

COLORADO BUSINESS REVIEW

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Powerful Partnerships and Leadership in Emerging Areas Continue to Grow CU's Impact on Aerospace

Mark Kennedy



ULA Delta IV rocket liftoff, carrying the GPS III SV-2 mission for the U.S. Air Force Space and Missile Systems Center. Photo courtesy of United Launch Alliance.

Given my last name, my lifelong fascination with space exploration may have been preordained.

One of my earliest memories is watching news coverage of John F. Kennedy's assassination, my large family huddled around our diminutive black and white

television. In the coming days, tributes to JFK poured forth celebrating his legacy and leadership, including his significant expansion of the U.S. space program and his famous call to land a man on the moon before the end of the 1960s.

IN THIS ISSUE

- PAGE 1** Powerful Partnerships and Leadership in Emerging Areas Continue to Grow CU's Impact on Aerospace
- PAGE 3** To Drive a Strong Economy, Shoot for the Stars
- PAGE 6** Over 70 Years of LASP Growth Fuels Space Exploration
- PAGE 9** Now is the Time to Push Further
- PAGE 11** Educating Aerospace Leaders in the Ann and H.J. Smead Department of Aerospace Engineering Sciences
- PAGE 14** Colorado's Aerospace Industry: The Supporting Ecosystem
- PAGE 19** In Pursuit of Winning U.S. Space Command
- PAGE 21** Streamlining External Engagement
- PAGE 22** Colorado: The Epicenter of National Security Space Capability
- PAGE 24** Lockheed Martin: How Our Colorado Footprint is Shaping the Future of Space
- PAGE 26** Center for National Security Initiatives – Building from Fundamental Research Capabilities to Applications in the Aerospace Defense Sector
- PAGE 28** Sierra Nevada Corporation in Colorado: Committed to Colorado in Air and Space
- PAGE 30** Leeds and Smead Collaborate on a Space Sustainability Initiative

Each space launch I watched with my classmates in our elementary school cafeteria further fueled my fixation on space. One of my first family vacations



Leeds School of Business
UNIVERSITY OF COLORADO **BOULDER**

FROM THE EDITOR

The aerospace industry is an economic driver in the state of Colorado, employing thousands of workers, performing research that leads to scientific and commercial discoveries, and providing technological solutions that impact our everyday lives. This issue of the *Colorado Business Review* focuses on the aerospace industry with articles written by business and education leaders. The publication describes the expertise of some of Colorado's leading aerospace companies; the focus of some of the key educational programs in the state; and the nexus between government, the universities, and the private sector.

Our next issue will present a midyear economic update. Look for it in July in your inbox.

Please contact me directly at 303-492-1147 with any comments or questions.

—Richard Wobbekind



CU President Mark Kennedy, second from left, poses with CU and LASP leadership during a tour of CU Boulder's Laboratory for Atmospheric and Space Physics (LASP) on July 1, 2019, Kennedy's first official day on the job. From left, CU Boulder Chancellor Phil DiStefano; Kennedy; Debbie Kennedy, Mark's wife; LASP director Dan Baker; Vice Chancellor for Research & Innovation Terri Fiez, and Provost Russell Moore. (Photo by Glenn Asakawa/University of Colorado)

outside my native state of Minnesota included a visit to the Kennedy Space Center. My younger brother was named after Neil Armstrong.

Moving beyond these anecdotes, JFK's vision and challenge to our nation to be a leader in space has resonated with me over the course of my life. Increasingly, I believe our country's freedom and democratic ideals hinge on retaining our innovative edge, which, in turn, hinges on our activities in space. The extent to which we continue to research, explore, discover, and secure space will define our future. The University of Colorado has long contributed to these efforts and helped drive Colorado's robust aerospace industry by meeting its research and workforce needs. Our impact continues to grow thanks to powerful partnerships and leadership in emerging areas.

The Place for Aerospace and More

CU is well established as the place to be for anyone interested in aerospace

education, research, and discovery: Our campuses have 20 affiliate astronauts who have served on the earliest Mercury missions, the space shuttle program, and the International Space Station; CU Boulder is number 1 in NASA funding among U.S. public universities; and its graduate and undergraduate aerospace engineering programs rank in the nation's top 10. Additionally, CU Boulder offers a space minor to students from any major with an over-arching background in all aspects of space – especially the ways in which it has transformed how we communicate, receive news, engage in commerce, and address issues critical to our future.

CU Boulder's Laboratory for Atmospheric and Space Physics (LASP) has been active in space for more than 70 years and has designed instruments for nearly 20 key space missions. As the only university-based Mission Operations & Data Systems center that trains and certifies undergraduates to perform

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To Drive a Strong Economy, Shoot for the Stars

Amy Guttman



The nation's next-generation GPS satellites are built by Lockheed Martin at the company's GPS III processing facility in Colorado. Photo courtesy of Lockheed Martin.

When it comes to building a strong economy, Colorado has proven it has the right stuff. For several years running, *U.S. News & World Report* has ranked our economy top in the nation. Despite a rise in unemployment in the fourth quarter of 2020—mainly due to Covid's impact on tourism, restaurants, and hospitality—our economic foundation remains strong. And when coupled with a lifestyle that is hard to beat, Colorado remains a magnet for business and talent alike.

Further, the diversity of industries working across the state is an important driver of our success. Case in point: Colorado's aerospace industry. It takes the top spot for employment concentration in the United States, with over 33,000 people working across aerospace sectors—an all-time high since the Metro Denver Economic Development

Corporation (EDC) began tracking aerospace data back in 2004.

"Colorado's aerospace industry is regarded nationally and internationally as one of the brightest lights in this universe. But closer to home, it may be one of our best-kept secrets, economically speaking," said J. J. Ament, CEO of the Metro Denver EDC, a nonprofit marketing and business development engine that works to attract and grow innovative companies and a talented workforce to Colorado. "The aerospace industry makes a tremendous impact that extends well beyond the people who work in it every day."

30% Industry Growth ... and Climbing

What started as a strategic site for military air defense in the 1950s, the Colorado aerospace industry has

certainly grown to critical mass—placing us second only to California in the size of our aerospace economy.

The 33,460 private aerospace employees span nearly 300 businesses, covering the complete spectrum of products and systems for commercial, military, and civil space applications. From prime contractors to startups, the wide range of Colorado aerospace companies is driving success and innovation, producing everything from planetary spacecraft, satellites, and launch systems, to cutting-edge navigation technology for GPS systems and satellite communication. The industry is made up of companies large and small. In fact, 63% of Colorado's aerospace companies have 10 or fewer employees.

Our aerospace ecosystem is further fueled by more than 200 space-related



Aerospace Day at the Colorado Capitol 2020. Photo courtesy of ICOSA Media.

PRIVATE SECTOR AEROSPACE PROFILE, 2020

Colorado United States

Direct employment, 2020	33,460	384,270
Number of direct companies, 2020	290	6,230
One-year direct employment growth, 2019-2020	10.0%	3.7%
Five-year direct employment growth, 2015-2020	30.1%	18.4%
Avg. annual direct employment growth, 2015-2020	5.4%	3.4%
Direct employment concentration	1.1%	0.2%
% of companies with <10 employees	62.8%	64.9%

Sources: Dun & Bradstreet, Inc., Hoover's Online Database; Market Analysis Profile, 2015-2020; Development Research Partners.

companies and suppliers, as well as a substantial national defense and civil space presence. The state is home to major space-related Department of Defense facilities and an incredible depth of NASA research and development activities.

With such robust activity in the ecosystem, the Colorado aerospace industry continues to outpace growth in the United States overall, with employment up by 10% in 2020, compared to only 3.7% at the national level. The average industry wage in Colorado is \$142,990, with the industry contributing more than \$4.3 billion to the state's annual payroll.

And while aerospace gains alone are impressive, the industry workforce supports an additional 170,340 jobs throughout Colorado, bringing direct and indirect employment to 232,610 workers.

“The aerospace industry has cemented itself as a key driver of our economy. And better yet, it’s offered stability to families across Colorado, especially when faced with a year of such uncertainty,” said Vicky Lea, Director of the Aerospace & Aviation Industry for the Metro Denver EDC, which houses the Colorado Space Coalition. A group of industry stakeholders who work to support and further advance Colorado’s aerospace industry, the Space Coalition’s mission centers on business recruitment and retention, industry promotion, and legislative advocacy efforts.



Blue Canyon Technologies technician examines a reaction wheel board. Photo courtesy of Blue Canyon Technologies.

Building a Stellar Global Hub for Interstellar Work

In recent years, Colorado has attracted its share of attention as aerospace companies from across the United States and beyond have sought to join our orbit. Industry insiders frequently reference the unique “center of gravity” that pulls in both aerospace talent and those companies looking to relocate to the state.

In 2020, Japanese aerospace company ispace U.S. Technologies chose to establish its headquarters in Metro Denver as it works to develop a lunar lander and establish industries on the moon. Luxembourg-headquartered Kleos Space S.A. also announced plans to open its principal U.S. engineering office in the region, creating up to 100 new jobs.

Their main reasons for relocation? The access to exceptional talent.

“There were a variety of factors for us, but one of the things that stood out was the accessibility of engineers. There’s a lot engineering talent here,” ispace U.S. CEO Kyle Acierno told CNBC following the company’s announcement last November.

Colorado’s education system is ripe with degree programs that support aerospace, providing the industry with an exceptional talent pipeline. For example, the University of Colorado Boulder and the U.S. Air Force Academy offer two of the top-10 programs for aerospace engineering. CU Boulder is also the top public university for NASA research

funding in the country. Metro State University of Denver houses multiple disciplines to answer the industry’s advanced manufacturing needs. The Colorado School of Mines’ Space Resources Program is the world’s first multidisciplinary graduate program in the developing field of space resources, and Colorado State University’s Cooperative Institute for Research in the Atmosphere is a unique partnership with the National Oceanic and Atmospheric Administration (NOAA), in the field of climate research.

“Colorado’s incredible higher education institutions, paired with strong industry partnerships, help build a quality pipeline of talent who continue to feed the success of our industry,” said Dr. Ron Sega, a co-chair of the Metro Denver EDC’s Colorado Space Coalition, a former astronaut, and a leader in developing systems engineering curriculum in collaboration with industry and universities across the state.

Resilient and Ready for 2021 ... and Beyond

Colorado’s aerospace industry has proven to be resilient in the face of the pandemic, with many existing projects deemed critical to national defense. New contracts awarded in 2020 included:

- U.S. Space Force selected United Launch Alliance and SpaceX to launch national security satellites for the U.S. military and intelligence agencies for five years.

- Lockheed Martin Space received a \$473.8 million contract for the U.S. Navy’s Trident II nuclear missiles through 2026. Nearly 80% of the work will be based in Jefferson County.
- U.S. Space Force added \$378 million for Raytheon Technologies Corp. to shift its hardware provider for its Colorado-based global positioning systems contract.

“These wins continue to position our state as a leader in aerospace,” said Michael Gass, Colorado Space Coalition co-chair and retired president and CEO of United Launch Alliance. “But they also show the long commitment the state has had to building a strong foundation to foster and grow this impactful industry.”

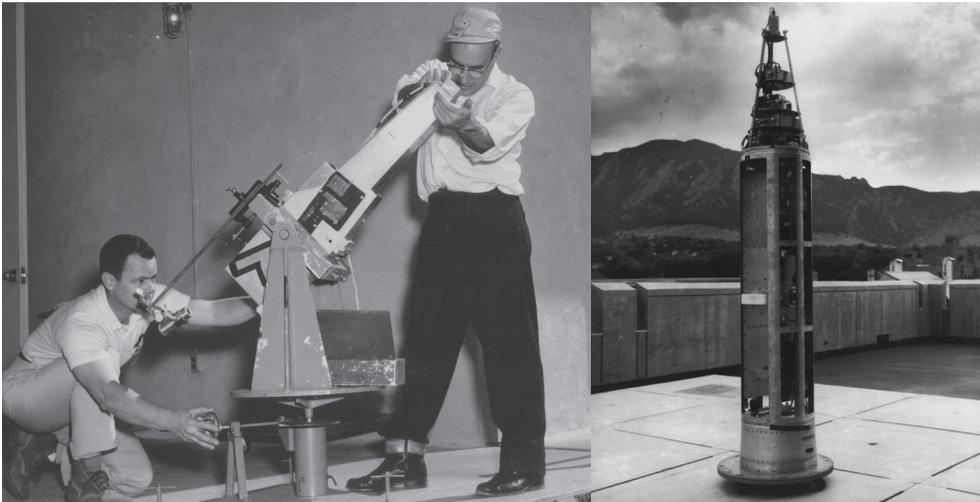
Colorado is continuing to position itself for success. From the addition of the Colorado Air and Space Port in Adams County to the Aerospace Corporation’s new \$100 million state-of-the-art research and development facility in Colorado Springs, leaders are optimistic about the continued growth and impact of aerospace.

“The sky is never the limit for aerospace in Colorado,” Lea said. “We’re coming into 2021 with plenty of momentum and the ambition to keep aiming higher.” 

Amy Guttmann is Director of Marketing & Brand Strategy at the Metro Denver EDC. She may be reached at Amy.Guttmann@metrodenver.org.

Over 70 Years of LASP Growth Fuels Space Exploration

Daniel Baker



Historical photos of LASP's beginnings as the CU Upper Air Laboratory. Photo courtesy of LASP (1948).



Emirates Mars Mission program personnel install a solar array on the Hope Probe at the University of Colorado LASP clean room in Boulder, CO. Photo courtesy of Emirates Mars Mission.

More than seven decades have taken the University of Colorado from its first exploratory rocket measurements of Earth's upper atmosphere to amazing investigations of every planet in the solar system—and beyond.

From its fledgling start as CU's Upper Air Laboratory in 1948 through its transition to the Laboratory for Atmospheric and Space Physics (LASP) in 1960, the institute has been notable among research university labs as a leader in space exploration through cutting-edge observations, engineering, mission operations, and data analysis. As a result, CU Boulder and LASP have led the way to a deeper understanding of the Sun, Earth, and solar system dynamics that informs global socioeconomic challenges such as climate change and space weather effects on our technical infrastructure. Today, LASP builds upon a legacy of forefront space missions to pursue the frontiers of modern space exploration and to expand humans' capability to address the unknown.

At any given time, multiple research endeavors are underway including conceptual studies, balloon flights, sounding rockets, small satellites, instruments, and medium-size autonomous spacecraft. All this is achieved with the involvement of local, national, and international partners. On February 9, LASP marked a collaborative milestone when the Emirates Mars Mission (EMM) spacecraft, Hope, achieved orbit around Mars, the culmination of a first-of-its-kind science and engineering partnership between LASP and the United Arab Emirates.

Science drives LASP. With a focus on our own solar system—including solar physics and influences, astrophysics, atmospheric studies, planetary sciences, and space physics—LASP services both

the experimental and theoretical aspects of science research. The expertise of LASP engineers spans generations. The depth of the staff's technical proficiency and organization mirror those of a medium-size aerospace company (with more than 600 employees).

Faculty, staff, and students are experienced and trained to create, develop, operate, assess, and support every aspect of a space mission. LASP is the only university institute to encompass the full cycle of space research from inception to completion by virtue of its collaborative workforce:

- Scientists are extensively involved in mission and instrument design to answer key research questions;
- Engineers and facility staff support the design and manufacture of spacecraft and instrumentation in support of the science goals;
- Operators manage the day-to-day mission and scientific operations for numerous spacecraft and instruments—LASP is one of only a few university-based mission operations centers in the world; and
- Data systems personnel ensure the delivery of scientific data to scientists and the public, continuing the cycle of space exploration.

This intimate collaboration of scientists, engineers, and operators maximizes scientific return.

LASP is committed to educating the next generation of space professionals. The lab is exceptional among university-based space institutes in the quantity and quality of jobs performed by over 140 student employees. Since the laboratory's inception, scientists and research professionals have worked side-by-side with CU students throughout entire missions. Students have made significant contributions to missions and projects including the Solar Mesosphere Explorer (SME), the first NASA mission to be operated by students; the Student Nitric Oxide Explorer (SNOE), a full spacecraft designed, built, tested, and integrated by students; and the Student Dust Counter



LASP mission operators currently manage the day-to-day mission and science operations for two satellites and more than 140 space science instruments. Photo courtesy of LASP.



LASP's in-house engineers and facilities support the design and manufacturing of scientific instrumentation for space missions. Photo courtesy of LASP.



LASP mentors CU engineering students, providing hands-on, real-life experience to train the next generation of space professions. Photo courtesy of LASP.

(SDC), the first student-built payload to fly on a NASA interplanetary mission. LASP's undergraduate and graduate students work in all areas including Science, Mission Operations & Data Systems, Engineering, and Administration. Their hands-on experience enables many who work at NASA, the Jet Propulsion Laboratory, SpaceX, and other aerospace sector companies to carry on the future of space exploration.

LASP is committed to building innovative education and outreach programs that connect scientists and engineers with the public. Joining forces with high-quality educational and scientific partners in Colorado and across the country, the lab creates dynamic Earth and space science programs tailored to the unique needs of students, teachers, and the public. Based on LASP's unparalleled record of success in designing and building space science instruments and end-to-end mission involvement, the lab's education and outreach efforts bring the excitement of space exploration to a wide variety of audiences.

All this is made possible through the integral relationship LASP has with the space community as a whole. LASP personnel participate in, and take leadership roles on, national advisory committees, contributing to the definition of our nation's space exploration priorities. In turn, LASP responds to new opportunities through proposals for funding, which in 2020 accounted for almost 32%, over \$100 million annually, of total CU research institute revenue. As an active member of the global space research community, LASP's connections and relationships are enduring and productive. The lab

routinely partners with other universities, the private sector, and international entities through contracts and grants as a prime contractor, sub-contractor, or vendor on multimillion-dollar missions. Several successful companies have been started by LASP personnel including Ball Aerospace and Blue Canyon Technologies. Former LASP students, scientists, and engineers are employed throughout the aerospace community in all aspects of government, commercial, academic, and international organizations.

LASP has never been more comprehensive in its capabilities or deep in its expertise. A growing staff provides exceptional strength in numerous areas of engineering, program management, and support services. The entire LASP "machine" is proven and ready to pursue the new generation of challenges brought about by the revolutionary commercialization of the space sector. As LASP ventures beyond the confines of our solar system and focuses on new approaches to better understand our home planet, the lab will become an even more capable and innovative force for good in the emerging realm of New Space. 

Daniel Baker is the Director of the Laboratory for Atmospheric and Space Physics (LASP), Distinguished Professor of Planetary and Space Physics, and the Moog-Broad Reach Endowed Chair of Space Sciences at the University of Colorado Boulder.

Now is the Time to Push Further

U.S. Representative Ed Perlmutter



U.S. Representative Ed Perlmutter (pictured center in a dark gray suit) tours the SAS Manufacturing when it opened a new facility in Arvada in September 2017. Photo courtesy of SAS Manufacturing.

This past year has been anything but expected. Thanks to the COVID-19 vaccine, we are finally turning the corner in combating this global pandemic which has devastated our communities, upended the lives of almost every American, and put millions of people out of work. As we pick ourselves back up and focus on the future, now is the time to invest in scientific discovery and advancing our exploration of the solar system. Our space programs have provided inspiration and aspiration since President John Kennedy declared we would send our astronauts to the Moon in 1961, and I believe a unifying goal for

all of us is to explore the unknown once again.

During the height of the pandemic, our aerospace programs proved once again their ability to inspire. On May 30, 2020, SpaceX launched American astronauts from American soil for the first time since the Space Shuttle retired in 2011. I watched this launch from my living room along with millions of Americans craving excitement and positivity. This successful launch represented the first time the U.S. launched humans on a commercially built and operated spacecraft to the International Space Station (ISS). This commercial crew program began under

the Obama-Biden Administration to support commercial development of key capabilities for the ISS and enable NASA to focus their human space exploration development efforts on the Moon and Mars.

On July 30, 2020, all attention was back on NASA as United Launch Alliance launched the Perseverance Rover to Mars. This was the result of years of planning, engineering, testing, and adaptation as the team learned how to safely keep the launch on schedule during the COVID-19 pandemic to meet the once every 26-month launch window for missions to Mars. Six months later,

on February 18, we all anxiously watched Perseverance land safely on the surface of Mars. Perseverance is now beginning its mission to continue searching for signs of life on Mars and preparing for human exploration of the red planet.

It is this ingenuity and excellence in engineering that gives me confidence we can do anything we put our minds to. Colorado aerospace companies include the best of the best as they have consistently met the challenges our country has for them. We have big multinational companies, we have established small- and medium-size businesses specializing in certain manufacturing or technologies, and we have startup companies with the right idea for the right moment in time. We benefit from having the best mix of civilian and military aerospace companies all leveraging their expertise for the mission at hand. In Colorado, we truly do have it all. And these companies and the thousands of aerospace workers adapted this past year to work safely during a pandemic to keep their programs on schedule.

Moving forward from this pandemic, we need to invest smartly in programs to support key national priorities, advance scientific progress, and create good-paying jobs. Put simply, now is the time to invest in and expand our aerospace

programs, which meet all of these goals. Investing in aerospace will inspire Americans and the next generation of scientists and engineers who will open doors for new technologies and answer new questions we cannot even imagine today.

We have never known exactly where our space exploration will take us, but the benefits we've seen on Earth from our investment in exploration since the Mercury Program 60 years ago have been tremendous. The promise of scientific advancement in medicine, research, engineering, and manufacturing through space exploration is exactly what we need right now.

Space exploration is hard, and it will require sustained investment from Congress and continued ingenuity by the smart people at NASA, universities, and the commercial space industry. Many people have seen my bumper sticker for human exploration of Mars – 2033: *We CAN Do This*. I have been using this bumper sticker to generate support for a simple message that we CAN do this if we commit ourselves to this goal and have the foresight to plan and invest wisely for the future. The time for that plan is now.

This plan starts with a successful Artemis program to land the first woman and the next man on the Moon so we can

use this as a learning and proving ground for the technologies and skills required for Mars missions. We will also advance our understanding of the Moon through the analysis of lunar resources and advancing NASA's use of In-Situ Resource Utilization which will support sustainable human space exploration. Colorado is already leading the charge on the utilization of space resources through our institutes of higher education and leading aerospace companies. The use of resources in space both on the Moon and eventually Mars will create new opportunities and improve our ability to understand and explore the solar system.

Space exploration enjoys broad bipartisan support in Congress. The Biden administration has already pledged its support for the Artemis program and continuing our space exploration missions. The job we have now is to work together to set ambitious and achievable timelines and budgets for NASA that get us to the Moon and onto Mars quickly. These are smart investments in our future, and I am confident we can all work together to do our part.

A mission of this magnitude is bigger than any one person, community, state, or nation, and it is the aspirational and inspirational medicine America and the world need to fully recover from the COVID-19 virus. I believe now is the time to move forward and look to the future. 



Ed Perlmutter is the U.S. Representative for Colorado's 7th Congressional District, encompassing Adams and Jefferson counties. In the 117th Congress, Ed serves on four committees in the House: Financial Services; Science, Space and Technology; Rules; and the Select Committee on the Modernization of Congress.



Photo courtesy of Smead Aerospace Engineering Sciences, College of Engineering and Applied Science at the University of Colorado Boulder.

Educating Aerospace Leaders in the Ann and H.J. Smead Department of Aerospace Engineering Sciences

Brian Argrow

Visit the Black Swift Technologies (BST) website and you will find in the company description: “...recognized for delivering reliable, robust, and highly accurate unmanned aircraft systems (UAS) capable of flying scientific payloads in demanding atmospheric environments. ...” A Boulder-based small business, BST was founded 10 years ago by a trio of PhD

graduates from the Ann and H. J. Smead Department of Aerospace Engineering Sciences at the University of Colorado Boulder. Ten years prior, BST founders Jack Elston, Maciej Stachura, and Cory Dixon were undergraduates or still in high school, while the American Institute of Aeronautics and Astronautics (AIAA) was organizing the first conferences in

the emerging area of “unmanned aerial vehicles” (UAVs), now referred to as unmanned aircraft systems (UAS), or just drones. When asked to reflect on the company’s 10-year journey, BST CEO Elston considers himself an example of how an entrepreneurial Smead Aerospace graduate can couple personal drive and knowledge with mentoring and research

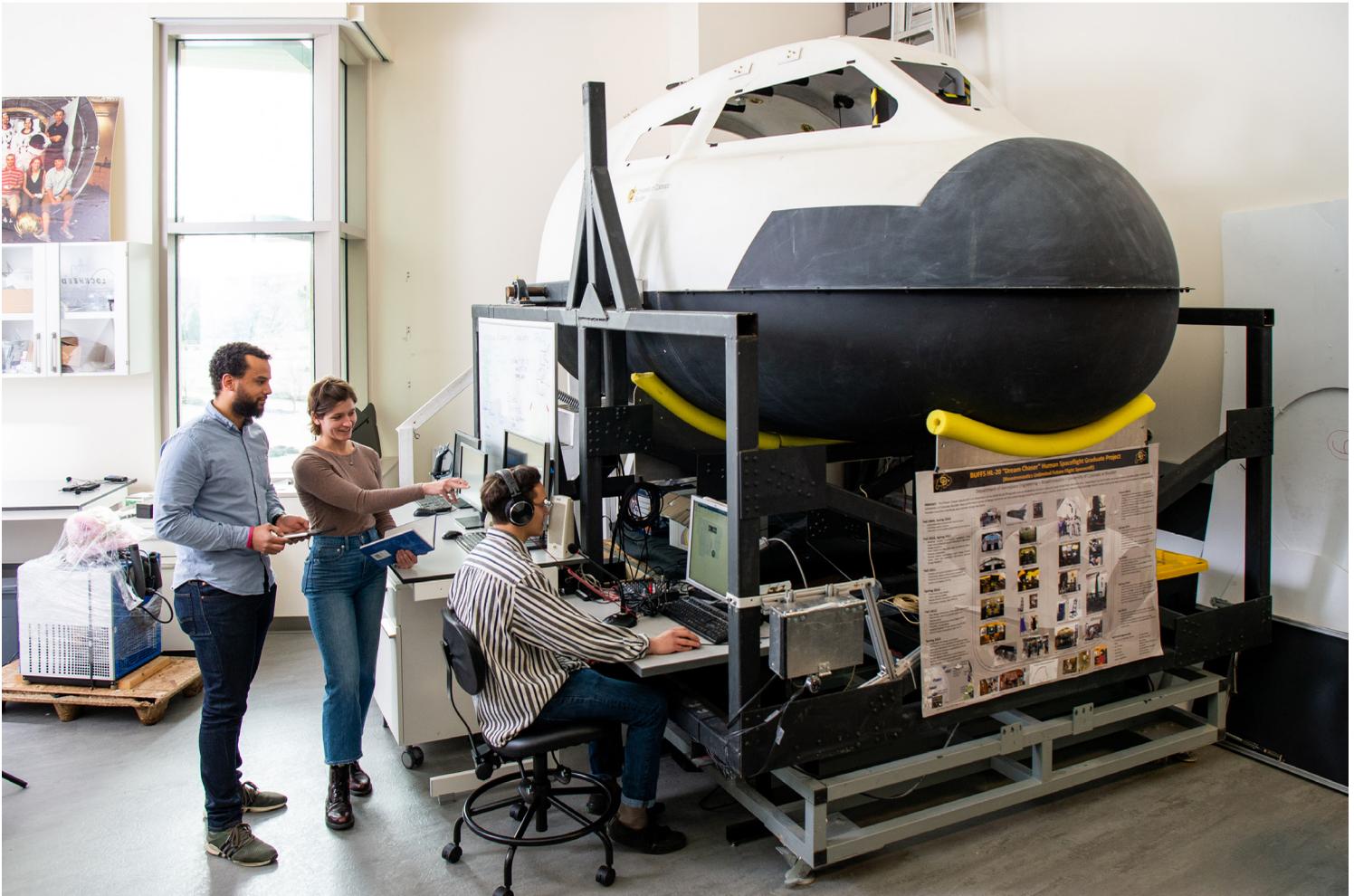


Photo courtesy of Smead Aerospace Engineering Sciences, College of Engineering and Applied Science at the University of Colorado Boulder.

experiences to establish a business that not only enables him to pursue his passion, but empowers him to contribute to the local aerospace economy.

The term *aerospace* first appeared in the 1950s, describing vehicles operating in the Earth's atmosphere and extending to the new class of vehicles beginning to operate in space outside the atmosphere. Since then, aerospace has evolved into a much broader rubric, encompassing the breadth of topics, subdisciplines, and technologies from aircraft and spacecraft to robotics and autonomous systems, and the software required for the automation and emerging intelligence of aerospace vehicles and systems.

Similar to GPS and smartphones, the emergence of drones exemplifies how disruptive technologies constantly

challenge aerospace engineering educators and educational institutions. Curricula must continuously evolve to balance the relatively slow changing foundational math and science, with emerging topics that require shifting emphasis in engineering-science topics, and greater shifts in skills and knowledge required to master the most important tools for applications and designs. Even more challenging is to integrate changes constrained by a total number of credit hours that has not changed for several decades. Smead Aerospace meets these challenges to ensure that a holder of a Smead Aerospace degree is certified as prepared for the evolving demands of the aerospace industry, as well as other industries and research institutions.

In every core course, the unique hands-on Smead Aerospace undergraduate curriculum integrates theory and hands-on laboratory experiences with product design. The curriculum culminates in the senior year with a year-long capstone project course where the seniors work in product teams to design, build, test, and verify a product prototype. Most of the projects are industry-funded, giving prospective employers the opportunity to observe potential employees in action. Recent graduate Nick Renninger (BS '19, MS '20) commented on his experience: *"I'm currently working at MITRE as an Autonomous Systems / AI engineer. It's been quite an interesting time. The work is mostly aligned with my grad thesis work, but I am so thankful for the breadth and depth of knowledge I have from*



Photo courtesy of Smead Aerospace Engineering Sciences, College of Engineering and Applied Science at the University of Colorado Boulder.

undergrad (especially the senior project); so much of it is useful!" Relating to the breadth of the "aerospace rubric," Renninger also noted, *"As an aside, I would also praise our ties with the CS /Applied Math departments. ... those minors continue to be helpful. Having a strong CS and math background helped a ton going into grad school and into my past and current jobs!"*

The word is out and demand for the Smead Aerospace programs resulted in a doubling of undergraduate enrollment from 560 in fall 2014 to 1,055 in fall 2020, while graduate student enrollments have increased from 130 MS and 127 PhD students in 2014, to 308 and 218, respectively, in fall 2020. These enrollment increases have pushed Smead Aerospace into the top-5 largest undergraduate and graduate aerospace engineering programs in the country. The August 2019 opening of the Aerospace Engineering Science Building is a testament to the CU Boulder investment in a department consistently ranked among the top-10 in the country.

When asked about her undergraduate experience, Smead Aerospace junior Caroline Dixon started by talking about her experience working in a Smead Aerospace research lab with CU Distinguished Professor Penny Axelrad, an expert in GPS and related technologies: *"The Smead Aerospace undergraduate program has a rigorous and rewarding curriculum that prepares students for their endeavors after graduation. In addition to my undergraduate curriculum, I have the privilege of working under Dr. Axelrad's mentorship on the CONTACT (Colorado Nanosat Atomic Clock Testbed) project. ..."*

Dixon continued to talk about how the curriculum, coupled with real-world research experience, is contributing to her development: *"...the experience of working in Dr. Axelrad's lab has been valuable for me because I am able to implement my undergraduate aerospace curriculum knowledge into a real-world aerospace engineering project. I am conducting low earth orbit simulation,*

temperature, and magnetic field testing on our chip scale atomic clock in order to characterize the stability of its clock signals and provide a baseline for the flight experiment. In the near future, I will be able to witness the results of our lab's work being launched into orbit, and that is incredibly exciting for all of us. My work on the chip scale atomic clock flight experiment has shown me what I am capable of and being able to meaningfully contribute to our lab team has increased my self-esteem as both a student and aerospace engineer." 

Brian Argrow is Professor and Chair of Smead Aerospace Engineering Sciences and Director of IRISS in the College of Engineering and Applied Science at the University of Colorado Boulder.

Colorado's Aerospace Industry: The Supporting Ecosystem

Anna Sernka

With the nation's second-largest aerospace economy, it is reasonable to wonder *what about Colorado makes it such an effective ecosystem for this industry?* The answer lies in a complex web of interactions between government entities, commercial players, and academic institutions.

Government entities involved in space activity, like the Department of Defense and NASA (National Aeronautics and

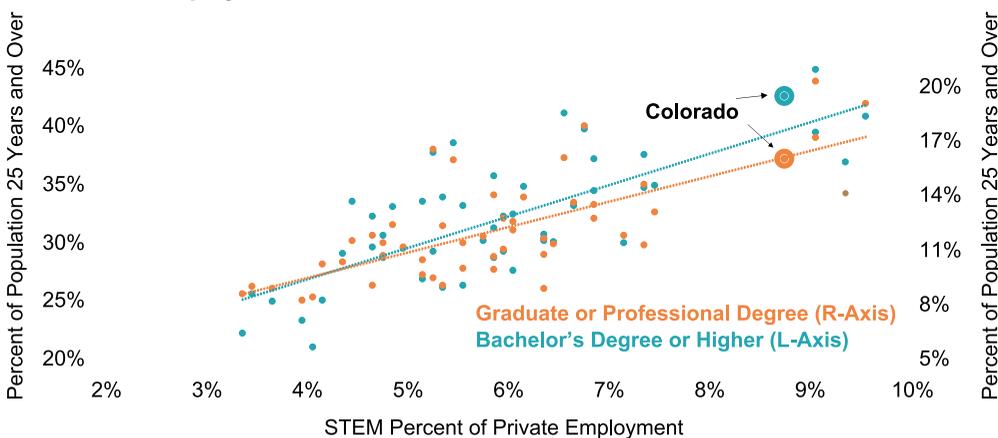
Space Administration), have long-standing relationships with Colorado. When the Cold War began, defense leaders scrambled for a strategic location and landed on Colorado, in part because it was out of range for enemy missiles being in the middle of the country. Today, nine out of the nation's top 10 major defense contractors are in Colorado. Understanding the benefits that Colorado has to offer, the U.S. Navy

recently announced plans to relocate its Strategic Systems Programs to Jefferson County from California, the only state currently ahead of Colorado in terms of the size of its aerospace economy. While defense put Colorado's aerospace industry on the map, it is now fueled by major NASA programs, according to Jay Lindell, a retired major general of the U.S. Air Force. Colorado receives the third-highest NASA funding of any state and the second-highest NASA funding per capita. NASA additionally provides the University of Colorado Boulder with more funding than any other public university, according to the National Science Foundation. In terms of Department of Defense funding per capita, Colorado again outperforms and ranks ninth in the nation. The future of the Department of Defense and NASA in Colorado continue to look bright as their budgets have remained constant despite the recent economic downturn. Of the SBIR/STTR grants that are awarded nationally, 51% are distributed through the Department of Defense or NASA. In Colorado, however, this percentage is nearly 60%.

The journey to space does not stop here—commercial players work in tandem with these government entities to support Colorado's aerospace ecosystem.

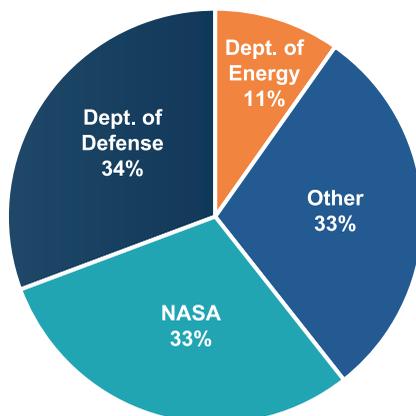
Industry leaders such as Ball Aerospace, Boeing, L3Harris, Lockheed Martin, Maxar Technologies, Northrop Grumman, Raytheon, Sierra Nevada Corporation, and United Launch Alliance attract contract work from the federal government, which funds approximately 80% of the industry. State leadership is committed to attracting and retaining these businesses through a lax regulatory environment as well as single-factor taxes and a low corporate tax rate. In 2021, Colorado's corporate income tax rate is 4.55%. Only nine other states have tax rates at or below 5%. The presence of these large players in aerospace makes it easy to forget that the majority of aerospace firms, 64.5%, have 10 or fewer employees. Startups and smaller firms often build specific elements for a project close in proximity to large

SCIENCE, TECHNOLOGY, ENGINEERING, AND MATH (STEM) Employment Concentration and Educational Attainment, 2019



Source: Bureau of Labor Statistics, OES 2019; Census, ACS.

COLORADO RESEARCH AWARDS BY AGENCY 2016 - 2020



Source: National Science Foundation.

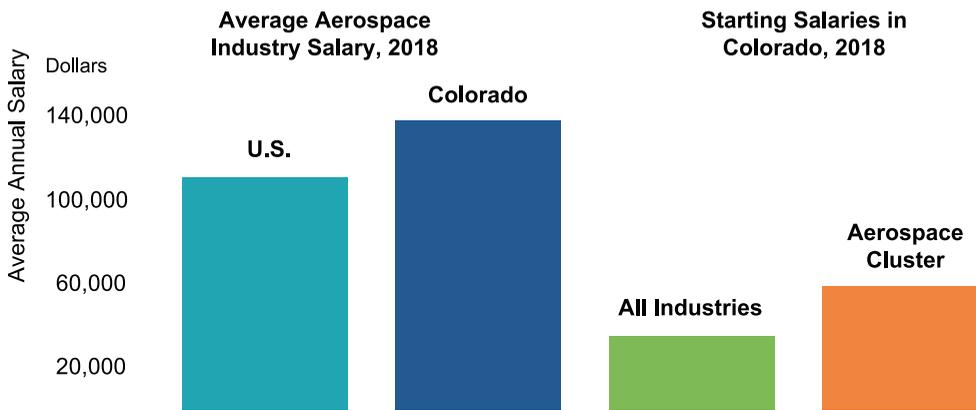
DEPARTMENT OF DEFENSE AND NASA FUNDING BY STATE 2016 - 2020

Federal Research Obligations for the Department of Defense and NASA by State 2018



Source: National Science Foundation.

AVERAGE SALARY



Source: Metro Denver EDC.

industry leaders, a mutually beneficial arrangement. The relationships between large firms and startups proved to be so important that both Boeing and Airbus created venture capital funds in the late 2010s. In the *Global Startup Ecosystem Report 2020* by Startup Genome, the Denver-Boulder region ranked with the top 30 most successful startup ecosystems in the world. There are even more overlapping networks that enhance the aerospace industry in Colorado—sectors like cyber and energy also play supporting roles in aerospace projects.

This unique environment draws not only businesses to Colorado, but workers as well. According to a Metro Denver EDC report, Colorado ranked first in the nation

for the number of private aerospace jobs per capita. When including both direct and indirect employment, close to 200,000 people work in aerospace in Colorado. On top of a high quality of life, workers are drawn to the state due to aerospace wages that are 24.4% higher than the national average. While the average annual aerospace industry salary in the United States was \$111,480 per year, it reached \$138,730 in Colorado in 2018. The starting salary in the aerospace cluster is also far higher; compared to the average starting salary across all industries in Colorado of \$35,540, workers starting in the aerospace cluster received a starting salary of \$59,800 in Colorado in 2018. Furthermore, Colorado

has the fifth-highest concentration (8.8% of the population) of STEM (Science, Technology, Engineering, and Math) jobs, following Virginia (9.1%), Massachusetts (9.1%), Washington (9.4%), and Maryland (9.6%). Attracting top talent is key to the aerospace industry's success, and this initiative is supported by academic institutions that provide not only research but a steady pipeline of educated workers.

Notable universities include the University of Colorado Boulder, which recently built an 180,000 square foot Aerospace Engineering Sciences Building and has faculty ranking in the top 8% nationally in research productivity. The U.S. Air Force Academy is currently ranked the top undergraduate program in aerospace engineering (where a doctoral is not offered) and hosts 20 research centers. Metro State University of Denver and Colorado State University created a dedicated Aerospace Engineering Science Building and a Cooperative Institute for Research in the Atmosphere, respectively. Colorado School of Mines built the first graduate program in space resources, and the University of Colorado at Colorado Springs is the Space Education Consortium's lead university to educate future aerospace workers.

Higher education R&D performance in Colorado reached almost \$1.5 billion in 2018 (15th in the nation), with almost half going toward Earth Sciences, Engineering, Physical Sciences, or Math and Computer Sciences, according to the National Science Foundation. Colorado also had almost 3.7 million square feet of academic research space in 2017, a figure that has continued to grow since the time of study. There were also 14,100 SEH (Science, Engineering, and Health) graduate students in Colorado institutions granting research-based degrees in 2018, the 15th-highest number in the nation.

Colorado outpaces the nation in its engineering and science-based academic offerings and research. Approximately 48% of the population 25 and older with a bachelor's degree or higher studied science, engineering, or related fields

AEROSPACE ECOSYSTEM 2021

A snapshot of aerospace activities and resources at CU Boulder and throughout Colorado.



ACCELERATORS

OEDIT Advanced Industries Accelerator Program • E-Space • Air Force Accelerator Powered by Techstars • Catalyst Campus • National Security Innovation Network

MILITARY

North American Aerospace Defense Command (NORAD) • U.S. Space Command (Provisional) • U.S. Northern Command • National Space Defense Center • U.S. Space Force Space Operations Command • Buckley Air Force Base • Peterson Air Force Base • Schriever Air Force Base • Cheyenne Mountain Air Force Station • Fort Carson Army Post

LABS & RESEARCH

Laboratory for Atmospheric and Space Physics (LASP) • Cooperative Institute for Research in the Environmental Sciences (CIRES) • Cooperative Institute for Research of the Atmosphere (CIRA) • JILA • Colorado Center for Astrodynamics Research (CCAR) • Research and Engineering Center for Unmanned Vehicles (RECUV) • BioServe Space Technologies (BioServe) • Aerospace Mechanics Research Center (AMReC) • Integrated Remote and In-Situ Sensing (IRISS) • Space Weather Technology, Research, and Education Center (SWx TREC) • National Snow and Ice Data Center • National Solar Observatory • Earth Science and Observation Center • Cooperative Institute for Research of the Atmosphere • National Center for Atmospheric Research (NCAR) • High Altitude Observatory • National Oceanic and Atmospheric Administration Boulder • National Institute for Standards and Technology • Center for National Security Initiatives (NSI) • CU Anschutz Center for Combat Medicine and Battlefield (COMBAT) Research • TAP Lab • UNAVCO

NONPROFITS

Colorado Space Business Roundtable • Colorado Space Coalition • Space Foundation • Colorado Chapter for Citizens for Space Exploration • Aerospace States Association • CO-LABS • AIAA—Rocky Mountain Chapter • Wings Over the Rockies • Aerospace Corporation • Space Information Sharing and Analysis Center (Space ISAC) • National Cybersecurity Center (NCC) • Rocky Mountain Section of the American Astronautical Society (AAS) • SRI International • The MITRE Corporation • Space Force Association • National Defense Industrial Association—Rocky Mountain Chapter • Air Force Association—Lance P. Sijan Chapter • Armed Forces Communications and Electronics Association (AFCEA)—Rocky Mountain Chapter



STATE GOVERNMENT

Colorado Division of Aeronautics • Colorado Office of
Economic Development and International Trade •
Colorado Aerospace and Defense Caucus •
Colorado Aeronautical Board

ACADEMICS & SPECIALTY AREAS AT CU BOULDER

Ann and H.J. Smead Dept of Aerospace Engineering Sciences • Dept of Astrophysics
and Planetary Sciences • Dept of Applied Math • Dept of Atmospheric and Oceanic
Sciences • Dept of Electrical, Computer, and Energy Engineering • Paul M. Rady
Dept of Mechanical Engineering • Dept of Physics • Colorado Space Grant
Consortium • Space Minor • Aerospace Ventures Earth & Space Sciences •
Aerospace Engineering Systems • Space Weather Space Situational Awareness •
Human and Robotic Exploration • Spacecraft Design • Instrument Development •
Small Satellites • Astrodynamics • Position, Navigation, and Timing • Unmanned
Aerial Systems • Bioastronautics Remote Sensing • RF and Electromagnetics •
Optics and Photonics • Sounding Rockets • Hypersonics
CLUBS: AIAA-CU Chapter • Boulder Astronomy & Space Society • CU Astronomy
Club • CU Robotics Club

EXAMPLE INDUSTRY LEADERS

Lockheed Martin • The Boeing Company • Northrop Grumman • L3Harris • Ball
Aerospace • Sierra Nevada Corporation • Raytheon • General Atomics • Maxar •
United Launch Alliance • Leidos • Blue Canyon Technologies • Red Canyon
Engineering • Astra • SPIRE Manufacturing • SEAKR Engineering • Advanced
Space • Orbital Microsystems • York Space Systems • Advanced Space •
Capella Space • CACI • Honeywell • Custom Microwave Inc. • DSoft Technology,
Engineering & Analysis, Inc. • Jacobs • Parsons Corporation

EDUCATIONAL INSTITUTIONS

U.S. Air Force Academy • University of Colorado Anschutz Medical
Campus • University of Colorado Boulder • University of Colorado
Colorado Springs • University of Colorado Denver • Colorado School of
Mines • Colorado State University • Metropolitan State University Denver



Photo by Casey A. Cass/CU Boulder.

in Colorado, compared to the national rate of approximately 45% in 2019. Additionally, Colorado outperforms the nation in the percentage of the population 25 and older with a bachelor's degree or higher in any field at 43%, compared to the national rate of 33% in 2019.

In addition, Metro Denver EDC identified a nine-county region where a significant amount of Colorado's key aerospace activities take place (Adams, Arapahoe, Boulder, Broomfield, Denver, Douglas, Jefferson, Larimer, and Weld counties). Here, 46.5% of the population

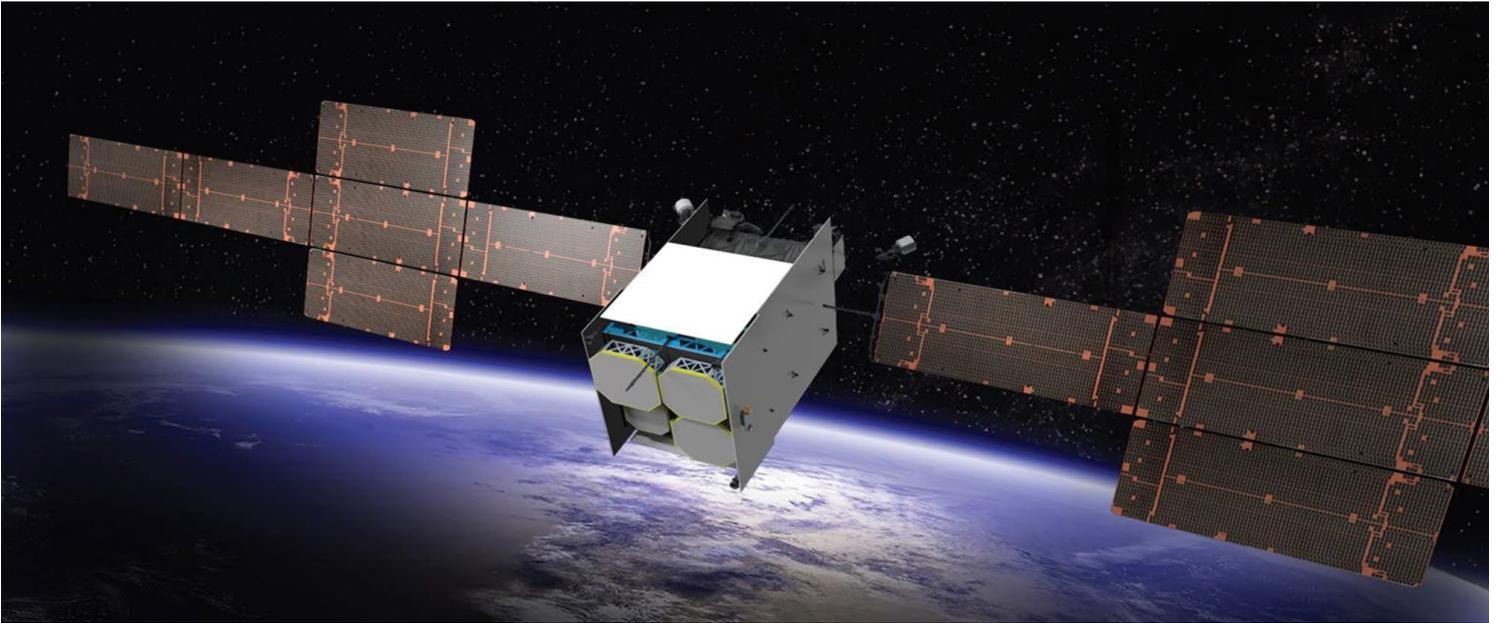
25 and older has a bachelor's degree or higher, a figure that is 3.5 percentage points higher than the overall state. Within this region, Boulder and Douglas counties have the highest levels of educational attainment with 64.8% and 58.1% of the population 25 and over having a bachelor's degree or higher, respectively. Colorado also has a higher concentration of its 25 and over population with a graduate or professional degree (16%), compared to the national rate of 12.8%. The ability to select workers from a talented pool is just another element that adds to the viability of Colorado's aerospace industry.

It would be impossible to pinpoint the industry's success on one thing, as it draws support from a wide range of players in the realm of government entities, commercial players, and academic institutions that interact in a way that is unique to Colorado. 

Anna Sernka is a Student Research Assistant with the BRD. She may be contacted at Anna.Sernka@colorado.edu.

In Pursuit of Winning U.S. Space Command

Reggie Ash



The Boeing Wideband Gapfiller Satellite is part of the Defense Satellite Communications system controlled at Schriever AFB, under the command of U.S. Space Command, as are all military satellites. Image courtesy of the Boeing Company.

Over two years ago, the Colorado Springs Chamber & EDC embarked on the Winning U.S. Space Command campaign to permanently house the command at Peterson Air Force Base (AFB). Space Command holds great economic impact opportunities for our community and state, and it bolsters our identity as the epicenter of national security space. While the campaign has taken twists and turns, and some bumps in the road, the on-going campaign has achieved some mid-course goals.

The economic impact of Space Command proves this is a valuable pursuit. According to the Colorado Space Coalition, the direct impact from Space Command's 1,400 high-paying jobs is over \$450 million. When including the multiplier effect of local purchases (direct and indirect), the economic impact grows to over \$1 billion. Additionally, the headquarters would include a military construction project approaching \$1 billion. Furthermore, combatant commands are often magnets for the defense and aerospace industry leading to accelerated growth.

Colorado and Colorado Springs

have long been considered the epicenter of national security space. ("National security space" is a term that differentiates the use of space for military and intelligence purposes, rather than the commercial endeavors more closely linked to NASA and private enterprise.) Since 1982, Peterson AFB has been home to the Department of Defense's (DoD) senior space official, which has alternately been the commanders of Air Force Space Command and U.S. Space Command. Yes, Space Command existed previously, calling Peterson AFB home from 1985 to 2002, when it was disbanded to create U.S. Northern Command focusing on defense of the homeland. President Trump re-established Space Command at Peterson AFB in August 2019.

We earn the label of the epicenter of national security space not just because of a military headquarters. Colorado has a significant preponderance of the Space Force's operational units, including eight of nine Space Deltas, and the Space Force's new Space Operations Command. Colorado is home to over 500 space-related companies and suppliers

that are leaders in creating innovative military space technologies. Catalyst Campus, a collaborative ecosystem where entrepreneurs and venture capital intersect with aerospace and defense industry to create community, spark innovation and stimulate business growth. The Space Foundation, headquartered in Colorado Springs, is the international leader advocating for the space industry through education, information, and collaboration. They also host the world's largest space industry symposium annually at The Broadmoor. It is no surprise Colorado has the largest concentration of aerospace employees in the country, in large part due to the talent pipeline created by a great university system.

The Colorado Springs Chamber & EDC began our campaign when the Air Force, the Executive Agent for space, began their typical basing process, designed to exclude outside influence. Despite the intent of isolation, politics can potentially creep into basing decisions. So, the Chamber & EDC led the community, generating advocacy



The Peterson-Schriever Garrison is home to preponderance of the DOD's operational space assets, including the National Space Defense Center, and 8 of 9 Space Deltas. Photo courtesy of the Colorado Springs Chamber and EDC.

letters from a variety of elected leaders, and proclamations from our Board of County Commissioners and City Council. During that first basing process, there were six finalists, four of which were in Colorado. Florida's Congressional delegation was not pleased to learn that they were not considered a finalist, even though the vast majority of their space industry is in the commercial sector. As Congressman Waltz noted in a December 2020 interview on Florida's Spectrum News, the Florida delegation, including Gov DeSantis, takes credit for changing the basing process to be more favorable to Florida. Marina Koren noted a January 2021 article in *The Atlantic* that Colorado was the original recommended site.

Once the Florida delegation convinced President Trump to change the process, the Air Force created a raw competition, pitting communities against each other under renewed and reinvigorated oversight by the White House. This is a highly unusual and seemingly political way to conduct a basing decision process intended to put U.S. national security first. In late 2019, we recognized the direct impact of presidential politics. We changed gears in our campaign, hiring consultants with D.C.-based political expertise who provided access to

D.C.-insiders and valuable insights into the White House decision-making process. They also helped us promote Colorado's defense and aerospace economy, so decision makers in D.C. would recognize Colorado as the only logical place for Space Command.

The parameters of the new process lacked transparency and did not allow for collaboration between communities and their installations. Additionally, the data they collected was suspect. For example, in rating the schools where Space Command families would send their children, the Air Force included schools a 90-minute drive from Peterson AFB. That is just one example of numerous flaws, which are likely due to Secretary Esper directing a unique process specifically for this basing decision. Despite those flaws, on January 11, 2021, Secretary of the Air Force Barbara Barrett went to the White House and recommended Peterson AFB as the permanent home of U.S. Space Command. President Trump wanted the headquarters in Florida, but his staff convinced him to at least pick the "red" state that was in second place: Alabama. Once the decision was made, the Air Force needed to support the Commander-in-Chief's decision, and they have defended the decision. These

details were confirmed by a senior White House official in the Trump administration.

The Colorado Springs Chamber & EDC continues to lead the Winning U.S. Space Command campaign, working closely with our elected leaders at all levels, especially with Governor Polis and our Congressional delegation. We are already seeing strong indications of support from members of Congress representing other states. At the request of Rep. Cooper (D-TN) and Rep. Garamendi (D-CA), the Office of the DoD Inspector General announced on February 19, that it has begun to review the basis for selecting Huntsville, Alabama, and the Government Accountability Office recently announced they will review the process, as requested by our Congressman Doug Lamborn. In the meantime, the Chamber & EDC, our elected leaders, and our partners throughout the state are asking the Biden administration to suspend all action to move the headquarters, review the process to determine the best advice of senior military leaders in both 2019 and 2021, and finally remove politics from the decision.

Washington, D.C. is likely to see lean budgets in the next few years due to the pandemic. Spending money to move Space Command, especially when its current headquarters is being renovated to house the command, is fiscally irresponsible. The Biden administration should reconsider the Trump administration's decision to move the combatant command out of its current facility, which was not an option under the recently completed process.

The basing process has been long and resource-intensive, but it is a worthwhile, valuable campaign. Our national security and our federal budget deserve a decision based on military leaders' best advice rather than presidential politics. The Chamber & EDC will continue to work with our elected leaders to ensure Space Command's critical mission is not interrupted and the headquarters remains here. 

Reggie Ash is the Chief Defense Development Officer at the Colorado Springs Chamber & EDC.

Streamlining External Engagement

George Hatcher

Hypersonics. Space Domain Awareness. Autonomous Systems. Just a few of the innovations that require strategic partnerships between industry and academia to advance the capabilities of the growing aerospace and defense ecosystem.

With Colorado being the #1 aerospace economy per capita, the University of Colorado Boulder (CU Boulder) is positioned to lead in these areas, amongst many others, while training the next generation workforce. Designated as an R1 research university with world-class faculty, CU Boulder is actively engaged in cutting edge research that prepares students to meet the evolving demands of today's challenges while providing unique access to many of the leading companies, and emerging small

companies, that make Colorado such an important destination for all things space.

As industry continues to innovate and become more agile to meet the needs of the aerospace ecosystem, so is CU Boulder. In close collaboration with our industry partners, in 2020, CU Boulder established the Industry & Foundation Relations (IFR) team to maximize its industry and foundation relationships. The IFR team serves as the central conduit for engaging with CU Boulder, while providing a holistic, cross-campus view of the university's top priorities. Centered around key themes for the university, this model allows companies to tap into CU Boulder quickly, matching internal and external expertise and needs, and in doing so, serve as a 'one stop shop' for new collaborative opportunities. This

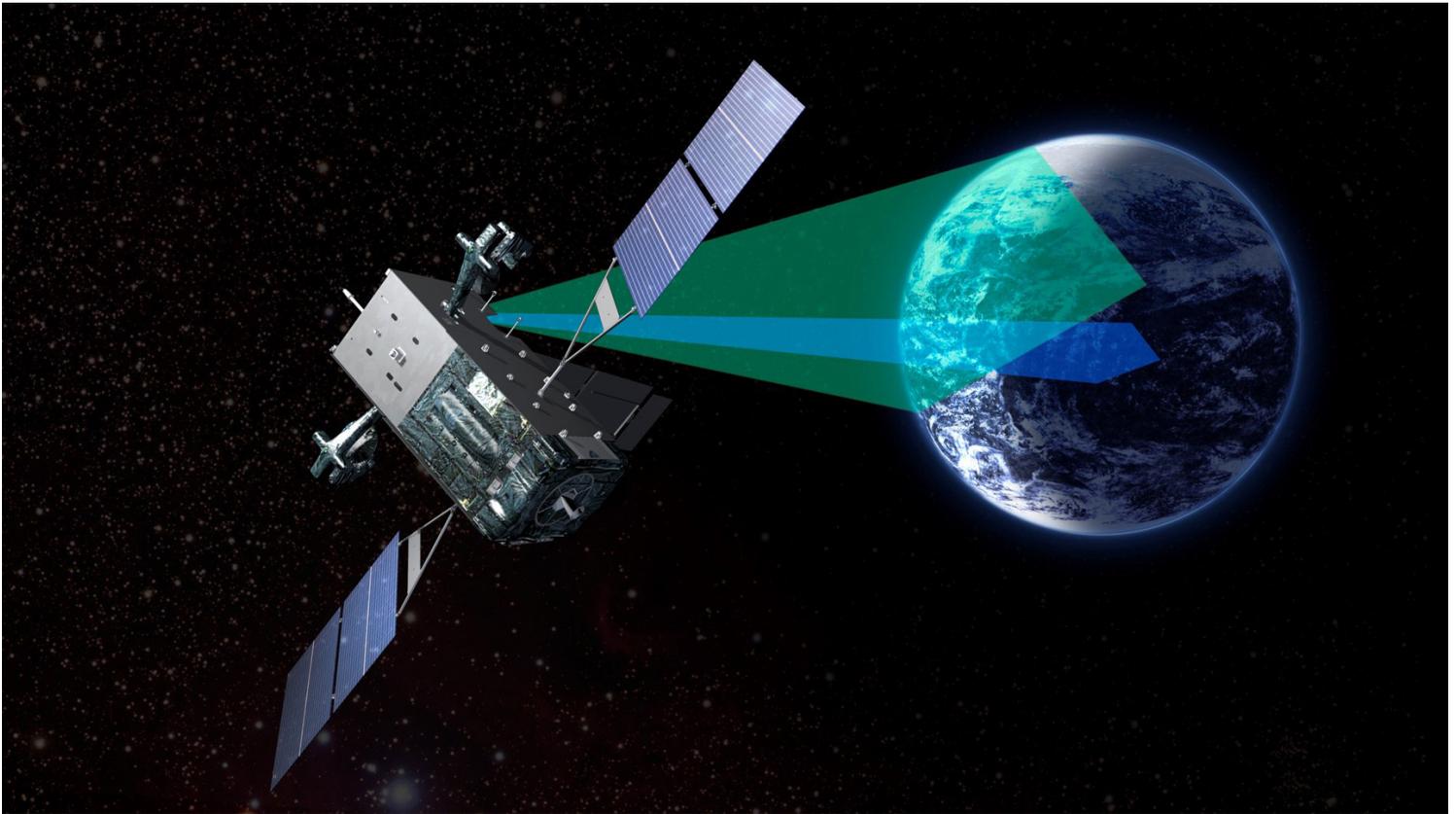
includes activities like pursuing joint research projects, investing in faculty research and development, and access to workforce development events.

For more information, or if you are a company looking to engage with CU Boulder in the areas of aerospace and defense, technology, sustainability, biosciences, innovation and entrepreneurship, and a number of other themes, please visit the IFR landing page: <https://www.colorado.edu/industry/about-us>. 

George Hatcher is Senior Managing Director of Industry Relations at the University of Colorado Boulder. He may be reached at George.HatcherIII@colorado.edu.



Laboratory for Atmospheric and Space Physics, CU Boulder.



Space-Based Infrared Satellite (Notional). Photo courtesy of SpaceNews, February 19, 2018.

Colorado: The Epicenter of National Security Space Capability

Jay Lindell

Colorado is home to our nation's most critical space capabilities that provide defense for our nation and our allies. The capabilities include precision navigation and timing signals, ballistic missile threat detection and warning, and communications systems that are vital for all national security operations. These capabilities are enabled by a significant defense space infrastructure; an innovative and thriving aerospace business ecosystem; and a highly educated, talented, and skilled workforce. These economic attributes not only provide for a strong national space-based defense capability, but also are a catalyst for the nation's largest per capita aerospace economy in the nation. Colorado is home to more than 500 companies and suppliers with over

33,000 employees that support more than 230,000 aerospace-related jobs across all industry sectors. With direct employment growth from 2019 to 2020 at 10.1%, the Colorado aerospace industry continues to grow faster than the national average of 3.7%, according to the *Colorado Space Coalition 2020, Aerospace Cluster Preview*.

There are three major defense systems as well as their associated command and control systems that best characterize Colorado as the epicenter of national security space capability, including the Global Positioning System (GPS), Space Based Infrared Satellites (SBIRS), and the Wideband Global Satellite Communications Systems (WGS). The GPS and WGS satellite systems are operated from the Peterson-Schriever

Space Force Garrison in Colorado Springs. The SBIRS system is operated from the Buckley Space Force Garrison just outside Aurora. Each of these systems is critical to our national security capability, and each system will be highlighted in more detail.

All of us understand the incredible capabilities that GPS provides to all of us daily. We rely on it to navigate and find the shortest or most traffic-free available routes to shopping locations, gas stations, and even to work. For military capability, encrypted signals are used that provide greater accuracy as well as other enhanced capability. This is especially critical for weapon systems to limit casualties and collateral damage. However, the most significant impact to our daily lives that GPS provides is

the timing signal. The GPS timing signal is synchronized with national atomic clocks and is accurate to a billionth of a second. According to GPS.gov, the precision timing signal provides world-wide synchronization for communication systems such as the internet, electrical power grids, financial networks, mobile phones, and automatic teller machines. Across the world, the impact of GPS in our daily lives is immeasurable.

In a 2019 GPS economic impact study hosted by the National Institute of Standards and Technology (NIST) in Boulder and conducted by the International Research Triangle Institute (RTI), the economic impact of the GPS system was evaluated. RTI examined 10 economic sectors of the U.S. economy that utilize GPS in their day-to-day business activities. These included precision agriculture, financial services, location-based services, mining, surveying, telecommunications, telematics, electricity, maritime navigation, and oil and gas industries. The takeaway was a \$1.4 trillion economic impact that the U.S. private sector has gained in economic benefits since GPS was made available to the private sector.

The GPS system is not only operated from Colorado, but most of the GPS satellites in operation today were produced in Colorado, and the next generation GPS III system consisting of 32 satellites will be built by Lockheed Martin Space based in Colorado. In addition, many of the satellites have been, and many more will be, launched into orbit by United Launch Alliance—also based in Colorado under a National Security Space Launch contract. GPS is an incredible capability free to the world that Colorado Springs-based Air Force Space Command provides.

SBIRS are produced by Lockheed Martin Space located in Colorado with assembly facilities at Sunnyvale, California. Many subcontractors in Colorado also contribute to the SBIRS' powerful satellites by providing sophisticated scanning and infrared surveillance sensors. These sensors also

allow the U.S. military to expand technical intelligence gathering and bolster situational awareness on the battlefield. The next SBIRS (SBIRS-5) is scheduled to be launched by United Launch Alliance this year.

In January 2020, Iran launched more than a dozen missiles at Iraqi bases hosting U.S. and Coalition troops during early morning hours when most military personnel were asleep in above ground targeted sleeping quarters. According to a January 8, 2020 article in *The Guardian*, Iran declared the strikes to be retaliation for the U.S.-admitted strike the week prior targeting an Iranian senior general in Iraq. Al-Asad airbase in Iraq's Anbar province was hit 17 times, including by two ballistic missiles that failed to detonate, according to the Iraqi government. A further five missiles were targeted at a base in the northern city of Erbil where U.S. forces were based. No American lives were lost, and none were seriously injured. The lives saved were credited with warning provided by SBIRS operators based at Buckley Space Force Base in Aurora. The warning communicated through secure satellite communications systems enabled U.S. troops in Iraq to take cover in prepared bunkers.

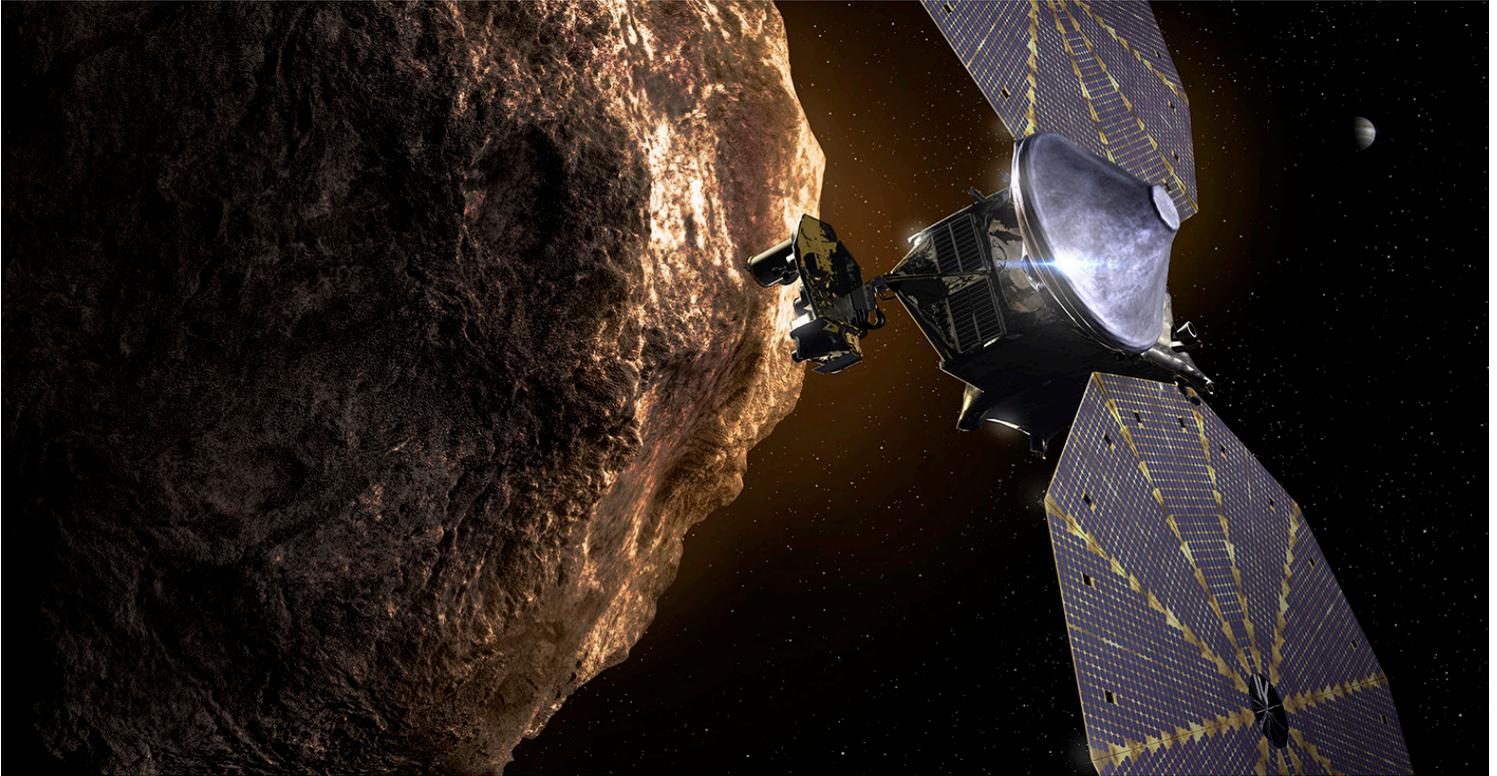
WGS provide the backbone of the U.S. military's global satellite communications with control and operations based at the Peterson-Schriever Garrison. According to the Air Force Space Command Public Affairs Office, the constellation provides a flexible, high-capacity communications for defense operations, presidential communications, State Department communications, allies, and other special users. The highly capable communications constellation is produced by Boeing in El Segundo, California, and comprises satellites in geosynchronous orbit with the latest launch in 2019 (WGS-10) by United Launch Alliance. International partners participating in the program include Australia, Canada, Denmark, Luxembourg, the Netherlands, and New Zealand.

Colorado is also the temporary home for U.S. Space Command and is the basing location for critical Department of Defense space operations which includes the National Space Defense Center at the Peterson-Schriever Garrison. Although Huntsville, Alabama was recently selected to be the eventual permanent home for U.S. Space Command, no other state in the nation has the preponderance of defense space systems operations, defense space production capabilities, a highly skilled and talented aerospace workforce, and a national security space headquarters, Air Force Space Command. Colorado is truly "the epicenter of national security space capability." 

Jay Lindell is Aerospace & Defense Industry Champion of Global Business Development at the Colorado Office of Economic Development & International Trade. He may be reached at Jay.Lindell@state.co.us.

Lockheed Martin: How Our Colorado Footprint is Shaping the Future of Space

Rick Ambrose



Artistic rendering of the Lucy spacecraft. Image courtesy of Lockheed Martin.

Lockheed Martin is a global security and aerospace company that solves complex challenges, advances scientific discovery, and delivers innovative solutions to help our customers keep people safe.

With approximately 110,000 employees spread across more than 375 facilities around the world, over 100 nations rely on our employees, products, and technologies to help them protect and connect their citizens while also gaining knowledge from the exploration of space. What many people may not realize is that much of our work supporting our customers' various missions happens right here in Colorado, the home of our Space business.

Our roots in Colorado run deep, tracing back to the 1950s when we built Titan

rockets at our Waterton facility in Littleton. Today, our aerospace legacy continues as our workforce builds satellites, spacecraft, and ground systems that do amazing things for both government and commercial customers alike. And our partnership with local universities and industry experts has created an aerospace ecosystem that continues to flourish, where Colorado ranks number one in the nation for per capita private aerospace employment.

Partnering Locally on NASA Missions

One great example of how we are continuing our history of partnerships with Colorado-based academic institutions is through our work on NASA missions. Here are just a few examples.

Lucy, the first mission to Jupiter's Trojan

asteroids, will be managed from Boulder at the Southwest Research Institute. Lucy will perform the first reconnaissance of the Jupiter Trojan asteroids orbiting the sun in tandem with the gas giant. Lucy's launch window opens in fall 2021, so we will see a lot of activity on that program this year. Lockheed Martin is proud to have designed and built, and will ultimately operate this spacecraft for NASA – all from Colorado.

The Lunar Trailblazer will help forge a path for humans to safely return to the Moon, thanks to its detailed study of lunar water. NASA's Lunar Trailblazer and Janus spacecraft both hail from our Waterton facility, and we are looking forward to finalizing their design phases this year in order to begin production next year. These are two of the first class

of three Small Innovative Missions for Planetary Exploration (SIMPLEx) missions for NASA – a cost-effective class of planetary science missions that are less than 400 pounds. Overall, we anticipate seeing this trend – small spacecraft that unite the best value with the best science – to continue to grow across the space industry.

And finally, we are a major subcontractor for Louisville-based Sierra Nevada Corporation that is building the Dream Chaser cargo spaceship. With the help of our Skunk Works® business in Fort Worth, Texas, we built the large composite body and wings of the spacecraft.

Investing in the Workforce and Technology of the Future

One important way we're building talent is by working with universities across Colorado, not only for recruitment, but also to develop technology. Some of our missions operate from the University of Colorado Boulder, our material characterization work comes from partnerships at Colorado School of Mines, and we work with Metropolitan State University of Denver to recruit some of the best aerospace technicians.

Our \$3 million partnership with CU Boulder is supporting academic programs in aerospace and electrical engineering aimed at cultivating the next generation of space engineers. The partnership includes a Lockheed Martin-endowed professorship and radio-frequency (RF) curriculum, with an RF-focused graduate certificate for electrical engineering and aerospace engineering students. Lockheed Martin also sponsors research with undergraduate and graduate students across a range of aerospace engineering disciplines.

We also provided a \$2.5 million grant to Colorado School of Mines in December 2015 to partner on additive manufacturing, helping to advance the industry and grow our talent pipeline. With headquarters at Colorado School of Mines, the Alliance for the Development of Additive Processing Technologies (ADAPT) was also developed to serve as an industry-academia consortium dedicated to solving challenges in additive manufacturing through data-

driven approaches. Lockheed Martin was one of the founding partners for ADAPT.

Our partnerships expand beyond the Denver Metro area. In southwestern Colorado, we're partnering with Fort Lewis College in Durango on solar research technology, with their Solar Innovation Park offering an opportunity to help expand advanced technology applications and economic opportunities in rural Colorado.

Working with small universities and businesses is a win-win all around, and we're looking forward to discovering even more opportunities to develop talent in our local communities.

Growing the Talent Pipeline

In order for our industry and state to sustain growth, we must address the increasing demand for science, technology, engineering and mathematics (STEM) talent. Lockheed Martin is collaborating with students and universities around Colorado on various technical programs, preparing them for careers in the aerospace industry and shaping the workforce of the future.

While we have invested in STEM programs across the nation for years – through organizations like FIRST Robotics, Project Lead the Way, and Girls Inc. – we are focused on fostering talent in our communities through partnerships with various schools and initiatives. For example, FIRST Robotics draws more than 1,400 students in Colorado, many of whom are considered for internships at our Colorado facilities.

In addition, Lockheed Martin has developed a Registered Apprenticeship program in partnership with the Colorado Department of Labor and Employment. The Advanced Manufacturing Technician Apprenticeship Program (AMTAP) was created in 2016 and designed to develop electronics manufacturing technicians and to ensure we have enough skilled workers to support major programs in this region. This paid training program provides on-the-job support for certification and qualification in production operations manufacturing techniques.

In the last three years, the Lockheed Martin Software Associate Degree Program (SWAP) has created a big



Graphic courtesy of Lockheed Martin.

impact in the state of Colorado. SWAP is a three-year development program designed to attract, develop, and retain early-career technical professionals in software and cyber-related careers. Students are accepted into the program before they graduate with their associate degree to accelerate the clearance process and to be ready to join Lockheed Martin after graduation.

We also realize the importance of hiring and supporting those who have served our country, and we're proud to partner with Hiring Our Heroes in support of its Corporate Fellowship Program in Colorado.

Through programs and partnerships like these, we will continue to inspire and learn from the next generation, strengthen the future talent pipeline, and advance the aerospace industry in Colorado and beyond – and I can't wait to see what we'll accomplish together next.

Rick Ambrose is Executive Vice President of Lockheed Martin Space.

Center for National Security Initiatives – Building from Fundamental Research Capabilities to Applications in the Aerospace Defense Sector

Iain D. Boyd



Hypersonic vehicles: a key priority for national security and a research focus at CU Boulder.

The aerospace defense sector is a vibrant ecosystem in the state of Colorado covering the full spectrum of activities including national security operations at military bases, development of technological capabilities by large industry and entrepreneurs, and basic research and workforce development at the state's universities. Across the sector, a very broad range of aerospace defense applications is being worked throughout the state for the air, space, and cyber domains of operation.

At the University of Colorado Boulder, the Center for National Security Initiatives (NSI) is a new effort aimed at increasing the engagement of the Boulder campus with all of the missions of the Department of Defense (DoD) and the Intelligence Community. Building on fundamental

research capabilities developed under funding from a variety of sources, NSI aims to facilitate its further development and application for national security challenges. With research projects staffed mainly by graduate students and postdoctoral fellows, the NSI activities will also contribute important contributions to much-needed workforce development in critical technologies.

A key foundation of NSI lies in CU Boulder's very strong aerospace capabilities. The university receives more funding from NASA than any other public university and the programs in the Department of Aerospace Engineering Sciences (AES) are ranked in the top 10 nationally at both the undergraduate and graduate levels among public universities. Students have tremendous educational

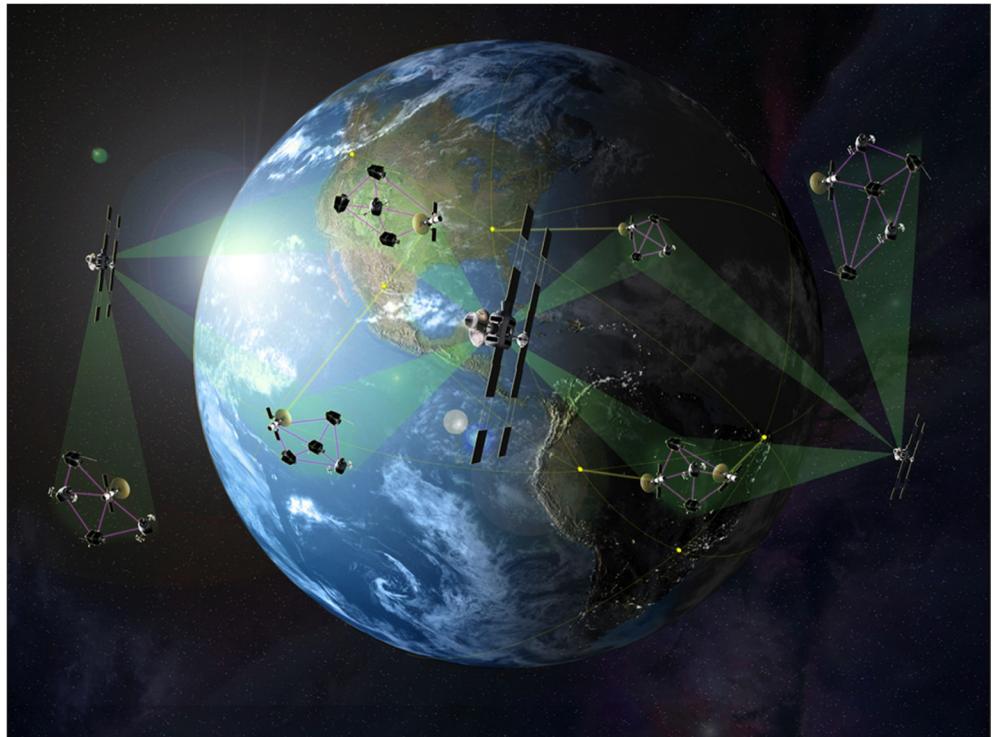
opportunities including invaluable hands-on experience gained through design-build-fly activities for Unmanned Air Systems (drones) and for CubeSats. CU has deployed more CubeSats in space than any other university in the nation.

A significant amount of basic research is being performed at CU Boulder that is motivated by aerospace defense applications. For example, the College of Engineering and Applied Sciences is investing internal funds to support the Hypersonic Vehicles Interdisciplinary Research Theme (HyVIRT) to expand the study of hypersonic systems that are a top priority for the Department of Defense. The goal of HyVIRT is to bring faculty with deep knowledge of specific hypersonic systems together with other faculty who are experts on

optimization to maximize hypersonic vehicle performance. In space research, telescopes on the roof of the AES building are used to track spacecraft in orbit. Sensors deployed around the globe are used by AES faculty to develop techniques to make use of GPS and signals from other satellites to improve navigation capabilities.

In addition to these aerospace activities, many unique research capabilities at CU Boulder have aerospace defense applications. For example, the quantum science laboratory JILA involves a close collaboration between CU and the National Institute of Standards and Technology (NIST), which is a component of the Department of Commerce (DOC). Based on quantum phenomena, JILA develops incredibly accurate atomic clocks and other sensing technologies that are relevant to the critical military mission of Positioning, Navigation, and Timing (PNT). The Collaborative Institute for Research on Environmental Sciences (CIRES) is a close collaboration between CU Boulder and the National Oceanic and Atmospheric Administration (NOAA), also a part of DOC. In helping to support weather operations, CU researchers develop capabilities based on data analytics to fuse large and disparate data sets into actionable information. This process has many similarities to key defense missions such as Intelligence, Surveillance, and Reconnaissance (ISR) and Space Domain Awareness (SDA).

NSI has been established through internal campus funding and is working in a variety of ways to increase campus engagement in national security research. For example, unique infrastructure is often required to participate in applied research for the DoD. NSI includes experienced staff with a detailed knowledge of contractual mechanisms and requirements that can be very different from those associated with basic research grants issued by organizations such as the National Science Foundation (NSF). Dedicated Information Technology systems are being acquired that can handle controlled, unclassified data



PNT: required for a wide range of national security missions and a research strength at CU Boulder.

that is sometimes required. Access to classified information is sometimes beneficial in working with DoD, and NSI manages security clearances for faculty when needed, and arranges access to classified facilities.

NSI staff are also working to develop new funding opportunities in the national security domain. For example, effective partnering is essential to making CU Boulder competitive for major DoD applied research awards. Opportunities are therefore actively being explored with many potential partners who may offer capabilities that are complementary to those that already exist at CU Boulder. These partners come from industry, nonprofit organizations, and other academic institutions, including all three sister campuses across the University of Colorado System in Colorado Springs, Denver, and the Anschutz Medical Campus. NSI is also engaging directly with the government to better understand their research priorities and to increase their awareness of CU's advanced research capabilities and interests.

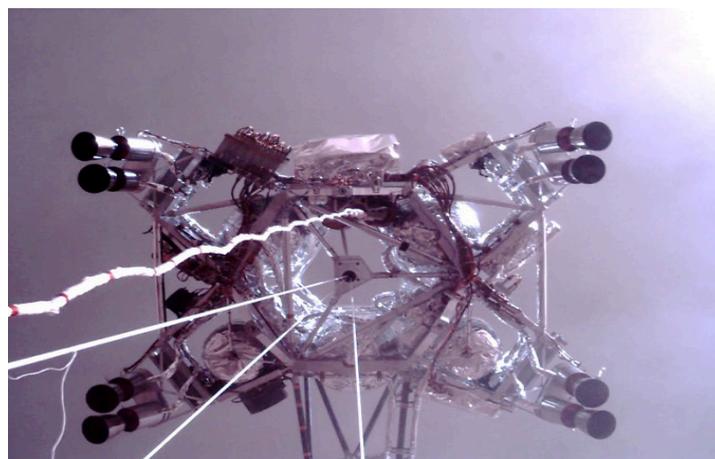
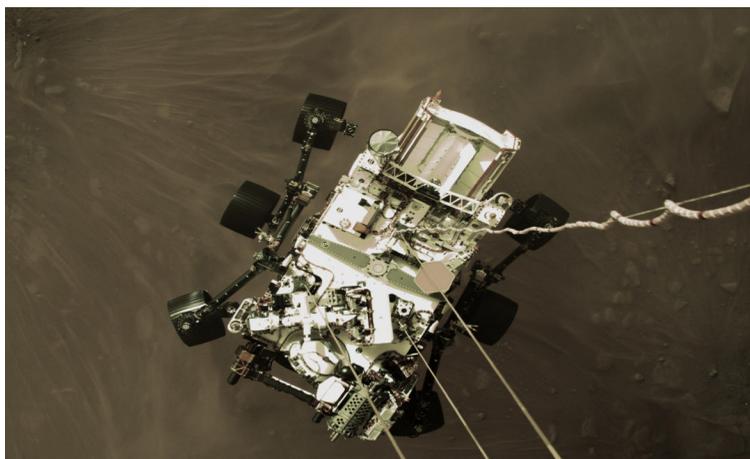
Now in its second year, NSI is on a strong growth path with active projects

underway and proposals submitted in a number of aerospace defense technologies including hypersonics, PNT, SDA, and satellite communications. These efforts involve over 40 CU faculty and involve support from a variety of sources including government, nonprofits, and prime contractors. As the flagship aerospace research university in the state of Colorado, working through NSI, CU Boulder looks forward to continued expansion of its capabilities and participation to become a leader in addressing the technological challenges of the Aerospace Defense sector. 

Iain D. Boyd is the Director of the Center for National Security Initiatives at the University of Colorado Boulder. He may be reached at Iain.Boyd@Colorado.edu.

Sierra Nevada Corporation: Committed to Colorado in Air and Space

Gregg Burgess and Betsy McDonald



SNC's Descent Brake lowering Perseverance to the surface of Mars. Image Credit: NASA/JPL Caltech.

“Tango Delta! Perseverance is safely on the surface of Mars.”

With those words, NASA's Jet Propulsion Laboratory (JPL)-built Perseverance rover, nicknamed “Percy,” completed its 309-million-mile journey to Mars February 18, 2021. The last 21 feet of the rover's commute was enabled by technology designed and built at Sierra Nevada Corporation (SNC) in Louisville, Colorado. SNC's Descent Brake did its job, unreeling three steel cables from the Sky Crane hovering over the Martian surface, to safely lower Percy for a soft landing. This is SNC's 14th mission to Mars alongside NASA, demonstrating the tech company's long and successful track record in delivering cutting-edge innovations to high-profile missions.

Best known publicly for SNC's Dream Chaser® spaceplane, SNC has deep roots in Colorado. Its 60-year legacy of state-of-the-art civil, military, and commercial solutions includes delivering more than 4,000 space systems, subsystems, and components to customers worldwide, and participation in more than 450 missions to space. With

1,900 talented people in Colorado across four campuses, SNC's success would not be possible without CU – there are 360+ CU graduates at the company!

SNC, owned by Chairwoman and President Eren Ozmen and CEO Fatih Ozmen, is a trusted leader in solving the world's toughest challenges through best-of-breed, open architecture engineering integrations in Space Systems, Commercial Solutions, and National Security and Defense. Under the Ozmen's leadership since 1994, SNC has grown from a small, Nevada-based company into a global enterprise via 20 strategic acquisitions. The company's Colorado journey began in 2005 through one of these acquisitions, Straight Flight, which laid the foundation for SNC's largest business area, Intelligence Surveillance and Reconnaissance, Aviation and Security (IAS), and allowed SNC to expand its offerings to include aircraft modification.

Starting with just four employees in Centennial, IAS is now 1,400+ strong in Centennial, Englewood, and Colorado Springs. IAS is a full-service prime contractor that integrates and operates

high-performance mission suites on manned and unmanned aircraft, delivering critical, timely capability to the U.S. government and allied nations. It also provides cybersecurity for critical infrastructure and is an FAA Diamond Award-winning provider of certified maintenance and repair for commercial aircraft. IAS encompasses 14 hangars across the region and draws upon the highly educated workforce and quality of life the area offers.

Also operating in Colorado is SNC's Mission Solutions and Technologies (MST) business area, working on Electronic Support items for Department of Defense customers in support of current operations. MST's core capabilities and customers originated in 1963 in Nevada, where SNC is headquartered, gaining speed and capabilities through the addition of talented engineers and support staff and the acquisition of companies such as Advanced Countermeasure Systems in 1998. As SNC capabilities in electronic and information systems grew, MST established itself in Centennial. This has

allowed the business area to capitalize on the area's adept workforce and the presence of key customers requiring specialized expertise in sensitive areas.

SNC's space journey began in 2008 with the acquisition of SpaceDev and Boulder's Starsys, followed by Littleton's Microsat Systems, Inc. These companies formed the core of Louisville-based SNC's Space Systems Group (SSG),

where the business area is assembling the Dream Chaser spaceplane. Under NASA's Commercial Resupply Services 2 (CRS-2) contract, Dream Chaser will undertake at least seven cargo missions to the International Space Station (ISS) and return to Earth by runway landing. Winning CRS-2 meant an expansion of SNC's Louisville workforce and that of

Centennial-based United Launch Alliance (ULA), the ISS mission launch provider.

Each Dream Chaser ISS mission also includes SNC's Shooting Star™ transport vehicle. Shooting Star provides substantial payload storage and facilitates cargo disposal when it burns up during re-entry into Earth's atmosphere. While CRS-2 is an unmanned space system that hosts astronauts while at the ISS, SNC's dream of building a manned spaceplane is still alive along with its vision of runway landings that return astronauts and other precious cargo home with a safe runway landing. Further, SNC has designed an inflatable, three-story LIFE habitat for NASA for its NextSTEP-2 project, demonstrating the enormous potential of inflatable structures for working, living, and thriving long term in space.

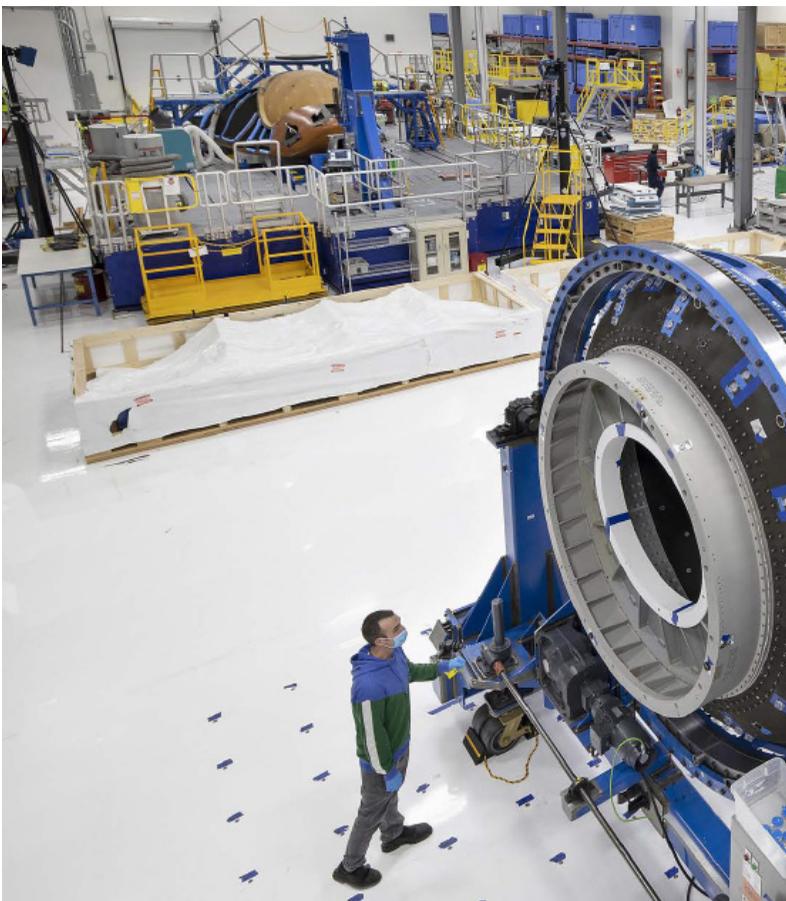
In addition to spacecraft and space exploration systems, SNC produces high-reliability precision mechanisms and solar panels for satellites, environmental systems for human life support in space, and propulsion systems for launch vehicles, satellites, and spaceplanes, including components for fellow members of the Colorado space ecosystem, Ball Aerospace, MAXAR, and Lockheed Martin Space.

As SNC continues to expand across the globe, Colorado operations remain at the heart of the company. In fact, SNC recently took occupancy of an 81-acre campus complex in Englewood. Bringing together more than 1,400 employees, every inch of the Rocky Mountain Campus was designed to encourage innovation, collaboration, and streamlined workflows. The state-of-the-art, 400,000-square-foot facility houses offices and laboratories. SNC is proud to be part of Colorado's robust business and academic aerospace ecosystem. 

Gregg Burgess is an executive at SNC's Aviation and Space groups, and Betsy McDonald is Senior Manager Communications at SNC.



SNC's mission enhancement capability includes facilities large enough for C-130 aircraft.



Dream Chaser Spaceplane and Shooting Star Transport Vehicle in assembly at Louisville, CO.

Leeds and Smead Collaborate on a Space Sustainability Initiative

Mark Meaney and Zack Donohew



Space exploration is a complex, technical, and expensive endeavor that traditionally has been the domain of government. However, commercial space sector activity is projected to grow and, indeed, continue to pace government space activities as technology advances and the costs of launching satellites into orbit continues to decrease. As more private-sector entities develop extraterrestrial ambitions, the sustainability of space activities is

increasingly at risk. While the domain of space is vast, low-earth orbit (LEO) is susceptible to degradation and depletion, including from space debris, satellite congestion, and radiofrequency interference. Furthermore, longer-term ambitions in space, such as asteroid mining and planetary colonization, arguably raise even larger sustainability concerns. Lack of attention to issues of sustainable development would mean that government and nongovernment

actors alike could face insurmountable problems in using the space domain effectively. Addressing the need for space sustainability means we can prevent negative trends from becoming norms and ensure that all actors can use the domain of space in an equitable manner.

SSI and the Tragedy of the Solar Commons

The Division of Social Responsibility and Sustainability (SRS) of the Leeds School of Business and the Smead Department of Aerospace Engineering Sciences of the College of Engineering and Applied Sciences have embarked on a Space and Sustainability Initiative (SSI). SSI serves as a way to bridge the two communities and accelerate collaboration with the commercial space sector. Funded by the CU Research and Innovation Seed Grant Program, the authors of this article serve as Principal Investigator (PI) and Co-Principal Investigator (Co-PI) along with Marcus Holzinger (Co-PI), Associate Professor at Smead and Associate Director of the Colorado Center for Astrodynamics Research (CCAR). The project team combines the business, entrepreneurial, and social responsibility expertise of Leeds faculty with the technical and space policy backgrounds of Smead faculty.

Outer space is often referred to as a “global commons,” though perhaps “solar commons” is more apropos for the scale we are talking about, due to the fact that its resources are not owned by one individual or nation, but rather are accessible to all humankind. Various treaties include phrases that define the exploration and use of outer space in these terms. The United Nations Outer Space Treaty recognizes “the common interest of all [hu]mankind in the progress and exploration and use of outer space

for peaceful purposes.” These terms and phrases define outer space as an open-access system. Nations thereby treat orbital space as a kind of communal pasture. Consequently, as space is inherently international, extremely difficult to own in whole or in part, and accessible to any actor who can develop or purchase the means to reach low-earth orbit or the moon, predictions of the tragedy of the solar commons are self-evident.

The concept of the tragedy of the commons describes a social dilemma that arises under special conditions. In sum, the tragedy of the commons is a problem in a shared, unregulated resource system in which individual users acting based on a rational pursuit of their own self-interest have an incentive toward unconstrained consumption of the resource at the expense of other individual users with no way to exclude anyone from consuming the resource. The tragedy of the commons can result in the degradation, depreciation, depletion, and even destruction of the resource. However, due to the work of Elinor Ostrom, a Nobel prize winner in economics, the tragedy of the commons is no longer considered inevitable. Ostrom has presented many cases of resource users deploying free market solutions by effectively self-organizing and sustainably managing a commons through the exercise of individual freedom and corporate collective action.

When the Outer Space Treaty was written, space exploration was strictly the province of the state, with few actors actively engaged in space exploration. Today, we are faced with the proliferation of commercial entities seeking to provide new services in space and on the Moon. If the commercial space industry is to avoid a tragedy of the solar commons, a solution along the lines of Ostrom’s self-governance framework must be applied to space exploration and extraction. The stakes for failing to manage the solar commons are high. The long-run value of the commercial satellite industry is estimated to be worth \$3 trillion by 2040 if well-managed. That estimate drops

to \$600 billion if the space industry continues to operate under a business-as-usual scenario that fails to address the collective management challenge. Instead of waiting on Federal and International agencies for regulation, the commercial space industry can proactively work together to address the issue of space sustainability through the application of the Ostrom governance framework of corporate collective action.

Commercial Space Industry Engagement

The SSI team has drawn on the combined power of its international, multidisciplinary networks to assemble an advisory board and working groups consisting of experts from the disparate communities of aerospace engineering, the commercial space industry, information technology, law, and public policy. Working group members include representatives from Amergint, Astroscale, AXA XL, Booz Allen Hamilton, Ball Aerospace, Celestial Insight, ComSpOC, Iridium, LeoLabs, Lockheed Martin, NASA JPL, OneWeb, Planet Labs, SES Satellites, SpaceX, and Secure World Foundation, among others. University engagement includes the Department of Aeronautics & Astronautics at MIT, the International Space University, and the Department of Aerospace Engineering and Engineering Mechanics at UT Austin. The working groups helped to constitute fora for the application of the Ostrom governance framework in a phase-in process.

For example, in Phase One of the project, the project team has gathered data from the U.S. Space Surveillance Network and other sources to determine the number of operational satellites by orbit in measuring the pervasiveness of the so-called “rules of the road” (RoR) problem. The problem of RoR occurs when operational satellites occupy the same orbit that can lead to the possibility of a conjunction or a near miss. In short, the possibility of conjunction raises critical questions about the need of norms of behavior to govern navigation as the number of objects in low-Earth orbit

(LEO) soars. With these data sets, the Team has used the Ostrom framework to encourage consensus among operators on norms of behavior that ought to undergird the resolution of RoR issues.

In Phase Two, the Team is working with members of a working group in conducting a values-based, commercial space industry market analysis through the application of the norms of behavior derived from Phase One. The Team is using the results of the market analysis to identify the essential features of a values-based, business model template for conducting the “business of space.” A values-based template is an essential part of developing best business practices that will help build confidence and trust with investors, insurers, and customers while ensuring business models are sustainable over the long term.

In Phase Three, the SSI Team is working with the support of working group members to link the norms of behavior for space sustainability to the broader corporate social responsibility and sustainability movement. Space-provided services and applications are part of the solutions to meet the targets of the UN Sustainable Development Goals (SDGs); however, providing space-based solutions to the SDGs requires a stable environment in orbit. The SSI team is making use of working group member expertise to help link the norms of behavior for space sustainability to the achievement of the SDGs as a metric for monitoring and tracking the impacts of the commercial space industry on society.

Phase Four will consist of dissemination. In this phase, the team will focus its efforts on the development of educational materials for undergraduate, graduate, and executive education. The intent is to inspire students to become ethically responsible business leaders of the commercial space industry. The Team will also produce white papers from the perspective of the private sector to inform decision-makers on how best to address such problems as space debris, satellite congestion, and radiofrequency interference.

continued at the bottom of p. 32...

Powerful Partnerships ... continued from p. 2

mission operations for NASA satellites, LASP is receiving global attention as I write this thanks to its key role in building the Hope spacecraft for the United Arab Emirates' first space mission to study Mars' atmosphere.

Back here on Earth, CU has become the place to be for those interested in learning, researching, and innovating in other areas as well. For over a decade, the University of Colorado Colorado Springs (UCCS) has been a pioneer in cybersecurity education, serving as a massive talent pipeline for the more than 125 cybersecurity companies located in the Pikes Peak region. In 2016, UCCS was instrumental in creating the National Cybersecurity Center (NCC), a nonprofit with a global and national mission to "secure the world." Among its programming, the NCC operates the world's only Space Information Sharing and Analysis Center (ISAC), which fosters collaboration across the global space industry to help companies and government agencies prepare for, and respond to, cyber incidents and disseminates intelligence among its members.

UCCS' leadership in the cybersecurity space will soar even higher with the opening of its Cyber Education and Research Center in early 2022. Consolidating its world-class cyber

research, education, and innovation under one roof, the center will be co-located with the NCC and its Space ISAC, bolstering existing industry and government collaborations and serving as fertile ground for new ones.

Strength in Numbers

All our campuses prepare the highly technical workforce and conduct research the aerospace sector and its satellite fields demand. Building off CU Boulder's National Security Initiative, in spring 2020 I created the CU National Security Advisory Group with faculty experts from all four campuses. The group is tasked with identifying existing strengths and collaborative opportunities to enhance our support for current and future national security-related projects and initiatives, especially in space, medical care, and cybersecurity. While CU faculty systemwide received more than \$49 million for research from the U.S. Department of Defense (DoD) in FY2019, I am confident we can further expand the university's role in federal national security efforts by coordinating our work and leveraging our assets and capabilities.

Given our proximity to numerous DoD installations in Colorado – and our leadership in healthcare, sustainability, energy, space, and quantum computing – CU is an ideal resource for our many security partners in the state and the

nation. When considering where to place the permanent home of U.S. Space Command, these factors serve as major selling points for making the case for Colorado, efforts in which CU has been instrumental. While we have hope Space Command may still remain in the Centennial State permanently, regardless of the outcome, CU will play a pivotal role in its research and operations and will continue to train and grow its workforce.

Just as I marveled at U.S. spaceflight as a child, I often marvel at the university's achievements in advancing space exploration, discovery, and security as CU's president. We continue to play a pivotal role in helping our state and nation answer JFK's call to be a leader in space. I know that by strengthening existing partnerships and forging new ones, CU's impact on aerospace will reach unimagined frontiers. 

Mark Kennedy is president of the University of Colorado.

COLORADO BUSINESS REVIEW



Leeds School of Business
UNIVERSITY OF COLORADO BOULDER

Space Sustainability Initiative ... continued from p. 31

Conclusion

Instead of waiting on federal and international agencies for regulation, the commercial space industry is working together to address the issue of space sustainability. Through the application of the Ostrom governance framework, the commercial space industry is working to develop and deploy norms of behavior based on common values that resolve the tragedy of the solar commons. Lack of attention to issues of sustainable development would mean that the

industry could face insurmountable problems in using the space domain effectively. 

Mark Meaney and Zack Donohew are both Scholars-In-Residence in the Division of Social Responsibility and Sustainability at the University of Colorado's Leeds School of Business. They may be reached at Mark.Meaney@Colorado.EDU and Zachary.Donohew@Colorado.EDU.

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