. He frequently teaches the Mechanical Systems Laboratory, which lets him interact with students and enjoy their ”aha!” moments in the smaller lab setting. He is fortunate to advise a fantastic research group with a great mix of graduate and undergraduate students who keep him on his toes. At UCF, he has served on the Undergraduate Council since 2016 and as chair since 2021, helped develop the Faculty Senate Student Success Council, and serves as vice chair of the Faculty Senate. He is an Associate Fellow of the American Institute of Aeronautics and Astronautics, where he serves as chair of the Adaptive Structures Technical Committee.

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Abstract
Technical progress has advanced the areas of futuristic modes of transportation and energy production, but fundamental knowledge gaps remain [1-3]. These gaps motivate the development of programs that will equip and train students to solve these research-heavy challenges in the modern workforce. Typical problems in these areas involve supersonics and hypersonic flight, as well as turbomachinery operating toward more efficient power generation. These problems span the disciplines of energy (and beyond), beckoning for multi-disciplinary research. The University of Central Florida (UCF) increasingly focuses on engineering and technology, and many recent initiatives align tightly with these goals. One key initiative is a Research Experiences for Undergraduates Site housed within the Center for Advanced Turbomachinery and Energy Research and the Department of Mechanical and Aerospace Engineering. The site unites multi-disciplinary projects around HYpersonic, Propulsive, Energetic, and Reusable Platforms (HYPER), which aligns with a significant focus on hypersonics at UCF. The site has now hosted 5 summer cohorts totaling 73 participants who have engaged in graduate-level research, professional development, industry tours, and computational software training. Results over the five cohorts demonstrate the HYPER experience encourages participants to pursue their interests, teaches them about multiple research approaches, and provides them a better understanding of how to conduct research. Notably, almost every student expressed satisfaction with their experience. In self-assessed abilities and attitudes, participants noted broad pre- to post-experience increases, with especially strong gains in interdisciplinary experience and aerospace knowledge.

Introduction and Objectives

Achieving futuristic modes of transportation and energy generation like hypersonic flight and carbon neutrality requires a research-ready workforce with multidisciplinary interests and awareness. The University of Central Florida educates and develops these next engineers by leveraging its prime Central Florida location in the heart of the space and technology industry, strong ties with the local engineering industry, and prevailing student interest in engineering and technology. It hosts the jointly funded NSF (through the Division of Engineering Education Centers) and DoD REU Site Advanced Technologies for HYpersonic, Propulsive, Energetic, and Reusable Platforms (HYPER), which cultivates and unites multidisciplinary interests to study advanced structures and systems with application to hypersonics, space, propulsion, and energy. Participants engage in a 10-week experience, conducting graduate-level research under a faculty mentor and alongside a graduate student teammate. In addition to the core research experience, HYPER incorporates a series of professional development seminars, technology training sessions, faculty mentor presentations, and social events.

HYPER has seven core objectives: (1) technically prepare students for graduate school and/or research oriented careers, (2) escalate students' abilities to simulate phenomena using multi-physics software, (3) improve participants' oral/written communication skills, (4) enhance participants' research skill/attitudes, (5) present an REU Site that is diverse in terms of student participation, (6) present an REU site involving students with fewer STEM opportunities, and (7) provide high-quality mentoring.

Program Elements and Assessment

Each HYPER participant engages in a research experience under the mentorship of one faculty member and at least one "near-peer" mentor, such as a graduate student (or occasionally post-doctoral fellow). In some cases, additional graduate and even undergraduate students assist as peer/near-peer mentors. Applicants can view prospective research projects and rank their top selections during the application process. The program website (https://cater.cecs.ucf.edu/hyper) includes an updated project list:

- Hypersonic Propulsion
- Analysis of Cooling Systems for a Hypersonic Leading Edge
- Continuum-Level Life Prediction of Materials under Combined Extreme Environments
- Evaluation of CFD Models for Solid-Propellant Rocket-Exhaust Modeling
- Atmospheric Entry, Descent and Landing (EDL) for Manned Mars Missions
- Additive Manufacturing of Ceramic Turbine Blades
- Fundamental Combustion Studies of Renewable Fuels for Hypersonic Propulsion and Rocket Engines
- Mechanics of Ultralightweight Origami-Core Hypersonic Structures
- Precision Cooling Loop for Space-Based Payloads
- Lightweight High-Temperature Carbon-Metal Radiator Structures
- 3D-Woven Polymer-Derived All-Oxide Ceramic Matrix Composites
- Damping of Anisotropic Composite Structures Under Extreme Multi-Axial Mechanical and Thermal Loads

Participants spend the bulk of their time conducting research, but 4-8 hours each week are reserved for professional develop activities, additional training on multiphysics software, and industry site visits, for example as seen in Figure 1. UCF hosts several REU sites, so participants also engage in social activities with the other students conducting summer research experiences to provide a stronger social bond beyond the HYPER cohort. Other groups at UCF, like the Office of

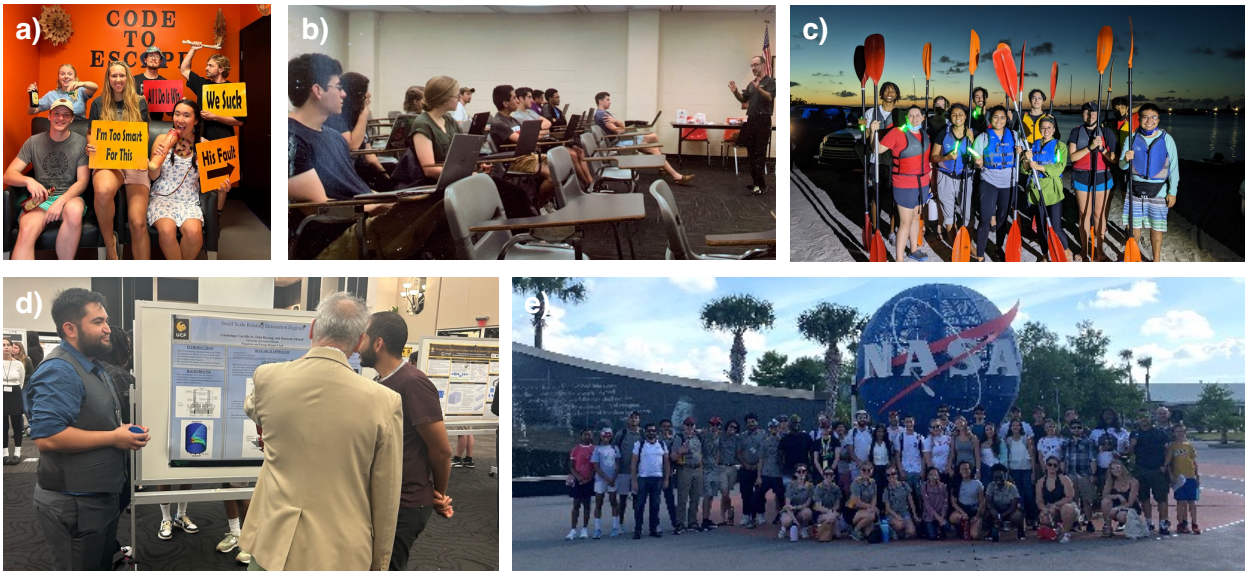

Figure 1: Students participate in social activities like escape rooms (a) and bioluminescent kayaking tours (c), technical training on ANSYS (b), an end-of-experience poster session (d), and industry site visits (e).

Undergraduate Research, are instrumental in delivering many of these professional development and social activities. In addition, the authors take care to provide additional engineering-specific activities to tailor professional development to the participants' career goals.

The Program Evaluation and Educational Research Group (PEER) conducts detailed independent assessment using pre-, mid-, and post-program surveys and focus groups, as well as post-experience feedback from faculty mentors [4-7]. The authors also conduct pre- and post-experience surveys and technical quizzes. For informal check-ins, the authors conduct a weekly group meeting with the participants. At these meetings, each student gives a very brief update (1-2 minutes), with 1-3 students presenting a couple slides to the entire group (2-5 minutes).

Recruitment and Scaling

Participant recruitment typically begins in December, with final cohort selection in early April. The first years of the initial (2019) and renewal (2023) awards have a compressed timeline spanning late March to early May. Based on comparisons with other sites and discussions with participants, the authors have worked to move up the application and decision deadlines. By moving them earlier in the Spring semester, the authors believe they still can attract a strong pool of candidates while also providing participants sufficient time to make informed decisions and arrange travel plans to UCF (Orlando, FL). Table 1 shows statistics for each year's applicant pool and selected cohort.

HYPER is extremely selective, with only 2.8% of applicants participating in the program. The acceptance rate has increased over time, both as recruitment becomes more targeted and as the HYPER team has successfully developed partnerships with external institutions to scale up the REU impact by approximately 50%. In planning for these additional participants, the HYPER team defines 12-14 projects each summer. Most projects are crafted so participants will conduct research via several techniques, such as physical experiments, numerical simulations, or analytical models. All applicants express their project preferences, which drive the participant-mentor pairing

Table 1: HYPER recruitment and selection data

Cohort	Applicants			Participants				
	All	Preferred	Semi-finalists	Total	Females	Under-represented Minorities	Home Univ. Students	Limited Research Opps
2019	703	246	20	11	4	6	2	3
2020	618	Site postponed due to coronavirus pandemic						
2021	419	352	19	14	7	5	4	4
2022	278	217	60	17	6	3	2	5
2023	236	177	39	16	9	8	1	9
2024	314	148	40	15	11	7	2	7
Total	**2568**	**1140**	**178**	**73**	**37**	**29**	**11**	**28**

process. Even with the extra participation slots, HYPER can accept only 4-5% of its applicants. Recognizing the outstanding applicant potential, the team continues to seek additional avenues to support a greater number of participants.

Results

HYPER presents a diverse REU site across several dimensions. For example, 38% of participants are from universities with limited research opportunities. An overwhelming majority (85%) come from outside UCF; these 62 students hail from 48 institutions across 23 states. Half of participants are female and 40% are underrepresented minorities. Participants overwhelmingly indicate the experience is challenging, teaches them about several major research approaches, encourages them to pursue their own interests, provides high-quality mentoring, and helps them decide if one of the MAE fields is right for them [7]. Faculty mentors also find the program worthwhile, with 90% rating their research partnership as effective.

The multi-disciplinary aspect of HYPER drives participant growth, with an average increase in self-reported scores from 2.35/5 before the experience to 3.58/5 in "Interdisciplinary Experience." Similarly, the experience produces a large increase in "Aerospace Knowledge," increasing from 2.77/5 to 3.76/5. Figure 2 shows these pre- to post-experience deltas for several categories, with smaller but still positive changes observed in most areas. The experience has little effect on participants' "Aerospace Attitudes;" however, this slight change may stem from the very high interest and excitement around aerospace topics before the HYPER experience (4.38/5).

In the most recent years, there is some evidence of a disconnect between participants' self-rated comfort with oral presentations and their actual behavior. For example, in 2023-24, participants reported their pre-experience comfort and ability in "Communication Efficacy" and "Oral Presentations" significantly higher than in 2019-2022. Despite this reportedly increased comfort and experience, most participants in 2023-24 were more reluctant to present a slide of their summer progress in a weekly research group meeting than in 2019-2022. One potential factor could be the larger number of students from institutions with limited research opportunities, which naturally includes more students without prior research experience. For example, it is possible that some of these students overestimate their comfort from a lack of experience; i.e., they do not know enough about presenting to realize they actually are not comfortable with it. It also is possible there is a COVID effect; many students in these latter cohorts where in high school when education switched

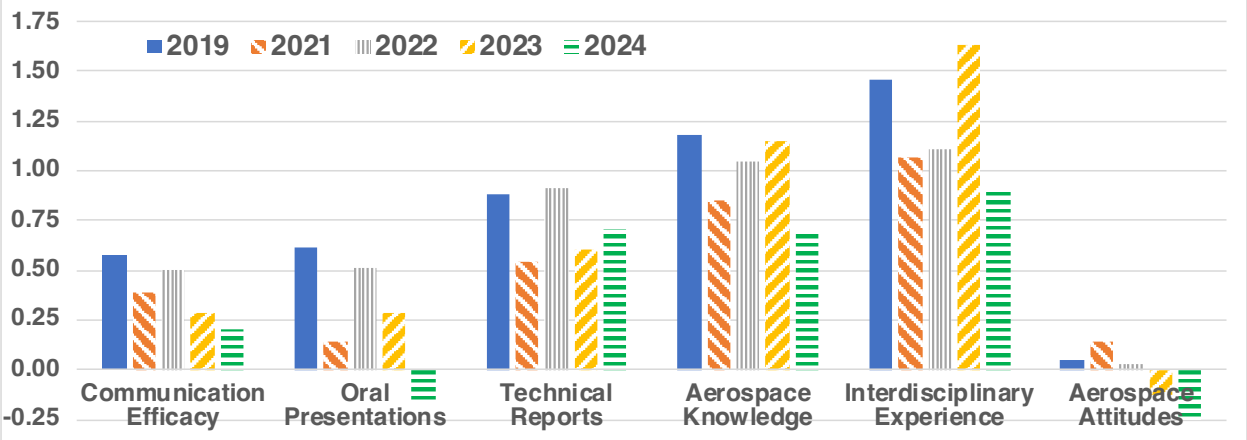

Figure 2: HYPER participant pre- to post-experience self-reported change in several categories

to a virtual delivery. Students may thus be more comfortable giving oral presentations in virtual meetings but still uncomfortable or inexperienced for in-person presentations. The authors are interested to see how these trends progress as future cohorts will have experienced high school and early college in a "post-COVID" format.

Conclusions

HYPER participants engaged in exciting, multidisciplinary research endeavors at UCF with mentoring from faculty members and graduate students. Participants overwhelmingly report satisfaction with the program and demonstrated rapid growth and achievements, conveying results via a poster session, oral presentation, and technical reports. Earlier and repeated communication of individual research expectations may further improve the research experience. The HYPER team's scaling efforts amplify its impact by expanding research opportunities to 50% more participants beyond those funded via NSF-DOD.

Acknowledgments

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References

[1] M. Ragab, F. M. Cheatwood, S. Hughes, J. DiNonno, R. Bodkin, A. Lowry, J. Kelly, and J. G. Reed, "Performance Efficient Launch Vehicle Recovery and Reuse," *AIAA SPACE 2016*, AIAA 2016-5321, 2016. doi: 10.2514/6.2016-5321

[2] E. J. Tuegel, A. R. Ingraffea, T. G. Eason, and S. M. Spottswood, "Reengineering Aircraft Structural Life Prediction Using a Digital Twin," *International Journal of Aerospace Engineering*, vol. 2011, p. 154798, 2011. doi: 10.1155/2011/154798

[3] Y. Huang, M. C. Leu, J. Mazumder, and A. Donmez, "Additive Manufacturing: Current State, Future Potential, Gaps and Needs, and Recommendations," *Journal of Manufacturing Science and Engineering*, vol. 137, no. 1, p. 014001, 2015. doi: 10.1115/1.4028725

[4] B. Swan, B. Adams, and A. Schwartz, "REU Site: Advanced Technologies for HYpersonic, Propulsive, Energetic and Reusable Platforms (HYPER) – Annual Summative Evaluation Report for Year 1," Technical Report No. 56UCFREU2019.Y1S, Program Evaluation and Educational Research Group (PEER), 2020.

[5] B. Swan, Y. Tazi, and E. Reese, "REU Site: Advanced Technologies for HYpersonic, Propulsive, Energetic and Reusable Platforms (HYPER) – Annual Summative Evaluation Report for Year 3," Technical Report No. 56UCFNSFREU2019.Y3S, Program Evaluation and Educational Research Group (PEER), 2022.

[6] B. Swan, I. Musengwa, and E. Reese, "REU Site: Advanced Technologies for HYpersonic, Propulsive, Energetic and Reusable Platforms (HYPER) – Annual Summative Evaluation Report for Year 4," Technical Report No. 56UCFNSFREU2019.Y4S, Program Evaluation and Educational Research Group (PEER), 2023.

[7] B. Swan, T. Wilson, and I. Musengwa, "REU Site: Advanced Technologies for HYpersonic, Propulsive, Energetic and Reusable Platforms (HYPER) – Annual Summative Evaluation Report for Year 1," Technical Report No. 88UCFNSFREU2023.1.Y1S, Program Evaluation and Educational Research Group (PEER), 2024.