DEPT. COMM. NO. 147

DEPARTMENT OF BUSINESS, ECONOMIC DEVELOPMENT & TOURISM

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December 29, 2016

The Honorable Ronald D. Kouchi,
President and Members
of the Senate
Twenty-Eighth State Legislature
State Capitol, Room 409
Honolulu, Hawaii 96813

The Honorable Joseph M. Souki,
Speaker and Members of the
House of Representatives
Twenty-Eighth State Legislature
State Capitol, Room 431
Honolulu, Hawaii 96813

Dear President Kouchi, Speaker Souki, and Members of the Legislature:

For your information and consideration, I am transmitting a copy of the Office of Aerospace's Developing A Strategic Roadmap for Aerospace in Hawaii, as required by HR26, 2016 Legislative Session, Hawaii Revised Statutes. In accordance with Section 93-16, Hawaii Revised Statutes, I am also informing you that the plan may be viewed electronically at: http://dbedt.hawaii.gov/overview/annual-reports-reports-to-the-legislature/.

Sincerely,

Luis P. Salaveria

Enclosure

c: Legislative Reference Bureau

HAWAII'S AEROSPACE INDUSTRY

DEVELOPING A STRATEGIC ROADMAP

FOR

EXPANSION AND DIVERSIFICATION

REPORT TO THE
GOVERNOR AND THE LEGISLATURE
OF THE
STATE OF HAWAII

Pursuant to
HR 26, 2016 Legislative Session

PREPARED BY

THE OFFICE OF AEROSPACE DEVELOPMENT
DEPT. OF BUSINESS, ECONOMIC DEVELOPMENT & TOURISM
STATE OF HAWAII

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report has been prepared by DBEDT's Office of Aerospace Development (OAD) to provide an overview of the nature and status of Hawaii's Aerospace Industry, along with recommendations for developing a strategic roadmap to help expand and diversify this industry statewide during FY 2018-22.

For the purpose of this study, "aerospace" is defined as "the branch of technology and industry concerned with both aviation and space flight"[1], and is subdivided into the following major subsectors for analysis: astronomy, civil aviation, commercial space launch, defense systems, robotics, information technology, and unmanned aerial systems.

Hawaii's strategic mid-Pacific/near-equatorial location, Moon/Mars-like terrain, resident expertise covering multiple aerospace-related technologies, and long-standing ties with space-faring nations throughout Asia and the Pacific, clearly afford strategic assets and capabilities that can be leveraged to realize humankind's full potential in space, and in so doing enable our State to engage as both a major contributor to and beneficiary of the global space enterprise.

This study highlights the key assets and capabilities that make aerospace a strategic growth sector for Hawaii's economy, as well as ongoing programs to promote development and diversification of this industry statewide. It then provides an overview of current priorities and projected trends for aerospace in global markets, followed by an analysis of this industry in key subsectors. It then explores creative pathways toward enhancing Hawaii's leadership role in and benefits from the global aerospace economy, focusing on key near-term programs with substantial promise for expansion and diversification.

The study concludes with recommendations for developing a sustainable aerospace roadmap for Hawaii that can enable our State to realize its full potential in this industry. Emphasis is placed on collaboration with Hawaii's Aerospace Advisory Committee to explore opportunities for enhancing aerospace sub-sectors statewide – identifying principal players (commercial and governmental), strategies and key milestones for development, as well as resources (both financial and manpower) essential for sustainable implementation.

[1] Oxford English Dictionary (https://en.oxforddictionaries.com/definition/aerospace)

"All of us have looked up at the stars at night, and thought of all the possibilities that lay in outer space. By developing our understanding of aerospace and creating new technologies to explore, we are at the forefront of innovation and stewarding a new economy for future generations."

Governor David Ige
2016 Aerospace Summit
Hawaii State Capitol

★ INTRODUCTION ★

PIONEERING THE FUTURE IN PARADISE: AEROSPACE AS A STRATEGIC GROWTH SECTOR FOR HAWAII'S ECONOMY

The aerospace industry has played a pivotal role in expanding and diversifying our national economy. From aviation to space exploration, aerospace research and development has forged new inroads to scientific discovery; dramatically advanced our national engineering and manufacturing expertise; pioneered innovation in communications technology and computer science; enhanced our surveillance of our home planet and understanding of the factors that drive weather systems and climate change; spurred spinoffs of commercial products that have significantly enhanced our qualities of life; enriched educational and training opportunities for K-12 and college students nationwide; and ultimately afforded new frontiers for humankind to explore and develop.

Today, aerospace holds an equal if not greater potential for mobilizing our nation's strategic assets and capabilities to enable innovation in science and technology that can uplift our national economy, enhance global security, promote STEM education to grow a technologically proficient workforce, improve healthcare diagnostics and delivery worldwide, advance global communications and remote sensing of critical resources, forge sustainable energy systems for our planet, and ultimately pioneer future pathways to space – phenomenal opportunities that will benefit all sectors of society (a rising tide that will lift many boats!).

Hawaii's strategic mid-Pacific/near-equatorial location, Moon/Mars-like terrain, resident expertise covering multiple aerospace-related technologies, and long-standing ties with space-faring nations throughout Asia and the Pacific, clearly afford strategic assets and capabilities that can be leveraged to realize humankind's full potential in space, and in so doing enable our State to engage as both a major contributor to and beneficiary of the global space enterprise.

Of course, Hawaii is no newcomer to aerospace, and for the past half century has played a seminal role in developing our national space program – beginning with astronaut training for the Apollo lunar missions and the development of world-class observatories on the Big Island. Over the past four decades, the University of Hawaii, the U.S. military, and numerous companies statewide have pioneered nationally-funded programs in planetary geosciences, satellite communications, space-based remote sensing and environmental monitoring, deep-space surveillance, and other areas employing aerospace-related technologies. Yet new opportunities are forthcoming in this industry that are ideally suited for our State – many of which hold substantial scientific, educational and commercial promise for residents statewide.

For example, the University of Hawaii is applying its resident expertise in adaptive optics and remote sensing toward the development of advanced sensor technologies for spaced-based observations of our planet. Local companies such as Oceanit, Raytheon Solipsys, NovaSol and Trex Enterprises are also leading national efforts to develop new sensors for atmospheric monitoring, land and coastal resource assessment, and both optical communications and electro-optical tracking.

In addition, major aerospace corporations such as Boeing, Lockheed Martin, Northrop Grumman, Raytheon and BAE Systems, already established in Hawaii, will have opportunities to expand their operations in the islands as a bridge to Asian and Pacific markets – especially in the development and delivery of advanced systems for aviation maintenance and training, air traffic control, satellite communications, and deep space tracking and reconnaissance.

Finally, Hawaii's unique geography and technological assets are ideally suited to support the commercial launch of next-generation aircraft, including spaceplanes, to carry small satellites, experimental payloads and tourists to space; the monitoring, management and mitigation of both man-made and natural disasters Pacific-wide; and the development of space-based power systems to capture sunlight as a renewable energy source for both interplanetary spacecraft and earth-based applications.

But the "case for aerospace" in Hawaii is even more compelling:

- *Aerospace can be an important driver in both creating and sustaining an "innovation economy".* It provides multiple (and inspiring!) opportunities to advance STEM (science, technology, engineering, and mathematics) education, and enables diverse research, technology transfer, and commercial development across many fields.

- *Aerospace is a growth industry that won't be exported once it matures*. It flourishes here because of where we are and what we have – a strategic mid-Pacific location, unique geographical assets, and resident expertise, all of which combine to give our State competitive advantages in this industry.

- *Hawaii already has expended considerable effort establishing key working relationships throughout the global aerospace community.* We can build upon our rich legacy and existing capabilities in aerospace to grow this industry statewide – especially through multinational partnerships and support.

- *Hawaii's aerospace sector requires only modest upfront investments to leverage substantial returns*. Again, this is largely related to the State's geographical and environmental advantages over land-locked states, which make us an ideal testbed for both robotic and human space exploration systems, as well as the development and validation of next-generation aviation technologies.

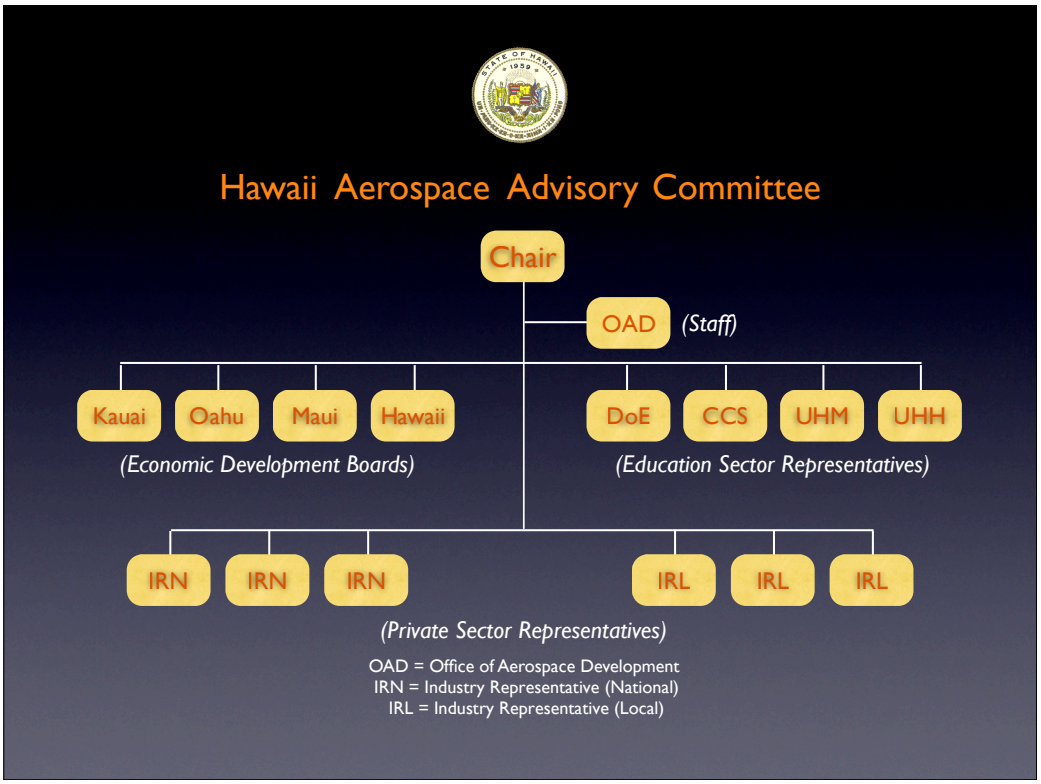
- *Growing global interest in Hawaii as a catalyst for space exploration*. NASA, along with other space agencies, universities, and aerospace corporations worldwide, recognize Hawaii's intrinsic advantages in aerospace, as well as our potential for promoting international dialogue and exchange, and have increasingly expressed interest in partnering with our State to seed multinational programs that can reduce the costs while enhancing the benefits of both robotic and human space missions.

PROMOTING AEROSPACE DEVELOPMENT STATEWIDE

Established through Act 149, Session Laws of 2007, within the Dept. of Business, Economic Development and Tourism (DBEDT), the Hawaii Office of Aerospace Development (OAD) provides a focal point within State government to facilitate dialogue and coordination among Hawaii's government, private and academic sectors, and between State-based entities and overseas organizations, both public and private, to promote the growth and diversification of Hawaii's aerospace industry.

Since its inception, OAD has played a major role in both facilitating and coordinating aerospace initiatives statewide, including major international conferences and workshops, multinational space agreements and coalitions, STEM education and public outreach programs, and the development and implementation of space exploration activities. In doing so, OAD has established extensive networks with state, national and international aerospace institutions and organizations, and is now well positioned to help leverage Hawaii's strategic advantages in this industry to expand and diversify Hawaii's leadership on the space frontier.

To assist with this effort, the Hawaii State Legislature (through Act 52, Session Laws of 2009) established the Hawaii Aerospace Advisory Committee (HAAC) to advise and assist OAD, the Legislature, and State agencies in monitoring, assessing and promoting aerospace development statewide. The Committee is comprised of leading aerospace industry executives, distinguished academicians from across the state, and economic development board representatives from Oahu, Kauai, Maui and Hawaii – all united with a common purpose to help the State diversify its economy and promote innovative education and employment opportunities for residents statewide.



★ AEROSPACE INDUSTRY MARKET OVERVIEW ★

GLOBAL AEROSPACE MARKETS: CURRENT PRIORITIES AND PROJECTED TRENDS

The global aerospace industry grew in 2015, although currency fluctuations caused the appearance of a decline from $329 billion in 2014 to $323 billion in 2015.[2] Due to the strong U.S. dollar and the ever-increasing levels of activity outside the United States, these fluctuations have a more noticeable impact than would have been the case in previous decades, when the U.S. share of the commercial aerospace industry was larger.

In 2015, revenues from commercial sectors continued to represent slightly more than three-quarters of all global economic activity in aerospace. Commercial products and services – including telecommunications, broadcasting, and Earth observation – constituted the largest sector, growing by 3.7% to reach $126.33 billion in 2015. Commercial infrastructure and support industries – including the manufacture of spacecraft, in-space platforms, and ground equipment, as well as launch services, independent research and development, and insurance – totaled $120.88 billion in 2015, a 5.2% decrease. The majority of this decline is attributable to global navigation satellite system (GNSS) receivers, whose revenues are benchmarked in euros and were subject to the change in currency exchange rates.

Global government space budgets declined by 4.8% in 2015, as spending totaled $76.52 billion. Government spending accounted for 24% of the global space economy, remaining unchanged from 2014. The U.S. government spent $44.57 billion on defense and non-defense space efforts in 2015, a 3.2% increase from 2014. Non-U.S. government space investment declined by 14.2% in dollar terms, totaling $31.95 billion in 2015.

The global aerospace industry (including defense) is expected to return to growth in 2016, with total sector revenues estimated to increase at 3.0 percent. This positive signal follows years of declining revenue growth of 3.2 percent in 2013, 1.9 percent growth in 2014, and an expected decline of minus 0.5 percent in 2015 as found by Deloitte Global in its 2015 Global aerospace and defense sector financial performance study. [3]

Over the last three years, global Aerospace and Defense industry revenue was largely impacted by decreased revenues in the United States defense subsector. The return to growth in 2016 is expected to be fueled by increases in the U.S. defense budget, a resurgence of global security threats, and growth in defense budgets of key nations worldwide. In addition, relatively stable growth in global gross domestic product (GDP), lower crude oil and other commodity prices, and continued increases in passenger travel demand are contributing to anticipated growth in production rates for next-generation commercial aircraft.

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[2] *The Space Report 2016*, Section 2.0 – The Space Economy, pp. 15-38, The Space Foundation.

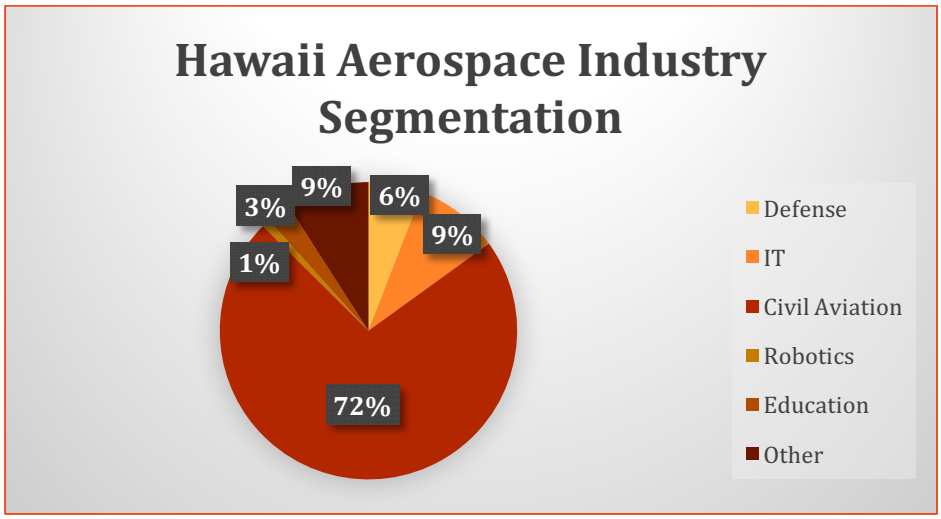
[3] *2016 Global Aerospace and Defense Sector Outlook*, Deloitte Touche Tohmatsu Limited (Deloitte Global) Consumer & Industrial Products Industry.

Defense budgets in the US, United Kingdom, France, Japan, several Middle Eastern countries, and other nations are increasing at a time when national security threats are being heightened. Global revenues in the defense subsector are expected to return to growth in 2016, as governments equip their armed forces with modern defense weapons platforms and next-generation technologies, including cyber, intelligence gathering, defense electronics, and precision strike capabilities.

The commercial aerospace subsector is expected to continue its decade-long trend of above-average growth rates, driven by growth in passenger travel demand and an accelerated equipment replacement cycle. Strong increases year over year of global revenue passenger kilometers are leading to an unprecedented level of aircraft production rates, which in 2015 were about twice the levels experienced 10 years ago.

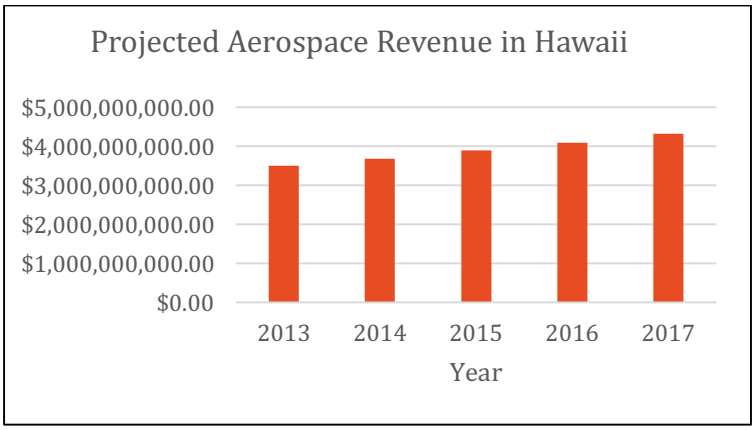
HAWAII'S AEROSPACE SECTOR: REVIEW OF INDUSTRY DEVELOPMENT STATEWIDE

The aerospace sector of Hawaii's economy represented ~5.5% of State GDP, or approximately $4 Billion in 2014, with a projected growth rate of ~5% through 2017.[4] The largest segment of Hawaii's aerospace industry (72%) comes from civil aviation, including flights in and out of Hawaii, helicopter tours, and ancillary support services such as refueling and maintenance. Information Technology (IT) also plays a significant role, accounting for 9% of the entire industry, followed by defense-related applications and robotics.



Projected through 2017, these aerospace segments are anticipated to remain fairly intact proportionately, with the highest growth rate occurring in robotics and information technology at 9.5% and 8.8% respectively, and the lowest projected to be defense at 0.6%. This industry is projected to grow at an approximate rate of 5.2% through 2017. The graph below indicates by the year 2017, the size of the aerospace industry within Hawaii is expected to be approximately $4.5 billion.[5]

[4] *Hawaii Aerospace Market Study 2013-2017*, Kogod School of Business, American University (Dec. 2014), p. 8.
[5] Ibid., p. 9.



[6]

In addition, a recent report (April 2016) issued by IHS Economics for the Aerospace Industries Association (AIA) indicated the overall impacts of the aerospace and defense industry on Hawaii's economy (on average from 2013-15) as follows:

ECONOMIC IMPACT OF A&D INDUSTRY ON HAWAII'S ECONOMY[7]

Impacts	**Employment** (# of workers)	**Output** (Million US $)	**Value Added** (Million US $)	**Labor Income** (Million US $)
Total:	2,100	408	207	156
Direct:	560	181	79	83
Indirect:	440	71	38	24
Induced:	1,100	156	89	49

The following narrative presents an overview of Hawaii's key aerospace subsectors, with recommendations for expanding and diversifying activities in each area.

ASTRONOMY

Hawaii has one of the largest astronomy sectors in the United States, with world-class observatories attracting scientists, research funds, students and visitors to the islands. There are twelve facilities housing thirteen research observatories representing eleven nations on Mauna Kea (Island of Hawaii). At Haleakalā on Maui, there is a mix of seven facilities, including astronomical observatories and telescopes operated by the Air Force to research man-made (rather than celestial) objects.

The astronomy sector in Hawaii generates sustained economic activity through purchases from local businesses, payment to employees, and spending by the astronomy community and visitors. Per a report from the University of Hawaii Economic Research Organization (UHERO), local astronomy related expenditures (assessed in calendar year 2012) were $58.43 million on Hawaii Island, $25.80 million on Oahu, $1.28 million on Kauai, and $2.58 million on Maui. Total astronomy-related spending statewide was $88.09 million.

[6] Kogod (ibid.), p. 8.

[7] HIS Economics. O'Neil, Brendan et al. "Aerospace and Defense Economic Impact Analysis: A report for the Aerospace Industries Association", Appendix (pp. 31-34).

Including indirect and induced benefits, and adjusting for inter-county feedback and spillover effects, the astronomy sector had a total impact of $167.86 million statewide. The largest impact was found to be in Hawaii County ($91.48 million), followed by Honolulu County ($68.43 million), with relatively small impacts in Maui County ($5.34 million) and Kauai County ($2.61 million). In addition, astronomy activities generated $52.26 million in earnings, 8.15 million in state taxes and 1,394 jobs statewide.[8]

Technical and administrative staff comprise most of an observatory's workforce. Technicians are mainly mechanical, electrical, and optical engineers. Per a Hawaii Island astronomy workforce survey undertaken in 2010 by the Hawaii County Workforce Investment Board (in collaboration with the Mauna Kea observatories), projections indicate that some 482 observatory jobs will open from 2010 through 2023. That averages more than 34 jobs a year over 14 years. Of these new jobs, over 330 openings in technology and nearly 150 openings in administration are anticipated. Most of these jobs will require a two-year associates degree or a four-year bachelor's degree. Other observatory staff include scientists (primarily researchers with doctoral degrees) and scientific support staff, such as telescope operators.

Looking to the future, astronomy in Hawaii can be a trailblazer for space exploration, charting unknown regions of the universe and searching for potentially habitable planets around nearby stars, as well as signs of life elsewhere in the universe. But this field also has more tangible cross sections with space exploration. For example, astronomical research in Hawaii has continually discovered new solar system bodies with potential impacts for our home planet, such as near-earth asteroids that could be used for mining (or that could potentially strike our planet and therefore require deflection).[9]

Both the Mauna Kea and Haleakala Observatories are studying the distribution and growth of "space debris" (a growing concern for launching payloads into both near-earth and geostationary orbits), and data from this research can be used by NASA and other space agencies in determining appropriate launch trajectories.

Technology development in conjunction with astronomical instrumentation will also provide opportunities for economic growth and diversification. The Institute for Astronomy at Hilo has a long history of developing and characterizing the largest near-infrared detectors, and those employed in NASA's James Webb Space Telescope were characterized and developed in Hawaii in collaboration with Teledyne Technologies.

The substantial astronomical infrastructure atop Hawaii's volcanoes places our State in a unique position to lead international studies in a variety of fields. However, as Günther Hasinger of the Institute for Astronomy has noted, "we are not data-limited – we are brain limited." As such, appropriation of funds to hire researchers at the graduate student, postdoctoral, or junior faculty level would make a substantial contribution toward enabling Hawaii to achieve its full potential in astronomical research and technology development.

[8] See http://uhero.hawaii.edu/products/view/472.

[9] The world's most powerful "Near Earth Object" (NEO) hunter telescope (Pan-STARRS1 on Haleakala) recently discovered a "quasi-moon" (asteroid) orbiting Earth that could well become a priority target for future space enterprise, including both mining and technology R&D.

In addition, a bill being introduced during the 2017 Legislative Session proposing formulation of the University of Hawaii's "Dark Night Skies Protection" initiative (originally launched in 2009 through DBEDT's Office of Aerospace Development as the "Starlight Reserve Strategy") will establish an advisory committee to help preserve dark night skies and reduce nighttime light pollution. This will not only be vitally important to support operation of Hawaii's two main astronomical observatories (atop Mauna Kea and Haleakala), but also to help reduce nighttime "skyglow" to protect endangered species, address concerns related to interference with circadian rhythms (including human), and significantly reduce expenditure of energy for nighttime illumination of highways, harbors, airports, and other facilities.

CIVIL AVIATION

As noted above, the aviation sub-sector is a major component of Hawaii's aerospace industry – estimated at over 72% of the total aerospace sector. Civil aviation includes aircraft manufacturing, airport operations, aircraft maintenance, and both international and domestic airlines. As the economy continues to grow out of the most recent recession, demand for commercial aircraft and the subsequent operations it requires will continue to increase.

The need for strong aviation capabilities for transportation in our island state is critical. However, Hawaii has many more requirements for aviation technologies (both fixed and rotary winged), including diverse applications in agriculture, search and rescue, law enforcement, medical services, power line assessments, and, of course, tourism. Local employment is substantial and diverse in areas where aviation figures prominently, including aircraft maintenance, pilots and flight crews, flight nurses, airport managers, educators and trainers, simulation maintenance technicians and operators, ticket counter and travel agents, baggage handlers, helicopter and fixed wing pilots, airport tower personnel, cargo loaders, associated truck and transportation personnel, food service providers, and other essential workforce.

The economic impact of this sub-sector on the State is significant, and the indicators for growth are strong. According to the Alliance for Aviation Across America[10], the State is home to 3,150 plots and 486 active general aviation aircraft servicing Hawaii's fifteen airports. This Alliance report cites a 2011 FAA study stating that "Hawaii's aviation system supports more than 182,000 jobs in the State, resulting in a payroll of more than $6.7 billion."

On both a nationwide and worldwide scale, the aviation industry is scheduled to expand and diversify. According to an analysis by Boeing[11], airlines will take delivery of tens of thousands of new commercial jetliners over the next 20 years, and the demand for personnel to fly and maintain those airplanes will be unprecedented – projected at 498,000 new commercial airline plots and 556,000 new maintenance technicians. The largest projected growth in pilot demand will be in the Asia-Pacific region, requiring a total of 192,300 new pilots.

[10] See: http://www.aviationacrossamerica.com/economic-impact/summary-of-economic-impact-of-general-aviation-in-hawaii/

[11] *2016 Boeing Pilot and Technician Outlook* – See: http://www.boeing.com/commercial/market/long-term-market/pilot-and-technician-outlook/

Data summarizing current and projected demand for aviation-related services in Hawaii from 2013-2021 is presented in the closing Appendix. Combining scheduled passenger and freight air transportation, our State's aviation sub-sector includes 8,164 jobs, with a projected growth rate of 8.1%.

Hawaii provides an airport system that connects Hawaii with the world and reflects our unique spirit of Aloha. Maintaining and improving the capabilities of the airports system to meet future demands of air commerce by modernizing and expanding facilities and infrastructure are well underway. Hawaii's unique location makes it especially attractive as a focus for all aspects of aeronautics for the pacific basin, including an unrealized potential for regional aviation maintenance and repair, as well as flight training. This substantial potential can be realized by promoting and facilitating widespread aeronautical industry participation in Hawaii to meet current and projected demands and opportunities.

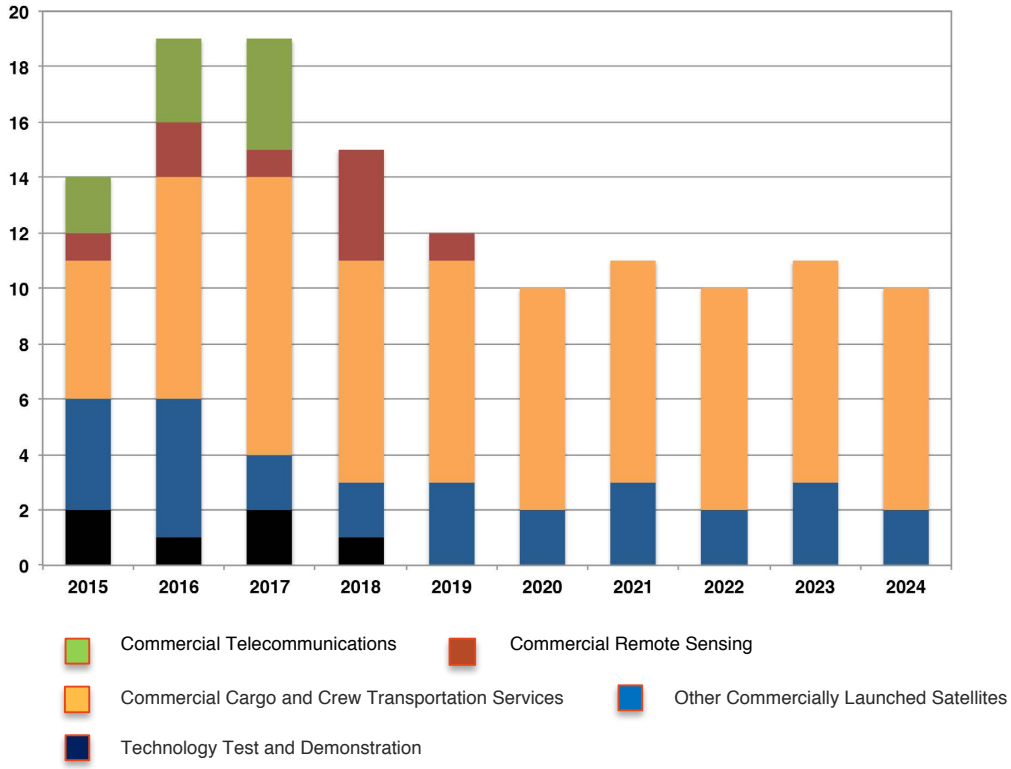
COMMERCIAL SPACE LAUNCH

Nineteen countries have, are developing, or are planning to host, spaceports. The term "spaceport" encompasses a wide variety of facilities. Some spaceports are used to launch multiple-staged rockets into Earth orbit or further into space, carrying probes, cargo, and/or astronauts. Others might be used for launching jet-like spacecraft from runways for a short suborbital hop to another location on the Earth's surface, much like regular aircraft. Still other spaceports are simply economical places to conduct short experiments with small rockets. All the activities from each of these differing use cases of spaceports rely on healthy and growing space support infrastructure across the globe. And all spaceports share a common purpose to provide facilities to lift an object into space, even if only for periods of time.

In the United States and its territories, 42% of the spaceports have active launch site operator licenses granted by the U.S. Federal Aviation Administration (FAA).[12] The remaining 58% of U.S. spaceports are either proposed, in development, or government-operated. Of the 24 current and future spaceports, 14 were used to conduct orbital or suborbital launches in 2015. Orbital launches were routinely conducted from two of those 14 during 2015: Cape Canaveral Air Force Station (CCAFS) in Florida, and Vandenberg Air Force Base (VAFB) in California. Florida hosted 85% of all orbital U.S. launches in 2015.

While most spaceports are developed by governments (whether national or local), one company continued its efforts during 2015 to add a U.S. spaceport. SpaceX broke ground for a new spaceport near Brownsville, Texas in 2014, stating it would start launching from this site in 2016.[13] The company increased activities for the $100 million complex, ending 2015 with site infrastructure and soil improvement projects. SpaceX also signed leases with the U.S. Air Force for space launch complexes – one at VAFB, California, and the other at CCAFS, Florida. Both complexes will be used to land SpaceX's Falcon 9 and Falcon Heavy reusable booster rockets.[14]

Number of Launches / Recent and Projected[15]



[12] "Active Licenses." *U.S. Federal Aviation Administration*. June 2015. http://www.faa.gov/data_research/commercial_space_data/licenses/#operatorLicenses.

[13] Jeff Foust. "SpaceX Breaks Ground on Texas Spaceport." *SpaceNews.com.* September 22, 2014. http://spacenews.com/41957spacex-breaks-ground-on-texas-spaceport/.

[14] Stephen Clark. "SpaceX leases property for landing pads at Cape Canaveral, Vandenberg." *SpaceFlightNow.com*. February 17, 2015. http://spaceflightnow.com/2015/02/17/spacex-leases-property-for-landing-pads-at-cape-canaveral-vandenberg/.

[15] *2015 Commercial Space Transportation Forecasts*; FAA Commercial Space Transportation (AST) and the Commercial Space Transportation Advisory Committee (COMSTAC); page 3.

In 2015, OAD conducted a site selection study that identified Kona International Airport (KOA) as the best site in Hawaii to establish a commercial spaceport that will support launch and landing of "spaceplanes" (horizontal launch and land vehicles) carrying satellites, experimental payloads, and tourists to space. An Environmental Assessment (supported through a matching grant from the Federal Aviation Administration) is now being completed that will enable our State to apply for a commercial spaceport license and initiate space launch operations from KOA by 2018. Several companies have also indicated interest in operating out of the Kona spaceport, and have initiated non-disclosure agreements with DBEDT to pursue their ongoing interest in space launch options from Hawaii.

Commercial interest has also been expressed in vertical launches from East Hawaii to support the rapidly growing small satellite market. The Alaska Aerospace Corporation has agreed to manage a Hawaii facility dedicated to orbital launch by training Hawaii citizens to conduct launch operations, providing $250K as matching funds to conduct an environmental assessment for the proposed operations. Both X-Bow Launch Systems and Rocket Lab USA are writing letters of commitment to use the proposed East Hawaii launch site, with the goal of building a Hawaii workforce dedicated to smallsat operations and vehicle production/assembly.

Small Satellite Market

We are on the cusp of a major revolution for the space, as more than 3,600 smallsats are expected to be launched over the next ten years – a significant increase from the previous decade.[16] The total market value of these satellites is anticipated to be more than $22 billion (manufacture and launch), a 76% increase over that of 2006-2015. This rate of growth is unprecedented for the space sector, and will bring about fundamental changes as both new and established industry players attempt to increase their capabilities to gain market share.

Including all third-party and in-house manufacturers, around 200 organizations built a smallsat between 2006 and 2015, and the coming decade predicts a similar pattern. Smallsat suppliers are entering the industry to capitalize on demand with flexible COTS equipment, reducing costs and development times. Larger integrators focusing on larger missions do not necessarily have the capacity to create these smaller, nominally lower-cost solutions at a profit, or have the platforms available to support small mission development.

In the next decade, launch services are expected to generate $5.3 billion, a 76% increase over the previous decade. Small-lift vehicles under development will add further specialized supply. Prices from Firefly, Rocket Lab and Virgin Galactic are not expected to undercut existing supply prices. However, with smallsat operators impacted by the launch bottleneck and affected by delays in ridesharing (despite higher prices per kilogram), the benefits of faster, dedicated access to space could become quite attractive to operators.

SmallSat Missions from Hawaii

Hawaii attempted its first rail launch of a University of Hawaii satellite (HawaiiSat-1) on a new three-stage solid rocket into polar orbit from the Pacific Missile Range on Kauai in October,

[16] Euroconsult, *Prospects for the Small Satellite Market* (July 2016).

2015. This 55 kg spacecraft, supporting the first proposed mission of the University's Hawaii Space Flight Laboratory (HSFL)[17], was designed as a platform for demonstrating a DARP-funded long-wave infrared hyper-spectral imaging system, and included a pair of cameras to provide wide and narrow view images of the Earth.

Although a rocket stage separation failure aborted this preliminary mission, HawaiiSat-1 was designed to be the first in a series of satellites manufactured and launched in Hawaii. It is currently anticipated to have at least two missions per year, although the actual frequency will depend upon the demand for new missions. Each new mission would involve ~30 individuals for ~3 years per mission. The model for development is one that already exists and has operated successfully in England, where academic departments at the University of Surrey first designed a small spacecraft in the late 1970's and subsequently grew a highly successful company (Surrey Satellite Technology Ltd.; http://www.sstl.co.uk) that now employs over 200 people and has become the world's premier provider of small (<500 kg) spacecraft by launching >30 spacecraft for several different countries over the past 20 years.

The potential in Hawaii is to transform the economics of achieving ready access to space. A typical Hawaii launch is projected to cost <$20 Million, including the design and construction of the payload and satellite. There are currently 44 states building small satellites at over 80 universities, so there is a strong potential market for rides into space. The costs of these small satellites range from 1-2 kg spacecraft that cost ~$20 - $30,000 to build and $40-$60,000 to launch, to the HawaiiSat-class spacecraft (60-80 kg) that cost $2 Million to build and $4.5 Million to launch. If Hawaii could capture part of this demand for access to space, it is projected that each mission would create ~20 jobs in Hawaii and generate $80 - $100,000 per year.

This new industry would leverage capabilities already in Hawaii, including the U.S. Navy's Pacific Missile Range Facility (PMRF), contractors such as Sandia National Laboratory, and HSFL. Facilities at HSFL include ~600 m^3 10,000-class clean rooms, a 1,000-class optical and semiconductor lab, a 2-meter diameter thermal vacuum chamber, a Dynamic Solutions 1.2-meter electrodynamic vibration table, attitude control test beds (a Helmholtz Cage), and a satellite mission operations center. An open-source mission operations software package (COSMOS) has also been written in-house for the simultaneous control of up to 100 satellites (or other platforms, such as unmanned aerial vehicles, or UAVs).[18]

The main objectives of a small satellite program in Hawaii are to (1) create a technically trained engineering/software workforce in Hawaii capable of building and operating multiple small satellites; and (2) provide cheap access to space for DoD, NASA and university payloads for short-duration (<5 year) demonstration missions. Hawaii-based small satellite launch capability would have recurring costs of ~$12-$15 Million per annum, inclusive of range costs (which are a fraction of current launch alternatives). Potential markets include:

1. The disaster management community, looking for on-orbit asset replacement or augmentation.

[17] HSFL's mission is to expand Hawaii's workforce with skills in engineering, math, remote sensing, and earth sciences. Since 2009, over 30 students and interns have been directly involved in the design, and fabrication of the spacecraft itself, as well as more than an additional 20 students who worked on supporting projects to analyze and test spacecraft components.

[18] See: http://www.hsfl.hawaii.edu

2. The development of pre-staged, modular spacecraft ready to launch rapidly/on demand (72 – 96 hour turnaround from initial flight decision).
3. Private or Federal agencies interested in the development of redundancy, within a constellation of small satellites.
4. Flight-testing of instruments/software for the private sector, DoD, or NASA for the low-cost on-orbit testing of innovative technologies.

Skill sets that need to be developed within the Hawaii community include:

1. Mission design/proposal preparation – scientists with numerous skill sets, including solar astronomy, oceanography, Earth science, and communications.
2. Small satellite design – optical, electrical and mechanical engineers.
3. Integration and test of satellites – electrical and mechanical engineers.
4. Mission planners and mission operators, including the expansion of tracking and data down-link capabilities.

Potential next steps to help grow the small satellite market opportunities in Hawaii include:

1. Develop routine (~twice per year) launch opportunities from PMRF and/or other site(s) within the State.
2. Transfer knowledge and personnel to the private sector via the development of small high-tech companies that build, operate, and control specific satellites.
3. Provision to the private sector of greater access to existing integration and test facilities in Hawaii, so that many of the support functions are conducted in-State.
4. Develop U.H. academic programs on aerospace technology, including electrical mechanical engineering and applications-focused instrument/mission design.

DEFENSE SYSTEMS

For the purposes of this report, we will adopt the definition of the Defense sub-sector of the aerospace industry as presented in Hawaii's Aerospace Market Study (2013-2017) by Kogod Business School at American University: "Defense within aerospace consists of missile systems, aircraft, drones, and all the repairs and technology that support these systems, including the design of aerospace and defense plans."

According to that study (and the Deloitte financial and economic impact analysis referenced therein)[19], there are 2,580 employees in the aerospace defense segment in Hawaii who generate approximately $590M of revenue annually. While the study notes that missile systems are one of the significant contributors to the Hawaii aerospace defense market, there are no further details on what the other impactful contributors are, or whether they are more service-based or manufacturing-based. Also not referenced in this study is the software and sensor work currently being conducted by both private industry and the University of Hawaii.

[19] See: https://www2.deloitte.com/content/dam/Deloitte/global/Documents/Manufacturing/gx-manufacturing-2016-global-ad-sector-outlook.pdf

To more effectively assess opportunities for growth in Hawaii's aerospace defense segment, it would be prudent to identify and catalog the State's existing capabilities and efforts that comprise the $590M in total annual revenue.

Although specifics on the details of Hawaii's current market share are missing, we can gain insight by knowing that the total U.S. aerospace defense market is approximately $200 Billion, and that Hawaii, at $590 Million, has captured only 0.3% of it. Given this, it can be safely inferred that our State has not saturated any part of this market, and that growth can be achieved in nearly all areas by capturing market shares from other states. That being said, having a large addressable market is not enough to ensure growth. In a highly competitive market such as the aerospace defense industry, discriminating capabilities are necessary.

The focus for growth in Hawaii, therefore, should be tied to local discriminators. Suggested discriminators include: (1) proximity to PACOM and the Component Commands; (2) access to military test ranges and training ranges that may now be more relevant for "the pivot to the Pacific"; and (3) designation of Hawaii (in partnership with Alaska and Oregon) as one of six (now seven) national FAA UAS test ranges.[20]

Given these discriminators, which market areas can Hawaii credibly capture, sustain, and grow? Due to costs and environmental hurdles related to establishing a heavy manufacturing capability in Hawaii, it is unlikely that the State would have viable growth opportunities in building manned (or large unmanned) aircraft, spacecraft, or missile systems. Nevertheless, prototyping and manufacturing of subsystems, such as sensors, control electronics, power sources, and ordinance, may be viable. Along with this light manufacturing, research and development for these types of subsystems and software could also be undertaken without large investments in infrastructure. While expanding this type of work in Hawaii would help grow our local market, there are no inherent discriminators that would make Hawaii better suited for this work than elsewhere in the country.

Although there are niche capabilities and technologies developed in Hawaii that could successfully serve as discriminators, this does not represent a robust basis for developing a strategic State plan. However, if we consider not just the development or manufacture of these subsystems and software packages, but also the testing of these products at military test ranges (or demonstration at military exercises like RIMPAC), then the aerospace defense industry in Hawaii might effectively leverage local geographic discriminators.

For instance, if the potential added military utility of testing at one of Hawaii's ranges, or a reduced cost by leveraging in-kind support from local bases, is found to be compelling, local companies and universities could potentially capture additional market share from their mainland competition.

With a sufficient stream of development and testing activities, there would also be an emerging local market opportunity to provide support infrastructure to facilitate more effective operations. Developing a payload testing infrastructure in Hawaii could prove a significant growth area that would enable secondary markets for workforce and revenue generation.

[20] See: https://www.faa.gov/news/updates/?newsId=75399

Examples include:

- Payload flight certification with the FAA (IA, DER, DAR).
- Warehousing and security.
- Depots for training, operations, servicing, and repair (cranes, hoists, fuel storage, battery charging, test equipment, and hazardous waste management).

Even mainland companies might elect to conduct testing activities in Hawaii if this support infrastructure were cost-competitive and provided added visibility with the nearby PACOM and Component Commands. A tertiary revenue source would be the money that these contractors would spend during their stay in Hawaii.

Potential next steps to support Hawaii's aerospace defense sub-sector in Hawaii:

1. Determine quantitatively what we're currently doing in this sub-sector (who's doing what, and how much this contributes to Hawaii's $590M aerospace defense total).
2. Establish contacts with the major players in this sub-sector to develop a better understanding of their current challenges and future vision/goals.
3. Determine what we can be done at the State level to promote optimal opportunities for growth in this sub-sector.
4. Work with military test ranges (e.g., the Pacific Missile Range Facility, the Pohakuloa Training Area, Marine Corps Training Area Bellows, Makua Military Reservation, Marine Corps Base Hawaii, Hickam Air Force Base) to both market what they do and determine what they could do to support Hawaii's aerospace defense community.

ROBOTICS

The branch of technology that deals with the design, construction, operation, and application of robots or automated machines, robotics has impacted industries from auto manufacturing and semi-conductors to life sciences and consumer goods. The robotics industry in North America is rapidly expanding, primarily fueled by strong demands from manufacturing companies in all sectors. A record 14,135 robots (valued at $788 million) were ordered from North American robotics companies in the first half of 2014. This marks an industry record for sales in the first half of a year.

The robotics industry has grown annually at a steady 26% rate nationally since 2010. The automotive industry has had the broadest application of robotics to revolutionize auto manufacturing, but other industries such as semiconductors, life sciences, food and consumer goods are also being transformed through robotic operations. It is now estimated that 230,000 robots are being utilized within the United States, placing the U.S. second only to Japan in applications of robotic technologies.[21]

[21] *North American Robotics Market Posts its Best Quarter Ever, Sets New Record for First Half of 2014*: http://www.robotics.org/content-detail.cfm/Industrial-Robotics-News/North-American-Robotics-Market-Posts-its-Best-Quarter-Ever-Sets-New-Record-for-First-Half-of-2014/content_id/4934

The robotics industry in Hawaii focuses heavily on both the development of educational programs and advancement of robotic systems for diverse applications in both research and commercial development. One area related to aerospace and rapidly advancing applications of robotics systems statewide is unmanned aerial systems, or UAS (as detailed below). Numerous competitions are also held statewide to help advance the development and application of robotics systems, including the FIRST in Hawaii Robotics Regional Competition (the "super bowl of smarts") presented by Oceanic Time Warner Cable), the Vex Robotics Competition (sponsored by Hawaiian Electric, Maui Electric, and Hawai'i Electric Light), and other programs designed to inspire the next generation of engineers and innovators pioneering new avenues for applications of robotics technologies in many fields.

Robots are also anticipated to play a critical role in the exploration and development of space. Hawaii's Pacific International Space Center for Exploration Systems (PISCES) is pioneering a variety of programs to test and evaluate robotic technologies on the Moon/Mars-like terrain on the Big Island, including the PISCES Robotic International Space Mining Competition (PRISM), field testing of lunar dust shields as part of a collaborative experiment involving PISCES, NASA Swamp Works at the Kennedy Space Center, and a Google Lunar X-Prize team; collaboration with NASA, Honeybee Robotics, ARGO, Hawaii County Dept. of R&D, and the State of Hawaii to develop prototype basalt-based landing pads that can be used to support future missions to the Moon and Mars, and other programs that will support future missions to the Moon, Mars, and other solar system bodies.

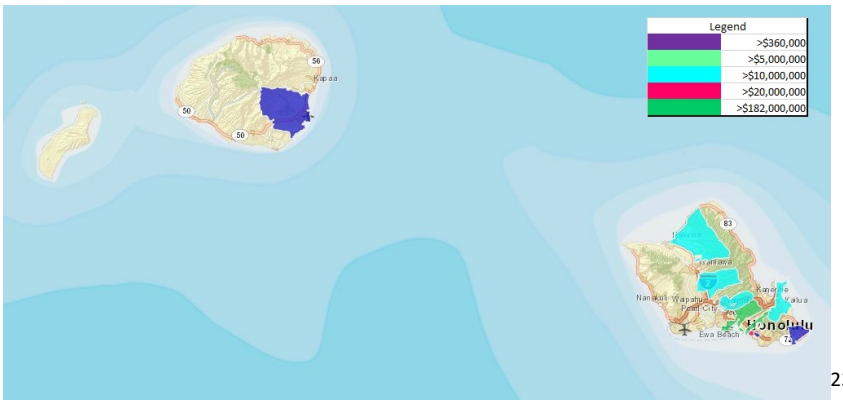
INFORMATION TECHNOLOGY (IT)

Information Technology (IT) plays a significant role in the aerospace Industry, which relies heavily on technologies that not only help send, receive, and store communications, but also maintains an extremely high level of security, safety, and reliability. These complex systems enable a broad range of applications – from protecting warfighters and ensuring that aircraft can take off and land, to maintaining robust telecommunications pathways that enable consumers to communicate. IT advances air traffic systems, enabling legacy aircraft fleets to integrate seamlessly within newer fleets. Without information technology, commercial and national security satellites would not be effective, space exploration would be limited, and manned space systems would be unable to proceed with various missions.

IT in Hawaii plays a major role in the local economy. Estimated annual revenues for companies operating in Hawaii that provide technology services impacting aerospace is approximately $285 million. The chart below breaks down IT revenue by zip code. Dark purple represents revenues up to $360 thousand, light blue represents revenues up to $10 Million, and light green revenues up to $182 Million.[22]

As indicated in the graphic below, the majority of IT revenue in Hawaii is generated through zip codes in and around Honolulu, where approximately $230 Million was generated in 2013. The largest company in this space is Hawaiian Telecom, which operates telecom networks, primarily through Satellites. Telecommunications and data storage and analysis are the largest providers in the IT services section of Hawaii that relate to aerospace.

[22] *The Kogod Report* (ibid.), p. 32.



[23]

The average IT company revenue growth rate within the United States is 8.8%. This includes breaking down Information Technology into various growth segments, such as communications equipment, computer hardware, computer networks, software and programming, etc. Based on this estimated rate, the above graphic indicates that by the year 2017, companies operating in Hawaii that specialize in Information Technology services that relate to Aerospace will have annual revenues in excess of $447 Million.[24] Additionally, in 2013 there were approximately 1,924 employees within these IT companies. Exhibit 20 also displays projections regarding the number of employees working in IT companies that relate to Aerospace through the year 2017.

UNMANNED AERIAL SYSTEMS

In March 2012, the Federal Aviation Administration announced that it was planning to establish six national ranges to serve as test and certification sites for Unmanned Aerial Systems (UAS). Hawaii, in partnership with the States of Alaska and Oregon, submitted an application to serve in this capacity, and the tri-state team was selected by the FAA (in December, 2013) as one of these sites.

Although Alaska and Oregon appropriated state funding to initiate their UAS test range operations (in the spring of 2014), legislation was not approved in Hawaii to support this program. However, a bill subsequently introduced during the 2015 session did appropriate funds to hire a chief operating officer to manage this program for the State. Although this funding was allocated to the Office of Aerospace Development within DBEDT, a memorandum of agreement with the University of Hawaii's Applied Research Laboratory (UH-ARL) was established that transferred funding (and operation) of this program to the University.

A major question now facing the State is how best to leverage UAS technologies and capabilities to enable substantial economic returns. Outside of government sponsored research and development, today there is very little economic impact from the handful of hobbyists and researchers currently operating UAS in Hawaii. This will likely remain the case until UAS are integrated with the national airspace.

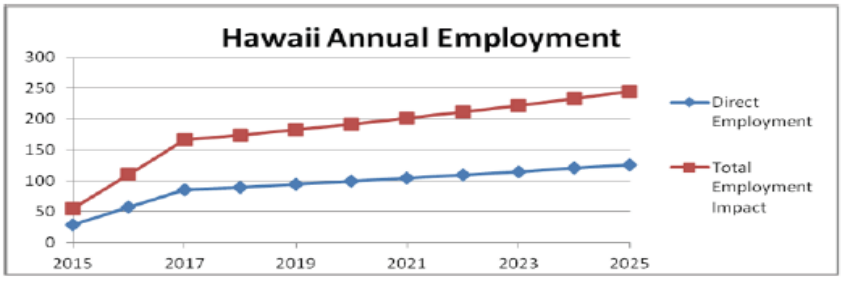
[23] *Kogod Report* (ibid.), p. 32.

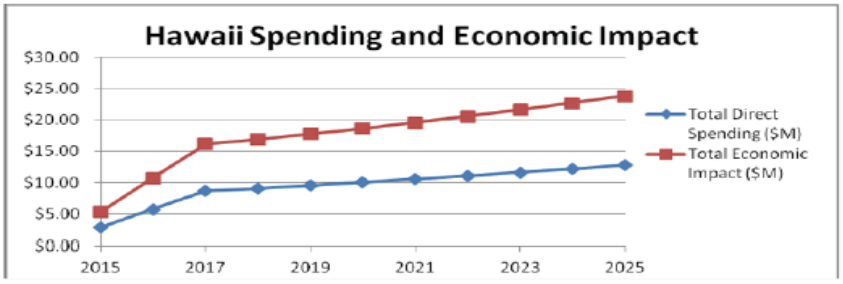
[24] Technology Sector Growth. (n.d.). Retrieved from CSI Market website: http://csimarket.com/Industry/Industry_Growth.php?s=1000

Limited studies have been undertaken to forecast the economic impact of UAS in the United States. In March of 2013, the Association for Unmanned Vehicle Systems International (AUVSI) undertook such a study, predicting that the economic impact of the integration of UAS into the national airspace will total more than $13.6 billion in the first three years of integration and will grow sustainably for the foreseeable future, cumulating to more than $82.1 billion between 2015 and 2025. Broken down by state, the same study predicts the UAS industry will have a total economic impact of nearly $25M over the next 10 years in Hawaii (see the graphic below), adding approximately 250 jobs.[25]

Hawaii's economy is ripe with opportunities to leverage this new technology and exceed the AUVSI forecast. Examples include the film industry, agriculture, resource and fisheries management (to include in the Northwest Hawaiian Islands), volcanology, and disaster response throughout the mid-Pacific region. With much of the public infrastructure in our state (water, telephone and power lines) traversing rugged terrain, UAS technology will be very useful in conducting inspections more economically. Not considered by the study would be the added factor of Hawaii as part of the Pan-Pacific UAS Test Range Complex, an FAA designated UAS Test Site led by the University of Hawaii at Fairbanks.

Hawaii Economic Impact						
Year	Direct Employment	Total Employment Impact	Total Direct Spending ($M)	Total Economic Impact ($M)	Total State Taxes ($K)	Percent Change Over Previous Year
2015	28	55	$2.89	$5.38	$65.11	
2016	57	111	$5.78	$10.76	$130.22	100%
2017	85	166	$8.67	$16.14	$195.33	50%
2018	90	174	$9.11	$16.94	$205.09	5%
2019	94	183	$9.56	$17.79	$215.35	5%
2020	99	192	$10.04	$18.68	$226.12	5%
2021	104	202	$10.54	$19.61	$237.42	5%
2022	109	212	$11.07	$20.59	$249.29	5%
2023	114	222	$11.62	$21.62	$261.76	5%
2024	120	234	$12.20	$22.70	$274.84	5%
2025	126	245	$12.81	$23.84	$288.59	5%





[25] The Economic Impact of UAS Systems Integration in the United States, AUVIS, March 2013.

The robust STEM and robotics programs in our local schools (both public and private) are preparing Hawaii's future workforce for this emerging technology. The State can best promote growth in this sector by:

1. Funding the establishment of PPUTRC testing in Hawaii.
2. Encouraging the use of UAS into resource management, law enforcement, and disaster response with the state to reap economic benefits through efficiencies.
3. Advocating for the study of related technologies as part of the curricula at the University of Hawaii.
4. Encouraging local investment in research and development of UAS technologies (platforms, sensors, links, artificial intelligence, and control).
5. Integrating UAS into local STEM and robotics programs.

We need to give thought to how the Hawaii FAA Test Site can support the research with meaningful test and evaluation. We know we have all the natural resources here (weather, diverse topography, airspace), but what about other resources such as range instrumentation and a secure network/data repository, and how can Hawaii assemble this on a limited or nonexistent budget? Part of the answer will be to leverage existing infrastructure operated by state and federal agencies, including the national guard, the armed services (particularly the Navy through the UARC), and our local FAA contingent. Partnering with broad industry contacts (not just traditional aerospace companies) will be critical in building a sustainable program.

Future of UAS in Hawaii

The targets we must aim for should address "levels of benefit" to the State of Hawaii. Several measures to ascertain progress might include:

1. Durable business development, both in the Supply and User side of our business community, embracing public safety and environmental quality control, but also extended to entertainment, tourism, and creative media sectors.
2. Positive socialization of UAS into Hawaii's daily infrastructure operations through community involvement and support.
3. Active workforce development thru K-12 STEM education.
4. Clear recognition and support from both the Legislative and Administration.

Standards and best practices for UAS use are emerging in the FAA, the Dept. of Human Services, and the Pan Pacific UAS Test Range Complex (PPUTRC). Incorporating these (modified for Hawaii's uniqueness) into a Drone Standard Operating Procedure (SOP) will be an important task that has already been requested by our State Senate.

From time to time these requirements will change, as the circumstances for the Ranges change. In fact currently FAA has asked the Test Ranges to help determine the path for the Ranges for next 5 years, now that Federal Aviation Regulation (FAR) 107 has been made law. This FAA initiative could introduce new project and range management, preparation, and security requirements, especially as the Ranges take on more challenging use cases and new technology for UAS.

There are very practical reasons for an SOP. For example, a Presidential action team recently developed UAS "best practices" in relation to privacy issues and the protection of civil rights. Compliance with these "best practices" is now required for UAS project funding from U.S. government grant sources. Similarly, the legal structure of the PPUTRC rests upon USG 49 Code para 41025, 'Public Aircraft Operation (PAO)', further defined by the OTA (Other Transaction Agreement) contract the FAA has issued to the University of Alaska. It is mandatory that the Hawaii component of the PPUTRC follow these strictures; and that the standards embedded become disseminated and followed as part of Community involvement. Compliance with Best Practices is also required for UAS project funding from USG grant sources.

An essential functionality underlying success of UAS for Hawaii will be creation of active intelligence from the world of UAS, distilled into supervectors showing where investment trends, development concepts, and potential threats to the business are collected, observed, and disseminated. UH providing that service to Hawaii – Legislature, Business community, Technology developers, Education, and Users – would be of great value.

The nature of Test Ranges has migrated from the initial concept of a defined land or water perimeter, with hard fixed installed systems such as communication, radar, RF, video collection systems, and security. Driven by FAA creation of state and national COA for the Ranges, the Ranges take on redefinition as 'virtual', meaning the collection of personnel, UAS equipment, certifications, flight test instrumentation and communication – and most importantly, Letters of Agreement with landowners allowing creation of test operations where appropriate and as needed. With the emergence of counterdrone technology as a major component of future UAS business, for example, a virtual range setup would include mainly "penetration tests" by various UAS against various defenses.

Discussion and analysis by all parties to testing, using all means to inform the task including tabletop or field experimentation, will be required to establish Range requirements as new test needs emerge, particularly for the more complex, challenging missions of UAS integration into the National Airspace. This does suggest the value of a parallel effort to create a fully virtual test range, based on supercomputer simulation writ large, which if available, would dramatically assist the PPUTRC and its customers in defining the most critical test requirements. This capability would also be of great assistance in designing UAS systems and in defining certification methods for such.

★ FOOTSTEPS TO THE FUTURE ★

KEY NEAR-TERM PROGRAMS FOR EXPANSION AND DIVERSIFICATION

Several programs supported by DBEDT's Office of Aerospace Development are currently underway, with the potential of significantly impacting our State economy. These programs are summarized below, followed by recommendations for developing a sustainable aerospace roadmap for Hawaii.

Kona International Air and Space Port

As the commercial space market continues to develop and mature, the State of Hawaii (by virtue of its near-equatorial, mid-Pacific location) is uniquely positioned to be an active participant in this industry. In March of 2013, DBEDT executed a contract with RS&H, Inc. to complete a technical analysis of potential spaceport infrastructure, a spaceport site selection study, and a National Environmental Policy Act (NEPA) environmental assessment report, or EA (including flight corridor development, risk analysis, and site plans to mitigate safety hazards related to launch operations - e.g., propellant storage and handling), development of launch site operation procedures, and other studies required for an application to the Federal Aviation Administration, Office of Commercial Space Transportation (FAA-AST), for a commercial Launch Site Operator's License (spaceport license) for the State of Hawaii.

This license will enable "spaceplanes" (horizontal launch and land vehicles) to operate out of Kona International Airport (KOA) at Keahole, carrying both people and experimental payloads/satellites to space, and bringing "space tourism" to our islands. Several aerospace companies have signed "non-disclosure" agreements with DBEDT to explore options for both satellite launch and space tourism operations out of Hawaii. Long-range plans include "point–to-point" flights carrying both people and cargo from Hawaii to Asia and Europe, as well as to space vehicles stationed in low-Earth and geosynchronous orbits. It is anticipated the EA will be completed in 2017, after which the State will officially apply for its commercial spaceport license from the FAA. Spaceplane companies will also have to obtain individual licenses to operate their spacecraft out of KOA.

Pacific Space Launch Complex

The emerging small commercial satellite market provides a unique opportunity for Hawaii to take the lead in providing space access to the communications, imaging, navigation, and data industry. Hawaii is geographically located at an ideal geographic location, at 19.8968° North, for the launching of satellites into Low Earth Equatorial Orbit (LEO). With more than 3,600 small satellites projected to be launched in the next decade, valued in excess of $22.0 Billion, Hawaii's geographic location and strong academic foundation in engineering and technologies provides a unique opportunity for the State to capitalize on this growth industry, providing tremendous economic benefits to the State.[26]

There has been increased interest expressed by the private-sector to establish space-oriented businesses in Hawaii, including small satellite processing and launch facilities in the State. The potential for private investment in the emerging small satellite industry in Hawaii is significant (the Office of Aerospace Development already has several "non-disclosure" agreements signed with commercial firms interested in launching from Hawaii), but successful development of this industry will ultimately require public-private partnerships. As this emerging market is rapidly transforming commercial access to space, it is imperative that our State demonstrate support for expanding this industry in Hawaii to successfully compete with other states and attract private investments.

To stimulate the small satellite commercial market in Hawaii, state government can play a strategic role in helping create a favorable business and political environment which would be competitive with other states in attracting aerospace companies to operate out of our State. Legislation is being introduced into the 2017 Session to provide financial support, with matching funds from the private sector through the Alaska Aerospace Corporation (AAC), to conduct the initial site selection, environmental, economic, and other studies required for establishing an equatorial launch platform on the east coast of the Big Island.

The Hawaii Island Economic Development Board is also developing a preliminary roadmap outlining the processes and efforts that will be required for this initiative, as well as a strategic public education and community engagement program aimed at fostering community understanding of the AAC's proposed project and development, along with an understanding of the likelihood of public acceptance and feasibility of successfully implementing this project.

Hawaii UAS Test Range

As noted above, the State of Hawaii was selected (in partnership with the states of Alaska and Oregon) was selected as one of six (now seven) national ranges to test and certify UAS operations. Moving forward, strategic State investments in UAS technologies and application should be considered from the standpoint of direct benefits to Hawaii – particularly measurable business benefits.

[26] OECD (2016), *Space and Innovation*, Executive Summary. OECD Publishing, Paris http://dx.doi.org/10.1787/9789264264014-en

Several measures associated with outcomes would apply here. For example:

1. Durable business opportunities (in both the Supply and User sides of our economic community) spanning the complete range of potential UAS service – i.e., public safety, environmental management, infrastructure development, commercial and military applications, STEM education, sports and entertainment, tourism, creative media, and agriculture.

2. Positive socialization of UAS into Hawaii's daily infrastructure operations through community involvement and support, including K-12 Education and community participation.

3. Workforce development through STEM education and training (as measured through both public and private school UAS programs).

4. Clear recognition and support at both Legislative and Administration levels, measured by both Legislative business investments and CODEL support of positive UAS Congressional efforts (including partnerships with other CODEL).

Hawaii-based UAS would fit into two separate business categories:

1. Broad efforts involving producers, users, consumers, educators, researchers, regulators, and lawmakers.

2. Narrower efforts defined through the Pan Pacific UAS Test Range Complex (PPUTRC), specifically addressing testing and evaluation under the Public Aircraft Operations federal doctrine.

Although Hawaii's UAS program will be managed under UH-ARL, it will be implemented within the terms and SOP of the University of Alaska's FAA OTA Test Range contract (which recently has added the State of Mississippi to the team). As such, a three-part strategy will need to be developed that applies to Hawaii's commercial and industrial certified UAS business in general; to educational and workforce development efforts; and to uncertified T&E under the PPUTRC structure. The last part was addressed through Act 208 (2015 Session). However, this element must rest upon a foundation of public acceptance and enable measurable benefits to Hawaii (looping back to the other two elements of the strategy).

The PPUTRC overall strategy will be established by action of the PPUTRC Board of Advisors starting in January 2017. This strategy will include business practices allowable under the University of Alaska FAA Contract, SOP for the four states comprising the PPUTRC, and work placement process, reporting, outreach, and advocacy.

In developing Hawaii's component of the PPUTRC, it will be important to focus on those elements of testing which would be of value to future business in Hawaii (coffee agriculture, for example), as well as to our educational system. Equally critical will be UAS manufacturers who find it expedient to run tests in Hawaii, landowners who look forward to participating in land use for UAS testing, and legislative action that removes barriers to success for Hawaii.

However, it would be unreasonable to assume Hawaii will initially measure up to fully-functioning test ranges with certified measuring equipment common to UAS testing, such as video, radar, lidar, theodolite, weather stations, instrument labs, chase aircraft, communication and data downlink systems - not to mention a fleet of UAS, as might be the case in other test ranges that have been up and running for many years (prior to the 2012 creation of FAA UAS Ranges). Thus the notion of a 'virtual' test range comes into focus - meaning the 'collection of personnel, UAS equipment, certifications, flight test instrumentation and communication, and (most importantly) Letters of Agreement with Landowners' allowing creation of test operations wherever appropriate and as needed.

With the emergence of counterdrone technology as a major part of future UAS business, for example, a Virtual Range setup would include primarily penetration tests by various UAS against various detection and defense schemes, set in surroundings that include the full range of 'natural' threats such as high wind and turbulence, RF signal reflection, RF interference, and/or visual shielding. Clearly the Range that accomplishes counterdrone testing would not be the same as that used for Aerodynamic or Certification testing. In fact, counterdrone applications tie in to drone racing, as the high skill dynamic decision-making in racing could translate into high skill evading countermeasures.

The ultimate success of UAS operations in Hawaii will depend upon the collection, dissemination and analysis of investment trends, development concepts, user needs, and implementation challenges, which in turn will help define business opportunities. As such, a broad range of potential users should be engaged in prescribing a roadmap to Hawaii's UAS future, including (but not limited to) representatives from: the State Dept. of Education; creative media/journalism/radio/TV/newspapers; the UHWO Creative Media Center; USPACOM and the National Guard; public safety agencies (police, fire, ocean safety, OEM, SWAT, FBI, EPA, U.S. Marshall); environment and public works (EPA, HDOT); community infrastructure (HECO, HC&D, BOWS, State harbors and airports); land and resource management (DLNR, A&B, KSBE), and agriculture (CTAHR, the Farm Bureau, large agricultural operators).

Pacific International Space Center for Exploration Systems (PISCES)

The Pacific International Space Center for Exploration Systems, or PISCES, is an R&D and educational/training institution headquartered on the island of Hawaii and dedicated to pioneering the development and application of innovative technologies to advance the robotic and human exploration, development, utilization, and settlement of space. This program was originally conceived through the former Japan-U.S. Science, Technology and Space Applications Program (JUSTSAP) coordinated through DBEDT and established at the University of Hawaii at Hilo (2007). The Center was founded on partnerships between industry, academia and the governments of space-faring nations around the world, but particularly those on the Pacific Rim, of which Hawai`i is the approximate geographic center.

PISCES' founding vision was to enable the development of three major facilities: (1) field sites for testing rovers and in-situ resource utilization (ISRU) systems; (2) an on-campus base facility housing classrooms, laboratories, offices, shops, and assembly areas; and (3) a simulated lunar outpost featuring habitats, an agricultural area, a solar cell farm, pilot-scale processing plants, other elements of an actual lunar outpost, and a public viewing station.

Technologies developed in PISCES and elsewhere will be tested, matured and integrated as appropriate into the operating outpost, in collaboration with governmental space agencies, as well as partnering universities and industry.

The PISCES business operating plan was designed to follow the model of an industry-university-government partnership center, which is predicated on leadership by faculty members of the host institution and partnering universities, coupled with involvement of companies from the United States, Japan, and other spacefaring nations, particularly those around the Pacific Rim, and assisted by a business development office. Major sources of potential non-State operational funding include the National Aeronautics and Space Agency (NASA), the Japan Advanced Exploration Agency (JAXA), and other space agencies, particularly those along the Pacific Rim of nations, augmented by investments from private industry based in participating countries. Primary customers of PISCES include the State of Hawai`i, its citizens and the residents of Hilo and the Big Island; the research and technology development program managers in NASA and other space agencies; researchers and program managers in the space-related industry; and the taxpayers of the U.S. and other spacefaring nations.

PISCES priorities during FY18-22 as envisioned by the PISCES staff and approved by the PISCES Board of Directors will focus on:

- Raising supplemental funds through various grant opportunities to support the PISCES Intern Program and R&D activities.
- Helping develop a basalt-based industry in Hawaii that can include (but not be limited to): basalt rebar manufacturing, basalt fiber manufacturing, basalt fiber products, and high performance/ultra-high performance concrete.
- Continuing to promote and participate in planetary robotic program development and analog site testing with various collaborators (public and private) to include but not be limited to NASA and aerospace-related agencies/institutions located in Canada, Korea, and Japan.
- Continuing to support, as appropriate, NASA's Laser Communications Ground Station Initiative.
- Participating in the initial planning stages, and as a potential partner involved with operations, of the proposed Multipurpose Processing Facility and Small Satellite Launch Initiative on the Big Island.
- Continuing to develop close collaboration with state-based academic institutions at the University of Hawaii at Hilo, Honolulu Community College, U.H. Manoa (including the Hawaii Space Flight Laboratory), and other programs as appropriate.
- Collaborating with the HI-SEAS (Hawaii Space Exploration Analog and Simulation) Program in the upgrade and fidelity improvement of their Mars Habitat.
- Supporting the development and implementation of the Lunar Base Vision established by Henk Rogers, PISCES Board Chairman.[27]

[27] PISCES programs and activities may be found online at: http://www.pacificspacecenter.com

Aviation Maintenance and Training

Hawaii's unique mid-Pacific location also well positions our State to serve as a center for both aircraft maintenance and the training of pilots (and other aviation personnel). The Aeronautics Maintenance Technology program at Honolulu Community College is designed to prepare individuals for Federal Aviation Administration certification as aircraft Airframe and Powerplant mechanics. Students in this program obtain knowledge and practical applications in such areas as hydraulics, sheet metal, electrical installation and troubleshooting, welding, the use of hand power tools, engine theory, troubleshooting and repair. The Aeronautics Maintenance Department program maintains an FAA-approved technical training facility with combined Airframe and Powerplant ratings – the only school of its kind in the Pacific Basin.

But Hawaii's potential for enhanced aviation training and maintenance is substantial, and could readily be achieved through appropriate investments in local infrastructure to both enhance ongoing training programs and enable servicing of commercial aircraft. As noted above, Hawaii's unique location makes it especially attractive as a focus for all aspects of aeronautics for the pacific basin, including an unrealized potential for regional aviation maintenance and repair, as well as flight training. In addition, the University of Hawaii at Hilo is working on a proposal to help launch a flight training program for fixed-wing pilots.

Multinational Lunar Outpost

During the October 2016 Aerospace Summit at the Hawaii State Capitol (sponsored and coordinated by DBEDT's Office of Aerospace Development), PISCES Board Chair Henk Rogers outlined a vision for developing a prototype lunar base on the Big Island that eventually could be deployed on the Moon. With terrain that closely simulates the regolith blanketing the lunar surface, the Big Island is well positioned to provide a testbed for technologies and habitats that eventually could support development of a Moon base.

The ongoing HI-SEAS Mars simulation habitat also supports possibilities for hosting a prototype "Moon base" on the Big Island. Going to the Moon has (among multiple space-faring nations) been proposed as the next step/proving ground for missions to Mars. Learning to live off the land (in-situ resource utilization) will be an important aspect of humanity becoming a multi-planetary species, and HI-SEAS could serve as an ideal testbed for such activity.

The concept of a Moon base has also been under discussion with a multinational team, formed during OAD's Next Giant Leap conference on the Big Island in November, 2014, that is now working to launch an International Lunar Decade, supported by various space agencies worldwide, that will provide a framework within to coordinate future lunar missions.

In addition, a Multinational Lunar Outpost scenario has been developed through the national Aerospace States Association, and a second "Giant Leap Conference", tentatively scheduled on the Big Island in October, 2017, will engage key players from NASA, the European Space Agency (ESA), the Japan Aerospace Development Agency (JAXA), other international space organizations, aerospace corporations, development agencies and universities worldwide in developing strategic options for a lunar return.

DEVELOPING A SUSTAINABLE AEROSPACE ROADMAP FOR HAWAII (FY18-22)

To pioneer a successful and sustainable pathway toward Hawaii's future in aerospace, several key factors need to be addressed which, collectively, will help secure the most beneficial and widespread returns on investment – a key factor which both legislators and administration officials agree should be the "bottom line" driving economic development.

1. ***Gaining community consensus on both Hawaii's aerospace vision and strategic goals for development.***

   As outlined at the beginning of this report, Hawaii's strategic mid-Pacific location, Moon/Mars-like terrain, and international connectivity with space-faring nations throughout the Asia-Pacific region well position our State to play a leadership role in a variety of aerospace-related initiatives. The key to successfully leveraging these strategic advantages will be to coordinate and pool resources among leading R&D and business development institutions and organizations statewide (e.g., county offices, economic development boards, statewide educational programs, industry associations) to present a united and welcoming front to potential investors who may wish to partner with Hawaii in programs of mutual interest.

   As such, our State should work toward developing a baseline vision and set of related goals for development that can be broadcast to the global aerospace community, which in turn could help catalyze public-private partnerships to enable the sharing of complementary resources and capabilities to help reduce the costs, enhance the benefits, and (hopefully) accelerate timetables for future aerospace enterprise. Hawaii's Aerospace Advisory Committee (HAAC) and the multiple institutions and organizations represented therein could (and should) play a leadership role in this effort in coordination with DBEDT's Aerospace Office.

2. ***Defining primary capabilities and strategies required to succeed.***

   In concert with the recommendations cited above, the HAAC (considering the broad aerospace community representation on this Committee) should form a working group to identify an optimal path forward, with specific reference to key assets and procedures that could be applied/followed to expand/diversify priority components of Hawaii's aerospace sector as well as to attract external investments in Hawaii-based

development (and diversification) programs. Knowing what capabilities and strategies will be required to succeed will in turn help define and justify State funding requests to be presented to the Legislature in the Governor's annual budget.

3. ***Identifying organizational and programmatic challenges for implementation.***

This will be critical in helping articulate (and implement) a sustainable roadmap for aerospace in Hawaii. Again, the HAAC (with the wealth of aerospace knowledge and experience represented on this Committee) should be able to help identify potential roadblocks toward implementing the vision set forth in this roadmap, including both governmental regulations and procedures that may impede creative, entrepreneurial approaches to diversifying Hawaii's aerospace economy.

4. ***Establishing a tactical plan with key milestones and budget for implementation.***

OAD has been working with Hawaii government, industry, and university leaders, as well as NASA, other governmental space agencies, and industry representatives, to help define both opportunities and priorities for aerospace development statewide. This is a work in progress, and will require input/guidance from the HAAC in formulating the proposed "roadmap" with realistic timetables and milestones (which in turn will help define a budget for implementation).

5. ***Pioneering aerospace education/training programs statewide.***

Aerospace-related education and training in Hawaii's middle and high schools will be seminal to inspiring/enabling local students to obtain advanced degrees in STEM disciplines, thereby enabling Hawaii residents to pursue new employment opportunities generated through our State's expanding aerospace sector. OAD has supported (and in some cases pioneered) innovative aerospace-related programs for high school and college students, including the annual Science Bowl (sponsored by the State Dept. of Education), the Real World Design Challenge (supported by the Federal Aviation Administration and private aerospace organizations), and other programs introducing students to multiple options/opportunities for careers in aerospace, and continues to explore innovative pathways toward expanding Hawaii's leadership in this industry.

APPENDIX

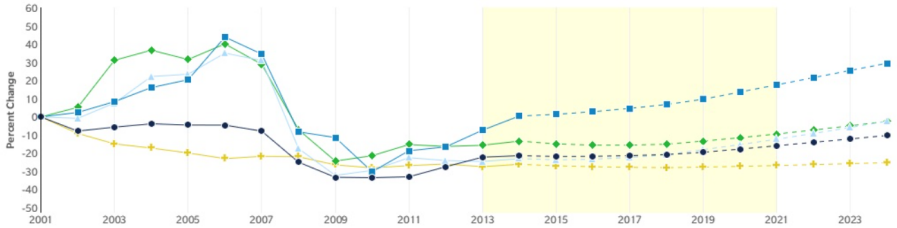
Aviation Sector Analysis

8,164	+8.1%	$78,015
Jobs (2014)	% Change (2013-2021)	Avg. Earnings Per Job (2014)
299% above National average	Nation: +0.9%	Nation: $93,216

Industry Detail

Establishments (2014)	56
Jobs Multiplier	Only Available for 6-Digit
Unemployed (11/2014)	Only Available for 2-Digit

Regional Trends



Region	2013 Jobs	2021 Jobs	% Change
Region	8,081	8,733	8.1%
Hilo, HI	451	573	26.9%
Kahului-Wailuku-Lahaina, HI	545	633	16.3%
Kapaa, HI	217	233	7.4%
United States	419,136	422,826	0.9%

Top Regional Businesses

Business Name	Industry	Local Employees
Hawaiian Airlines, Inc.	Scheduled Passenger Air Transportation (481111)	451
Aloha Air Cargo	Scheduled Freight Air Transportation (481112)	309
Island Air	Scheduled Passenger Air Transportation (481111)	157
Courier Corporation Of Hawaii	Scheduled Freight Air Transportation (481112)	130
Japan Airlines Co. Ltd.	Scheduled Passenger Air Transportation (481111)	100

Source: Equifax Business-Level Data

DISCLAIMER: Business Data by Equifax is third-party data provided by EMSI to its customers as a convenience, and EMSI does not endorse or warrant its accuracy or consistency with other published EMSI data.

Occupations Employed by this Industry

Description	Employed in Industry (2014)	% of Total Jobs in Industry (2014)
Reservation and Transportation Ticket Agents and Travel Clerks	2,025	24.8%
Aircraft Mechanics and Service Technicians	560	6.9%
Airline Pilots, Copilots, and Flight Engineers	1,283	15.7%
Flight Attendants	1,256	15.4%
Transportation Workers, All Other	761	9.3%

Industry Gender Breakdown

Gender	2014 Jobs	2014 Percent
Males	4,383	53.7%
Females	3,782	46.3%

Industry Age Breakdown

Age	2014 Jobs	2014 Percent
14-18	7	0.1%
19-24	341	4.2%
25-34	1,321	16.2%
35-44	1,859	22.8%
45-54	2,568	31.5%
55-64	1,680	20.6%
65+	389	4.8%