GUAM SCIENCE AND TECHNOLOGY ECONOMIC DIVERSITY PLAN 2024-2029

GUAM EPSCoR
ECOSYSTEMS COLLABORATORIUM FOR CORALS AND OCEANS

UNIVERSITY OF GUAM
UNIBETSEDÅT GUÅHAN

GUAM NSF EPSCoR
ADVANCING GEOGRAPHIC DIVERSITY IN STEM

GUAM ECONOMIC DEVELOPMENT AUTHORITY
Moving Forward

Science and Technology Steering Committee
University of Guam
Guam NSF EPSCoR

EXECUTIVE SUMMARY

Introduction

The purpose of Guam NSF EPSCOR is to develop Guam's capacity as a premier research and STEM education hub by bolstering sustainability, economic development, informed decision-making and engaging communities in 21st-century science and engineering activities. In order to maximize the impact on the community and economy, Guam NSF EPSCoR established the Science and Technology Steering Committee as an independent organization which included research, business and government representatives in Guam. Consisting of 15 voting members, the S&T Committee was led by Co-Chairs Melanie Mendiola, Guam Economic Development Authority Administrator and Roderick Boss, CEO of Docomo Pacific. The Vice-Chair was Robert Underwood, President Emeritus of the University of Guam. He was the primary coordinator of meetings and the preparation of this report.

Utilizing the four pillars necessary for a science-based, economic diversification plan, the S&T Committee identified five Areas of Opportunity (AOs). The pillars were the Guam NSF EPSCoR-generated Collaboratorium, STEM Capacity Building in educational institutions, STEM Infrastructure in the private sector and Entrepreneurship/Innovation support. The five AOs were Aquaculture, Information Technology, Renewable Energy, Natural Resources and Additive Manufacturing. The S&T Committee met with representatives of industries, research units, business incubators and government planners to outline specific ideas and plans for the AOs.

Understanding Guam's Economy

The S&T Committee also analyzed the challenges inherent in the geography, environment and economy of Guam. Guam's economy is primarily dependent on federal spending and tourism. Realizing that the visitor industry had been affected by the Covid-19 Pandemic and that there were opportunities available in future defense spending, the S&T reviewed the possibilities of the 5 AO's within those economic sectors as well as strengthening other sectors. The anticipated growth of military spending offers but does not guarantee possibilities without intentional planning and support.

Building a Foundation for a STEM-Based Economy

The S&T Committee also analyzed STEM Capacity development in the Guam Department of Education, Guam Community College, private schools, charter schools and the University of Guam. While many of these efforts were encouraging, there was a lack of coordinated effort and sustained evaluation of how STEM was being advanced. Achievement rates, technical programs and graduation in STEM related education were outlined in this report in great detail. Current STEM preparation in K-12 education is inadequate, but preparation for technical jobs appears more promising. STEM infrastructure in the private sector was limited except in telecommunications, a few engineering firms and some innovative attempts to utilize new technologies in aquaculture, renewable energy and additive manufacturing.

As with the lack of coordination in STEM Capacity building and infrastructure, there was little sustained effort in developing a supportive infrastructure that would bring research, entrepreneurship and innovative STEM based ideas together in a way that would generate a truly diversified economy. The need for closer collaboration between educational institutions, private sector involvement, researchers, government planners and entrepreneurs must be addressed if diversification was going to become a reality. The building blocks exist but have not been fully integrated into mutually supportive structures and incubators.

The 5 Areas of Opportunity

The five AOs were addressed through conversations and contributions by experts, entrepreneurs, and researchers in each field. Various efforts at aquaculture have only had moderate success. Through a new government sponsored Guam Aquaculture Innovation Center (GAIC), the center will provide facilities to support the incubation of aquaculture-related businesses as well as the demonstration and commercialization of applied research. The GAIC will jumpstart the development of multiple facilities over time with the goal of Guam becoming a regional hub of aquaculture based on research and local knowledge.

Information technology and cybersecurity offers tremendous possibilities for diversification. The establishment of Data Centers by private companies, ongoing cybersecurity issues and the growth of informational technology for nearly every human activity offers a viable series of sustainable economic activities. Cybersecurity curriculum in all postsecondary institutions, coding camps in the private sector, cyber competition events and introduction of the utilization of Artificial Intelligence (AI) early in school curriculum offers many possibilities which demand coordination and require research.

Renewable energy offers many STEM-based applications for technical and professional fields across a variety of career paths. Eleven percent (11 %) of the island's electricity generating capacity is currently provided by renewable sources of energy. Guam's Renewable Portfolio Standard (RPS) requires that 50% of the island's power come from renewable sources by 2035—eventually reaching 100% by 2045. In order to meet this objective a variety of renewable energy sources which go beyond solar panels. Partnerships with energy labs, the introduction of renewable energy as a curricular area in technical and degree programs will require even more partnership between utilities, private companies and researchers to validate and compare different options.

The utilization and protection of Guam's natural resources offers a wealth of opportunities for sustainable development and economic growth through the integration of university research, STEM education programs, and innovative economic strategies. Government of Guam Executive Order 2019-23 established the G3 Working Group. The UOG Center for Island Sustainability & Sea Grant was assigned to facilitate this public-private island-wide initiative and spearhead the development of the G3 Action Framework. This framework encompasses hundreds of goals and action items that guide the sustainable development of a green economy while dealing with challenges ranging from climate change to invasive species.

In 2022, the Government of Guam contracted the Applied Science & Technology Research Organization of America (ASTRO America), a national non-profit research institute and think tank, to conduct a comprehensive analysis to determine the viability of a local additive manufacturing industry in Guam. The baseline study concluded that Guam possesses the basic building blocks for establishing a local high-tech manufacturing industry, including a demand to support activities of the Department of Defense, a favorable business climate to attract public and private investments, potential workforce development capabilities, and the University of Guam's ability to partner with other advanced research institutions.

The most crucial recommendation in the evolution of Additive Manufacturing from idea to viable industry is the creation of the Guam Additive Manufacturing and Materials Accelerator (GAMMA) Center. The GAMMA Center, a business incubator and market-to-lab facility hosted by the University of Guam will serve as the focal point of this new-to-Guam manufacturing capability. Focused on additive manufacturing, robotics, automation, and advanced materials, the GAMMA Project will expand Guam's capability in supporting the defense industry, creating tertiary industries using these technologies, and training individuals for sustainable jobs.

Measuring a Knowledge-Based Economy

Data collection outside of the general macroeconomic indicators poses a challenge for the S&T Committee. Moreover, as the S&T Plan is implemented through a variety of future EPSCoR activities, the need to assess societal progress towards economic and science goals is critical. The current state of tracking is largely decentralized, and the timing is sporadic. A comprehensive Index is necessary to measure progress towards a knowledge-based economy. Instruments have been developed by organizations like the Milken Institute for other jurisdictions.

The S&T Committee acknowledges the shortcomings of existing date collection on Guam and the lack of fit of measurements utilized in other areas. Collecting this data will not only help Guam understand the component activities necessary for a strong knowledge-based economy, it will also suggest ways to effectively coordinate research agendas, educational activities, and innovative economic projects.

The Guam Science and Technology Index (S&T Index) will rely on a variety of data sources. Some of these include obvious ones such as investments in basic STEM education, technical training, and research in higher education. Other data sources are in rudimentary form or do not yet exist in Guam. These include Industry R&D investments and identifying businesses which are primarily STEM-dependent. With this Index, Guam can better assess whether progress is made towards a knowledge-based economy. This will not only diversify the island's economy but contribute to the full utilization of the innovative and creative talent of Guam's people.

Looking Ahead

STEM opportunities have increased considerably thanks to two NSF EPSCoR Track-1 awards and an NSF INCLUDES award. These have provided access to facilities, first-class training in the application and use of instrumentation in cutting edge research, scholarships and internships, and networking opportunities for students. Students engaged in unique peer mentoring seminars throughout their research fellowship that focus on the connection between research, culture, and identity to enhance community voices in science and technology. These past activities provide a firm foundation for future EPSCoR projects.

The E-RISE RII program supports the incubation of research teams and products in a scientific topical area that links to research priorities identified in the submitting jurisdiction's approved Science and Technology (S&T) Plan. E-RISE projects are expected to be designed to allow for the incubation of teams that develop an area of research and contribute to the development of a STEM-trained workforce relevant to the project's topic area.

For the 2024 submission to NSF's E-RISE RII request for proposals, the development of the UOG Biodiversity Research Center will be the focus. The Center will bring together units and researchers from diverse fields. Workforce development activities will focus on creating internship and training opportunities with local resource management agencies. Translation of research results into models to inform climate change readiness, in particular the preservation of natural resources, will rely on integration of research results across the team using data science approaches and modeling.

In the future, the S&T Committee will play a larger formal role in the implementation of this plan. The S&T Committee will be an integral part in the co-production of EPSCoR activities in research, partnerships, coordination with other federal agencies. The S&T Committee will assist in the formation of incubators as well as provide advice and expertise on participation in other NSF-sponsored centers and local/regional translational activities. It will ensure the completion of the Index proposed to assess progress towards a knowledge-based economy.

The Guam S&T Economic Diversity Plan was adopted by the S&T Committee on June 12, 2024.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I: INTRODUCTION

The Guam Science and Technology (S&T) Economic Diversity Plan was developed under the auspices of the NSF Established Program to Stimulate Competitive Research- Guam Ecosystems Collaboratorium for Corals and Oceans (EPSCoR-GECCO) at the University of Guam. The purpose of Guam NSF EPSCOR is to develop Guam's capacity as a premier research and STEM education hub by bolstering sustainability, economic development, and informed decision-making and engaging communities in 21st-century science and engineering activities.

Guam NSF EPSCoR established the Science and Technology Steering Committee as a major vehicle to carry out this purpose. In its By-Laws, the stated function of the S&T Committee is as follows:

The Committee acts as an independent organization on behalf of the broader research, business and government interests of Guam. The Committee promotes innovation, collaboration, and excellence towards the goals of a world-class research and development enterprise in Guam that is an engine for economic diversification, prosperity, and social justice.

The S&T Committee is co-chaired by Guam Economic Development Authority (GEDA) Administrator Melanie Mendiola and Docomo CEO Rod Boss. It is facilitated by University of Guam President Emeritus Robert Underwood who serves as the Vice-Chair. Under Guam NSF EPSCoR, the S&T Committee developed this plan through the expertise of the Committee itself and Project staff. Additionally, there was widespread consultation with community stakeholders, STEM subject matter experts, and island leadership. The membership of the S&T Committee is listed in the Appendix.

The National Science Foundation's EPSCoR program pursues a mission to enhance the research competitiveness of targeted jurisdictions (state, territory or commonwealth) by strengthening science, technology, engineering and mathematics (STEM) capacity and capability through a diverse portfolio of investments from talent development to local infrastructure. The EPSCoR program envisions its jurisdictions as recognized contributors to the national and global STEM research enterprise. Guam EPSCoR contributes to this national effort through its innovative research agenda in a unique geographical location with economic challenges. The S&T Plan endeavors to fulfill this broad mission by bringing together research projects, government agencies, educational institutions, and the private sector to build a knowledge-based economy based on expanding STEM capacity.

Purpose

The specific purpose of the S&T Plan is to assist in the diversification of Guam’s economy by strengthening its STEM-based knowledge economy, and to establish benchmarks by which to measure progress. The plan is designed to be a strategic vision for Guam, and not a work plan. The S&T economic diversification plan based upon developing four pillars of support:

1. Micronesian/International Research Collaboratorium
2. STEM Capacity Building
3. STEM Infrastructure
4. Entrepreneurship and Innovation Across Industries

Additionally, the S&T Committee identified five areas of opportunity (AO) that will be supported by the four core areas. These five areas are:

1. Aquaculture
2. Information Technology, Data Science and Cybersecurity
3. Renewable Energy
4. Natural Resources and Sustainability
5. Additive Manufacturing

These five areas of economic opportunity are the basis for science-based and research-energized economic growth which will facilitate Guam's future economic viability and sustainability. In order to achieve this level of economic development, the island's educational institutions, researchers, governmental agencies, and private sector will work together to develop an island-wide STEM support structure that accomplishes the following:

1. Builds STEM Capacity in educational institutions to prepare students to engage in professions that utilize science and technology.
2. Develops a STEM Infrastructure built by the local government, private sector, and stakeholders to generate economic activities and ready the island for a STEM-infused economic future.
3. Incubates STEM-based activities and projects that bridge academic research with entrepreneurial creativity.
4. Grows the STEM ecosystem through a cycle of research and economic activities supported through the regional and international partnerships generated by GECCO today with other partners and future NSF-EPSCoR funding.

The model of the Four Pillars is presented in Figure 1.

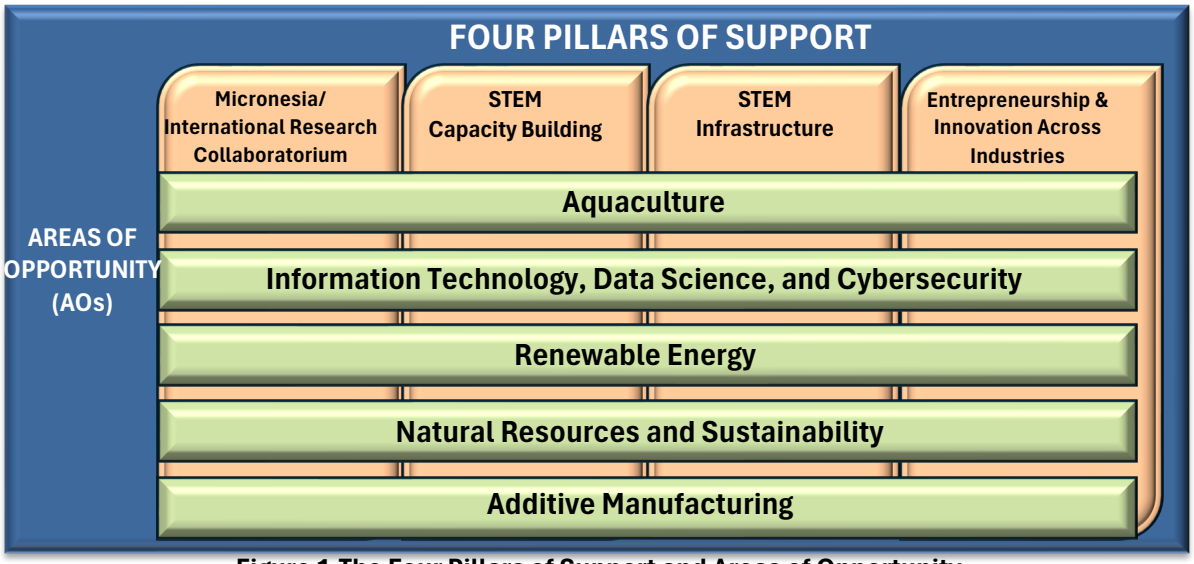


Figure 1.The Four Pillars of Support and Areas of Opportunity

To build a diverse economy, the Areas of Opportunity (AOs) are viewed through the lens of the four pillars and their respective connections. For a first round of vetting, existing planning documents from the Guam Economic Development Authority including the Comprehensive Economic Development

Plan, Aquaculture Feasibility Study, and others were analyzed. In addition, multiple meetings were held to capture input from a variety of stakeholders. These documents and others are listed in Sources Consulted after the Appendix.

Identifying specific AOs required extensive discussion in terms of practicable possibilities as well as a review of the literature and any previous related activities. The general observation was that through the decades, economic activities in Guam have been undisciplined and without the required mix of educational resources, research and development, and economic investments necessary to be successful and sustainable. The symbiotic relationship between research and economic activity seems obvious to those familiar with the Land Grant mission of the University and activities. To local policy persons and nonacademic stakeholders, however, articulating the community benefit that results from a STEM-centric ecosystem remains a work in progress.

Through the work of the S&T Committee, however, representatives across stakeholder groups are represented who may press forward a STEM driven economic agenda. These particular Areas of Opportunity were selected because connections are manifestly the strongest between university generated research via Guam NSF EPSCoR and other units and economic activities being undertaken by the government and private sector.

CHAPTER II: SETTING THE TABLE: UNDERSTANDING GUAM'S ECONOMY

Current Economic Indicators

The Gross Domestic Product of Guam as of 2022 is $6.9 billion with the primary contributors being private construction investments and tourism. Like other states and territories, Guam's economy was crippled by the COVID19 pandemic and subsequently buoyed by federal stimulus funding. What provided additional tailwinds to aid in Guam's recovery was construction spending aligned with the rapid military buildup in Guam.

The economic impacts of tourism, defense, and pandemic federal stimulus monies have caused inflationary pressures similar to the continental United States. The Consumer Price Index rose 25% from 2019 to 2023. The greatest contributors were food (26%), housing (21%), and medical care (36%). The literature is mixed with regard to the effects of defense spending on the growth of the US economy. Further, even less literature exists with regard to defense communities experiencing expansion. However, some of the common themes include trade-offs between defense spending and infrastructure investment and the squeezing out effect of the industry versus others in terms of physical and human capital.

Unemployment is at 4.1% in 2024. Prepandemic unemployment was approximately 3.6% and this reached 19.4% at its height during the pandemic. To handle the construction workload, there are 5,395 H2B Visa Workers who augment the local workforce. Guam-based talent varies across industries, especially STEM related fields.

Two Main Industries: Tourism and Defense

With its proximity to Asia, Guam's two main industries have historically been tourism and defense. Prior to the COVID19 pandemic, the tourism industry attracted 1.6 million visitors annually, accounting for $2.5 billion in local sales and providing over 21,000 jobs (a third of Guam's workforce, including indirect and induced). According to the Guam Visitors Bureau (GVB), visitor spending decreased from $1.8 billion in 2019 to $88 million in 2021. As a consequence, tourism-related jobs decreased from 23,100 in 2019 to 12,425 in 2021.

Typhoon Mawar, which hit Guam in May of 2023, caused extensive damage across the island interrupting water and power services as well as cellular services for weeks, with some areas experiencing outages for more than six weeks. The economic damage caused by the typhoon slowed the island's recovery from the COVID19 pandemic. Nearly one year after Typhoon Mawar, tourism arrivals are still 50% below pre-pandemic numbers, but show improvement. Additionally, the primary source markets for visitors are Japan and Korea. Korean visitors have returned at a greater pace than visitors from Japan, much of which is due to the weakened Yen versus Dollar rate at the current time.

With tourism's sluggish recovery, defense spending has become a critical contributor to the local economy. The 2025 Executive Budget Request from the governor of Guam indicates Guam's economic recovery is expected to continue, prompted by a significant increase in construction activity related to the military build-up in Guam and the Commonwealth of the Mariana Islands (CNMI). The governor's 2025 Executive Budget Request states, "Gross receipt taxes paid for construction increased from $48.2 million in FY 2020 to $70.7 million for FY 2023."

With Guam having the only military facilities on U.S. soil in the Western Pacific Ocean, the island is critical for extending and protecting American strategic power in the Indo-Pacific Arena. INDOPACOM, headquartered in Hawai'i exercises command and control for joint forces in its area of responsibility including Guam, with the US Navy as the lead military branch although there is a strong US Air Force presence and a growing US Army presence.

There are estimated to be 6,400 active service members stationed in Guam supported by 11,616 total personnel excluding private contractors. The Department of Defense currently owns approximately 25% of land throughout the island. Considering the geographic proximity of the island to nuclear capable missiles from North Korea and the People's Republic of China, the "defense of Guam" is a priority of the Department of Defense as evidenced by $3.5 billion spent between Fiscal Years 2015 and 2023.

As geopolitical competition increased in the broader IndoPacific Region, National Defense Authorization Act funding related to the military buildup on Guam has increased from approximately $290.5 million in 2020 to over $4.2 billion in 2024. Military construction proposed requests amount to $7.3 billion. Marine Realignment projects equate to $8.7 billion. The Pacific Deterrence Initiative is a regional plan to improve presence, logistics, exercises, infrastructure, and strength of allied partners with a total investment of $60 billion in the region, $6 billion to $8 billion of which is expected for Guam. Lastly, the Missile Defense Agency and Polaris Point Submarine Base have estimates of $838 million and $14 billion respectively for projects in excess of "core" build up projects mentioned earlier.

High levels of economic activity are all associated with anything related to the military buildup, most significantly in the industries of: construction, shipping, banking services, and U.S. air carriers. While these industries do have applied STEM applications, the S&T Committee sees the four Areas of Opportunity as the most universally beneficial industries that will not only contribute to national defense advancement, but also to the economic advancement and diversification of the island.

Economic Diversification Initiatives

To develop and grow other local industries, Governor Lourdes A. Leon Guerrero established an Economic Diversification Working Group in 2020 to consider existing and new market sectors to expand Guam's economic potential within social, environmental, and economic goals. The Governor's directive to the Economic Diversification Working Group was to address the following:

- Enhance Existing Infrastructure and Expand for New Development
- Develop Economic Diversification with Viable Industries
- Explore Ways to Promote Potential New Industries
- Expand Workforce Development Opportunities

- Foster Island Sustainability through a Circular Economy and with Island Wisdom

The S&T Economic Diversification Plan endeavors to expand upon the Governor's directive with a focus on investing in STEM to drive research, collaboration, and incubation of new ventures and industries.

The Guam Comprehensive Economic Development Strategy (CEDS) 2020-2025 provides a framework to achieve sustainable economic development goals for the island. The document has since been updated to reflect the impact of the COVID-19 pandemic locally and to highlight recovery strategies guided by priorities of the Governor Leon Guerrero's Economic Diversification Working Group. The resulting Guam CEDS 2020-2025 Pandemic Recovery Update includes project priorities that encourage economic diversification efforts focused on STEM-related initiatives and infrastructure.

Projects that appeared in the CEDS 2020-25 document include projects that would lead to increased and improved STEM infrastructure on the island, including the development of an aquaculture innovation center, agriculture technology, the development of a tech park, fiber optics, and renewable energy from multiple sources including solar power. Initiated in previous CEDS, feasibility studies have been completed for commercial aquaculture and additive manufacturing which has led to follow-on actions involving the early-stage development of a regional aquaculture innovation center and additive manufacturing incubator. For data collection, the Guam Customs and Quarantine Agency is rolling out the Harmonized Coding and Commodities System to track imports and exports. This data collection is helpful in planning forthcoming AO activities.

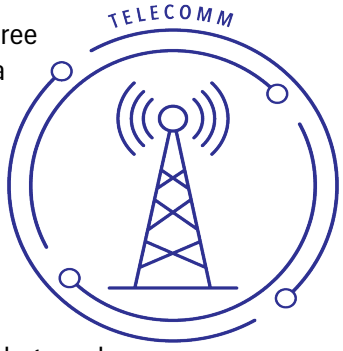
The U.S. Department of Commerce awarded Guam $156 million in Broadband Equity Access Deployment (BEAD) funding to increase access to reliable high-speed internet for the island. The Office of Infrastructure Policy and Development submitted Guam's plan for approval, which includes workforce development at multiple levels, a solar powered data center, and attracting content delivery networks to the island. BEAD funding will be used to strengthen the carrier-neutral Mariana Islands Internet Exchange (MARIIX) and the Guam Open Research Education Exchange (GOREX) to create a robust core infrastructure across multiple sectors.

The National Security Agency funding opportunity to benefit Guam also funds workforce development with a focus on cybersecurity. BEAD, National Security Agency, and other awards, such as the $62M US EPA residential solar project, provide funding to develop Guam's STEM curriculum and workforce at multiple levels to create pipelines for skill development from high school to higher education and through to industry.

While the BEAD, NSA, and USEPA funding were unrelated to Department of Defense funding, the defense nexus has created an environment for certain industries in Guam under the Economic Diversification Working Group to have a natural advantage. These include Aquaculture, Additive Manufacturing and Telecommunications. Aquaculture promotes food security; additive manufacturing has applications in ship and submarine repair and cybersecurity needs across the board means greater interest in telecommunications. The necessary STEM applications in workforce and asset development in these three areas provide a nexus for additional federal support from the Department of Defense and related agencies.

Connecting Industry, Research and STEM Workforce Through Incubators

Notwithstanding the expansion and contraction of defense funding, post pandemic federal aid, and the state of tourism, the critical mission of the S&T Committee is to achieve greater economic sustainability through STEM-based diversification. This S&T Plan outlines how this can be accomplished in five specific areas through building research capacity, promoting entrepreneurship, innovation through incubators and attracting investment to scale industry initiatives.

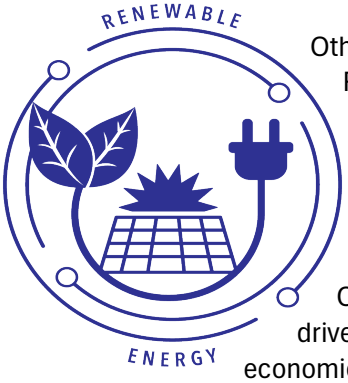


To date, the most significant private investment among the three industries is in telecommunications. Guam currently has 12 undersea cables landing on the island with four more announced by Google in the last three months as part of its Pacific Connect Initiative. To put it into perspective, the entire island of Taiwan has 14 cables. The Pacific Connect Initiative is meant to improve telecommunications resilience in the region and redundancy in the event of a catastrophic disaster or act of war in the region.

The need for a professional, skilled workforce in Information Technology and cybersecurity should be addressed within the Guam context. According to some news reports (Maggie Miller, "America's Potential Achilles' Heel in a Cyber Battle with China," Politico, (9/16/2023), Guam is a major center of cybersecurity competition issues due to international rivalry along global and security lines. Large data set capacity and interest in establishing a data center in Guam both facilitates and requires research. This Guam and regional focus provide opportunities which can be addressed through collaboration between Government, the private sector, and researchers. This suggests the formation of an incubator that addresses training needs, identifies potential private sector opportunities, and utilizes research.

The second industry attracting private investment is Additive Manufacturing, which has many innovative applications. The Department of Defense looks to Additive Manufacturing to support the island's security submarine industrial base. At first, Additive Manufacturing seemed more exploratory and less tied to near term commercial activity. However, following the completion of the feasibility study by GEDA, there were a number of partnerships that show early signs of promise to bridge research, innovation and practice. The most recent investment of $500K from the Department of Defense for educational planning at the University of Guam, Guam Community College, and Colorado School of Mines, an R1 institution, to develop the early workforce for this industry including a seamless transfer program (2+2) in mechanical engineering to support workforce development within the field. This is a strong indicator of the DOD's affinity to this industry. Concurrent with the workforce plan, there are also early plans for a research, certification, testing and incubator laboratory. The laboratory can offer third-party certification for parts produced through the additive manufacturing process. Five students from Guam will attend a 16-week additive manufacturing training in Danville, Virginia in July 2024 to learn how to use production scale machinery. The University of Guam's Guam Green Growth Initiative also features the G-3 Circular Economy Makerspace and Innovation Hub which facilitates small business and artistic and sustainability projects.

Lastly, the aquaculture industry has implications for regional food security, but also innovations in the area of food production. The Pacific Ocean surrounding Guam boasts the biodiversity undersea comparable to that of the Amazon Rainforest above ground. Guam and neighboring islands have experimental sites for various research and studies, but the scaling of research into industry opportunity has been sparse. With the frequency of flights to Asia coming in and leaving Guam, there is potential to perform unique research on marine life in the region and then bridge that knowledge into commerce in the seafood and aquarium trade markets of Asia and the world. Through an Aquaculture Innovation Center that serves as an incubator for research and entrepreneurship, the odds of bridging research and practice and subsequently scaling that practice for economic gains is within reach.



Other areas like Renewable Energy and the protection of Natural Resources generated collaborative activities over the past two decades. However, they have not coalesced into specific incubators which offer the best opportunity for moving forward. Incubators for these areas should be specified in the full implementation of this plan.

Connecting the energy behind economic diversification and a STEM-driven, knowledge-based economy is the best chance for long-term economic sustainability which utilizes local talent, entrepreneurial energy, and Guam-based research. The Guam EPSCoR S&T Committee understands the necessity of providing foundational support for STEM in all economic activities to ensure the best chance for sustainable and diversified economic activity. The Committee also understands the need for four foundational steps necessary to provide this support across the public, private and educational sectors. These are the four pillars of the EPSCoR S&T Plan.

CHAPTER III: BUILDING A FOUNDATION FOR A STEM-BASED ECONOMY- THE PILLARS

A STEM-based economy will not develop without planning, investment, and commitment. The role of the EPSCoR S&T Plan is to draw attention to necessary investments by educational institutions and the private sector and to identify gaps not supported by current funding. A successful knowledge-based economy requires STEM capacity building in all educational institutions and activities which are based on specific and concrete K-12 STEM educational objectives. This needs to be paired with actual workforce development activities in the private sector and the identification of federal and private sector investment in a strong STEM infrastructure. The economic benefits from this STEM capacity and STEM infrastructure must be made manifest in Entrepreneurship and Innovation across specific opportunity areas. The mechanisms for enabling this include research centers, incubators, and possible regional and international partnerships.

Micronesia/International Research Collaboratorium

The role of the Micronesian Collaboratorium in providing a network of research for all these efforts is critical. The Collaboratorium becomes a multi-faceted venue for the collection of research on a local, regional, and international basis. It will feature, but not be limited to, research institutional partnerships. These partnerships will help identify possibilities for use-inspired research to bridge into beneficial community action, be it economic diversification or otherwise. The Collaboratorium is essential and organizes as well as makes useful the research activities conducted by Guam NSF EPSCoR, the broader University of Guam community, and institutions conducting research in Guam and the Micronesian Region.

Over the years, the Collaboratorium has engaged with different institutions for research-oriented purposes. In cyberinfrastructure, Guam NSF EPSCoR was pivotal in leveraging Guam's strategic position to establish the Guam Open Research & Education Exchange (GOREX), connecting UOG with a diverse group of partners to improve Pacific-wide research and education networks. More recently, Guam NSF EPSCoR began participating in the Oklahoma University Regional Research Store which guarantees Guam NSF EPSCoR access to long-term data storage and archival solutions. In research, relationships have been established nationally and internationally with German, British, Australian, Japanese and U.S. institutions in marine genomics. Special emphasis has been given to the development of a Biorepository Team which attracted other researchers. In a recent (2024) "Bioblitz" activity, roughly 3000 specimens were collected over 20 days in Guam. Estimates are that 10-15% of these specimens are new to science or so-far unrecorded species for Guam. Similar international researcher networks conducted extensive studies on squirrel and soldier fish (both family Holocentridae). These specimens are added to the over 30,000 curated marine specimens at the University of Guam.

A series of partnerships to advance both economic advancements and STEM capacity in the region include the following: Pacific Northwest National Laboratory (PNNL), the Arizona State University Julie Ann Wrigley Global Futures Laboratory, the Guam Department of Education, Guam Science and

Discovery Society, the Society for the Advancement of Chicanos/Hispanics, and Native Americans in Science (SACNAS), Jeju National University, Sloan Foundation, NSF INCLUDES SEAS Islands Alliance, and NSF Cultural Transformation in the Geosciences Community (CTGC) Navigating Home.

Guam NSF EPSCoR launched its first Bioblitz in February 2024, an international collaboration to catalog the diversity of marine organisms found along the coasts of Guam. The research team surveyed around 50 sites through dives, intertidal walks, and snorkeling to collect organisms such as crabs, shrimps, worms, and mollusks. Over a thousand species were collected, resulting in hundreds of new marine biological records and species housed at the GECCO Biorepository to serve as a testament to the island's rich biodiversity. (Pictured, from left: Dr. Svetlana Maslakova, University of Oregon; Dr. Gustav Paulay, Florida Museum; Diana Noto, Guam NSF EPSCoR Graduate Research Assistant; Dr. Kristine White, Georgia College & State University; and Garret O'Donnell, Guam NSF EPSCoR Graduate Research Assistant).

Graduate students from UOG as well as scientists from Saipan attended a workshop called Jungle Histology: Fish Gonad Analysis at the UOG Marine Laboratory to learn how to determine the sex and maturity of reef fishes. The workshop provided training in the aging of fish and gonad histology - important skills for fisheries scientists and managers. (TOP: Andrew O'Neill, a Guam NSF EPSCoR Graduate Research Assistant, dissects a fish. BOTTOM: Naomi Billimon, a student at the Northern Marianas college in Saipan and an intern with the CNMI Division of Fish and Wildlife, examines fish gonads using a microscope.)

STEM Capacity

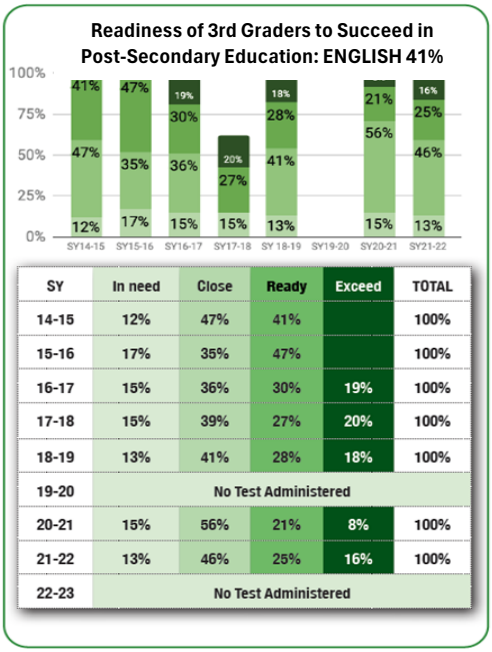
K-12 Education

STEM Capacity building in Guam is extensive and covers multiple efforts by the Guam Department of Education (GDOE), Charter Schools, as well as the Guam Community College and the University of Guam. Increased attention to developing STEM capacity in recent years reflects national and international trends about the environment and climate change, technological advancement, and the local need to diversify the economy.

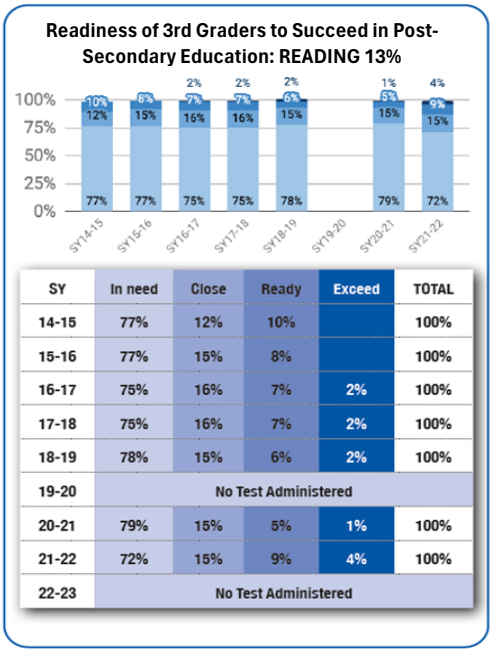
As part of its standard curriculum, the GDOE expends more resources than GCC and UOG in the teaching of science and, especially, math. These subjects are given a great deal of attention, and many supplemental programs are provided on their behalf. GDOE historically assesses English, Reading, and Math Skills through a variety of instruments over the years. The results have not been encouraging.

Specific to Math and Science, the testing for the past few years has been interrupted by the COVID19 pandemic. GDOE administered the ACT Aspire Testing program for a number of grades to assess readiness for success in post-secondary education in 2023. "Ready" means a 50% chance of success at college level and "exceed" means they are likely to succeed. The following tables from the Annual State of Public Education Report SY 22-23 (ASPER) provide evidence of student readiness for grade level work in the major curricular areas. The scores for 3rd grade and 6th are used since they are the only ones that include both Math and Science. Although students perform a little better in science, the results indicate significant challenges in STEM overall. By comparison, the results in English and Reading are encouraging and demonstrate greater success.

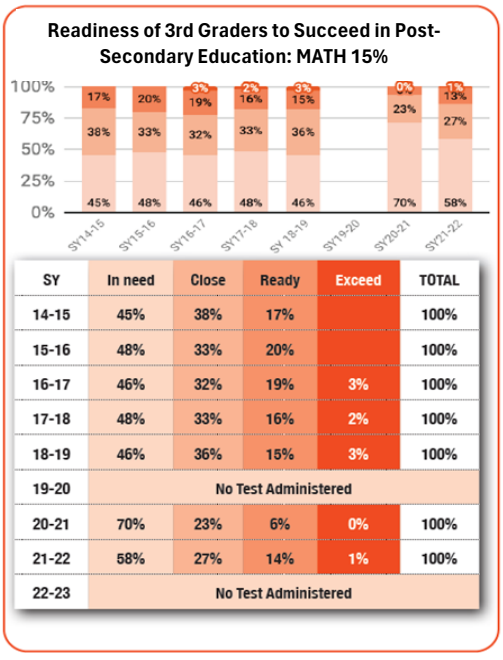
Figure 2. Post-Secondary Readiness – 3rd Grade (ASPER, October 2023)



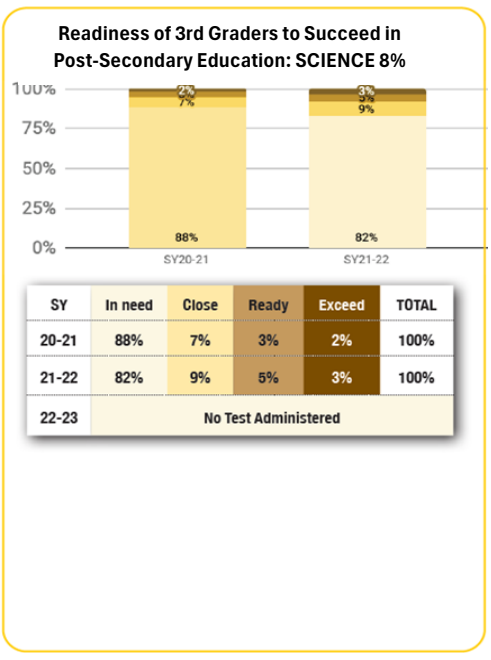
SY	In need	Close	Ready	Exceed	TOTAL
14-15	12%	47%	41%		100%
15-16	17%	35%	47%		100%
16-17	15%	36%	30%	19%	100%
17-18	15%	39%	27%	20%	100%
18-19	13%	41%	28%	18%	100%
19-20	No Test Administered				
20-21	15%	56%	21%	8%	100%
21-22	13%	46%	25%	16%	100%
22-23	No Test Administered				



SY	In need	Close	Ready	Exceed	TOTAL
14-15	77%	12%	10%		100%
15-16	77%	15%	8%		100%
16-17	75%	16%	7%	2%	100%
17-18	75%	16%	7%	2%	100%
18-19	78%	15%	6%	2%	100%
19-20	No Test Administered				
20-21	79%	15%	5%	1%	100%
21-22	72%	15%	9%	4%	100%
22-23	No Test Administered				

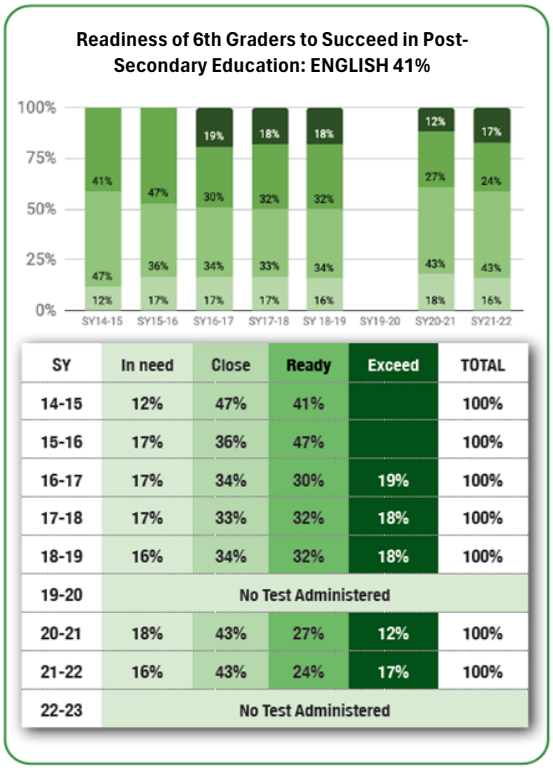


SY	In need	Close	Ready	Exceed	TOTAL
14-15	45%	38%	17%		100%
15-16	48%	33%	20%		100%
16-17	46%	32%	19%	3%	100%
17-18	48%	33%	16%	2%	100%
18-19	46%	36%	15%	3%	100%
19-20	No Test Administered				
20-21	70%	23%	6%	0%	100%
21-22	58%	27%	14%	1%	100%
22-23	No Test Administered				

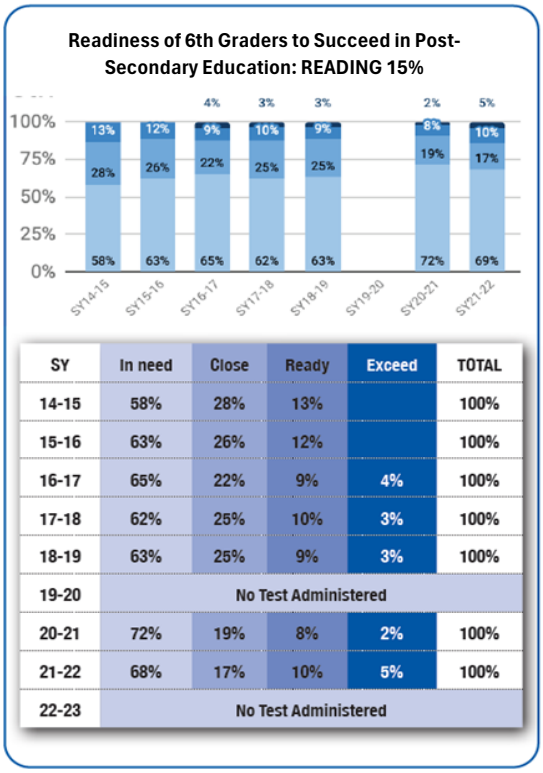


SY	In need	Close	Ready	Exceed	TOTAL
20-21	88%	7%	3%	2%	100%
21-22	82%	9%	5%	3%	100%
22-23	No Test Administered				

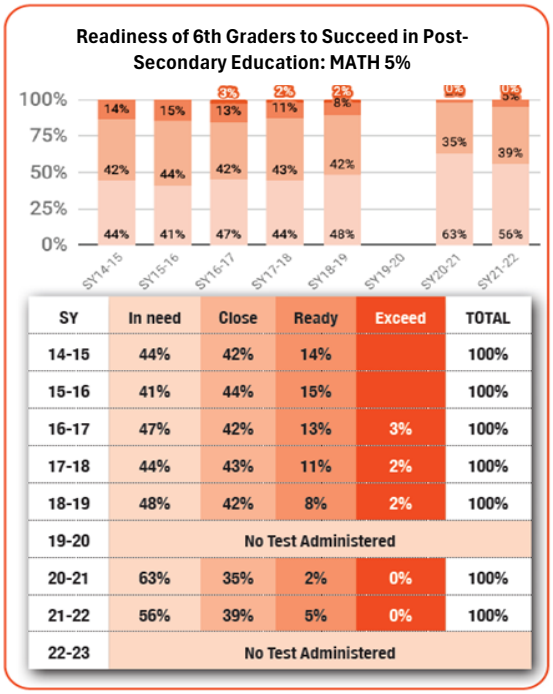
Figure 3. Post-Secondary Readiness – 6th Grade (ASPER, October 2023)



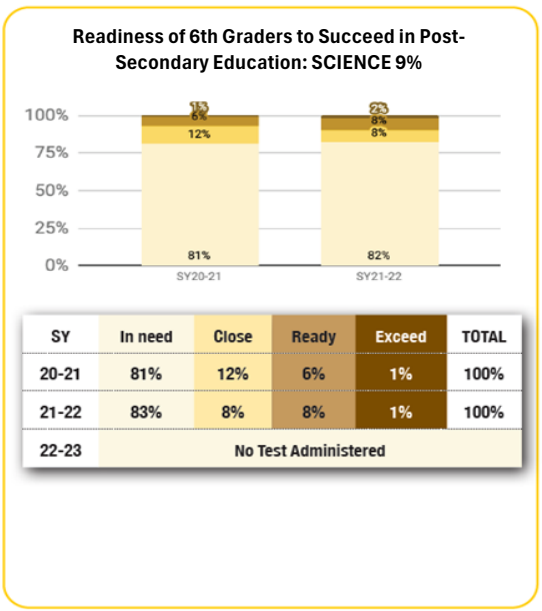
SY	In need	Close	Ready	Exceed	TOTAL
14-15	12%	47%	41%		100%
15-16	17%	36%	47%		100%
16-17	17%	34%	30%	19%	100%
17-18	17%	33%	32%	18%	100%
18-19	16%	34%	32%	18%	100%
19-20	No Test Administered				
20-21	18%	43%	27%	12%	100%
21-22	16%	43%	24%	17%	100%
22-23	No Test Administered				



SY	In need	Close	Ready	Exceed	TOTAL
14-15	58%	28%	13%		100%
15-16	63%	26%	12%		100%
16-17	65%	22%	9%	4%	100%
17-18	62%	25%	10%	3%	100%
18-19	63%	25%	9%	3%	100%
19-20	No Test Administered				
20-21	72%	19%	8%	2%	100%
21-22	68%	17%	10%	5%	100%
22-23	No Test Administered				



SY	In need	Close	Ready	Exceed	TOTAL
14-15	44%	42%	14%		100%
15-16	41%	44%	15%		100%
16-17	47%	42%	13%	3%	100%
17-18	44%	43%	11%	2%	100%
18-19	48%	42%	8%	2%	100%
19-20	No Test Administered				
20-21	63%	35%	2%	0%	100%
21-22	56%	39%	5%	0%	100%
22-23	No Test Administered				



SY	In need	Close	Ready	Exceed	TOTAL
20-21	81%	12%	6%	1%	100%
21-22	83%	8%	8%	1%	100%
22-23	No Test Administered				

Assessment in GDOE is undergoing changes. They are currently using the Smarter Balanced Package of Testing produced by Pearson for English Language Arts and Math. Next year they will incorporate the NGSS Science Assessment. Testing will occur from the 3rd to the 8th grade and the third year in high school. In conjunction with the Guam Community College, GDOE assesses workforce preparation

through the administration of the ACT WorkKeys testing. This is a broad-based assessment of capacity to enter the workforce, but it does measure basic math and thinking skills. Similar to ACT Aspire which is generally used to assess readiness for postsecondary education, ACT WorkKeys assesses readiness for the workplace. Understanding workplace documents, solving applied mathematical problems and interpreting information in graphic formats are assessed. Almost all high school students participate in the assessment and are given a rating ranging from Bronze to Silver to Gold to Platinum.

The results of this assessment from School Year (SY) 2014/2015 to SY 22/23 are presented below in Figure 4 from the ASPER Report, p. 23.

Table 1. ACT WorkKeys Readiness for Work

	BRONZE	SILVER	GOLD	PLATINUM	TOTAL RECEIVED
SY 13-14	116	170	95	0	381
TOTAL TESTED	395	395	395	395	395
	29%	43%	24%	0%	96%
SY 14-15	277	313	40	1	631
TOTAL TESTED	1,088	1,088	1,088	1,088	1,088
	25%	29%	4%	0%	58%
SY 15-16	193	223	54	0	470
TOTAL TESTED	591	591	591	591	591
	33%	38%	9%	0%	80%
SY 16-17	122	165	19	0	306
TOTAL TESTED	411	411	411	411	411
	30%	40%	5%	0%	74%
SY 17-18	317	291	92	68	768
TOTAL TESTED	910	910	910	910	910
	35%	32%	10%	7%	84%
SY 18-19	399	257	149	98	903
TOTAL TESTED	1,089	1,089	1,089	1,089	1,089
	37%	24%	14%	9%	83%
SY 19-20	35	39	17	4	95
TOTAL TESTED	147	147	147	147	147
	24%	27%	12%	3%	65%
SY 20-21	29	30	20	7	86
TOTAL TESTED	98	98	98	98	98
	29.6%	30.6%	20.4%	7.1%	87.8%
SY 21-22	170	186	84	45	485
TOTAL TESTED	583	583	583	583	583
	29%	32%	14%	8%	83%
SY 22-23	**1,048**	**549**	**275**	**128**	**2,000**
TOTAL TESTED	**3,054**	**3,054**	**3,054**	**3,054**	**3,054**
	34.32%	**17.98%**	**9.00%**	**4.19%**	**65.49%**

The results are mixed and show some decline in the most recent report of the GDOE. The greatest specific effort of GDOE in terms of science is the federally funded Life Readiness program. This program funds a wide range of science teaching and learning programs through professional

development, procurement of STEM supplies/equipment, sponsoring special academic events and youth development programs. STEM cadres are organized by schools who help facilitate training activities, collect data, and share resources. Topics for training and lesson development include "block coding," and engineering which include drone and robotics projects. Funded at $1.2 million for the past three years, the Life Readiness also directly assists teachers and encourages STEAM which is STEM with art.

There are a great deal of STEM-related activities in K-12 throughout the island including the Annual Science Fair and a number of programs at both UOG and GCC which introduce college-level content to promising students. The relative impact of these activities is not reflected in the assessment instruments, but the affected students do attend and succeed in UOG and GCC degree programs.

Private schools were previously offered the opportunity to participate in ACT Aspire Testing. Currently, Father Duenas High School, along with other Catholic elementary and middle schools and the three Charter Schools identified below participate in the Smarter Balanced Assessment. St John's School (Episcopal) does not but instead utilize MAP NWEA. They do not test specifically for science, but half of their students are in the International Baccalaureate (IB) program and all students take some IB courses.

Currently, there are several charter schools focused on STEM education. iLearn Academy provides a Grade K-5 curriculum for 740 students. SIFA (Science is Fun and Awesome) Learning Academy Charter School offers a Grades K-8 curriculum focused on robotics and mechanical engineering for 348 students. CareerTech High School currently has 75 students enrolled and provides certificate training in technical fields.

In addition to this, there is a major supplemental effort by the Department of Defense Starbase Program. This effort provides funding for STEM programs via the Guam Army National Guard. It is part of over 80 similar academies across the United States. Participants receive 25 hours of STEM curriculum and instruction over the course of one week. Students who participate are challenged with "hands-on, minds-on" experiential activities that promote inquiry, critical thinking, problem solving, effective communication and collaboration.

Since its inception in 2021, DOD Starbase Guam has provided these lessons directly to over 3,200 underserved 5th grade students across the island in GDOE, charter, private and DODEA (Department of Defense) schools. DOD Starbase also provides supplemental instructional materials and outreach events. For the past two fiscal years and likely for the upcoming, DOD Starbase is given $793,000 to carry out its activities.

Guam Community College

The Guam Community College (GCC)is a multi-faceted public career and technical educational institution which offers over 50 different fields of study. These programs prepare students for entry-level employment in career and technical fields as well as transfer to four-year programs at other institutions of higher education. GCC also offers programs off-campus in businesses and all public high schools as part of its responsibility as the State Agency for Career and Technical Education.

Several of the degree and certificate programs have a direct STEM nexus and contribute to the island's economic growth. Certificate programs can be created for specific STEM-related employment opportunities in conjunction with many of the incubators which are contemplated in this plan.

Table 2. Guam Community College Degree Completion

Completers: Degree (Conferral)

Academic Year	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Bachelor of Science						
Career and Technical Education[29]	—	—	—	—	—	1
Associate of Arts						
Culinary Arts	15	16	14	19	16	13
Education	36	30	26	10	18	8
Liberal Studies[30]	29	16	9	7	15	11
Subtotal	**80**	**62**	**49**	**36**	**49**	**32**
Associate of Science						
Accounting	18	11	10	4	17	14
Automotive Service Technology (AST)[31]	5	11	0	0	0	0
AST – General Service Technician[32]	0	0	4	3	5	7
AST – Master Service Technician[33]	0	0	3	4	1	6
Civil Engineering Technology[34]	1	0	2	0	1	6
Computer Networking[35]	14	5	10	14	16	23
Computer Science	12	14	13	7	12	29
Criminal Justice	24	28	30	31	17	29
Early Childhood Education	37	25	29	30	18	17
Emergency Management[36]	0	0	0	0	0	0
Food & Beverage Management[37]	3	0	1	0	0	0
Foodservice Management[38]	—	—	—	7	4	4
Hospitality Industry Management[39]	6	1	1	1	0	0
Hotel Operations & Management[40]	4	1	0	0	0	0
Human Services[41]	10	9	7	6	13	12
International Hotel Management [42]	—	2	6	2	9	3
Marketing	16	7	14	15	10	13
Medical Assisting	12	20	18	19	18	11
Office Technology	3	1	4	3	4	2
Practical Nursing	—	—	0	19	13	0
Pre-Architectural Drafting[43]	2	5	3	0	1	5
Supervision & Management	11	9	14	3	12	9
Surveying Technology[44]	0	1	0	0	0	2
Tourism & Travel Management[45]	18	6	15	17	14	9
Visual Communication	18	15	5	19	11	15
Subtotal	**214**	**171**	**189**	**204**	**196**	**216**

Table 3. Guam Community College Certificate Completion

Completers: Certificate and Other Programs (Conferral)

Academic Year	2017-2018	2018-2019	2019-2020	2020-2021	2021-2022	2022-2023
Certificate						
Accounting	—	—	—	—	—	—
Automotive Service Technology (AST)	1	1	9	4	4	9
Automotive Technology	—	—	—	—	—	—
Computer Aided Design & Drafting[46]	1	4	3	0	0	1
Computer Science	1	0	2	0	0	1
Construction Technology	4	6	6	0	5	4
Criminal Justice	25	8	9	15	9	11
Early Childhood Education	18	21	21	16	12	7
Education	1	0	2	0	1	2
Emergency Management[47]	0	0	0	0	0	0
Environmental Technician	0	1	1	0	0	0
Family Services	3	2	1	5	12	11
Fire Science	0	0	0	0	0	0
Medical Assisting	13	21	19	20	20	12
Medium/Heavy Truck Diesel Tech[48]	0	0	0	0	0	0
Office Technology	0	0	5	2	3	3
Practical Nursing[49]	17	0	0	0	0	0
Sign Language Interpreting	—	10	6	1	0	1
Supervision & Management	2	2	0	0	2	2
Surveying Technology	0	0	0	0	0	1
Subtotal	**86**	**76**	**84**	**63**	**68**	**65**
Other						
Adult High School Diploma[50]	38	22	52	30	27	51
Criminal Justice Industry Certificate	2	0	0	0	0	0
High School Equivalency	38	17	8	0	0	0
Cosmetology Industry Certificate [51]	0	0	0	0	1	0
Journeyworker Certificate	20	26	27	4	6	3
Nursing Assistant Industry Certification	4	0	7	0	0	0
Subtotal	**102**	**65**	**94**	**34**	**34**	**54**
GRAND TOTAL	**482**	**374**	**416**	**337**	**347**	**368**

Source: GCC Fact Book, Volume 1-17; Banner

University of Guam

The University of Guam (UOG) is an open-admission USDA Land Grant and now Sea Grant Institution. It has historically been the primary baccalaureate-degree granting institution in Guam and the Micronesian Region. It offers master's programs and recently added a Doctorate in Education program. Its mission is Ina Deskubre Setbe (Enlighten, Discover, Serve) and proclaims its fundamental purpose as "to empower the region by uniting island wisdom with universal sources of enlightenment to support exceptional education discovery and service that respect and benefit local and global communities."

Since the beginning of the institution, UOG's primary effort has been the granting of degrees. The record of degree completion for the past decade in a variety of fields is listed below in Table 6.

Table 4. UOG Degree Completion UOG Fact Book 2022-2023, pp. 41-43

Number of Degrees Granted by Academic Year, Degree Level, and Major

DEGREE LEVEL	MAJOR	2012 2013	2013 2014	2014 2015	2015 2016	2016 2017	2017 2018	2018 2019	2019 2020	2020 2021	2021 2022	2022 2023*
Undergraduate Programs												
ASSOCIATE	Nursing	0										
BACHELORS	Accounting	38	22	39	32	31	31	34	15	21	28	22
	Agriculture and Life Sciences							1	6	7	11	9
	Anthropology	5	7	1	6	3	4	0	4	3	2	2
	Biology	9	11	22	17	34	19	28	35	39	33	48
	Business Administration	60	60	86	89	94	107	103	103	101	84	70
	CHamoru Language, Elementary ED.	1	1	1	2	0	0	1	1	0	0	0
	CHamoru Language, Secondary ED.	2	0	1								
	CHamoru Studies										7	10
	Chemistry	2	2	3	5	6	6	4	9	16	9	10
	Civil Engineering										19	9
	Communication Studies	19	12	17	18	18	18	14	15	12	8	17
	Computer Info System	8	10	7	5	7	8	5	8	6	7	3
	Computer Science	3	3	8	10	3	9	17	9	10	15	6
	Consumer & Family Science	5	6	6	7	4	2	1	2	2		
	Criminal Justice	40	47	33	45	38	41	49	34	62	40	32
	Early Childhood/Elementary ED.	5	5	4	1	1	5	6	2	0	0	0
	East Asian Studies	0	0	1	1							
	Elementary Education	43	45	38	32	28	30	31	26	29	22	22
	English & ESL	1		1	0	0	0	0	0	0	0	0
	English	24	23	29	36	31	22	33	18	16	16	11
	Fine Arts/Art	7	3	6	4	9	8	15	1	8	6	7
	Fine Arts/Music	0	1	0	1	1	2	4	2	3	0	1
	Fine Arts/Theater	3	2	1	2	3	2	0	3	1	1	0
	Health Sciences	16	26	18	30	27	20	21	33	16	16	13
	Health, PE, Recreation and Dance											
	History	4	2	4	3	1	2	4	5	6	4	3
	Interdisciplinary Arts & Sciences	1	0	0	0	0	1					
	Japanese Studies	0	0	1	0	0	1	1	0	0	0	0
	Mathematics	5	16	6	14	10	12	11	13	12	5	5
	Nursing	30	24	32	23	13	31	32	26	29	32	17
	Pacific Asian Studies Program	0	0	1	9	3	3	8	7	1	2	0
	Philosophy	1	3	2	0	1	0	0	4	1	3	0
	Physical Ed./School Health	0	6	3	5	0	5	2	1	1	1	0
	Political Science	6	9	4	6	3	3	11	11	4	6	6
	Psychology	15	6	19	14	19	22	22	18	24	15	17
	Public Admin	9	17	15	10	7	18	12	10	14	10	16
	Secondary Education	5	14	17	10	12	12	5	17	25	27	12
	Social Studies Secondary ED.	7	0	0	0	0	0	0	0	0	0	0
	Social Work	6	13	12	20	17	25	24	23	29	13	23
	Sociology	4	5	5	8	10	10	5	7	4	0	3
	Special Education	9	6	7	6	3	5	5	3	1	0	0
	Tropical Agri W/Applied Emphasis	2	4	4	2	2	0	0	1	2	0	0
	Tropical Agriculture Research	0	1	1	0	1	1	2	0	1	0	0
Subtotal Undergraduate Programs		395	412	455	473	440	485	511	472	506	442	394
Prior Year Variance		8%	4%	10%	4%	-7%	10%	5%	-8%	7%	-13%	-11%
Graduate Programs												
MASTERS	Accountancy											0
	Admin & Supervision	7	3	4	7	2	8	3	5	2	1	2
	Art	0	0	1	0	0	1	1	0	0	0	0
	Biology	1	3	1	3	7	7	4	7	6	7	4
	Professional MBA	7	14	8	14	14	16	6	10	13	11	9
	Clinical Psychology	7	5	2	3	1	5	4	2	1	5	0
	Counseling	17	17	3	6	7	15	19	12	20	19	8
	Elementary Education	0	0	0	0	0	0	4	2	5	4	2
	English	0	2	3	2	3	2	5	3	5	3	0
	Environmental Science	6	2	5	0	3	0	3	8	0	3	4
	Innovations in Teaching & Learning											7
	Language & Literacy	0	0	0	0	0	0	0	0	0	0	0

	Micronesian Studies	1	0	0	0	3	0	1	1	3	0	0
	Public Administration	25	30	39	35	35	26	26	44	28	26	39
	Reading	0	16	12	16	14	14	16	22	24	16	21
	Sec Teaching: Practitioner	13	11	9	13	13	1		1	0	0	0
	Secondary ED. (MAT)	0	0	0	0	0	0	4	9	8	20	16
	Sec Teaching: Researcher	2	0	2	0	0	11	0	0	0	0	0
	Secondary ED. (MED)	1	11	2	8	11	3	5	12	4	0	4
	Special Education	19	0	7	2	7	0	9	0	9	9	0
	Sustainable Agriculture, Food, & Natural Resources	0	0	0	0	0	0	1	3	0	2	2
	Teaching English as A Second Language	2	0	4	5	0	3	3	4	7	3	0
Subtotal Graduate Programs		108	114	102	114	120	112	114	145	135	129	118
Prior Year Variance		-13%	6%	-11%	12%	5%	-7%	2%	27%	-7%	-4%	-9%
Total		503	526	557	587	560	597	625	617	641	571	512
Prior Year Variance		3%	5%	6%	5%	-5%	7%	5%	-1%	4%	-11%	-20%

Source: Colleague; ACAD.CREDENTIALS
*Pending complete recording of 2023 Finakpo' (Summer) graduates

The record of STEM-related degrees is steady even in the midst of declining enrollments experienced by nearly all postsecondary institutions. Biology remains strong. Civil Engineering has now become a degree at the University in the past three years and has strong enrollments. Agricultural & Life Sciences and Health Sciences are also STEM degrees, making UOG's record strong. UOG also offers a Master of Science in biology, Environmental Science (EV) and in Sustainable Agriculture Food & Natural Resources (SAFNR). Beginning in Fanuchanan (Fall) 2024, the MS in Data Science will be accepting students. These graduate programs could be significant contributors to the development of a knowledge-based economy. In addition to these degree programs, the community service programs of the UOG are extensive through its Cooperative Extension and Outreach programs, the Center for Island Sustainability and Sea Grant programs.

In spite of the challenge of declining student enrollment in many degree programs at UOG, UOG maintains a robust research agenda. Established research units like the Marine Laboratory, Water Environmental Research Institution of the Western Pacific (WERI), Western Pacific Tropical Research Center (WPTRC) and Micronesian Area Research Center (MARC) have an extensive record of science, agricultural and social science research. This effort has been enhanced dramatically by major National Science Foundation grants, most notably Guam NSF EPSCoR.

Between 2012 and 2022, the University of Guam's rank advanced from 378 to 284 in the National Science Foundation ranking by total research and development expenditures. As of 2022, UOG is in the 68th percentile of 890 institutions. This underscores the progress the institution and faculty have made in attracting federal research dollars in recent years.

Table 5. University of Guam Research Ranking (2012-2022)

Data Year	Total R&D Expenditures			Research space		
	Rank	Percentile	Institutions ranked	Rank	Percentile	Institutions ranked
2022	284	68.5	890	-	-	-
2021	291	32.6	909	324	55.9	583
2020	323	35.9	915	-	-	-
2019	321	35.7	913	427	72.7	589
2018	326	36.4	910	-	-	-
2017	337	38.1	897	449	78.3	575
2016	357	40.4	895	-	-	-
2015	374	42.2	897	431	75.8	570
2014	362	41.3	887	-	-	-
2013	375	42.9	884	437	74.5	588
2012	378	42.9	892	-	-	-

Source: National Center for Science and Engineering Statistics, Higher Education R&D Survey.

Lynn Galang, an integrative biology major at UOG and a former Guam NSF EPSCoR undergraduate student researcher, reaches into a coral tank at the UOG Marine Laboratory.

However, research space has not kept pace with research dollars. UOG is in the 55th percentile of 583 institutions ranked in terms of research space. Clearly, more laboratory space for research and development is necessary to further advance UOG's rank and support S&T economic diversification. Guam Community College is not currently ranked. UOG efforts to secure R&D funding in the future should be coordinated to include university-community college partnerships as encouraged by NSF. These partnerships will continue to be the focus of the S&T Committee with regard to growing a stronger STEM Infrastructure.

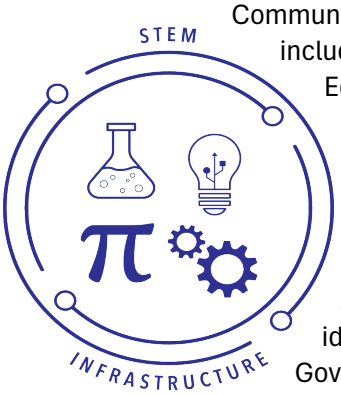
In UOG Outreach and Community Service activities, STEM education programs, like 4H, are equipping Guam's workforce with the skills needed to thrive in a diversified, green economy. Recent NSF EPSCoR, INCLUDES, and CTGC investments created over 250 new research and training opportunities for Pacific Island students in Guam and Micronesia at high school, undergraduate, graduate, postdoc, and early-career levels. By increased investment in STEM education at all levels, from K-12 schools to higher education institutions, Guam can cultivate a talent pool capable of driving innovation and technological advancements in key sectors such as renewable energy, environmental conservation, and sustainable tourism, as well as water management, forestry, and land conservation.

Guam NSF EPSCoR along with the NSF INCLUDES: SEAS Islands Alliance Guam Hub regularly hold near peer sessions to allow their program participants to learn new skills, network, and receive guidance on their research projects.

Beyond the classroom, the UOG CIS & Sea Grant outreach team engaged over 2,553 school participants (including students and educators) in 2023 and 6,642 event participants. Moreover, capacity building programs supported 42 students through Sea Grant, and NSF INCLUDES. Guam EPSCoR provided research internship opportunities for 70 undergraduate students since 2015 and 20% of these students went on to pursue master's degrees at UOG. Graduate student support was another key focus of GECCO, with 44 students that were supported in their pursuit of master's degrees. By the time of writing, 52% of master's students successfully completed their degree program and 18% have since enrolled in PhD programs while others entered the workforce. The benefit of this established pathway for training and degree programs have led to employment opportunities in local resource management agencies. Fostering close connections between research units and education at the new School of Engineering, the College of Natural and Applied Sciences, CIS/Sea Grant, Marine Lab and other campus units increase the potential for the development of innovative and sustainable products. The existing relationships provide a glidepath to the development of a future Higher Education Pathways Core in a new UOG EPSCoR.

STEM Infrastructure - Government and Private Sector Support

The COVID19 pandemic illuminated the Government of Guam's shortcomings in existing STEM infrastructure. As such, a push by the Government of Guam to modernize various once manual systems has taken place over the past five years. These include but are not limited to: the replacement of legacy financial and human resources software with an integrated cloud-backup financial management information system, the replacement of manual input of bills of lading to a harmonized commodities coding system at Customs and Quarantine, from an in person to a fully online business privilege tax filing system, and others.



Communications gaps became apparent delivery of online learning to all grades including at the college and University level. The Guam Department of Education, the Guam Community College, and the University of Guam utilized federal funding towards increasing individual accessibility of students in the home and village centers (Mayors Offices). To keep up with this pace of upgrades, the Government of Guam invested in cybersecurity training and bootcamps for existing personnel, but also expanded use of private contractors to work with both hardware and software. Additionally, to address the emerging latency challenges identified during the rollouts of all of the aforementioned programs, the Government of Guam submitted and were rewarded a Broadband Equity

Access and Deployment Grant. Guam was awarded $156 million for BEAD, and this is expected to be deployed over the next three to five years. Through this grant, there is the ability to work with private partners in the following areas:

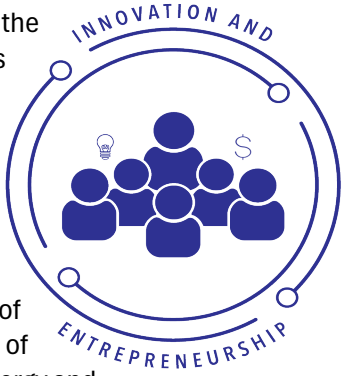
- Research, data collection, training on broadband deployment and access.
- Deployment projects to make internet accessible or upgrade projects to address latency
- Installing internet and Wi-Fi into multi-unit residential buildings
- Addressing issues of digital equity
- Workforce development and vocational training

The private sector utilizes various government incentive programs for workforce development training including the Guam Registered Apprenticeship Program (GRAP) to exchange training and apprenticeships in technician level jobs with tax credits towards territorial business privilege tax. The latest annual report lists 25 companies claiming a total of $10.5 million in tax credits under GRAP. Industries represented within the report include ship repair, telecommunications, and healthcare among others.

The private sector has also made multiple investments in the space of S&T Infrastructure by way of subsea cables and data centers. At the current time, there are 12 undersea cables making their way to Guam. Google announced additional cables throughout the Pacific through their Pacific Connect Initiative. This effort is meant to provide reliability and resilience not only for Guam but for surrounding islands throughout Oceania. Infrastructure improvements on the ground include the Alupang Data Center, a 31,000 Square Foot space built to Tier III standards with 4.0 megawatts of power capacity. This construction is expected to be completed in 2025.

Entrepreneurship and Innovation Across Industries

In order to successfully diversify the economy of Guam, a number of vehicles must be put in place in order to facilitate new economic activity that relies on innovation, an entrepreneurial spirit, and research. These will be developed through incubators which have a foundation in continuing research and the development of a STEM-prepared workforce. These building blocks exist but have not been fully integrated into mutually supportive structures or incubators.



UOG has been successful in attracting federal research dollars in the sciences, especially from the National Science Foundation (NSF) and its Established Program to Stimulate Competitive Research (EPSCoR) that provided two awards to UOG totaling $26M. The institution's first philanthropic award from the Sloan Foundation Corporation is the first successful foray into seeking private foundation investments in STEM.

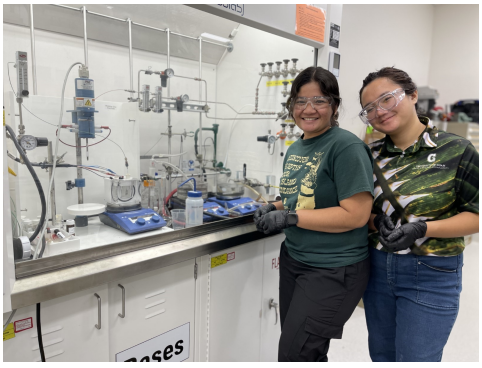
In 2022, UOG and GCC began to partner with Pacific Northwest National Laboratory (PNNL) on multiple grant applications from the Department of Energy (DOE). A key growth indicator will be to measure the number of successful awards Guam and PNNL obtain with a focus on renewable energy and advanced computing. DOE awarded two grants to Guam and PNNL, one to train UOG faculty and students in fundamental research to optimize extracting hydrogen from seawater and the procurement of equipment to support continuous experimental works and STEM education at UOG, and the second grant to measure wave energy production to support the aquaculture innovation center. In addition,

PNNL and UOG partnered to evaluate the feasibility of deploying marine renewable energy systems such as wave energy converters and/or ocean thermal energy conversion as renewable energy sources for powering aquaculture operations. Siting and energy generation potential and multi-use cases are explored in this project as well, such as seawater air conditioning. The research dollars have been invaluable for the advancement of knowledge and have teed up an opportunity for the emerging talent in these research areas to work on building commerce on this innovation.

In 2019, the Guam Economic Development entered a partnership with local non-profit Guam Unique Merchandise and Art (GUMA) which translates to "home" in CHamoru. to provide incubator services on behalf of GEDA to accelerate getting small businesses off the ground. This space began as cottage industry type makers and small and micro businesses; however, the entrepreneurs are starting to venture into more technology driven ventures. This micro business incubator and the UOG Center for Island Sustainability Makers Space both serve as community incubators for small business and entrepreneurs.

Historically, venture capital investment in startups has not been tracked or documented in Guam. In 2022, GEDA received the Department of the Treasury State Small Business Credit Initiative funding to provide loan and venture capital to entrepreneurs. In response to this, GEDA set up a wholly owned company named *Destinu Guam* to be the main conduit for the venture capital portion of funding which equates to approximately $58 million over 6 years. *Destinu Guam* has the capability to build funding from private and angel investors. The Venture Capital funding under SSBCI is meant to accelerate the growth of its ventures through pre-seed, seed, or even later stage funding.

With current small business incubators, the University of Guam research capacity, and government and private investments in economic diversification initiatives including aquaculture, additive manufacturing, and telecommunications, the natural next step is scaling and focusing existing efforts towards S&T driven and supported incubator spaces.



Anna Mallari and Merry Remetira, two civil engineering students from UOG, learned how to convert seawater into renewable energy as part of a collaboration between UOG and the U.S. Department of Energy's Pacific Northwest National Laboratory to establish a diverse and equitable recruitment and retention program to build UOG and Guam's future energy workforce. Both Mallari and Remetira are former Guam NSF EPSCoR undergraduate student researchers.

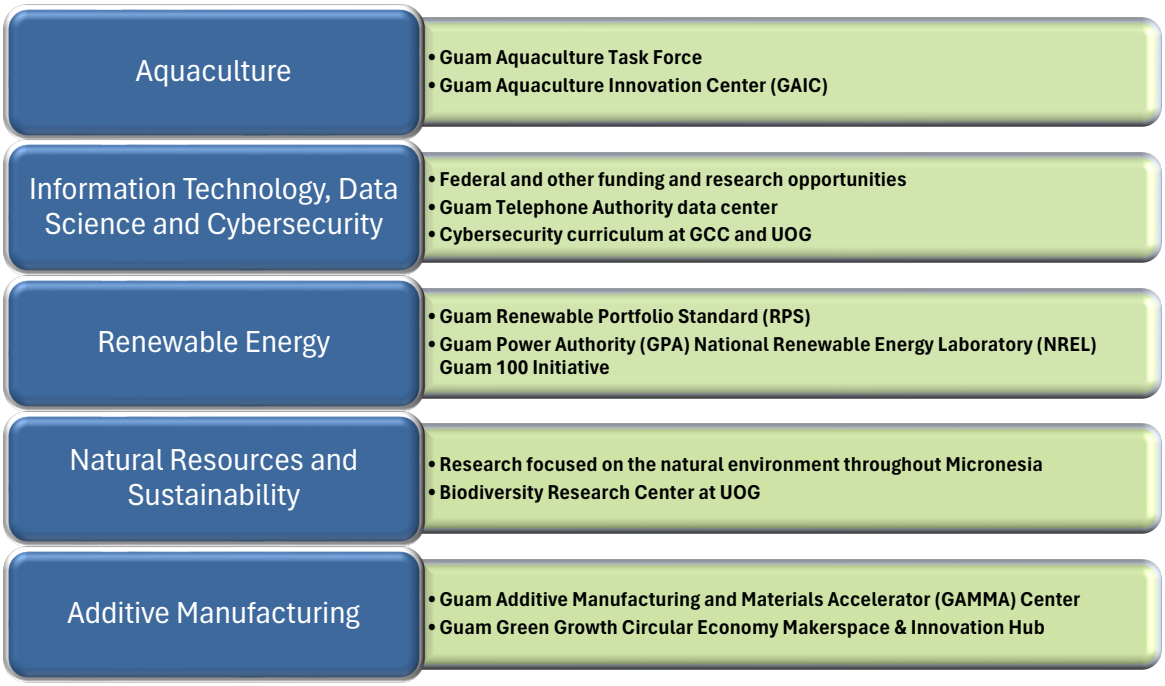
CHAPTER IV: OPPORTUNITY AREAS AND PROJECTS- FIVE AREAS OF ECONOMIC GROWTH

The vetting process in identifying the areas of opportunity (AO) involved meeting two or more of the following criteria: 1) articulated in the Governor's Economic Diversification Working Group, 2) appearance in the Comprehensive Economic Development Strategies document, 3) Formal presentation and discourse during S&T Meetings, 4) Existing area of academic research with potential to feed into one or more AOs, and 5) complement existing industries such as tourism or defense with research and economic opportunities.

Some AOs which, while important, were not included in the document for multiple reasons. Healthcare, for example was not included because there are existing complex multiple regional and territorial efforts to address healthcare workforce and infrastructure led by policy makers. The S&T Committee also did not include speculative activities such as carbon offsets, which was deemed too risky to make the case for the mobilization of great amounts of resources and research activities. These selected AOs offer Guam not only economic growth but provide a solid foundation for connecting, research, workforce development and the aspiration to develop a diversified economy.

The model for the five AOs is detailed in Figure 2.

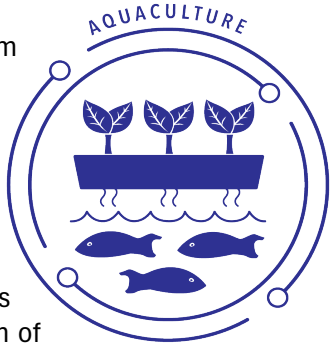
Figure 4. The Five Areas of Economic Opportunity



Aquaculture

Guam and the islands of Micronesia contain a unique and expansive marine biodiversity that has the potential to bring the region to the forefront of a thriving Blue Economy. In 2019, Governor Lourdes A.

Leon Guerrero established the Guam Aquaculture Task Force to develop a sustainable aquaculture industry that leverages the island's natural resources and geographic location.



There have been several and sporadic efforts in aquaculture in Guam and the region in the past. Neighboring islands in Micronesia have developed sustained mariculture of black pearls, natural sponges, giant clams and other marine species of high value exports. In Guam, there have been some past successes in the production of shrimp, tilapia, catfish, freshwater eels, softshell turtles and others. The existing STEM infrastructure in aquaculture has also aged. The decline of aquaculture production beginning in 2005 was primarily a result of the reduced production and eventual cessation of production from the largest aquaculture farm in Guam. Stakeholders reported the aging of farmers, waning investor interest, and available workforce as reasons for the reduction of aquaculture farms. Traditional farmers were producing low margin products including tilapia and common shrimp varieties for direct sale via farmers market settings.

What emerged during the engagement of the Guam Aquaculture Task Force was the collaborative resources available in Guam and the neighboring islands which were undertaking aquaculture experiments, but not producing at a level that would result in financial gains. Through the work of the task force, there is already a committee of stakeholders to serve as the aquaculture collaboratorium at both regional and global levels. The task force has two representatives that also sit on the S&T Committee.

With regard to STEM Education, the task force has members representing education from elementary to post-baccalaureate. Tracks identified range from traditional fields of science and marine biology to tradesman work in fields such as water quality technicians. Some existing educational resources could be accelerated through dedicated track at the high school, community college, and University level that are geared towards feeding this industry.

Some resources locally that could serve as immediate infrastructure include a 35+acre farm in Inalahan to serve as a valuable research and training facility or a commercial production farm for fish, shrimp and other products. There is locally raised shrimp and tilapia available from the Guam Aquaculture Training and Development Center under a private lease with the University of Guam. UOG researchers previously cultivated the "specific pathogen-free: or SPF shrimp being raised at the hatchery, which means no antibiotics or chemicals are needed or used as the shrimp are disease-free unlike imported frozen shrimp. The demand for SPF shrimp throughout Southeast Asia is high as shrimp in those countries routinely test positive for certain pathogens and banned chemical substances.

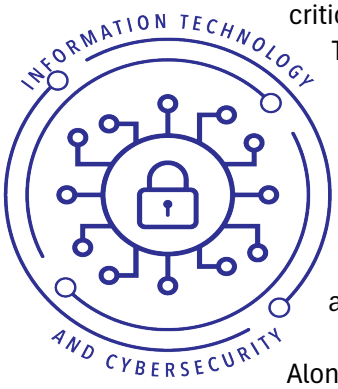
Additionally, the availability of an incubator site for freshwater, brackish water, and saltwater aquaculture would offer opportunities for student and investor research. Building on recommendations from the 2023 Guam Aquaculture Feasibility Study funded by the U.S. Economic Development Administration, local government and industry aquaculture stakeholders have identified a phased approach to delivering an ecosystem of aquaculture research, business incubation, and services centered around the development of a Guam Aquaculture Innovation Center (GAIC).

GAIC would provide facilities to support the incubation of aquaculture-related businesses as well as the demonstration and commercialization of applied research. The GAIC will jumpstart the development of multiple facilities over time with the goal of Guam becoming a regional hub of aquaculture innovation. This aquaculture initiative utilizes all 4 pillars of the S&T Core with a prioritization in the order of STEM Capacity Building; STEM Infrastructure; Entrepreneurship and Innovation; Micronesia/International Research Collaboratorium. UOG is also a partner under the Phase I NSF Engine awarded to the University of Hawaii: Climate Resilient Food Innovation Network, which focuses on aquaculture. The group is preparing an application for Phase II.

The University of Guam Sea Grant bolsters the island's aquaculture industry by offering free workshops and distributing recirculating aquaculture systems to nonprofit organizations and community partners. This aquaculture system, managed by Guahan Sustainable Culture, fully operates on solar energy and produces tilapia.

Information Technology, Data Science and Cybersecurity

As the world emerges from the COVID-19 pandemic, it is abundantly clear that the ways in which people communicate, learn, engage in business, and manage everyday life have been forever changed. The reliance upon technology to maintain contact with each other, to keep our infrastructure and critical systems running, and to meet basic needs had grown tenfold. Typhoon Mawar in May 2023 demonstrated further that Guam's communications infrastructure was so much more critical to the island economy than it had been during past typhoons. The Biden-Harris administration investments in the nation's science and technology infrastructure with the CHIPS Act, and specifically in Guam's infrastructure through InternetForAll and Broadband Equity Access and Development (BEAD) funding reinforce the fact that internet access is no longer a luxury but a necessity.



Along with the threat of natural disasters, Guam must deal with threats from other nation-states due to its position as the westernmost footprint of U.S. soil within the Indo-Pacific area of operations. Cyberwarfare is likely to play a key part of geopolitical conflicts in the future, as with the Russia-Ukraine war, and there is evidence that some countries have already compromised critical infrastructure networks in pre-posturing for future cyberattacks, as with the PRC-sponsored group Volt Typhoon's infiltration of networks across the U.S. and Guam. The large number of submarine fiber cable landings in waters around Guam and other Micronesia islands is both an area of opportunity for information and communication technology as well as an area of concern for cybersecurity.

Moving forward, Guam must balance the need to be connected to the world with the need to protect and secure our infrastructure and assets. And, as we embrace the use of new technologies, such as Artificial Intelligence (AI), and look for new economic opportunities, we should be mindful of this balance.

Building upon existing network exchanges such as the Guam Open Research and Education Exchange (GOREX) and the Mariana Islands Internet Exchange (MARIIX), the Collaboratorium can expand educational and economic opportunities through new networks and projects. Researchers can take advantage of the high-speed computing cluster at UOG, or work across one of the data exchanges to utilize clusters at partner universities.

A number of federal grants secured by UOG and involving collaboration with other universities or partners require some level of IT and cybersecurity support, such as the current Guam EPSCoR project and the NIH-funded Micronesia Data Laboratory. Most federal grants require a Data Management Plan that includes how to make results available to the public to share research as widely as possible. This helps translate research into community and economic activity. The Collaboratorium also feeds results of research and partnerships into IT and cybersecurity readiness for Guam, such as Department of Homeland Security internships at Pacific Northwest National Laboratory (PNNL) for UOG students and sharing of results of ongoing research in cybersecurity.

The Guam Telephone Authority is constructing a data center in Alupang near where submarine cables will come ashore. A new commercial data exchange (the Guam Exchange) was initiated by Citadel Pacific Ltd. in 2024 to transform Guam into an information and communications technology hub by taking advantage of all submarine cable landings in Guam's waters. These developments are the precursor of many such projects which could be expanded through extensive Department of Defense projects.

In order to take advantage of these opportunities, significant effort needs to be extended in STEM capacity building. This includes improving overall digital literacy of the public at all levels to specific training and degree programs from K-12 and postsecondary education. Cybersecurity is everyone's responsibility from personal uses of common technologies to sophisticated research and data collection. Outreach efforts and degree programs should always include reminders and lessons about how to use technology safely and responsibly.

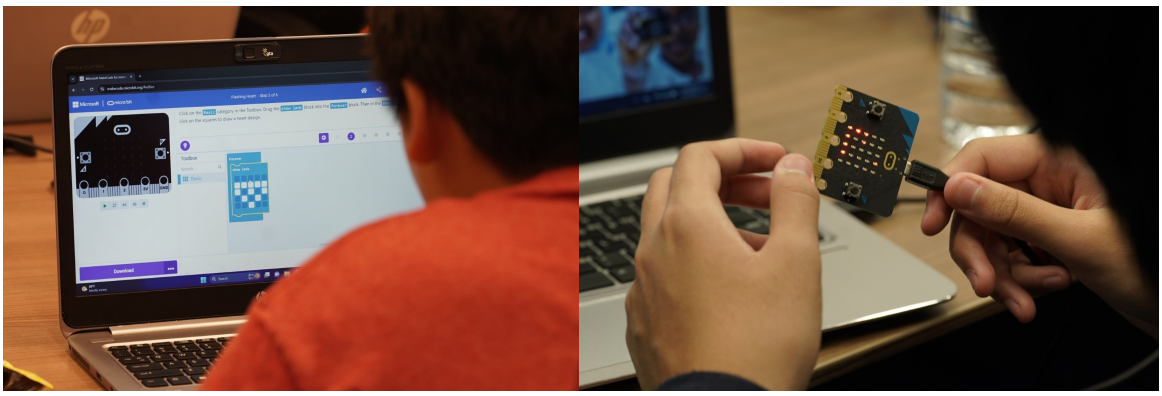
As we create opportunities for students in K-12 to see STEM as a career pathway, we should endeavor to include specific opportunities in IT and cybersecurity to engage students in these fields before graduating from high school. The K-12 system is a natural pipeline into GCC and UOG for developing the workforce needed to meet the demand for IT and cybersecurity professionals on Guam. IT and cybersecurity are components of all STEM fields, and STEM capacity building naturally involves use of information and communication technology and should include how to secure and protect data collected or used in different STEM careers.

Development of the cybersecurity curriculum at GCC and UOG that will lead to Associate of Science and Bachelor of Science degrees or certificates, and prepare students for industry-standard certifications, is a key component of the cybersecurity workforce development plan. These programs must include hands-on experiences for the students, so they enter the workforce with technical skills and practical experience using these skills. In addition, as GCC and UOG develop their cybersecurity curriculum, they should incorporate knowledge units (KUs) for the National Center of Academic

Excellence in Cyber Defense (NCAE-CD) designation, so these programs can apply for NCAE-CD designation within three years of being established. This designation affirms that the curriculum meets NSA standards, meets local industry needs, and provides students with practical experience. It will also give GCC and UOG the opportunity to apply for federal funding solicitations only available to NCAE designated institutions.

In spring 2024, through its internal curriculum process, GCC updated its Associate of Science in Computer Networking to an Associate of Science in Information Technology. This revised program in Information Technology is a program of study that prepares students for entry-level employment in the field of Information Technology (IT). Technical requirement classes are designed to give students a firm foundation in the basics of computer operations, repair, network medium design and installation, enterprise networking, security and cybersecurity operations. The GCC secondary Electronics program which has a dual credit agreement with the Associates of Science in Information Technology have also been updated to reflect the changes at the postsecondary level. This means that students who earn a Certificate of Mastery will be able to earn college credits in the Associate of Science in Information Technology upon graduating from high school.

Additional opportunities that are less formal may include coding workshops, “hack-a-thons”, cyber competitions at the college level, and mentoring of high school students. E-sports, online gaming, and game development may be other ways to engage students, who may later choose to follow a career pathway in IT, communications, or cybersecurity.



The Guam Green Growth (G3) Circular Economy Makerspace and Innovation Hub partnered with GTA Teleguam to host a summer coding and robotics workshop that combined technological education with environmental stewardship.

12 students aged 12 to 16 were taught basic coding skills, programmed robots to drive through a racetrack, designed 3D printed items, and learned how to create circular economy products.

A strong information and communications backbone is necessary for enhancing and strengthening Guam’s STEM infrastructure. IT and cybersecurity professionals are necessary to build and sustain this infrastructure, especially with anticipated capital improvements in broadband access for the island. Private sector as well as government-sponsored activities will be investing more in new technologies which are now considered standard. We are on the threshold of the applications of AI and, in the near future, there will be quantum computing across all economic as well as governmental and social activities.

A robust and resilient local economy needs the growth of business and industries that are sustainable, and growth of our own local talent pool in STEM. There are many opportunities for entrepreneurs on Guam to establish new businesses or expand existing businesses in areas of IT, communications, and cybersecurity, and for innovation in the use of newer technologies, like AI. In collaboration with government and educational institutions, the private sector will need to provide upskilling or cross-training for employees who wish to enhance their skills or switch career fields, and who may not need the full programs of study at GCC or UOG.

There will be opportunities to provide IT and/or cybersecurity services on a contractual basis to other companies or agencies, such as HIPAA-compliant data management, or penetration testing of IT systems. Regionally and internationally, there may be opportunities to provide remote network monitoring or other services to companies not based on Guam as well as establish additional data centers on Guam.

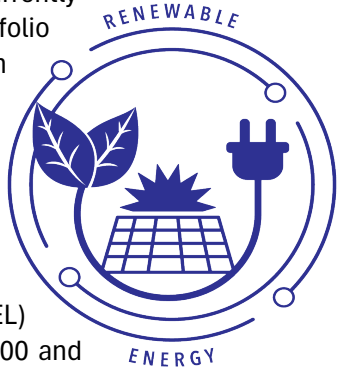
The creation of an IT incubator will be useful in assisting individuals who may not have much business experience but who wish to develop an idea for a tech-based business, such as a mobile app or online shop. There may also be multiplier factors in combining two or more of these AOs with IT. Additive manufacturing could provide locally sourced parts for communications and IT devices. Renewable energy and aquaculture investments and activities will require cybersecurity and technology which will monitor systems and provide alerts as necessary.

Current Guam EPSCoR provides UOG math and computer students with summer research opportunities that provide hands-on experience in data science, analyzing and modeling datasets collected by faculty-led research teams. Future EPSCoR proposals should leverage and expand on these activities. For example, the development of a Biodiversity Research Center will require support in data science, database management and cybersecurity expertise to safeguard data shared publicly. The establishment of centers and incubators of research will provide training opportunities through internships to support the growth of Guam's IT workforce. The new UOG MS in Data Science beginning in Fanuchanan (Fall) 2024 will add inestimably to the STEM capacity of the island.

Coordination between educational institutions (GCC, UOG) and employers (GovGuam agencies, local telecommunications industry, etc.) is important in ensuring the skills and certifications of students in these programs continue to meet the needs of the island.

Renewable Energy

Eleven percent (11 %) of the island's electricity generating capacity is currently provided by renewable sources of energy. Guam's Renewable Portfolio Standard (RPS) requires that 50% of the island's power come from renewable sources by 2035—eventually reaching 100% by 2045. These standards are pushing Guam to advance its energy targets—making it a prime location to expand and invest in renewable energy technology. Increasing energy demands for AI and new technologies requires a full exploration of all possible renewable energy sources.



GPA has partnered with the National Renewable Energy Laboratory (NREL) on the Guam 100 Initiative. Following the success of the Los Angeles 100 and Puerto Rico 100, NREL will model and analyze community-driven pathways to achieve 100%

renewable energy in Guam while ensuring the reliability of the grid. These pathways will be based on input and feedback from a local advisory group of GovGuam, academia, and private industry to ensure the research reflects what matters most to the people who live and work in the community.

At present, the Guam Power Authority (GPA) has two (2) solar facilities with a 96.6 MW total capacity and one (1) small 275 kW wind turbine pilot project. As part of its Phase IV bid, GPA intends to increase its renewable energy generation to 50%. While current renewable energy sources have traditionally been solar photovoltaics, there is still great potential in exploring other sources of clean energy.

There is great potential in Guam for an on-shore Ocean Thermal Energy Conversion (OTEC) plant. This can provide 24/7 stable continuous green power and has proven reliable at sites such as the Hawaii Renewable Energy Facility and Kumejima Facility in Okinawa. Latest developments in directional drilling and pipe and heat exchange materials make this a stronger possibility for Guam. OTEC can provide the energy and freshwater needed for producing hydrogen fuel from seawater while supporting aquaculture, cold seawater air conditioning while reaching the island's renewable energy goals.

Over the years, the UOG Center for Island Sustainability, GPA, and the Guam Energy Office (GEO) have partnered to conduct research on local energy consumption and implement educational programs to promote various energy conservation measures. In 2023, the three partners linked with GEDA to submit a US EPA Solar for All proposal. They were successfully awarded $62.5 million in funding. Starting in Fall 2024, this substantial investment will empower low and moderate-income households across Guam with access to renewable energy solutions through the establishment of a low-interest revolving loan and grant fund. As part of the program, UOG is planning to establish a G3 Renewable Energy Corps as a workforce development program to ensure there is a trained workforce for installation and maintenance of solar PV systems.

The current workforce in renewable energy are largely installers and service technicians. However, there is a growing demand for specialized electricians, power plant operators, and journeymen in this area of specialization. GPA has existing apprenticeship and internship programs with GCC and UOG. While these programs have largely focused on training journeymen and engineers in typical utility and energy generation skills, GPA is expanding these programs to include a focus on renewable energy.

Members of the Guam Green Growth Conservation Corps install solar panels. (From left: Connor Law, Michael Jude Hernandez, Javier Mercado)

The Solar for All collaboration will facilitate research and information gathering at the University of Guam, create a financial conduit to facilitate investment in the clean energy industry and communicate benefits and pathways for involvement to the general public.

The current demand for renewable energy is also anticipated to stimulate innovation in entrepreneurs involved in the renewable energy industry. In 2023, UOG collaborated with Pacific Northwest National Laboratory (PNNL) to explore the potential of hydrogen energy for Guam using seawater electrolysis, potentially generating a fuel source that can be stored and used when renewable electricity is not available.

There is also growing interest in microgrids, which are a group of interconnected loads and distributed energy resources that can act as a single controllable entity in relation to the grid. In 2021, a private enterprise installed its first microgrid to power its standalone business in a highly trafficked commercial area of the island. This is the first commercial site operating off of the power grid. The benefit of microgrids is that they can connect and disconnect from the main power grid to operate in grid-connected or island mode when needed. The model demonstrated by the private enterprise is expected to be improved, refined, and replicated, but can only occur with collaboration between private and public entities as the latter controls the permitting for such projects.

Natural Resources, Sustainable Development and Cultivating a Green Economy

Guam offers a wealth of opportunities for sustainable development and economic growth through the integration of university research, STEM education programs, and innovative economic strategies. With a focus on protecting and sustaining its natural resources, Guam continues to position itself as a model of green growth and environmental stewardship in the region while fostering economic opportunities for its residents.

There is relatively immense abundance in Guam's natural resources providing significant economic, biological, and cultural value to our island community. However, these natural resources are threatened by global climate change and local environmental stressors, including: invasive species such as brown tree snakes, feral ungulates, and coconut rhinoceros beetles; poor land-use development practices; land erosion and subsequent sedimentation on coral reefs; and more. Understanding and mitigating these impacts requires a STEM workforce and research centers/incubators that focus on understanding the changing ecosystem services provided by Guam's natural resources. Protecting these ecosystems and using them for sustainable economic opportunity is a challenge that Guam and other similarly positioned jurisdictions face.

Research focused on the natural environment throughout Micronesia plays a critical role in identifying sustainable solutions to environmental challenges, while contributing to economic activity. UOG is at the forefront of research initiatives focused on biodiversity conservation, sustainable agriculture (including use of local and value-added food), aquaculture and fisheries, renewable energy, and climate change adaptation. Recent research projects investigated nutrient thresholds to protect water quality; coral reef resilience and restoration; nearshore fishery dynamics and stock assessments; studies on marine megafauna (e.g., sea turtle and manta ray biology); the origins and diversity of Guam's and Micronesia's flora; *Serianthes* biocultural heritage; post-typhoon forest restoration; feasibility study for co-locating development of the ocean-energy systems with a proposed aquaculture innovation center; the first coral genetics research in the CNMI; and threats posed by invasive species or predators such as the crown-of-thorns starfish (COTS) that decimate corals reefs during outbreaks. GCC is currently working with UOG through a Next Gen grant on updating its Environmental Technician certification into an Associate of Science in Environmental Health to

eventually feed into UOG through a 2+2 program. Progress has been made with GCC offering an Environmental Technician Bootcamp in summer 2024.

The Coral Common Garden Project, funded by Guam NSF EPSCOR, studies how reef-building corals respond to climate change.

Colin Anthony, a research associate at the University of Guam Marine Laboratory and a former Guam NSF EPSCoR Graduate Research Assistant, is handling coral cuttings for the project.

Guam is home to the most diverse coral reefs in the United States with over 375 species of coral, over 1000 species of reef, nearshore pelagic and freshwater fish, and 225 species of algae. The island is adjacent to the Challenger Deep in the Mariana Trench, the deepest point in the world's oceans teeming with undiscovered biodiversity. Terrestrial habitats are home to 327 species of native plants. There is no telling what discoveries and innovations lay beneath. Guam, UOG, and its partners have just begun to uncover more possibilities thanks to the NSF EPSCoR investments that are stimulating new competitive research through the funding of research infrastructure. Traditional practitioners are now faculty at UOG increasing our understanding of the healing properties of rare and endangered plants. There is enormous potential in the region's biodiversity for medical cures and marine natural products. Many solutions developed and incubated in Guam can be scaled across Micronesia and beyond. UOG is well-positioned to lead these efforts with its Guam NSF EPSCoR, Western Pacific Tropical Research Center (WPTRC), Center for Island Sustainability and Sea Grant (CIS/SG), and Marine Laboratory programs.

Effective conservation and management of natural resources and identification of biosecurity risks requires comprehensive knowledge of existing biodiversity and its change through time. Biological collections represent an important resource in this endeavor. Guam NSF EPSCoR laid the foundation for collections-based biodiversity research through its Biorepository by providing the infrastructure for curation, database management, and sharing of biodiversity information. Leveraging these efforts to establish a Biodiversity Research Center at UOG that integrates biodiversity collections across campus will be an important step to allow for longitudinal studies that evaluate changes in Guam's natural resources through time, identification of indicators of change, and tipping points that may threaten the ecosystem services provided by Guam's natural resources. Building capacity in data science and AI will be necessary to fully exploit these datasets and allow for predictions to inform management, policy, and development of sustainable practices for natural resource usage.

From corals to crabs to algae and fish, the Guam NSF EPSCoR GECCO Biorepository is a collection of thousands of marine fauna and flora specimens that serves as an archive of the biodiversity found within the Micronesian region.

Moreover, we continue to leverage technology through our NASA Guam Space Grant and NASA Guam EPSCoR programs which recently announced applications for its fourth cohort of the UOG Drone Corps program. The Drone Corps provides educational and training opportunities including flight missions that benefit our island's natural resources and promotes innovative environmental protection. NASA Guam Space Grant Drone Corps has collected numerous data sets from invasive species infestation in specific areas to post Typhoon Mawar damage.

Students who are a part of the Guam NSF EPSCoR Summer Math Research Program learn how to develop mathematical models of coral reef dynamics and present their research projects at the end of their summer term.

Sustainable Development

During the 2019 U.N. General Assembly, the Governor of Guam pledged the island's commitment to be a founding member of the Local2030 Islands Network and implement the 17 U.N. Sustainable Development Goals in locally and culturally effective ways. Executive Order 2019-23 was issued to establish the G3 Working Group, representing a public-private partnership aimed at ensuring a sustainable and prosperous future for Guam. UOG Center for Island Sustainability & Sea Grant was assigned to facilitate the island-wide initiative and spearhead the development of the G3 Action Framework, which encompasses hundreds of goals and action items that guide the sustainable development of Guam. Progress is tracked on the G3 Dashboard, an online public and transparent platform logging local actions contributing to a sustainable global future. Guam NSF EPSCoR Education and Workforce Development served as a catalyst for launching the G3 Initiative.

Two of the biggest sustainability challenges to islands are an overreliance on imports, and overproduction of waste. The G3 Circular Economy Makerspace and Innovation Hub (G3 Hub) is a central ongoing implementation project to address these challenges. The G3 Hub was established at the CHamoru Village in 2022. The objective is to divert waste from the landfill by presenting innovative alternatives that transform waste into marketable commodities, accelerating transition to the circular economy, which is a $4.5 trillion opportunity worldwide according to the Ellen MacArthur Foundation. Entrepreneurs and artists are now able to gather in facilities filled with tools and equipment to transform waste products into marketable products with support from workshops and business development educational resources. This effort can serve as the core of a future Incubator that focuses specifically on economic projects related to the protection of Natural Resources.

G3 is now recognized as a bright spot in international settings as a leader in the sustainable development of islands. It has attracted U.S. State Department and Department of Navy Funding for expansion activities. In 2024, the funding allowed G3 to support the launch of Palau Green Growth and CNMI Green Growth. In the second half of 2024, G3 is supporting FSM and RMI to launch their green growth initiatives.

Guam has the potential to become a leader in green growth and sustainable development by leveraging university research, STEM education programs, and innovative economic strategies. By prioritizing the protection and sustainability of its natural resources, Guam can build a resilient economy that benefits both current and future generations while preserving the island's unique beauty and biodiversity. Through the G3 Initiative, Guam is developing tangible solutions to sustainability challenges and contributing to a green economy for the island region. Partnerships to establish Green Growth initiatives with the governments of the Northern Marianas and Palau have already been established. These efforts can be incorporated into future incubator networks in the next NSF EPSCoR project for UOG.

Additive Manufacturing

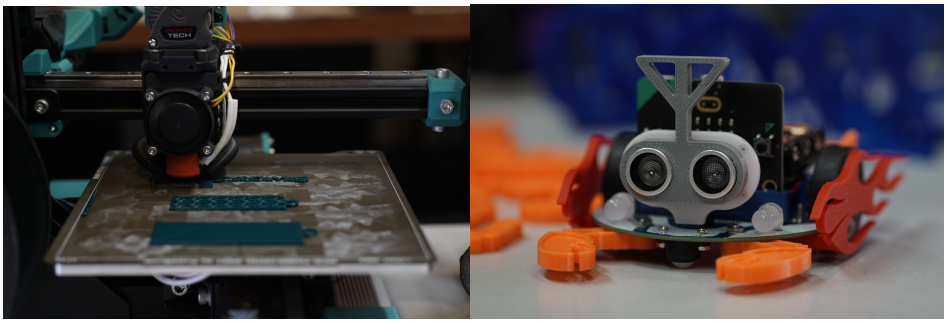
In 2022, the Leon Guerrero Administration commissioned the Applied Science & Technology Research Organization of America (ASTRO America), a national non-profit research institute and think tank, to conduct a comprehensive analysis to determine the viability of a local additive manufacturing industry on Guam. The baseline study concluded that Guam possesses the basic building blocks for establishing a local high-tech manufacturing industry, including a demand to support the needs of the Department of Defense, a favorable business climate to attract public and private investments,

potential workforce development capabilities, and the University of Guam's ability to partner with other advanced research institutions.

The most crucial recommendation in the evolution of Additive Manufacturing from idea to viable industry is the creation of the Guam Additive Manufacturing and Materials Accelerator (GAMMA) Center. The GAMMA Center, a business incubator and market-to-lab facility hosted by the University of Guam will serve as the focal point of this new-to-Guam manufacturing capability. Focused on additive manufacturing, robotics, automation, and advanced materials, the GAMMA Project will expand Guam's capability in supporting the defense industry, creating tertiary industries using these technologies, and training individuals for sustainable jobs.

To get this project off the ground, a meeting took place in February 2024 to move a project plan forward among three partners, the Government of Guam, the US Navy, and ASTRO America. The project has a dual mission of: 1) advancing national security by giving the submarine industrial base abilities to print components on-demand at the point-of-need; and 2) supporting economic development in Guam, forming a workforce skilled in key science, technology, engineering, and mathematics (STEM) careers, while also building out a new industry sector on-island, capable of delivering complex components for the federal, government, and private sectors.

With the Guam Economic Development Authority and the University of Guam as lead consortium members, the consortium involves research partners from the Guam Community College and Colorado School of Mines, various local government agencies, industry groups including Big Metal Additive, Boeing, Sinavia, and others, regional industry groups, and labor and workforce organizations. The Guam Green Growth Circular Economy Makerspace & Innovation Hub may provide an avenue for the recruitment of talent and an important pathway for workforce development in these emerging technologies. Additionally, UOG School of Engineering faculty are at the forefront of additive manufacturing based on recycling of used concrete materials.



A 3D printer at the Guam Green Growth Circular Economy Makerspace & Innovation Hub, which was acquired through Guam NSF EPSCoR, is a tool that allows members of the facility to create and prototype products, manufacture parts to extend the longevity of specialized equipment, and act as an educational resource to aspiring builders. (Left: 3D printer creating a set of keychains. Right: Parts for a small robot were produced with a 3D printer during a coding workshop at the G3 Makerspace to demonstrate the versatility of the tool.)

The opportunity areas and projects outlined above have the potential to support economic development and diversification rooted in use-inspired research for the benefit of Guam's society. Centers and incubators for research and development will be a necessary foundation to further develop the opportunities identified. UOG and its centers and labs have been at the center of STEM

research in Guam. Makerspaces and innovation centers, such as the envisioned aquaculture innovation center will be essential to allow for the translation of research into economic activity. Investments to support education programming from K-12 to higher education will be important to build the STEM-trained workforce necessary to support the economic opportunities envisioned by the S&T Committee.

Centers and Incubators

Supporting the growth of opportunity areas outlined above will rely on centers and incubators that build teams to conduct scientific research aligned with the priority areas outlined above. The training of a STEM-educated workforce in these centers and incubators will be a crucial component to provide the necessary workforce to make implementation of identified projects a success. To be successful, these centers and incubators need to foster collaboration in cross-cutting research themes that support the implementation of priority projects in Guam.

The Guam Green Growth Circular Economy Makerspace and Innovation Hub is a shared experimental space where members can use a variety of tools and equipment such as a laser cutter, CNC router, and a 3D printer to create sustainable products. The facility offers a variety of classes like this laser engraving and cutting workshop so that members can operate these machines independently.

Guam NSF EPSCoR's role will be to facilitate the development of research teams and STEM education by supporting students on their career pathway from undergraduate to graduate school through research opportunities and mentoring. The vision is to develop the existing EPSCoR office into a hub to support Guam's R&D enterprise, providing support to teams of researchers from project development to project administration. It is expected that this support will increase R&D activity focused on use-inspired research in support of economic activity. The current S&T Plan provides the baseline for current R&D expenditures and human capital investment in Guam. Success of Guam NSF EPSCoR will mean increased federal grant funds for R&D and increases in STEM degrees awarded, in particular at the graduate level. As one of the smallest EPSCoR jurisdictions, Guam will depend on external partnerships and collaborations to further its R&D enterprise. Here, Guam EPSCoR's Collaboratorium will be tasked with identifying and cultivating strategic partnerships that align with the opportunity areas identified in the S&T Plan.

Past and current Guam NSF EPSCoR research has focused on the impacts of climate change and habitat degradation on Guam's natural resources. These efforts have led to a growth in expertise at UOG through the hire of new faculty and increasing outputs of scientific publications that raise the profile of UOG's existing research centers and increase the competitiveness of grant proposals.

The vision for Guam NSF EPSCoR going forward is to foster collaborative, use-inspired research in support of the natural resources and sustainable development opportunity areas. We intend to

leverage NSF's prior investments in marine biodiversity research at UOG to develop a Biodiversity Research Center. This center will be a hub for coordinating research investigating environmental impacts on Guam's natural resources and changes in the ecosystem services provided by these resources. Establishment of an aquaculture industry that envisions the development of local species of fish as a product will rely on information and expertise in Guam's existing marine biodiversity. Siting and establishing aquaculture facilities or marine renewable energy systems will require assessment and mitigation of impacts, which relies on expertise and knowledge of Guam's biodiversity. Consequently, the mission of the Biodiversity Research Center will be to work with local agencies to train a workforce capable of supporting the development of an aquaculture industry and a circular economy under the G3 initiative. As a hub for generating, analyzing, and sharing of biodiversity data, the Biodiversity Research Center will require a workforce trained in IT and data science. To address this issue, training opportunities will be created through internships and research opportunities. It is anticipated that these activities will provide trained individuals that will grow Guam's IT workforce.

CHAPTER V: MEASURING PROGRESS TOWARDS A KNOWLEDGE BASED ECONOMY

Data collection outside of the general macroeconomic indicators poses a challenge for the S&T Committee. Moreover, as the S&T Plan is implemented through a variety of future EPSCoR activities, the need to assess societal progress towards economic and science goals is critical. The current state of tracking is largely decentralized and the timing is sporadic.

The S&T Committee acknowledges the shortcomings of the status quo and as such is committed to a more cohesive and robust tracking mechanism that assigns benchmarks and a schedule of assessment. This will increase ability to assess the robustness of the research being conducted and how it translates to practice in the incubator setting or in any external activities. Collecting this data will not only help Guam understand the component activities necessary for a strong knowledge-based economy, it will suggest ways of effectively coordinating research agendas, educational activities and innovative economic projects.

In the United States, the Milken Institute provides such assessments for states, regions and even cities. Guam is not yet included in those assessments. Additionally, due to the size and certain unique factors that differentiate Guam from a state or county, making comparisons to other jurisdictions either internationally or nationally may not be an accurate gauge of progress. Consequently, this S&T Plan sets forth an adapted instrument from the Milken Institute measure of a knowledge economy.

This *adapted* instrument to measure the knowledge economy captures what is available, identifies assessment gaps, and ultimately readies the island for eventual side by side comparison with states or other jurisdictions. Most importantly, it establishes a benchmark to assess our readiness for and progress towards a knowledge-based economy.

The committee has named the measure the "Guam-based Science and Technology Index (S&T Index)" to serve as a benchmark to gauge the island's strengths in tech-based economic growth, skilled workforce, entrepreneurship, and future capacity as reflected in investments in research and development and higher education. The Index will measure different pillars essential to Guam's science and technology economy over time: 1) research and development inputs, 2) human capital investment, 3) technology and science skilled workforce, 4) educational support for STEM, and 5) entrepreneurial investment and business growth. When possible, the S&T Index will be compared to national averages to track Guam's growth and relative standing to other states and territories. Lastly, the S&T Index will gauge Guam's capacity to compete with other jurisdictions in knowledge-based and innovation-based economies. It will serve as a guide for policymakers and the private sector in developing coordinated strategies to participate in these new and emerging economic activities.

Guam Science and Technology Index: Data Sources

The Guam Science and Technology Index (S&T Index) will rely on a variety of data sources. Some of these include obvious ones such as investments in STEM education, technical training and research and development in higher education. Other data sources are in rudimentary form or do not yet exist

in Guam. These include Industry R&D investments and identifying businesses which are primarily STEM-dependent.
Through this new Index, Guam can better assess whether progress is made towards deepening a knowledge and technology-based economy. This will not only diversify the island's economy but contribute to the utilization of the innovative and creative talent of our people.

The S&T Index will measure different pillars essential to Guam's science and technology economy over time: research and development inputs, human capital investment, human capital output, technology and science workforce, and entrepreneurial investment and business growth.

Further, sub-index measures will mirror the methodologies of the Milken Institute State Science and Science Index (highlighted in the sub-indexes below) when local data allows or when comparable data is available.

In developing the S&T Index, several data gaps have been identified and some key elements are not currently available. Government of Guam agencies like GEDA and the Bureau of Statistics and Plans have been involved in developing this instrument. GEDA is particularly committed to improving analytics and data gathering when related to economic development and as such, is factoring increased budget towards variables not currently tracked for future data gathering. Moving forward, they will explore federal resources and agencies to obtain technical guidance and support from national entities such as the Milken Institute to secure the necessary data on a timely basis. This has never been conceptualized in this manner, so significant data collection activities, analysis and coordination between GEDA and the S&T Committee will be part of the Committee's expanded responsibilities going forward.

Baseline Index Summary

The bases for comparison will be made by examining data input over time in five specific areas as explained below. Chronological comparisons or a longitudinal approach allows Guam to be measured against itself over time instead of annual comparisons as are given in the Milken Institute. Given the unique circumstances in Guam, a longitudinal rather than a comparative assessment will be more useful. The basic elements of the S&T Index were proposed by a team which included S&T Committee members, representatives of the Guam Economic Development Authority (GEDA) and the GovGuam Bureau of Statistics and Plans (BSP).

Figure 5. Guam Science and Technology Index

INPUTS	2020	2021	2022	2023
RDI				
HCI				
HCO				
TSW				
FIBG				

Each part of the index is calculated using the following measures:

- **RDI:** Percentage of total R&D (federal, industry, academic) funding per capita increasing over time.
- **HCI:** Appropriations for each educational institutional framework
- **HCO:** Percentage of residents with bachelor's degrees, master's degrees, and doctorates per capita, including a percentage with STEM-related degrees. Average test scores compared to national average. Proportion of households with access to computers and broadband compared to national average.
- **TSW:** Percentage of workforce and apprentices in STEM-related occupations/positions per capita compared to national average.
- **EIBG:** Percentage of STEM-related businesses compared to overall number of businesses.

The weighting of the precise data input for entry into the Index as outlined above will be finalized under the guidance of a new S&T Committee. Other data sets may also be considered in the implementation of the Index.

Research and Development Inputs

The sub-index measures public and private R&D investments, including Guam's capacity to attract STEM-related funding and create opportunities for commercialization of innovative research.

FEDERAL R&D EXPENDITURES				
	FY2020	**FY2021**	**FY2022**	**FY2023**
Dollar Amount of STEM-Related Federal Grants to GDOE- CCCLR Project	$649,319	$1,236,630	$1,281,043	$1,033,625
Dollar Amount of STEM-Related Federal Grants Awarded to GovGuam Agencies	$245,701	$48,910	$0	$62,500
Number of STEM-Related Federal Grants Awarded to GovGuam Agencies	3	1	0	1
Number of GovGuam Agencies with STEM-related Federal Grants	1	1	0	1

Source: Guam Bureau of Budget and Management Research. BBMR.

INDUSTRY R&D EXPENDITURES				
	2020	**2021**	**2022**	**2023**
Dollars Spent by Companies on Primary and Applied Research	1/	1/	1/	1/
Number of Companies Funding Primary and Applied Research	1/	1/	1/	1/
Core Seed Expenditures, Training Certifying Water Facility Operators and Pesticide Applicators				

***Sources:** Creation of business survey administered by the Guam Chamber of Commerce or UOG School of Business and Public Administration
1/ Data not available.

ACADEMIC R&D EXPENDITURES				
	FY2020	**FY2021**	**FY2022**	**FY2023**
UOG Budget Spent on R&D	$21,331,664	$20,390,869	$19,610,674	-
GCC Budget Spent on R&D	$0.00	$0.00	$0.00	-

Total Higher Education Budget Spent on R&D	$21,331,664	$20,390,869	$19,610,674	-

***Sources:** UOG- Financial Statements, Required Supplementary Information, and Supplementary and Other Information University of Guam /GCC annual budget. UOG- Financial Statements, Required Supplementary Information, and Supplementary and Other Information University of Guam (FY22-pg. 21; FY21 & FY20-pg.16)

Human Capital Investment

The sub-index measures public investment in education and the workforce, education/training available to Guam residents and the skill levels of the island's current and future workforce that can attract potential employers and investors as well as support high tech industries.

STANDARDIZED TEST SCORES				
	AY 2020	**AY 2021**	**AY 2022**	**AY 2023**
Standardized STEM Tests - % "ready" or "exceeds"	-	-	-	-
Standardized Language Arts, Reading Tests - % "ready or exceeds"	-	-	-	-

Source: GDOE - Research Planning and Evaluation ASPER

GOVERNMENT OF GUAM EDUCATION SPENDING				
	FY 2020	**FY 2021**	**FY 2022**	**FY2023**
General Fund Allocation	$678,641,533	$649,697,305	$638,892,543	$747,038,067
Public Education Allocation	$219,854,237	$206,992,545	$204,965,854	$231,120,315
Percentage of Public Education Allocation	32%	32%	32%	31%
University of Guam Operations (General Fund) Budget Act	$27,661,845	$26,056,761	$25,056,761	$24,789,185
Guam Community College Operations (General Fund) Budget Act	$17,135,109	$16,074,975	$15,825,631	$16,076,412
Total Appropriations for Higher Education	$53,835,831	$51,940,387	$52,890,876	$56,570,397

Sources: BBMR GovGuam Budget NOTE: Total Appropriations for Higher Education: UOG + GCC
FY20: (UOG - $34,214,231.60/ GCC - $19,621,599)
FY21: (UOG - $31,494,356 / GCC - $20,446,031)
FY22: (UOG - $32,661,865 / GCC - $20,229,011)
FY23: (UOG - $34,043,570 / GCC - $22,526,827)
*UOG figures are from the fiscal year 4th quarterly reports; GCC figures are total appropriations provided by Dr. Mary Okada via email

UNIVERSITY OF GUAM DEGREES CONFERRED				
	AY 2019 - 2020	**AY 2020-2021**	**AY 2021-2022**	**AY 2022-2023**
Bachelor's	466	500	428	394
Agriculture and Life Sciences	6	6	11	9
Biology	35	39	33	48
Chemistry	9	16	9	10
Civil Engineering	–	–	19	9
Computer Info System	8	6	7	3
Computer Science	9	10	15	6
Health Sciences	33	16	16	13
Mathematics	13	12	5	5
Nursing	26	29	32	17

Master's	144	135	126	118
Biology	7	6	6	4
Environmental Science	8	0	3	4
Sustainable Agriculture, Food, & Natural Resources	3	0	2	2

***Source:** University of Guam 2021-2022 Fact Book

GUAM COMMUNITY COLLEGE: Graduates and Breakdown of Degree Conferred				
	AY 2019-2020	**AY 2020-2021**	**AY 2021-2022**	**AY 2022-2023**
Graduates	416	337	347	368
Bachelor of Science	0	0	0	1
Associate Degree	338	240	245	248
Journey Worker Cert. (Apprenticeship)	27	4	6	3
Adult High School Diploma	52	30	27	51
High School Equivalency	8	0	0	0

Source: Guam Community College; Provided by Dr. Mary Okada

GUAM COMMUNITY COLLEGE: Fall Enrollment					
	FA 2019	**FA 2020**	**FA 2021**	**FA 2022**	**FA 2023**
Bachelor of Science in Career and Technical Education	0	22	10	9	7
Associate Degree	1196	1166	1180	1242	1072
Journey Worker Certificates (Apprenticeship)	136	120	121	113	127
Adult High School Diploma	121	93	85	100	84

Source: Guam Community College; Provided by Dr. Mary Okada

UNIVERSITY OF GUAM: Fall Enrollment					
	FA 2019	**FA 2020**	**FA 2021**	**FA 2022**	**FA 2023**
Bachelor of Science	1329	1382	1259	1220	1267
Master of Science	69	68	83	77	77
Adult High School Diploma	n/a	n/a	n/a	n/a	n/a
High School Equivalency	n/a	n/a	n/a	n/a	n/a

Source: University of Guam; Provided by Marlena Pangelinan, Vice Provost for Institutional Effectiveness

CHARTER SCHOOLS			
	iLearn Academy	**Guahan Academy Charter School**	**SIFA Learning Academy Charter School**
FY19 Enrollment	620	740	233
FY19 Revenues	$3,970,271	$4,725,248	$1,418,504
FY19 Expenses	$3,642,669	$4,483,220	$2,506,696
FY20 Enrollment	756	740	309
FY20 Revenues	$4,094,292	$5,761,187	$1,918,036
FY20 Expenses	$3,862,709	$5,761,187	$3,277,000
FY21 Enrollment	620	740	346
FY21 Revenues	$5,085,640	$7,054,321	$3,892,541
FY21 Expenses	$4,507,470	$4,744,209	$2,701,913
FY22 Enrollment	740	765	342

FY22 Revenues	$4,847,946	$6,215,364	$4,923,263
FY22 Expenses	$5,084,872	$6,547,631	$4,666,055

Source: iLearn Academy, Guahan Academy Charter School, SIFA Learning Academy Charter School CCR Reports, 2019 Financial Statements (SIFA)

ACCESS TO TECHNOLOGY					
	2020	**2021**	**2022**	**2023**	**2024**
Percentage of Households with Computers	95.0	N/A	N/A	N/A	N/A
Percentage of Households with Broadband SOURCE: INTERNET SERVICE PROVIDERS	85.1	N/A	N/A	N/A	N/A
Number of Computers Available in Village Mayor's Offices SOURCE: VILLAGE MAYOR'S	41	56	79	88	104
Number of Computers Available in Village Mayor's Offices for Community Use	4	5	9	10	22

Sources: 2020 Guam Demographic and Housing Characteristics file. FCC National Broadband Map Village Mayors (https://broadbandmap.fcc.gov/location-summary/mobile?version=jun2023&lon=144.75093&lat=13.47513&addr_full=Hagatna%2C+Hag%C3%A5t%C3%B1a+96910%2C+Guam&zoom=15.00&env=0&tech=tech4g)
https://broadbandmap.fcc.gov/area-summary/fixed?version=jun2023&geoid=6698&type=congress&zoom=8.75&vlon=144.786297&vlat=13.444400&br=r&speed=100_20&tech=1_2_3_4_5_6_7_8
https://www.census.gov/library/stories/2022/10/2020-island-areas-computer-internet-use.html

Human Capital Output

The sub-index measures the skill levels of the island's current and future workforce that can attract potential employers and investors as well as support high tech industries.

STANDARDIZED TEST SCORES				
	AY 2020	**AY 2021**	**AY 2022**	**AY 2023**
ACT Aspire Assessments	-	-	-	-
Smarter Balance Assessments	-	-	-	-

Source: GDOE

GUAM EDUCATIONAL ATTAINMENT (2020)		
	Number	**Percent**
High School graduates	34,372	37.7%
Bachelor's degrees	23,089	25.3%
Graduate or professional degrees	5,538	6.1%

Source : DECIA Guam Demographic Profile. American Community Survey does not gather information for Guam.

Technology and Science Workforce

The sub-index measures the technical capacity of the local workforce to support high tech industries represented by the number of workers concentrated in scientific and engineering occupations relative to Guam's total employment and in comparison, to the national average.

OCCUPATIONAL EMPLOYMENT					
Occupations	**2019**	**2020**	**2021**	**2022**	**2023**

All Occupations	63,630	64,820	58,390	59,470	64,680
Computer and Information Systems Managers	60	70	90	-	-
Architectural and Engineering Managers	60	50	60	50	50
Computer and Mathematical Occupations	700	760	740	770	790
Computer Systems Analysts	70	80		-	-
Computer Network Support Specialists	90	90	-	50	-
Computer User Support Specialists	210	230	230	180	200
Network and Computer Systems Administrators	90	70	-	-	70
Computer Occupations, All Other	130	160	-	-	-
Architecture and Engineering Occupations	1,100	1,070	950	970	1,120
Architects, Except Landscape and Naval	50	50	60	60	70
Civil Engineers	260	260	280	310	320
Electrical Engineers	70	50	60	60	180
Electrical Engineers, Except Computer	40	30	-	-	-
Industrial Engineers	50	60	-	-	-
Mechanical Engineers	40	40	40	40	60
Engineers, All Other	40	40	-	-	-
Architectural and Civil Drafters	110	100	70	80	40
Life, Physical, and Social Science Occupations	470	550	580	670	680

Source: U.S. Bureau of Labor Statistics – State Occupational Employment and Wage Estimates
https://www.bls.gov/regions/west/news-release/occupationalemploymentandwages_guam.htm

APPRENTICESHIPS				
	FY2020	**FY2021**	**FY2022**	**FY2023**
Number of STEM-related apprentices	16	1	3	5
Number of STEM-related companies in Guam Registered Apprenticeship Program	1	1	7	2

Sources: Guam Registered Apprenticeship Program / Guam Department of Labor

Entrepreneurial Investment and Business Growth

The sub-index measures STEM-related business growth and investments in entrepreneurship.

STEM-RELATED BUSINESSES				
	2020	**2021**	**2022**	**2023**
Guam Chamber of Commerce Total Members	435	395	405	455
Guam Chamber of Commerce STEM-Related Members	-	-	-	-
Guam Women's Chamber of Commerce Total Members	-	-	-	-
Guam Women's Chamber of Commerce STEM-Related Members	-	-	-	-
Companies in High Tech NAICS Code	-	-	-	-

Source: Guam Chamber of Commerce

BUSINESS FORMATION				
	2020	**2021**	**2022**	**2023**
Number of Current Business Licenses	857	418	776	980
Number of New Business Licenses	14,552	13,602	10,457	14,769
Number of Current Business Licenses for STEM-related Industries	-	-	-	-
Number of New Business Licenses for STEM-related Industries	-	-	-	-

Source: Department of Revenue and Taxation [Note: DRT can only provide a number of current and new business licenses for "General Activities" only pursuant to Title 11 GCA CH 76 Section 76101.]

CAPITAL INVESTMENT ACTIVITY				
	2020	2021	2022	2023
Number of Small Business Loans Awarded by Banks to STEM-related Businesses	-	-	-	-
Dollar Amount of Small Business Loans Awarded by Banks to STEM-related Businesses	-	-	-	-
Number of Businesses with State Small Business Credit Initiative (SSBCI) funding	-	-	-	-
Dollar Amount of Tech-Related Venture Capital Investments	-	-	-	-
Number of Patents Issued	-	-	-	43

***Sources:** GEDA's Venture Capital Program, creation of bank survey implemented by Guam Bankers Association, United States Patent and Trademark Office
Number of Patents Issued: https://tmsearch.uspto.gov/search/search-results searched "Guam" as of May 3, 2024.

CHAPTER VI: LOOKING AHEAD – THE NEXT STEPS

The presentation of this S&T Plan implies that many steps can be taken towards implementation based on a cooperative process. However, the real success will depend on the continuation and strengthening of the S&T committee structure and collaboration with Guam's NSF EPSCoR-funded research activities. These cooperative efforts will attract funding to support the development of a STEM-capable workforce and new economic activities through NSF investments and other funding opportunities.

The current state of STEM higher education on Guam relies on the University of Guam (UOG) as a primary driver. The Guam Community College performs two major functions. They are technical and biomedical training, and the preparation of two-year associate degree students for transition to four-year institutions on Guam (UOG) or elsewhere. UOG provides students with access to training and research experiences with the opportunity to earn baccalaureate degrees in STEM fields and, later, master's degrees in biology, Environmental Science and Data Science.

STEM opportunities have increased considerably thanks to two NSF EPSCoR Track-1 awards and NSF INCLUDES awards. These have provided access to facilities, first-class training in the application and use of instrumentation in cutting edge research, scholarships and internships, and networking opportunities for both graduate and undergraduate students. Additionally, students engage in unique near peer mentoring seminars throughout their research fellowship focusing on the connection between research, culture, and identity to impact science and community identities and voice in science communication.

The combined research experience and mentoring seminars yield numerous students being accepted to present at and earn recognition at national conferences and earn prestigious awards such as the NSF Graduate Research Fellowship (GRFP). Undergraduate Student Research Experience (SRE) programs have been successful in placing students in graduate programs or successful careers, and many of these students have the distinction of being first-generation college graduates. EPSCoR Track-1 awards have also been instrumental in the recruitment and training of post-doctoral fellows, as well. Current programs that provide these opportunities must be expanded to accommodate more students from Guam and the region.

The Guam Department of Education efforts in STEM include programs such as robotics and coding. The NSF INCLUDES SEAS Islands Alliance high school summer internship fills a gap by providing environmental research opportunities in a mentoring ecosystem. In one year, the call for applications yielded 100 applicants for 10 spots. This unique design provides HS students with a full research experience supported by numerous near peer mentors and culminating in an end of programming science symposium where students have the opportunity to compete at the International Science and Engineering Fair (ISEF). Currently, only the first-place recipient in the Island Wide Science Fair moves onto the ISEF. Through the INCLUDES High School summer internship program, one of our participants becomes the second Guam representative to the ISEF.

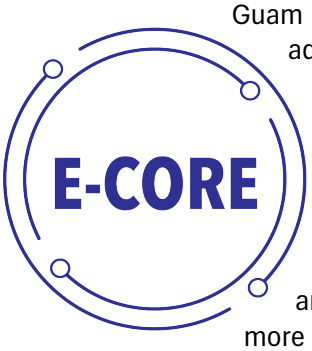
The National Science Foundation, including EPSCoR, is recognizing that global competition in science, engineering and technology is growing and intense. In response to this challenge and to bolster U.S. economic competitiveness and sustainability, NSF funding opportunities emphasize use-inspired research that has implementation in a time bound manner that will be of immediate benefit to society. Networks involving partnerships between researchers, government agencies and private industry will be critical to implement and foster a use-inspired and translational R&D enterprise that can fuel economic diversification and growth.

Beyond EPSCoR, NSF's Directorate for Technology, Innovation and Partnerships (TIP) is the lead vehicle for fostering diverse innovation ecosystems. Programs in the TIP directorate invest in basic research with the goal to stimulate innovative ideas and activities and their translation into solutions with societal impact. The development of a STEM-trained workforce is at the core of these activities. Regional Innovation Engines, coalitions of diverse entities, including educational institutions and industry, are one of the TIP directorate's key initiatives for stimulating the economy and job creation. The Enabling Partnerships to Increase Innovation Capacity Program (EPIIC) is designed to prepare institutions of higher education with limited research capacity to participate in larger coalitions such as a regional innovation engine, a funding opportunity that should be explored to increase the capacity and competitiveness of our institutions of higher education.

A Renewed and Focused Guam NSF EPSCoR

In order to take full advantage of these opportunities, the direction of the University of Guam's NSF EPSCoR activities must be in full alignment towards use-inspired research and a broader network of collaborations beyond current GECCO (2020-202 activities. This will also be reflected in a renewed Science and Technology Committee structure and activities. Funding for these activities will be sought through two new EPSCoR RII programs: E-CORE (RII) and E-RISE (RII).

E-CORE is defined as "Collaborations for Optimizing Research Ecosystems (NSF 23-587)". The goal of this program is "to align EPSCoR programmatic goals with levels of innovation in research ecosystems within EPSCoR-eligible jurisdictions in order to develop a dynamic and sustainable ecosystem." Within a jurisdiction, this program provides a "framework to capture and connect the range of academic, nonprofit, and private sector organizations that contribute to jurisdiction-wide competitiveness in STEM."



Guam NSF EPSCoR is submitting through UOG an E-CORE proposal in 2024 that addresses four core areas: Administrative, Research Support, Academic Infrastructure and Research Facilities, and Higher Education. The Administrative Core will connect individuals, teams, institutions, and sectors to improve Guam's R&D competitiveness through creating a coordinated jurisdiction-wide culture of inclusion that builds a network that places participants in an inclusive research environment. The Research Support Core will provide management in administrative, fiscal, and scientific aspects of projects undertaken in collaboration with one or more partners.

According to the program solicitation (NSF 23-587), this may focus especially on administrative elements that are not available to the entire network of partners, and if available, will allow them to fully engage and participate in the jurisdiction-wide scientific enterprise, including enhancing research

support infrastructure including higher education STEM activities). The Academic Infrastructure and Research Facilities Core will leverage existing or aid in the establishment and coordination of a core facility or facilities that facilitate(s) the research focus of any center-like activities, EPSCoR funded projects, and/or research activities related to the S&T plan for the jurisdiction. Special efforts will be made to coordinate the funded projects and research with the Government of Guam's economic diversification plan including incubators.

This core may also support the acquisition or equipment, and/or the Alteration and Renovation (A&R) costs to improve existing research infrastructure and laboratories. The Higher Education Pathways Core will connect students to scientific fields of interest to Guam in support of center-like activities within a facility, NSF EPSCoR-funded projects, and/or activities related to the S&T plan for Guam. There has already been significant effort in specifying different routes to Higher Education Pathways through a variety of undergraduate research experiences and outreach to students in K-12. Together, this four core-program will greatly expand Guam's research ecosystem while providing the means to respond to Guam's research capacity needs and priorities.

The E-RISE RII program supports the incubation of research teams and products in a scientific topical area that links to research priorities identified in the submitting jurisdiction's approved Science and Technology (S&T) Plan. A key component of E-RISE is the development and implementation of a sustainable and broad network of institutions and organizations (e.g., academia, government, industry) within the jurisdiction that will increase STEM capacity and competitiveness. E-RISE projects are expected to be designed to allow for the incubation of teams that develop an area of research and contribute to the development of a STEM-trained workforce relevant to the project's topic area.

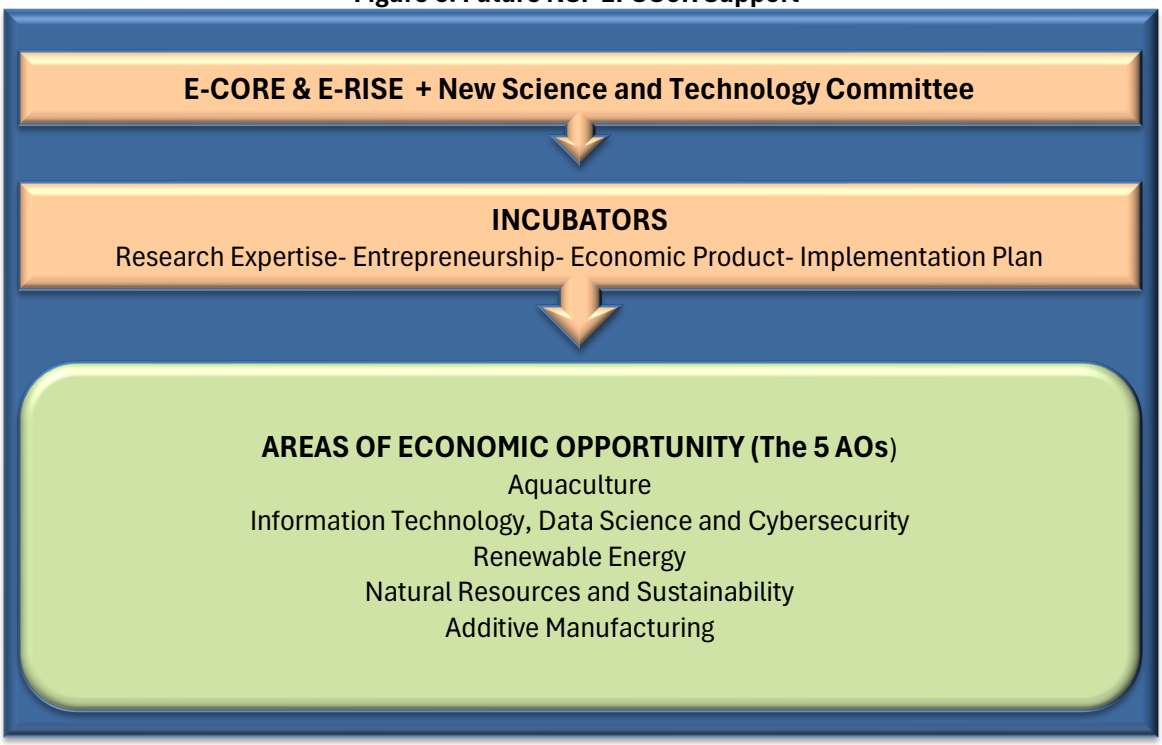
For the 2024 submission to NSF's E-RISE RII request for proposals, the development of the UOG Biodiversity Research Center will be the focus. The vision is to build on prior NSF EPSCoR investments in biodiversity research to establish the organizational structure for a Biodiversity Research Center at UOG that spans units and researchers from diverse fields. Workforce development activities will focus on creating internship and training opportunities with local resource management agencies. Leveraging IT training and internship programs at UOG and GCC will be pivotal for tackling the challenges of data management and integration of diverse data sources and types produced by this effort. Translation of research results into models to inform climate change readiness, in particular the preservation of natural resources, will rely on integration of research results across the team using data science approaches and modeling.

The new Micro-Computed Tomography (CT) scanner at the University of Guam acquired by Guam NSF EPSCoR supports projects associated with the GECCO Biorepository with a non-invasive method of studying specimens, generating three-dimensional images of internal structures such as skeletons or organs. Using the scanner, researchers can visualize the internal structures of various organisms such as corals, sponges, mollusks, shrimp, or fish. Scans of different specimens can provide a deeper understanding of marine life in the Marianas and the region by offering valuable insight into internal anatomy and how species differ from one another. In addition to the life sciences, micro-CT scanning may enable studies of the internal structure of materials or archeological specimens. Photo: An example of an image produced by the Micro-CT scanner.)

The utilization of Research and Development is not meant to be a one-directional activity. It provides feedback through a network that fosters "use-inspired" R and D. The NSF Directorate for Technology, Innovation and Partnerships (TIP) is the lead vehicle for establishing Regional Innovation Centers and ancillary networks and centers. Under TIP, a future University of Guam EPSCoR project outside of E-CORE and E-RISE should consider working towards broader participation in these Research Innovation Engines as a producer and facilitator and not just a consumer. The unique position of the University and its research agenda could place UOG in serious competition for a future Research Innovation Engine.

The Scanning Electron Microscope (SEM) at the Microscopy Teaching & Research Laboratory enables scientists and students to obtain high-resolution images, conduct elemental analyses of samples, and generate surface topographies of samples at a high resolution. The SEM, which was acquired through Guam NSF EPSCoR, enables a variety of applications: researchers have discovered new species of microalgae, studied macroalgae, and performed elemental analysis to determine the chemical composition of samples. (Left: The SEM at the Microscopy Teaching & Research Laboratory at the University of Guam. Right: A student examining a sample through the SEM.)

Figure 6. Future NSF EPSCoR Support



The New Science and Technology Committee

A more immediate and additional exciting possibility is the reformatting of the S&T Committee structure and operations as expected as part of the next cycle of applications. In the new cycle, the S&T Committee will be formally a part of the E-CORE proposal through a linkage provided by a S&T Coordinator. The S&T Committee will be seen as an integral part in the co-production of EPSCoR activities in research, partnerships, coordination with other federal agencies. The S&T Committee will participate in the formation of incubators as well as provide advice and expertise on participation in other NSF-sponsored centers and local/regional translational activities. It will also take on the responsibility of monitoring progress towards a knowledge-based economy as outlined in Chapter 5 of this report.

The next S&T Committee will include the extensive base of support that has been provided by the current committee. This level of continuity and support for the future is strong and identified below. The next S&T Committee will be supported with staff and resources to carry out expanded functions and the capacity to implement major features of this plan. Under the current structure, the Co-Chairs are representatives of the local government and private sector respectively. A balance of government, private sector and educator/researcher membership will be essential to the success of the new S&T Committee. The Vice-Chair currently functions as the coordinator and manager of activities. The Vice-Chair or, more appropriately, S&T-Guam EPSCoR Coordinator position, will be funded by an NSF E-CORE award to Guam NSF EPSCoR.

The major coordinating function of the S&T Committee is to become an active participant and supporter of Incubators for all the five AOs identified in this report. Some, such as Aquaculture, Natural Resources and Additive Manufacturing are already underway. The other areas need some foundational work. The S&T Committee will work with Government and Private Sector partners in these incubators. Each incubator will work towards specific economic products and include research expertise, higher education pathway partners and entrepreneurial expertise and services.

This reinvigorated plan will include expanded coordination with services available at the UOG School of Business and Public Administration. These include the Center for Entrepreneurship and Innovation, Guam Apex Accelerator and the Pacific Islands Small Business Development Center (SBDC). In combination with existing GEDA services and the various Chambers of Commerce, the incubators will be generators of diversified economic activities as outlined in this plan.

Sustainability in these diversified activities must be defined both in terms of their economic success as well as positive environmental impact. For future activities generated by EPSCoR, the foundational role of research must remain central to the development of these projects. The Biodiversity Research Center will be an important bridge between scientific knowledge, STEM preparation and STEM infrastructure as well as a facilitator of knowledge-based economic projects. The Center will conduct research essential for the protection of the biodiversity of Guam. This research will have applications in the 5 AOs, especially in Aquaculture and Natural Resources. The Center will provide guidance and respond to requests for ideas and research data on various aspects of the 5 AOs. The level of coordination between the Center, the S&T Committee, educational institutions and the private sector will facilitate the extensive growth of Guam's knowledge based economy and economic diversification.

Commitment to the Future

While preparing this report, the S&T Committee consulted with a number of individuals and representatives of various entities in the educational, government and private sectors of Guam. The level of commitment was high not only in preparing this report, but in working towards future collaboration towards the goals and objectives that have been outlined. Special levels of involvement and commitment to future endeavors in keeping with this plan were made by the following individuals:

Dr. Leslie Aquino, EPSCoR-NASA, College of Natural and Applied Sciences, UOG
Mr. David Camacho, Representing the Superintendent of Guam Department of Education
Dr. Michael Chan, Dean School of Technology and Student Services, Guam Community College
Mr. David Crisostomo, Aquaculture Specialist, UOG SeaGrant
Mr. Andrew Gayle, Guam Telephone Authority
Mr.. Mike Gawel Retired Environmental Resource Manager, National Park Service and University of Guam Educator
Mr. Gary Hiles, Chief Economist, Guam Department of Labor
Ms. Lola Leon Guerrero, Director of Bureau of Statistics and Plans, Government of Guam
Ms. Melanie Mendiola, Administrator, Guam Economic Development Authority
Dr. Ross Miller, Western Pacific Tropical Research Center, CNAS, UOG
Ms. Cathleen Moore-Linn, Director, Research Corporation of the University of Guam
Dr. Leah Beth Naholowaa, Director Starbase Guam, Department of Defense
Dr. Austin Shelton, Director of Center for Island Sustainability, UOG SeaGrant
Mr. Melvin Tabilas, Guam Economic Development Authority
Ms. Laurie Tumaneng , Guam Power Authority
Dr. Albert Valentine, School of Business and Public Administration, UOG

Acknowledgements and Writing Team

There were many individuals and staff members in different agencies, institutions and businesses which contributed to the preparation of this report. Those who contributed to the writing and editing deserve a special “si Yu’os ma’ase’” and recognition for their efforts. These include the following:

Dr. Leslie Aquino, UOG College of Natural and Applied Sciences
Dr. Sara Bolduc, Sara Bolduc Planning and Evaluation LLC
Mr. David Crisostomo, Extension Agent UOG SeaGrant
Ms. Amanda Dedicatoria, Guam NSF EPSCoR
Mr. Mike Gawel, Retired Environmental Resource Manager, National Park Service and University of Guam Educator
Mr. Jordan Jugo, Guam NSF EPSCoR
Ms. Melanie Mendiola, GEDA
Ms. Lola Leon Guerrero, BSP
Ms. Cathleen Moore-Linn, RCUOG
Dr. Cheryl Sangueza, UOG School of Education
Dr. Austin Shelton, Director of Center for Island Sustainability, Sea Grant
Ms. Laurie Tumaneng, GPA
Dr. Robert Underwood, President Emeritus
Ms. Marissa Villaverde, Guam NSF EPSCoR

Sources Consulted

Annual State of Public Education Report (ASPER) SY 2022-23. Superintendent Kenneth Swanson, Guam Department of Education. Prepared by Research Planning and Evaluation Division, GDOE.

Bureau of Economic Analysis, "Gross Domestic Product for Guam, 2022", 15 April 2024, Gross Domestic Product for Guam, 2022 | U.S. Bureau of Economic Analysis (BEA).

Bureau of Labor Statistics. "Current Employment Statistics", September 2023, Bureau of Labor Statistics – Government of Guam.

Congressional Research Service. "Guam: Defense Infrastructure and Readiness", 3 August 2023, crsreports.congress.gov/product/pdf/R/R47643/2.

Guam Economic Development Authority. "Guam Aquaculture Feasibility Study", 15 March 2022.

Guam Economic Development Authority, "Guam Additive Manufacturing and Materials Accelerator", May 2023, MS_ASTRO_GuamReport_20230502_MAIN.pdf - Google Drive.

Guam Economic Development Authority. "Guam Comprehensive Economic Development Strategy: 2020 - 2025 Pandemic Update", 22 August 2024. Special Projects – GEDA Guam (investguam.com).

Guam Office of Infrastructure Policy and Development. *Internet For All Guam*. 2024. https://broadband.guam.gov/sites/default/files/Guam_BEAD_Initial_Proposal_Vol_1_Final.pdf

Guam Office of Infrastructure Policy and Development. *Guam Broadband Infrastructure 5 Year Action Plan*. 2023. https://governor.guam.gov/wp-content/uploads/2023/08/Guam-5-Year-Action-Plan-Final-082823.pdf

Milken Institute. "State Technology and Science Index", 20 November 2020. State Technology and Science Index 2020 (milken institute.org).

United States Congress. "Congressional Guidance for a National Maritime Strategy", 30 April 2024. congressional_guidance_for_a_national_maritime_strategy.pdf (house.gov).

University of Guam Regional Center for Public Policy. "Submarine Cables on Guam White Paper", May 2022, Microsoft Word - Submarine Cables WhitePaper - 5-23-22 revised V1.docx (live-geda-guam.pantheonsite.io).

Valentine, Albert https://ojs.bonviewpress.com/index.php/GLCE/article/view/2309

Appendices

A. S&T Committee Membership

Melanie Mendiola, CEO, GEDA, Co-Chair
Robert Underwood, President Emeritus, UOG, Vice Chair
Sylvia Calvo, Program Consultant, GDOE
Mike Chan, Dean School of Technology, GCC
Mike Gawel, Retired Environmental Resources Manager, National Park Service
Andrew Gayle, Chief Operating Officer, GTA Teleguam
Gary Hiles, Chief Economist, GDOL
Leah Naholowaa, Director, Starbase Guam (DOD)
Laurie Tumaneng, Chief of Staff, Officer of the Vice Speaker
Albert Valentine, Asst. Professor of Global Resource Management, UOG
Ross Miller, Professor of Entomology, UOG
Tanisha Aflague, Cooperative Extension & Outreach Coordinator, UOG
Lola Leon Guerrero, Director, Guam Bureau of Statistics and Plans

Previous Members:
Rod Boss, CEO Docomo Pacific, Co-Chair
Geri Leon Guerrero Adztech
Frank Lujan, Chief Technology Office, GovGuam Office of Technology
Joanne Muna, DOD Contractor
Ken Rekdahl, PE Duenas and Associates

Non-Voting Members:
Aquino, Lelsie
Bastian Bentlage
Terry Donaldson
Anita Enriquez-Borja
Rachael Leon Guerrero
Cathleen Moore-Linn
Cheryl Sangueza
Austin Shelton
Melvin Tabilas

B. S&T Committee Bylaws

C. Meeting Agendas and Minutes

C.1. Meeting 1 (May 2021)
C.2. Meeting 2 (June 2021)
C.3. Meeting 3 (September 2021)
C.4. Meeting 4 (January 2022)
C.5. Meeting 5 (April 2022)
C.6. Meeting 6 (June 2022)
C.7. Meeting 7 (October 2022)

C.8. Meeting 8 (November 2022)
C.9. Meeting 9 (February 2023)
C.10. Meeting 10 (April 2023)
C.11. Meeting 11 (November 2023)
C.12. Meeting 12 (April 2024)