Introducing Undergraduates to Restricted Research

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***Abstract*—This work-in-progress Innovative Practice paper discusses a formalized classroom experience that introduces undergraduate engineering students to restricted research opportunities and careers, consistent with the charter of the Virginia Tech Hume Center. Specifically, this paper highlights the creation and results from two initial offerings of a sophomore-level multi-disciplinary engineering course that explores unique national security engineering topics, ranging from technical deep dives that stress unique engineering design requirements, tear downs of real platforms, design methodologies relevant to the Department of Defense (DoD) and Intelligence Community (IC), traditional focuses on research methods, and an overview of the U.S. security clearance process. Further, students are prepared to engage in restricted research opportunities on campus, either as part of an individual faculty member's research or as part of the Hume Center's adaptation of the Vertically Integrated Projects (VIP) experiential learning program. Early post-course survey results confirm that the class encourages students towards future career opportunities in national defense.**

***Index Terms*—undergraduate research, experiential learning, ITAR, national security, STEM, workforce development**

I. Introduction

In the United States, the DoD and the broader defense industrial base are consistently among the largest employers of Science, Technology, Engineering, and Mathematics (STEM) graduates [1]. Moreover, in-demand skills such as computer science, engineering, and mathematics are in particular short supply. Another challenge beyond the STEM talent shortage, which many universities are working to remedy, is that jobs supporting national security generally require the ability of the employee to obtain a security clearance, which requires U.S. citizenship and a background investigation. Moreover, it can be difficult to share with students what their future career prospects are in fields like machine learning if the underlying application space of national defense is one that we keep hidden due to restrictions of the International Trade in Arms Regulations (ITAR), Export Administration Regulations (EAR), or formal classification guidelines (i.e., *restricted* research) [2]–[4]. Ongoing debates exist surrounding the impacts of export control regulations in higher education [5]–[8], with some schools largely refusing to conduct restricted research [9]; Virginia Tech's foundation is in support of U.S. national defense [10], [11], with robust research portfolios and research compliance protocols [12].

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This work-in-progress paper describes a nascent curricular foundation at Virginia Tech for introducing undergraduate students to restricted research topics. These efforts are derived from a larger adaptation of the Vertically Integrated Projects (VIP) consortium's [13] model for establishing long-term hands-on multi-disciplinary experiential learning efforts. The Hume Center's adaptation places an additional emphasis on creating clearable U.S. citizen student pipelines to support national security; this targeted workforce development flavor incorporates active pooled engagement from researchers at DoD labs, the DoD STEM community, and the IC. A second addition is the incorporation of a formalized curricular experience aimed at introducing students to the underlying subject matter of restricted research. This general structure is shown in Fig. 1, where we draw from first-/second-year engineering and mathematics students, encourage them towards on-campus and future career opportunities in Defense, and then recruit them to participate in these thematically aligned VIP projects. DoD stakeholders have already engaged in these projects to offer feedback, funding, and in many cases, job opportunities. Students often gain 2-3 years of experience through their project and contribute to peer reviewed academic papers that assist them with the option of attending graduate school and/or gaining notice from employers.

As a component of this larger VIP@VT infrastructure, the *Intro to Restricted Research* (I2RR) course is a unique gateway, presenting students with additional insight towards their future career directions. Similar ITAR-restricted experiences are routinely incorporated as part of senior design experiences [14], research labs [15], [16], and extracurricular experiences [17] across the nation. The content of an *Intro to Restricted Research* course is naturally subject to ITAR controls, presenting challenges in enrollment processes, distributing course materials, and/or ensuring equal access at a public university. Nevertheless, overwhelming support from the DoD/IC, university administration, and Hume faculty have made this class possible, with future plans aiming to explore discipline specific DoD/IC applications of classroom topics and expansion of restricted research publication opportunities.

This paper outlines the I2RR class in Section II, followed by student feedback and survey results in Section III, which validates the effectiveness of our approach. Goals for extending this baseline to multi-university delivery and Defense-oriented technical electives are presented in Section IV.

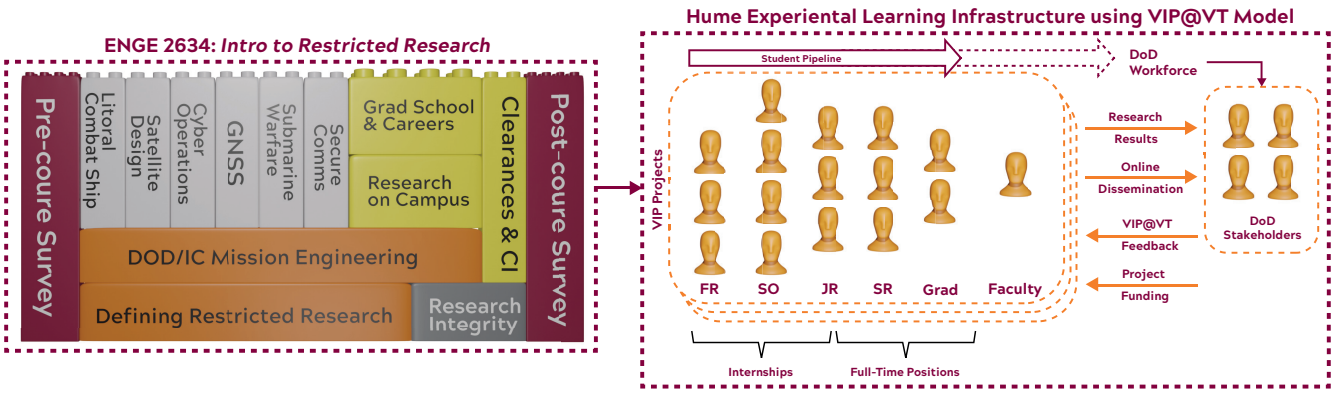

Fig. 1. Experiential learning structure, beginning with recruitment via an *Introduction to Restricted Research* course, generating interest in thematic multi-disciplinary research projects / student pipelines spanning many years.

II. The I2RR Course

In preparing students to participate in on-campus experiential learning activities, our team identified four core focus areas:

- Research methods, emphasizing research safety, ethics, and documenting results;
- Research restrictions and the DoD clearance process, with emphasis on ITAR, EAR, and proprietary considerations;
- Core missions in the DoD, beginning with requirements-based mission engineering and proceeding to technical deep dives into a variety of DoD systems; and
- Career preparation, including hands-on research opportunities on campus, in graduate school, and future opportunities at national labs or in industry.

A. I2RR: Course Content

The class itself is structured as a once-weekly evening seminar, recently approved as ENGE 2634, which is held in a secured lecture hall. To comply with ITAR restrictions, students are not permitted to use computers or any other recording devices – obvious adjustments are made in remote delivery of such content, yet robust credentials authentication and emphasis on what constitutes an ITAR-controlled space are provided to the students. Additionally, all students sign a non-disclosure agreement as part of a Technology Control Plan (TCP) that delineates how course material is to be handled.

Research method topics originally represented ≈40% of the course sessions and were modeled loosely after a research introductions course taught in Virginia Tech's Honors College. Feedback from the students strongly indicated lower interest in these topics, leading to a revision with a single course session overview of *research integrity*, with extensive links to resources on campus. In reviewing the training modules associated with the Institutional Review Board (IRB), lab safety, and research ethics, we have found the emphasis on biological and social sciences to dominate, suggesting that it may be possible to improve delivery for engineering students, most of whom do not encounter these facets of research outside their introductory science labs [18].

B. ITAR Compliance

The second topic area is an expansion on our Office of Export and Secure Research's Compliance's (OESRC) training and TCP process that is required for all students and faculty engaged in restricted research. The added focus on restricted technologies, as defined in the U.S. Munitions List (USML), prepares students for the broader discussions of Defense applications. We couple that introduction with live discussions of the DoD clearance process, personnel background investigations, and the counterintelligence (CI) process, all of which help orient them to the fact that universities are a prime target for research exfiltration [19].

C. DoD/IC Technology Deep Dives

The dominant component of the course is a series of technical deep dives centered on (1) mission engineering that explores the synthesis / decomposition of military-oriented design requirements; (2) multi-disciplinary design, construction, and use of specific DoD platforms; and (3) introduction to how non-commercial requirements (e.g., resiliency to battle damage or assured access to radio frequency (RF) spectrum) drastically affect operational decisions. In the current offering of the course, these technical deep dives have included sessions on the Littoral Combat Ship (LCS), satellite design, the Global Positioning Satellite (GPS) constellation, RF spectrum dominance, submarine warfare, cyber operations, and the Apache attack helicopter. An example from the LCS session is how students start with the LCS's place within the U.S. Navy's fleet composition, the near- real time configurability of LCS mission packages, practical constraints of operating in littoral waters, the specific objectives and constraints of anti-submarine warfare / mine countermeasures / surface warfare, and lessons learned over the 20 year lifetime of the platform. By balancing the content between researchers and users, students learn about engineering successes and failures on a platform like the Apache from designers and former pilots. Current semester guest speakers have included representatives from Naval Surface Warfare Center (NSWC) Dahlgren, NSWC Crane, Naval

Undersea Warfare Center (NUWC) Newport, and CACI; future classes will weave in researchers from other national labs. Student feedback on these application-oriented technical deep-dive sessions has been overwhelmingly positive, and represents ≈50% of the current syllabus.

D. Future Opportunities

Our final topic area seeks to identify and connect students to hands-on opportunities that exist on campus and after graduation. By having faculty members actively performing restricted research come in to present, the class acts as a mutually beneficial matchmaking environment, as well as a targeted recruitment pool for graduate school and future careers by DoD/IC sponsors that value prior insight into national security engineering. Additionally, students are required to attend three lab tours on campus, learning more about these hands-on opportunities and gaining small-group introductions to the faculty members. In the Hume Center alone, we have seen a nearly 25% matriculation rate from the I2RR course into ongoing experiential learning and traineeship programs.

III. Course Effectiveness

Given the unique adaptation of a traditional *research methods* course to emphasize national security, we have solicited and incorporated feedback from both students and DoD researchers. Given initial sponsorship by the Office of Naval Research (ONR), a greater engagement has been sought and obtained from U.S. Navy labs. With 38 students from 7 STEM majors in the first offering of the class, 33 students provided their input to a post-course survey.

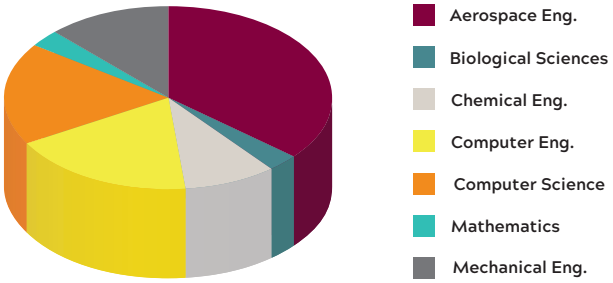

Fig. 2. Multi-disciplinary experience with students from 7 STEM majors.

A. Surveys and Feedback

The dominant question in our analysis is whether the course contributes to students' interest in pursuing a career in national security; on a 5-point Likert scale [20], 82% of students confirmed that the class contributed to their being somewhat or much more likely to be interested in a career in national security; as shown in Fig. 3, those responses are most heavily concentrated among students with the highest Grade Point Averages (GPA), suggesting positive responses among top students. Future surveys will seek to determine whether there is any specific causation to this correlation.

An additional question was solicitation of I2RR's impact on their plans for attending graduate school, with 15 students responding they are *More Likely* vs. 1 responding *Less Likely* to attend. Next was whether I2RR helped encourage them *towards a career where you intend to work, conduct research in, or teach in a STEM field for at least 3 years after graduation;* 7% of students were *Not Sure*, while 43% responded *Probably Yes*, and 50% responded *Definitely Yes*. Finally, students were requested to offer their opinion as to the most and least impactful classes of the semester – surprisingly, 61% of students agreed that the most impactful session was the single deep-dive lecture performing a teardown of the LCS, while 12% called out deep-dive segments from other lectures, and 9% called out learning about specific restricted research activities on campus. Responses were more scattered for the least impactful session, yet a pattern existed around traditional topics within research methodologies. This overwhelming interest in the LCS lecture led to an inversion of the course approach prior to the second (current) offering, where 7/15 sessions are now allocated to distinct deep dive topics, and the research methods topics are used to support discussion, but only in the context of the application.

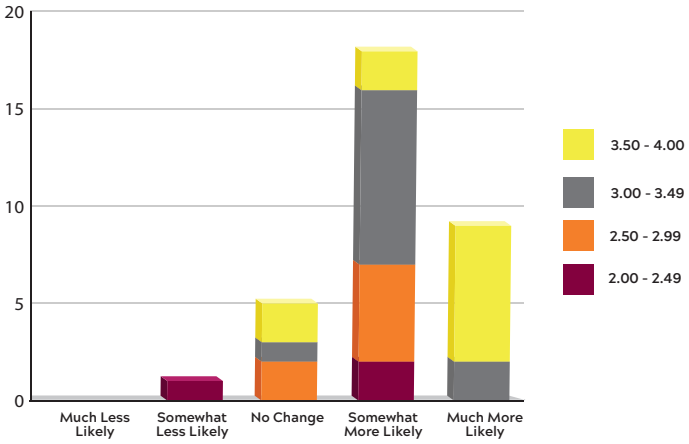

Fig. 3. Student survey responses to whether the I2RR class has increased or decreased their likelihood of pursuing a career in national security, segmented by student GPA.

B. Ongoing Focuses

Evolutions of the I2RR course are ongoing, with near-term objectives including (1) opening controlled access to partner universities and (2) establishing an endowed fund to teach the non-mainstream class in perpetuity. Our recent experiences with socially distanced course delivery represented a particular challenge for ITAR compliance in the course's second offering, yet the infrastructure developed to remotely deliver the course to *on* campus students solves the vast majority of challenges for distributing to other schools. Corporate sponsorship by CACI is already enabling improved recruitment tools, and government sponsors have been consistently willing to share their knowledge and experience with the class, bringing with them real operational examples. Investments by the Office of the Secretary of Defense have already enabled pushing the class to become a permanent offering.

IV. Interim Conclusions and Future Goals

Although a limited sample size to date, the preliminary results of the *Intro to Restricted Research* course as an in-classroom experience have been highly encouraging. Student feedback demonstrates that the course material does, in fact, provide them with more insight into national security career paths; moreover, the coupling of the course with immediate opportunities to engage in on-campus restricted experiential learning ensures that they can exercise that knowledge quickly. Further, DoD stakeholder engagement is extremely positive, representative both of the demand for STEM talent and the culture of service to grow the next generation of DoD/IC practitioners.

Building upon these initial positive indicators leads to a few strategic questions that will become the focus of future work:

- Would discipline-specific courses, such as a "Defense Technologies in ECE" class, be more effective in introducing students to those career paths, or does the multi-disciplinary approach offer a better return?
- Can, and should, ITAR-restricted sections of discipline specific engineering courses (or course modules) be weaved into the curriculum, even including their consideration in ABET accreditation?
- What is the best approach for remote delivery of ITAR-controlled course content to students at partner universities that do not have a sizeable restricted restricted research infrastructure?
- Where can results from undergraduate-level restricted research activities be published, and yet still meet the academic rigor of a peer-reviewed conference or journal?

The fundamental goal of these questions is seeking to integrate the classroom experience more closely with the hands-on experiential learning opportunities. Based upon feedback from employers, and our lab's anecdotal experiences working in both academia and industry, we see the value in bridging those two approaches such that research and application are integral to the theory learned in the classroom.

Addressing the first two of these questions, we aim to establish either undergraduate-level technical electives (ideally) or short-course appendices to many of the junior-/senior-level electives that can augment a student's understanding of defense applications of the underlying classroom material; this requires engaged faculty with instructor-level understanding of the material and an integration with the course outlines as they evolve. An initial repository of supplementary course content has already been developed, with initial emphasis on RF spectrum dominance; goals exist to expand that repository to a true multi-disciplinary library that is accessible on controlled infrastructure at the Hume Center. As for single- vs. multi-disciplinary focuses, we see competing dynamics. Departmental curriculum committees appear reasonably open to new technical electives, provided they support ABET accreditation, yet the logistics required to incorporate restricted content are likely only justifiable if the full course is controlled. On the other hand, employers in the national defense space often value an understanding of the application nearly on par with the analytical experiences.

The third question for remote delivery of the I2RR course and/or related materials is currently being prototyped as a result of COVID-19, offering a template for future expansion. We believe that Virginia Tech's approved servers will be capable of supporting the establishment of an initial consortium of universities, as well as provide lessons-learned guidance to other schools seeking to establish their own restricted research environments. Proofs-of-concept are already in place for a multi-university VIP research project between Virginia Tech and Morehouse College, where the ITAR-supported project content and computing resources leverage VT's infrastructure. Discussions are ongoing to remotely deliver the course to Morehouse College and the University of Indianapolis in Spring of 2022.

Finally, on the question of publishing results from restricted research, we are familiar with a variety of journals and/or conference special sessions that permit submission of ITAR-restricted papers, yet the indexing and searchability of the papers significantly lags that of dominant sources like IEEE or ACM. In some ways, the Defense Technical Information Center (DTIC) acts as a similar repository, yet it is not particularly accessible to academic researchers. As a result, we strongly advocate for and are actively seeking to create an academically-oriented restricted research publication; the goal is to provide a similar peer-review rigor for researchers seeking to publish their work (with meaningful impact factors and contributions to h-/$i10$-indices) and a searchable repository that can promote collaboration amongst this niche research community. We believe that offering researchers a publication venue will contribute to them being less resistant to publication restrictions in research contracts and also help safeguard information by not trying to talk around relevant aspects of technical discovery in open journals.

The end goal of all of these efforts is to normalize the infrastructure and approaches to engaging undergraduates in restricted research activities; more work remains.

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