7. Facilities, Equipment, and Other Resources

Whittier College is an officially recognized Hispanic Serving Institution (HSI), with a mission to elevate traditionally under-represented students into professional science and engineering. Piece by piece, we have established a research lab capable of supporting complex projects. This growth includes the EPA with NSWC Corona that has facilitated technology transfers of lab equipment. We have also used a start-up grant to prepare our lab. Finally, we have a strong tradition of privately-funded undergraduate research fellowships at Whittier College, including the W. M. Keck, Fletcher-Jones, and Ondrasik-Groce Fellowships. Having used these instruments to prepare our institution, we are well-equipped to perform the proposed work. We first describe the *laboratory and office space* provided by Whittier College. Second, we describe the *computational resources* we have acquired that are relevant for the proposal. Third, we discuss our *additive manufacturing* resources. Fourth, we discuss our *RF testing and calibration* resources. Finally, we focus on *human resources* by demonstrating a track record of mentoring undergraduate researchers through research fellowships.

Laboratory and Office Space. Whittier College has provided us with a 30×30 ft. laboratory in our Science and Learning Center (SLC). This facility includes powered tables with ethernet, storage space, and tool cabinets. The lab securely houses our RF testing and calibration equipment. Several students can comfortably work alongside each other on electronics and engineering projects. We have also been provided with a 40×30 ft. teaching laboratory, home to computer science and physics laboratory courses. During Summer, the lab is available for research, and is home to electronics tools, cables, and a soldering station. The SLC also has a 15×15 ft. machine shop, home to standard machine tools for traditional RF antenna construction, including: a mill, lathe, drill press, band saw, and safety equipment. Finally, Whittier College has provided me with a secure office that is home to our System76 Thelio.

Computational Resources. Using our start-up grant, we acquired the System76 Thelio with AMD Ryzen Threadripper 3990x 64-core, 128 thread CPU. The system has 0.5 GB of volatile memory per thread, 4.3 TB of permanent storage, and a NVIDIA GeForce GTX 1650 GPU. The system was used in Summer 2022 to create our 3D open-source CAD models of broadband RF antennas, and to run the associated CEM computations in parallel. Running our CEM calculations in parallel accelerated results by an order of magnitude. The Thelio can accommodate multiple on-campus users, limited by the 0.5 GB of memory per thread. To facilitate scanning large parameter spaces for optimized phased array designs using machine learning, we will begin by using the Thelio as a training ground. As the complexity of the research grows, we can expand to a more powerful system. We will perform market research on (for example) the System76 Ibex GPU server line before upgrading.

3D Printing Resources. We have a MakerBot Replicator Z18 in our machine shop, and we have upgraded it with an Olsson Ruby extruder tip. The ruby tip facilitates 3D printing with the Electrifi filament we propose to use. We are therefore equipped to start our project using the MakerBot and Electrifi filament. We plan to upgrade as necessary to Prusa or TriLab printers, since these are recommended by experts for use with Electrifi. The SLC is home to staff in our department and the Department of Chemistry who have experience repairing and operating our 3D printer. Thus, we are well-equipped to begin a multi-year project based on additive manufacturing with novel materials.

RF Testing and Calibration Resources. NSWC Corona has donated RF bench testing equipment to our lab, shown in Tab. 7. Our network analyzer and power sensors can perform S-parameter measurements over [9 kHz - 6 GHz] for our antennas under test (AUT). Our signal generator can create calibration signals for our calibration antennas and AUT over [250 kHz - 6 GHz]. Our calibration antennas serve as benchmark devices for comparison to our 3D printed AUT. Regular calibration is required for these devices, and our calibration kits serve this purpose.

Using our start-up grant, we acquired a Tektronix MDO 3024. This mixed domain oscilloscope (MDO) is equipped with four analog RF channels, and a fifth RF channel as spectrum analyzer. The MDO 3024 accepts 16 digital inputs synchronously with the analog channels. The scope is perfect for low-frequency testing and verification of RF antennas and circuits. Our laboratory is therefore well-equipped to complete the proposed work. We plan to upgrade the bandwidth of the MDO 3024, which should be increased from 200 MHz to at least 1.5 GHz.

Human Resources. Our research in CEM and additive manufacturing to date has been completed with significant contributions from diverse undergraduates. We provide a summary of contributions from undergraduate personnel, and ONR faculty fellowships, to the early stages of this work in Tab. 7. These researchers have diverse majors, including our 3-2 Engineering Program (Wildanger), Physics and Math double major (Hartig), and Math/Integrated Computer Science (Gómez-Reed and Householder), and Physics and Astronomy (Goodman and Smith). These students have begun science and engineering roles with the Laser Interferometer Gravitational-Wave Observatory (LIGO) Collaboration, the University of Southern California (USC), and The Aerospace Corporation. Whittier College has a good track record of mentoring undergraduate research fellows. We seek to expand this practice through NSF-sponsored opportunities in additive manufacturing, CEM, and machine learning. Finally, we have senior personnel who will help with the proposed work, including grant coordinators and department administrators prepared to handle acquisitions and budget tracking. Our project planning analysis takes their valuable work into consideration.

Equipment
Rohde and Schwartz ZVL6 Network Analyzer
Rohde and Schwartz NRP-91 Power Sensors (2)
Aeroflex 3416 Digital RF Signal Generator
Calibration antenna kits (2)
Calibration kits for Network Analyzer (2)

Student/Professor	Grant Opportunity	Yr.
J. C. Hanson	ONR Faculty Fellow	'22
D. Goodman	Summer researcher	'22
A. Householder	Summer researcher	'22
R. Hartig	Ondrasik-Groce Fellow	'22
J. C. Hanson	ONR Faculty Fellow	'21
A. Wildanger	Fletcher Jones Fellow	'21
J. C. Hanson	ONR Faculty Fellow	'20
R. Hartig	Fletcher Jones Fellow	'20
J. P. Gómez-Reed	Ondrasik-Groce Fellow	'19
J. P. Gómez-Reed	Keck Fellow	'18
C. Smith	Keck Fellow	'18

FIGURE 7. (Left) RF testing and calibration equipment donated by NSWC Corona. (Right) Undergraduate researchers, and fellowships awarded to our group by year.

Collaboration with Prof. Fred Park Professor Fred Park is currently the chair of the Department of Mathematics and Computer Science. We have included a letter of collaboration from Prof. Park to highlight a significant collaboration. First, our project planning calls for market research dedicated to the selection of an appropriate GPU/multi-core server to handle computational work for our CEM and machine learning research projects. Prof. Park will bring significant experience to bear in the system design, as his research has been focused on machine learning and computation. This experience will also be of great value in other areas. First, Prof. Park's experience will aid the course integration of our CEM/machine learning work into our upper division courses. Second, Prof. Park will provide guidance to myself and my students in the application of machine learning techniques to CEM. My students and I will gain experience through his Machine Learning course, and through one-on-one collaboration. Finally, once we do acquire the GPU/multi-core server, we will work as a team to maintain it as a shared resource. The server we envision will be of sufficient complexity that it will require us to manage it through the duration of the grant. In the long term, Prof. Park and myself will coordinate server maintenance and management through our IT staff.