19-06 FINAL REPORT:

Joint Center for Aerospace Technology Innovation Sunset Review

LEGISLATIVE AUDITOR'S CONCLUSION:

The Legislature should continue the JCATI program because it is meeting legislative intent to pursue joint university-industry research, enhance the education of students, and work with aerospace firms in Washington.

December 2019

In 2012, the Legislature created the Joint Center for Aerospace Technology Innovation (JCATI) to pursue joint university-industry aerospace research, enhance the education of students, and work directly with aerospace firms in Washington. JCATI sunsets July 1, 2020, unless there is legislative action. The Sunset Act requires the Joint Legislative Audit and Review Committee (JLARC) to conduct a performance review in the year before the expiration date.

JCATI is meeting legislative intent to pursue joint university-industry aerospace research in Washington

JCATI is meeting legislative intent by achieving the three goals set for the program:

1. **Pursue university-industry research.** JCATI is administering a competitive grant program that funds university-industry aerospace research projects. Between fiscal years 2013 and 2019, it awarded $9 million for 109 grants. JCATI has also hosted annual symposiums that include presentations by students, professors, and aerospace professionals on JCATI-funded projects and emerging industry trends.
2. **Enhance the education of students.** To date, the program has provided grant funding and research opportunities for 65 professors and 392 students from the University of Washington, Washington State University, Western Washington University, and Central Washington University.
3. **Work with aerospace firms in Washington.** The grants have funded university-industry partnerships with 64 aerospace firms. Of those, 50 firms have had a presence in Washington. Grants have included at least one firm partner with a presence in Washington.

The program is efficient and economical

JCATI spends an average of 86% of its budget directly on grant awards. To reduce the administrative burden on grant applicants and recipients, it follows the established grant procedures of the National Science Foundation. Aerospace firm partners contributed the equivalent of $7 million in cash support or in-kind donations to the research efforts from fiscal years 2013 through 2019.

JCATI is unique in its focus on both Washington's aerospace industry and student education

JCATI is unique when compared to three federal grant programs that fund similar research. It is the only program that requires involvement from Washington's public four-year institutions and Washington-based aerospace firms. It is also the only one that has a requirement to enhance the education of students by working on industry-focused research.

Legislative Auditor recommends continuing the program

The Legislature should continue JCATI because it is meeting legislative intent to pursue university-industry aerospace research, enhance the education of students, and work with aerospace firms in Washington. Without legislative action, JCATI will end on July 1, 2020.

JCATI concurs with these recommendations. You can find additional information on the Recommendations tab.

Committee Action to Distribute Report

On December 4, 2019 this report was approved for distribution by the Joint Legislative Audit and Review Committee.

Action to distribute this report does not imply the Committee agrees or disagrees with the Legislative Auditor recommendations.

REPORT DETAILS
1. JCATI is meeting legislative intent

JCATI is meeting legislative intent to pursue university-industry research, enhance the education of students, and work with Washington's aerospace firms

The Legislature created the Joint Center for Aerospace Technology Innovation (JCATI) in 2012 to increase collaboration between the aerospace industry and Washington's public universities. JCATI was tasked with achieving three goals:

1. Pursue joint university-industry research in new technologies relevant to aerospace.
2. Enhance the education of students through industry-focused research.

3. Work directly with small, medium, and large[1] Washington-based aerospace firms to identify research and technology needs.

JCATI is housed at the University of Washington, overseen by a 9-person, governor-appointed board of directors, and supported by a program manager and part-time executive director.

Between fiscal years 2013 to 2019, JCATI awarded 109 research grants and hosted annual aerospace symposiums

The Legislature appropriated $3 million to JCATI in each biennium since 2012. JCATI used these funds to provide research grants and host annual aerospace symposiums.

JCATI has awarded a total of $9 million in research grants. The awards have supported:

- 109 research projects. Individual grant awards have ranged between $41,000 and $127,000. Research topics include aircraft systems, biofuels, composites, fluids and structures, manufacturing processes, space systems, and unmanned aerial vehicles. A full list of grants is in Appendix A.
- 65 professors, 226 undergraduate, and 166 graduate students from the University of Washington, Washington State University, Western Washington University, and Central Washington University.

Fifty aerospace firms with a presence in Washington have partnered with JCATI. These include small, medium, and large firms. An additional 14 firms located outside of Washington have also contributed to the research.

In addition to awarding grants, JCATI hosts annual symposiums that provide opportunities for professors, students, and aerospace professionals to network, share information on JCATI-funded research projects, and listen to speakers discussing industry trends and future research needs.

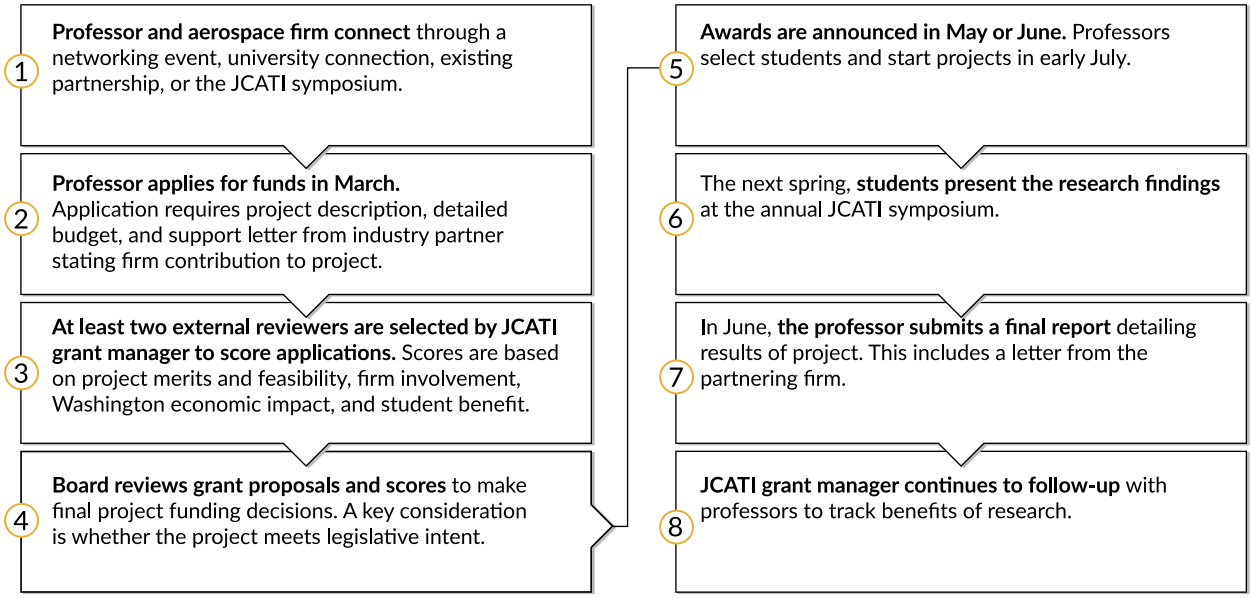
The grant application and selection process ensures joint university-industry participation in research

JCATI grants are designed to foster university-industry collaboration. A professor from a four-year public university in Washington initiates the application process by submitting a research proposal to the JCATI Board. Each proposal must include a letter from a Washington-based aerospace firm that specifies in-kind or cash contributions to support the research.

The proposals must include a plan to transfer the results of the research to the participating firm. Each JCATI grant provides one year of funding. Professors reapply each year if a project requires multiple years of funding.

[1] ❶ Small firms have less than 500 employees.
❷ Medium firms have between 500 and 1,500 employees.
❸ Large firms have over 1,500 employees.

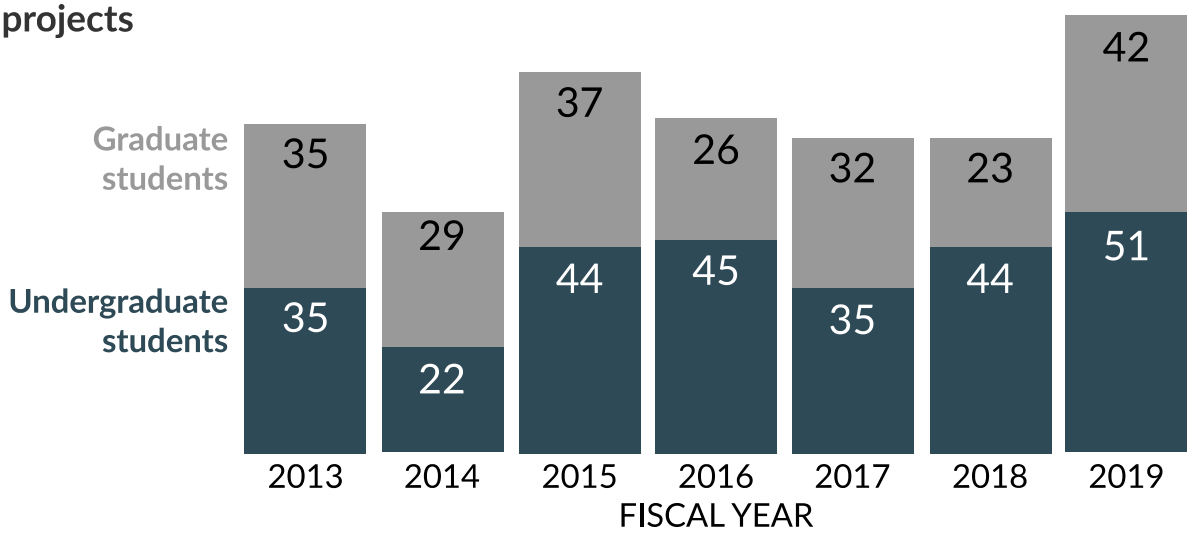
Exhibit 1.1: Grant application and selection process involves professors, industry partners, external reviewers, and board



Source: JLARC staff depiction of grant process.

JCATI enhances educational opportunities for students

Exhibit 1.2: Undergraduate and graduate students are involved in JCATI projects



Source: JLARC staff analysis of project final reports. *This chart displays number of students each year. If a student is involved in more than one funding cycle, they will be counted each year they participated.

Undergraduate and graduate students participate in the vast majority of JCATI-funded research projects. Many projects include multiple students. Six projects to date did not directly include undergraduate or graduate students, but the project team included post-doctoral researchers.

In addition to their work on industry-focused research projects, students are also expected to present the results of their research at JCATI's annual aerospace symposium.

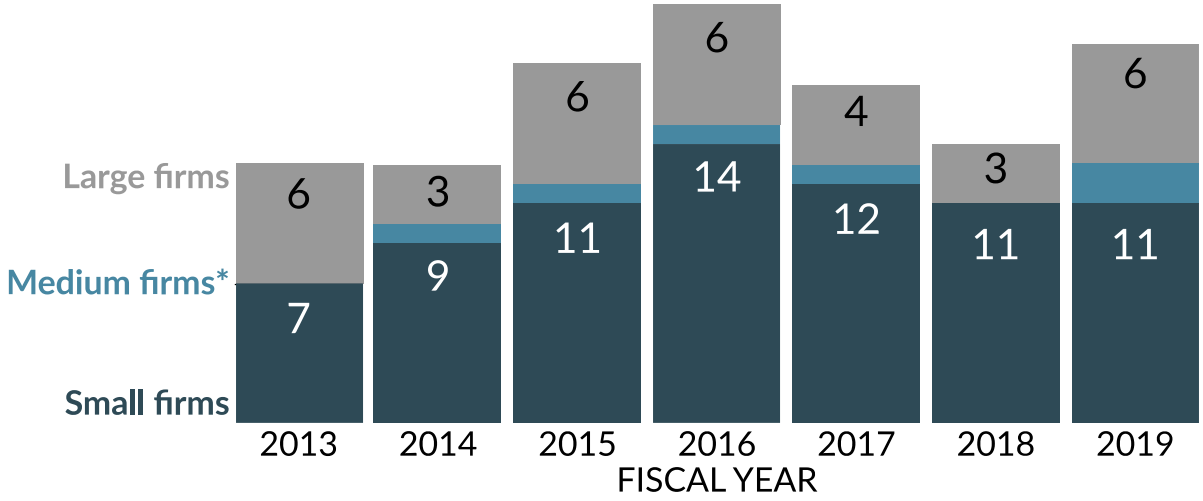
JCATI works directly with small, medium, and large aerospace firms in Washington

Firms of all sizes have participated in JCATI-funded research. JCATI uses the U.S. Small Business Administration definitions of business sizes to identify small, medium, and large firms that have an office or facility located in Washington:

- Small firms have less than 500 employees.
- Medium firms have between 500 and 1,500 employees.
- Large firms have over 1,500 employees.

To date, all of JCATI's research awards have involved one or more firms located in Washington. The full list of participating firms is in Appendix A.

Exhibit 1.3: 64 firms have been involved in JCATI-funded research



*Number of Medium Firms: 2014 = 1; 2015 = 1; 2016 = 1; 2017 = 1 2019 = 2.
Source: JCATI staff. If a firm is involved in more than one grant award, that firm will be counted more than once.

2. Program is efficient and economical

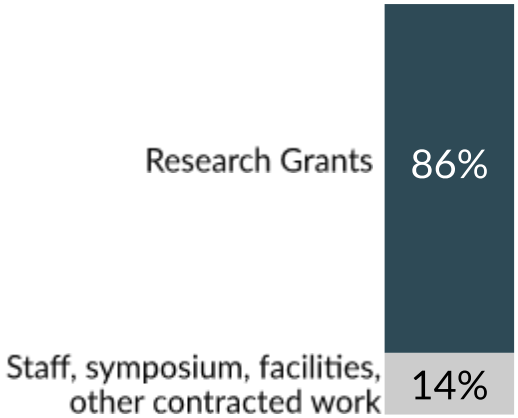
JCATI is operating in an efficient and economical manner

JCATI spends an average of 86% of its budget on grant awards

Since 2012, JCATI has received $3 million per biennium in state appropriations. This is the program's only source of funding for administration and grant awards. From fiscal years 2013 through 2019, JCATI has spent an average of 86% of its funds directly on research grant awards. The other 14% paid for staff salaries and benefits, the annual aerospace symposium, facilities, and other contract work.

JCATI has 1.2 full-time employees, including a full-time program manager and a part-time executive director.

Exhibit 2.1: Average JCATI budget allocation from FY 13-19



Source: JLARC staff analysis.

JCATI's board and staff review and oversee grant expenditures

JCATI is governed by a 9-member, governor-appointed board of directors. Per statute, board membership includes a nonvoting chair and 8 voting members who represent small, medium, and large aerospace firms, labor, aerospace industry associations, and higher education.

JCATI's board and staff review and oversee grant expenditures throughout the award cycle.

During the application and selection process:

- JCATI's request for proposals (RFP) specify the type of research that the program will fund and how those funds can be spent.
- Professors must provide an itemized budget, which is reviewed by a university representative and the JCATI program manager.
- To reduce the administrative burden on grant applicant and recipients, JCATI models the grant process after the National Science Foundation (NSF). This is an established program familiar to many professors and grant managers.
- External reviewers score the applications. The scoring criteria aligns with legislative intent and assesses the feasibility of the project with respect to time and budget.
- The JCATI Board makes final funding decisions. They discuss whether applications meet legislative intent to fund university-industry research, enhance the education of students, and advance Washington's aerospace industry.

After the awards are granted:

- Professors are required to submit a final report detailing the results of the project, including the student and firm involvement.
- Research results for all projects are presented at an annual JCATI symposium, which provides a level of accountability that the project will be completed on time and as proposed.
- The JCATI program manager continues to follow-up with professors to track whether students are involved in the aerospace industry after the JCATI project ends, if research led to technology transfer to the industry, and whether research led to other funding opportunities. JCATI describes these metrics in biennial reports to the Legislature.

Aerospace firms make in-kind or cash contributions to support research projects

To qualify for a JCATI grant, a professor from a public university in Washington must partner with at least one Washington aerospace firm that has identified a research need. Grant proposals are assessed by the amount a firm contributes to a project, as well as other factors. Firm contributions may include cash or in-kind donations, such as consulting hours, facility access, research materials and equipment, and testing services.

Exhibit 2.2: Aerospace firms must contribute to JCATI-funded research projects

Fiscal Year	Number of grant awards	JCATI grant award amounts (rounded)	Firm contribution (in-kind & cash) to grant projects (rounded)
2013	18	$1,369,000	$637,000
2014	16	$1,275,000	$1,304,000
2015	16	$1,291,000	$1,013,000
2016	15	$1,254,000	$1,075,000
2017	15	$1,318,000	$831,000
2018	13	$1,105,000	$1,025,000
2019	16	$1,438,000	$827,000*

***In-kind contributions reported as of August 2019.**

Source: JCATI performance measurement reports, JCATI staff, and JLARC staff analysis of project proposals.

JCATI grants are worth more than face value to professors because universities waive indirect costs and graduate student tuition

JCATI maintains a cost sharing agreement with universities that prohibits using grant funds to pay for indirect costs or graduate student tuition. As a result, JCATI grants are worth more than their face value to the professors leading the projects.

Exhibit 2.3: Estimated JCATI grant award value for FY 17-18

JCATI AWARD FY 17-18	$2,423,000
INDIRECT COSTS WAIVED	+ $1,171,000
GRADUATE TUITION WAIVED	+ $475,000
TOTAL	$4,069,000

Source: JLARC staff analysis.

Exhibit 2.3 shows that JCATI grant awards totaling $2,423,000 for fiscal years 2017-18 are actually worth $4,069,000 when waived costs are considered. For fiscal years 2017 and 2018, JCATI estimates that the total amount of waived costs and fees for its grant awards was $1,646,000. While this waiver is a benefit to the professors, university grant administrators report that the universities still incur these costs and absorb them within their own budgets.

3. Unique focus on WA aerospace

Unlike other major grant programs, JCATI is specifically focused on research that supports Washington's aerospace industry

JCATI is unique compared to three federal grant programs that fund aerospace research

JLARC staff compared JCATI grants to three federal grant programs run by the National Science Foundation (NSF), Department of Defense (DoD), and Small Business Technology Transfer (STTR). University professors and grant managers in Washington commonly cited these three programs as sources of funding for aerospace research.

- **NSF**: A federal agency created to advance the nation's health, prosperity, and welfare by supporting research and education in all fields of science and engineering.
- **DoD**: A federal agency that manages the military forces needed to protect national security interests. Several agencies under the DoD offer grants for research, including the Defense Advanced Research Projects Agency (DARPA) and Office of Naval Research (ONR).
- **STTR**: A federal program that is focused on expanding public/private sector partnerships by requiring small businesses to formally collaborate with research institutions in order to

receive federal grant funds. The main goal of the program is to bridge the gap between basic science research and the commercialization of resulting innovations.

JCATI is unique when compared to these three federal programs. It is the only one that requires:

- Professors from a Washington four-year, public higher education institution.
- At least one industry partner with a presence in Washington.
- Projects must have a benefit and impact in Washington.

JCATI also differs from these programs in its exclusive focus on aerospace research and its requirement to enhance the education of university students.

Exhibit 3.1: JCATI is unique in its focus on supporting Washington's aerospace industry and university students

	JCATI	NSF	DoD	STTR
State program	✓			
Federal program		✓	✓	✓
Research must benefit WA	✓			
Professor must be at a public, four-year institution in WA	✓			
Grant open to a national pool of researchers		✓	✓	✓
Requires an aerospace industry partner located in WA	✓			
Program goal to enhance student education	✓			
Length of grant	1 year	2-5 years	2-5 years	1-3 years
Time from proposal submission to award notification	3 months	6-9 months	6-9 months	6-9 months

Source: JLARC staff comparison of state and federal grant programs.

JLARC staff did not find similar programs in other states

JLARC staff worked with the National Council of State Legislatures (NCSL) to review other states' aerospace research programs. NCSL did not identify any other state programs similar to JCATI. In 2017, California's legislature introduced a proposal to fund a similar research program, but no program has been established yet.

4. Answers to questions in Sunset Act

The Legislature should continue the JCATI program because it is meeting legislative intent

The Sunset Act directs JLARC to consider four questions

The 2012 legislation that created JCATI (SB 5982) included a sunset clause. Programs included within the Sunset Act (RCW 43.131) will terminate on a specified date without further legislative action. In the year prior to termination, JLARC staff are required to conduct a performance audit of the program to answer the following four questions:

1. **Has JCATI complied with legislative intent?**

   Yes. The JCATI Board and program staff have developed the program around its three legislative goals: to pursue university-industry research, enhance the education of students, and work with Washington's aerospace firms. JCATI has made funding decisions to advance these goals.

2. **Does JCATI provide for efficient and economical management of research grants?**

   Yes. JCATI spends an average of 86% of its budget directly on aerospace grants. The rest is used to pay for staff salaries and benefits, the annual aerospace symposium, facilities, and other contract work.

   To reduce the administrative burden on grant applicants and recipients, JCATI follows the National Science Foundation grant procedures. These are well established and familiar to many university researchers and grant managers.

3. **Has JCATI achieved expected performance measures?**

   Yes. JCATI has three performance measures that it annually tracks and reports to JLARC:

   1. **Number of small, medium and large firms participating in projects.** 64 firms have participated in JCATI-funded projects. Fifty firms had a presence in Washington and all projects had at least one Washington firm partner. The majority of firms are classified as small, with less than 500 employees.
   2. **Number of students involved in projects.** 226 undergraduate and 166 graduate students from University of Washington, Washington State University, Western Washington University, and Central Washington University have participated in JCATI-funded projects.
   3. **Amount of in-kind contributions**. Firms have contributed the equivalent of $7 million in the form of cash, consultation, materials, facility space, and testing to the projects.

4. **Is JCATI duplicative of activities by another entity?**

No. While there are other grant programs that fund research at four-year institutions, those programs are not specifically focused on Washington's aerospace industry, oriented towards enhancing the education of students, and require a university-industry partnership.

Appendix A: JCATI grants awarded from fiscal years 2013 to 2019

JCATI awarded 109 grants since program began

Exhibit A1: Summary of JCATI grant awards from fiscal years 2013 to 2019

Click on a column heading to sort by that column.

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
2016	WSU	Ahring, Birgitte	3 Rivers Catalyst; Clean Vantage LLC	An innovative new pathway for producing cost-effective aviation biofuels from woody biomass with high product yields	Biofuels	$99,961
2016	WSU	Bandyopadhyay, Amit	Aerojet Rocketdyne	Additive manufacturing of bimetallic and porous materials for space applications	Manufacturing processes; Space systems	$65,769
2017	WSU	Bandyopadhyay, Amit	Aerojet Rocketdyne	Additive manufacturing of multi-material structures for space application	Manufacturing processes	$69,548
2013	WSU	Bandyopadhyay, Amit	Aerojet Rocketdyne	Additive manufacturing of Aerojet's propellant tank and ceramic components	Manufacturing processes; Space systems	$59,561
2014	WSU	Bandyopadhyay, Amit	Aerojet Rocketdyne	Additive manufacturing of high temperature composites and bimetallic structures for Aerojet's environmentally	Manufacturing processes; Space systems	$68,693

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
				sustainable rocket engines		
2014	WSU	Banerjee, Soumik	The Boeing Company	Design of molecularly tailored electrolytes for high performance lithium batteries	Aircraft systems	$69,279
2019	UW	Boyle, Linda	Esterline	Capturing workload and stress among commercial aircraft pilots to enhance pilot-aircraft interfaces	Aircraft systems	$99,884
2018	UW	Boyle, Linda	Esterline	The effectiveness of an immersive operator control station to enhance situation awareness	Aircraft systems	$99,442
2014	WSU	Chaudhuri, Santanu	The Boeing Company	High performance aerospace alloys: corrosion resistant microstructure design toolkit	Fluids & Structures	$90,000
2013	WSU	Chaudhuri, Santanu	Triumph Composite Systems	Combined computational/experimental approach to optimize manufacturing process of carbon reinforced composite parts to improve mechanical/corrosion performance	Composites; Manufacturing processes	$100,000
2015	UW	Dabiri, Dana	The Boeing Company	Development of high resolution wall pressure and wall shear stress measurement system	Fluids & Structures	$81,000
2013	UW	Devasia, Santosh	The Boeing Company; HEATCON	Embedded sectional heater for temperature control of composite-damage repair	Composites; Manufacturing processes	$48,290

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
2017	WSU	Englund, Karl	Global Fiberglass Solutions; Zoltek	Integration of recycled thermoplastic and thermoset based carbon fiber reinforced composites into value-added composites	Composites; Manufacturing processes	$74,696
2015	WSU	Englund, Karl	Triumph Composite Systems	Recycling of carbon reinforced thermoplastic composite wastes for the aerospace industry	Composites; Manufacturing processes	$72,540
2013	UW	Feraboli, Paolo	Automobili Lamborghini SpA	Forged composite technology for aerospace industry in Washington state	Composites; Manufacturing processes	$81,109
2017	UW	Ferrante, Antonio	The Boeing Company	Direct numerical simulation of an aft-body flow	Fluids & Structures	$88,477
2015	WSU	Garcia-Perez, Manuel	Conrad Industries; The Boeing Company	Production and testing of aviation fuel formed by blends of hydrotreated renewable jet and hydrotreated pyrolytic oil cuts	Biofuels	$70,772
2018	WWU	Gill, David	Zodiac Aerospace	Reducing flagging and fraying in composite sandwich panel machining	Composites; Manufacturing processes	$78,928
2015	WSU	Heo, Deukhyoun	The Boeing Company; Linear Signal; Teramics LLC	Energy-efficient linear beamforming receiver for airborne wireless communications	Aircraft systems	$63,000
2018	WSU	Heo, Deukhyoun	The Boeing Company	Phased array beamformers and low-noise power management systems	Aircraft systems	$80,000

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
				for future system-on-chip (SOC) application		
2019	WSU	Heo, Deukhyoun	The Boeing Company	Highly linear and energy-efficient frequency-tunable beamforming transceiver for airborne phased-array communications	Aircraft systems	$80,000
2013	WWU	Hoekstra, Nicole	Zodiac Aerospace	Characterization of composite panel manufacturing for aerospace applications	Composites; Manufacturing processes	$100,000
2015	WWU	Hoekstra, Nicole	Zodiac Aerospace	Development of fasteners for aircraft interiors	Composites; Manufacturing processes	$100,000
2018	UW	Hwang, Jenq-Neng	Robodub	Camera self-calibration for drone autopilot	Unmanned aerial vehicle	$57,675
2015	UW	Jen, Alex	The Boeing Company	Detection of mechanical and thermal damage in carbon fiber composites using fluorescence imaging	Composites; Manufacturing processes	$100,000
2016	UW	Jen, Alex	The Boeing Company	Detection of mechanical and thermal damage in carbon fiber composites using fluorescence imaging	Composites; Manufacturing processes	$92,728
2016	WSU	Kessler, Michael	International Polyol Chemicals, Inc. (IPCI)	Bio-based acrylonitrile for low-cost, renewable carbon fiber	Composites; Manufacturing processes	$84,060
2017	WSU	Kessler, Michael	International Polyol	Catalytic conversion of lignocellulosic sugar to	Composites;	$98,867

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
			Chemicals, Inc. (IPCI)	acrylonitrile for low-cost renewable carbon fiber	Manufacturing processes	
2013	WSU	Kim, Dave	The Boeing Company	Characterization and mitigation of drilled composite surface defects in aircraft assembly	Composites; Manufacturing processes	$41,634
2015	UW	Knowlen, Carl	EnergeticX LLC	Baffled-tube ram accelerator technology development	Aircraft systems	$85,200
2017	UW	Knowlen, Carl	HyperSciences, Inc.; Systima Technologies	High pressure baffled-tube ram accelerator	Space systems	$87,766
2014	UW	Kramlich, John	Imperium Renewables, Inc.; E3 Energy Partners; The Boeing Company	Advanced bio-derived aviation fuel combustion: particulate emissions, NOx1 and flame stability	Biofuels	$81,527
2013	UW	Kramlich, John	The Boeing Company; Imperium Renewables, Inc.; E3 Energy Partners Consulting Engineers	Emissions and combustion stability of advanced bio-derived aviation fuels	Biofuels	$85,074
2015	UW	Kurosaka, Mitsuru	Aerojet Rocketdyne; OptiNav, Inc.; GHKN Engineering	The continuous rotating detonation engine for propulsion	Aircraft systems	$85,000
2016	WWU	Larson, Nicole	Zodiac Aerospace	Characterization of prepreg materials using destructive and non-destructive testing	Composites; Manufact	$99,902

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
					uring processes	
2013	WSU	Leachman, Jacob	Aerojet Rocketdyne	Characterization facility for gelled cryogenic fuels	Space systems	$50,000
2019	WSU	Leachman, Jacob	Blue Origin	Development of a material test stand for new-age cryogenic fuel bladders	Aircraft systems	$100,000
2015	WSU	Leachman, Jacob	Insitu	Development of an insulation-free cryogenic hydrogen fuel tank for ScanEagle	Manufacturing processes; Unmanned aerial vehicle	$75,000
2016	WSU	Leachman, Jacob	Insitu	Liquid hydrogen fueled ScanEagle Phase II: reducing tank manufacturing cost and increasing the efficiency of small-modular hydrogen liquifaction	Manufacturing processes; Unmanned aerial vehicle	$75,000
2017	WSU	Leachman, Jacob	Insitu	Liquid hydrogen fueled ScanEagle Phase III: ground support liquefier development	Manufacturing processes; Unmanned aerial vehicle	$100,000
2014	WSU	Lei, Hanwu	MS Sustainables LLC; USS International Group LLP; Gen-X Energy Group	Aromatic hydrocarbons for aviation biofuels from lignocellulosic biomass	Biofuels	$89,984
2015	WSU	Lei, Hanwu	MS Sustainables LLC; USS International	Hydrogen saving process for cycloalkanes in jet fuels from diverse	Biofuels	$80,000

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
			Group LLP; Gen-X Energy Group	Washington state forest biomasses		
2013	WSU	Liu, Chen-Ching	The Boeing Company	Developing a battery-extender auxiliary power unit (BE-APU) for next-generation commercial airplanes	Aircraft systems	$84,930
2014	WSU	Liu, Chen-Ching	The Boeing Company	Developing a battery-extender auxiliary power unit (BE-APU) for next-generation commercial airplanes	Aircraft systems	$127,000
2015	WSU	Liu, Chen-Ching	The Boeing Company	Developing a battery-extender auxiliary power unit (BE-APU) for next-generation commercial airplanes: Phase 3-Real-Time Validation	Aircraft systems	$100,000
2019	WSU	Liu, Hang	Cascade Quality Molding	Manufacturing injection molded aerospace interior parts using lightweight thermoplastic polymer composites	Composites; Manufacturing processes	$92,004
2018	WSU	Liu, Tian	Ultra Polymers	Lightweight high-performance polymers for aerospace interiors	Composites; Manufacturing processes	$55,000
2016	UW	Lum, Christopher	Hood Technology Corporation; Insitu; Sagetech; Advanced Navigation Positioning Corporation	Specialization, testing and integration of NextGen technologies on unmanned aerial systems	Unmanned aerial vehicle	$84,311

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
2014	UW	Lum, Christopher	Insitu	Collaboration and control of multiple unmanned aerial systems	Unmanned aerial vehicle	$85,460
2019	UW	Lum, Christopher	The Boeing Company	Experimental validation of flow field measurements for swept wings with ice accretitations	Fluids & Structures	$80,951
2013	WSU	Lynn, Kelvin	The Boeing Company	Positrons in shape memory NiTi alloys	Fluids & Structures	$93,435
2018	UW	MacKenzie, Devin	The Boeing Company	Printed flexible thermocouple arrays for improved aerospace safety monitoring and manufacturing	Composites; Manufacturing processes	$93,417
2014	UW	Mamidala, Ramulu	The Boeing Company	Positrons in shape memory NiTi alloys	Fluids & Structures	$66,945
2019	UW	Mamishev, Alex	Aerojet Rocketdyne	Electrohydrodynamic propulsion and control of aerial vehicles	Aircraft systems	$90,000
2018	UW	Mamishev, Alex	GT Engineering	Detection of incipient heat damage in composite materials	Composites	$91,200
2019	WSU	Matveev, Konstantin	Applewhite Aero	Precision aerial delivery via low-weight, low-cost UAS	Unmanned aerial vehicle	$92,468
2013	UW	McCormack, Edward	Aerovel	Snow depths from the heights: developing a mission-specific civilian unmanned aircraft system for sensing the mountain snowpack	Unmanned aerial vehicle	$91,533
2018	WWU	Misasi, John	Zodiac Aerospace	Scalable formulation of aerospace interior resins	Composites; Manufacturing processes	$88,878

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
2019	WWU	Misasi, John	Zodiac Aerospace	Demonstration of benzoxazine prepregs for aircraft interior composites	Composites; Manufacturing processes	$92,687
2016	UW	Morgansen, Kristi	Aerojet Rocketdyne	High power SEP for autonomous spacecraft operations	Space systems	$85,025
2014	UW	Morgansen, Kristi	Aerojet Rocketdyne	Advanced altitude control for solar electric propulsion spacecraft: analysis, modeling and simulations	Space systems	$90,000
2015	UW	Morgansen, Kristi	Aerojet Rocketdyne	Guidance, navigation and control autonomy for asteroid sample return missions for solar electric propulsion spacecraft	Space systems	$68,570
2018	UW	Morgansen, Kristi	Fizikl	Autonomous warehouse physical inventory using multiple quadrotors	Unmanned aerial vehicle	$99,127
2017	UW	Morgansen, Kristi	Robodub	Modeling and control of a shape actuated quadrotor	Unmanned aerial vehicle	$95,357
2016	UW	Narang, Anshu	Safran Engineering Services	Continuation based trim and stability analysis for airworthiness certification of transport category airplanes	Aircraft systems	$77,097
2019	WSU	Nassiri, Somayeh	Global Fiberglass Solutions	Processing method and performance database for carbon fiber composite reinforced polymeric concrete	Composites; Manufacturing processes	$80,000

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
2013	UW	O'Donnell, Matt	The Boeing Company	Multimode laser ultrasonics: precise measurement of ultrasound characteristics for composite structure evaluation	Composites; Manufacturing processes	$77,725
2017	WWU	Peyron, Mark	Zodiac Aerospace	Transitioning new and re-invented thermoset resins from the lab into aerospace composites	Composites; Manufacturing processes	$99,500
2013	UW	Mamidala, Ramulu	The Boeing Company	Real-time inspection while drilling composites	Composites; Manufacturing processes	$67,929
2017	UW	Reynolds, Matt	Echodyne	Reconfigurable airborne radar imaging with dynamic metamaterial antennas	Aircraft systems	$99,899
2014	WWU	Rider, David	Zodiac Aerospace	Next generation resins for aerospace composites in Washington	Composites; Manufacturing processes	$90,000
2014	WSU	Ringo, John	The Boeing Company; Jazz Semiconductor; Linear Signal	Beamforming receiver for mobile aircraft communication - a CDIDIC related project	Aircraft systems	$90,000
2013	WSU	Ringo, John	Linear Signal	Beamforming receiver for mobile aircraft communications - a CDADIC related project	Aircraft systems	$75,000
2019	WSU	Roy, Sandip	Echodyne; Prescient Designs	Analytics for airspace intruder identification	Aircraft systems	$100,000

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
2017	UW	Roy, Sumit	Insitu	Advancing state-of-the-art UAS networking and communication with software defined radios	Unmanned aerial vehicle	$97,324
2019	UW	Rudell, Jacques Christophe	The Boeing Company	Integrated CMOS millimeter-wave phased array transceivers with highly-digital elements and self-interference cancellation for radar and communication applications	Aircraft systems	$100,000
2015	UW	Rudell, Jacques Christophe	The Boeing Company; Marvell Semiconductor	Area and power optimization techniques for ultra-wideband CMOS mm-wave transceivers	Aircraft systems	$85,000
2019	UW	Salviato, Marco	Composite Technology Recycling Center; Chomarat; ES3	Design and development of non-conventional, damage tolerant and recyclable structures based on discontinuous fiber composites	Composites; Manufacturing processes	$100,000
2014	UW	Shen, I-Yeu	The Boeing Company	Development of lead zirconate titanate (PZT)-silane nano-composite thing film sensors	Composites; Manufacturing processes	$57,374
2013	UW	Shi, Richard	The Boeing Company	High sensitivity optical receiver	Aircraft systems	$99,661
2014	UW	Shi, Richard	The Boeing Company	High sensitivity plastic fiber optical tranceivers	Aircraft systems	$87,026
2014	UW	Slough, John	MSNW LLC	Test facility for insulator materials employed in space propulsion, power and communication	Space systems	$81,000

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
2014	WSU	Smith, Lloyd	The Boeing Company	The effect of bond line thickness variation on joint strength	Composites; Manufacturing processes	$52,813
2015	WSU	Smith, Lloyd	The Boeing Company	Material property effects on the fatigue behavior of adhesively bonded joints	Composites; Manufacturing processes	$73,668
2019	UW	Subramanian, Venkat	BAE Systems; WiBotic	Model-based BMS and pack design for current and next generation lithium batteries for aerospace applications	Aircraft systems	$100,000
2019	WSU	Swensen, John	HeliTrak	Real-time extraction of helicopter analog gauge data using deep neural networks	Aircraft systems	$80,775
2013	UW	Taya, Minoru	Toray Composite Materials America, Inc.; Nabtesco Aerospace, Inc.	Development of low-cost and reliable joining method for composite structures by fe-based shape memory alloy	Composites; Manufacturing processes	$92,144
2017	UW	Taya, Minoru	Toray Composite Materials America, Inc.; Quest Integrated	Development of a new structural health monitoring based on magnetic nanoparticle-tagged polymer composites by magneto-optic image method	Composites; Manufacturing processes	$73,253
2017	WSU	Taylor, Matthew	Applewhite Aero	Precision aerial delivery via low-weight, low-cost UAS	Unmanned aerial vehicle	$75,000
2018	WSU	Taylor, Matthew	Applewhite Aero	Precision aerial delivery via low-weight, low-cost UAS	Unmanned aerial vehicle	$79,441

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
2014	UW	Tuttle, Mark	The Boeing Company; HEATCON	Embedded sectional heater for temperature control of composite-damage repair	Composites; Manufacturing processes	$47,500
2015	UW	Tuttle, Mark	The Boeing Company; HEATCON	Embedded sectioned heating at bond-line for composite-damage repair	Composites; Manufacturing processes	$51,927
2018	UW	Vagners, Juris	Hood Technology Corporation; Sagetech; Insitu; Advanced Navigation Positioning Corporation	UAV operations in GPS denied skies	Unmanned aerial vehicle	$87,223
2019	UW	Waas, Tony	Blue Origin; MTorres; Toray Composite Materials America, Inc.	Manufacturing and buckling study of curved steered sandwich panels using automated fiber placement (AFP) and out-of-autoclave (OOA) for space launch vehicles	Composites; Manufacturing processes	$99,000
2018	UW	Waas, Tony	Electroimpact	Design and processing tools for advanced automated fiber placement (AFP) Technology	Composites; Manufacturing processes	$99,999
2016	WSU	Wang, Jinwu	Forest Concepts, LLC; Weyerhaeuser	Mechanical pretreatment to produce cellulosic sugars on a demonstration scale	Biofuels	$60,324
2015	WSU	Wang, Jinwu	Forest Concepts,	Mechanical pretreatment to	Biofuels	$98,929

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
			LLC; Boise Cascade	produce cellulosic sugars at a pilot scale		
2017	UW	Winglee, Robert	Aerojet Rocketdyne; Eagle Harbor Technologies	Pulsed plasma thruster for small satellites and upper atmospheric UAVs	Space; Unmanned aerial vehicle	$100,000
2016	UW	Winglee, Robert	Aerojet Rocketdyne; Andrews Space; Tethers Unlimited; Eagle Harbor Technologies	Advanced CubeSat system development	Space systems	$100,000
2013	UW	Winglee, Robert	Eagle Harbor Technologies	Enhancing electric propulsion systems in Washington state	Space systems	$49,850
2019	WSU	Yang, Bin	Mercurius Biofuels LLC	Lignin-based jet fuel pilot plant	Biofuels	$50,000
2016	WSU	Yang, Bin	The Boeing Company	Catalytic upgrading of biomass-derived lignin to new biojet fuel and its qualification and performance testing	Biofuels	$93,523
2017	UW	Yang, JK	Think Composites; Chomarat; Toray Composite Materials America, Inc.	Development of high performance ductile composites based on hybrid C-ply technology	Composites; Manufacturing processes	$73,000
2016	UW	Yang, JK	Think Composites; Toray Composite Materials America, Inc.; Chomarat	Design and fabrication of composite wing structures using non-conventional C-ply technology	Composites; Manufacturing processes	$70,000

Fiscal Year	School	Professor	Industry Partners	Project Title	Research Category*	Amount of Grant Award
2016	WSU	Zhang, Jinwen	Global Fiberglass Solutions	Mild chemical recycling of carbon fiber reinforced thermoset waste and full utilization of recyclates	Composites; Manufacturing processes	$87,020
2017	WSU	Zhang, Jinwen	Global Fiberglass Solutions	Mild chemical recycling of carbon fiber reinforced thermoset wastes and application development of full utilization of the recyclates	Composites; Manufacturing processes	$85,777
2016	WSU	Zhang, Xiao	InnovaTek	A novel pathway to convert lignin to jet fuel and carbon fiber precursors: optimizing conversion yield	Biofuels	$79,115
2013	WSU	Zhong, Katie	N/A	Bio-based solid polymeric electrolytes for a safer higher performance lithium ion battery, critically needed for future generations of commercial aircraft	Aircraft systems	$71,479
2018	WSU	Zhong, Katie	UniEnergy Technologies	A gummy electrolyte with damage-tolerance and thermal-protection capabilities for safer li-ion batteries	Aircraft systems	$94,457
2019	CWU (capstone project)	Johnson, Craig	The Boeing Company	Recycle processor for commercial aircraft wing trimmings	Composites; Manufacturing processes	$5,000
2018	CWU (capstone project)	Johnson, Craig	The Boeing Company	Recycle processor for 777 wing trimmings	Composites; Manufacturing processes	$5,000

Source: JCATI staff.

* Descriptions of research categories

- **Aircraft systems** refers to the primary systems that can be found on most airplanes, including engine, propulsion, auxiliary power unit, flight control, electrical, communication, and environmental control systems.
- **Biofuels** are transportation fuels made from biomass.
- **Composites** are defined as two or more materials that are combined to achieve superior performance than what is possible with the starting materials.
- **Fluids and structures** is the field of studying the interaction of a structure with an internal or surrounding fluid.
- **Manufacturing processes** are the steps through which raw materials are transformed and assembled into an aircraft.
- **Space systems** refers to any project related to outer space.
- **Unmanned Aerial Vehicles (UAV)** do not have a pilot on-board and are controlled remotely.

Appendix B: Applicable statutes

JCATI's enabling statute and Sunset Act provisions

Joint center for aerospace technology innovation.

RCW 28B.155.010

(1) The joint center for aerospace technology innovation is created to:

(a) Pursue joint industry-university research in computing, manufacturing efficiency, materials/structures innovation, and other new technologies that can be used in aerospace firms;

(b) Enhance the education of students in the engineering departments of the University of Washington, Washington State University, and other participating institutions through industry-focused research; and

(c) Work directly with existing small, medium-sized, and large aerospace firms and aerospace industry associations to identify research needs and opportunities to transfer off-the-shelf technologies that would benefit such firms.

(2) The center shall be operated and administered as a multi-institutional education and research center, conducting research and development programs in various locations within Washington under the joint authority of the University of Washington and Washington State University. The initial administrative offices of the center shall be west of the crest of the Cascade mountains. In order to meet aerospace industry needs, the facilities and resources of the center must be made available to all four-year institutions of higher education as defined in RCW 28B.10.016.

Resources include, but are not limited to, internships, on-the-job training, and research opportunities for undergraduate and graduate students and faculty.

(3) The powers of the center are vested in and shall be exercised by a board of directors. The board shall consist of nine members appointed by the governor. The governor shall appoint a nonvoting chair. Of the eight voting members, one member shall represent small aerospace firms, one member shall represent medium-sized firms, one member shall represent large aerospace firms, one member shall represent labor, two members shall represent aerospace industry associations, and two members shall represent higher education. The terms of the initial members shall be staggered.

(4) The board shall hire an executive director. The executive director shall hire such staff as the board deems necessary to operate the center. Staff support may be provided from among the cooperating institutions through cooperative agreements to the extent funds are available. The executive director may enter into cooperative agreements for programs and research with public and private organizations including state and nonstate agencies consistent with policies of the participating institutions.

(5) The board must:

(a) Work with aerospace industry associations and aerospace firms of all sizes to identify the research areas that will benefit the intermediate and long-term economic vitality of the Washington aerospace industry;

(b) Identify entrepreneurial researchers to join or lead research teams in the research areas specified in (a) of this subsection and the steps the University of Washington and Washington State University will take to recruit such researchers;

(c) Assist firms to integrate existing technologies into their operations and align the activities of the center with those of impact Washington to enhance services available to aerospace firms;

(d) Develop internships, on-the-job training, research, and other opportunities and ensure that all undergraduate and graduate students enrolled in an aerospace engineering curriculum have direct experience with aerospace firms;

(e) Assist researchers and firms in safeguarding intellectual property while advancing industry innovation;(f) Develop and strengthen university-industry relationships through promotion of faculty collaboration with industry, and sponsor at least one annual symposium focusing on aerospace research in the state of Washington;

(g) Encourage a full range of projects from small research projects that meet the specific needs of a smaller company to large scale, multipartner projects;

(h) Develop nonstate support of the center's research activities through leveraging dollars from federal and private for-profit and nonprofit sources;

(i) Leverage its financial impact through joint support arrangements on a project-by-project basis as appropriate;

(j) Establish mechanisms for soliciting and evaluating proposals and for making awards and reporting on technological progress, financial leverage, and other measures of impact;

(k) By June 30, 2013, develop an operating plan that includes the specific processes, methods, or mechanisms the center will use to accomplish each of its duties as set out in this subsection; and

(l) Report biennially to the legislature and the governor about the impact of the center's work on the state's economy and the aerospace sector, with projections of future impact, providing indicators of its impact, and outlining ideas for enhancing benefits to the state. The report must be coordinated with the governor's office , and the department of commerce.

[2014 c 174 § 3; 2014 c 112 § 102; 2012 c 242 § 1.]

NOTES:Reviser's note: This section was amended by 2014 c 112 § 102 and by 2014 c 174 § 3, each without reference to the other. Both amendments are incorporated in the publication of this section under RCW 1.12.025(2). For rule of construction, see RCW 1.12.025(1).

Sunset Act application: See note following chapter digest.

Intent—2014 c 174: See note following RCW 28B.50.902.

Sunset Act: Findings. (Expires June 30, 2025.)

RCW 43.131.020

The state legislature finds that state entities may fail to deliver services as effectively and efficiently as is expected by the general public and as originally contemplated by the legislature. It further finds that state government actions have produced a substantial increase in numbers of entities, growth of programs, and proliferation of rules, and that the entire process has evolved without sufficient legislative and executive oversight, regulatory accountability, or a system of checks and balances. The legislature further finds that by establishing a system for the termination, continuation, or modification of state entities, coupled with a system of scheduled review of such entities, it will be in a better position to: Evaluate the need for the continued existence of existing and future state entities; assess the effectiveness and performance of agencies, boards, commissions, and programs; and ensure public accountability. The legislature recognizes that the executive branch shares in this duty and responsibility to assure that state government operates in an efficient, orderly, and responsive manner.

[2000 c 189 § 1; 1977 ex.s. c 289 § 2.]

Sunset Act: Program and fiscal review—Reports. (Expires June 30, 2025.)

RCW 43.131.051

The joint legislative audit and review committee shall conduct a program and fiscal review of any entity scheduled for termination under this chapter. This program and fiscal review shall be completed and a preliminary report prepared during the calendar year prior to the date established for termination. These reports shall be prepared in the manner set forth in RCW

44.28.071 and 44.28.075. Upon completion of its preliminary report, the joint legislative audit and review committee shall transmit copies of the report to the office of financial management and any affected entity. The final report shall include the response, if any, of the affected entity and the office of financial management in the same manner as set forth in RCW 44.28.088, except the affected entity and the office of financial management shall have sixty days to respond to the report. The joint legislative audit and review committee shall transmit the final report to the legislature, to the state entity affected, to the governor, and to the state library.

[2000 c 189 § 4.]

Sunset Act: Scope of review—Recommendations to the legislature. (Expires June 30, 2025.)

RCW 43.131.071

(1) In conducting the review of an entity, the joint legislative audit and review committee shall determine the scope and objectives of the review and consider, but not be limited to, the following factors, if applicable:

(a) The extent to which the entity has complied with legislative intent;

(b) The extent to which the entity is operating in an efficient and economical manner which results in optimum performance;

(c) The extent to which the entity is operating in the public interest by controlling costs;

(d) The extent to which the entity duplicates the activities of other entities or of the private sector;

(e) The extent to which the entity is meeting the performance measures developed under RCW 43.131.061; and

(f) The possible impact of the termination or modification of the entity.

(2) After completing the review under subsection (1) of this section, the committee shall make its recommendations to the legislature.

[2000 c 189 § 6.]

Sunset Act: Joint center for aerospace technology innovation—Termination.

RCW 43.131.417

The joint center for aerospace technology innovation shall be terminated July 1, 2020, as provided in RCW 43.131.418.

[2013 2nd sp.s. c 24 § 2; 2012 c 242 § 3.]

Sunset Act: Joint center for aerospace technology innovation—Repeal.

RCW 43.131.418

The following acts or parts of acts, as now existing or hereafter amended, are each repealed, effective July 1, 2021:

(1) RCW 28B.155.010 and 2014 c 112 s 102 & 2012 c 242 s 1; and

(2) RCW 28B.155.020 and 2012 c 242 s 2.

[2014 c 112 § 122; 2013 2nd sp.s. c 24 § 3; 2012 c 242 § 4.]

RECOMMENDATIONS & RESPONSES
Legislative Auditor Recommendation

The Legislative Auditor recommends continuing JCATI

Recommendation: The Legislature should continue JCATI because the legislative intent to pursue industry-university aerospace research, enhance the education of students, and work with aerospace firms in Washington is being met.

Without this legislative action, JCATI will end.

Legislation Required:	Yes. Absent specific action by the Legislature, Chapter 28B.155 will expire July 1, 2020.
Fiscal Impact:	$3 million a biennium if funded at current level
Implementation Date:	June 30, 2020
Agency Response:	JCATI concurs

JCATI Response

October 21, 2019

Keenan Konopaski
Legislative Auditor
Joint Legislative Audit and Review Committee
106 11th Ave SW
PO Box 40910
Olympia, WA 98504-0910

Dear Mr. Konopaski,

The Joint Legislative Audit and Review Committee's (JLARC) Sunset Review of the Joint Center for Aerospace Technology Innovation (JCATI) recommended :

"The Legislature should continue JCATI because the legislative intent to pursue industry-university aerospace research, enhance the education of students, and work with aerospace firms in Washington is being met"

As JCATI Executive Director, I concur with JLARC's recommendation.

We very much appreciate the time and effort put forth by the JLARC auditors during our sunset review.

Sincerely,

Mehran Mesbahi
JCATI Executive Director

236 AERB, Box 352250, Seattle, WA 98195-2250
206.685.8063 www.jcati.org

Current Recommendation Status

The Legislative Auditor recommendation was implemented in the 2020 legislative session. RCW 43.1361.417.

MORE ABOUT THIS REVIEW
Audit Authority

The Joint Legislative Audit and Review Committee (JLARC) works to make state government operations more efficient and effective. The Committee is comprised of an equal number of House members and Senators, Democrats and Republicans.

JLARC's non-partisan staff auditors, under the direction of the Legislative Auditor, conduct performance audits, program evaluations, sunset reviews, and other analyses assigned by the Legislature and the Committee.

The statutory authority for JLARC, established in Chapter 44.28 RCW, requires the Legislative Auditor to ensure that JLARC studies are conducted in accordance with Generally Accepted Government Auditing Standards, as applicable to the scope of the audit. This study was conducted in accordance with those applicable standards. Those standards require auditors to plan and perform audits to obtain sufficient, appropriate evidence to provide a reasonable basis for findings and conclusions based on the audit objectives. The evidence obtained for this JLARC report provides a reasonable basis for the enclosed findings and conclusions, and any exceptions to the application of audit standards have been explicitly disclosed in the body of this report.

Committee Action to Distribute Report

On December 4, 2019 this report was approved for distribution by the Joint Legislative Audit and Review Committee.

Action to distribute this report does not imply the Committee agrees or disagrees with the Legislative Auditor recommendations.

Study Questions

Proposed Study Questions: Joint Center for Aerospace Technology Innovation

State of Washington Joint Legislative Audit and Review Committee — March 2019

Sunset review of the Joint Center for Aerospace Technology Innovation (JCATI)

In 2012, the Legislature created JCATI (pronounced "juh-kaa-tea") to increase collaboration between the aerospace industry and Washington's public universities. The intent is to promote economic development and job creation through collaboration.

JCATI focuses on three goals:

1. Pursue joint industry-university research in new technologies relevant to aerospace.
2. Enhance education of university engineering students through industry-focused research.
3. Work with aerospace firms and industry associations to identify the industry's research needs.

JCATI funds research and organizes an annual aerospace symposium

JCATI is housed at the University of Washington and is guided by a Governor-appointed Board of Directors.

JCATI provides competitive grant funding to Washington's public universities for industry-focused aerospace research. It funds approximately 16 projects annually, and grants have ranged from $30,000-$127,000 per project. JCATI also organizes an annual symposium on Washington's latest aerospace research for industry representatives and academics.

The Legislature appropriated $3 million to JCATI in the 2017-19 biennium.

JCATI is scheduled to sunset in 2020

JCATI is subject to the Sunset Act (RCW 43.131) and will automatically terminate unless the Legislature reauthorizes it. The Sunset Act directs JLARC to review entities in the year prior to their termination date. JCATI has developed performance measures to facilitate the evaluation.

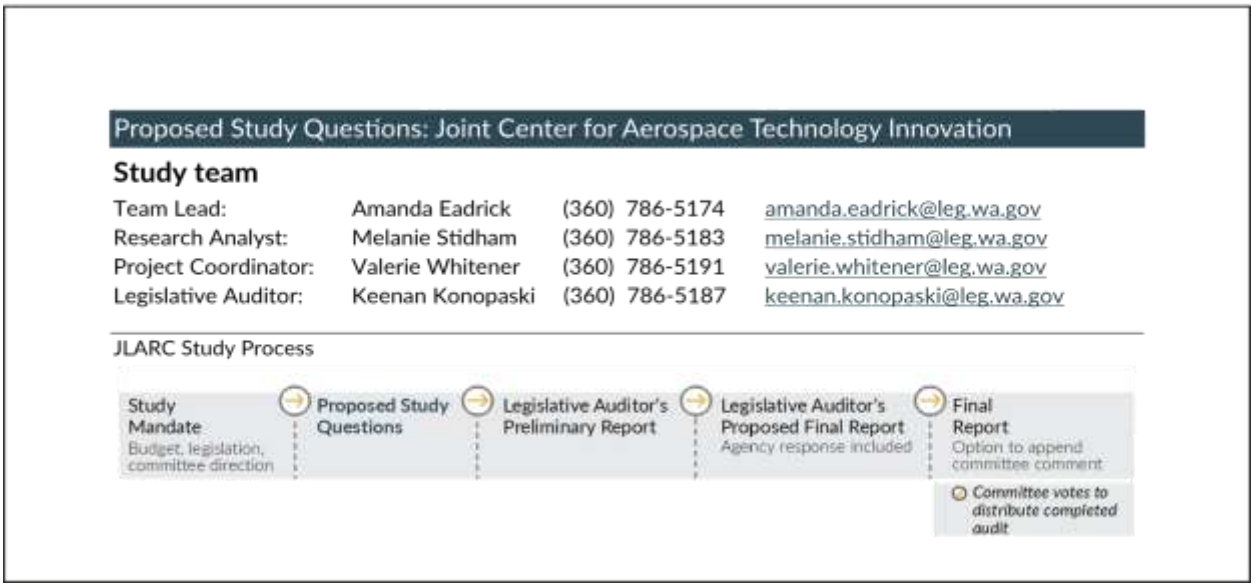
This study will answer the following questions

1. To what extent has JCATI complied with the legislative intent to pursue industry-university research, enhance the education of students, and work with aerospace firms?
2. To what extent does JCATI provide for efficient and economical management of research grants, with adequate cost and management controls in place?
3. To what extent has JCATI achieved its performance measures?
4. To what extent does JCATI duplicate the activities of another agency or the private sector?

Study timeframe

Preliminary Report: September 2019 Proposed Final Report: December 2019

Joint Legislative Audit & Review Committee, 106 11th Ave SW, Olympia, WA 98501
(360) 786-5171 • (360) 786-5180 (fax) • JLARC@leg.wa.gov • www.jlarc.leg.wa.gov
Keenan Konopaski, Washington State Legislative Auditor



Methodology

The methodology JLARC staff use when conducting analyses is tailored to the scope of each study, but generally includes the following:

- **Interviews** with stakeholders, agency representatives, and other relevant organizations or individuals.
- **Site visits** to entities that are under review.
- **Document reviews**, including applicable laws and regulations, agency policies and procedures pertaining to study objectives, and published reports, audits or studies on relevant topics.
- **Data analysis**, which may include data collected by agencies and/or data compiled by JLARC staff. Data collection sometimes involves surveys or focus groups.
- **Consultation with experts** when warranted. JLARC staff consult with technical experts when necessary to plan our work, to obtain specialized analysis from experts in the field, and to verify results.

The methods used in this study were conducted in accordance with Generally Accepted Government Auditing Standards.

More details about specific methods related to individual study objectives are described in the body of the report under the report details tab or in technical appendices.

CONTACT
JLARC Authors

Amanda Eadrick, **Research Analyst,** 360-786-5174

Melanie Stidham, **Research Analyst,** 360-786-5183

Valerie Whitener, Audit Coordinator

Keenan Konopaski, Legislative Auditor

JLARC Members

Senators

Bob Hasegawa
Mark Mullet, Chair
Rebecca Saldaña
Shelly Short
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Noel Frame
Larry Hoff
Christine Kilduff
Vicki Kraft
Ed Orcutt, Vice Chair
Gerry Pollet, Assistant Secretary
Drew Stokesbary

Washington Joint Legislative Audit and Review Committee

106 11th Avenue SW, Suite 2500
PO Box 40910
Olympia, WA 98504-0910

Phone: 360-786-5171
Fax: 360-786-5180
Email: JLARC@leg.wa.gov