FINAL REPORT

CASCADE II Project 8
Cybersecurity for Space Systems Phase 1
1 July 2021

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Executive Summary

Our national competitors and adversaries have taken unprecedented steps to grow their capacity to operate in space and have turned space into a warfighting domain. In order to maintain dominance in the non-terrestrial environment the United States needs to better understand and make both government and the public aware of the threats to American security at the nexus of space and cybersecurity. Moreover, to grow our country's commercial opportunities, the United States needs to innovate in the field of space by bringing new cyber assets into use in America's launch infrastructure and by ensuring that those cyber technologies are secure. Most generally, California and the United States must build a civilian workforce which is capable of filling America's technological and cybersecurity needs moving forward. The complex, intertwining nexus of cybersecurity and space must be a top priority to maintain national security and economic advantage.

Through this CASCADE II Grant the California Cybersecurity Institute (CCI) and the Digital Transformation Hub (DxHub)—both parts of the broader academic community at California Polytechnic State University in San Luis Obispo (Cal Poly)—tackled each of those concerns by utilizing its assets in innovative public-private initiatives. The efforts of this grant were completed through a series of "challenges" addressing key aspects for protecting and expanding America's operational capabilities in space:

1. To take stock of cybersecurity challenges, needs, and threats in space, and to grow public awareness of these issues, CCI and Cal Poly hosted two Cybersecurity and Space Symposia, one in October 2020 (Task 8.4) and one in April 2021 (Task 8.5).

2. To improve the United States' space readiness and to innovate new solutions to strengthen America's commercial launch capabilities, CCI and the DxHub formed a collaborative partnership with Vandenberg Space Force Base (Vandenberg SFB):

   a. to build a prototype hybrid cloud environment around weather data streams required to safely launch (Task 8.6 Weather);

   b. to design a prototype hybrid cloud "Automated Range User Interface" to provide a gateway for new commercial launch customers to initiate a relationship with Vandenberg SFB (Task 8.7 TurboLaunch); and

   c. to create a cloud-based data processing and analysis framework in which companies looking to launch from Vandenberg SFB would create a "digital twin" of their launch vehicle (Task 8.9 Digital Twin).

3. To provide secure communications for small satellites and nanosatellites—a growing sector in space for both commercial and government programs—CCI and Cal Poly designed and built an encryption device for CubeSats (Task 8.8 Teensy).

4. To study the educational needs of Californians generally and Cal Poly students more specifically, CCI oversaw two strategic initiatives by Cal Poly faculty for "Revolutionizing the Tech Workforce" and "Transforming Access to Cybersecurity in California," simultaneously building the long-term operational capacity of Cal Poly and CCI itself to ensure long-term impact on educational structures (Task 8.10).

5. To enhance workforce development (Task 8.11), CCI focused its efforts on:

   a. providing data literacy and cybersecurity education for employees of regional companies involved in the commercialization of space and information technology;

   b. creating career events and advice for higher education students contemplating careers at the nexus of space and cybersecurity; and

   c. completing outreach to industry leaders and decision-makers in the emerging field of cybersecurity as it applies to space.

CASCADE II Project 8 Overview

Space and Cybersecurity

When most people think of "space" they immediately focus on NASA and space exploration. But the domain is essential across many aspects of American national and economic security. As the National Security Space Strategy notes,

Space capabilities provide the United States and our allies unprecedented advantages in national decision-making, military operations, and homeland security. Space systems provide national security decision-makers with unfettered global access and create a decision advantage by enabling a rapid and tailored response to global challenges. Moreover, space systems are vital to monitoring strategic and military developments as well as supporting treaty monitoring and arms control verification. Space systems are also critical in our ability to respond to natural and man-made disasters and monitor long-term environmental trends. Space systems allow people and governments around the world to see with clarity, communicate with certainty, navigate with accuracy, and operate with assurance.

With the growth of commercial space activities since the publication of that National Security Space Strategy, space has become ever more central to American economic security. As the 2020 Defense Space Strategy notes, "Commercial space

activities provide national and homeland security benefits with new technologies and services and create new economic opportunities in established and emerging markets. The same activities, however, also create challenges in protecting critical technology, ensuring operational security, and maintaining strategic advantages."

Moreover, in the 21st century, the United States' dominance in space is being threatened by our competitors and adversaries. As the Defense Intelligence Agency (DIA) concluded in 2019, "new risks for space-enabled services have emerged. Having seen the benefits of space-enabled operations, some foreign governments are developing capabilities that threaten others' ability to use space." Russia and China top the list of competitors and adversaries that are pursuing these new capabilities, but North Korea and Iran are also highlighted in the report. As that report also notes, "The advantage the United States holds in space—and its perceived dependence on it—will drive actors to improve their abilities to access and operate in and through space. These improvements can pose a threat to space-based services across the military, commercial, and civil space sectors."

But competition in space does not occur in a vacuum. Simultaneously the United States faces malicious cyber campaigns that threaten American national and economic security, as well. As the May 2021 Executive Order on "Improving American Cybersecurity" makes clear, "cyber campaigns threaten the public sector, the

private sector, and ultimately the American people's security and privacy." Thus,

The Federal Government must improve its efforts to identify, deter, protect against, detect, and respond to these actions and actors. The Federal Government must also carefully examine what occurred during any major cyber incident and apply lessons learned. But cybersecurity requires more than government action. Protecting our Nation from malicious cyber actors requires the Federal Government to partner with the private sector. The private sector must adapt to the continuously changing threat environment, ensure its products are built and operate securely, and partner with the Federal Government to foster a more secure cyberspace.

This CASCADE II grant seeks to address these growing challenges where Space and Cybersecurity overlap.

As America becomes increasingly dependent on space related assets, the cybersecurity needs required to assure that these assets remain controlled for U.S. national interests becomes more critical. The transmission of design concepts and plans for the build, launch, and operations of spacecraft by way of terrestrial networks must remain secure to prevent exploitation by those intending to harm both private and public organizations. While at the same time critical launch communications and control data must be monitored and secured to prevent interference during launch operations to prevent catastrophic adverse events that

would cause economic and potentially physical harm. Once in orbit, spacecraft data transmission for communications, command and control, as well as acquired sensor data must be kept secure during both upload and download to prevent interception and disruption to limit global impacts to critical infrastructure, navigation, and supply chains.

In order to maintain dominance in the non-terrestrial environment the United States needs to better understand and make the public aware of the threats to American security at the nexus of space and cybersecurity. Moreover, to grow our country's commercial opportunities, the United States needs to innovate in the field of space by bringing new cyber assets into use in America's launch infrastructure and by ensuring that those cyber technologies are secure. Most generally, California and the United States must build a civilian workforce which is capable of filling America's technological and cybersecurity needs moving forward. The complex, intertwining nexus of cybersecurity and space must be a top priority to maintain national security and economic advantage.

Finally, as the White House "Executive Order on Improving Cybersecurity" states, these myriad problems can only be solved by fostering public-private partnerships and executing on actions. The projects outlined and completed during this grant either bring government audiences together with leaders from the private sector in forums meant to educate the public or leverage innovative private technology and problem-solving know-how to address government needs, ranging from technical solutions to workforce development.

Cal Poly, a comprehensive polytechnic

university located in San Luis Obispo on California's Central Coast, is a lynchpin in these public-private partnerships. Cal Poly's California Cybersecurity Institute (CCI) and its DxHub are the bridge that allow government and private industry to connect more easily with each other. In some tasks Cal Poly leverages its credibility with the public to host events that teach the public about the nature of the threats America faces and the opportunities for countering those threats. In some tasks listed below Cal Poly provides the deep bench of academic and research expertise to solve applied problems. In other tasks, Cal Poly utilizes its strengths as a teaching university to foster the necessary learning—in government, in industry, and in the workforce of tomorrow—to assist the government sector and the private sector to prototype solutions that can be scaled to address massive areas of concern. Through these actions, Cal Poly is helping to maintain America's national and economic security as the country adjusts to an ever-shifting strategic environment.

Scope of Work

In the scope of work completed in July 2019, Cal Poly's unique requirements included holding two Space and Cybersecurity symposiums to foster stakeholder engagement based on the identified DoD and commercial space needs and to develop a deeper relationship with key partners where space and cybersecurity overlap (Tasks 8.4 and 8.5).

In addition, CCI and the DxHub also identified seven specific Space Operations Challenges:

1. Small Satellite Design (original Task 8.6);
2. Multi-Satellite Launch Capabilities

(original Task 8.7);
3. Secure Space Communication (original Task 8.8);
4. Cloud-based Space Data Processing and Analysis (original Task 8.9);
5. Secure Satellite Command and Control (original Task 8.10);
6. Educational Opportunities for Space and Cybersecurity (original Task 8.11); and
7. Workforce Development for Space and Cyber (original Task 8.12).

In response to deepening partnerships and knowledge gained of U.S. Department of Defense priorities over the course of this grant, Cal Poly CCI and the DxHub evolved and expanded the design of Space Operations Challenges based on the approach to problem solving.

As Cal Poly's relationship with Vandenberg SFB deepened, and following a signed Educational Partnership Agreement in March 2020, Cal Poly learned that Small Satellite Design, while easily achievable through Cal Poly's CubeSat program, it was a minimal impact challenge for Vandenberg. As a result, in order to create greater value and return for DoD, Cal Poly evolved challenge focus to building a proto-type Hybrid Cloud environment to better serve Vandenberg SFB's needs to create their "Range of the Future Initiative," with a focus on weather as an unclassified opportunity for government-public-private innovation (Task 8.6). Vandenberg SFB also requested support for its Space Port of the Future initiative, and particularly overcoming problems to allow its customers to decrease the time to launch. According to Chief of Space Operations General Jay Raymond,

the approach for the "Range of the Future Initiative" is best summarized as a response to the question, " how do we position ourselves to get after the warfighting requirements that we're going to need from a joint capability?" Space Force identifies this as an effort to create "on-demand, assured access to space." To address the time to launch problem set, CCI and the DxHub began working on both a short-term solution—a range user interface dubbed TurboLaunch—and a more sophisticated and long-term digital engineering program for launch customers—named Digital Twin. Secure Space Communication and Secure Satellite Command and Control needed to be considered one challenge because Cal Poly learned that it is impossible to Communication, Command & Control separately, and the problems posed could be resolved with a single integrated system known within the team as Teensy (explained in Task 8.8). Both Educational Opportunities for Space and Cybersecurity (Task 8.10) and Workforce Development for Space and Cyber (Task 8.11) were refined based on engagement feedback with partner organizations in industry, the military, and education. Given how linked education is to workforce development, there was significant synergy between those two tasks. California and Cal Poly, in particular, now have a much better path forward to ensure that the state of California is prepared for the threats and opportunities of the future.

The specific challenges with Vandenberg SFB engage cutting edge, innovative hybrid cloud computing technologies, which provide an opportunity to revolutionize how the Space Force manages its data and processes. Getting to this point involved in depth conversations with base leadership and required educating various

levels of Vandenberg civilian and military staff about techniques and technologies already embraced by private industry and/or academia. Too often there can be a disconnect between academia, industry, and government, unless there is a longer history or legacy of engagement between the institutions and the DoD. This is particularly true for teaching-focused university that serves a diverse population, like the California State University system (of which Cal Poly is a part). This grant showed that the challenge process can jumpstart and build these important relationships between government, academic institutions, and the private sector where they did not exist before.

Thus, even more than the specific accomplishments summarized in this report the Prototype Hybrid Cloud Environment for weather, the TurboLaunch, and the Digital Twin provide ample evidence of the efficacy and importance of academic-private-government coordination to maintain the United States' operational and defensive capabilities as threats morph across multiple fields of contact.

Based on agreement with OPR, the final challenges included:

1. Task 8.6: Building a Prototype Hybrid Cloud Environment around the weather data injection streams required to safely launch (Weather);
2. Task 8.7: Multiple Satellite Launch Capabilities, to support Vandenberg SFB in creating its "Space Port of the Future" and "accelerating time to launch" through the creation of an "Automated Range User Interface" (TurboLaunch);
3. Task 8.8: Secure Space Communication,

for small satellites (Teensy);

4. Task 8.9: Cloud Based Data Processing and Analysis, to support Vandenberg SFB in creating its "Space Port of the Future" and "accelerating time to launch" through the creation of an "Automated Range User Interface" (Digital Twin);

5. Task 8.10: Educational Opportunities for Space and Cybersecurity, by focusing on higher education opportunities for California students particularly at Cal Poly; and

6. Task 8.11: Workforce Development for Space and Cyber, by providing both digital literacy and cybersecurity training for regional workers involved in the commercialization of space, career events for higher education students, and outreach to industry leaders in the emerging field of cybersecurity as it applies to space.
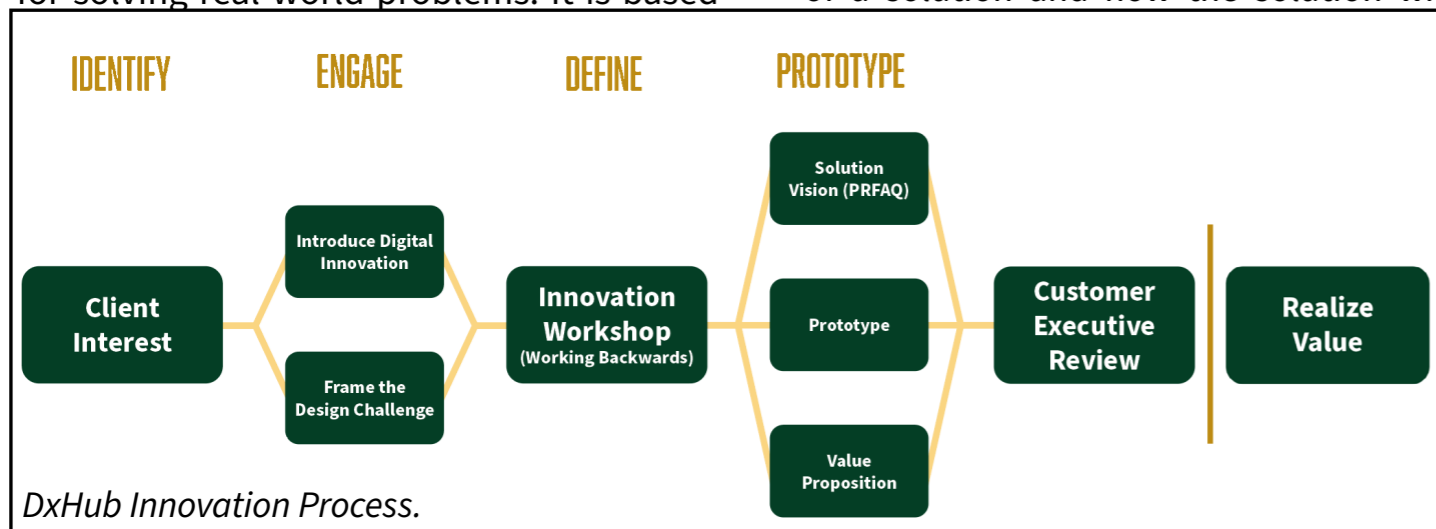
The "Challenge" Process for the CASCADE II Framework

As noted above, the work completed in a majority of tasks in the grant utilized the DxHub's "challenge" problem-solving model. The "challenge" procedure is a framework for solving real-world problems. It is based on a set of best practices and procedures created by Cal Poly's Digital Transformation Hub (DxHub), which itself draws from the experience, in part, of Amazon Web Service's (AWS) "working backwards" product development strategy.

As a process framework, these challenges are not single events, like a conference or a symposium. Rather, challenges involve a series of engagements with clients across a number of stages, including:

- First, an intake form is created when the challenge is accepted by the DxHub and its Cal Poly partners like the California Cybersecurity Institute (CCI).

- Next, the DxHub and its partners host a one- or two-day workshop event in which the client meets with subject/domain experts to define the problem that they want to solve. The innovation workshop is guided by 5 key questions, defining the core components of the problem that needs to be solved through the engagement process.

- The third step is for the DxHub and its partners to create a fictitious Press Release and Frequently Asked Questions (PR/FAQ) document. The press release contains concise information about the problem definition, the customer impact, benefits of a solution and how the solution will solve this problem. The PR/FAQ document is then revised in consultation with the client.

- As a next step, the client, technical and domain experts meet in a solutions workshop to brainstorm a number of possible technical solutions to the problem set identified and explained in the previous stages.

- The DxHub and its partners (including domain experts) then devise a prototype to the identified and analyzed problem or problem set to bring the solution to life for the client.

- Finally, meetings between and communications among the DxHub team and the client continue with critiques shared of the prototype so that it can be further refined. The process is complete when a clear vision of the solution is provided through a minimally viable prototype.

In terms of CASCADE II grant reporting, the second stage of the challenge process is reflected in the problem framing workshops listed in 8.6a, 8.7a, 8.8a, 8.9a, 8.10a, and 8.11 a. The "flyers" referred to in sections 8.6h, 8.7h, 8.8h, 8.9h, 8.10h, and 8.11h are the PR/FAQ documents completed in the middle of the challenge process. The challenge process is considered complete when a prototype has been created and accepted by the client.

Redefining the Challenge Process on the Fly during a Pandemic

For this CASCADE II grant, the typical challenge process was refined and re-imagined 1) to work in the new operational realities created by the Covid-19 pandemic, and 2) to function when the client is an exceptionally bureaucratically complex entity like Vandenberg SFB.

With the public health restrictions put in place in response to the Covid-19 pandemic, convening 2-day workshops in a shared physical space was no longer feasible. While holding virtual 2-day workshops is possible, Zoom fatigue is a real thing and the DxHub and CCI believed that day-long virtual meetings would just not be as productive as face-to-face events had been before Covid-19. Therefore, the DxHub and CCI decided to shift to a model of constant engagement. So, rather than the traditional model of regular communication punctuated by intense and lengthy collaboration workshops, the DxHub and the CCI were in regular contact and frequent communication with client stakeholders and leadership bodies, in shorter but much more numerous meetings. Nonetheless, the same stages of solution development were completed.

The CCI and the DxHub also had to modify the typical challenge process to work with a complex bureaucratic institution under internal transformation. Over the course of the grant, Vandenberg Air Force Base became Vandenberg Space Force Base, the base workforce went through a major reorganization and a new commanding officer took over the post, among other smaller shifts.

Prior to the CASCADE II grant Cal Poly had no formalized relations with Vandenberg SFB. Therefore, before even beginning the problem framing stage, Cal Poly and Vandenberg SFB needed to compose and gain approval for an Educational Partnership Agreement (EPA). Even after the

DxHub Innovation Process.

EPA was signed in March 2020, Vandenberg has myriad approval processes that need to be completed within individual challenges. (Most clients to complete the DxHub challenge process had been individual companies, non-profit organizations, or small local government agencies, groups with straightforward leadership structures with much fewer regulations and existing procedures.) These administrative hurdles have added significant time to the work that has been completed and caused some slippage. Additionally, because there are multiple decision-making levels within Vandenberg, the Air Force, and Department of Defense leadership structures and stakeholders, scheduling of single workshops where all necessary decision-makers can be in attendance would be difficult if not impossible. So again, the DxHub and CCI have pursued a strategy of constant engagement, meeting with multiple levels of the Vandenberg leadership structures on an as needed basis, rather than in 2-day workshops. These meetings with different levels of stakeholders at Vandenberg have been documented throughout the monthly reports.

Each of the key tasks included in this grant are addressed below, based on the final numbering scheme. Each section discusses the purpose, successes, and limitations of each of these tasks, and each section includes a separate list of key lessons to take away from CCI and the DxHub's experiences completing the work in this grant.

In addition to the efforts covered by the specific tasks outlined in the original grant's scope of work, CCI is providing a three-year road map to grow the workforce development program related to space in coordination with California's Employment Training Panel (ETP). The road map also includes growing Cal Poly's educational programs in both cybersecurity and space, and enhancing the ways the university will be supporting efforts at Vandenberg SFB. CCI is also providing a sustainability plan that clarifies and defines objectives necessary to fully execute on a future phase 2 component, based on partner commitment and funding opportunities identified beyond additional DoD/OEA funding.

Notes

1. National Security Space Strategy, Unclassified Summary, January 2011 (accessed 6/21/2021 via www.hsdl.org).

2. Department of Defense, "Defense Space Strategy Summary," June 2020 (accessed 06/21/2021 via https://media.defense.gov/2020/Jun/17/2002317391/-1/-1/1/2020_DEFENSE_SPACE_STRATEGY_SUMMARY.PDF)

3. Defense Intelligence Agency, "Challenges to Security in Space," January 2019 (accessed 6/21/2021, https://media.defense.gov/2019/Feb/11/2002088710/-1/-1/1/SPACE-SECURITY-CHALLENGES.PDF).

4. The White House, "Executive Order on Improving Cybersecurity," May 21, 2021 (accessed on 6/21/021 via https://www.whitehouse.gov/briefing-room/presidential-actions/2021/05/12/executive-order-on-improving-the-nations-cybersecurity/).

Scope and Structure of Completed Tasks

Task 8.2: Engagement Meetings with Identified Partners Focused on Opportunities for Collaboration to Develop Space and Cyber Programs in the State of California.

Summary

Both CCI and the DxHub were able to leverage their existing networks and Cal Poly's national reputation for exceptional engineering and aerospace programs to meet with both private and governmental agencies from both California and across the federal space, bringing a "whole of government" and "whole of commercial" approach to investigate, understand, and solve problems at the nexus of space and cybersecurity.

Work Completed

Significant new partnerships also grew out the efforts made related to the subtasks in this grant. Given the wide variety of tasks included in this CASCADE II grant, this list of entities with whom CCI engaged includes a similarly wide variety of companies and organizations:

- from small, local IT and cybersecurity firms (like Digital West and Clever Ducks) to international technology innovators in space and cybersecurity like AWS, IBM, and CISCO, as well as more specialized CA-based cybersecurity and IT companies like Ninjio, Bugcrowd, and FireEye;
- from small businesses working in defense manufacturing like Maverick Space to multinational players like SpaceX and Northrup Grumman;
- from companies and non-profits working in research and development, like the Levenhall group and SRI International, to major philanthropic groups, like The William and Flora Hewlett Foundation, who are focused on improving America's cybersecurity readiness; and
- from workforce development groups like CMTC and Journey's Map to other institutions of higher education like Purdue University and San Jose State University.

Across all of these engagements, CCI kept the needs and interests of the DoD at the front of their concerns, meeting with representatives from the California Military Department, United States Strategic Command, the Office of the Secretary of Defense, the National Reconnaissance Office, the Defense Innovation Unit, NASA, and the Jet Propulsion Laboratory. Because of the shared location on California's Central Coast, CCI worked most closely with the leadership of Vandenberg Space Force Base and the 30th Space Wing, meeting at least monthly, but quite often meeting either weekly or daily on specific tasks.

Figure 1: Sectors from which contracts and agreements were finalized. By economic sector based on Table 1 on the next page.
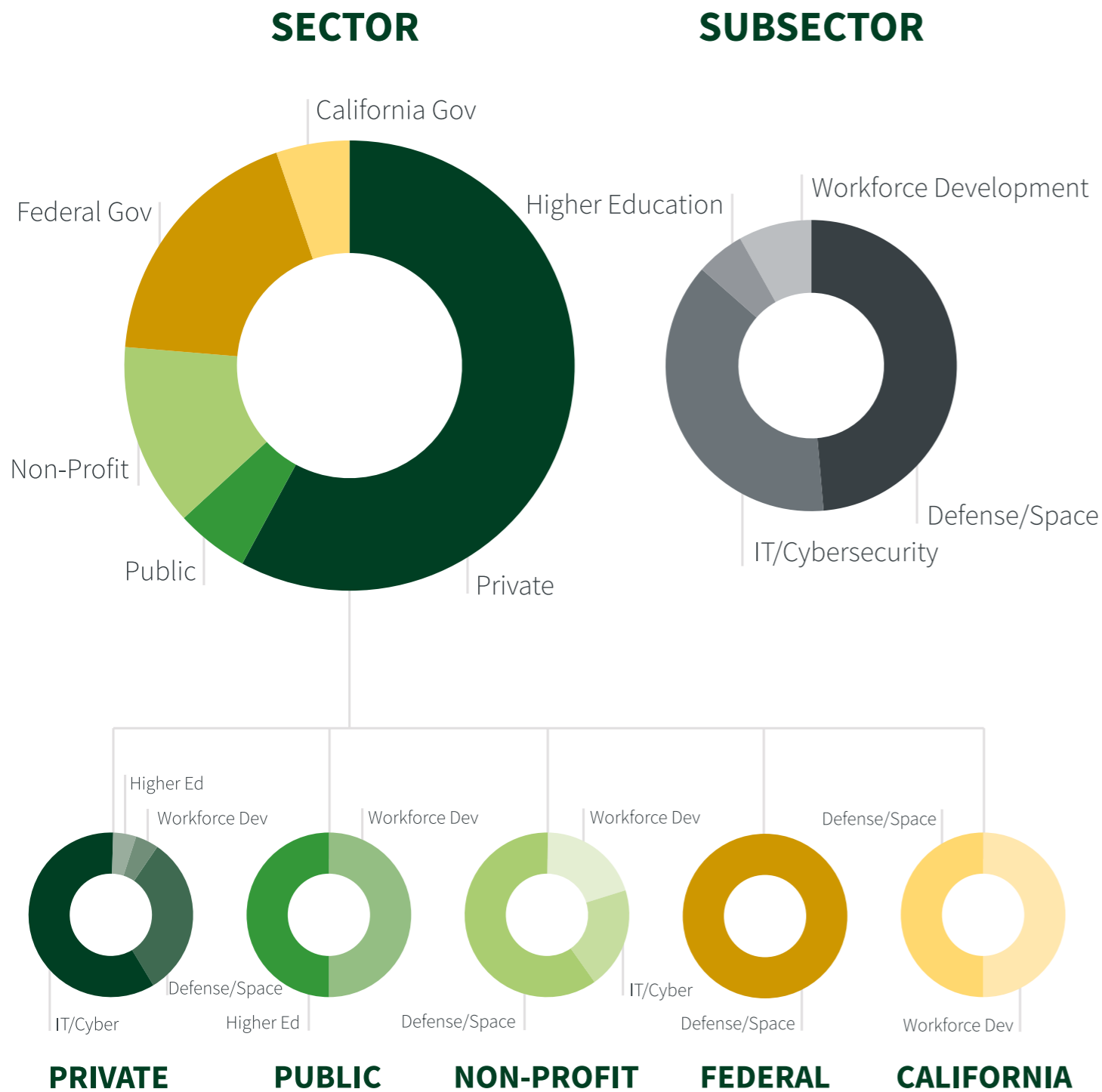

SECTOR **SUBSECTOR**

California Gov
Federal Gov
Non-Profit
Public
Private
Higher Education

Workforce Development
Defense/Space
IT/Cybersecurity

Higher Ed
Workforce Dev
IT/Cyber
Defense/Space

Workforce Dev
Higher Ed
Defense/Space

Workforce Dev
Defense/Space
IT/Cyber

Defense/Space
Defense/Space

Workforce Dev

PRIVATE **PUBLIC** **NON-PROFIT** **FEDERAL** **CALIFORNIA**

In Task 8.2, CCI **exceeded assessment metrics by over 75%** by hosting **37 partners** (goal: 21) focused on opportunities for collaboration to develop space and cyber programs in the State of California.

Table 1. Task 8.2. Individual engagements focused on opportunities for collaboration to develop space and cyber programs in the State of California

Name	Sector
California Military Department	California Government – Space/Defense
California Employment Training Panel (ETP)	California Government – Workforce Development
United States Strategic Command	Federal Government – Defense/Space
Office of the Secretary of Defense	Federal Government – Defense/Space
National Reconnaissance Office	Federal Government – Defense/Space
Vandenberg SFB / 30th Space Wing	Federal Government – Defense/Space
Jet Propulsion Laboratory (JPL)	Federal Government – Defense/Space
National Aeronautics and Space Administration	Federal Government – Defense/Space
Defense Innovation Unit (DIU)	Federal Government – Defense/Space
National Security Space Association	Non-Profit – Defense/Space
R Street	Non-Profit – Defense/Space
Levenhall Group	Non-Profit – Defense/Space
Hewlett Foundation	Non-Profit – IT/Cybersecurity
California NIST Manufacturing Extension Partner (CMTC)	Non-Profit – Workforce Development
SRI International (SRI)	Private – Defense/Space
Maxar Technologies	Private – Defense/Space
SpaceX	Private – Defense/Space
Maverick Space	Private – Defense/Space
Trust Automation	Private – Defense/Space
Northrop Grumman	Private – Defense/Space
Purdue University	Private – Higher Education
Amazon Web Services (AWS)	Private – IT/Cybersecurity
Fire Eye	Private – IT/Cybersecurity
Ninjio	Private – IT/Cybersecurity
IBM	Private – IT/Cybersecurity
Parsons Corporation	Private – IT/Cybersecurity
Bugcrowd	Private – IT/Cybersecurity
Chevron Corporation	Private – IT/Cybersecurity
CISCO Systems	Private – IT/Cybersecurity
Palo Alto Networks	Private – IT/Cybersecurity
Digital West	Private – IT/Cybersecurity
Clever Ducks	Private – IT/Cybersecurity
CIO Tech Solutions	Private – IT/Cybersecurity
Revamp IT	Private – IT/Cybersecurity
Journey's Map	Private – Workforce Development
San Jose State University	Public – Higher Education
Space Information Sharing Analysis Center (Space ISAC)	Public/Private – Defense/Space

In terms of Partnership Agreements that CCI was tasked with signing (8.2a), the executed agreements provide evidence again of CCI, the DxHub, and Cal Poly's ability to work in multiple spheres. These agreements also highlight the institutions' flexibility and adaptability to solve problems as they arise. Here the agreements fall into a few different categories:

- Training Agreements: Working through ETP, CCI signed 6 training agreements to provide data literacy and cybersecurity training to employees from local space and defense manufacturing companies (Maverick Space and Trust Automation) as well as local IT/cybersecurity providers (Digital West, Clever Ducks, CIO Tech Solutions, and Revamp IT). Supports Task 8.11.

- Operational Expansion Grants with the Hewlett Foundation: CCI signed two agreements with the William and Flora Hewlett Foundation as part of the foundation's Cyber Initiative. These grants allow CCI to expand its own capabilities consistent with the goals of the CASCADE II and include support to begin a podcast and newsletter series focused on Space and Cybersecurity and $600,000 to hire an advancement and development officer specifically devoted to building CCI's endowment. CCI is the first center or institute at Cal Poly to have its own endowment officer, a key sign of the university administration's commitment to the center, as well as further evidence of the center's continuing impact in the field of space and cybersecurity. Supports Tasks 8.10 and 8.11.

- Teaming Agreements with SRI International and the Levenhall Group: CCI signed one teaming agreement with SRI International and one with Levenhall.

Both SRI International and Levenhall are focused on R&D and bringing new products to market, providing CCI with important information and advice on understanding the shifting field of cybersecurity and space, but also providing a platform for CCI's work to have a follow-on effect on both defense manufacturing and the local economy. Supports Tasks 8.4 and 8.8.

- A Long-Term Lease with the California Military Department: CCI signed its first long-term lease (five years) with the California Military Department for office space located at Camp San Luis Obispo. This is another important step to foster CCI's longevity and show its continuing growth and impact in both California and beyond. Supports all tasks in this grant.

- A Services Agreement and Letter of Intent with Journey's Map, Inc.: Journey's Map software provides an interactive learning map designed to engage users in exploring life's possibilities and providing personalized directions while navigating life's major educational and professional transitions. Cal Poly and Journey's Map are teaming up to create a first of its kind interactive learning map so that Californian's can plan for the jobs of the future at the nexus of space and cybersecurity. Supports Task 8.11.

- Agreements with Amazon Web Services (AWS): CCI signed two agreements with AWS. First is a ground station partnership agreement to allow Cal Poly and the DxHub to collaborate more closely on AWS's growing involvement in space and satellite development. The second is an Educational Authorized Training Partnership (the first of its kind in the U.S.), which gives Cal Poly and its partners access to AWS training programs. Supports Tasks 8.6, 8.7, 8.8, and 8.9.

- Educational Partnership Agreements with United States Strategic Command and Vandenberg Space Force Base and the 30th Space Wing: These agreements formalized the relationship between Cal Poly and these two DoD partners, a step necessary for any official work to commence. The EPA with Vandenberg and the 30th Space Wing has proven particularly essential as most of the collaboration on Tasks 8.6, 8.7, and 8.9 could not begin before this agreement was signed. This agreement launched Cal Poly into a new level of coordination and collaboration with Vandenberg, not only enhancing the work of this grant but allowing research and educational efforts to blossom across the university with the home of the United States Space Force's Western Range. Supports Tasks 8.4, 8.5, 8.6, 8.7, and 8.9.

> In Task 8.2a, CCI **exceeded assessment metrics by 60%** by signing **16 partnership agreements** (goal: 10).

Figure 1a: Sectors from which partnership agreements were finalized. By economic sector based on Table 1a on the next page.
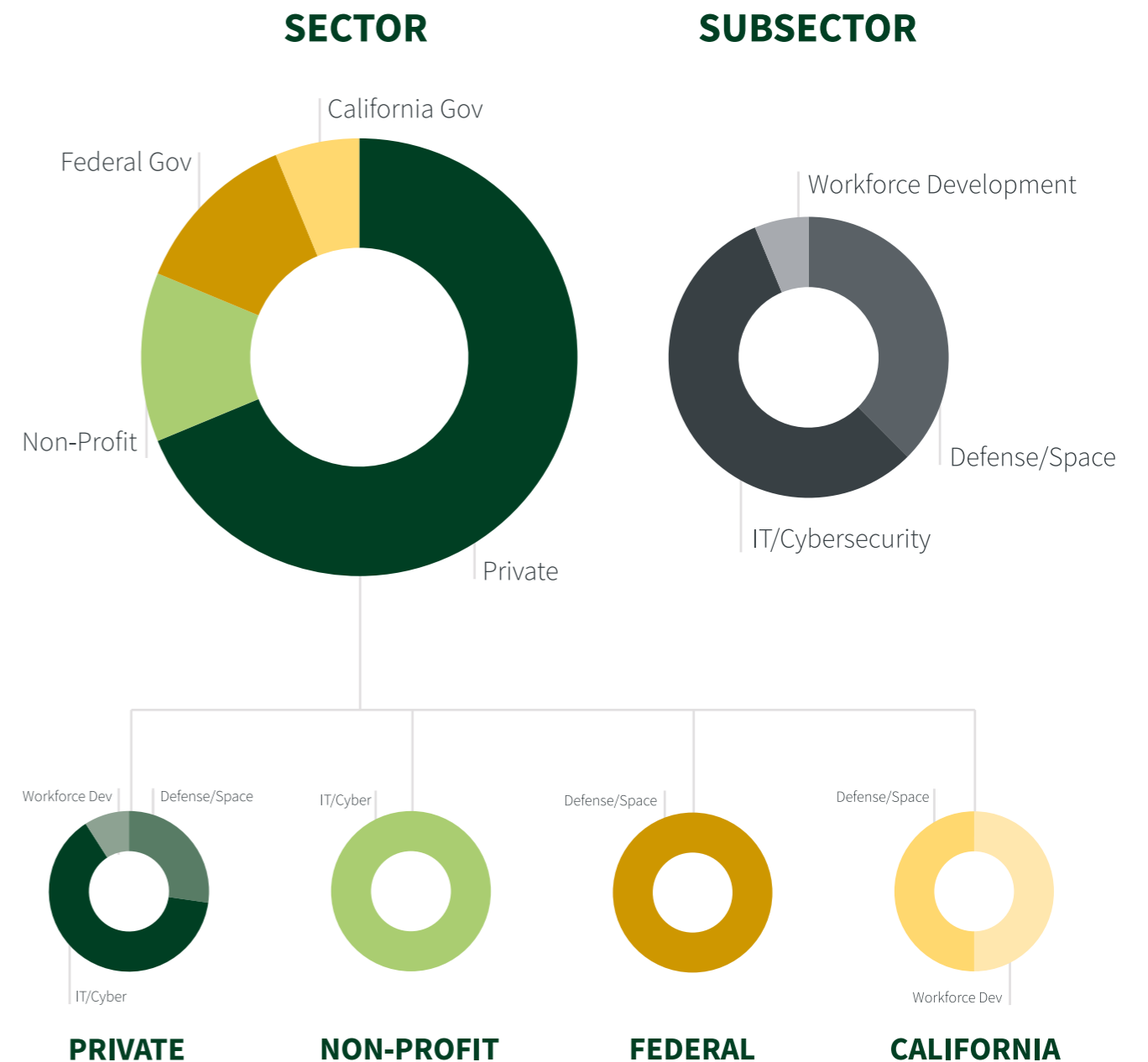

SECTOR

SUBSECTOR

PRIVATE   NON-PROFIT   FEDERAL   CALIFORNIA

Table 1a. Task 8.2a Partnership Agreements

Name	Sector	Purpose
Amazon Web Services (AWS)	IT/Cybersecurity - Private	Ground Station Partnership Agreement
Amazon Web Services (AWS)	IT/Cybersecurity - Private	Educational Authorized Training Partnership
California Military Department	Defense/Space - California Government	Long-term lease for office space at Camp San Luis
CIO Tech Solutions	IT/Cybersecurity - Private	Training Agreement - Digital Literacy and Cybersecurity
Clever Ducks	IT/Cybersecurity - Private	Training Agreement - Digital Literacy and Cybersecurity
Digital West	IT/Cybersecurity - Private	Training Agreement - Digital Literacy and Cybersecurity
Journey's Map	Workforce Development – Private	Services Agreement and Letter of Intent
Levenhall Group	Defense/Space - Private	Teaming Agreement
Maverick Space	Defense/Space - Private	Training Agreement - Digital Literacy and Cybersecurity
Revamp IT	IT/Cybersecurity - Private	Training Agreement - Digital Literacy and Cybersecurity
SRI International (SRI)	Defense/Space - Private	Teaming Agreement
Trust Automation	IT/Cybersecurity - Private	Training Agreement - Digital Literacy and Cybersecurity
United States Strategic Command	Defense/Space - Federal Government	Educational Partnership Agreement
Vandenberg SFB / 30th Space Wing	Defense/Space - Federal Government	Educational Partnership Agreement
William and Flora Hewlett Foundation	IT/Cybersecurity - Non-Profit	Operational Expansion Grant - Newsletter and Podcast Series
William and Flora Hewlett Foundation	IT/Cybersecurity - Non-Profit	Operational Expansion Grant - Grants Development Officer

Lessons Learned

✓ **This is another demonstration that only through public private partnerships can issues of workforce development, national defense, and cybersecurity in space be identified and addressed.**

✓ **The workforce development side is dependent upon organizational maturity and awareness. This is often lacking in the small- and medium-sized businesses (SMB) market space.**

✓ **Due to COVID 19 we were unable to fully integrate these relationships into the University's larger ecosystem of public sector partners. It will be something we look to bring to maturity moving forward.**

Task 8.4: First Space Summit

Summary

The First Space and Cybersecurity Symposium was held entirely virtually on October 5-8, 2020. The event attracted over 780 registrants from over 13 countries connected to over 200 individual businesses, schools, and other organizations.

Work Completed

Local and national participants in the First Space and Cybersecurity Symposium included: California Lieutenant Governor's Office, California Labor & Workforce Development Office, U.S. Space Command, DOD Office of the Secretary of Defense, National Security Agency, SRI International, Amazon AWS, R Street, Hewlett Foundation, Jet Propulsion Laboratory (JPL), SpaceX, Northrup Grumman, IBM, and Parsons.

Overall the symposium included 11 different sessions spread out over four days. Topics and Speakers included:

Day 1

- "Defending Satellite & Space Infrastructure from Cyber Threats," with Maj. Gen. John E. Shaw (Combined Force Space Component Commander, U.S. Space Command, Vandenberg AFB) and Roland Coelho (CEO, Maverick Space Systems)
- "Defending Launch Infrastructure from Cyber Threats," with Col. Anthony J. Mastalir (then Commander, 30th Space Wing and Western Launch and Test Range, Vandenberg Air Force Base)

Day 2

- "Space Cybersecurity: The Department of Defense Perspective" with Arsenio "Bong" Gumahad II (Director, C4/ISR Division, Office of the Under Secretary of Defense for Acquisition and Sustainment Department of Defense) and Chris Henson (Technical Director of Space and Weapons Cybersecurity Solutions, National Security Agency)
- "Cybersecurity Workforce Development Through Public-Private Partnerships" with Arsenio "Bong" Gumahad II, Dr. Jeffrey D. Armstrong (President, California Polytechnic State University San Luis Obispo), and Steven D. Jaques (Founder, National Security Space Association)
- "From Data to Decisions: Using Virtualized Ground Networks to Get your Space Data Faster" with Bill Carlin (business development lead for AWS Ground Station) and Paul Jurasin (Director, Cal Poly Digital Transformation Hub)

Day 3

- "Preparing Students for the Jobs of Tomorrow & Today" with Dr. Amy Fleischer (Dean, Cal Poly College of Engineering), William J. Britton (Cal Poly Vice President Information Technology/CIO & California Cybersecurity Institute Director) and Dr. Trung T. Pham (Faculty at Cyberworx and Department of Computer Science, United States Air Force Academy)
- "Industry Success in Developing Space-Cybersecurity Resources" with Brig. Gen. Steve "Bucky" Butow (Director, Space Portfolio Defense Innovation Unit), Preston Miller (Chief Information Security Officer, JPL NASA), and Maj. Gen. Clinton E. Crosier (Director, Aerospace and Satellite Solutions, Amazon Web Services)

- "DxHub: Innovation and the Student Perspective" with Paul Jurasin (Director, Cal Poly Digital Transformation Hub) and Danielle Knell (Cal Poly student and DxHub employee)

Day 4

- "Addressing the Cybersecurity Workforce Gap" with Steward Knox, (Under Secretary, California Labor & Workforce Development Office)
- "California's Role in Supporting America's Space & Cybersecurity Future" with Eleni Kounalakis (California Lieutenant Governor), John Furrier (Co-Founder, SiliconANGLE Media, Inc.), and Bill Britton

From October 5 to October 19, 2020, there were over 2,000 session views of the posted videos. For synopses of each session as well as links to recordings of the talks, see: https://cci.calpoly.edu/events/space-cybersecurity-symposium-2020

To promote the event, CCI Marketing and Communications Coordinator Makenna Downing finalized the social media plan for the October event, including LinkedIn, Facebook, and Twitter. In early September, Cal Poly produced a press release for the event, which was distributed through Cal Poly distributions lists, as well as various social media accounts and outlets. The marketing team also created a distribution list of relevant trade reporters, as well as a targeted list of publications for both a California audience and a broader national news audience. CCI also compiled a distribution list of individual local and national journalists who were writing articles related to space and/or cybersecurity. Finally in September, the team created a one-page flyer for distribution to contacts at other universities and at California and national corporations and defense contractors interested in cybersecurity in space. These outreach and PR plans were then implemented the first week of October for optimal effect and excitement about the Space and Cybersecurity Symposium.

Space and Cybersecurity Symposium Event Analysis.

164

Session Views
10/14 – 10/19
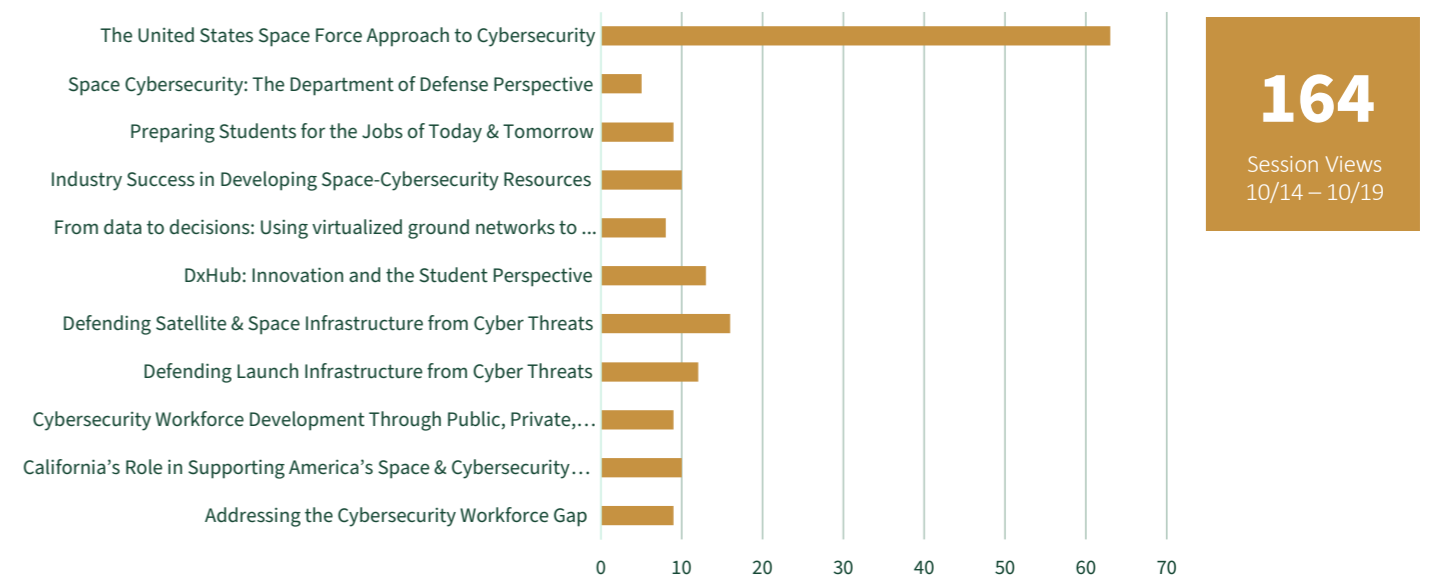
Lessons Learned

✓ **This was the first virtual summit Cal Poly hosted during Covid 19. It was significantly easier to support our speakers with pre-recorded sessions with live Q & A, but the collaboration normally present at these events was difficult to achieve.**

✓ **Utilizing an interactive video platform with integrated scheduling features provided attendees with a better customer experience than more generic video conference platforms do.**

✓ **Coupling these workshops with workforce development activities is critical to populate follow-on action for the SMB community.**

✓ **Properly scaling these events requires at least a year of planning and coordination with dedicated resources and financial partnerships.**

Task 8.5: Second Space Summit

Summary

The Second Space and Cybersecurity Symposium was combined with the annual CubeSat Developers Workshop, held April 27-29, 2021. It was an all-virtual event like the first symposium.

Work Completed

Overall, the CubeSat Developers Workshop attracted 1,542 registrants from over 52 countries representing over 900 businesses, non-profits, educational institutions, and other organizations, a significant increase over the first symposium. About 400 individuals from private companies registered for the talks and sessions, with about 150 registrants from government (both civil and military). Students, faculty, and individuals from non-profit organizations made up the rest of the registrants. Notable businesses and research groups that sent representatives include Aerospace Corporation, Blue Canyon Technologies, Boeing, General Dynamics, Hypergiant Industries, IBM, Kall Morris Inc., Leaf Space, Lockheed Martin, Moog Space and Defense, NASA Ames Research Center, NASA Jet Propulsion Laboratory, NASA Goddard Flight Space Center, Northrup Grumman, Planet Labs, Pumpkin Space Systems, Raytheon, SecureWorks, SRI International, VACCO Industries, Xona Space Systems, and XinaBox, among others. Students and faculty from the world and across California, particularly from the CSU and UC systems, also attended in significant numbers.

Rather than create another stand-alone event like the first symposium, CCI chose to focus its efforts for the second event on a specific community within the broader space ecosystem. Because of its existing relationship with the CubeSat Lab at Cal Poly

and CCI's deep knowledge of cybersecurity and innovation issues in small satellites based on the Teensy project (Task 8.8), CCI decided to partner with the small satellite community and provide additional content through the 2021 annual CubeSat Developer's Conference, highlighting space, cybersecurity, and workforce development in California. By collaborating with an existing event, the effort was assured to have a built-in audience with guaranteed attendance, a key consideration during a pandemic.

The keynote addresses (referenced below) were pre-recorded and included live Q and A sessions as they were initially aired. In addition to four keynote addresses, the conference included 13 thematic sessions with multiple presenters each, 17 poster presentations, and a virtual exhibitors hall for 36 companies. All of the event information can be accessed through the Cube Sat Developers Workshop 2021 website: https://www.cubesatdw.org/. All of the recorded events remain available to watch through Cal Poly's CubeSat Lab YouTube channel: https://www.youtube.com/channel/UCENz0fNHsDR8Kz3jM6C_VWw.

Based on CCI's work on Teensy, it was clear that the small satellite community need greater cybersecurity awareness; CubeSats are not yet built and operated with a cybersecurity mindset. The most popular session during the conference was a live Q & A session focused on CubeSats and cybersecurity that attracted over 170 unique views.

Collaborating with Cal Poly's CubeSat lab (the official host for the event), CCI arranged for three keynote addresses during the CubeSat developers conference, all focused on connecting the Department of Defense with the CubeSat community and providing information on the growing necessity for improved cybersecurity protocols and procedures at all levels from development to launch to operation in a non-terrestrial environment.

Important pieces of the conference which were specifically coordinated by CCI included:

- The first keynote was given by Mr. Bong Arsenio Gumahad II, Director of the Command, Control, Communications, Computers/Intelligence, Surveillance, & Reconnaissance (C4/ISR) Division in the Office of the Under Secretary of Defense for Acquisition and Sustainment (A&S). Approximately 140 unique visitors watched

Mr. Bong Arsenio Gumahad II

  the first keynote address by Bong Arsenio Gumahad II.
- The second keynote address was given by Colonel Matthew Cantore, United States Space Force, Commander, Space Delta 2. Over 50 individual registrants viewed this session.

- The third keynote address, focused on the issue of cybersecurity and space, was given by Mr. Joseph Trujillo, Space Cyber Resiliency Lead at the Air Force Research Lab. This session had just under 90 unique visitors.
- To provide California-specific information regarding innovation and workforce opportunities in the state and based on work on Task 8.11, CCI designed and chaired a Workforce Development Panel which included: Robert Meyer, Director of Economic Development at the Employment Training Panel; Paul Jurasin, Director of New Programs and Digital Transformation Hub (DxHub) at Cal Poly; Kaina Pereira, Senior Advisor Business Development and International Trade at the California Governor's Office of Business and Economic Development (GoBiz); and Tim Chrisman, Co-Founder and Executive Director at Foundation for the Future (an education and advocacy non-profit dedicated to creating a federally chartered, public-private corporation for space infrastructure development, and ultimately, enabling space access for everyone, f4f.space). The workforce panel brought in nearly 60 visitors.

Lessons Learned

✓ **Although the First Space and Cybersecurity Symposium was a success, teaming up with an existing annual event proved to be a much more efficient use of time and manpower. Moving forward, CCI and the DxHub will focus on adding content (panels, events, etc., keynote addresses) to ongoing national and international events to maximize impact and ensure sustainability in its efforts.**

✓ **Properly scaling these events requires at least a year of planning and coordination with dedicated resources and financial partnerships.**

✓ **Public-facing events like symposia are exceptionally useful for raising awareness and providing points of first contact with potential new partners, but further research opportunities and future partnership agreements typically take between one year and three years after an event to reach maturity.**

# Task 8.6: Digital Transformation Hub Challenge: Building

Summary

Problem framing discussions with Vandenberg SFB, CCI, and the DxHub highlighted Vandenberg's present need to create a hybrid cloud data center/hosting platform for its "Range of the Future" initiative. Hybrid cloud systems combine physical servers with cloud coordination capabilities all in a strictly secure and seamless framework. Steve Rogers, Range Technical Director, 30th Operations Group, identified that the first hybrid cloud challenge would focus on weather, given that this data poses fewer security risks and is an integral part of commercial space operations. In August, the prototype weather system user interface received full approval from Vandenberg SFB in August and the task web story, "Transforming Access to Weather Data at the Western Range" was published, showcasing the completed work.

Work Completed

To complete this challenge, the DxHub, AWS, and Kurt Colvin (Cal Poly Professor of Industrial and Manufacturing Engineering) are building a pilot version of the graphical user interface (GUI) for the weather system that will then be paired with back-end changes to Vandenberg's current systems. Darren Kraker (AWS/DxHub) and student assistants are working on the GUI, while Nick Osterber (AWS/DxHub) is coordinating with Steve Rogers to make the back-end changes necessary for the new hybrid cloud system to function. This challenge is focused on creating the prototype GUI. The current version of the user interface for the weather system can be found here: https://www.figma.com/proto/OqrFyZd2YJ5iEVz8j46ECA/Vandenberg?node-id=310%3A11925&scaling=min-zoom&page-id=0%3A1.

After significant engagement with the Vandenberg SFB team on the proposed area of utilizing hybrid cloud computing to promote efficiency in Vandenberg SFB's processes, it was apparent that the organization and its personnel were not in a position to understand or leverage the benefits of the proposed digital transformation to a hybrid

cloud environment. So, to demonstrate what is possible with cloud-based space data processing and analysis (telemetry and collected data), Vandenberg SFB and Cal Poly picked a data set that is utilized by commercial entities with minimal national security or clearance concerns. This is why weather data was chosen as a test case to demonstrate what would or could be possible with a hybrid cloud environment. Collectively by completing the Five Questions process and the PR/FAQ process, the group decided to build a prototype hybrid cloud environment around weather and use this "low hanging fruit" to validate what is or what is not possible.


Weather Data Visualization Prototype
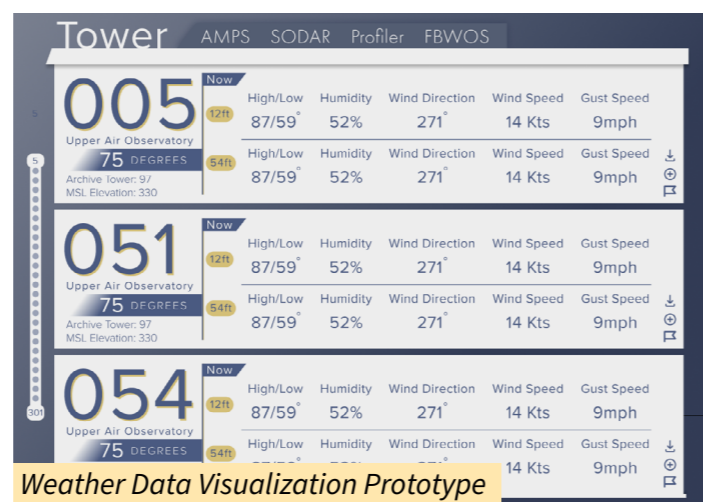
Even this "low-hanging fruit" proved complex with significant learning occurring on both sides of the equation. As part of the process,

the Cal Poly Team (primarily Kurt Colvin, Darren Kraker and Nick Osterber, along with selected Cal Poly students) had to learn about Vandenberg's existing data collection processes for weather data (like real-time wind data), as well as the use of historical data for launch decisions and the current ways that commercial customers interface with Vandenberg's existing weather information system, including creating a survey to gauge the user experience of Vandenberg's weather system. In early 2021, Kurt Colvin together with Darren Kraker and Nick Osterber from AWS met with Steve Rogers and others on his team to learn more about Platform One (P1)—a modern cloud-era platform that provides valuable tooling, hosts CI/CD DevSecOps pipelines, and offers a secure Kubernetes platform for hosting microservices—and the P1 Space Camp Survival Guide.

Attaining official Task Orders for the challenge was also a lengthy process as both Vandenberg SFB and the Space Force in general went through various leadership changes, reorganizations, and restructurings during the grant period.

Over the course of the engagements, it also became clear that many of the staff and leadership at Vandenberg were not fully aware of the advantages that a hybrid-cloud computing system had for Vandenberg's problems. In September 2020, Nick Osterber, Martin Minnich, Kurt Colvin and a Cal Poly student assistant provided training to selected Vandenberg personnel including security engineers, mission solutions managers, innovation techs, and system engineers on the shared responsibility of hybrid cloud computing systems, the basics of AWS cloud architectures, and cost modelling So CCI prepared a brief training for and working

environment of a hybrid cloud-computing system.

Weather Data Visualization Prototype
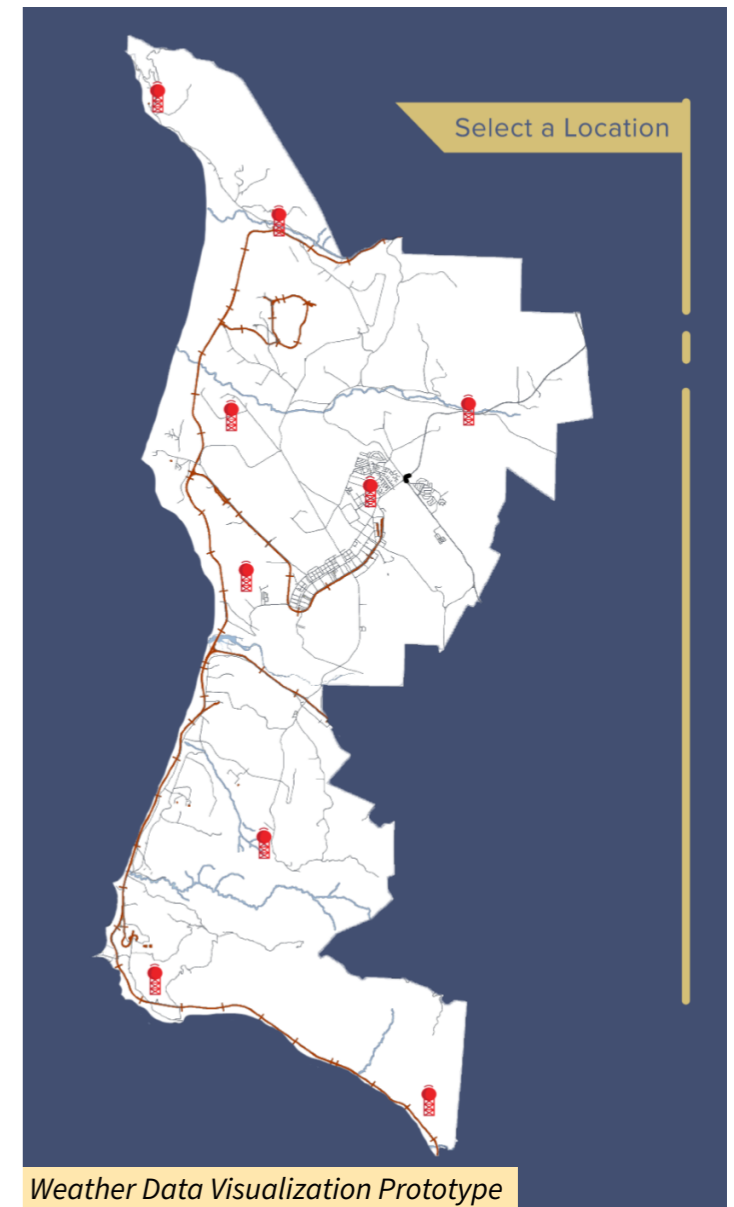
Through February, March, and April, the Cal Poly team and the Vandenberg SFB team continued to meet to define the problem and innovate solutions. Then in late March, Minnich, Kraker, and Osterbur met with Col. Kris Barcomb (Commander, 30th Operations group), Steve Rogers, and Tom Stevens from Vandenberg AFB. Kraker presented his findings that creating the Weather prototype on P1 would be about 5-10 times more difficult than using AWS GovCloud as the hosting platform. Col. Barcom asked for an analysis of what it would take to build on AWS GovCloud versus P1 regarding costs, speed,

efficiency, etc. The decision was then made to create the prototype for the Weather system on AWS GovCloud, not P1.

This is exactly how the AWS working backward and DxHub challenge process is meant to work. Only after going through the 5 questions step, completing the PR/FAQs, and then beginning the prototyping process do the decision-making bodies within the client organization (Col. Barcomb) have all of the information necessary to know how best to proceed with a final product. The challenge process is as much about educating the customer about their choices as creating an actual prototype. The process allows the customer to understand their options, the potential vehicles for success, the resources needed, and the potential capabilities of the final product. Moreover, this has saved Vandenberg significant time and resources for pursuing the full, completed product, if the leadership chooses to do so after the completion of this task.

Following a no-cost extension granted at the end of June, CCI presented the finalized user interface for the weather system to both Vandenberg SFB leadership and to RGNext (a joint venture between Raytheon Company and General Dynamics Information Technology), increasing the reach and impact of the project. Following meetings in July during which Kraker worked with Rogers to educate RGNext about the work that had been completed by CCI and the DxHub, RGNext— the primary contractor at Vandenberg SFB— was tasked with leading the weather strategy moving forward.

The task was completed in August after the Press Release was given final approval by the Public Affairs Office at Vandenberg

SFB and the DxHub published its web story, "Transforming Access to the Weather Data at the Western Range." The web story summarizes the problems addressed and the work completed, and includes links to the Press Release, a diagram of the process being created for a cloud-based weather system, as well as a Figma mock-up of the prototype user interface and a clickable version as well.

Lessons Learned

✓ Work on this project could only fully commence after the signing of the Educational Partnership Agreement between Cal Poly and Vandenberg SFB, showing how important institutionalizing these relationships is. Now that Cal Poly has that EPA, the university and the DxHub can continue collaborate with Vandenberg, creating a much more sustainable relationship thanks to the groundwork forged during this grant.

✓ Work with Vandenberg SFB often slowed as decisions made their way up the chain of command of this complex bureaucracy. The reorganization of the air force base as a Space Force Base, also created some difficulties. The success of this project shows that the challenge process and working backwards process can be successful within the DoD culture and with large-scale clients in general.
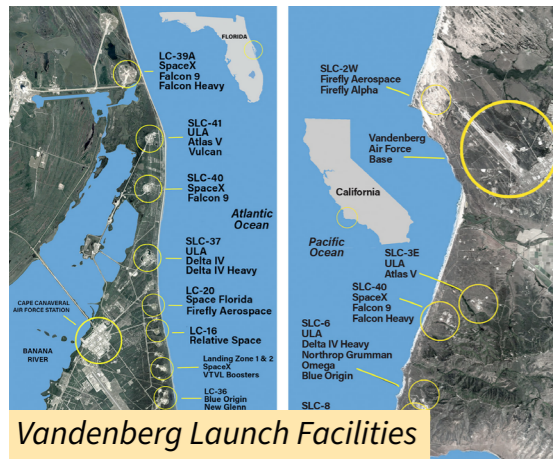
✓ Due to the delays caused by leadership changes and other bureaucratic complexities at Vandenberg SFB, CCI should have built more time into the original grant application to be able to successfully navigate complex hierarchical structures and bureaucracies in the federal government, as well as provide a time cushion for unexpected coordination restarts due to job turnover in those bureaucracies.

✓ This engagement demonstrates the important role that Cal Poly as a public academic institution (with deep expertise in both research and teaching) can play as an intermediary in the relationship between government entities and private industry, specifically in this case by educating the military about the innovative methods and emerging technologies that are embraced by academia and business to improve both efficiency and outcomes.

Task 8.7: Digital Transformation Hub Challenge: Multiple Satellite Launch Capabilities (TurboLaunch)

Summary

Following the problem framing workshop, the focus of this challenge was to assist Vandenberg SFB with the development of the Space Port of the Future, part of the Space Force's Range of the Future 2028 Initiative. Specifically, the team identified "accelerating time to launch" as a desire and focus common to many stakeholders in the satellite launch industry. As Chief of Space Operations Gen. John W. "Jay" Raymond noted, "The space domain is defined by speed." Thus, Space Force is embracing new technologies and new processes to allow for tactically responsive launch, which "seeks to introduce speed, agility, and flexibility into the launch enterprise in order to respond to dynamic changes in the space domain or an operational theater and insert or replace assets on orbit much faster than standard timelines to meet emerging combatant command requirements."


Vandenberg Launch Facilities

Together with Vandenberg SFB (and well in advance of Gen. Raymond's public comments on tactically responsive launch), CCI decided to pursue two solution tracks to the "accelerating time to launch" problem: a short-term solution track and a long-term solution track. Task 8.7 (TurboLaunch) is that short-term solution. (For details on the long-term solution, see Task 8.9 below.)

Within that broad category, the specific purpose of this challenge is to create a prototype for an improved gateway for new commercial launch customers to initiate a relationship with Vandenberg. In essence, it will be a "storefront" for commercial entities to learn about working with Vandenberg SFB and speed the time it takes to gain approval for and be able to launch a new vehicle. Currently, this is a long, documentation-intensive process that can last up to 5 years for some customers. Many companies don't make it through to launch a vehicle. The challenge is intended to provide prototype solutions to this problem with the potential to cut approval time in half. As of fall 2020, the project was named "Automated Range User interface" by the leadership at Vandenberg AFB, with the internal nickname TurboLaunch. At the end

Autonomous Flight Safety Implementation Memo
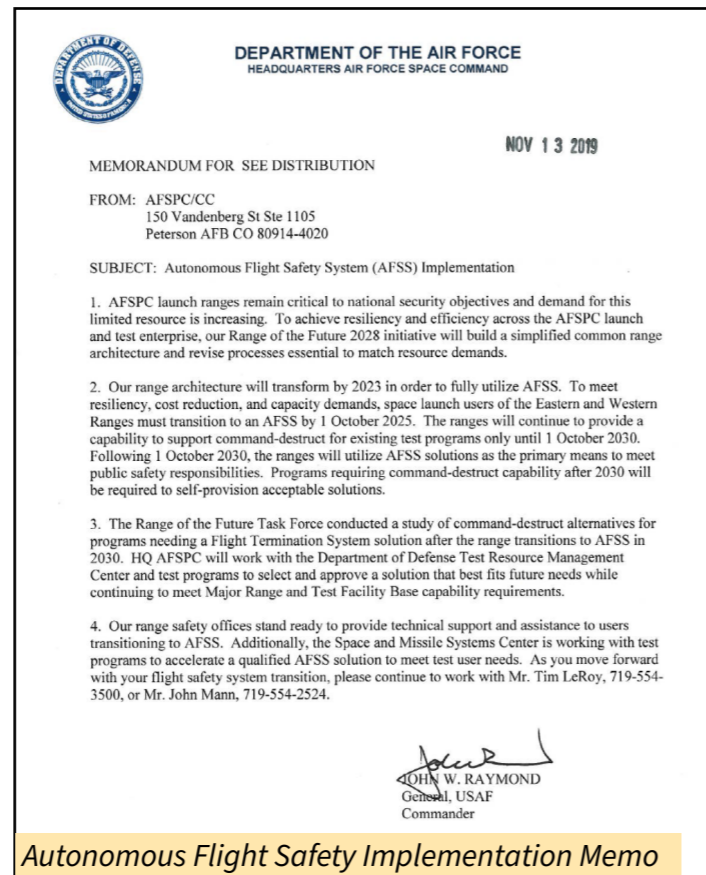
of June TurboLaunch received full approval from the Public Affairs office at Vandenberg SFB and in July the DxHub published the web story, "Transforming Customers' Experience at in Launching Rockets at the Western Range," showcasing the completed work.

Work Completed

This "time to launch" challenge was strategically placed to follow sequentially after the agreement with Vandenberg AFB to focus on creating a working, secure hybrid cloud environment was confirmed and after progress was complete on solving the higher priority concerns about developing infrastructure and skills for a hybrid cloud capability, as explained in Task 8.6.

Again, there was a significant learning period to understand the nature of the problem and to iterate possible solutions. Initial conversations, primarily with Steve Rogers at Vandenberg SFB, focused on broad strategy. Throughout the fall of 2020, Martin Minnich, Kurt Colvin, and Cal Poly student assistants met with small and large groups of Vandenberg staff led by Rogers, to study and analyze Vandenberg's onboarding process for commercial space customers, to meet with support departments from the base, and to understand the new customer introduction processes. All of this was done in order to better understand existing policies for processing and supporting commercial launches on base. The CCI team then met independently to iterate potential solutions. At the end of this learning process and the collaborative creation of the Five Questions document and the DxHub's solutions workshop, Cal Poly and Vandenberg made the collective decision to pursue two-tracks to accelerate time to launch: a short-term solution track and a

long-term solution track. TurboLaunch is that short-term solution. (For details on the long-term solution, see Task 8.9 below.)

Throughout the winter and early spring, coordination with base leadership slowed, due to a service-wide reorganization of the Space Force launched in December 2020. The order required the reorganization of the wing/group categories at Vandenberg and has meant the removal of a middle level in the bureaucratic hierarchy, disrupting the time and ability for key partners at Vandenberg SFB to complete work with the Cal Poly team. CCI's key working partner at Vandenberg (Steve Rogers and his office), however, were higher in authority after the restructuring which then helped to limit decision-making delays moving forward. Happily, the PR/FAQs were finally approved for this task in March. The prototyping process could then begin in earnest. Through March, April, May, and June Kurt Colvin, Darren Kraker, Nick Osterber, Martin Minnich, and Cal Poly student assistants met regularly with staff at Vandenberg SFB, particularly Khrystal Jure, Greg Caresio, Dan Freedman, and Oliva Gillingham. Together these teams are iteratively building the minimum viable prototype of the Range User Interface using Figma (a web-based graphics editor and prototyping tool). In May, the final minimum viable prototype of TurboLaunch was completed.

It also appears that the Eastern Range is also interested in implementing a similar program, providing evidence of the CASCADE II program's national effect.

Minor edits to the PR/FAQ and the web story continued to be made throughout June in consultation with the Public Affairs office, with documents awaiting final review by the new commanding officer at Vandenberg. The change of command ceremony took place at Vandenberg SFB on June 11. Col. Robert A. Long assumed command of Space Launch Delta 30, responsible for spacelift and range operation in support of national and combatant commander requirements, and operational and developmental missile system testing for the Department of Defense.

Following a no-cost extension granted at the end of June, the Public Affairs office provided approval for the PRFAQ. In July the DxHub published the web story on TurboLaunch, "Transforming Customers' Experience at in Launching Rockets at the Western Range." The web story summarizes the problems addressed and the work completed, and includes links to the Press Release, a Frequently Asked Questions document, and both a static (.pdf) version and a clickable version (Figma) of the user interface for TurboLaunch.

Lessons Learned

✓ **Work on this project could only fully commence after the signing of the Educational Partnership Agreement between Cal Poly and Vandenberg SFB, showing how important institutionalizing these relationships is. Now that Cal Poly has that EPA, the university and the DxHub can continue collaborate with Vandenberg, creating a much more sustainable relationship thanks to the groundwork forged during this grant.**

✓ **The Tasks in this grant build on one-another. Task 8.7 relied on the upskilling and teaching about hybrid cloud technologies that was central to Task 8.6. This cumulative and multiplicative effect are further evidence of the ways that this grant is creating a sustainable and fruitful relationship between Cal Poly, AWS, and Vandenberg SFB.**

✓ **Work with Vandenberg SFB often slowed as decisions made their way up the chain of command of this complex bureaucracy. The reorganization of the air force base as a Space Force Base, also created some delays. The success of this project shows that the challenge process and working backwards process can be successful within the DoD culture and with large-scale clients in general.**

✓ **Due to the delays caused by leadership changes and other bureaucratic complexities at Vandenberg SFB, CCI should have built more time into the original grant application to be able to successfully navigate complex hierarchical structures and bureaucracies in the federal government, as well as provide a time cushion for unexpected coordination restarts due to job turnover in those bureaucracies.**

✓ **This engagement proves the important role that Cal Poly as a public academic institution (with deep expertise in both research and teaching) can play as an intermediary and translator in the relationship between government entities and private industry, specifically in this case by educating the military about the efficient and cutting-edge techniques for graphical user interfaces and prototyping software that are already part of academia and business, to improve both efficiency and outcomes.**

Task 8.8: Digital Transformation Hub Challenge: Secure Space Communication (Teensy)

Summary

Following the problem framing workshop, the focus of this challenge was to create a working prototype for encrypted communications for CubeSat and small (50-200 kg) commercial satellites. Developers of SmallSats (satellites under 180 kilograms) often operate with lean teams and limited budgets in the $100,000-200,000 range. Data security via encryption is often a secondary consideration due to the technical and resource requirements and expense involved. Yet, a satellite's core value proposition and monetary value is the data that it acquires and transmits. Without data encryption, the plain text data is vulnerable to interception by anyone with an inexpensive radio receiver, antenna, and desktop computer.

The prototype Teensy Encryption Device was created in May 2020 with the final web story, "Democratizing Cybersecurity in SmallSats with Teensy Encryption Device," published in September 2020. The encryption device meets certification requirements, is open source, and created information and guidelines for the community at large. Although the task is considered complete for the terms of this grant, CCI has continued to work with the prototype to get it into commercial production, primarily by engaging with the Levenhall group to assist in moving the prototype through the STTR process.

In collaboration with RGNext and Vandenberg SFB staff, CCI and the DxHub completed a final PRFAQ document focused on an antenna integration project use case. But the PRFAQ


for this challenge did not go through the full Vandenberg SFB public affairs office review, nor was a full prototype for the antenna integration project created because—after collaborations with Vandenberg SFB and RGNext on the opportunities created by digital engineering and digital twinning—it became evident that a transformative project of this magnitude would need approval from the leadership at Cape Canaveral SFB. This is exactly how the Challenge Process is supposed to work. By fostering deep discussions about problems the client (Vandenberg SFB) faces, the Cal Poly team could then educate both the technical staff and leadership about potential, cutting-edge solutions (digital engineering and digital twinning in this case).

Work Completed

Two tasks from the original Scope of Work—Tasks 8.8 (secure space communication) and 8.10 (secure space command and control)—were combined into this single task, because the encryption/decryption concerns and mechanisms are the same for communications from a ground station to the satellite for command and control, and from the satellite to a ground station for communication.

Additionally, the initial intent of this task was to engage with private space companies on these topics. Over the first six months of the grant, the Cal Poly team consistently ran into
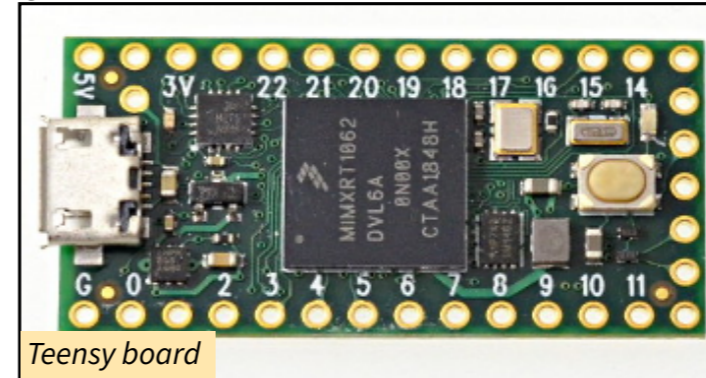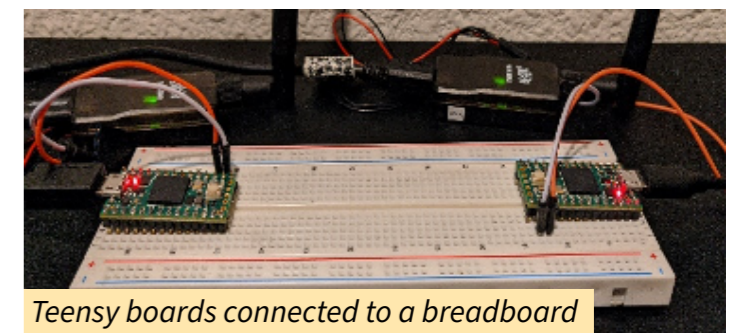

Teensy board

the problem of locating suitable commercial partners. CCI engaged regularly with a wide range of potential partners, surpassing the goals for those metrics set in the Scope of Work (see Task 8.2 above). Potential partners showed clear interest in the projects and see the value of them. However, given the ultra-competitive environment of commercial satellite operations and satellite companies' concerns about sharing intellectual property, it was exceptionally difficult to get commercial partners on board. This was a key "lesson learned" across this and other challenges. CCI, therefore, made the decision to make Cal Poly's CubeSat Lab the "customer" for this challenge.

John Bellardo, professor of Computer Science and (then) director of Cal Poly's CubeSat Lab, completed the challenge intake form with the DxHub and AWS in May 2020. The project, however, was regularly supported by CCI's Weekly Space Systems Group, which in addition to Dr. Bellardo, included:

- Dr. Kurt Colvin, Professor of Industrial Management and Engineering;
- Dr. G. Andrew Fricker, Assistant Professor in the Social Sciences Department with expertise in commercial mapping and surveying as well as three years as a researcher at NASA's Jet Propulsion Laboratory;
- Steve Dunton, faculty in the Electrical Engineering Department with over 30 years of engineering experience focused primarily on satellite payloads and electronics development, including leading multiple technology insertion programs for Boeing Satellite Systems;
- Dan Wait, faculty in the Aerospace Engineering Department with over 15 years of aerospace and systems development experience, including projects at NASA JPL and other small businesses; and
- Ryan Matteson, the Deputy Chief Information Officer (CIO) of Information Technology Services at Cal Poly.

With the support and consultation from the Weekly Space Systems Group, Kurt Colvin and a small team of Cal Poly undergraduate and graduate students designed, prototyped, and demonstrated an ultra-low-cost encryption hardware and software

Teensy boards connected to a breadboard

package using open-source encryption libraries and off-the-shelf products. The Teensy Encryption Device (TED) provides a secure method for encrypting and decrypting data communications sent through a satellite radio communications link between a satellite and ground station. The module sits between any flight computer and a communications radio. This device allows manufacturers of small satellites to quickly implement an inexpensive, open-source solution that complies with licensing encryption requirements. TED is optimized to be a low-power, small footprint device. The device is based on a commercially available ~$20 microcontroller featuring the ARM Cortex-M7 processor.

To raise public awareness of Teensy, the Cal Poly team brought out partners to participate in DEFCON's August 2020 aerospace village to raise awareness on why this prototype Teensy Encryption Device can and will solve an existing problem. (DefCon is an annual conference for amateur and professional hackers.) CCI sponsored a presentation/session by James
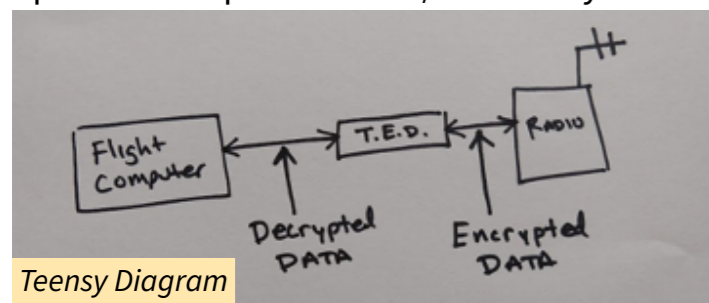
Teensy Diagram

Pavur highlighting the vulnerabilities of broadband satellite communications, using $300 in home television equipment to hack satellite communications (https://www. youtube.com/watch?v=ku0Q_Wey4K0). This presentation served as an advertisement of the proof of need for secure communications equipment for small satellites, reaching a wide variety of audiences in the hacking and cybersecurity communities. Penetration tester for Secureworks, Eric Escobar, also

hosted a CCI-linked workshop at DefCon focused on building a CubeSat simulator, a low-cost satellite emulator that transmits UHF radio telemetry—another advertisement of the use of small satellites to the hacking and cybersecurity community. This event attracted over 385 participants.

Although the task was considered complete for the terms of this grant by September 2020, CCI continued to work with the prototype to move it toward commercial production. Together with the CubeSat Lab at Cal Poly, Dr. Colvin tested Teensy under both launch and space environments.

Moreover, CCI began an engagement with the Levenhall group to assist in moving the prototype through the SBIR/STTR process. (See 8.2 for info on Levenhall). CCI also worked with Levenhall's commercial subsidiary QuickCarl on the Stage 1 STTR process. To aid in this effort, Kurt Colvin and Ryan Vannucci (digital media coordinator at CCI) also created a marketing video for Levenhall which can be found here: https:// www.youtube.com/watch?v=ImhZ4QABVTw. Work on this STTR also allowed Cal Poly to place student interns with QuickCarl to support the process and give students hands on experience in the public-private nexus for defense manufacturing. The Phase I STTR for Teensy will be completed on July 3.

Beginning in May 2021, Levenhall, QuickCarl, i-Blades (a mobile device technology firm), and SRI International (see 8.2 for details) held a kickoff meeting to coordinate submitting the Phase 2 STTR for Teensy. The group has received a sponsorship letter from 130th Air Force Rescue Squadron in the 163rd Attack Wing.

Lessons Learned

✓ **Private companies, including small and medium businesses can be reticent to work with public research institutes on innovative technology out of concerns that their innovations and intellectual property might be at risk in the collaboration. Engagement with commercial partners was much easier after the prototype had been built and certified.**

✓ **CCI and the DxHub's ability to turn to "internal" partners like the CubeSat lab when commercial partners were hard to secure is a testament to CCI's nimble approach to problem solving and the deep bench of academic and intellectual talent at a world-class polytechnic university, talent that CCI can draw from on an as-needed basis.**

✓ **Although Cal Poly became its own client in this challenge, this successful development process proves the usefulness of the working backwards and challenge process for product development in a research environment.**

✓ **As a nationally recognized polytechnic, Cal Poly is a known entity for research. However, the creation of the Teensy device indicates that this university is also well prepared to partner with private industry to bring research innovations to market, in this case through the STTR process.**

Task 8.9: Digital Transformation Hub Challenge: Cloud Based Data Processing and Analysis (Digital Twin)

Summary

Following the problem framing workshop, the focus of this challenge was to assist Vandenberg SFB with the development of the Space Port of the Future, part of the Space Force's Range of the Future 2028 Initiative. Specifically, the team identified "accelerating time to launch" as a desire and focus common to many stakeholders in the satellite launch industry. As Chief of Space Operations Gen. John W. "Jay" Raymond noted, "The space domain is defined by speed." Thus, Space Force is embracing new technologies and new processes to allow for tactically responsive launch, which "seeks to introduce speed, agility, and flexibility into the launch enterprise in order to respond to dynamic changes in the space domain or an operational theater and insert or replace assets on orbit much faster than standard timelines to meet emerging combatant command requirements."[1]

Together with Vandenberg SFB (and well in advance of Gen. Raymond's public comments on tactically responsive launch), CCI decided to pursue two solution tracks to the "accelerating time to launch" problem: a short-term solution track and a long-term solution track. The focus of this challenge is the long-term solution for the "Automated Range User Interface": to create a cloud-based data processing and analysis framework in which companies looking to launch from Vandenberg would create a "digital twin" of their launch vehicle.

Simplifying, the digital twin concept is an electronic/information model that includes all aspects of a company's vehicle design, the required documentation for launch, and a digital workflow for the processes to test and operate the launch vehicle. The digital twin concept builds off of advances in other industries (physical equipment maintenance, 3D modeling, fleet maintenance, wind turbines, buildings, etc.), to create an entirely digital process for launch approval.

In collaboration with RGNext and Vandenberg SFB staff, CCI and the DxHub completed a final PRFAQ document focused on an antenna integration project use case. But the PRFAQ for this challenge did not go through the full Vandenberg SFB public affairs office review, nor was a full prototype for the antenna integration project created because—after collaborations with Vandenberg SFB and RGNext on the opportunities created by digital engineering and digital twinning—it became evident that a transformative project of this magnitude would need approval from the leadership at Cape Canaveral SFB. This is exactly how the Challenge Process is supposed to work. By fostering deep discussions about problems the client (Vandenberg SFB) faces, the Cal Poly team could then educate both the technical staff and leadership about potential, cutting-edge solutions (digital engineering and digital twinning in this case).

[1] Secretary of the Air Force Public Affairs, "U.S. Space Force Launches First Tactically Responsive Launch Mission," dated June 13, 2021

Work Completed

The original focus for this task was Cloud-based Space Data Processing and Analysis. From the initiation of the grant until mid-2020, Kurt Colvin and the Weekly Space Systems Group met to discuss the possibilities of utilizing publicly available data streams from NOAA satellites to

monitor terrestrial phenomena, particularly regarding vegetation. One particular point of interest developed around using satellite sensor data to track wildfire damage across California in real time, through Natural Burn Rate analyses and visualizations. Kurt Colvin spent significant effort studying how this real time data from satellites could be gathered, in collaboration with Amazon Ground Station. He also investigated potential data management and data parsing processes to extract the necessary information from the massive streams of data that NOAA satellites constantly transmit. Dr. Colvin documented his process for scrubbing raw data from NOAA satellites and automating the cleaning of that data from Level 0 to Level 1 for use in Natural Burn Rate analyses and visualizations, in order to better track damage from wildfires. NOAA satellites transmit myriad streams of sensor data, which could be similarly scrubbed, organized, and cleaned to be used for other real-time analyses and visualizations.

The team searched for partners to work with on this topic in the small- and medium-business community. But, like with Task 8.8 Teensy, Cal Poly had difficulty finding partner organizations who were willing to share their intellectual property and collaborate. CCI also reached out to various California government agencies, most notably the California Office of Emergency Services (CalOES) and CalFire to potentially partner on the wildfire project.

While CalOES and CalFire showed interest and support, these groups did not have the necessary bandwidth or resources for experimental or novel solutions to recognized problems. So, they too were reluctant to join officially as partners in this challenge. Without identified partners, CCI and the DxHub could not identify the specific use-case scenario that the challenge process would focus upon for Cloud-based Space Data Processing and Analysis. After Cal Poly signed the EPA with Vandenberg SFB (VSFB) and after "accelerate time to launch" was identified as a priority for the base leadership, work on this project shifted to the Digital Twin concept. As a long-term solution, Digital Twin built on the foundational work of both Task 8.6 Weather and Task 8.7 TurboLaunch. The efforts in Task 8.6 to upskill the Vandenberg staff and leadership about the potential for hybrid cloud computing was an essential piece that allowed this task to progress. Similarly, the data collection and process analysis of the launch procedures at Vandenberg SFB that took part in Task 8.6, provided insights essential to pursuing Digital Twin. Therefore, the team purposefully staggered this task after those previous two.

Martin Minnich, Kurt Colvin, and Nick Osterbur (the lead on this task) met multiple times through October 2020 with key members of the Vandenberg team. In the AWS working backwards process, this grouping has

completed the solutions workshop and began the process of finalizing a rough draft of the PR/FAQ. During the solutions workshop, the Cal Poly Team and Vandenberg SFB staff made the determination to pursue two separate tracks for a short-term solution (Task 8.7) and this long-term track (Digital Twin). Through December and January Osterbur and Colvin met sporadically with Steve Rogers and his team at VSFB to refine the PR/FAQs and coordinated efforts to draft the 5-questions document which is an important piece of the DxHub's phased model. This document answers the questions: Who is the Client?, What is the opportunity? Is the key benefit clear? How do we know? And, What does the customer experience look like?). This step provides ample opportunity for a deep dive into the problem and multiple means of compiling potential solutions.

Throughout the winter and early spring, coordination with base leadership slowed, due to a service-wide reorganization of the Space Force launched in December 2020. The order required the reorganization of the wing/group categories at Vandenberg SFB and has meant the removal of a middle level in the bureaucratic hierarchy, disrupting the time and ability for key partners at VSFB to complete work with the Cal Poly team. CCI's key working partner at VSFB (Steve Rogers and his office), however, were higher in authority after the restructuring, which then helped to limit decision-making delays moving forward.

Initial prototyping of a solution began in earnest during this slowdown and the Cal Poly team added Cal Poly student assistants to the work. At a March meeting with Kurt Colvin, Martin Minnich, and Nick Osterbur from CCI/DxHub and Steve Rogers and Tom Stevens from VSFB, the 5-questions document were updated and finalized. Col. Joe Tringe, Lead of the Nondestructive Evaluation Group at

Lawrence Livermore National Laboratory has also become interested in the digital engineering problem set with the Digital Twin project and is interested in collaborating to bring the prototype to life. In April, CCI and the DxHub focused on collecting research on other digital engineering projects (rapid engineering using computer-generated integration for design, build, test) already being developed within the Department of Defense. The goal was to better understand parallels with existing programs in the Air Force, for example, as CCI and the DxHub promote digital engineering at Vandenberg SFB and within the Space Force. This research process is also designed to find the most viable, focused use case for which to provide some kind of ultimate prototype.

During May, with Cal Poly's support Steve Rogers began working with RGNext (https://www.rgnext.com/) to bring them into the design and decision process to help determine a specific customer use case for the launch process with the Digital Twin. Finding a specific, discrete customer problem to be solved is a key part of the challenge process, which can then be modelled to function at scale. RGNext is a joint venture between Raytheon and General Dynamics Information Technology that works as the key private sector contractor at Vandenberg.

Following a no-cost extension granted at the end of June, CCI and the DxHub continued to collaborate with both Steve Rogers and RGNext in order to find a proper use-case for the Digital Twin concept. By the end of August, Kurt Colvin, Nick Osterbur, and Marty Minnich decided in collaboration with Anthony LoGrande (VSFB) and Nick Perlson (RGNext) to focus on a telemetry antenna integration project for this task. In September, Colvin completed the task by submitting the final PRFAQ for the antenna integration project.

The PRFAQ for this challenge did not go through the full Vandenberg SFB public affairs office review, nor was a full prototype for the antenna integration project created because—after consulting with Vandenberg SFB and RGNext on the opportunities created by digital engineering and digital twinning—it became evident that a transformative project of this magnitude would need approval from the leadership at Cape Canaveral SFB. Moving forward, representatives from Cal Poly and AWS will be meeting with personnel and leadership at Cape Canaveral SFB, as well as existing contacts at Vandenberg SFB, to continue the discussion of a commercial cloud computing initiative for the Space Force.

More important than the specific deliverables for this task, the Digital Twin challenge is driving government awareness about the possibilities of digital engineering in the space sector. Discussions between Vandenberg SFB and Cal Poly are driving government understanding of this important new technology; leading the discussions and helping base leadership with landscaping to determine the best path forward add value. The broad outcome of this task will ultimately be to raise awareness of the possibilities offered by these revolutionary technologies—in digital engineering and modelling in this particular instance—so that the government becomes fully educated on the topic and can make informed decisions moving forward when it comes to harnessing the ongoing digital transformation of space and cybersecurity.

This is exactly how the Challenge Process is supposed to work. By fostering deep discussions about problems the client (Vandenberg SFB) faces, the Cal Poly team could then educate both the technical staff and leadership about potential, cutting-edge solutions (digital engineering and digital

twinning in this case). Vandenberg SFB and Cape Canaveral SFB are now further studying the potential for digital engineering on the antenna case and the broader usefulness of cloud computing across processes utilized by both the Western and Eastern Ranges. As the Cal Poly team has shown in this challenge, cloud computing and digital engineering have the potential to provide significant efficiency boosts and cost reductions for planning and processes across the Space Force.

Lessons Learned

✓ Private companies, including small and medium businesses can be reticent to work with public research institutes on innovative technology out of concerns that their innovations and intellectual property might be at risk in the collaboration. When potential partners have been government agencies (like CalOES or CalFire) there has been interest and support, but given that these groups have limited bandwidth or resources for experimental or novel solutions to recognized problems, they too have been reluctant to join officially as partners in these challenges.

✓ Work on this project could only fully commence after the signing of the Educational Partnership Agreement between Cal Poly and Vandenberg SFB, showing how important institutionalizing these relationships is. Now that Cal Poly has that EPA, the university and the DxHub can continue collaborate with Vandenberg, creating a much more sustainable relationship thanks to the groundwork forged during this grant.

✓ The Tasks in this grant related to Vandenberg AFB build on one-another. Like Task 8.7, Task 8.9 relied on the upskilling and teaching about hybrid cloud technologies that was central to Task 8.6. Information gathered about launch protocols and customer experiences in Task 8.7 inform the problem framing and prototyping exercises in this task. This cumulative and multiplicative effect are further evidence of the ways that this grant is creating a sustainable and fruitful relationship between Cal Poly, AWS, and Vandenberg SFB. In future grant applications, CCI will need to better schedule this staging of challenges to provide more time for some tasks to grow before others are begun.

✓ Work with Vandenberg SFB often slowed as decisions made their way up the chain of command of this complex bureaucracy. The reorganization of the Air Force Base as a Space Force Base, also created some delays. The success of this project shows that the challenge process and working backwards process can be successful within the DoD culture and with large-scale clients in general.

✓ Due to the delays caused by leadership changes and other bureaucratic complexities at Vandenberg SFB, CCI should have built more time into the original grant application to be able to successfully navigate complex hierarchical structures and bureaucracies in the federal government, as well as provide a time cushion for unexpected coordination restarts due to job turnover in those bureaucracies.

✓ This engagement proves the important role that Cal Poly as a public academic institution (with deep expertise in both research and teaching) can play as an intermediary and translator in the relationship between government entities and private industry, specifically in this case by educating the military about the efficient and cutting-edge techniques for graphical user interfaces and prototyping software that are already part of academia and business, to improve both efficiency and outcomes.

Task 8.10: Digital Transformation Hub Challenge: Education Opportunities for Space and Cybersecurity

Summary

The objective of this task is to study the educational needs of Californians and Cal Poly, and to propose innovative solutions to provide California's students with courses and curriculum in education so that they will have the knowledge and skills to succeed in the overlapping fields of Space and Cybersecurity, whether they go on to careers in government, private industry, or academia.

The funded work that CCI has completed in this task is overwhelmingly focused on curriculum at the post-secondary level. However, CCI has come to recognize that educational interventions need to come early in students' lives. By the time many students matriculate into a four-year university they have already decided their basic career path; Cal Poly goes as far as requiring students to apply for admission to a specific college and major, and changing majors or colleges can be very difficult. Therefore, CCI is also reporting some of its ongoing efforts to get K-12 students interested in STEM education with a focus on space, cybersecurity, and the areas where these two topics overlap. No federal funds supported these K-12 efforts, but they are being reported here as an important focus for CCI's efforts on education.

While the AWS challenge model is well suited for engaging with "customers" outside of higher education and even individual units within the university, CCI has found that the challenge model is not well suited to engage with larger, interdisciplinary teams of university faculty. Faculty require greater flexibility and closely guard their control over curriculum and curriculum development. The challenge model therefore is being loosened for this task.

Work Completed

Post-Secondary Educational Initiatives

The CCI and Cal Poly are at the forefront of the emerging field of Space and Cybersecurity, thanks in part to this CASCADE II grant. Working within an undergraduate and master's granting university, however, has made it abundantly clear that for college and post-graduate students, individual universities across the state and across the country set the curriculum and program requirements individually. Given the relatively long time-horizons for university administration decision making, doctrines of shared governance between administration and faculty, and drawn-out curriculum processes, the reality is that for colleges and universities, curricular changes take years to take effect. With these long time-horizons for developing and implementing curricular changes, the "challenge" model originally proposed as part of this project is not fully applicable.

Nonetheless, in order to study and understand the needs for curricular innovation in Space and Cybersecurity, CCI has been given program oversight over two Cal Poly-funded projects focused on education in four-year institutions. Both of these projects

are part of the university's Tech Workforce Strategic Research Initiative (SRI). This SRI is broken up into two constituent programs: Revolutionizing the Tech Workforce (RTW) and Transforming Access to Cybersecurity in California (TrACC). TRW is primarily focused on assessing workforce needs as both a current snapshot and in a manner to allow for ongoing longitudinal analyses of trends in hiring of graduates into cybersecurity fields. This assessment of workforce needs will help inform the curriculum design process moving forward, ensuring that Cal Poly students are trained in the skills future employers (including the defense sector) need and require. TrACC focused on promoting and experimenting with a cross-disciplinary educational model that teaches traditional technical cybersecurity skills and combines them with professional development and exposure to public policy. This educational model is novel, in part, because it should provide students with direct, hands-on exposure to research and problem solving at the intersection of cybersecurity and public policy.

Cal Poly's office for Research, Economic Development, and Graduate Education has awarded $150,000 as "seed funding" for these two overlapping projects, in part to lay the groundwork for future efforts. The university's goals for the RTW and TrACC projects are to create an educated and technologically advanced workforce, well versed in developments and solutions to problems regarding cybersecurity. Both projects are attempts to survey new and emerging problems related to cybersecurity and revise and revamp the curriculum and programs the university offers to educate the workforce of tomorrow. As seen in the 2020 SolarWind's cyberattack, the 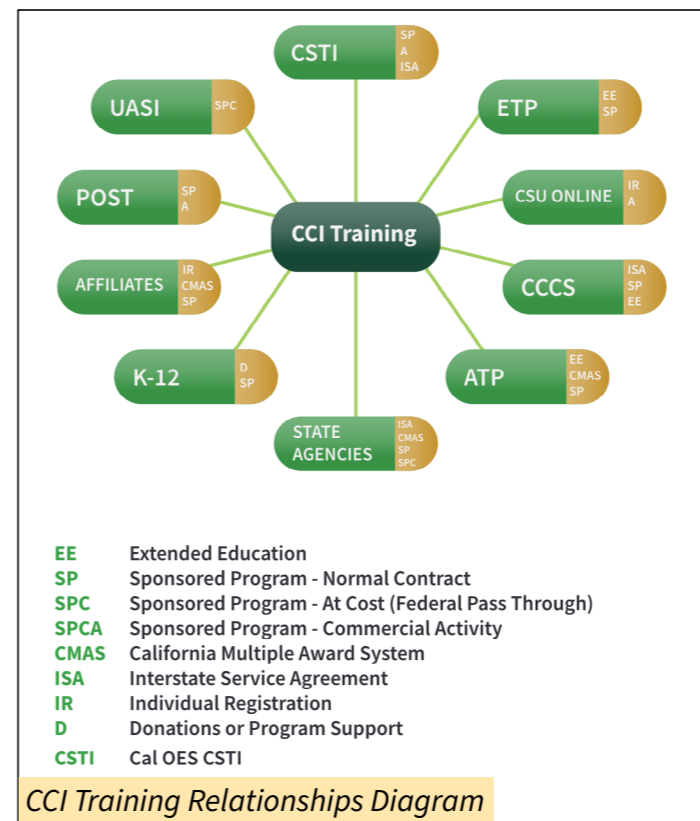U.S. government remains vulnerable to breaches by foreign adversaries. CCI's expectation is that a portion of the students trained through these developing educational programs—in both STEM degrees and policy applications—will work in the defense industry or with the U.S. government either as private contractors or in the uniformed services. Broadly speaking, having a well-trained and knowledgeable group of college graduates will provide the DoD and other government agencies with the contractors, policy analysts, and war fighters they need and will need in the 21st century.

In terms of deliverables produced by these two initiatives, paid for by Cal Poly but being coordinated with CCI, RTW has produced two grant applications for futher support: 1) a Public Interest Technology University Network Challenge Grant, submitted in Summer 2020; and a National Science Foundation (NSF) Future of Work at the Human-Technology Frontier Planning Grant, submitted in winter quarter 2021 focused on assessing the profession of ethical technology for the future of tech work. TrACC has produced a single grant application to the National Science Foundation (NSF) Innovations in Graduate Education Grant, "Integrated Training Education and Research for Cybersecurity Evolution through Policy and Technology (InTERCEPT)," submitted in Fall 2020. This grant is focused on creating a Master's degree program that combines hands-on technical education in cybersecurity with professional development and exposure to public policy in an innovative cross-disciplinary environment.

In addition, Dr. Bruce DeBruhl (Associate Professor in Computer Science and Software Engineering) has been working to have Cal Poly be designated a National Center of Academic Excellence in Cybersecurity, with a focus on Cybersecurity operations. This program is managed by the National Cryptological School of the National Security Agency. Dr. DeBruhl's efforts have included mapping out the entire course content for new cybersecurity focused degrees and determining the university's future needs to adjust to changing career paths for students. Dr. DeBruhl, who is also a member of the team working on TrACC, has completed the submission for this initiative which is being reviewed by the university president and provost (the two highest administrative officials at Cal Poly). CCI has acted in a supporting role for this internal Cal Poly initiative, aiding Dr. DeBruhl in his efforts when possible, advocating for the initiative, and injecting space-related content and opportunities as necessary.

In February 2021, working together with Cal Poly's division of Research, Economic Development and Graduate Education, CCI and the DxHub have drafted a business plan to found a Space and Cyber Institute at Cal Poly.

CCI Training Relationships Diagram

EE	Extended Education
SP	Sponsored Program - Normal Contract
SPC	Sponsored Program - At Cost (Federal Pass Through)
SPCA	Sponsored Program - Commercial Activity
CMAS	California Multiple Award System
ISA	Interstate Service Agreement
IR	Individual Registration
D	Donations or Program Support
CSTI	Cal OES CSTI

The purpose of the new institute is to fill the critical demand for highly skilled cyber experts in the space industry. Additionally, students and faculty from Business, Engineering, Liberal Arts, Science and Math, Agriculture, and Architecture will work together along with industry and government to solve key challenges regarding the development of a secure space economy.

In addition, given the long time-horizons it takes to shape curriculum and massive,

CCI Funded Research and Training Pamphlet

bureaucratic institutions like Cal Poly to shift to new and emerging workforce needs, CCI has been working to grow its profile within the university administration, among students, and within the faculty. In part, this has been done by showing the money and resources that CCI has brought to the University. The two largest grants that CCI has brought into the University thus far are two DoD grants run through the California Office of Planning and Research, including this CASCADE II grant.

Winning the grant and bringing in faculty to work with CCI through all of these tasks breeds more success and good will within the university community. Similarly, the training relationships that CCI has grown with ETP and other California-based institutions over the

course of this grant provides further evidence of CCI's impact on the California economy, again proving the CCI's worth to the faculty, staff, and administration of the university. The success of CASCADE and the drive for public private partnerships allowed the CCI to become a grant engine and workforce development bridge for the University. While it may seem odd to report winning a grant as part of the work within that very same grant, this is how the momentum and psyche of university community's work. Faculty are more likely to work with a center or institute if that center or institute has a track record of raising funds. Just by getting a grant of this magnitude, CCI raised its profile on campus and improved its attractiveness as a partner on campus. There is an important feedback loop between getting grant support and attracting faculty interest in order to pursue new grants and new initiatives.

Perhaps most importantly, in March 2021 the Hewlett Foundation has granted Cal Poly $150,000 to hire an advancement and development officer specifically devoted to building the CCI's endowment, with the goal of raising $50 million total. Hewlett has pledged an additional $450,000 to fund a subsequent three years for that fundraising position. CCI is the first center or institute on campus to have its own endowment officer, a major win for the ability of CCI to continue to shape and promote the development of cybersecurity and space programs on campus and throughout California. It is precisely by possessing a large endowment that research institutes survive year after year on university campuses and have the largesse and influence to promote the long-term change in curriculum on which this CASCADE II grant is focused. The CCI has also been included in the university's 2030 fundraising campaign. CASCADE II directly impacted the willingness

of Hewlett to fund this initiative. CCI's success with CASCADE II was also part of the university administration's decision to make an exception and allow an institute or center to self-fund an advancement officer and incorporate that effort into the university's capitol fundraising campaign.

Moreover, there is a symbiotic effect at work here: while Hewlett had been invested in small ways in CCI already it was because of the CCI's success at winning and implementing this CASCADE II grant that Hewlett was willing to make a much larger investment into CCI and the causes of cybersecurity and space at Cal Poly. Without the CASCADE II grant, Hewlett may well have not supported CCI's request for a development officer; without this development officer, CCI would not be able to build the kind of stable and resource abundant research institute needed to transform the curriculum and educational culture at Cal Poly to value and support cybersecurity and space programs.

It is difficult to overemphasize how transformative this support from the Hewlett Foundation and university development office is for CCI and the sustainability of its efforts to shape curriculum and research over the long term. Although no CASCADE II funds were utilized in the effort to build this outcome, without this CASCADE II grant to show the CCI's maturing capabilities it would not have happened.

K-12 Educational Initiatives

Although not directly part of the scope of this CASCADE II grant (and not utilizing any CASCADE funds), CCI continues to engage with educational activities for shaping secondary education, because K-12 education is the key feeder for higher education. Over the course of this grant, CCI continued to work

to expose middle school and high school students to the possibility of combining interests in computing and cybersecurity with applications in space.

In order to increase the visibility of efforts to introduce younger students to the possibilities of combining interests in space and satellite technology with cybersecurity, CCI staff worked throughout July 2020 to prepare for its virtual presence at the Aerospace Village at that year's DefCon—an annual conference for amateur and professional hackers held virtually in August. For a teaser trailer of CCI's efforts, see: https://www.youtube.com/watch?v=NGRVrURPeJU.

From August 5-8 at DefCon, CCI successfully launched Project Allenium—a cyber challenge designed for K-12 age students, comprised of a multi-layered cybercrime plot written by student employees from Cal Poly, complete with complex characters, physical and digital evidence chains, and puzzles that challenge participants are required to search through and analyze to solve a satellite hacking crime. Although the total number of users was not high, engagement and enthusiasm from those individuals who did participate was significant. Notably, some hackers played through the scenarios with their own children.

Project Allenium virtual room

Most importantly, offering Project Allenium at DefCon increased awareness of CCI's work at the nexus of cyber and space.

Project Allenium simultaneously allowed CCI to testing the platform for later use as part of the annual California Cyber Innovation Challenge (CCIC), which Cal Poly was scheduled to host in October 2020. Defcon provided a beta test which exposed a few small glitches, which could then be addressed. Beyond small fixes the DefCon experience highlighted the need for enhanced briefings for participants on the backstory so they have a better idea of what is expected of them and why they are involved. The beta test also showed that user experience varied widely, so the CCI team created two versions of the challenge for different experience levels.

Building off the lessons learned at DefCon to improve its product, CCI used Project Allenium as the basis to pursue a space and cyber theme for the October 2-4, 2020, California Cyber Innovation Challenge (CCIC), conducted virtually. CCIC is an annual event that has been hosted by CCI since 2017. The CCIC is a statewide high school cybersecurity competition designed to introduce more students to cybersecurity as a future course of study and career. CIC is open to all California high and middle schools. The event features teams competing in two divisions selected from the regional qualifying rounds and an "At-Large" application process. The first division is for more experienced clubs and the second division is for middle schools and other teams that are newer to this type of exercise. CCI provides online training materials for both students and their educator coaches (see, https://cci.calpoly.edu/events/ccic-2020/ccic-2020-training).

For the October 2020 competition CCI created an immersive virtual environment in which a satellite crashes to the Earth, leaving amateur cybersleuths to determine how the crash occurred, who caused it and why. In total over 400 middle and high school students

on 78 teams competed in two divisions. Students began the competition by working on Amazon Web Services 3D Sumerian and Discord platforms to collect evidence and solve the cyber satellite crime. Challenge teams, coaches, event sponsors and event staff communicated via Discord, a voice and text chat app for groups of gamers. During the challenge, CCIC organizers conducted activities, information booths and cyber


Project Allenium virtual room

related puzzles that students could participate in via Discord and social media. Once the first phase of the challenge was completed on Oct. 3, the CCIC team selected the top five teams from each division to advance to the next round. Those 10 teams on Oct. 4 presented their evidence and solutions to a panel of judges, who evaluated each group's efforts to solving the cyber-crime. Judges included academics, military and government officials, students, security researchers, cybersecurity professionals, representatives from the U.S. Department of Commerce's National Institute of Standards and Technology laboratory, private industry and a DEF CON Goon, one of the staff of that annual hacking convention.

The event featured welcoming remarks on Oct. 2 from Vint Cerf, one of "the fathers of the internet," and Jeff Moss, founder of DEF CON, the world's largest, longest continuously run underground hacking conference, and Black Hat, which has evolved from a single event in Las Vegas, Nevada, to the most respected international information security event series. Former NASA CIO Renee Wynn served as one of the judges for the competition and

gave the closing remarks. For further details on the event see: https://cci.calpoly.edu events/ccic/2020/home.
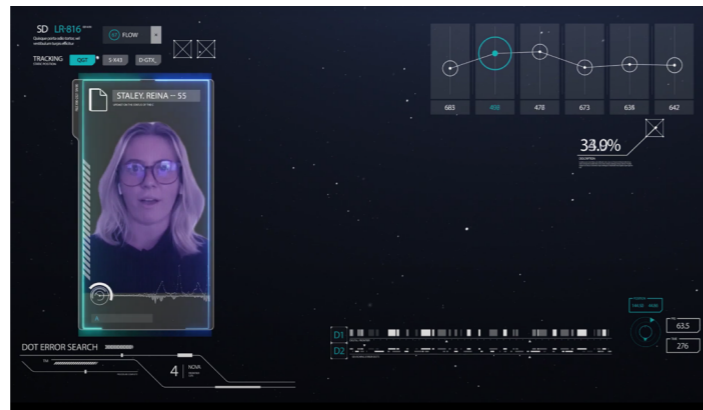
CCIC Teaser Trailer

An important off-shoot of the CCIC competition is CCI's Cyber to Schools Program which partners with the tech industry to provide mentors and coaches for schools planning to compete in the CCIC competition. CCI is currently working with CISCO, Siemens, NVIDIA, Fortinet, Amazon AWS, Splunk, and Palo Alto Networks (the world's largest cybersecurity firm shaping the cloud-centric future) to pair cyber professionals with middle and high school students looking to learn more about opportunities in cyber.

In March 2021, CCI has also made important strides in having its Cyber to Schools program sponsored by the K-12 STEM programs fostered by Vandenberg SFB and the Space and Missile Command (SMC) in Los Angeles. These STEM programs are funded by the Department of Defense "for the purpose of improving the mathematics and scientific knowledge and skills of elementary and secondary school

Bree Zedar, CCIC Student Project Lead

students and faculty members." These endorsements and agreements between Cal Poly and Vandenberg AFB and SMC (see Task 8.2 for details) will provide much greater reach and institutional legitimacy to CCI's Cyber to Schools program, acting as a force multiplier for the CCIs programs to increase awareness of space and cyber educational and vocational opportunities to today's primary and secondary education students with an eye toward front loading the workforce pipeline toward those areas.

Although no CASCADE II funding is being utilized for these activities, the connection between this CASCADE II grant and these new MOUs regarding STEM education is irrefutable. It is only through CASCADE II that CCI has been able to increase its profile within the Western Range and Space Force and gain the respect of commanders and administrators at SMC and Vandenberg AFB. If the leadership at these two bases had not seen CCI's capabilities, these opportunities to shape hundreds (if not thousands) of students lives would not have happened.

In March 2021, CCI finalized a program with the Kansas City public schools—leveraged through CCI's connections to Siemens—to offer free summer school training in cybersecurity and digital literacy to middle and high school students. (See Success Stories for more detail.) This opportunity was presented to CCI by Siemens who had existing connections and collaborations with the Black Chamber of Commerce in Kansas City, who then pitched the idea to the Kansas City school district. This opportunity with the Kansas City schools and the Black Chamber of Commerce provides an excellent opportunity to create a large-scale pilot program, receive feedback from both students and teachers, provide metrics for assessment, and run the programs through an entire cycle. The ultimate goal is to take lessons learned from

implementing the program in Kansas City's minority-serving school district, improve on the summer program, and then offer it to high schools throughout California. While the project falls outside of OPR's geographic area of interest, it was an opportunity that could not be passed up and will help to drive workforce development in the United States (an obvious interest for the Department of Defense).

Over June, July, and August the Cyber to Schools pilot program trained over 700 students. In September, the Cyber to Schools program began delivering training to about 35 middle and high school students from Kansas City, Missouri, and the Cherokee Nation, with another 70 students preparing to join up within the next few months. Several new schools in Lawndale, Bakersfield, Inglewood, and the Chumash tribe showed interested, as well, in signing up for Cyber to Schools programs, proving the potential for a wide impact on California's future workforce.

To develop and implement this program CCI has teamed with corporations like Verizon, community organizations like the Kansas City Black Chamber of Commerce, and local and tribal governments like the Cherokee Nation—an exceptional example of Cal Poly and CCI's abilities to leverage public-private partnerships to bring real world results. Three students who completed the pilot program this past summer have already been hired on year-long internships in tech-related positions that will help launch digital transformation clubs and relevant training opportunities for other student in the community.

Again, no CASCADE funds have been used in these K-12 initiatives, but the impact of early intervention for workforce development is a clear lesson from CCI's position at the nexus of these public-private educational programs.

Lessons Learned

✓ While the AWS challenge model is well suited for engaging with "customers" outside of higher education and even individual units within the University, CCI has found that it is not well suited to engage with larger, interdisciplinary teams of university faculty. Faculty require greater flexibility and closely guard their control over curriculum and curriculum development.

✓ Changes in curriculum and teaching take a very long time—at least two-years to create a new course and over five or ten years when the curricular or institutional changes are more dynamic—and so building momentum and creating sustainability of effort are essential to success. Developing and nurturing relationships with individual faculty members is an essential part of fostering that sustainability of effort.

✓ Students choose subject areas for study before getting to college or university campuses. Career choices can also be made very early. Therefore, it is essential to expand efforts to include the K-12 age group to groom students for later success. In order to have students studying space and cybersecurity in college, you not only need to have the relevant coursework at the post-secondary level, you also need to expose those students to the topic before they are college aged.

✓ Education and workforce development are inextricably linked. There is no useful means of separating them.

Task 8.11: Complete Digital Transformation Hub Challenge: Workforce Development Space and Cybersecurity

Summary

As CCI has become ensconced in the space and cybersecurity eco-system it became clear that a single "challenge" process would not apply well for workforce development; there were too many potential clients, and each would need a tailored approach to solve their problems.

Rather, CCI has approached workforce development through three different streams:

» data literacy and cybersecurity education for employees of regional companies involved in the commercialization of space;

» career events and career advice for higher education students contemplating opportunities and paths for future jobs at the nexus of space and cybersecurity; and

» outreach to industry leaders and decision-makers in the emerging field of cybersecurity as it applies to space.

Work Completed

Data Literacy and Cybersecurity Education Programs

Regarding the data literacy and cybersecurity education programs, CCI worked throughout 2020 and into spring 2021 to recruit small- and medium-sized businesses on the Central Coast for workforce development courses related to data literacy and cybersecurity. In total, CCI signed six training agreements through the ETP system:

- In Summer 2020, CCI finalized and signed a training agreement with Trust Automation (a San Luis Obispo-based company that designs, builds, and supports control and power management systems) to provide their 113 employees with 32 hours of digital literacy and cybersecurity training.

- Following meetings with Marty Minnich, Ron McFarland (CMTC), Charles Buthe

(CMTC), and Roland Coelho (CEO Maverick Space), Maverick Space signed a training agreement in October 2020 so that Maverick Space will be able to obtain DFARS and NIST certifications for DoD compliance. Maverick Space Systems is a new California-based space technology company working in the small satellite market, with seven employees.

- In Fall 2020, CCI signed a training agreement with Digital West, similar to its agreement with Trust Automation. This agreement had to be scrapped after Digital West was acquired by Wave Broadband—a division of Astound Broadband, the sixth largest cable operator in the United States. Because of limitations on workforce size, Digital West no longer qualifies as an ETP client.

- In Winter 2021, CCI negotiated an agreement with Clever Ducks to provide digital literacy and cybersecurity training to their employees, through ETP. Clever

Ducks is a San Luis Obispo-based IT management and consulting firm focused on cloud computing solutions, back-up and disaster recovery, IT planning and budgeting, and IT security.
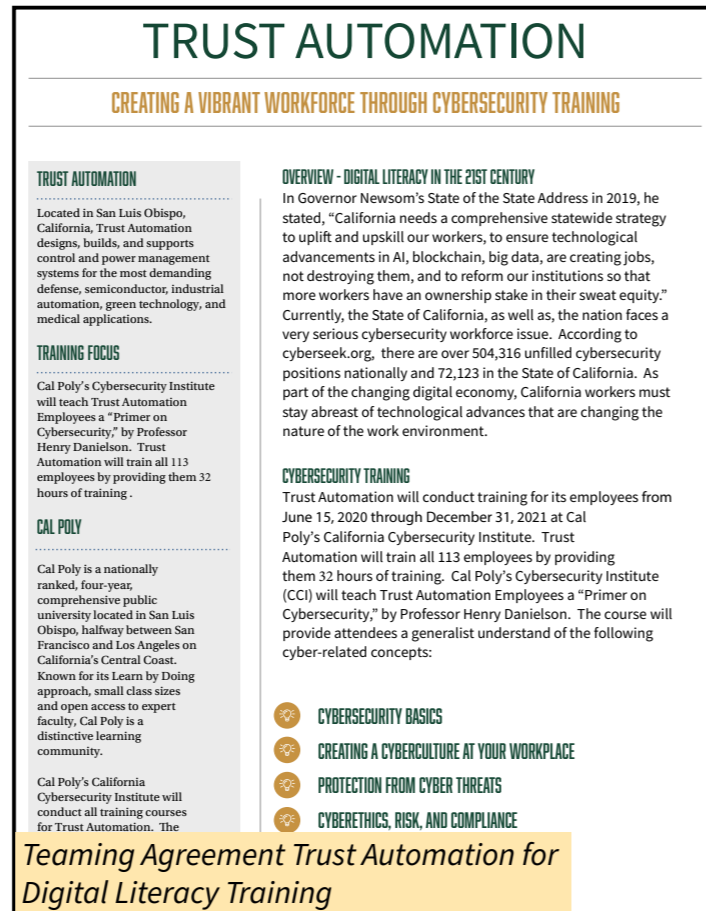
- In February 2021, CCI negotiated an agreement with CIO Solutions to provide a similar package of digital literacy and cybersecurity training to their employees, through ETP. CIO Solutions has been providing the Central Coast of California with business technology consulting and network management services since 1986, emphasizing premium all-inclusive network management and support, private cloud computing, virtualization solutions, and enterprise storage design.

- In Winter 2021, CCI also negotiated an agreement with Revamp IT to provide digital literacy and cybersecurity training to their employees, through ETP. Revamp IT is an IT consulting and management firm that works in San Luis Obispo and Santa Barbara Counties to help local businesses reach the next level by leveraging cutting edge technology, including DevOps, Cloud Native, Public Cloud, Containers & Microservices, SD-WAN, Cyber Security, and Digital Transformation.

Throughout Summer and Fall 2021, CCI technical advisor and course instructor, Henry Danielson worked to create the content that would fulfill the needs of largest and earliest client for workforce training: Trust Automation. Modules for the course, totaling 10 hours of training focus on the following key topics:

1. Basic Cybersecurity Principals, CIA Triad, Vocabulary, and Passwords;

2. Creating a Culture at your Business on Cybersecurity Best Practices;

3. Protecting Yourself from Cyber Threats;

4. Ethics, Risk, Compliance, and Cybersecurity;

5. Mobile Devices and Basic Cybersecurity Tools; and

6. Social Engineering and Defense Techniques for any Cyber Scam

Designing the curriculum, based on Dr. Danielson's previous experience and his

TRUST AUTOMATION

CREATING A VIBRANT WORKFORCE THROUGH CYBERSECURITY TRAINING

TRUST AUTOMATION

Located in San Luis Obispo, California, Trust Automation designs, builds, and supports control and power management systems for the most demanding defense, semiconductor, industrial automation, green technology, and medical applications.

TRAINING FOCUS

Cal Poly's Cybersecurity Institute will teach Trust Automation Employees a "Primer on Cybersecurity," by Professor Henry Danielson. Trust Automation will train all 113 employees by providing them 32 hours of training .

CAL POLY

Cal Poly is a nationally ranked, four-year, comprehensive public university located in San Luis Obispo, halfway between San Francisco and Los Angeles on California's Central Coast. Known for its Learn by Doing approach, small class sizes and open access to expert faculty, Cal Poly is a distinctive learning community.

Cal Poly's California Cybersecurity Institute will conduct all training courses for Trust Automation. The

OVERVIEW - DIGITAL LITERACY IN THE 21ST CENTURY

In Governor Newsom's State of the State Address in 2019, he stated, "California needs a comprehensive statewide strategy to uplift and upskill our workers, to ensure technological advancements in AI, blockchain, big data, are creating jobs, not destroying them, and to reform our institutions so that more workers have an ownership stake in their sweat equity." Currently, the State of California, as well as, the nation faces a very serious cybersecurity workforce issue. According to cyberseek.org, there are over 504,316 unfilled cybersecurity positions nationally and 72,123 in the State of California. As part of the changing digital economy, California workers must stay abreast of technological advances that are changing the nature of the work environment.

CYBERSECURITY TRAINING

Trust Automation will conduct training for its employees from June 15, 2020 through December 31, 2021 at Cal Poly's California Cybersecurity Institute. Trust Automation will train all 113 employees by providing them 32 hours of training. Cal Poly's Cybersecurity Institute (CCI) will teach Trust Automation Employees a "Primer on Cybersecurity," by Professor Henry Danielson. The course will provide attendees a generalist understand of the following cyber-related concepts:

- CYBERSECURITY BASICS
- CREATING A CYBERCULTURE AT YOUR WORKPLACE
- PROTECTION FROM CYBER THREATS
- CYBERETHICS, RISK, AND COMPLIANCE

Teaming Agreement Trust Automation for Digital Literacy Training

credentials (see Appendix 1: Biographies of Key Individuals Mentioned Throughout the Report) was relatively straightforward with 8 of 10 hours of content created over the summer of 2020. Delivering a training course during a pandemic, however, added significant complications. CCI team members Danielson, Danielle Borrelli, and Ryan Vannucci made a site visit to Trust Automation during the summer of 2020 to test their recording equipment and broadcasting capabilities for the modules. The first of four training modules was delivered to employees in September, but then procedures had to

be reevaluated after San Luis Obispo County entered the Purple Tier in California's Covid 19 tracking system in the late Fall of 2020. A break in training took place over the holidays, and it was only in May 2021 that training could resume with Trust Automation employees, by which time all 10 hours of training materials had been created.

Recruitment of new clients slowed in the spring of 2021, with CCI focusing instead on fulfilling the five active training agreements already signed. This included creating assessment materials (like a student evaluation survey) to be distributed after teaching was complete.

Following a no-cost extension granted in June, Maverick Space completed their sixth and final employee training module, led by Henry Danielson. During July ETP documentation was prepared to close the course. In mid-August, Maverick Space's employees returned their evaluation survey's providing feedback to CCI on the program. These self-evaluations provided clear evidence that students improved their knowledge of cybersecurity, that they would recommend the trainings to other businesses, and that there were either likely or very likely to use the information they learned in the course.

In August, Henry Danielson also provided 4 hours of digital literacy training to 17 employees of Omni Metal Finishing (omnimetal.com), located in Fountain Valley, CA. Omni is a leading international supplier of engineered metal finishing to Aerospace, Defense, Space, Armament, Electronics and Industrial markets, and the company partners with leading Aerospace companies in new surface development programs. This training arrangement was facilitated by El Camino College, providing clear evidence of

the importance of the collaborations fostered by the CASCADE II network.

In terms of efforts to promote workforce development outside of California's Central Coast, CCI and Cal Poly partnered with California State University Fresno on a U.S. Department of Labor Youth Apprenticeship Readiness Grant Program application. The grant is designed to address the shortage of cybersecurity professional in critical workforce sectors like healthcare and civil service through both training, certification, and registered apprenticeships. This is a comprehensive and statewide strategy—aimed at students and young workers between the ages of 16 and 24—to expand access to careers in cybersecurity to all of California, irrespective of geographic region or demographic breakdown. If the grant is funded, CCI committed to aiding in establishing cyber apprenticeships with educator/employer partners, to seek small and medium businesses to develop and expand apprenticeships, and to provide related technical instruction as needed for employer partners. These proposed activities have a clear synergistic and amplifying effect on the partnerships and training opportunities formed in the space sector with government agencies and private companies through this CASCADE grant.

Journeys Map Website

## Career Events and Career Advice for Higher Education Students

Regarding career events and career advice for higher education students contemplating opportunities and paths for future jobs at the nexus of space and cybersecurity, CCI signed a services agreement and Letter of Intent in August 2020 for sponsored projects with Journey's Map, Inc. Journey's Map software provides an interactive learning map designed to engage users in exploring life's possibilities and providing personalized directions while navigating life's major educational and professional transitions. Cal Poly and Journey's Map are teaming to create a first of its kind interactive learning map so that Californians can plan for the jobs of the future at the nexus of space and cybersecurity. Specifically, CCI and Cal Poly have been and will continue to advise Journey's Map on the educational steps (college courses), trainings, and certifications that individuals interested in space and cybersecurity need to attain jobs and find success.
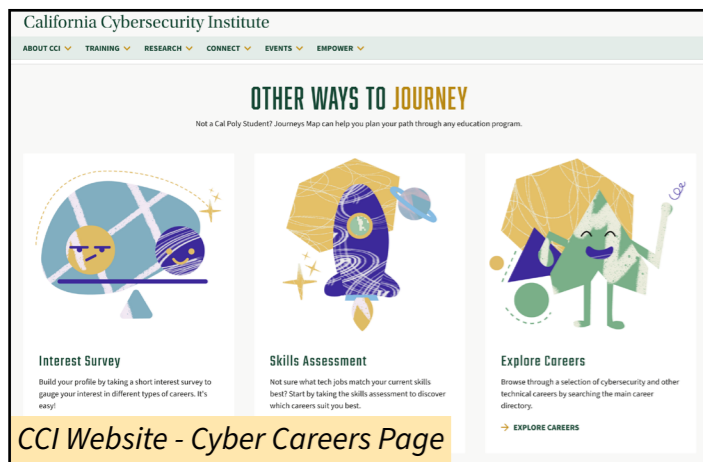
CCI Website - Cyber Careers Page

To aid in this endeavor, CCI built an "Explore Cyber Careers" page to its website (https://cci.calpoly.edu/training/explore-cybersecurity-careers). The site includes general information, including links to access free and low-cost training resources so that individuals can sample cybersecurity concepts and topics and get ahead by building basic skills. In addition to general information, Cal Poly students and other interested individuals can access the Journey's Map application through this CCI webpage. That means that anyone
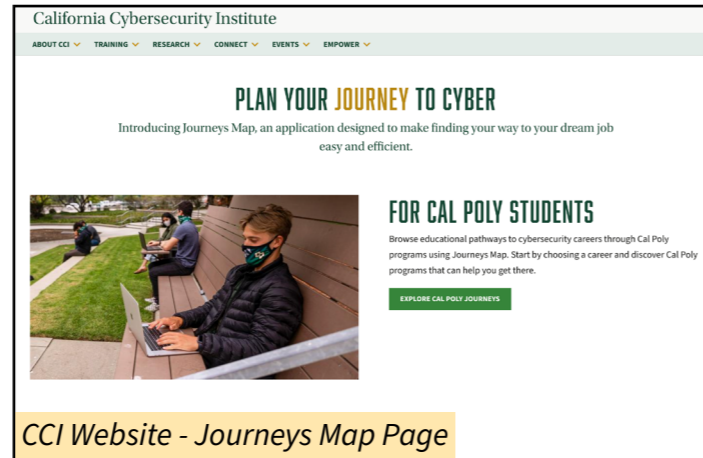

CCI Website - Journeys Map Page

with an internet connection can access interactive technology which asks a series of questions of students looking for career advice and individuals thinking of upskilling or changing careers. Based on those answers, users are then provided up-to-date advice on how to pursue the high-tech cybersecurity- and space-related careers of the future. CCI has been promoting the service on its social media accounts and through its Space and Cybersecurity Newsletter (see below for more details).

To increase outreach on workforce development for Cal Poly students, staff, and alumni specifically, CCI took part in a "State of Cybersecurity in 2020" event in October 2020, hosted by Cal Poly Career Services. The virtual event included comments from the lead for academic engagement of the NICE program at NIST, as well as a keynote from the vice president and managing partner for IBM's Global Security Services. A panel discussion included representatives from CrowdStrike, Cyber Chicks Consulting, BugCrowd, Cisco, and Splunk.

Outreach to Industry Leaders and Decision Makers

The final focus for this task was outreach to industry leaders and decision-makers in the emerging field of cybersecurity as it applies to space. As an early "win" in this endeavor CCI collaborated with Ninjio to get Ninjio to produce a first-of-its-kind cybersecurity and space video, highlighting how physical
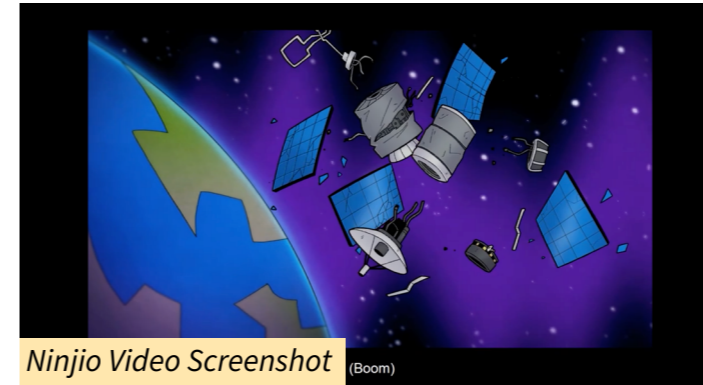
Ninjio Video Screenshot (Boom)

breaches could affect satellite operations and safety. Ninjio is a cyber security awareness training platform that uses engaging, 3-4- minute micro-learning "Hollywood storytelling episodes" to empower employees, executives, organizations and their families to become defenders against cyber security threats. Ninjio serves some of the largest companies in the world and has changed the behavior of hundreds of thousands of people through engaging, emotionally driven storytelling. To view the episode, see: https://web.microsoftstream.com/video/8403a232-e4b5-4238-af49-c12326b9b6f2.

Thanks to the success of the First Space and Cybersecurity Symposium held in October 2020 (Task 8.4), it was clear that there was interest among C-suite employees, program managers, and DoD contractors for more information on what was happening at the nexus of space and cybersecurity. To fill this need, CCI worked to create a beta version of a monthly newsletter designed to inform decision makers of news and developments regarding cybersecurity in space. This was designed to include actionable information from a different perspective, all tied into the work that Cal Poly and CCI was already doing. It was designed as an informational effort to keep California and national entities engaged with this rapidly developing field and aware of changing needs and structures for workforce training and development, among other topics. In order to create the prototype version, CCI recruited the following partners to select stories to highlight and to make editorial decisions:

- Cal Poly Faculty including John Bellardo, Patrick Lin (Professor, Philosophy Department), and Keith Abney (Lecturer, Philosophy Department);
- Cal Poly staff including Martin Minnich, Dustin Debrum (Manager, Application, Data, & Integration Services Operations, Cal Poly Information Technology Services), Henry Danielson, Ryan Vannucci, Nicole McCleaf (Information Technology Consultant, Cal Poly Information Technology Services), and Ryan Nugent (Cal Poly CubeSat Lab Co-Principal Investigator);

- R Street Resident Fellow on National Security and Cybersecurity Kathryn Waldron; and
- Eric Escobar, a Security Principal Consultant at Secureworks.

Sid Voorakarra, Senior Vice President at Strategies 360 agreed to serve as editor-in-chief.

After the beta version was created, CCI began publishing the Space and Cybersecurity Newsletter monthly, beginning in November 2021 (https://cci.calpoly.edu/connect/space-

Lessons Learned

✓ As a teaching university with deep research knowledge and a very positive reputation among industry professionals, Cal Poly—and by extension CCI—are well suited to provide information products like newsletters to industry leaders and decision makers.

✓ As a well-regarded four-year college in the CSU system, particularly regarding its engineering and aerospace programs, Cal Poly is well prepared to design and implement creative ways to get more students interested in careers at the nexus of space and cybersecurity.

✓ Based on the depth of knowledge and skill at Cal Poly, the university is well positioned to create innovative data literacy and cybersecurity programs for industry; as a well-regarded community partner and a trusted voice in the community, Cal Poly is also adept at gaining the trust of local employers to sign ETP agreements for training. Delivering that cybersecurity and data literacy training to the employees, however, has proven difficult, particularly during a pandemic. CCI is currently revising its policies and practices to ensure that trainings are planned in a single time frame, so that employees (and their managers) do not lose focus between learning modules.

Three-Year Roadmap for the Space Program in California

Outside of the scope of the CASCADE II Program, CCI define's its collective vision for the future as efforts designed to grow Cal Poly to be able to:

Establish the University as the nation's premier cybersecurity institute for research and applied training in cyber and space;

Develop and operate the state of California's official Cyber Training Range;

- Provide funding for faculty and fellowship positions within Cal Poly's colleges;
- Grow a slew of unclassified and classified research portfolios to establish a "Best of the West" designation for Universities for National Defense;
- Lead the State of California's efforts to grow the commercial space and cyber economy; and
- Lead a portion of the U.S. Space Force's Cybersecurity Research and Training Curriculum.

As a subset of those broad goals for CCI, the long-term impact of this CASCADE II grant comes primarily through the capacity building that has occurred and in the relationships that have been solidified over the course of this grant. For example, all of the efforts mentioned above in Task 8.10— both the development of curriculum and programs at Cal Poly like InTERCEPT, and the efforts like Cyber-to-Schools and CCIC focused on K-12 students—continue in an ongoing basis to build workforce preparedness at multiple levels. The project to have Cal Poly be designated a National Center of Academic Excellence in Cybersecurity, with a focus on Cybersecurity operations, is particularly exciting. With that designation, the university would be much more competitive for future federal grants, leading to growth in research, curriculum, and hands-on-learning opportunities, precisely calibrated to produce better workers.

Central to the Space Program in California is Cal Poly's growing relationship with Vandenberg SFB, codified by the Educational Partnership Agreement. While the tasks of the grant have a finite timeframe, Cal Poly and CCI's commitment to growing economic activity at the nexus of space and cybersecurity continues. CCI has just placed a full-time student assistant with Steve Rogers at Vandenberg AFB to determine the areas where future collaboration between CCI and the base could be most effective. CCI and the DxHub are also developing a "Voice of the Customer" program to improve communication between Vandenberg SFB and various workforce and economic development agencies across the state. Specifically, this network is meant to provide small- and medium-businesses with information so that they can be more competitive in fulfilling the space force base's future needs.

More grandly, in August 2020 leaders from the State of California (GoBiz), REACH, Space Launch Delta 30 (then the 30th Space Wing), Cal Poly State University, and Deloitte announced
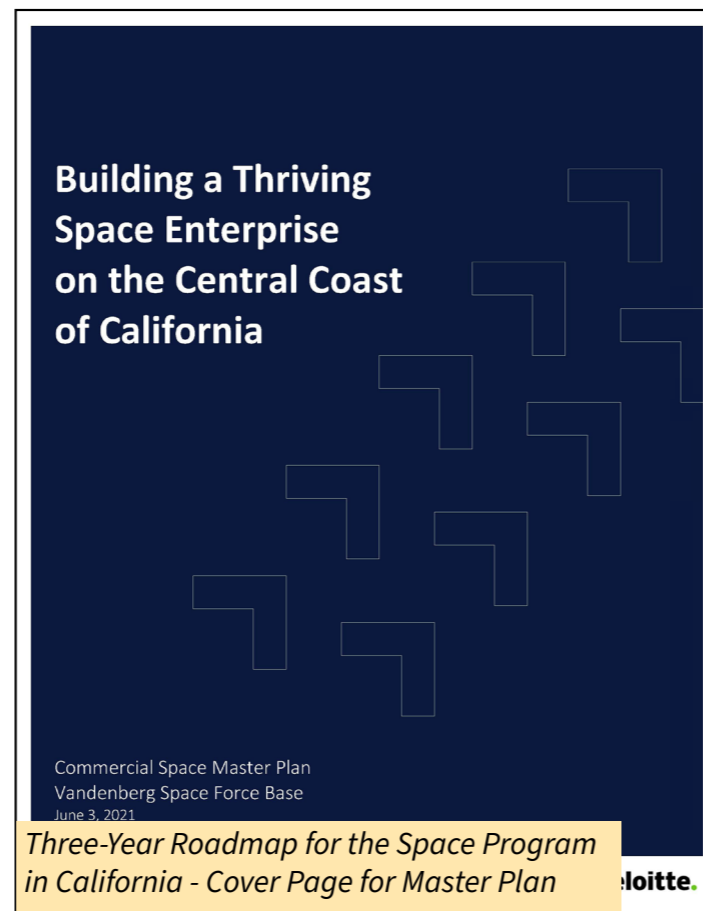
a commitment through a memorandum of understanding to develop a shared vision for a thriving spaceport at Vandenberg Space Force Base and the surrounding area. REACH is a Regional Economic Action Coalition uniting public, private and civic leaders across the Central Coast of California. In early 2021, the County of Santa Barbara joined the MOU and collectively, this group has been working tirelessly to advance the development of the Central Coast space ecosystem. The working relationship between CCI, the DxHub, and Vandenberg SFB was one of the building blocks that allowed this broader coalition, including Cal Poly, to be formed.

In terms of the grand, strategic vision for California, Cal Poly has already completed an economic impact statement about the space industry for this coalition and on June 3, 2021, this strategic partnership released its Commercial Space Master Plan Vandenberg Space Force Base, titled "Building a Thriving Space Enterprise on the Central Coast of California." The master plan seeks to complete the following goals by 2030:

- Attract Space Industry Activities to the Central Coast, by strengthening the ecosystem by establishing a concierge entity to support attraction efforts, focusing on attracting additional launch services providers and other space industry companies, and improving the regulatory and business environment.

- Modernize and Invest in Infrastructure, particularly regarding on-base launch-supporting infrastructure, on-base transportation and logistics infrastructure, and off-base infrastructure such as a new mission development zone to support increased commercial activities.

- Strengthen the Central Coast Space Identity, by establishing a clear, modern brand for the Central Coast space ecosystem, integrating space ecosystem development efforts with regional quality of life attributes, focusing on workforce development and economic mobility, and informing regional housing and transportation development.

(For a complete copy of the Master Plan see: https://reachcentralcoast.org/wp-content/uploads/Commercial-Space-Master-Plan.pdf. The economic impact statement and the master plan were created without using any CASCADE II or DoD funds, but CCI and the DxHub were consulted on the future of space on the Central Coast as part of Cal Poly's internal processes.)

Building a Thriving Space Enterprise on the Central Coast of California

Commercial Space Master Plan
Vandenberg Space Force Base
June 3, 2021

Three-Year Roadmap for the Space Program in California - Cover Page for Master Plan

In terms its individual contributions, CCI continues to focus on the issue of workforce development, a key part of the master plan mentioned above. As part of the work for this CASCADE II grant and as an extension of the workforce training activities explained in Task 8.11, the CCI began conversations with the California Community Colleges in October 2020 about a teaming agreement to begin offering digital literacy and cybersecurity content as part of the consortium's Career Technical Education (CTE) programs. This teaming agreement creates a functional relationship between Cal Poly and the consortium of community colleges. In turn, this relationship through CTE will allow CCI to begin offering professional certificates and professional development for AWS cloud training in partnership with the California's Community Colleges.

As the work of this grant has shown, the present and future of launch infrastructure and launch processes are in hybrid cloud and cloud computing. So, to have the workforce needed for space commercialization to occur, more and more Californians need to have the skills to operate in the cloud environment, while maintaining proper cybersecurity protocols to protect national and economic security. CCI is now, and will continue, working with ETP to deploy and deliver Amazon Web Services (AWS) training programs statewide. As an AWS Partner Network (APN) Training Partner, the CCI is able to train the California workforce on cloud optimization. In addition, the CCI is partnering with Upskill California to launch an AWS training effort with the CCI and 29 California Community Colleges, allowing these organizations to more effectively upskill, reskill, and retrain Californians. By partnering with UpSkill California and California's entire network of community

colleges, CCI has been able to successfully leverage its individual relationship with AWS for the benefit of the entire state; thereby growing the cyber-capable workforce to fill the jobs created by space commercialization in the near term.

Sustainability Plan for a Potential Phase 2 Component

The COVID-19 Pandemic has disrupted the economy and our society, but it has also upended our government's ability to respond to and plan for threats and opportunities facing the state and the nation. Cyber threats, for example, persist today and will only grow in magnitude the longer these issues are delayed. Moving our society to a virtual workforce has opened the opportunity for hackers to affect the lives of professionals working online.

Some areas with specific cybersecurity concerns where the CCI is already spearheading or participating in state and national conversations include the Department of Defense supply chain, adoption of cloud technology, innovation, intellectual property theft and industrial espionage, the convergence of space and cybersecurity, election security, privacy and surveillance (the threat of which is exacerbated by COVID-19 realities), 5G networking, artificial intelligence, machine learning, workforce development disparity between socially or economically challenged demographics, and cyber education programs and opportunities for all (K-12).

In terms of its long-term strategic vision, the CCI will reposition itself as a national leader in cybersecurity that strategically impacts the future of our university, state, and country. The CCI envisions a bold approach to position Cal Poly as a leading institution at the forefront of national defense and global commercial, technological advancements and related workforce development. To achieve this vision, it will require a university-wide shared agenda that fosters collaborative leadership and resource allocation.

WILLIAM + FLORA
Hewlett Foundation

The Hewlett Foundation has pledged $600,000 to support a four-year position to grow CCI's endowment with a goal of raising $50 million total.

Through the Hewlett Foundation's network, CCI is working with Michael D. Rubin & Associates to begin a fund development strategy that will allow CCI and Cal Poly to initiate state and federal grant requests pursuant to the holistic university's fund development engagement matrix. This partnership comes at no expense to the CCI or University. However, it is incumbent upon this team to provide significant direction and oversight to identify as many opportunities as possible.

Moreover, as explained in Task 8.10 above, in March 2021 the Hewlett Foundation granted Cal Poly $150,000 to hire an advancement and development officer specifically devoted to building the CCI's endowment. Hewlett has pledged an additional $450,000 to fund a subsequent three years for that fundraising position. CCI is the first center or institute on campus to have its own endowment officer. The CCI has also been included in the university's 2030 fundraising campaign. CASCADE II directly impacted the willingness of Hewlett to fund this initiative. CCI's success with CASCADE II was also part of the university administration's decision to make an exception and allow an institute or center to self-fund an advancement officer and incorporate that effort into the university's capitol fundraising campaign.

These efforts are all focused on raising an endowment of $50 million total for the CCI. The California Cybersecurity Institute estimates a $50 million endowment would generate nearly $2 million a year (3.5% return) to cover the CCI staff and one faculty position in the each of Cal Poly's six colleges. This funding would create an interdisciplinary and unified effort focused on expanding the university research leadership, and student learn by doing opportunities.

It is precisely by possessing a large endowment that research institutes survive year after year on university campuses. Endowments also provide centers like CCI with the largesse and influence to promote the long-term change in curriculum and consistent workforce development, research, or other initiatives.

Cal Poly has an unparalleled opportunity to take the lead in the preparation of the next generation of digital, cyber, and space engineers, operators, and supporting workforce. This lead comes from continuing the efforts to combine studies and research opportunities in the convergence of cybersecurity and space. While COVID-19 has brought havoc to our daily lives, healthcare systems and political infrastructures, it has created a window for new innovations that will disrupt traditional models of social life and economic development. That opportunity is only available to those who recognize it and lead efforts to change. We have the foundation, the pillars, and the strategic partnerships to secure our position as that leader both in California and nationally.

Appendix 1: Biographies of Key Individuals Mentioned Throughout the Report

CCI Team Members

Martin Minnich is the Program Manager of the California Cybersecurity Institute (CCI). Martin is a visionary and strategic leader, United States Marine Corps and Special Forces Veteran, warfighter, problem solver, innovative thinker, and author. He served ten years achieving the rank of Gunnery Sergeant before commissioning and retiring as a Captain in the United States Marine Corps. In 2012, Martin received the prestigious Fed 100 award for the performance of his team and the Emergency 0peration Center after the devastating Tomodachi Earthquake in Japan where for the first several days all U.S. emergency operational support for Japan was executed from MCAS Iwakuni. Martin has a Bachelor of Arts in History from the University of Kansas. At the CCI he develops and implements cybersecurity training programs for the CCI and has responsibility for management policies and strategy for technology innovation, information security, service resiliency and effective use of technology to support Cal Poly CCI objectives. As Program Manager, Minnich provides independent and objective evaluation of technology training issues, both current state and proposed solutions, has authority to specify frameworks and processes for achieving these goals, and reports progress and barriers to the Vice President for Information Technology and Chief Information Officer.

Danielle Borrelli is the Operations Coordinator at the CCI and the Program Lead for the Trafficking Investigations Hub (TIH). She develops and delivers training and technical resources that address the role of technology in recruiting and exploiting victims of human trafficking. In addition, Danielle is a local, regional, and international anti-human trafficking advocate with ten years of experience in prevention, intervention, and direct services work. Previously serving on the San Luis Obispo (SLO) County's District Attorney's Human Trafficking Task Force as their Housing Subcommittee Chair, Danielle has helped start and consulted on the development and sustainability of four separate housing programs. Danielle also works with schools and businesses to provide training in human trafficking awareness. Danielle was recently named California Polytechnic State University's Employee of the Year for 2018–19, SLO Tribune's Top 20 under 40 for 2019, and Jordan Cunningham's 35th District Woman of the Year.

Kurt Colvin is an Engineering professor at Cal Polytechnic State University, San Luis Obispo. His interests include: systems engineering; data acquisition, analysis, and visualization; flight test engineering; and cloud computing technologies. Colvin is also a certified Amazon Web Services (AWS) instructor and helps lead Cal Poly's AWS Training Program. He is an AWS certified solutions architect, developer, and system operations admin.

Henry Danielson is CCI's Technical Advisor, responsible for creating and presenting curriculum and coursework on cybersecurity, digital literacy, incident response, digital forensics, OSINT/ social engineering, and creating technical challenges for middle and high school students. Additionally, Danielson has supported and managed components of the California Cybersecurity Innovation Challenge (CCIC) since 2017. During 2020, Danielson was project manager for the CCIC, where he restructured the program to bring a 3D virtual cybersecurity learning environment to over 500 California students.

Gregory F. Domber assists CCI in grant development and grant reporting tasks. He has a Ph.D. in history and is the author of Empowering Revolution: America, Poland, and the End of the Cold War (University of North Carolina Press, 2014).

Makenna Downing is the Marketing and Communications Coordinator at the CCI. She develops all marketing and communication content for the CCI and related projects. Makenna also directs the marketing and communications interns at the CCI and works closely with the Media Coordinator to facilitate media projects and outreach efforts. Makenna has a Bachelor of Arts degree in Communications with an emphasis in Public Relations and a Master of Science degree in Marketing. She has previously worked for different marketing agencies and is skilled in developing creative content and deploying marketing strategies and tactics.

Matt Timmer is an administrative assistant at the CCI. He helps manage the CCI's training portfolio and administrative operations. Matt is proficient in AutoCAD, Photoshop, Illustrator, and Microsoft Office programs. He has a bachelor's degree in computer engineering and helps coordinate events, projects, and programs at the CCI. Matt also works with the CCI marketing team to conduct outreach efforts and coordinate meetings with outside organizations.

Ryan Vannucci is the Digital Media Coordinator at the California Cybersecurity Institute (CCI) with a demonstrated history of working in the higher education field in a tech-related capacity. Skilled in management, media production, content marketing, marketing strategy, and content analysis. He is a strong media and communication professional with a Bachelor of Science - BS in Liberal Arts & Engineering Studies from California Polytechnic State University-San Luis Obispo focused in Digital Media Production and Computer Graphics Programming.

DxHub Team Members

Paul F. Jurasin is the Director and co-founder of the Cal Poly Digital Transformation Hub, leading a public/private digital innovation team focused on initiatives for moving public sector organizations into the future. He works with leading industry partners to develop new, technology-oriented programs to promote digital transformation while providing enhanced "learn by doing" experiences for students. Paul provides strategic leadership and executive relationship development with non-profit, government, and educational institutions as the leader of one of the first members in the Amazon Web Services Cloud Innovation Center program. He is a regular speaker at conferences and events on topics involving innovation methods and digital transformation. Paul has more than 30 years of experience with digital transformation initiatives in both commercial and public sector organizations.

Nick Osterbur is the Digital Innovation Lead at Amazon Web Services Worldwide Public Sector at the Cal Poly DxHub. Osterbur works with the DxHub team to implement policy, strategic planning, and data analysis in order to solve challenges that are being experienced in the education, government, and non-profit organizations and industries. Osterbur helps implement the technology expertise of AWS throughout the efforts of the Cal Poly DxHub.

Darren Kraker is currently a Software Engineer at Cal Poly and works with the DxHub. He has a BS in Physics and a BA in Mathematics and has been a Software Engineer at Boeing, Starbucks, and Cal Poly. He joined Cal Poly in 2000 and has served as Developer, Manager of Application Development and Technology Strategist in ITS. He is currently Cloud Solution Development Manager at the Cal Poly Digital Transformation Hub. In this role, he works with students and faculty to bring lean protoypesprototypes to life. He enjoys helping others using cloud resources to solve technical challenges in new ways. Kraker is also a certified AWS instructor and helps lead the Cal Poly AWS Training Program.

Key Vandenberg SFB Team Members

Steve Rogers is the Range Technical Director for the United States Air Force at Vandenberg Space Force BsaeBase. He is a spacelift and test range professional focused on helping federal ranges adopt the appropriate technologies, processes, and culture necessary to meet emerging military and commercial industry demands and achieve operational excellence.

Samuel T. Casazza is a GS-14, USSF, SPOC 30 SW/JAC.

Gregory Caresio is a an office automation clerk at Vandenberg Space Force Base, a GS-14, USSF, SPOC 30 SW/XPR.

Daniel Freedman is a Program Manager at Vandenberg Space Force Base, with 20-years experience in high-paced engineering environments, leading global project management in avionics, construction, technology, and military industries.

Khrystal Jure is a GS-13, USSF, SPOC 30 SW/XPR.

Anthony Logrande is 1st Lt., USSF, SPOC 2 SLS/MSS.

Tom Stevens is the launch technical director for the 30th Operations Group at Vandenberg Space Force Base.

Other key team members include Emili Weis and William Schmeiser.

Cal Poly Weekly Space Systems Group Members

Dr. John Bellardo is an Associate Professor of Computer Science at California Polytechnic State University in San Luis Obispo and one of two faculty advisors for the school's CubeSat and PolySat research laboratories. He advises most aspects of satellite design, construction, and operation including Cal Poly's distributed tracking station infrastructure. He is actively involved in researching satellite technologies and processes to redefine what CubeSats are capable of doing, streamline development, reduce size, and reduce costs. His most recent CubeSat flight missions are IPEX and ExoCube. IPEX, launched in December 2013, tests onboard autonomy as a precursor to larger NASA satellites. ExoCube, launched in January 2015, flies a small mass spectrometer capable of differentiating between particles with an atomic mass less than 40. In addition, Dr. Bellardo has an extensive relationship with NASA, JPL, Northrop Grumman, Lockheed Martin, Boeing, and other programs that will complement the CASCADE effort.

Kurt Colvin is an Engineering professor at Cal Polytechnic State University, San Luis Obispo. His interests include: systems engineering; data acquisition, analysis, and visualization; flight test engineering; and cloud computing technologies. Colvin is also a certified Amazon Web Services (AWS) instructor and helps lead Cal Poly's AWS Training Program. He is an AWS certified solutions architect, developer, and system operations admin.

Steve Dunton is faculty in Electrical Engineering Department at Cal Poly. Mr. Dunton joined the faculty in 2017 with over thirty years of engineering experience focused primarily on satellite payloads and electronics development. He has led multiple technology insertion programs for Boeing Satellite Systems. Some recent examples include the Australian Defense Force's UHF Hosted Payload and Boeing's Generation 6 and 7 digital channelizers.

Dr. G. Andrew Fricker is an Assistant Professor in the Social Sciences Department at Cal Poly. Dr. Fricker's research interests include spatial ecology, forest community ecology, environmental modeling, active remote sensing (LiDAR) and imaging spectroscopy (hyperspectral imagery), Geographic Information Systems (GIS) and computational geography. Prior to joining Cal Poly, he spent more than eight years working for non-profits, startups and multinational corporations in the commercial mapping and surveying industry and three years working as a researcher at NASA's Jet Propulsion Laboratory.

Ryan Matteson is the Deputy Chief Information Officer (CIO) of Information Technology Services at Cal Poly. His responsibilities include making sure that three main areas (Information Security, Policy, and Technology) happen on a continuous, on-going basis. His team protects the campus community from cyber threats and strengthens Cal Poly's presence on the internet. His position also includes proactively, preparing for Cal Poly's future by looking into

all the technological changes to come, and adapting as needed, such as the current push to transition into the Cloud. His active certifications include Certified Information System Auditor (CISA), Certified Information Systems Security Professional (CISSP), Amazon Web Services Security Specialty, Amazon Web Services Sys-ops Administrator-Associate, Amazon Web Services Big Data Specialty, and Amazon Web Services Solutions Architect Associate. As an AWS certified instructor, Matteson helps lead the Cal Poly AWS Training Program.

Dan Wait is faculty in the Aerospace Engineering Department at Cal Poly. Mr. Wait has over 15 years of aerospace and systems development experience, having worked on projects at NASA JPL and other small businesses. While working for JPL he had the pleasure of working on Cassini, Dawn, the Space Interferometry Mission (SIM), Mars Science Lab (MSL), and Aquarius missions, spanning pre-PDR through flight operations phases, and ground system, flight system, and project system design, integration, and test. He was also a Mars 2020 flight systems engineer with NASA.

Cal Poly Student Interns and Assistants

Miles Aikens is a Computer Science student at Cal Poly, working for Amazon AWS as a part of their Jr. Developer program. He's fluent with C, C++, Python, Java, Javascript, and bash, as well as several other technologies like git and CI/CD. He is well trained in all of the AWS toolset and was assigned to the DxHub at Cal Poly.

Ryan Christiansen is a research analyst for Cal Poly CCI and works closely with Vandenberg Space Force Base. He is currently studying political science at Cal Poly with a concentration in global politics. Ryan works on several different systems including Python, Bash, and Unix and has completed computer science courses that aid with his policy research.

Chloe Heinz is a graphic designer at the Cal Poly DxHub. She has a Bachelor of Science degree in Graphic Communications from Cal Poly. She brings ideas to visual life by way of wire-framing and prototyping. Chloe manages the creation of storyboards and mobile app/website mockups from the stages of ideation, revision, and the delivery of final assets and collaborates with solutions architects to integrate system and interaction models into visual concepts. She applies Amazon's "Working Backwards" design-thinking to understand and design for the user's desired experience.

Chase Peak is an experienced Solutions Architect with a demonstrated history of working in with Amazon Web Services (AWS) technology. He is skilled in Python (Programming Language), Project Management, Public Speaking, and Software Architecture Modeling. He is a strong engineering professional with a Bachelor of Science - BS in Applied Mathematics with a concentration in Computer Science from California Polytechnic State University-San Luis Obispo.

Bree Zedar worked as an Immersive Set Designer for Cal Poly CCI. She is studying mechanical engineering at Cal Poly. In her role at the CCI, Bree reverse-engineered 3-day cyber crime simulation for Cyber Innovation Challenge, adapting it to virtual space over 90-day span. She also managed team of 25 interns over 1-year period, setting and meeting deadlines to facilitate cyber-competition serving 600+ candidates. Bree designed and implemented live-immersive digital forensics to gain experience in error reduction and excellent interpersonal communication skills.

Eric Zhong completed his mechanical engineering bachelor's degree at Cal Poly and is currently a student in the Engineering/Industrial Management master's program, also at Cal Poly. Among other positions he has been a Project Engineering Intern at Phillips 66 and a Project Management Intern at Tesla.

Appendix 2: Cost Sharing in the Public-Private Partnership

As explained in multiple tasks listed in the body of this final report, public-private partnerships are at the heart of the work in this project. As this report also tried to prove, the CCI and the DxHub—as an extension of Cal Poly—were an important interlocutor between public (particularly government entities) and the private sector. Cal Poly was an innovative and integral piece needed to make these public-private partnerships effective and produce results.

As part of a comprehensive polytechnic state university, CCI understands this is precisely the role it should be playing as part of the California State University's overarching role as an economic engine for the state. Cal Poly is meant to act as an intermediary between government and private entities, whether this is providing workforce training for small satellite companies, holding large public events and symposia, developing new secure technologies, or solving Vandenberg SFB's technical challenges.

The CCI and Cal Poly have also expended significant resources as matching funds to ensure the success of this project. The center and the university are philosophically and literally invested in making public-private partnerships produce results. A summary of those matching funds and how they were utilized appears in the tables below and on the next page.

Cost Share			
Name	**Dollar Amount Contributed Effort**		
Martin Minnich	Wage	Benefits	Total
November	$795.73	$425.07	$1,220.80
December	$795.74	$425.06	$1,220.80
January	$795.74	$425.06	$1,220.80
February	$795.74	$425.06	$1,220.80
March	$795.73	$425.07	$1,220.80
April	$2,678.00	$1,478.47	$4,156.47
May	$1,071.10	$591.39	$1,662.49
June	$1,071.20	$591.39	$1,662.59
July	$1,071.20	$591.39	$1,662.59
August	$856.96	$591.39	$1,448.35
September	$856.96	$591.39	$1,448.35
October	$856.96	$591.39	$1,448.35
November	$856.96	$591.39	$1,448.35
December	$856.96	$591.39	$1,448.35
January	$856.96	$591.39	$1,448.35
February	$856.96	$591.39	$1,448.35
March	$856.96	$473.11	$1,330.07
April	$856.96	$473.11	$1,330.07
May	$856.96	$473.11	$1,330.07
June	$856.96	$473.11	$1,330.07
Total	$19,296.74	$11,410.13	$30,706.87

Cost Share			
Name	**Dollar Amount Contributed Effort**		
Paul Jurasin	Wage	Benefits	Total
November	$932.80	$498.27	$1,431.07
December	$932.80	$498.27	$1,431.07
January	$932.80	$498.27	$1,431.07
February	$932.80	$498.27	$1,431.07
March	$932.80	$498.27	$1,431.07
April	$2,062.01	$1,138.39	$3,200.40
May	$1,249.70	$689.93	$1,939.63
June	$1,249.70	$689.93	$1,939.63
July	$1,249.70	$689.93	$1,939.63
August	$374.91	$206.98	$581.89
September	$374.91	$206.98	$581.89
October	$374.91	$206.98	$581.89
November	$374.91	$206.98	$581.89
December	$249.94	$137.99	$387.93
January	$249.94	$137.99	$387.93
February	$249.94	$137.99	$387.93
March	$249.94	$137.99	$387.93
April	$249.94	$137.99	$387.93
May	$0.00	$0.00	$0.00
June	$0.00	$0.00	$0.00
Total	$13,224.45	$7,217.40	$20,441.85

Cost Share	Dollar Amount Contributed Effort						To Date
Name	Dollar Amount Contributed Effort						
	Total Salary and Benefits	Travel	Hosting	Feedly	Journey Maps	Hewlett Foundation Award 47258 (Grant #2020-1612)	
November	$2,651.87						$2,651.87
December	$2,651.87	$679.86	$237.53				$3,569.26
January	$2,651.87						$2,651.87
February	$2,651.87						$2,651.87
March	$2,651.87						$2,651.87
April	$7,356.87						$7,356.87
May	$3,602.12						$3,602.12
June	$3,602.22						$3,602.22
July	$3,602.22						$3,602.22
August	$2,030.24	$3,148.57					$5,178.81
September	$2,030.24						$2,030.24
October	$2,030.24						$2,030.24
November	$2,030.24						$2,030.24
December	$1,836.28						$1,836.28
January	$1,836.28			$1,650.00	$1,066.67	$24,992.49	$29,545.44
February	$1,836.28			$1,650.00	$1,066.67		$4,552.95
March	$1,718.00			$1,650.00	$1,066.67		$4,434.67
April	$1,718.00			$1,650.00	$1,066.67		$4,434.67
May	$1,330.07			$1,650.00	$1,066.67		$4,046.74
June	$1,330.07			$1,650.00	$1,066.67		$4,046.74
Sub Total	$51,148.72	$3,828.43	$237.53	$9,900.00	$6,400.00	$24,992.49	$96,507.17
IDC	$8,439.54	$631.69	$39.19	$1,633.50	$1,056.00	$4,123.76	$15,923.68
Total	**$59,588.26**	**$4,460.12**	**$276.72**	**$11,533.50**	**$7,456.00**	**$29,116.25**	**$112,430.85**