

8. BUDGET JUSTIFICATION

We have crafted a budget that contains the personnel, equipment, travel expenses and other costs required by the proposed project. Our budget reflects the fringe benefits and other indirect costs associated with Whittier College. With the professional help and advice of our colleagues, we have created a budget that provides for the project needs while aligning with appropriate budget guidelines. Namely, the final figure does not exceed the minimum dollar amount specified for CAREER proposals within the Directorate for Engineering (ENG) by more than 10%.

This is a 60-month project for the period 1-July-2024 through 30-June-2029 totaling \$526,221.

Senior Key Personnel (\$81,915)

Prof. Jordan Hanson, Principal Investigator and Assistant Professor of Physics will direct all phases of the project at Whittier College. In order to accomplish grant objectives, Dr. Hanson will commit 2 person months annually during the summer calculated on his projected institutional base salary effective 1-July-2024. Whittier College faculty work on 10-month academic year contracts. Due to the small size of our Department of Physics and Astronomy, we are not requesting academic year course releases. Rather, our project plans engage undergraduate researchers throughout Project Years 1-5 to accomplish our work.

Other Personnel (\$158,169)

Undergraduate Researchers (\$111,332): Our project planning calls for undergraduate researchers during the academic year (AY), and summer research internships. The average number of AY students we hope to recruit is 4 per year, but this number is modified depending on the Project Year. For example, our Project Plan calls for an additional undergraduate worker in Project Year 2 to act as Spanish language translator for our EASTLOS application (see Project Description for details). In Project Year 4, certain projects have already concluded. Thus, our budget only calls for two AY researchers in Semesters 7 and 8. Regarding the undergraduate summer internships, we typically assume three per year, but in Project Year 2 we only require one student to finish the initial work accomplished in Semesters 1 and 2. By performing this analysis, we intend to minimize budgetary impact while completing our work. AY undergraduate wages are calculated at California minimum wage \$15.50/hour for 10 hours per week for 13 weeks each semester. Summer undergraduate wages are calculated at California minimum wage for 18 hours per week for 10 weeks.

Post-baccalaureate Researchers (\$46,837): In our personnel budget, we also include institutional wisdom gained after several years of mentoring undergraduates who have earned fellowships. Whittier College is an undergraduate institution, meaning we lose experienced juniors and seniors soon after we recruit them. In other cases, first-year and sophomore recruits transfer to other institutions before a project finishes. Thus, we have included two “post-baccalaureate” researcher positions annually calculated at \$25/hour at 19 hours per week for 10 weeks over the summer. Candidates may be recently graduated seniors looking to continue engineering work as their job search in the private sector progresses. Other categories of students for these roles include students in our 3-2 engineering program, who leave Whittier College after three years, and students applying to graduate school. For students in these situations, we hope to retain talent for our project work, and to provide them with key experiences they will use in the workforce. These students will be given some advisory and mentorship responsibilities as they work alongside their

younger colleagues. In this way, the budget reflects the organizational structure we will execute.

An annual salary or wage increment of 2% has been estimated every July 1. If funded, costs applied will be based on the actual/current year salaries.

Fringe Benefits (\$13,500)

Faculty additional compensation (summer salary) at Whittier College is currently assessed at an average of 8.49%. Academic year student employee wages incur payroll deductions only at an average of 0.33%. Summer student employees and part-time hourly employees are currently assessed at an average of 7.98%. Fringe benefits are calculated based on current estimated average rates. If funded, current/actual fringe benefits, payroll, and insurance rates will be applied.

Equipment (\$69,000)

RF Test Bench Equipment (\$37,000): Our budget calls for two major pieces of scientific equipment. The first is a mixed-domain oscilloscope (MDO) with bandwidth greater than 1.5 GHz estimated at \$37,000. This will allow us to visualize received signals from antennas-under-test (AUTs) in the time-domain. Collecting data in the time-domain, for example, will allow us to discover reflected signals that represent faulty coaxial cable connections between the AUTs and transmitters. Though the MDO can provide frequency domain data, we already have a network analyzer capable of providing spectral information over a 6 GHz bandwidth. We will use the network analyzer to collect S-parameter and radiation pattern data in the frequency domain. Thus, the exploratory quotes we have obtained for the MDO focus on time-domain precision, number of RF channels, and measurement features in the time-domain. The main driver of cost for MDOs is bandwidth, which must be ≥ 1.5 GHz for our proposed designs.

GPU Server (\$32,000): The next major equipment item reflects the need for computational resources estimated at \$32,000. We seek to purchase a new System76 GPU/multi-core server in Ibex product line. This new system would be used for machine learning and CEM calculations while supporting course integration goals by increasing our capacity for computational research. Given the complexity of the proposed system, we have allocated time in our Project Planning to the appropriate level of market research. We envision a central server that will allow faculty from the Depts. of Physics and Astronomy, and Mathematics and Computer Science to perform computational work with job-scheduling. Thus, we could utilize our System76 Thelio (see Facilities, Equipment, and Other Resources documentation) for initial CEM runs, and the shared server for calculations that require more power. Prof. Fred Park (current chair of Computer Science and Mathematics Dept.) has the experience to utilize a GPU server for projects that would complement our research. This approach bolsters our efforts to integrate our research and educational endeavors, for students could obtain server accounts used for course work in Machine Learning or Introduction to Data Science with Python.

Travel (\$10,461)

To present our work to the physics, engineering, and geoscience communities, we are targeting specific conferences in online and in-person formats. Our Project Plan calls for online attendance of the International Cosmic Ray Conference (ICRC). In 2025, ICRC will be held in Geneva, Switzerland. We have already presented online at ICRC 2021, with no technical issues. Our budget reflects our intent to attend ICRC 2025 and ICRC 2027 online in Years 2 and 4 with registration estimated at \$300. We will also target domestic conferences Years 2 through 5 such as the April Meeting of

the American Physical Society (APS), the Annual Meeting of the American Geophysical Union (AGU), and the IEEE Wireless and Microwave Technology Conference (WAMICON). Rates for this general conference plan are based on historical costs and are estimated as follows: registration \$700; roundtrip airfare \$500; lodging \$250/night for 3 nights; average per diem \$60 for 4 days; ground transportation at \$200 with a 2% annual increase on all rates.

Other Direct Costs (\$59,448)

Materials and Supplies (\$44,069): In the category of Other Direct Costs, we include smaller hardware items, and other fees and expenses. First, we spread the cost of 10 3D printers over Project Years 1-5. We investigated the price of the Prusa MK4 line of printers as our baseline of \$1,200 with a 2% annual price increase. We seek to purchase ten printers for two reasons. The first is that we would like to integrate this fleet of printers into our curriculum, allowing students to gain engineering experience in future courses. The second reason is that we are attempting to print phased arrays, meaning we will print multiple RF antenna elements simultaneously. This approach allows us to print an array of the appropriate size, in parallel. In addition, the printers can serve as backups to one another in case a printer needs maintenance. We choose to spread the cost of the printers over Project Years 1-5 in order to gain experience with the preferred model before proceeding with more purchases. Our second budget request in this category is the Electrifi conductive 3D printer filament projected at \$194 per roll with a 2% annual increase. We elected to spread the cost of the Electrifi rolls over Project Years 1-5, to prevent rolls from expiring if exposed to moisture when not being used.

As with any RF lab, we need a small allocation projected at \$500 yearly with a 2% annual increase for RF coaxial cables, connectors, and filters. Whittier College has used Pasternack, Inc., a local RF company, as a preferred vendor for such purchases in the past. Another part available at Pasternack is the adjustable RF phase shifter in Year 2 estimated at \$13,190 (1,740 each) for eight phase shifters. Compatible with coaxial cable setups, these components will allow us to do beam forming and beam steering with our RF antennas acting as a phased array. This will allow us to confirm array behavior without purchasing expensive RF integrated circuits. This approach also avoids spending time and money on firmware design. Firmware associated with the phased arrays we develop is inevitably going to be re-developed by other groups, and we felt this approach is cleaner.

For the development and testing of our EASTLOS app for Android Mobile, we plan to acquire four mobile devices running Android OS projected at \$500 each in Year 3. This will allow us to test our application in a real-world setting. As we are aware of the various regulations surrounding the purchase of mobile phones, we do not intend to purchase data plans for these devices. Rather, we will rely on Whittier College WiFi and USB connections to test our app functionality.

In Project Years 3-5, we include budget requests for drone parts estimated at \$1,000 per year with a 2% annual increase. These include parts like carbon fiber tubing as structural components, quad-rotor motors, transceivers, GPS antennas, and small solar panels. The portion of our 3D printing budget already includes material for hull construction, and we have 3D printed drone hulls in the past. We already have the machine shop tools and soldering station in our labs (see Facilities, Equipment, and Other Resources). Thus, we are minimizing budgetary impact, while planning to construct at least one new drone designed with RF phased array via open-source CEM.

Publication/Documentation/Dissemination (\$6,000): Finally, we include resources for the publication of results from our intellectual and service activities. We are targeting at least two journals:

Electronics (MDPI), and The American Journal of Physics. In our analysis, we use the usual journal fees for Electronics, converted from CHF to \$2,500 USD in Years 2 and 3. We have chosen this journal because it is open-access. This boosts access for our students and our institution, which cannot purchase a wide variety of engineering journals. We also discovered this line of research from a review article in Electronics, so it is a natural choice. For the analysis of our educational data collected with the EASTLOS app, we are targeting The American Journal of Physics, published by the American Association of Physics Teachers (AAPT) in Year 4 and estimated at \$1,000. The focus of this journal is physics education.

Professional Services (\$9,379): Part of our proposed service activity is the organization of our bilingual STEM lecture series in Years 1 through 5. We include a \$500 speaker honorarium and travel expenses estimated at \$1,322 in Year 1 with a 2% annual increase for these services (airfare \$500; lodging for 2 nights at \$250/night; GSA Los Angeles per diem at \$74 for 3 days; \$100 ground transportation). We seek to use these resources to attract quality speakers in order to enrich the educational experience of our students.

Total Direct Costs: \$392,493

Indirect Costs: \$133,728: Indirect Costs are estimated in accordance with the approved indirect cost rate agreement dated 29-March-2021, with the Department of Health and Human Services (DHHS), the federal cognizant agency for Whittier College. The applicable indirect cost rate for the proposed period is 55.7% of direct salary and wages including vacation, holiday, sick pay, and other paid absences but excluding all other fringe benefits.

Total Direct and Indirect Costs: \$526,221