## 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. Part of this growth includes establishing a public-private partnership with a US Navy Lab called an educational partnership agreement (EPA). Our EPA has facilitated technology transfers that will greatly benefit our proposed research. Further, we have already used start-up grants 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 my group our own laboratory in our Science and Learning Center (SLC), completed in 2016. This  $30 \times 30$  ft. facility includes lab tables with power rails and ethernet, storage cabinets and drawers, a fume hood, a tool cabinet, and a closet. This lab is home to our RF testing and calibration equipment, and it is a secure facility. Several students can comfortably work alongside each other on electronics and engineering projects. The lab has a variety of coaxial cables and electronics tools. We have also been provided with a  $40 \times 30$  ft. teaching laboratory. During the academic year, the teaching lab is home to computer science and physics laboratory courses. During the Summer, the lab is available for research, and is home to electronics tools and cables, and a soldering station. Whittier College has also provided a  $15 \times 15$  ft. machine shop. The SLC machine shop is 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 desktop computer.

Computational Resources. Using our start-up grant, we acquired the System76 Thelio desktop system 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. Multiple on-campus users can utilize this system as a CEM server. The number of simultaneous users or jobs is limited by the 0.5 GB of memory per thread. The system can be easily upgraded to handle more users. To facilitate scanning large parameter spaces for optimized phased array designs using machine learning, we will begin by using the Thelio system as a training ground for our more complex runs. The Thelio can be easily upgraded with more memory and storage. As the complexity of the research grows, we can expand to a more powerful system as neccessary. Because of our experience with System76, we will perform market research on the System76 Jackal and Ibex GPU server lines before recommending upgrades.

**3D Printing Resources.** The SLC machine shop is also home to our MakerBot Replicator Z18, and we have since upgraded it with an Olsson Ruby extruder tip. The ruby tip can withstand higher extruder temperatures without changing shape over time. This makes it a better choice for 3D printing with the Electrifi filament we propose to use. We are therefore equipped to start our project using the MakerBot 3D printer and the rolls of Electrifi filament already in our labs. We plan to upgrade as necessary to Prusa and TriLab printers, since these are recommended by experts for use with the Electrifi metal-doped filament. 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. We have now begun the EPA between Whittier College and NSWC Corona. Through the technology transfer portion of the EPA, NSWC Corona has provided RF bench testing equipment that is perfectly suited to the proposed work. A list of instruments transferred from NSWC Corona between 2020 and 2023 is 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 have also 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 can also accept 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, and this minimizes budgetary impact. The main area to upgrade is 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. Lisa Newton is our Associate Director of Research and Sponsored Programs, and Nayeli Camacho is the administrator for Physics and Astronomy handling acquisition and purchase orders. We also have technicians who help maintain our 3D printing and shop resources. Our project planning analysis takes their valuable work into consideration.

	J. C. Hanson	ONR Faculty Fellow	′22
	D. Goodman	Summer researcher	′22
Equipment	A. Householder	Summer researcher	′22
Rohde and Schwartz ZVL6 Network Analyzer	R. Hartig	Ondrasik-Groce Fellow	′22
Rohde and Schwartz NRP-91 Power Sensors (2)	J. C. Hanson	ONR Faculty Fellow	′21
Aeroflex 3416 Digital RF Signal Generator	<ul> <li>A. Wildanger</li> </ul>	Fletcher Jones Fellow	′21
Calibration antenna kits (2)	J. C. Hanson	ONR Faculty Fellow	′20
Calibration kits for Network Analyzer (2)	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

Student/Professor

**Grant Opportunity** 

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