SE:SA

SPACE EDUCATION & STRATEGIC APPLICATIONS

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Melissa Layne, Ed.D. *Editor-in-Chief*

THE

INAUGURAL CONFERENCE ISSUE

PART 2

PSO

SE:SA SPACE EDUCATION & STRATEGIC APPLICATIONS

SPACE EDUCATION AND STRATEGIC APPLICATIONS JOURNAL

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PSO

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Editorial

Melissa Layne

American Public University System

Dear *SESA* Readers,

The inaugural 2020 Space Education & Strategic Applications conference in October was certainly a testament to perseverance and commitment. Originally scheduled six months earlier in April as an in-person event, organizers were forced to postpone the conference to October using a virtual platform. Despite this rapid and dynamic pivot to hold a virtual conference, our sponsors, American Public University System (APUS) and Policy Studies Organization (PSO), were well-equipped to rise to the occasion. However, we were careful not to be *too* sure of ourselves lest something terribly wrong were to occur!

As the conference date was nearing, we continued to experience an increasing influx of presentations; so, what was supposed to be a one-day event, now became two full days for the space community to gather in "our virtual space."

Dr. Vernon Smith, Provost at APUS, served as our Master of Ceremonies by opening the conference with a lively and motivational introduction, and ended by expressing sincere gratitude to presenters, attendees, and organizers. Our presenters shared their extensive knowledge around a variety of space-related topics via sessions, roundtables, panels, fireside chats, and keynotes. As a newcomer to the space conference scene, SESA's plenary addresses were quite impressive, and included NASA's Julielynn Wong, Stacy Kubicek from Lockheed Martin, Natalie Panek of Mission Systems MDA, and Emily Calandrelli, host of the Emily's Wonder Lab. The most anticipated session was that of the Honorable Barbara Barret, Secretary of the U.S. Air Force. For session video recordings go to https://whova.com/embedded/event/seasa_202010/?utc_source=ems

This issue highlights the truly outstanding work from some of our presenters—many of whom have expressed their excitement for the next SESA conference taking place on **September 23rd and 24th, 2021.** Mark your calendars!

The following pages provide a glimpse of some of our conference data in addition to attendee / presenter responses to our end-of-conference survey.

Melissa Layne, Ed.D.

Editor-in-Chief, SESA

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SESA Conference Fast Facts

- Over 500 registrants
- Over ten countries represented
- Five plenary speakers
- Session Attendance: Sessions averaged between 70-80 viewers
- Reporters / Editors in attendance: *Popular Mechanics, Sky and Telescope, and Aviation Week*

Presenter and Attendee Responses

"Best two days on space imaginable. The APU professors were impressive and so was everyone. What a great, great event."

"I couldn't agree more. Way superior to other online conferences I have seen."

"Congratulations again on a very successful conference!

I'm enjoying the presentations I've attended."

"Thank you very much for the honor and privilege of attending this year's space conference. I enjoyed it immensely. It was very informative and the speakers were excellent! I very much look forward to attending next year and possibly presenting."

"It was a pleasure speaking for your conference recently, and thank you so much for your lovely speaking gifts! I really enjoyed the most excellent SWAG from APUS."

"You have done a great job."

"Thanks again for a great conference; I really enjoyed the meetings - lots of great talks and information! Thank you for the opportunity to present there as well.

I like what you folks are up to, and I'm a little interested in AMU's programs."

"I would recommend this conference to others."

"Please invite me back directly next year—if you have a mailing list for SE:SA 2021 specifically, I would appreciate being included…Thank you for including me this year and hope you find value in my feedback."

“We recommend the conference to all of the students at my children’s elementary school. It would be great to develop a program that just speaks to students- they are the future of any space program.”

“The topics covered were important and relevant.”

“Keep doing what you are doing. You are building the next decade of thinkers.”

“I enjoyed the presentation from Susan IP, the Plenary session by Secretary Barrett, Kristen Miller's presentation, and many others. It was a fantastic variety of speakers!”

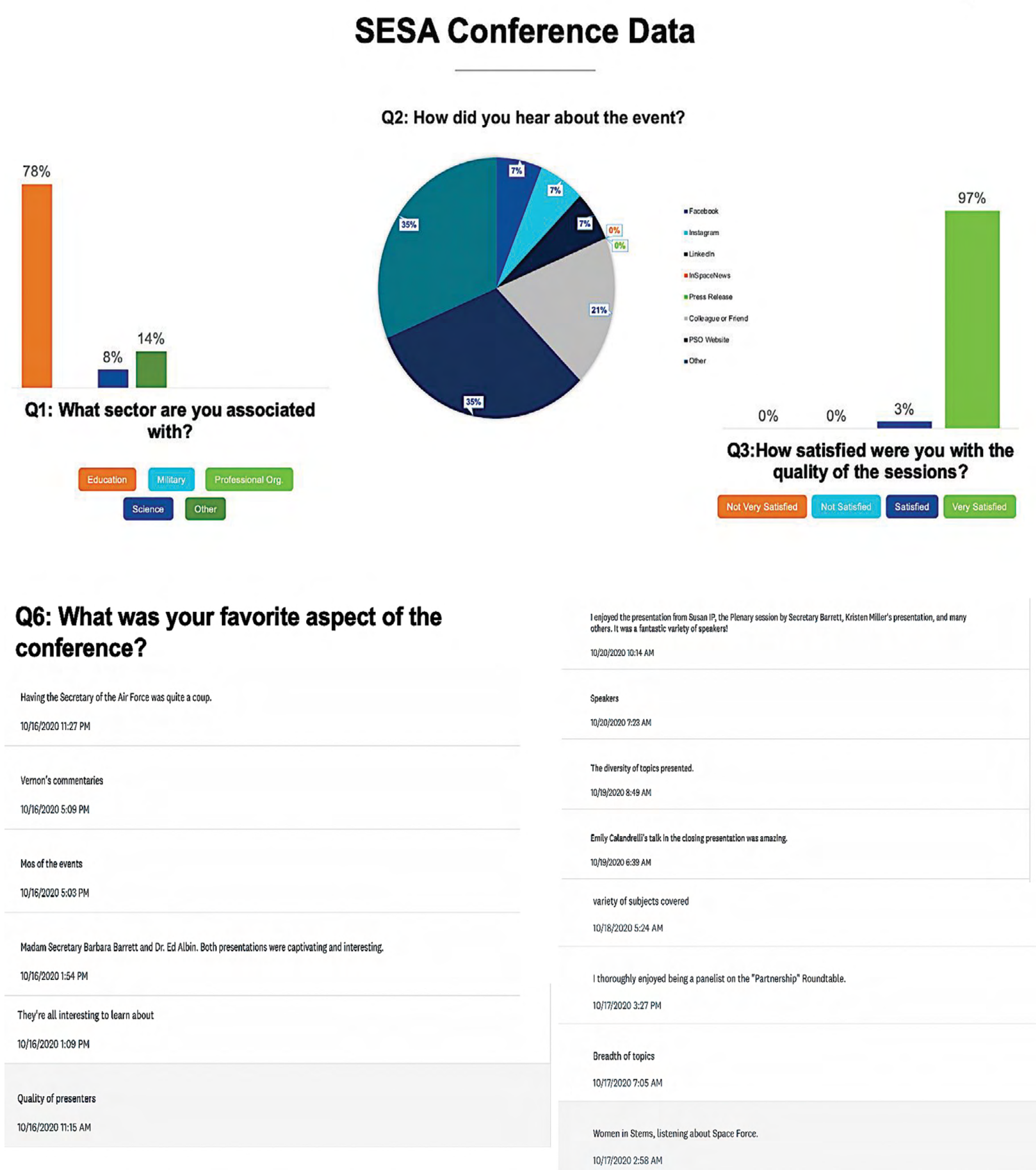
“The organizers for this conference did a fantastic job—especially since it was their first SESA conference!”

“I thoroughly enjoyed being a panelist on the "Partnership" Roundtable. It was a great conference for it being the first.”

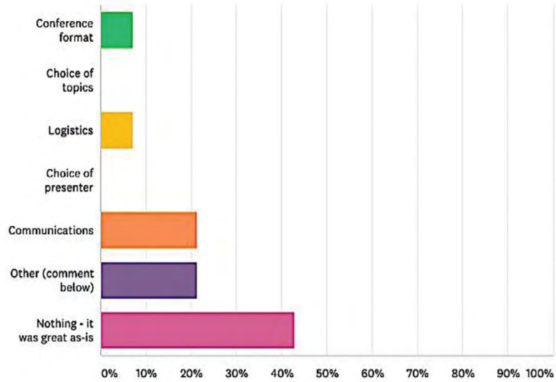
“I hope you will use the conference to continue to make the public aware of certificate and degree programs in space studies.”

“Presentations were captivating and interesting.”

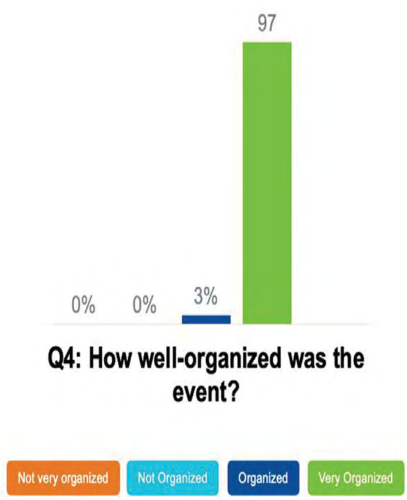
“I found a lot of the discussions to be extremely interesting (even if most was out of my realm of understanding).”

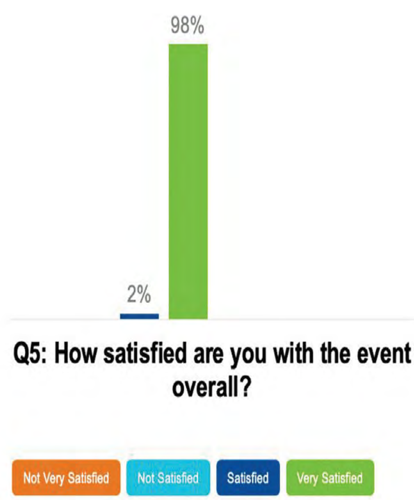

SESA Conference Data
Q2: How did you hear about the event?
7%
7%
7%
0%
0%
35%
21%
35%
Facebook
Instagram
LinkedIn
InSpaceNews
Press Release
Colleague or Friend
PSO Website
Other
78%
8%
14%
Q1: What sector are you associated with?
Education
Military
Professional Org.
Science
Other
97%
0%
0%
3%
Q3:How satisfied were you with the quality of the sessions?
Not Very Satisfied
Not Satisfied
Satisfied
Very Satisfied
Q6: What was your favorite aspect of the conference?
Having the Secretary of the Air Force was quite a coup.
10/16/2020 11:27 PM
Vernon's commentaries
10/16/2020 5:09 PM
Mos of the events
10/16/2020 5:03 PM
Madam Secretary Barbara Barrett and Dr. Ed Albin. Both presentations were captivating and interesting.
10/16/2020 1:54 PM
They're all interesting to learn about
10/16/2020 1:09 PM
Quality of presenters
10/16/2020 11:15 AM
I enjoyed the presentation from Susan IP, the Plenary session by Secretary Barrett, Kristen Miller's presentation, and many others. It was a fantastic variety of speakers!
10/20/2020 10:14 AM
Speakers
10/20/2020 7:23 AM
The diversity of topics presented.
10/19/2020 8:49 AM
Emily Calandrelli's talk in the closing presentation was amazing.
10/19/2020 6:39 AM
variety of subjects covered
10/18/2020 5:24 AM
I thoroughly enjoyed being a panelist on the "Partnership" Roundtable.
10/17/2020 3:27 PM
Breadth of topics
10/17/2020 7:05 AM
Women in Stems, listening about Space Force.
10/17/2020 2:58 AM

Q7: What could we improve?



ANSWER CHOICES	RESPONSES
Conference format	7.14%
Choice of topics	0.00%
Logistics	7.14%
Choice of presenter	0.00%
Communications	21.43%
Other (comment below)	21.43%
Nothing - it was great as-is	42.86%





An Interview with Dr. Lorenza Cooper

Dr. Kandis Y. Boyd Wyatt
American Public University System

Dr. Lorenza Cooper is a life-long Atmospheric Scientist and serves as an Assistant Professor at American Public University System. Dr. Cooper serves as a lead instructor and course developer of all meteorology courses offered at the University. In this capacity, he plans and prepares curriculum that remains relevant in a rapidly advancing discipline. His focus is on his students, and he establishes learning outcomes to best position students in a competitive career environment. For students with an interest in learning more about the weather, Dr. Cooper initiates and facilitates discussions to promote critical thinking, as well as providing quality and timely feedback to assist students in successfully achieving course objectives. We are featuring Dr. Cooper in this edition of *SESA* to highlight the connections between the atmosphere and many aspects of physical science.

Dr. Wyatt: Can you start by talking about how a career in meteorology has impacted your life, both personally and professionally?

Dr. Cooper: *All meteorologists have an obsession with the beauty and power behind weather. Hurricane Hugo inspired me. As a child I remember running to the window whenever there was a storm. Its power and strength amazed me. Ever since, meteorology has been my passion and I pursued courses in atmospheric science in school. I never knew that meteorology was a major. I saw the broadcast meteorologists on tv—many of whom were reading a script. Now I realize that meteorology is interdisciplinary, and there are linkages between meteorology, geology, and space. I became a storm chaser, and I was honored to receive a fellowship with both NASA and NOAA. Who knew my fascination with weather could blossom into a career? My kids have also caught the bug, and are intrigued by weather as well.*

Dr. Wyatt: How do you separate prevailing thought from science and data when it comes to atmospheric science?

Dr. Cooper: *Atmospheric Science not only means the here and now, but includes a historical perspective of the past. There are weather records dating back to the 1800s. These data collections help researchers draw climatic trends. It's important to focus on the data to develop scientifically sound conclusions. In the courses I teach, I strive to create a relationship between weather and life experiences. Weather affects our lives on a daily basis. In the classroom, the theories and abstractness of weather can become*

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more concrete. We can see both the national and international implications of weather on a daily basis.

Dr. Wyatt: APUS has a large number of students and a plethora of disciplines. How does weather relate to other careers offered by APU?

Dr. Cooper: *It's important to see the connections between meteorology and all major disciplines. Let me discuss a few. For careers in business, there are monetary implications to weather. For example, a wind storm would produce a prolonged power outage, affecting millions of residents. For those in the health field, flooding can cause standing water which results in unhealthy conditions. In fact, we are in the midst of a pandemic because of a temperature-dependent airborne virus, so understanding how air quality, temperature, and circulation patterns affect humans is important. Entomology, which is the study of insects, highlighted how Malaria was transported via insects. Hurricanes can affect life and property when they prevent damaged areas from receiving supplies in a timely manner. So, Disaster Relief efforts can affect the supply and demand of an area both before the storm when purchasing items and afterwards when conducting recovery efforts. A single event can affect the hotel industry, the ability to provide fuel (gas) to impacted areas, and may limit food distribution. There are many more questions to consider which impacts various careers such as:*

- *Is this impacting a town, county, state, or region?*
- *Is the weather instantaneous?*
- *Are the impacts easily addressed?*

Dr. Wyatt: There have been discussions about creating a Space Force? How will weather impact this emerging field?

Dr. Cooper: *This is another area in which weather is key, literally. Weather is the core/center between atmosphere and space. Imagine the type of weather that may be encountered as you travel through the atmosphere into space. Satellite imagery, GPS, cell phone coverage are all impacted by space weather. Solar flares can affect radio signals, and the ability to communicate from one country to another.*

Clouds cover a huge surface area of the earth, and many areas are cloud covered the majority of the year. Satellite imagery helps us understand the interactions of weather on the surface of the earth, over oceans, and throughout the "column" from the earth to the upper atmosphere. At APUS, we have courses that delve into these very facets of the earth's atmosphere to highlight why understanding space weather is critical.

Dr. Wyatt: You are currently the course creator for several atmospheric science courses at APUS? Can you tell us about these courses?

Dr. Cooper: *APUS provides several courses for individuals to expand their knowledge of atmospheric science. There are four meteorology courses—one of which is the SPST465 Space Weather Course. The space weather course investigates weather throughout the at-*

mosphere such as Venus, Mars, and Jupiter. Our SCI137, Introduction to Meteorology Course (general science requirement), investigates various phenomena of weather to include tornadoes, floods, fires, and hurricanes. The course is three credits, but if you include a lab component, the course is four credits.

For the more advanced we offer a course on Atmospheric Dynamics. Thermodynamics is the movement of weather from one level to another (temperature and wind). It's important to understand these fluctuations on a microscale (50 meters) to a macroscale (5000 meters).

What's great about these courses is that there is a weekly discussion forum that helps students make connections to real-time weather occurrences. For example, the latest hurricane, storm, or blizzard can affect those who have careers in Health, Computer Science, STEM, and Business.

Dr. Wyatt: Who should enroll in these courses? Are they for anyone, or just to those pursuing a degree in science?

Dr. Cooper: *Introduction to Meteorology is open to everyone. This course fulfills an APUS general education requirement. I see students from a variety of majors enrolled in the course—including health, natural sciences, emergency management, transpor-tation and logistics, and fire science. Everyone can benefit from a diverse discussion that includes a variety of perspectives.*

Dr. Wyatt: How can a certificate benefit someone in a closely related scientific field?

Dr. Cooper: *The possibilities are endless with an APUS certificate in Meteorology. APUS has many fields of study, so this certificate compliments the stellar coursework offered at the University. The courses are more than just learning about the interdisciplinary implications of meteorology. They also provide critical thinking, practical research applications, and an evolved train of thought when it comes to the atmosphere.*

Dr. Wyatt: What are the connections between weather and space, artificial intelligence (AI), hydrology, air quality, modeling, oceanography, and climate science?

Dr. Cooper: *Weather connects to just about every discipline. Let me give you a few examples. Artificial Intelligence (AI), can use data to create business forecasts models for energy security, solar energy, and wind energy. Many businesses will conduct a weather analysis to ensure the land is not in a flood plain before starting a construction project. Wind Farms conduct a similar analysis when searching for the best locations to create these farms. Understanding these trends over time is the very definition of climate science. Climate, which is weather over time, has never been stagnant, and continues to evolve. Water is the most precious resource, and hydrology can identify impacts when too much water (flooding) or too little water (drought) affects an area. More than 70% of the earth is covered by water, so it's also important to have oceanographers who an-*

alyze sea level rise, underwater currents, and carbon dioxide trends.

Dr. Wyatt: What are some resources you have used or provided in the past to help individuals become more aware of the atmospheric sciences?

Dr. Cooper: *The field of meteorology and atmospheric science continues to expand. I encourage people to review peer-reviewed journals, such as Space Education & Strategic Applications (SESA), for advancements in weather. For atmospheric sciences, I recommend the American Meteorological Society's periodical, called the Bulletin of the American Meteorological Society, for peer reviewed work. For real-time information about weather, I encourage reviewing operational meteorology webpages such as the Storm Prediction Center (www.spc.noaa.gov) which provides around the clock forecasts and updates for the United States. In addition, many government websites provide access to data at no cost, and provide a wealth of information.*

Commentary: Orbital Dynamics for National Security Lawyers

Jordan Foley
Georgetown University Law Center

Abstract

Space is harsh, and does not operate like terrestrial environments. For national security lawyers and those advising commanders in operational law choices, drawing direct comparisons to maritime, littoral, and air regimes is a flawed assumption. Space is not uniform. Space domains impose different constraints and support different operating options. The overall goal of this article is to demystify and help normalize outer space, so national security lawyers can add value to the overall mission. By introducing Juris Doctors to conceptual insights of space physics implications, they can better develop frameworks for understanding operational choices.

Keywords: orbital dynamics, national security lawyers, space, LEO, GEO, HEO, MEO

Comentario: Dinámica orbital para abogados de seguridad nacional

Resumen

El espacio es duro y no funciona como los entornos terrestres. Para los abogados de seguridad nacional y aquellos que asesoran a los comandantes en las elecciones de leyes operativas, establecer comparaciones directas con los regímenes marítimo, litoral y aéreo es una suposición errónea. El espacio no es uniforme. Los dominios espaciales imponen diferentes restricciones y admiten diferentes opciones operativas. El objetivo general de este artículo es desmitificar y ayudar a normalizar el espacio exterior, para que los abogados de seguridad nacional puedan agregar valor a la misión general. Al introducir a los Juris Doctor en conocimientos conceptuales de las implicaciones de la física espacial, pueden desarrollar mejor los marcos para comprender las opciones operativas.

Palabras clave: dinámica orbital, abogados de seguridad nacional, espacio, LEO, GEO, HEO, MEO, doctores juris

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评论文：国防律师应理解的轨道动态

摘要

太空是恶劣的，其运作模式不同于陆地环境。对国防律师和那些为长官提供操作性法律选择咨询的人士而言，将太空与海上、沿海、航空系统作直接比较是一个有瑕疵的假设。太空并不是均一的。太空领域施加了不同限制，并支持不同的操作选择。本文的总体目标是阐明并帮助将外太空正常化，以便国防律师能对整体太空任务作贡献。通过让职业法律博士（Juris Doctors）理解有关太空物理影响的概念，他们能更好地制定用于理解操作选择的框架。

关键词：（太空）轨道动态，国防律师，太空，LEO，-GEO，HEO，MEO，职业法律博士

Luke Skywalker: Why don't you outrun them? I thought you said this thing was fast.

Han Solo: Watch your mouth, kid, or you're going to find yourself floating home. We'll be safe enough once we make the jump to hyperspace ...

Obi Wan Kenobi: How long before you make the jump to lightspeed?

Han: It'll take a few moments to get the coordinates from the navicomputer.

Luke: Are you kidding—at the rate they're gaining?

Han: Traveling through hyperspace isn't like dusting crops ...

Star Wars Episode IV - A New Hope

I'll be checking a lifelong goal off my list: quote Star Wars in an academic publication. That wasn't just for a laugh. Han is right—"Traveling through hyperspace isn't like dusting crops." Science fiction or not, there is a valuable lesson in the old smuggler's statement. Space is harsh and does not operate like terrestrial environments. For the national security lawyer and those advising commanders in operational law choices, drawing direct comparisons to maritime, littoral, and air regimes is a flawed assumption. Space is not uniform. Space domains impose different constraints and support different operating options.

"Orbital Dynamics for National Security Lawyers" is a purposefully "dry" title. The overall goal of this article is to demystify and help normalize outer space, so national security lawyers can add value to the overall mission. By introducing Juris Doctors to conceptual insights of space physics implications they can better develop frameworks for understanding operational choices. While the title may be dry, I hope my sci-fi references make a discussion on astrodynamics more palatable for those who took a look at undergraduate calculus and ran the other way.

There's a lot to cover. Orbital dynamics is just one subset of the many PhDs associated with the engineers, scientists, and physicists working in the field. In 2020, we are starting to see different professions flock to outer space for lucrative opportunities—enter stage right, businesspeople and lawyers. The proliferation of private space companies, like SpaceX and Blue Origin, are reshaping a *modus operandi* thought once to be the sole province of government entities. That's because space is an expensive medium. Pre-launch costs are in the tens of millions of dollars and take years to plan and execute. Satellites require an extensive ground support structure, including control centers and command and control infrastructure. SpaceX breaking onto the stage shows private companies can compete in space commerce—with business opportunities comes the need for legal support.

International law directs State and non-State actors' conduct in outer space. You might be familiar with the 1967 Outer Space Treaty (OST). We can call this the "magna carta" of Space Law. It's foundational. However, space law has been around since even before then. Numerous earlier UN Resolutions expressed legal principles for outer space prior to the OST, but they did not become binding until incorporated into a treaty in 1967. Every spacefaring state is a party to the OST, and several provisions have become principles of customary international law, too.

There's quite a time gap between the last crewed moon landing in 1972 and now, yet the topic of space law has never been more important. How do we manage private actor's and investor's expectations in this domain? How do we think about military forces in outer space? After all, this past year has seen the establishment of the U.S. Space Force and significant private sector achievements in outer space. So, it's not the Millennium Falcon jumping to hyperspace, but we are approaching an era of increased operations in outer space.

Believe it or not, there is a lack of international consensus on how we approach space law. Some believe a carefully framed legal order should be established, potentially through an international leasing system modeled on the United Nations Convention on the Law of the Sea (UNCLOS), to preserve the original goals and purposes of the OST during this new space age. Others are skeptical about any regime and believe most proposals would be rejected by major spacefaring countries.

But, at the very least, there has to be consensus on where outer space *begins*. Wrong. The start of outer space is not as clear as you might assume. The distance between Earth and space is about 62 miles (100 kilometers), which is called the Karman line. By general accord, the Karman line is the altitude where suborbital space begins or where the planet's boundary ends. In other words, it represents the border between the Earth's atmosphere and outer space. The Karman line is conventionally used as the start of outer space in space treaties and for aerospace records keeping. Historically, the lowest satellite orbits have had perigees as low as 80-90 km. The U.S. Air Force actually considered all X-15 flights above 80 km as astronautical flights and gave those pilots astronaut wings. There have been objections, particularly in the United States, to defining any legal boundary of space on the grounds that it could cause disputes about airspace violations below the boundary, or that too high a boundary could inhibit future space activities.

In Carl Sagan's science fiction novel *Contact*, which was later adapted to a movie bearing the same title, the main character played by Jodi Foster exclaims at the grandeur of outer space, "No words to describe it. Poetry! They should have sent a poet." If you are 0 for 2 now with movie references, you have some mandatory viewing after you're done reading. Sending a poet on this mission to capture extraterrestrial beauty in words is an interesting proposition. Of course, there will be many times we will encounter legal issues in outer space, and I don't think anyone would cry, "We should have sent a *lawyer*!" —but we are going to need lawyers. In particular, national security lawyers will be vital. It is about time to think about many aspects of space law. The focus of this article is how we equip national security lawyers with the tools they need to understand outer space and provide valuable legal advice for those companies and warfighters dependent upon their services.

Lawyers becoming experts in a technical field is not a novel concept. For example, lawyers practicing in medical malpractice have more knowledge about medical procedures and doctors' conduct than a layman, but at the same time, very few of those attorneys have an M.D. In medical malpractice cases, lawyers will still lean on experts, such as physicians in that particular field, to inform their arguments. To ask an attorney to be an expert in cardiothoracic and neurological surgery while maintaining proficiency in the law doesn't seem reasonable. However, in preparing for a particular case, we expect that attorney to be knowledgeable. After all, advocates must package and present complex material to a judge or jury. Just like a medical malpractice attorney must understand general surgery as it pertains to the case, lawyers involved in space law must understand orbital mechanics. I am not asking an attorney to, like a NASA engineer, use Keplerian elements in a two-line element set to maintain location information on all man-made objects in Earth's orbit. I am just proposing a training module that gets a lawyer up to speed on the space environment like those medical malpractice lawyers preparing for their next big, technical case. As a J.D. candidate, Navy Space Cadre Operations Officer, former Nuclear Submariner, and future JAG, I am positioned to offer some sort of well-packaged training for national security lawyers. This article is me beginning my quest to encourage all lawyers involved in space law to seek to understand the physics. In starting with orbital dynamics, we are drinking from a firehose, but I'm trying to slow the flow. Let's give it a whirl, and the next sections will hopefully have you walking away with newfound knowledge and desire to learn more about outer space.

Let's say it out loud, "Orbits are complex." Space is not "uniform" and orbits serve different functions. Because different orbits bring different utilities and problems, we need to plan our missions accordingly. Not to mention, changing orbital domains is difficult, so planning occurs pre-launch. Once on orbit, satellite path is largely determined by physics and not the operator, so we need to understand how the space environment will impact the spacecraft or else we will see limited functionality. The orbits we will focus on are Low Earth Orbit (LEO), Mid Earth Orbit (MEO), Geosynchronous and Geostationary Orbit (GEO), and Highly Eccentric Orbit (HEO). I don't have a pneumonic to remember these by like we had in grade school for the planets: "My Very Educated Mother Just Served Us Nine ..."—sorry, Pluto. However, the names are pretty descriptive. Let's start with the orbit closest to Earth.

LEO is a nearly circular orbit below 1,500 km altitude. LEO satellites travel ~ 43,000 km in 90 minutes, without effort. A major feature is this orbit is close to the ground, so cheap launches get spacecraft into LEO. It is a relatively benign radiation environment with low atmospheric drag. A spacecraft in LEO will gain eventual global coverage. Common uses of LEO are for imaging, weather, and communications.

MEO consist of orbits between LEO and GEO, often at 20,000 km. Some major features of MEO are that there is good continuous coverage with multiple satellites, but it is a harsh radiation environment. The primary use of MEO is for navigation. This orbit is where the GPS constellation lives.

GEO consists of circular equatorial orbits near 35,000 km altitude. A major feature of GEO is its continuous regional coverage, but its high launch costs and great distance from earth make it a challenging orbit to reach. Common uses are for navigation, communication, weather, and imaging. While geosynchronous satellites can have any inclination, the key difference to geostationary orbit is the fact that they lie on the same plane as the equator. For a constant ground track, satellites will be in geostationary orbit. The difference is subtle, but important in understanding this orbit's utility. For example, geostationary communication satellites are useful because they are visible from a large area of the Earth's surface, extending 81° away in both latitude and longitude. They appear stationary in the sky, which eliminates the need for ground stations to have movable antennas. See *Fig 1. GEO Satellite Ground Coverage* below.

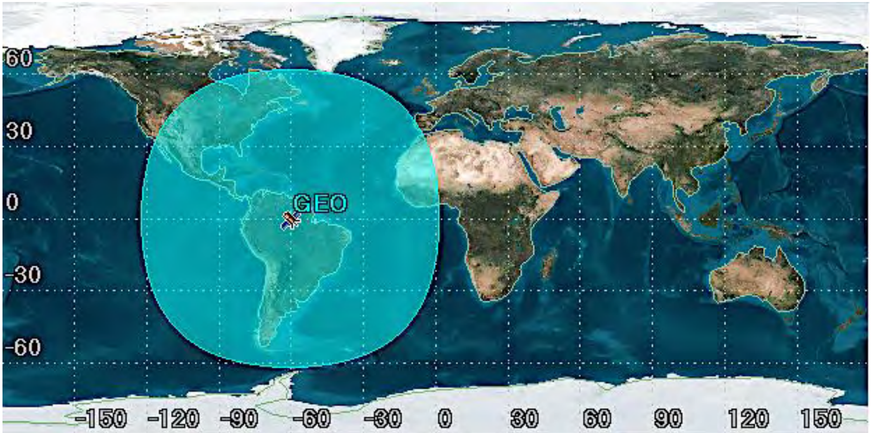

Fig 1. GEO Satellite Ground Coverage

HEO has orbits with altitude of perigee (defined as the point in the orbit of the moon or a satellite at which it is nearest to the earth) near LEO and altitude of apogee (defined as the highest point in the development of something; a climax or culmination) near GEO. Some features of HEO are long dwell times at apogee, and apogee can provide polar coverage. Most common uses are communications and transfer orbits from LEO to GEO.

Let's be clear. Getting from orbit to orbit once in space is not easy. As you saw, distances are vast and require a lot of fuel. Fuel is important in space. Typical spacecraft do not carry enough fuel to allow frequent dramatic orbit changes. The fuel carried is mostly to counteract orbit perturbations, also known as "station keeping." Fuel is often the limiting factor for satellite lifetime. Large changes must be preplanned as part of launch and operating budget. Orbit changes can be just a one-time expense to attain desired orbit. Remember that distance is thought about differently in space, so moderate altitude changes are actually hundreds of kilometers. Overall, orbit changes are costly and not simple.

As you can see, each orbit lends itself to different missions based on coverage and rotation. HEO, with its long dwell times at apogee and polar coverage, is a good orbit for optical spy satellites focused on that region. With their near continuous coverage, GEO makes for a great orbit for launch detection satellites. LEO is the cheapest and easiest orbit to enter, so many spacecrafts live here out of necessity, but continuous coverage can be achieved with multiple satellites. MEO (See Figure 2 below) is where GPS satellites orbit, because each satellite circles the Earth twice a day, and with an expandable 24-slot satellite constellation, GPS gets constant coverage.

There are also many classifications of orbits which vary in distance and synchronicity. Understanding LEO, MEO, GEO, and HEO are different distances from Earth is important, but we need to also think about the spacecraft

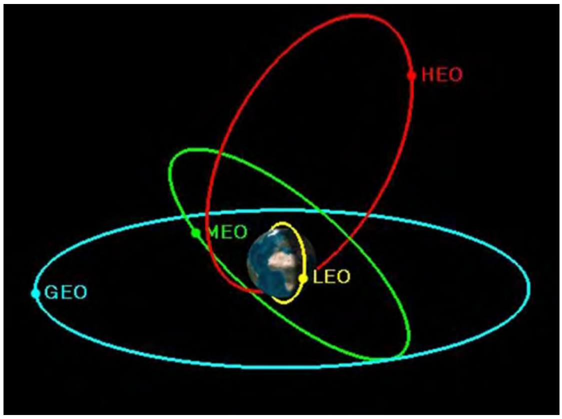

Figure 2. MEO Satellite Ground Coverage

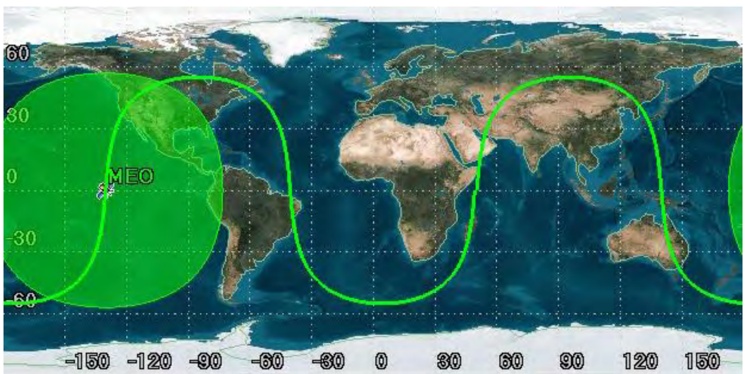

Figure 3. Summary Graphic of Orbits

in orbit and how many times it will orbit Earth. This is called a synchronicity classification. Not only do we consider which orbit, but also the number of times that orbiting body will pass over a point on earth. For example, the large majority of imaging sensors are on sun-synchronous orbits. This orbit allows the satellite to fly over the same area at the same time of day and provide nearly global coverage over a period of typically one to two weeks.

Think of synchronicity of orbits as the number and frequency of rotations around Earth. That is a pretty simplistic way to understand these classifications, but for our purposes we just need to be able to define the types of synchronicity classifications and the benefits they bring. This means the track of the satellite, as seen from the central body, will repeat after a fixed number of orbits. We will discuss synchronous, semi-synchronous, and sun-synchronous orbits. A synchronous orbit is an orbit in which a body (usually a satellite) has a period equal to the average rotational period of the body being orbited (usually a planet) and in the same direction of rotation as that body. Simply put, a synchronous orbit is an orbit in which the orbiting object (for example, an artificial satellite or a moon) takes the same amount of time to complete an orbit as it takes the object it is orbiting to rotate once.

A semi-synchronous orbit is an orbit with a period equal to half the average rotational period of the body being orbited, and in the same direction as that body's rotation. For Earth, a semi-synchronous orbit is considered a medium Earth orbit, with a period of just under 12 hours, like the GPS constellation in MEO.

A sun-synchronous orbit (also called a helio-synchronous orbit) is a nearly polar orbit around a planet, in which the satellite passes over any given point of the planet's surface at the same local mean solar time. A sun-synchronous orbit is useful for imaging, spy, and weather satellites, because every time that the satellite is overhead, the surface illumination angle on the planet underneath it will be nearly the same. This consistent lighting is a useful characteristic for satellites that image the Earth's surface in visible or infrared wavelengths, such as weather and spy satellites; and for other remote-sensing satellites, such as those carrying ocean and atmospheric remote-sensing instruments that require sunlight. For example, a satellite in sun-synchronous orbit might ascend across the equator twelve times a day each time at approximately 1400 mean local time.

If you're a lawyer reading this, you're probably asking yourself, *"Why am I learning about this?"* I am glad you asked. While space is vast, that does not mean two satellites will never collide causing a liability issue. In fact, we had a collision about ten years ago. In February 2009, Cosmos 2251, an inactive Russian satellite, collided with an active commercial communications satellite operated by U.S.-based Iridium Satellite LLC. The incident occurred approximately 800 km above Siberia. The collision produced almost 2,000 pieces of debris and many thousands of pieces more that are too small to track. Much of this debris will remain in orbit for decades or longer, posing a collision risk to other objects in LEO. This was the first-ever collision between two satellites in orbit, and it served as a wake-up call for the entire space community to the threat that space debris poses to active satellites as well as of the long-term negative impact catastrophic collisions can have on the space environment. The Liability Convention dictates that for damages which occur on orbit, fault must be determined. However, a legal definition does not currently exist for fault within the context of the Convention. The Cosmos-Iridium collision forced the space community to come to grips with the reality of today's space environment.

This is where our medical malpractice analogy diverges. In medical malpractice cases, expert witnesses provide input on the defendant's actions with respect to current medical standards and procedures. The attorneys in those cases are also relying on a wealth of case law, both State and Federal. In space law, we do not have case law. This field of law is predominantly governed by treaties. Without case law and only limited treaties, understanding the space

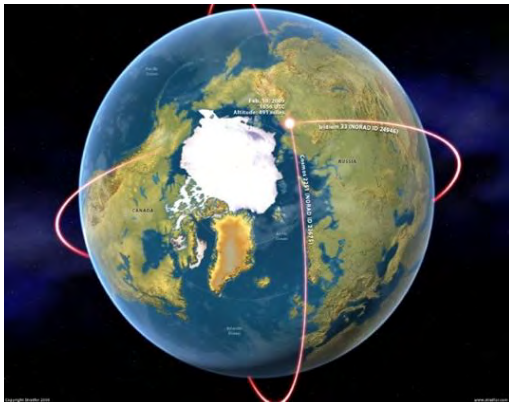

Figure 4. Cosmos-Iridium Collison

environment is crucial. For one, if you did not know there were different orbits with different characteristics, you'd have a rough time speaking up for your client. Not to mention, your client, someone well educated in the field, might lose faith in your abilities. Lawyers need to be more knowledgeable about the space operating environment to properly apply the existing legal regime or develop novel legal concepts.

From a national security perspective, space capabilities have proven to be a significant force multiplier when integrated into military operations. Countries must protect assured access through the synergy of cyberspace, space, and electronic operations. Joint forces rely on space assets and capabilities such as intelligence, surveillance, and reconnaissance. Formalizing the U.S. Space Force means more national security lawyers will need to be well versed in not only orbital dynamics but understanding the space environment.

On December 20, 2019, the United States Space Force (USSF) became the sixth branch of the Armed Forces. The Space Force was established within the Department of the Air Force with the enactment of the 2020 National Defense Authorization Act. The Secretary of the Air Force is responsible for organizing, training, and equipping the Space Force as a separate, distinct military uniformed service. U.S. Space Command (SPACECOM) is a geographic combatant command (CCMD) with responsibility for fighting anywhere above 100 km. "So just as we have recognized land, air, sea and cyber as vital warfighting domains, we will now treat space as an independent region overseen by a new unified, geographic combatant command," President Donald Trump said at a ceremony standing up SPACECOM. In defining SPACECOM's area of responsibility, U.S. policy begins this CCMD's duties at the Karman line.

From pre-launch (before a spacecraft leaves the ground) to orbit (the spacecraft enters outer space and begins to rotate around Earth), the space environment challenges all space-based missions. After reading this brief overview of orbital dynamics, we now understand that space is not "uniform" and orbits serve different functions. Orbits are complex, but the major takeaway is they are different and offer advantages and disadvantages for certain missions. Understanding the differences between orbits is an important first step in understanding why some orbits are preferred for certain missions. Adversaries, both State and non-State actors, will exploit the availability of space-based capabilities to support their operations. In keeping with the principles of joint operations, this makes it incumbent on the U.S. to deny adversaries the ability to utilize space capabilities and services. To that extent, the U.S. military is organized to meet its objectives in space. National security lawyers should be equally equipped to enable space missions.

"Traveling through hyperspace isn't like dusting crops," and space law is not like the law of the sea or any other terrestrial law. The new space age is placing unique requirements on people and industries formerly unassociated with the space race. National security lawyers must become technically proficient to best advocate for clients. Whether these lawyers are on the D.C. beltway or beyond, the law will be better formed by advocates who understand the operating domain of outer space.

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Commentary: A Star Story of War: NATO's Dangerous Plan for Space Domination

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Abstract

For the Indigenous peoples of the land that is now Canada, the heavens are where life originated. The Anishinaabeg believe that when humans die, they pass through the spirit world to the stars. At night, they see their ancestors dance across the sky. For the Indigenous people, there is a sacred, spiritual connection between the earth and the star world. In the constellations, the Anishinaabeg see loons, moose, bear, thunderbirds, and turtles. They have their own names for the constellations. The Big Dipper Stars are known as the Fisher Stars. The Pleiades star cluster is known as the Seven Daughters of the Moon and Sun. The light and patterns in the sky guide their hunting and ceremonies. The Indigenous people remind us that there is one sky, but many ways of seeing and understanding it. How do our Western governments and militaries view the sky? What is their star story? Outer space is seen as a new contested area of competition, conflict and power projection.

Keywords: star, Indigenous, Anishinaabeg, NATO, UN, space domination, Space Force, National Defense Authorization Act, Conference of Defence Associations Institute

Una historia de guerra estelar: el peligroso plan de la OTAN para dominar el espacio

Resumen

Para los pueblos indígenas de la tierra que ahora es Canadá, los cielos son el origen de la vida. Los Anishinaabeg creen que cuando los humanos mueren, atraviesan el mundo espiritual hasta las estrellas. Por la noche, ven a sus antepasados bailar por el cielo. Para los indígenas, existe una conexión espiritual sagrada entre la tierra y el mundo de las estrellas. En las constelaciones, los Anishinaabeg ven somormujos, alces, osos, pájaros del trueno y tortugas. Tienen sus propios nombres para las constelaciones. Las Big Dipper Stars

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se conocen como Fisher Stars. El cúmulo de estrellas de las Pléyades se conoce como las Siete Hijas de la Luna y el Sol. La luz y los patrones en el cielo guían su caza y ceremonias. Los indígenas nos recuerdan que hay un cielo, pero muchas formas de verlo y entenderlo. ¿Cómo ven el cielo nuestros gobiernos y militares occidentales? ¿Cuál es su historia estrella? El espacio ultraterrestre se ve como una nueva área en disputa de competencia, conflicto y proyección de poder.

Palabras clave: estrella, OTAN, ONU, dominio espacial, Fuerza Espacial, Ley de Autorización de Defensa Nacional, Instituto de Asociaciones de la Conferencia de Defensa

星空战争故事：北约危险的太空主导计划

摘要

对居住在如今属于加拿大领土的土著人民而言，天空是生命起源的地方。阿尼新纳贝格人（Anishinaabeg）相信当人们去世时，他们通过精神世界前往星空。在晚上，他们看见祖先在星空中跳舞。对土著人民而言，地球和星空世界之间存在一个神圣的精神联系。在各星座中，阿尼新纳贝格人看见潜鸟、麋鹿、熊、雷鸟和海龟。他们给不同星座赋予自己创造的名字。北斗七星被他们称作鱼貂星（Fisher Stars）。昴宿星团被称作月亮和太阳的七个女儿（Seven Daughters of the Moon and Sun）。天空中的光和模式指引他们的狩猎和仪式。土著人民提醒我们，虽然仅有一个天空，但却有多个看待和解读它的方式。我们的西方政府和军事如何看待天空？他们的星空故事是什么？外太空被视为一个关于竞争、冲突和权力投射的新争夺领域。

关键词：星球，北约，联合国，太空主导，太空军，国防授权法，国防协会会议研究所

1. Introduction

For this year's World Space Week, I've been contemplating Indigenous cosmological knowledge and teachings. I live in Waterloo, Ontario on the traditional territory of the Anishinaabeg, Haudenosaunee, and Neutral peoples along the Grand River. With their oral tradition, they have passed on their unique stories of the sky and stars.

For the Indigenous peoples of the land that is now Canada, the heavens are where life originated. The Anishinaabeg believe that when humans die, they pass through the spirit world to the stars. At night, they see their ancestors dance across the sky. For the Indigenous people, there is a sacred, spiritual connection between the earth and the star world.

In the constellations, the Anishinaabeg see loons, moose, bear, thunderbirds, and turtles. They have their own names for the constellations. The Big Dipper Stars are known as the Fisher Stars. The Pleiades star cluster is known as the Seven Daughters of the Moon and Sun. The light and patterns in the sky guide their hunting and ceremonies.

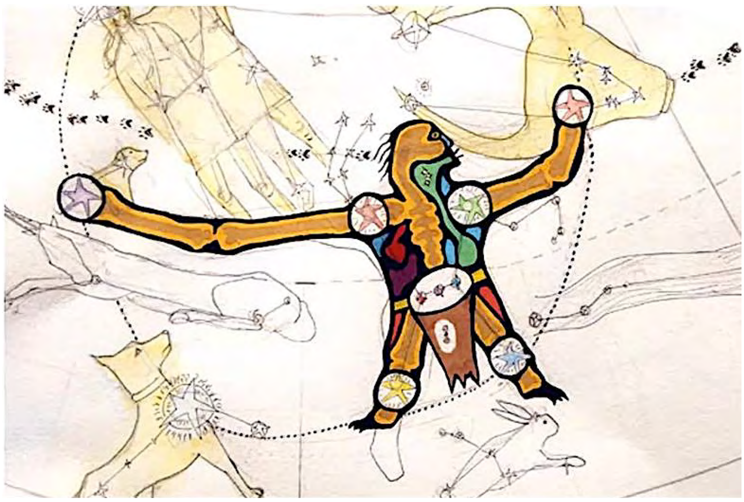

Figure 1. Sky Star Map

The Indigenous people remind us that there is one sky, but many ways of seeing and understanding it. How do our Western governments and militaries view the sky? What is their star story? Outer space is seen as a new contested area of competition, conflict and power projection.

Over the past two years, the United States and its North Atlantic Treaty Organization (NATO) allies have launched a dangerous narrative of space as a place for war. Last August, when President Trump launched the new military service "Space Force," he said space will be the next "war fighting domain." NATO is perpetuating this perilous conceptualization.

2. North Atlantic Treaty Organization (NATO) and Expanding Militarism

NATO is an aggressive, nuclear-armed Western military alliance that is dominated by the United States. It is comprised of 30 members, including Canada, which was one of the twelve founding members in 1949. NATO also has its so-called "partnership for peace" program that includes 40 non-member countries, such as Australia, New Zealand, Japan, South Korea and Afghanistan. With a neocolonial, militarized view of security, the alliance is expanding.

In 2018, Colombia became NATO's first Latin American partner. Yet Colombia is a narco-state ruled by the right-wing government of President Ivan Duque. The Colombian government has connections to drug trafficking and is undermining the 2016 peace deal in the country. Colombia is one of the most militarized and violent countries in South America. According to the non-governmental organization Global Witness, Colombia is a country where journalists are threatened and attacked and where human rights defenders are being killed in the hundreds. Last year, 300 human rights defenders and social movement leaders were murdered. Colombia is one of the closest U.S. allies in the region and has escalated conflict with its neighbour, Venezuela.

Just as we must critically question why Colombia is the first country that NATO has partnered with in Latin America, so too must we raise concerns about the alliance's expansion into space.

3. NATO and Space for War-Making

At the 2018 NATO Summit in Brussels, leaders of the allied countries stated that space is essential for their security, and they agreed to develop a Space Policy. The following year, the NATO Defence Ministers met at the alliance's headquarters and adopted their first Space Policy. Until that point, the transatlantic alliance did not have a space mandate.

In December 2019, at the Leaders' summit in London, NATO members announced space as a fifth domain alongside air, land, sea, and cyberspace. NATO Secretary General Jens Stoltenberg stated, "We have declared space an operational domain recognising its importance in keeping us safe and tackling security challenges, while upholding international law." Although he said NATO has no intention to put weapons in space, there is a lack of transparency about the alliance's plans.

NATO's Space Policy is not publicly available. I contacted NATO Headquarters to ask for a copy, and they replied that it is classified. We can only speculate on what NATO's plans for space are based on its belligerent operations on Earth and its destabilizing expansion in Eastern Europe and Latin America.

Currently, there are more than 2,000 satellites orbiting the Earth, approximately half of which are owned by NATO member countries. The alliance operates its own satellite communications (SATCOM) programme. Though some of those satellites are defunct, they are still orbiting the Earth and carrying the NATO logo. Last year, NATO authorized 1 billion EUR for a new SATCOM service over the next 15 years.

Figure 2. Popular Mechanics headline "NATO Is Preparing for War in Space"
Courtesy Getty Images

Figure 3. Space Week Tweet by SHAPE NATO Allied Command Operations

NATO chiefly relies on the national space capabilities from its dominant members, the United States, United Kingdom, and Germany, to provide data and services, such as imagery, navigation, targeting and early warning. These space capabilities enable NATO's war-making.

Last October, NATO announced its new Space Center at its Allied Air Command at Ramstein Air Base in Germany. NATO and the U.S. have used the space capabilities at Ramstein to direct their military operations and drone strikes in Iraq, Syria, Afghanistan, and Pakistan.

Russia and China are the only peer competitors to NATO in space. It is troubling that the transatlantic alliance constantly invokes adversarial Cold War rhetoric against these two countries. On Earth, NATO has also threateningly positioned its soldiers and weapons systems closer to Russia's and China's borders. Conflict in space between NATO and Russia or China could be disastrous and risk an all-out nuclear war.

Yet Russia and China don't want space used as a new battleground. At the United Nations Conference on Disarmament, they have put forward their joint draft treaty on the prevention of an arms race in outer space in 2008, 2014, and 2018. However, primarily because of NATO member countries' reluctance and opposition, this draft treaty to prevent war in space has not moved forward at the UN.

4. NATO Military Spending and Profiting from Weapons

In the mid-1990s, American weapons manufacturers pushed for NATO expansion into Eastern Europe. They saw the region as a new subsidized market for their weapons systems. Today, NATO members are required to modernize their militaries and upgrade their capabilities across all domains to stay interoperable with allies.

In 2014, at the Wales Summit, NATO members pledged to increase their defence budgets to 2% of GDP by 2024 and to spend 20% of that amount on procurement including space technologies. Over the past five years, military spending by alliance members has increased drastically.

Just as conflict and competition on the Earth is good for profit-making for the weapons manufacturers, so too is it in space. Two years ago, it was reported that the U.S. military was not keen on a new Space Force because many defense officials thought it would be redundant and too costly.

Yet congressmen, backed by defence contractors, pushed for a new space service in the National Defense Authorization Act (NDAA) in 2018. The following year, Mark Esper, the U.S. Secretary of Defense at the time, strongly advocated for Space Force. Esper, though, was the former top lobbyist for Raytheon, a contractor that manufactures space and airborne sensor systems used by the U.S. military.

In Canada, the Conference of Defence Associations Institute (CDAI) applauded Trump's announcement of Space Force. The CDAI said "U.S. Space Force was a good idea" and that Canada should have one too. It is not surprising that this Canadian industry group, which is funded by the U.S. weapons manufacturers—Raytheon, Lockheed Martin, and L3 Harris—is supportive of a Canadian space force. Other NATO allies are also establishing new space forces such as the United Kingdom and France.

With well-funded public relations and lobbying, the weapons manufacturers magnify the U.S. military's and NATO's view of space as a warfighting domain to serve their private, profit-making interests. At this time when funding is desperately needed for the global health care crisis, the climate emergency and to achieve the United Nations' Sustainable Development Goals, NATO's pressure on members to spend more on their militaries is grossly irresponsible.

5. Creating a New Star Story of Cooperation and Peace

Earlier this year, NATO Secretary General Jens Stoltenberg announced a new plan entitled, *NATO 2030: United for a New Era*. It is an initiative to keep NATO strong militarily and to expand it politically. For outer space, the alliance sees it as essential to its "ability to win on the battlefield." We cannot let NATO weaponize and dictate our star story.

Figure 4. NATO Keep Space for Peace.

We do not need NATO at all. The United Nations comprises all 193 member countries and has inclusive agencies, legal instruments, and diplomatic mechanisms that facilitate cooperation and conflict mediation. It is through the UN that countries should establish the shared norms and state behaviour for the peaceful uses of space. Similar to the Anishinaabeg, space should be a site of shared heritage and humanity. With Indigenous wisdom and international solidarity, the story of space as a global common that needs to be protected and preserved for peace is possible.

Tamara Lorincz is a PhD candidate at the Balsillie School of International Affairs at Wilfrid Laurier University, and a board director of the Global Network Against Weapons and Nuclear Power in Space. She is also a member of the Canadian Voice of Women for Peace and a fellow with the Canadian Foreign Policy Institute.

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Crossing the Chasm ... Space Edition

Tim Chrisman

Foundation for The Future (F4F)

Image credit: F4F

Abstract

We face a "race" to the stars that requires a joint public-private sector entity designed to fund and support space development and infrastructure, similar to the building of the Erie Canal, the Transcontinental Railroad, and supporting our air, sea, and road highways serving the public. But now, our focus is on space.

Balancing the needs of industry, taxpayers, workers, and our children requires the U.S. to deploy a full range of financial, policy, and/or educational tools. This is best accomplished through creating a single entity with the mandate, authority, and reach to effect change at the speed of innovation. The best way to achieve this is by forming a Space Public-private Advanced Commercialization Enterprise (SPACE) Corporation.

Keywords: Space Public-private Advanced Commercialization Enterprise (SPACE) Corporation, Space Corp, private and public sector, economy, investment, policy, space access, space sustainability, space support

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Cruzando el abismo… Edición espacial

Resumen

Nos enfrentamos a una "carrera" hacia las estrellas que requiere una entidad conjunta del sector público y privado diseñada para financiar y respaldar el desarrollo y la infraestructura espaciales, similar a la construcción del Canal Erie, el Ferrocarril Transcontinental, y respaldar nuestro aire, mar y carretera. carreteras al servicio del público. Pero ahora, nuestro enfoque está en el espacio.

Para equilibrar las necesidades de la industria, los contribuyentes, los trabajadores y nuestros hijos, EE. UU. Debe implementar una gama completa de herramientas financieras, políticas y educativas. Esto se logra mejor mediante la creación de una entidad única con el mandato, la autoridad y el alcance para efectuar cambios a la velocidad de la innovación. La mejor manera de lograrlo es formando una Corporación de Empresa de Comercialización Avanzada Pública-Privada Espacial (SPACE).

Palabras clave: Space Public-private Advanced Commercialization Enterprise (SPACE) Corporation, Space Corp, sector público y privado, economía, inversión, políticas, acceso al espacio, sostenibilidad espacial, apoyo espacial

跨越分歧（太空版）

摘要

我们面临一场通往星球的“竞赛”，这场竞赛需要由公共-私人部门共同组成的实体，用于出资和支持太空发展和基础设施，类似于建设伊利运河、横贯大陆铁路，和支持为公众服务的航空航海设施以及高速公路。不过现在，我们的重点是太空。

在产业、纳税者、工人、后代的需求之间寻求平衡，需要美国实行一整套金融、政策和/或教育工具。完成此举的最佳方法则是建立一个拥有授权、权力、和以创新的速度完成变革的影响力的单一实体，即建立一个太空公共-私人先进商业化企业（SPACE）集团。

关键词：太空公共-私人先进商业化企业（SPACE）集团，太空集团，私人和公共部门，经济，投资，政策，空间接入，空间可持续发展，空间支持

Introduction

Staying at home, waiting to run out of resources, or to be wiped out by the next disaster is not America's style. We demand better alternatives to meeting our energy needs than carpeting our purple mountains with solar cells, blackening the sky with wind generators, or clogging our air with pollution.

Interestingly, our genetic makeup somehow prevents humankind from shying away from embarking on a great adventure, or flatly refusing to engage in a challenge that may seem impossible at first glance. We push boundaries—whether these boundaries exist on land, sea, air, or ... in space. What greater challenge is there than to build homes in a lifeless vacuum? What greater adventure is there than exploring a limitless frontier? For Americans, this is who we are, and what we do.

What is SPACE Corp?

At Foundation for the Future (F4F), we have a single goal: to make space boring. The routine and ubiquitous kind of boring. We continually work to enable innovation in the realm of space development, specifically creating secure, sustainable, and reliable space infrastructure. Our mission is to serve as the bridge between civil space and federal government policy—from technology developments in space transportation to the education of the next generation of space workforce. We aim to foster a diverse and collaborative ecosystem made up of companies, innovators, and leaders who are building the future of America's space exploration initiatives and strategies.

Unlocking America's next economic frontier can be reached only by laying the foundation now for America's next century in space. Only by stoking the flames of limitless innovation, inclusion, and radical transparency can we disrupt the status quo. That disruption is needed if we are to cross the market-based chasm between the plans and ambitions of current space entrepreneurs, and the rest of America.

This sort of disruption should not be approached lightly. Indeed, the best solution is one that builds upon the bi-partisan space policy that was initiated during the Kennedy-Johnson presidencies in direct response to Sputnik, Soviet-manned space travels, and our directive to be the first on the Moon with Apollo. We face a similar "race" to the stars that requires a joint public-private sector entity designed to fund and support space development and infrastructure, similar to the building of the Erie Canal, the Transcontinental Railroad, and supporting our air, sea, and road highways serving the public. But now, our focus is on space.

Balancing the needs of industry, taxpayers, workers, and our children requires the U.S. to deploy a full range of financial, policy, and/or educational tools. This is best accomplished through creating a single entity with the mandate, authority, and reach to effect change at the speed of innovation. The best way to achieve this is by forming a Space Public-private Advanced Commercialization Enterprise (SPACE) Corporation.

What Would SPACE Corp Do?

The SPACE Corporation would be created by Congress and incorporated as a for-profit entity rather than an agency under the U.S. government. Building on the model of the 1960s Commercial Satellite Corporation (COMSAT), our proposal calls for the SPACE Corp to issue space infrastructure bonds, space development loans, and the ability to buy and sell shares of stock. Additionally, the SPACE Corp would use other financial instruments such as microloans, research grants, and educational programs in cooperation and coordination with existing science and space government research institutions.

All of these tools and partnerships would focus on supporting projects that ensure easy access to space and that are capable of supporting homes and businesses—and most importantly, to increase economic opportunity for all Americans. It would be necessary for SPACE Corp's projects to fall into one of these three categories:

- *Space Access:* This refers to getting *to, from*, and *through* space. By investing in partnerships and projects that reduce the costs of sending people, machines, and materials, SPACE Corp will lower the barriers to entry for space entrepreneurs.

- *Space Sustainability*: This refers to technologies required to live, work, and survive off-world. The goal is an ability for Americans to show up in space and be able to focus on building and running their lives or businesses, rather than fighting to simply survive.

- *Space Support*: This refers to tools, technologies, and capabilities which directly benefit the rest of us, while enabling a space economy. Whether this includes advanced material foundries around the country or space-based solar power, investments to support space-related activities such as these will offer immediate benefits to Americans at home.

Why Now?

One barrier standing in the way of SPACE Corp becoming a reality is the transportation infrastructure needed to launch more humans into space—and more often. Expanding access to space is essential to achieve a more equitable future for space exploration, as well as a sustainable ecosystem supporting humans living safely in space.

From improving economic opportunities, to uniting a divided country, to ensuring a free and fair world, space infrastructure is a boring solution to our most pressing problems.

United States history has evidenced that by lowering barriers to invest in major infrastructure improvements following economic downturns, the economy provides room for hundreds of thousands of new jobs. An investment in the future of space, for example, supports diverse industries such

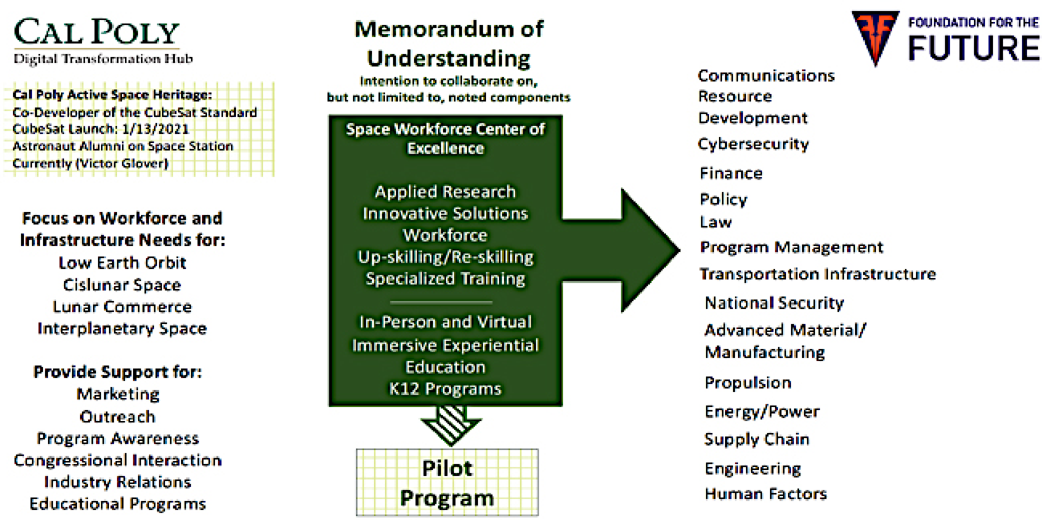

Figure 1. Collaboration components between Cal Poly and Foundation for the Future

as advanced materials manufacturing, green energy, and shipping and logistics.

Outer space holds virtually limitless amounts of energy and raw materials—from Helium-3 fuel on the Moon for clean fusion reactors, to heavy metals and volatile gases from the asteroids—which can be harvested for use on Earth and in space. Quality of life can be improved directly by using these resources and indirectly by moving hazardous and polluting industries and/or their waste products from planet Earth.

Technology developed for use in space possess the potential for direct use on Earth. In fields such as medicine, future construction, as shown throughout NASA's history and its NASA Technology Transfer program, will allow for private corporations and investors to license NASA-developed technology for commercial distribution and consumption. A renewed investment in space infrastructure will also require new facilities, workforces, and supply chains nationwide.

Security

There also exists a looming fear that the U.S. will fall behind countries such as China, India, or even the European Union (EU) in the 21st-century's rapidly-accelerating space race. To ensure this does not occur, the government needs a new leader supporting collaboration between the government-backed efforts of NASA and Space Force and the civilian business sector.

China's planting of the flag on the Moon late last year should have had the same impetus of Russia's launch of the satellite Sputnik, or the orbital flight of Russian Astronaut Uri Gagarin, which propelled America's manned Apollo Missions to the moon during the latter half of the 20th century.

For the past decade, Russia and China have each sought supremacy in space, but now as China has surpassed Russia in space-based spending and launches, cooperation between the two is taking shape. Russia has signaled its desire to reduce partnership with the U.S. while increasing its cooperation with China.

Maintaining U.S. space security requires investment, not only in military capacity, but in the infrastructure needed to support the engine of U.S. success around the world as well as American innovators and the economy they build.

Unity

America is a nation founded on the frontier. From our first settlers to landing on the moon, we are a nation that has sought out each new frontier and molded it in our image. It was those frontiers that captured the imagination of dreamers, agitators and troublemakers alike. Space is the ultimate, boundless frontier. No society has ever gone wrong betting on the frontier. Nations are invigorated spiritually, and prosper economically, by challenging and finding new uses for new frontiers. Over many decades, however, the benefits gained from this exploration came at a cost from the exploitation of vulnerable populations.

For example, in the 18th century we conquered the North American land. Riding wagons and horses, we expanded from the east to the west. Building off of slave labor, our economy developed.

In the 19th century, we conquered the world's oceans. Our trading ships visited every port on the planet, therefore enabling new exports. This success was supported through child labor, other exploited populations, and a domineering patriarchy.

In the 20th century, America took to the skies. Our planes won two world wars, resupplied starving cities, and ultimately made travel to anywhere accessible to the masses. This was possible because our planes also carried soldiers, bombs, and nuclear weapons.

Now, in the 21st century, space is open to us. And, for the first time in our country's history, we can explore, develop, and prosper using our own labor. We can access the riches of the solar system without exploiting others. We can expand our communities without jeopardizing the Earth we call home. That is to say ... we can finally, truly, experience the self-sufficient, non-controversial America that we once envisioned when we were children.

What Got Us *Here* Won't Get Us *There*

A renewed investment in space infrastructure, financing, and development will take a combined partnership between the public and private sectors—something the U.S. has shown to do effectively, from the COMSAT Act in 1962. Although controversial at the time, the COMSAT Act triggered the development of technology which enabled President Kennedy to communicate to Apollo astronauts Neil Armstrong and Edwin Aldrin on the surface of the moon. Five years and a new president later, President Lyndon B. Johnson reported to Congress,

> “The Communications Satellite Act of 1962 [has] brought mankind to the threshold of a full-time global communications service to which all nations of the world may have equal access.”
>
> *President Lyndon B. Johnson's March 17, 1967 Report to Congress*

The COMSAT Act continues to serve as a positive contributor to the public-private space sectors, as evidenced by the success of recent SpaceX launches.

Creating a new public-private partnership in the form of SPACE Corp, a federally chartered enterprise would serve a vital role in planning, financing, and the administration of basic infrastructure to, from, and through space. This corporation would accomplish its primary goals while offering key support to other branches and agencies within the U.S. government, while simultaneously remaining revenue-positive to the U.S. Treasury.

Our proposal is not unique, but rather a combination of the best and most researched ideas from across the intellectual spectrum. Its strength lies in its focus on outcomes, and the idea that when united, we are capable of wild, ambitious, and “what-was-thought-to-be-impossible” dreams. But maybe most importantly, it reminds us that the impossible never stays that way for long.

***Tim Chrisman** is the founder and executive director of Foundation for The Future (*f4f.space*), author of Humanity in Space, a look at the future of the second century of human spaceflight, and former CIA intelligence officer and retired Army Special Operations officer. Foundation for The Future is focused on unleashing America's potential through the creation of smart space infrastructure.*

Emerging US Government and Military Literature on the U.S. Space Force

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Abstract

Established in 2018, the U.S. Space Force is the newest branch of the U.S. military. The reality of space as an arena for international geopolitical and military competition has been around for decades in scholarly literature and publicly accessible government information resources. This work examines recently published U.S. Government and military literature on Space Force. These works examine various economic, military, and political aspects of this entity and how it may affect U.S. national security policy in years to come. Public opinion polls on space force are also included. An additional objective of this work is enabling readers to use their analysis of this lecture to explore potential business contracting opportunities, contacting their congressional representatives, and participating in the federal regulatory process to express their views on Space Force developments.

Keywords: United States Space Force, military astronautics, space policy, government oversight, government contracting, public awareness

Literatura militar y gubernamental emergente de EE. UU. Sobre la Fuerza espacial de EE. UU.

Resumen

Establecida en 2018, la Fuerza Espacial de EE. UU. Es la rama más nueva del ejército de EE. UU. La realidad del espacio como arena para la competencia geopolítica y militar internacional ha existido durante décadas en la literatura académica y en los recursos de información del gobierno de acceso público. Este trabajo examina la literatura militar y del gobierno de EE. UU. Recientemente publicada sobre la Fuerza Espacial. Estos trabajos examinan varios aspectos económicos, militares y políticos de esta entidad y cómo puede afectar la política de seguridad nacional de Estados Unidos en los próximos años. También se incluyen encuestas de opinión

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pública sobre la fuerza espacial. Un objetivo adicional de este trabajo es permitir a los lectores utilizar su análisis de esta conferencia para explorar posibles oportunidades de contratación comercial, contactar a sus representantes en el Congreso y participar en el proceso regulatorio federal para expresar sus puntos de vista sobre los desarrollos de la Fuerza Espacial.

Palabras clave: Fuerza espacial de los Estados Unidos, astronáutica militar, política espacial, supervisión gubernamental, contratación gubernamental, conciencia pública

关于美国太空军的新兴美国政府及军事文献

摘要

成立于2018年，美国太空军是美国最新的军事分支。几十年里，学术文献和公共存取的政府信息资源都对太空作为国际地缘政治和军事竞争的舞台一事进行了研究。本文分析了近期发表的有关太空军的美国政府及军事文献。这些文献分析了关于太空军的不同经济方面、军事方面、政治方面，以及其如何能影响未来几年里美国的国防政策。（本文）还包括了关于太空军的民意测验。本文的一个额外目标是帮助读者使用各自对这篇文章的分析，来探究潜在的商业承包机遇、联系各自的国会代表、并参与联邦监管过程，以期表达各自关于太空军发展的观点。

关键词：美国太空军，军事宇航学，太空政策，政府监督，政府承包，公共意识

Introduction

Established in 2018, the U.S. Space Force is the newest branch of the U.S. military. The reality of space as an arena for international geopolitical and military competition has been around for decades in scholarly literature and publicly accessible government information resources. This work examines recently published U.S. Government and military literature on Space Force. These works examine various economic, military, and political aspects of this entity and how it may affect U.S. national security policy in years to come. Public opinion polls on space force are also included. An additional objective of this work is enabling readers to use their analysis of this lecture to explore potential business contracting opportunities, contacting their congressional representatives, and participating in the federal regulatory process to express their views on Space Force developments.

Recent Legislative Developments

The United States Space Force (USSF) is the newest branch of the U.S. armed forces. Its establishment has been a long time in development and its future direction remains unknown. However, it is possible to begin gaining an understanding of its nature and mission through publicly accessible U.S. Government and military information resources. On December 18, 2018, President Donald Trump sent a memorandum to the Secretary of Defense authorizing establishment of United States Space Command as a unified geographic combatant command (White House, 2018). USSF was statutorily established in the Fiscal Year (FY) 2020 National Defense Authorization Act signed by Trump on December 19, 2020. USSF was established to be led by a presidentially appointed and Senate-confirmed Chief of Space Operations (CSO) from Air Force officers serving at presidential pleasure who is also a member of the Joint Chiefs of Staff. USSF organizational functions and duties include:

- Providing U.S. freedom of operation in, from, and to space;
- Being organized, trained, and equipped to engage in prompt and sustained space operations;
- Protecting U.S. interests in space;
- Deterring aggression in, from, and to space; and
- Conducting space operations (Public Law 116-92).

This law established the first U.S. armed service branch since the July 26, 1947 National Security Act establishing the U.S. Air Force (Public Law 80-253). U.S. military service involvement in space has been a hallmark characteristic of U.S. national security policymaking for many decades prior to USSF. Each armed service branch has engaged in extensive space policymaking and the U.S. intelligence community also uses space assets to further national security objectives (Chapman, 2008; Laurie, 2001; Ruffner, 1995; Spires, 2007).

USSF currently and the CSO are headquartered in the Pentagon (U.S. Space Force, 2020). Its organizational directorates and their responsibilities include:

- Executive Staff providing command and control and executing major acquisition decisions.
- USSF/S1 Directorate of Manpower, Personnel, and Services providing manpower resource solutions and supporting airmen with USSF.
- USSF S2/3/6 Directorate of Integrated Air, Space, Cyberspace, and Intelligence, Surveillance, and Reconnaissance (ISR) Operations integrating space and cyberspace operations with air, land, and maritime domains.

- USSF/S4 Directorate of Logistics, Engineering, and Force Protection providing cyberspace weapons systems sustainment solutions and coordinating infrastructure and force protection from Air Force installations and mission support center; and
- USSF/S5/8/9 Directorate of Strategic Plans, Programs, Requirements, and Analysis coordinating space and cyberspace planning; analyzing space and cyberspace requirements; and developing space and cyberspace policy. (U.S. Space Force 2020b)

USSF facilities are located at Buckley Air Force Base (AFB), CO; Los Angeles AFB, CA; Patrick AFB, FL; Peterson AFB, CO; Schriever AFB, CO; and Vandenberg, AFB, CA (U.S. Space Force 2020c). Its initial allocated operation and maintenance budget for FY 2020 was $72,436 million (Public Law 116-92). Congressional authorizing committees had not reached agreement on FY 2021 space force funding as of October 1, 2020. In its defense spending report, the House Appropriations Committee included the following figures for the Space Force's congressional budget request, its previous year funding level, and the House's funding recommendations for the following categories:

Operation and Maintenance

FY 2020 Appropriation	FY 2021 Budget Request	Committee Year Recommendation	Change from Budget Request
$40,000,000	$2,531,294,000	$2,498,544,000	-$32,750,000 (House Report 116-453)

Procurement

FY 2020 Appropriation	FY 2021 Budget Request	Committee Year Recommendation	Change from Budget Request
0	$2,446,064,000	$2,289,934,000	-$156,030,000 (House Report 116-453)

Research, Development, Test, and Evaluation

FY 2020 Appropriation	FY 2021 Budget Request	Committee Year Recommendation	Change from Budget Request
0	$10,327,595,000	$10,187,840,000	-$139,755,000 House Report 116-453)

The House Committee went on to stress its desire that USSF devote its budget resources to assure space capabilities can support combat commands during conflict and that more time, attention, and funding will be focused on funding support capabilities including the weather satellite program and future strategic communications program. This document expressed concern that the Air Force has no Senate-confirmed civilian leader focusing exclusively on space with authority over acquisition, budget, and long-term planning. Additional concern was expressed over transferring Army, Navy, and other defense agencies into USSF saying it would not support such transfers without assurance that they will not negatively affect these organizations or national security (House Report 116-453).

The Senate's FY 2021 defense spending report on USSF made the following budget allocations:

Operation and Maintenance	$2,530,894
Research, Development, Test, and Evaluation	$10,301,095
Procurement	$2,458,564 (U.S. Congress, Senate Committee on Armed Services, 2020a).

Additional provisions in the Senate USSF report stress the vital importance of strategic satellite communication to national security and the presence of a 7-year gap in resilient capability coverage; problematic communications in the northernmost latitudes; and developments in low and medium earth orbital communications which could enhance communication quality in these regions. Further language in this report included prohibiting the involuntary transfer of civilian or military personnel into USSF out of concern that such transfers would be counterproductive to successful deployment; encouraging the development of mobile launch capabilities to mitigate existing threats from hostile forces and natural disasters in fixed range launch infrastructure; and requiring developing and demonstrating a proliferated low-earth orbit sensing, tracking, and data transport architecture along with integrating next generation space capabilities including hypersonic and ballistic missile tracking space sensors payloads. This version also required the Secretary of the Air Force to submit to Congress a report on the potential for countries such as China to enter the global commercial space launch market by January 1, 2021. The extent that House and Senate committee reports on space launch will be reconciled remains uncertain (U.S. Congress. Senate Committee on Armed Services, 2020).

Air University Press Literature

Air University at Maxwell AFB, AL is the U.S. Air Force's professional military educational institution. Its multiple academic and research entities produce historical perspectives and contemporary analysis of subjects pertaining to aerospace operations. This has been particularly true for space warfare and the USSF with many of these publications freely available through Air University Press. Publications postulating on military uses of space to advance U.S. and allied aerospace interests have produced for multiple decades and the subsequent section will document some of these examples. Mowthorpe's 2001 analysis provides detailed coverage of U.S. military space policy beginning with the Eisenhower Administration (Mowthorpe, 2001).

Military spacepower was a key feature of *Air and Space Power Journal* in November/December 2014. Hayden stressed the need for spacepower to develop a war fighting doctrine comparable to the air, land, and sea-power doctrines developed by Guido Douhet, Karl von Clausewitz, and Alfred Thayer Mahan. This analysis stressed that current joint U.S. military doctrine defined space superiority as "the degree of dominance in space of one force over any others that permits the conduct of its operations at a given time and place without prohibitive interference from space-based threats." Hayden also asserted that space professionals cannot afford to wait for the time when the battlefield is shaped from space but must develop a coherent space warfighting doctrine to prevent disastrous effects on U.S. lives and interests (Hayden, 2014).

This journal's same issue saw Cesul argue that the U.S. should develop a space control strategy to:

1. Control the electromagnetic (EM) spectrum over and within a locale at a time and severity of our choosing to enable U.S. freedom of action and information dominance

2. Counter, both kinetically and non-kinetically, adversary space and counterspace systems directly threatening U.S. assets in space or terrestrially, with preference to options that minimize disruptions to U.S. and allied capabilities while defeating the enemy kill chain as early as possible in a crisis situation; and

3. Utilize a command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) posture (including the development of SSA architecture) that allows the United States to develop and execute space control plans and operations, specifically provide indications and warnings of catastrophic space events, discover indications and warning of impending hostile space control activities, maintain custody of threat systems, and deliver intelligence to support space control options (Cesul, 2014).

Military space threats from great power rivals such as China and Russia are generally recognized as the biggest concerns of U.S. military space policy planning. It is necessary, however, to think outside the usual parameters of military strategic planning when contemplating military threat scenarios. An example of this is provided by a work explaining that threats to U.S. interests in space may originate from non-state actors aspiring to challenge the existing international order, overturn political and economic situations in their countries, and profiting from insufficient attention paid to them by international nations. Such scenarios could involve attacking Global Positioning System (GPS) assets which could have spillover effects against U.S. military and civilian assets, attacking astronauts or satellite communication links, using cyberattacks to decapitate space launch facilities, commercial competitors attacking each other, and the originators of these attacks being individuals and organizations who may not easily subject to criminal prosecution and punishment under national and international law (Miller, 2019).

Whitney, Thompson, and Park stress how U.S. national security space requirements have evolved since the 1982 establishment of Air Force Space Command. They note China and Russia have increased their military space emphasis from organizational structure and spending in kinetic physical and nonphysical kinetic threats to countering the U.S. in space. During 2015-2016, China established its Strategic Support Force (SSF) to coordinate its military space, cyber, and electronic warfare capabilities. SSF established a Space System department charged with providing the military with communications, computers, intelligence, surveillance, and reconnaissance capabilities as part of an orbital counterspace mission which could include radiofrequency systems to jam satellite communications and GPS and using malicious software to disrupt computer network operations in satellite tracking and ground control systems.

During 2015, Russian military space forces were subordinated into the Russian Aerospace Forces with responsibility for monitoring space objects to identify and prevent potential space threats to Russia and handling spacecraft launches and controlling and managing satellite systems for civilian and military missions. Moscow is also likely to use lasers to temporarily dazzle or permanently blind optical sensors while microwave weapons can disrupt or disable electronics on Low Earth Orbit remote-sensing and missile defense satellites. Recommendations made in 2017 by U.S. Strategic Command commander General John Hyten (now Vice-Chair of the Joint Chiefs of Staff) for establishing a military space force included:

- Overseeing the acquisition, development, and deployment of military space and tactically employed strategic level and ground control segments;
- Acting as the single authority for enterprise-wide defense system architect and integrator for overall space architecture;
- Creating a rapid space capabilities office to quickly design and acquire major new and affordable space capabilities;
- Establishing a national security space executive committee providing strategic and policy guidance for all DOD space acquisitions (Whitney, Thompson, Park, 2019)

Townsend notes that current U.S. military doctrine includes no definition of space power; asserts that developing a theory of space power is difficult because space is an untested domain unlike the sea and that space is an untested domain due to the absence of empirical evidence on conflict in space; contends that space command is achieved through presence, coercion, and force; and a key to space power involves "acquiring the human and technical resources to increase one's freedom of action, while aiming to reduce an opponent's." This treaties goes on to maintain that space power alone cannot determine terrestrial conflict's outcome or attain terrestrial political objectives; that the country with the most significant commercial space industrial base will have the largest orbital presence and the greatest amount of space control and power; military space power strategy must account for the presence of commercial satellites; rival countries recognition of acute U.S. military dependence on space assets has spurred redefining space as a war-fighting domain; and that achieving information dominance as an integral factor in achieving victory or defeat will be an integral factor in increasing the strength of the case for establishing a separate Space Force (Townsend, 2019).

Grosselin observed that during an outgoing interview in May 2019 that Secretary of the Air Force Heather Wilson identified developing a warfighting culture as the Air Force space mission's most pressing challenge. The author contends that the Air Force and USSF must transition from a space serving culture to a space-warfighting culture with war-fighting cultures being adversary centric focusing on a competent and lethal adversary threatening American interests. Consequently, USSF must handle uncertainty by seizing the initiative through decentralized execution and mission command principles; pursuing innovation by continuously seeking military advantage over adversaries; assuming key roles as tacticians, mission planners, and battle managers; and measuring success by winning in a competitive environment (Grosselin, 2020).

This treatise concludes by stressing three themes including: space being vital to national power and prosperity, military space forces being an interdependent element of the Joint Force, and military space force demanding unique expertise. Specific aspects of each of these criteria include national space power involves exploiting economic, information, military, and political elements and information derived from space-based remote sensing being a core of U.S. global information dominance; without space capabilities joint operations revert to bloody early twentieth century Industrial Age warfare featuring mass concentration of force-on-force violence and indiscriminate destruction; and space mastery including the entire space environment encompassing space flight physics and engineering and predictive understanding of the interests and behaviors of civil, commercial, and foreign space actors (Grosselin, 2020).

In their proposed legislative framework for USSF, Grant and Neil propose amending Title 10 Section F of the *United States Code* with the following language describing USSF's primary duties:

> Subject to the requirements of international law, the Space Force shall enforce or assist in the enforcement of all applicable federal laws in, on, and surrounding terrestrial spaceports and those locations in space subject to the jurisdiction of the United States. It shall engage in space surveillance or interdiction to enforce or assist in the enforcement of the laws of the United States. It shall administer laws and promulgate and enforce regulations for the promotion of life and safety of life and property in space. It shall develop, establish, maintain, and operate, with due regard to the requirements of national defense, rescue facilities, as needed, for the promotion of safety in space. It shall, in coordination with NASA, engage in scientific research and exploration of space and heavenly bodies. It shall maintain a state of readiness to function as a specialized service in the joint force in wartime, including the fulfillment of Space Defense command responsibilities (Grant and Neil, 2020).

Recent DOD and USSF Policy Documents

Policy documents on U.S. military space policy were produced by DOD and the White House even before USSF's statutory establishment. *DOD Directive 5100.*96 dated June 9, 2017 established policy, assigned responsibilities, and established relationships for governing the DOD Space Enterprise; established the Defense Space Council; established the position of Principal Department of Defense Space Advisor (DPSA); and designated the Secretary of the Air Force as PDSA. PDSA responsibilities included monitoring and overseeing the performance of DOD's space portfolio including assessing space-related threats, requirements, and architectures, programs, and their synchronization; conducting an annual strategic assessment including prioritized programmatic choices for space capabilities; and overseeing development of long-term mission area capabilities including program and budget submissions (U.S. Department of Defense, 2017).

Space Policy Directive 4 establishing USSF was issued by President Trump on February 19, 2019. It began by stressing how integral space has become to American economic prosperity, national security, and modern warfare. This document proceeded to note that while the U.S. has historically maintained a space technology edge over potential adversaries that those adversaries are advancing their space capabilities and actively developing methods to deny the U.S. use of space in a crisis or conflict. Trump directed DOD to develop USSF to deter and counter threats in space with USSF being authorized to organize, train, and equip military space forces to ensure the U.S. has unrestricted access and freedom to operate in space and provide critical capabilities to joint and coalition forces in peacetime and across the conflict spectrum (Space Policy Directive 4, 2019).

Space Policy Directive 5 issued on September 4, 2020, enumerated cybersecurity principles for space systems. It began by stressing how space systems rely on information and networks from design conceptualization through launch and flight operations and that such systems can be degraded through spoofing sensor data; corrupting sensor systems; jamming or sending unauthorized guidance and control commands; injecting malicious code; and conducting denial-of-service attacks. Consequently, this directive urged developing space systems and their supporting infrastructure, including software, using risk-based cybersecurity-informed engineering. Additional attributes of space cybersecurity include allowing operators or automated control systems to retain or recover positive control of space vehicles; protecting against unauthorized access to critical space vehicle functions; protecting ground systems by adopting cybersecurity best practices; managing supply chain risks affecting space system cybersecurity through tracking manufactured products; requiring sourcing from trusted suppliers; identifying counterfeit, fraudulent, and malicious equipment, and accessing all available risk mitigation measures (Space Policy Directive 5, 2020).

June 2020 saw USSF issue its doctrinal capstone publication. This aspirational document stressed the following as U.S. military spacepower guiding principles:

- The U.S. desires a peaceful, secure, stable, and accessible space domain. Strength and security in space enables freedom of action in other warfighting domains while contributing to international security and stability. The U.S. must adapt its national security space organizations, doctrine, and capabilities to deter and defeat aggression and protect national interests in space.

- The space domain is the area above the altitude where atmospheric effects on airborne objects become negligible. The value of the space domain arises from an ability to conduct activities with unrivaled reach, persistence, endurance, and responsiveness, while affording legal overflight of any location on the earth. Because of these attributes, *space power* is inherently global.

- Military space forces are the warfighters who protect, defend, and project space power. They provide support, security, stability, and strategic effects by employing spacepower in, from, and to the space domain. This necessitates close collaboration and cooperation with the U.S. Government, Allies, and partners and in accordance with domestic and international law.

- Not only are space operations global, they are also multi-domain. A successful attack against any one segment (or combination of segments), whether terrestrial, link, or space, of the space architecture can neutralize a space capability;

therefore, space domain access, maneuver, and exploitation require deliberate and synchronized defensive operations across all three segments.

- As a lean, mission-focused, digital service, the United States Space Force values organizational agility, innovation, and boldness. Elevating these traits starts with empowering small teams and prizing measured risk-taking as opportunities to rapidly lean and adapt (U.S. Space Force 2020(d).

USSF cornerstone responsibilities include preserving freedom of action, enabling joint lethality and effectiveness, and provide independent options. These responsibilities are fed by these core competencies: space security, combat power projection, space mobility, and logistics, information mobility, and space domain awareness. These core competencies mandate specialization in orbital warfare, space electromagnetic warfare, space battle management, space access and sustainment, military intelligence, cyber operations, and engineering/ acquisitions (U.S. Space Force 2020(d).

This publication also stressed that military space forces need to study select engagements, battles, and campaigns in depth in order to understand warfare's human element. It notes studying warfare from any domain in depth allows warfighters to better forecast pressures high-intensity conflict will place on their combat responsibilities, how decisions were made, and how uncertainty, friction, and chaos influenced those decisions. Such knowledge highlights how luck, timing, and biases impact the course of a military engagement. USSF's capstone doctrine also stresses that military space forces must study warfare in its political and social context based on the imperative of understanding war as an extension of national policy within the context of political goals combatants aim to achieve (U.S. Space Force 2020(d).

This same month saw DOD issue its *Defense Space Strategy Summary*. It began by noting space's emergence as a distinct warfighting domain, demanding enterprise-side changes to policies, strategies, operations, and investments, capabilities, and expertise for a new strategic environment. This summary noted that China and Russia have weaponized space to reduce U.S. and allied military effectiveness and challenge freedom of operation in space. Consequently, exponential increases in global commercial and international space activities enhance the complexity of the space environment (U.S. Department of Defense, 2020a).

Areas of military space emphasis for USSF include building a comprehensive military advantage in space; integrating military spacepower into national, joint, and combined operations, shaping the strategic environment, and cooperating with allies, partners, industry, and other U.S. Government departments and agencies. Specific implementation of these aspirations involves developing and documenting doctrinal foundations of military space power, developing and expanding space warfighting expertise and culture, developing and fielding capabilities countering hostile use of space; integrating space warfighting operations, intelligence, capabilities, and personnel into military plans and staff; planning, exercising, and executing joint and combined operations across the conflict spectrum; informing international and public audiences of growing hostile threats in space; deterring adversary aggression against the space interests of the U.S. and its allies and commercial interests; coordinating space messaging; promoting standards and behavior space norms favorable to the U.S. and its allies; aligning with allies and partners on space policy; and expanding cooperative research, development, and acquisition with allies and partners (U.S. Department of Defense, 2020a).

Business Contracting Opportunities

Establishing a new federal agency provides potentially lucrative contracting opportunities for the private sector and for academic research grants for eligible entities. System for Awards Management (SAM) is the U.S. Government's website for doing business with the federal government. There is limited information on space force contracting opportunities in SAM as of early October 2020. This is likely to change as USSF gets organized. It is currently possible to find information on SAM registered companies such as Space Exploration Technologies Corporation (popularly known as Space-X). Types of information on Space-X available in SAM its registration status including activation and expiration dates, the name of the Space-X employee responsible for updating its information, and the organization's physical address (System for Award Management, 2020). On August 7, 2020 USSF and the National Reconnaissance Office (NRO) awarded phase two launch contracts to United Launch Alliance (ULA) and Space-X for launch service contracts worth $337 million and $316 million respectively between Fiscal Years 2020-2024. Intended launch dates are in the second and fourth quarters of Fiscal Year 2022 (U.S. Space Force, 2020e).

Grants.gov provides one-stop access for individuals, institutions, and organizations seeking posted or forecasted federal grants from USSF and other agencies. An example of a recently posted USSF related grant is Funding Opportunity Number FA9453-17-S-0005 entitled Research Options for Space Enterprise Technologies (RESOT). This grant was posted on February 14, 2018 by the Air Force Research Laboratory (AFRL) at Kirtland, AFB, NM. The grant notes that AFRL's Space Vehicles Directorate wishes to receive proposals from entities wanting to offer advance state of the art technology and scientific knowledge supporting space systems including payload adapters, on-orbit systems, communications links, ground systems, and user equipment. The contract's estimated program funding is $467 million with the application closing date being September 28, 2022. Additional contract attributes include basic and advanced research, advanced component and technology development, prototyping, and system development and demonstration. Such development and demonstration should span the range from concept and laboratory experimentation to testing/demonstration in a relevant environment involving design, development, analysis, fabrication, integration, characterization, testing/experimentation, and demonstration of hardware and software products. AFRL employee Ambros Montoya is listed as the contact individual and his e-mail is provided. Technical and legal requirements are also included in each grant (Grants.gov, 2018).

Documentation of federal government spending by budget function, agency spending, and object class is provided by usaspending.gov/ from Fiscal Year 2008-present. An example of a current USSF contract and its spending data and history is provided by contract FA251718F9021. Awarded by DOD to Apogee Engineering Ltd, LLC of Colorado Springs, CO on July 19, 2018, this $4.5 million contract was issued by Air Force Space Command. Its purpose involved Apogee preparing training product development support for the ready space crew program and space mission force to create training products for the 460th Operations Support Squadron, 1st Space Operations Squadron, and 4th Space Control Squadron and provide assistance to Air Force Space Command Headquarters on implementing space mission force efforts. The contract's initial end date was August 26, 2020 with its current end date being February 26, 2024 (Usaspending.gov, 2020).

Legal and Regulatory Resources

Despite its recent establishment legal and regulatory information resources on USSF are emerging. U.S. federal laws are codified in the *United States Code (USC)* which is broken up into 54 different title or subject areas. Laws pertaining to USSF are in Title 10 of the *USC* which covers U.S. military forces. Sections 9081-9083 of Title 10 cover USSF with section 9081 covering the principal reasons for USSF's establishment; section 9082 covering the role played by the CSO who receives a four year presidential appointment and enumerates the duties of this individual; and section 9083 establishes an office career field for space authorizing the Secretary of the Air Force to develop career paths for officers with technical competence in space-related matters including developing space doctrine and concepts of operations; developing space systems; and operating space systems. This statutory imprint and corpus will expand in subsequent years as USSF does with congressional direction and depending on developments in U.S. and global military space activities and technologies (U.S. House of Representatives, Office of Law Revision Counsel, 2020).

It remains to be seen how USSF will impact U.S. military and international law though some literature on this subject is emerging. Some scholars argue that military activity in space is already prohibited and should remain prohibited, while others argue that states can use force in space for self-defense and resolving international disputes and that space weapons provide greater precision, fewer casualties and destruction, and more effective crisis bargaining between states (Yoo, 2020; Ramey, 2000; King, 2016).

Federal regulations on USSF and business contracting will be important study fields for those analyzing USSF activities. These regulations provide legally binding guidance to USSF and other federal agencies on how to implement congressionally passed and presidentially signed laws. The complete text of federal regulations can be found in the *Code of Federal Regulations (CFR)* which is published collaboratively by the National Archives Office of the Federal Register and the U.S. Government Publishing Office and updated annually on a rotating basis throughout the year. The CFR is broken down into 50 different titles or subject areas (U.S. Government Publishing Office, 2020a, U.S. National Archives and Records Administration, 2020a).

Currently there are no specific USSF regulations in the CFR though that will inevitably change as this force is stood up and developed. Possible locations for USSF regulations in the CFR include Title 32 Parts 800-1099 which cover the U.S. Air Force (U.S. Government Publishing Office 2020b, U.S. National Archives and Records Administration, 2020b).

The *Federal Register* is published daily each week, except for federal holidays, by the National Archives and Records Administration. It serves as the U.S. Government's official daily publication for rules, proposed rules, notices of federal agencies and organizations, and executive orders and other presidential documents (U.S. Government Publishing Office, 2020c).

Examples of *Federal Register* documents on USSF have been included in previously referenced presidential documents in this document. Proposed rules are also a critical component within the *Federal Register* with an example of one concerning USSF appearing September 15, 2020 proposed Army rule allowing USSF personnel to be eligible for burial at Arlington National Cemetery (U.S. Department of Defense, 2020b).

Interested individuals and organizations can issue public comments on proposed federal agency regulations in the *Federal Register* under the Administrative Procedure Act by the deadline date specified in individual *Federal Register* documents. The deadline for public comment on the aforementioned Army regulation was November 16, 2020. These public comments can influence how agencies enforce federal laws and regulations. Such comments are submitted through the regulations.gov/ website administered by (U.S. National Archives and Records Administration, 2020a; Shapiro, 2013; Balla, Beck, Meehan, Prasad, 2020).

Public comments submitted to regulations.gov range from conspiratorial complaints to detailed and insightful analyses of issues being addressed by proposed regulations. A March 26, 2020 Competitive Enterprise Institute comment on a January 13, 2020 Office of Management and Budget notice to federal agencies providing guidance for regulating artificial intelligence applications complained that USSF's establishment locked in a top-down approach toward private sector artificial intelligence and that USSF would inevitably alter freedoms and private commercial space activities and is likely to heavily influence technology and investment and evolution in a nascent economic sector. More public comments on USSF will occur as this force evolves (Competitive Enterprise Institute, 2020).

Legislative Oversight

Congressional oversight of USSF and other government agencies and their programs is authorized by Article I Sections 7-8 of the U.S. Constitution and is a critical component of documenting the successes, failures, and ambiguities inherent in these programs and informing public debate on these subjects. Committee members and their professional staff can possess and gain significant professional subject expertise of government agencies and programs within their jurisdiction (Zwirn, 1988; Curry, 2019).

Congressional Committee Hearings

A key example of congressional oversight occurs through congressional committee hearings in which witnesses from multiple government agencies, military armed service branches, and numerous other sources present legally sworn testimony representing multiple perspectives on operational and management topics confronting these programs which may affect congressional funding of these programs. There is considerable public access to these congressional committee hearings even on some sensitive national security topics (Lawrence, M.B. 2020, Davis, C.M., and Oleszek, W.J. 2020).

The congressional committees that will review USSF programs and activities are the House and Senate Armed Services Committees and their designated functional subcommittees and the House and Senate Appropriations Committees Subcommittees on Defense (U.S. Congress, Senate Committee on Armed Services, 2020b). Publicly accessible congressional committee hearings on USSF may occur as part of annual defense spending legislation or as part of oversight of USSF program component performance. An April 3, 2019 House Armed Services Committee Subcommittee on Strategic Forces hearing examined upcoming fiscal year priorities for national security space programs. Witnesses testifying included Government Accountability Office (GAO) official Cristina Chaplain, the Director of that agency's Contracting and National Security Audit Division; Assistant Secretary of Defense for Homeland Defense and Global Security Kenneth Rapuano, and Air Force Space Commander General John W. Raymond. Rapuano contended that USSF would catalyze space's transformation as a warfighting domain while also providing the undivided attention, advocacy, and leadership to develop personnel, doctrine, and capabilities necessary to maintain unrestricted access and to fight and win in space. Raymond noted the establishment of a space Rapid Capabilities Office at Kirtland, AFB and Chaplain observed that space acquisition activities would occur at agencies outside of USSF including the Missile Defense Agency, National Reconnaissance Office, and some military space service activities (U.S. Congress, House Armed Services Committee, 2020).

Rep. Mo Brooks (R-AL) asked Rapuano what happens to other military space entities such as Army and Space Missile Command, and Navy Space and Naval War Systems Command under DOD's USSF proposal. Rapuano replied that organic space capabilities necessary for individual services would stay within those services and that global capabilities beyond the capacity of individual services such as GPS would go to USSF. Brooks then asked whether existing military space capabilities such as the Army's Redstone Arsenal in Alabama would be able to use its existing space funding expertise and leverage in USSF. Rapuano responded saying USSF's Space Development Agency would not replace or displace existing institutions working in space development and acquisition (U.S. Congress. House Armed Services Committee, 2020).

Congressional Support Agencies

Congressional oversight and analysis of USSF activities is also conducted by congressional support agencies including the Congressional Budget Office (CBO), Congressional Research Service (CRS), and Government Accountability Office (GAO). Established in 1975, CBO conducts objective and non-partisan analysis of the federal budget for Congress, prepares cost estimates for legislation reported by congressional committees, and prepares reports on the budgetary implications of federal programs (U.S. Congressional Budget Office, 2020a).

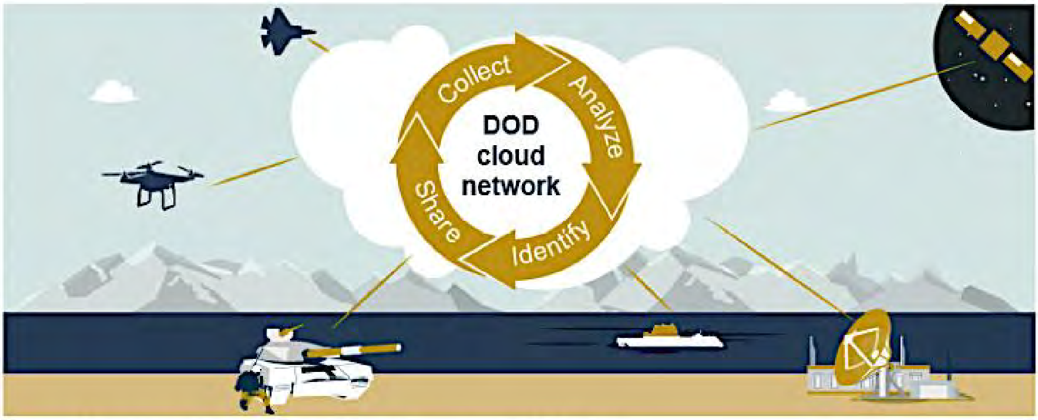
An example of a USSF-related CBO analysis was a June 2020 report on the costs of creating a Space National Guard within USSF. CBO prepared two cost scenarios with a smaller Space National Guard consisting of 1,500 existing personnel in the Air National Guard and Army National Guard being transferred to the new Space National Guard which CBO estimated would cause DOD to incur \$100 million in additional costs and one-time costs of \$20 million for constructing additional facilities. A scenario producing the creation of a larger Space National Guard consisting of 4,900-5,800 personnel would see DOD incur \$385-\$490 million in additional annual costs and one-time costs of \$400-\$900 million for constructing new facilities and equipping new units (U.S. Congressional Budget Office, 2020b).

The Congressional Research Service (CRS) is a branch of the Library of Congress providing members of Congress and congressional committee and staff with unbiased reports on public policy issues, tailored confidential memoranda, briefings, and consultations, seminars and workshops, and expert congressional testimony (Congressional Research Service, 2020). CRS reports encompass the spectrum of public policy issues addressed by Congress. USSF has been the subject of many CRS reports. A representative example includes the April 6, 2020 memorandum *Defense Primer: The United States Space Force*. Contents of this document include providing legislative background on USSF's provenance, noting its estimated civilian and military personnel total is approximately 16,000; its field units including centers covering personnel, intelligence, doctrine, warfare, professional military education, and testing; and its major acquisition programs including National Security Space Launch, Global Positioning System products, Space-Based Overhead Persistent Infrared (OPIR) Systems, and Satellite Communications Projects (McCall, S. 2020).

GAO was established by Congress in 1921. It is an independent nonpartisan agency examining how tax dollars are spent and providing Congress and federal agencies with objective and reliable information to help the government safe money and work more efficiently. Individual members of Congress can request reports from GAO and upon accepting a request GAO assembles a team to initiate the audit work. This team meets with GAO experts, agency stakeholders, and management to design an audit method that is fact-based and supports findings and potential recommendations in a process typically lasting three months. Completed draft reports are sent to agencies for comment and most reports are publicly released about 14 days after receiving agency comments (U.S. Government Accountability Office, 2020a).

USSF's recent establishment means that there are not any reports yet explicitly covering its operations. However, there are numerous GAO reports available covering the management performance of DOD military space activities. An example is an April 2020 GAO report on the Air Force's planned Advance Battle Management System (ABMS). This system is intended to consist of a network of intelligence, surveillance, and reconnaissance sensors utilizing cloud-based data sharing to equip warfighters with battlespace awareness for air, land, sea, space, and cyber domains. The FY 2021 presidential budget request for this program is $302 million.

GAO noted that the Air Force had established an ABMS management structure with unclear decision-making authorities; that there is no business case defining ABMS requirements; no plan to ensure that technologies are mature when needed; and no cost estimate or affordability analysis. Consequently, GAO recommended the Assistant Secretary of the Air Force for Acquisition, Technology, and Logistics direct the Chief Architect to develop a plan for attaining mature technologies for each ABMS development area with quarterly updates to Congress; prepare a cost estimate in accordance with cost estimate leading practices which is updated regularly with quarterly congressional updates; preparing program affordability analysis with quarterly congressional updates; and formalizing and docu-



Source: GAO analysis of Department of Defense information. | GAO-20-389

Figure 1. Concept of Advanced Battle Management System

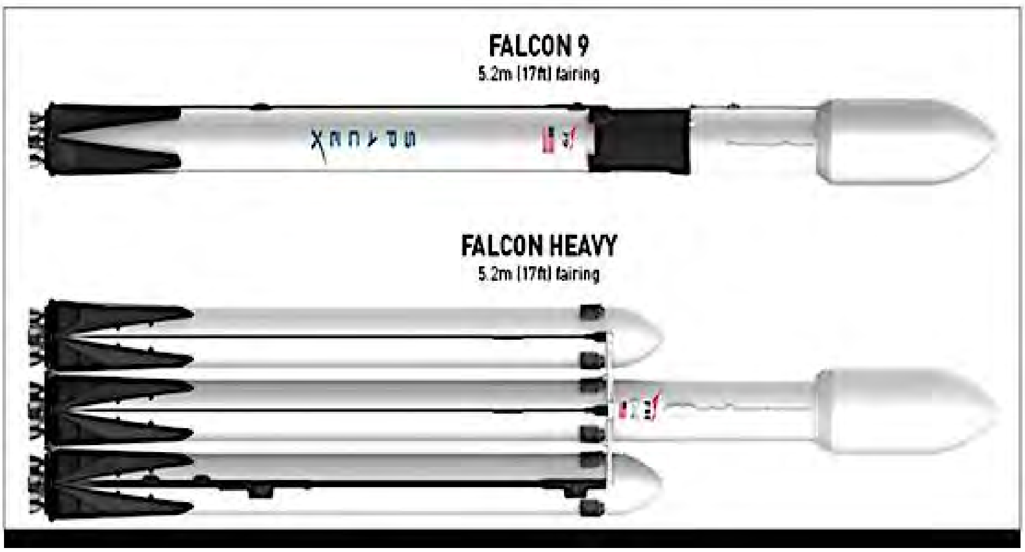


Figure 2. SpaceX's Falcon 9 and Falcon Heavy Launch Vehicles
Source: SpaceX, January 2020.

menting acquisition authority and decision-making responsibilities within the Air Force involved in ABMS executing and planning. DOD agreed with all of GAO's recommendations although it is not uncommon for an agency whose programs are reviewed by GAO to disagree with report findings (U.S. Government Accountability Office, 2020b).

DOD Oversight

The Defense Department (DOD) also has entities conducting oversight of the management performance of its own programs. One of these entities is its Office of Inspector General (DODIG). This agency, along with many other federal agency inspectors general, was established in 1978. Its purpose includes detecting, deterring, and preventing fraud, waste, and abuse in DOD programs and operations; promoting DOD's economy, efficiency, and effectiveness; and helping ensure ethical conduct throughout DOD. DOD's Inspector General is presidentially appointed and requires Senate confirmation and this office also has the authority to issue criminal penalties if fraud is committed by agency employees or private sector contractors (Friedes, 1992, Department of Defense Office of Inspector General, 2020(a), U.S. House of Representatives Office of Law Revision Counsel, 2020b).

An example of a DODIG report pertaining to USSF was released on September 4, 2020 and evaluated Air Force certification of space launch vehicles. This report's intent was determining whether Air Force Space and Missile Center (SMC) officials complied with the Air Force Launch Services New Entrant Certification Guide (NECG) when certifying launch system designs for National Security Space Launch (NSSL) SpaceX Falcon launch vehicles. DODIG concluded that SMC generally complied with Air Force Launch Services (NECG) and SMC Operating Instruction 17-001 when certifying the capabilities of SpaceX Falcon launch vehicles. DODIG expressed concern that SMC did not assess the risk of permitting previously used launch vehicle components on subsequent Falcon vehicle launches. Significant portions of this report were redacted for national security reasons and because SMC later provided DODIG with documentation not provided during the initial review causing DODIG to withdraw its initial recommendations (U.S. Department of Defense, Office of Inspector General, 2020b).

DOD's Director of Operational Test and Evaluation (DOT&E) is located within the Office of the Secretary of Defense and was established in 1983. Its purpose is providing independent and objective assessments so military personnel have confidence in their equipment to fulfill mission requirements. Early and frequent testing is critical to ensuring combat credible systems and that such testing is relevant to the defense acquisition process. Its current priorities include securing software and cybersecurity, increasing prototyping and experimentation, integrating test and evaluation, improving test infrastructure, improving modeling and simulation use, ensuring a capable workforce, and ensuring DOT&E relevance to DOD (Public Law 98-94, U.S. Department of Defense, Director of Operational Test and Evaluation, 2020a).

DOT&E's annual report provides detailed coverage of military programs encompassing DOD, individual armed service branches, and multifunctional programs covering ballistic missile defense, live fire test and evaluation, cyber assessments, joint test and evaluation, and the Center for Countermeasures. It also provides contractor information, budgetary expenditures, candid assessments of program strengths and weaknesses, and recommendations for enhancing program quality. USSF programs will be covered by DOT&E as are space-oriented programs of all armed service branches. The FY 2019 report opens by noting that cybersecurity test and evaluation testing and training for space-based systems remain the office's greatest challenges and that DOD intends to invest $100 billion in space systems over the next decade. It also stressed that DOD is unable to adequately assess the operational effectiveness, survivability, and suitability of space-based systems (Department of Defense, Technology, and Evaluation, 2020b).

This report's assessment of the Air Force's Global Positioning System (GPS) noted that schedule slips from GPS segments had caused operational testing delays. This document acknowledged progress GPS had made but warned of significant remaining operational risks including more work being required to comprehensively replicate space threats, their effect on the space segment, mitigation efforts, and the strategy to conduct operational space segment testing using realistic threats and the Military GPS User Equipment program continues experiencing delays integrating new technology into lead platforms and in developing final software and hardware builds by vendors (Department of Defense, Technology, and Evaluation, 2020b).

This document also described the Air Force Space Fence (SF) program which is a surveillance-based S-band radar system detecting, tracking, identifying and characterizing man-made and naturally occurring Earth-orbiting space objects. SF is currently deploying at the Kwajalein Atoll and the Reagan Test Site Operations Center in Huntsville, AL with a forthcoming unfunded site scheduled for Australia. DOT&E noted that SF had demonstrated the capability to many small previously untracked or cataloged objects but that the presence of only one sensor site it lacks the power or coverage to be able to continuously track or maintain awareness of small objects (Department of Defense, Technology, and Evaluation, 2020b).

Public Opinion Polls

USSF's ongoing political and economic viability depends on continuing public support and funding for its activities. Three polls in 2018-2019 reflect mixed public opinion on the desirability of establishing a new armed service branch. An August 2018 CNN poll of 1,002 respondents asked if the U.S. should establish a new military branch to protect U.S. assets in space: 37% said yes, 55% said no, and 8% had no opinion (Roper Center for Public Opinion Research, 2018).

A May 2019 Pew Research Center poll found asking 1,087 individuals whether they approved or disapproved of establishing a new military branch called the Space Force received the following responses:

Strongly Approve 10%

Somewhat Approve 26%

Somewhat Disapprove 27%

Strongly Disapprove 33%

No Answer 4% (Roper Center for Public Opinion Research, 2019a).

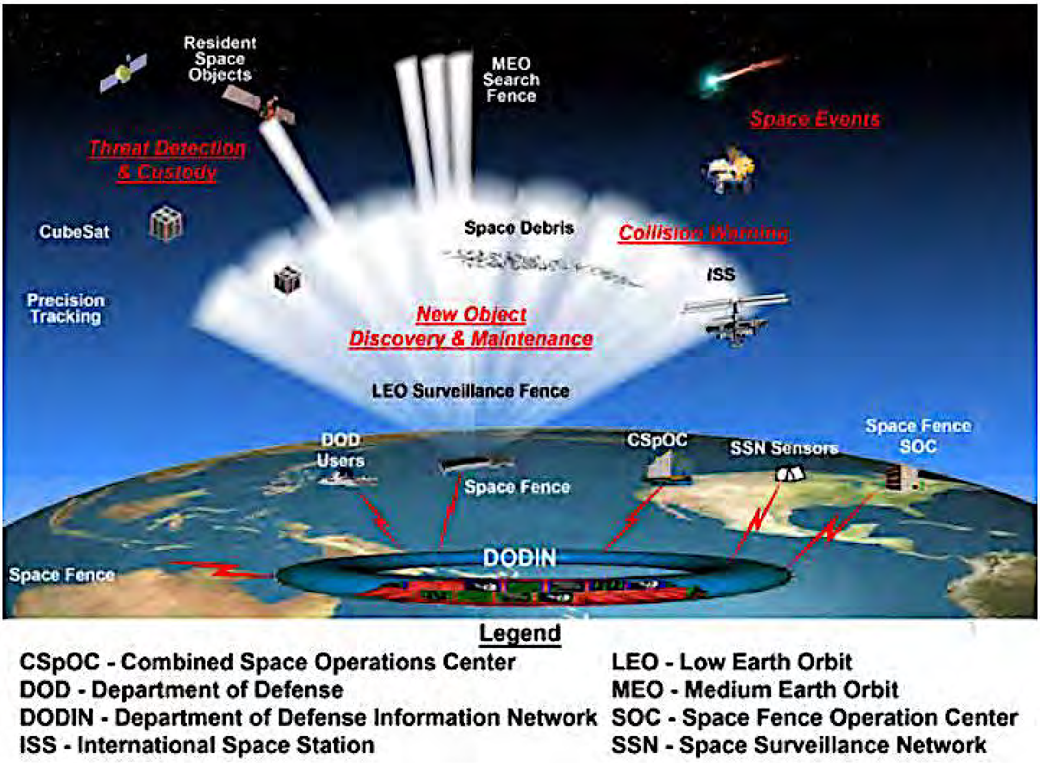


Figure 3. Components of the Space Fence

A May-June 2019 Pew Research Center poll asking 1,284 individuals whether they approved or disapproved of establishing a Space Force produced these responses:

Strong Approve 15%

Somewhat Approve 30%

Somewhat Disapprove 22%

Strongly Disapprove 31%

No Answer 2% (Roper Center for Public Opinion Research, 2019b).

Conclusion

This article has demonstrated that there is a significant corpus of publicly accessible research on USSF to facilitate public knowledge, discussion, and debate on this entity and its multiple diplomatic, economic, military, and political implications for the U.S. and its allies. It has shown that discussion of possible U.S. military involvement in space has generated debate and controversy for multiple decades. USSF will transform U.S. civilian and military law and the legal architecture of international law (Tepper, 2020). Numerous scholarly works have documented how increasing U.S. and international military activity in space will have global repercussions on the economies and societies of world nations and the conduct of military operations (DeBlois, 1999; Dolman, 2001; Brown, 2006, Chapman, 2008; Dolman 2001; Johnson-Freese, 2017).

Publicly accessible government communications and literature on USSF document how this armed service may potentially impact the U.S. economy, business opportunities, the geographic dispersion of government contracting, domestic and international law, U.S. foreign relations, the successes, failures, and ambiguities of program performance, and the financial costs of USSF in comparison when other governmental funding priorities. These information resources also provide the opportunity to inform the public about the need for the U.S. and its allies to address the increasing national security importance of space due to the emergency of great power rivals like China and Russia who seek to use space to disrupt, disable, and destroy U.S. civilian economic and military dependence on space (U.S. Space Force, 2020d; U.S. Department of Defense, 2020a).

In an August 4, 1822 letter former President James Madison wrote "Knowledge will forever govern ignorance: and a people who mean to be their own Governors, must arm themselves with the power which knowledge gives" (Madison, J. 1822). The creation of the first new U.S. military branch in over seven decades means Americans and the world must educate themselves on the multifaceted aspects of USSF and how it will impact civilian and military policy in subsequent decades. USSF will also impact our personal economic lives and governmental finance as well. If Americans desired to be informed about USSF activities they must utilize the publicly accessible literature on this subject to inform themselves when communicating with their congressional representatives, participate in the federal regulatory process, engage in commercial activities, and participate in emerging national and international debate on space's increasing military importance.

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The APUS Supernova Search Program: A Scientific Leadership and Research Opportunity for Graduate and Undergraduate Students

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Abstract

Providing hands-on learning experiences for students in space-related education programs is a challenge and particularly so for programs that are offered 100% online. The American Public University System (APUS) offers Bachelor of Science and Master of Science degree programs in Space Studies that are delivered completely online. To date, 559 graduate students and 405 undergraduate students from around the globe have completed degrees since the inception of our program. The unique aspect of our program is its emphasis on the use of astronomical observations to provide opportunities for students to participate in authentic research opportunities and to develop instrumentation for their research. APUS operates a 24-inch Planewave robotic telescope fitted with an SBIG STX-16803 charge-couple device camera, located in Charles Town, West Virginia. This instrument is an integral component of the undergraduate and graduate education in space studies that we provide. Currently, we use this instrument in a supernova search program where students process images of several dozen galaxies obtained from a periodic survey of the sky and then compare the observations to reference images using blink-comparison software. This program is an excellent research opportunity for both graduate and undergraduate space studies students. Students in the leadership group research, design, and test components of the supernova search program; under faculty direction, they engage in evaluating software and supervise small groups of students who analyze and study the images as they search for possible supernova events. This opportunity supports their classroom learning and provides a means for all students in the program to participate in

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meaningful scientific research. Currently, 177 galaxies in six different regions of the sky are regularly observed in this program.

Keywords: supernova, online education, graduate research

El programa de búsqueda de supernovas de APUS: un liderazgo científico y una oportunidad de investigación para estudiantes de posgrado y pregrado

Resumen

Proporcionar experiencias prácticas de aprendizaje a los estudiantes en los programas de educación relacionados con el espacio es un desafío y especialmente para los programas que se ofrecen 100% en línea. El Sistema Universitario Público Estadounidense (APUS) ofrece programas de licenciatura y maestría en estudios espaciales que se imparten completamente en línea. Hasta la fecha, 559 estudiantes graduados y 405 estudiantes universitarios de todo el mundo han completado sus títulos desde el inicio de nuestro programa. El aspecto único de nuestro programa es su énfasis en el uso de observaciones astronómicas para brindar oportunidades para que los estudiantes participen en oportunidades de investigación auténticas y para desarrollar instrumentación para su investigación. APUS opera un telescopio robótico Planewave de 24 pulgadas equipado con una cámara de dispositivo de carga-par SBIG STX-16803, ubicado en Charles Town, Virginia Occidental. Este instrumento es un componente integral de la educación de pregrado y posgrado en estudios espaciales que brindamos. Actualmente usamos este instrumento en un programa de búsqueda de supernovas donde los estudiantes procesan imágenes de varias docenas de galaxias obtenidas de un estudio periódico del cielo y luego comparan las observaciones con imágenes de referencia utilizando un software de comparación de parpadeos. Este programa es una excelente oportunidad de investigación para estudiantes de estudios espaciales de posgrado y pregrado. Los estudiantes del grupo de liderazgo investigan, diseñan y prueban componentes del programa de búsqueda de supernovas; bajo la dirección de la facultad, se involucran en la evaluación de software y supervisan a pequeños grupos de estudiantes que analizan y estudian las imágenes mientras buscan posibles eventos de supernovas. Esta oportunidad apoya su aprendizaje en el aula y proporciona un medio para que todos los estudiantes del programa participen en una investigación científica significativa. Actualmente, 177 galaxias en seis regiones diferentes del cielo se observan regularmente en este programa.

Palabras clave: supernova, educación en línea, investigación de posgrado

美国公立大学系统（APUS）超新星搜索项目：一项针对研究生和本科生的科学领导力及研究机遇

摘要

为太空相关教育专业的学生提供实践学习体验是具有挑战性的，对那些完全提供线上教学的专业而言尤为如此。美国公立大学系统（APUS）为太空研究专业的本科生及研究生提供全线上教学。自该专业成立以来，全球已有559名研究生和405名本科生获得了相关学位。该专业的独特点在于其聚焦于使用宇航观察来为学生提供机遇，参与真实项目并为其研究提供一系列工具。APUS操作一个24英寸的Planewave机器望远镜，搭配一个SBIG STX-16803型号的CCD相机，该设备位于西弗吉尼亚州查尔斯镇。该设备是我们所提供的太空研究本科专业及研究生专业的一部分。目前我们在一项超新星搜索项目中使用该设备，其中学生对从关于太空的周期性检验中获得的几十个星系图像进行处理，随后使用闪视比较软件（blink-comparison software）将观察发现与参考图像进行比较。该项目对太空专业本科生及研究生而言是一次绝佳的研究机遇。领导力小组中的学生对超新星搜索项目的各部分进行研究、设计和测试；在教师的指导下，他们参与评价软件并监督学生小组，后者一边搜索可能的超新星事件，一边分析和研究图像。这一机遇促进了学生的课堂学习，并为该专业的所有学生提供途径参与有意义的科学研究。目前，该项目对太空中6个不同区域里的177个星系进行定期观察。

关键词：超新星，网络教育，研究生研究

Acronyms/Abbreviations

The following acronyms/abbreviations are used in this paper: Corrected Dall-Kirkham 24 inch (CDK24) telescope; charge-coupled device (CCD) camera; American Public University System (APUS); the Panoramic Survey Telescope and Rapid Response system (Pan-STARRS1); the Public ESO Spectroscopic Survey of Transient Objects (PESSTO); Backyard observatory supernova search (BOSS); American Public University System Search for Supernovae (APUS SSN); Puckett Observatory Supernova Search (POSS); Chilean Automatic Supernova Search (CHASE); Lick Observatory Nearby Galaxy Supernova Search (NGSS); Luminous – red – green – blue (LRGB) filters; European Space Agency (ESA); Data Verification Analyst (DVA).

1. Objective

To discuss the unique aspects of the APUS SSN program with an emphasis on the student run aspects of the program. To describe the successes of the program to date, and to suggest areas of improvement for the future.

2. Introduction

The purpose of this research program is two-fold: first and foremost, the purpose is to provide APUS space studies students with the opportunity to develop leadership skills and gain relevant observational experience by creating and supervising a complex research program. The secondary purpose of the program is to document new supernova events throughout the universe to advance scientific knowledge in the community.

2.1 Student Leadership

It is common practice for graduate, and often even undergraduate, students to engage in formal research as part of their education. This is typically achieved by working with a faculty mentor. What is lacking in many STEM education programs, however, is the opportunity for students to take a lead role in the design of the research itself. Learning what is necessary to implement a successful research program is an invaluable experience that can set students apart from their peers in the field. This experience also directly translates to important career skills, better preparing students to be successful in future job opportunities.

2.1.1 Hands-On Learning Opportunities

Hands on learning activities have been shown to increase student interest and mastery in the sciences. Bloom's taxonomy defines the highest level of thinking as that of "creation," which is the ability to "produce new or original work" [1]. Students who participate in original research programs at both the undergraduate and the graduate level thus have an opportunity to participate in the highest level of thinking/ learning.

2.1.2 Supervisory Role

Scientific research today is often performed as part of a group. Learning to navigate and lead in a group research project is a vital skill that will be increasingly important for science students looking to be competitive in the field. Students need to know how to work together to achieve meaningful results in research. The ability to organize group participation in a program, to motivate consistent and timely participation, to troubleshoot and resolve problems that arise, and to monitor results are invaluable skills in the scientific job market.

2.2 Supernova Science

Supernovae are highly violent events that release an enormous amount of energy over a very short period of time (astronomically speaking). There are two main types of supernovae; thermonuclear supernovae (Type I) are produced when material is accreted onto a white dwarf star from a companion star. When the mass of the white dwarf exceeds the Chandrasehkar limit, a supernova is the result. Core collapse supernovae are produced at the end of the life of a massive star and result from the implosion of the star's iron core. These include Type II, which keep their H-rich envelopes prior to the explosion; Type Ib, which lose their outer layers but retained their He-rich envelopes; and Type Ic, which lose both their H and He layers. Both types of supernovae produce roughly the same amount of energy over the same time period. Type I supernova have peak luminosities of about ten billion solar luminosities over a time period of a few weeks, while Type II supernovae peak at about one billion solar luminosities, but fade much more slowly [2]. The light curves and spectra differ for each type of supernova and represent an important identification tool after the initial detection is made. This study will search for both types of supernova without regard to the conditions that led to the event.

2.2.1 Distance Measurements

Supernovae are of interest in the astronomical community because their high luminosities make them easily to detect in even very distant galaxies. Because their peak luminosities and luminosity profiles are very well known, observations of distant supernovae can be used to very accurately determine the distances to their host galaxies. Thus, they are effective standard candles. Detecting and analyzing new supernovae events is thus highly important for the astronomical community.

2.2.2 Discovery Statistics

In a galaxy about the size of the Milky Way, it is estimated that one supernova explosion occurs roughly every 50 years [3]. If there are approximately 100 - 200 billion galaxies in the observable universe [4], this corresponds to roughly ten billion observable supernova per year in the universe, or one per second.

2.3 Current Programs

There are currently several supernova search programs in existence in the astronomical community. These range from large scale, professionally funded efforts to small group studies to individuals, and even amateur astronomers. This paper will briefly describe the Supernova Hunters program, the Boss Team, CHASE, and the Lick Observatory NGSS, as well as the work of a few individuals to give an overview of the current state of the field.

2.3.1 The Supernova Hunters Program

The Supernova Hunters program is a citizen science supernova identification program [5]. This program uses the Zooniverse platform to search data from the Pan-STARRS1 all sky search database. Pan-STARRS1 scans the sky several times each month searching for transient objects (which includes supernovae). Zooniverse provides an interface for users to access and analyze this data; each observation is viewed and classified by multiple users before being flagged for further observation; this minimizes the statistical probability of erroneous “detections” from the Zooniverse user community, which consists almost entirely of untrained participants. Possible supernova candidates are further evaluated by the PESSTO team. Thus, the Supernova Hunters program represents a partnership between professional astronomers and the public in the search for supernova candidates. To date, over 1 million classifications of transient objects (potential supernova candidates) have been made by nearly 6000 citizens. The program has identified 450 supernova candidates and 2 confirmed supernovae [6]. The program is currently paused while improvements to the analysis system are being made.

2.3.2 The Boss Team

The Boss Team is an Australia/New Zealand based group of amateur astronomers who work together to identify supernova candidates using personal telescopes. They supply data to the Central Bureau of Astronomical Telegrams, which is operated by the Harvard-Smithsonian Center for Astrophysics, for further observation and classification by professional astronomers. To date the BOSS team has identified nearly 200 potential supernova candidates, and has discovered more than 50 confirmed supernovae. [7]

2.3.3 CHASE

CHASE is a supernova search project that targets supernovae observations visible in the southern hemisphere. They use a group of 5 robotic 40 cm telescopes located on Cerro Tololo to observe 6,300 nearby galaxies on a regular basis (roughly 250 a night) using an 80 second exposure. [15] An automated calibration and comparison scheme allows the program to process the data nearly in real time. In their first four years of operation, they discovered 130 confirmed supernovae events. [15]

2.3.4 Lick NGSS

The Lick NGSS program was one of the first programs to use CCD imaging and image-subtraction techniques to regularly observe a large sample of galaxies. NGSS observed a total of 14, 882 galaxies over a period of 11 years, totaling millions of observations of galaxies and resulting in more than one thousand confirmed supernovae, spanning all supernovae types. [16]

2.3.5 POSS

POSS is a group of 18 amateur astronomers under the direction of founder Tim Puckett, an award-winning amateur astronomer and astro-photographer [8]. Team members are located around the world and work together to discover and verify supernova candidates. Since 1994, the POSS team has discovered over 270 supernovae.

2.3.6 Individual Astronomers

In addition to the programs described above, there are a number of individual astronomers, both professional and amateur, who also conduct supernova search programs. This paper will describe only one of particular note whose unique abilities have made him especially prominent in the field; however, there are many others. The most legendary supernova hunter is Australian amateur astronomer Robert Evens. In the 40 years he has been observing, Evens has discovered a total of 42 supernovae in his career using only a backyard telescope, paper, and a near perfect photographic memory of galactic star fields. He holds the record for visual discoveries of supernovae. [9]

2.4 APUS SSN

While there are many programs and individuals searching for supernovas, the APUS SSN program is unique in that it is performed entirely by graduate and undergraduate students (under faculty direction). Students in the leadership group design and oversee the working of the program, and both graduate and undergraduate students participate in the potential supernova candidate identification. This program thus represents a unique opportunity for students to participate in formal astronomical research. It also provides a means for students to develop valuable leadership skills in a scientific setting.

3. Material and Methods

The methods described in this paper were originally developed through the work of APUS master's students Cary Hatch and Bradley Pellington, who each fulfilled the role of "project lead graduate student." The method has been updated and streamlined through the work of the current project leadership team, which consists of APUS students Christopher Colvin, Jason Cushard, and Terry Trevino, as well as Melanie Crowson, Director of Education at the PARI Research Institute and former project lead graduate student at APUS. Jason and Terry are the current project lead researchers; Christopher is our Data Verification Analyst (DVA), and Melanie provides observational support and follow up observations for any transients identified. These individuals will hereafter be referred to as the "leadership team."

3.1 The APUS Telescope

APUS owns and operates a research grade telescope for faculty and student use. The telescope is housed in a fully automated 22.5' hemisphere dome on top of the Information Technology building on the APUS campus in Charles Town, WV, elevation 170 m. The telescope is a planewave CDK24, with an aperture of 24 inches and focal length of 155.98 inches. The focal ratio is f/6.5. It is paired with a 16.8-megapixel SBIG STX-16803 CCD camera; the array size is 4096 x 4096. It is also equipped with an SBIG FW-7 LRGB filter wheel. The telescope is fully robotic, able to be operated completely remotely, and can incorporate autonomous scripts.

3.2 Galaxies Observed

The galaxies observed in this project were chosen from 6 different regions of the sky. The chosen regions are designed to rise successively over the course of the night. This maximizes the amount of observing time as well as making efficient use of the telescope resources. The galaxies include a range of type and viewing angle; all are 11^{th} magnitude or brighter. A total of one hundred and seventy-seven galaxies can be observed nightly. Specifically, twenty-six galaxies are observed from the Pegasus region, sixteen from the Camelopardus/ Eridanus region, thirty-seven from the Ursa Major region, twenty from the Leo/Hydra region, forty-two from the Virgo region, and thirty-six from the Coma Berenices/Canes Venatici region (see Appendix A for more details). The telescope is automated using the Orchestrate software in order to transition smoothly between observational regions over the course of the night.

3.3 Observations

The observations are 60 second exposures using a standard L filter. The data is then calibrated by subtracting dark frames, flat fields, and bias frames; this processing compensates for irregularities in the CCD itself. The short length of the exposure is sufficient to provide a reasonably good quality image of the host galaxy and can easily capture any supernova events due to their high luminosities. The methods have been tested and proven capable of detecting transient events with brightness as low as 16th magnitude in a 60 second exposure. Typical supernovae brightness is well above this limit, even several weeks after the occurrence of the initial event.

3.4 Data Analysis

Once the data has been obtained and calibrated, it is analyzed by students in the Space Studies program using a procedure developed by the leadership team. The basic procedure involves comparing the obtained galaxy images with reference images of each galaxy which have been observed using the APUS telescope with the same observational parameters. The comparison allows the students to determine if any transient events exist. Such events constitute potential supernova candidates and are flagged for further analysis.

3.4.1 Blink Comparison Process

The images are analyzed using the Aladin Software program. Each image is loaded into the program, along with the reference galaxy images. The observer then selects 5-6 stars in the data image and marks the same stars in the reference image. Aladin uses these reference points to properly align the images. A visual comparison is performed using a blink comparison method. Aladin generates a composite, animated image that "blinks" back and forth between the reference and observed images. Because they are so bright, supernova can be easily seen as the images blink. Space Studies students work in teams under the guidance of the lead researchers to perform this part of the process, which affords them the opportunity to work with real data, perform visual data analysis, and potentially be part of the discovery process. Students log transient objects for further study; these logs are monitored by the team leaders, and potential supernova candidates are recorded for review and further observations.

3.4.2 Further Analysis

Once a transient object has been identified and confirmed, the team leader reports to the DVA for further study. There are several possibilities that must be ruled out before a supernova discovery can be confirmed. These include CCD effects such as hot pixels, photon leaking from previous images, and changes in seeing. CCD effects can be easily eliminated by follow up observations of the galaxy. False positives can also result from observational effects such as cosmic rays, asteroids in the foreground of the observation, and detection of a variable star. These possibilities must be evaluated through the use of Astrometrica (for asteroid verification) and variable star catalogs before the detection can be confirmed. Finally, a potential supernova discovery must be double checked to ensure that the observation is not a previously discovered supernova event. Once these possibilities have been eliminated, the DVA reports the detection to the community for confirmation, and further observations can be made to determine the properties of the supernova.

3.5 Faculty/Student Roles

Faculty perform an important supporting role in the program. The faculty provide the reference images for the galaxy comparisons and create the scripting that allows automated observing of the different sky regions. All observations are made under faculty supervision, with the leadership team assisting. Faculty also perform further study of supernova candidates to confirm the discovery and collect data on the supernova event.

The leadership group participates actively in the design and operation of the project. Cary Hatch (M.S. 3/2019) designed the original evaluation process for the data—the programs and instructions for aligning the data files and for blinking the images. Bradley Pellington (M.S. 10/2019), built on Hatch's work by extending the instruction manual students use to participate in the program and by designing and implementing the interface that allows students to work with the images and provides accountability (see section 3.5.1). Pellington also completed beta testing of the program and initiated the research phase. The current leadership team has streamlined the analysis procedure by piloting the use of Aladin to combine the alignment and comparison stages of analysis (which were formally completed as part of a two-step process). The new procedure uses a single step to both align and compare the images, which has resulted in a significant increase in the speed and efficiency of the analysis process. The leadership team has also created an autonomous, self-paced training procedure for new member onboarding and has developed a formal procedure for analysis of potential transient detections.

The current leadership group has also pioneered the use of a team structure in the research project. Members of the leadership team each recruit, train, and supervise a small team of students as they work to analyze the observations. The teams report directly to the lead researchers, who monitor results and help troubleshoot any problems that arise during the analysis.

3.5.1 Program Accountability

In any research program that involves multiple participants, a key factor is accountability. Data must be processed quickly, and results communicated in a short time frame, in order to confirm and further study supernova candidates before they fade below detection limits.

In the APUS SSN program, accountability is the sole responsibility of the leadership team. These students are responsible for communicating with both faculty and student program participants to ensure that all images are processed in an orderly and timely fashion and that no data is overlooked. The leadership team monitors the progress of data through the analysis process and is the point of contact for any technical issues that arise. The leadership team must also communicate regularly with the faculty to ensure that potential supernova candidates are reported for future study.

To manage this process, the team designed an observatory Google Drive account to provide organization and easy access to the data. The drive includes separate folders for each stage of the process as well as a check-out sheet where students can record which data they are analysing and any transient objects in the data. The simplicity of the system is its greatest asset; it is user friendly and effective, easily monitored, and fairly maintenance free. This system has been an important factor in creating a program that runs smoothly and efficiently.

4. Theory and Calculation

It is important to establish the feasibility of a long-term research program such as the APUS SSN. Two factors are of primary concern here: the probability of detection and the timeframe of detection. Both are pivotal in determining the projected success rate of the program.

4.1 Probability of Detection

The probability of detection relates to the likelihood that the current program will observe a supernova when it occurs. This probability depends on a balance between two key factors: the rate of supernovae in the Universe and the sample size of the galaxies observed in the program.

4.1.1 Supernova Rate

The number of supernovae which occur yearly in the Universe has been studied by many groups; it varies by supernova type as well as by galaxy type, mass, and even the wavelength of observation and the inclination of the observed galaxy. These rates have been established fairly accurately in recent years; here, we will rely on the measurements by the Lick NGSS program, which computed rates for samples of nearby (local) galaxies based on CCD imaging and modern imaging subtraction techniques for a sample of 1000 supernovae spanning Types Ia, Ibc, and II. [14]

The supernova rate in the Milky Way galaxy is a well-established rate. The Lick observatory NGSS program estimates this rate at 2.84 ± 0.60 SNe per century [14], a number which is consistent with published supernovae rates from other groups using a variety of techniques. They then calculated rates as a function of galaxy mass and supernova type for nearby galaxies. For our purposes, the volumetric rate averaged over early and late type galaxies is sufficient. They report volume rates of 0.301 (Type Ia), 0.258 (Type Ib,c) and 0.447 (Type II) in units of (10^{-4} SN Mpc^{-3} yr^{-1}). [14] Our sample comprises a radius of approximately 19.8; assuming a spherical distribution, this gives a volume of roughly 32.5 x 10^4 Mpc^3. Thus, we can expect rates of 0.98 yr^{-1} (Type Ia); 0.83 yr^{-1} (Type Ib,c); 1.45 yr^{-1} (Type II), or roughly 3 per year. Note that this assumes complete sampling of the galaxies in the volume, however.

In addition, a supernova event does not necessarily mean a detection. A more useful indication of potential success for our study is perhaps given by established detection rates from similar studies, normalized by the number of observers (telescopes used) and detection capability. Based on observational rates, an estimate of a 2-3 detections per year is reasonable [12]. For comparison, the POSS group reports roughly 15 – 20 supernova detections per year using two telescopes, while the BOSS team reports 9 – 15 detections an average per year using 6 telescopes. [7, 8]

4.1.2 Sample Probability

The number of galaxies regularly observed in the research program directly relates to the probability of detection; the larger the sample size, the more likely a detection will be made. The APUS SSN sample contains 177 galaxies in multiple regions of the sky. Assuming a conservative one observable event per year in given the sample volume, this implies roughly 4200 observations per detection. Observational success rates of similar programs report approximately 1 supernova detection per one thousand observations. [7] [8]

4.2 Observational Timeframe

Supernova peak very quickly and decay over a period of a few weeks to a few months, depending on the type of the supernova (see Fig. 1).

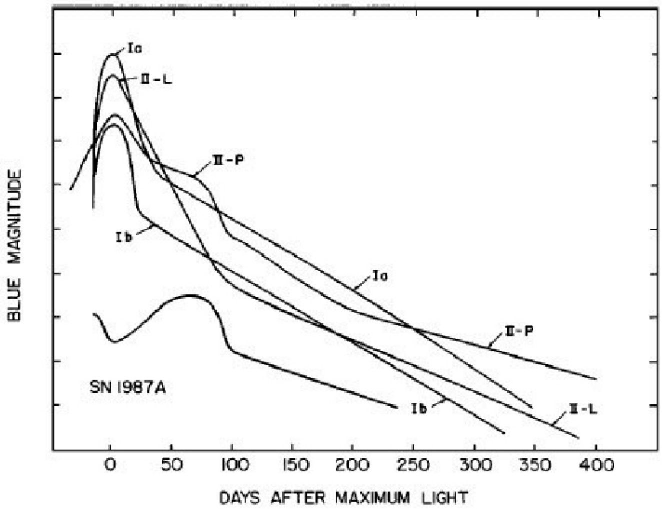

Fig. 1. Supernova lightcurves as a function of time. Image credit: Nadyozhin [13]

For galaxies of 11th magnitude or brighter, the APUS telescope is capable of detecting the light from a typical supernova for approximately 20 - 30 days. This means that each galaxy should be observed a minimum of twice a month in order to ensure that the event is still visible. Weekly observations are preferable in order to detect a supernova as quickly as possible after the event.

5. Results

The APUS SSN program has now completed the testing phase and is currently in operation.

5.1 Testing Phase

Under the direction of (then) lead graduate student Bradley Pellington, a group of two APUS Space Studies students participated in the testing phase of the SSN program from July 27, 2019 through August 4, 2019. The students analyzed 15 images using the process outlined in section 2. The testing revealed that adjustments were needed in the instruction manual as well as an additional column for comments in the spreadsheet.

5.2 Research Phase

The SSN project is currently fully operational. Approximately 30 APUS Space Studies students are working under the supervision of the leadership team to analyze galaxy images and identify transient objects. Collectively, the students have analyzed hundreds of images at the time of this writing. Figures 2 and 3 show typical galaxy images from the SSN program. Both face-on and edge-on galaxy candidates are included in the galaxy sample.

A number of minor variations due to cosmic rays have been noted, and some photon leakage due to an exceptionally bright star in one of the images was reported. The group has confirmed detection of several transient events, including several asteroids and the identification of some known variable stars (Figure 4) as well as the detection of the previously reported May 6, 2020 supernova in M61, designation 2020jfo (Figure 5).

While not the supernovae discoveries hoped for, these detections indicate that the process is working. To date, no potential new supernovae candidates have been found, but progress is hopeful and on track for the future.

Fig. 2. NGC 628, Pegasus Region, APUS Observatory, June 2019. Image credit: K. Miller

Fig. 3. NGC 891, Pegasus Region, APUS Observatory, June 2019. Image credit: K. Miller

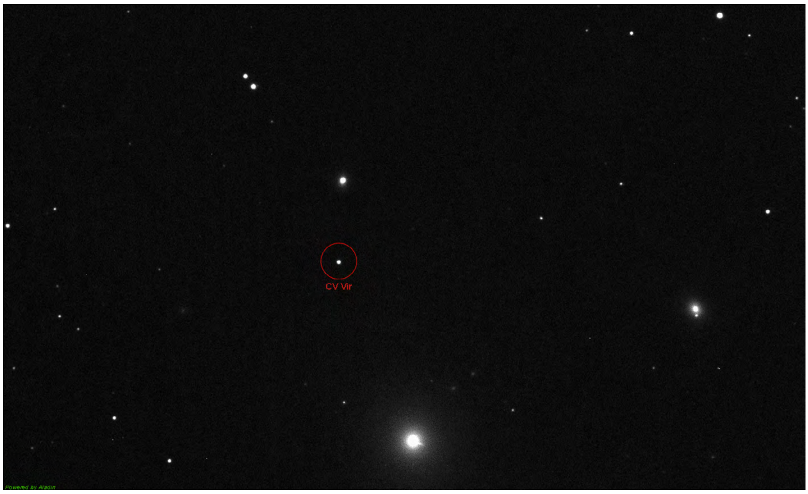

Figure 4: Detection of known variable star CV Vir. APUS Observatory, April 2020. Image credit: K. Miller

Figure 5: Detection of supernova 2020jfo in M61, APUS Observatory, May 2020. Image credit: K. Miller

6. Discussion

The main value of this program lies in the research opportunities afforded to both graduate and undergraduate students. Six APUS space studies students, from both the undergraduate and graduate programs, have gained the experience of developing a research program. The first lead student pioneered the development of programs that would work effectively in the APUS online environment. This work allowed the program to function remotely and smoothly. The second lead student completed testing of the program and developed the interface that allows students to participate in the program. The supervisory nature of his position provides a unique research experience. Both lead students also gained observational experience through the use of the APUS telescope to observe the galaxies in the program. The current leadership team has streamlined and improved the analysis procedure, developed an effective training program for students who join the research initiative, implemented a successful team-based approach, formalized the detection procedure, and supervised the transition from the testing to the research phase of the program. The combination of authentic observational and program management experience gives these students a unique advantage in future academic studies and also distinguishes them in the job market.

Space Studies students who choose to participate in the program also benefit greatly. Students have the opportunity to work with real observational data in fits format (the standard for astronomical imaging). They learn to analyze the images and detect transient features, which gives them experience in data interpretation. The hands-on nature of this experience is invaluable and particularly unique for students in an online university program.

7. Conclusion

This paper details the creation of a student run, faculty supported, supernova search research program using the APUS 24-inch Planewave telescope. The program has been developed, tested, and successfully implemented by APUS Space Studies students, who direct both graduate and undergraduate students in analyzing the data. This program has the potential to contribute significantly to the scientific community through the detection of new supernova events. It also provides meaningful leadership opportunities for APUS graduate students, and authentic research experience for undergraduates.

Acknowledgements

The authors gratefully acknowledge APUS's commitment to excellence in both undergraduate and graduate online education, and the school's support of the Space Studies program through the purchase and maintenance of a dedicated, research grade telescope.

Limitations and Bias

This study is limited in the number of galaxies surveyed. The galaxy group represents an intentional bias towards nearby galaxies (high Z galaxies are excluded), primarily due to observational constraints.

Appendix A (List of Galaxies Observed)

Region	Galaxy	RA	Dec	Mag.
Pegasus	NGC 7217	22^h07^m	31°21’	11
Pegasus	NGC 7331	22^h37^m	34°24’	10.4
Pegasus	NGC 7479	23^h04^m	12°19’	11.6
Pegasus	NGC 7640	23^h22^m	40°50’	11.1
Pegasus	NGC 224	00^h42^m	41°16’	3.44
Pegasus	NGC 488	01^h21^m	15°24’	10.4
Pegasus	NGC 598	01^h33^m	30°39’	5.72
Pegasus	NGC 628	01^h36^m	15°47’	10
Pegasus	NGC 672	01^h47^m	27°25’	11.5
Pegasus	NGC 772	01^h59^m	19°00’	10.3
Pegasus	NGC 891	02^h22^m	42°21’	10.8
Pegasus	NGC 925	02^h27^m	33°34’	10.7
Pegasus	NGC 7606	23^h19^m	-08°29’	10.8
Pegasus	NGC 7727	23^h39^m	-12°17’	11.5
Pegasus	NGC 45	00^h14^m	-23°10’	10.4
Pegasus	NGC 157	00^h34^m	-08°23’	10.4
Pegasus	NGC 247	00^h47^m	-20°45’	9.9
Pegasus	NGC 253	00^h47^m	-25°17’	8
Pegasus	NGC 578	01^h30^m	-22°40’	10.63
Pegasus	NGC 720	01^h53^m	-13°44’	10.2
Pegasus	NGC 908	02^h23^m	-21°14’	10.4
Pegasus	NGC 936	02^h27^m	-01°09’	10.2
Pegasus	NGC 1055	02^h41^m	00°26’	11.4
Pegasus	NGC 1068	02^h42^m	00°00’	9.61
Pegasus	NGC 1073	02^h43^m	01°22’	10.8
Pegasus	NGC 1087	02^h46^m	-00°29’	11.4
Cam/Eri	IC 342	03^h46^m	68°05’	9.1
Cam/Eri	NGC 1961	05^h42^m	69°22’	10.9
Cam/Eri	NGC 2146	06^h18^m	78°21’	11.38
Cam/Eri	NGC 2336	07^h27^m	80°10’	10.3
Cam/Eri	NGC 2403	07^h36^m	65°36’	8.9
Cam/Eri	NGC 2655	08^h55^m	78°13’	10.1
Cam/Eri	NGC 2683	08^h52^m	33°25’	10.6

Cam/Eri	NGC 1187	03^h02^m	-22°52'	11.4
Cam/Eri	NGC 1232	03^h09^m	-20°34'	10.9
Cam/Eri	NGC 1300	03^h19^m	-19°24'	11.4
Cam/Eri	NGC 1332	03^h26^m	-21°20'	7.05
Cam/Eri	NGC 1395	03^h38^m	-23°01'	9.8
Cam/Eri	NGC 1398	03^h38^m	-26°20'	10.63
Cam/Eri	NGC 1637	04^h41^m	-20°51'	11.5
Cam/Eri	NGC 1964	05^h33^m	-21°56'	10.8
Ursa Maj	NGC 2681	08^h53^m	51°18'	11.1
Ursa Maj	NGC 2841	09^h22^m	50°58'	10.1
Ursa Maj	NGC 2976	09^h47^m	67°54'	10.8
Ursa Maj	NGC 2985	09^h50^m	72°16'	10.4
Ursa Maj	NGC 3031	09^h55^m	69°03'	6.94
Ursa Maj	NGC 3034	09^h55^m	69°40'	8.41
Ursa Maj	NGC 3077	10^h03^m	68°44'	10.6
Ursa Maj	NGC 3184	10^h18^m	41°25'	10.4
Ursa Maj	NGC 3198	10^h19^m	45°32'	10.3
Ursa Maj	NGC 3310	10^h38^m	53°30'	11.2
Ursa Maj	NGC 3319	10^h39^m	41°41'	11.07
Ursa Maj	NGC 3359	10^h46^m	63°13'	10.57
Ursa Maj	NGC 3368	10^h46^m	11°49'	10.1
Ursa Maj	NGC 3556	11^h11^m	55°40'	10.7
Ursa Maj	NGC 3631	11^h21^m	53°10'	10.1
Ursa Maj	NGC 3675	11^h26^m	43°35'	10
Ursa Maj	NGC 3718	11^h32^m	53°04'	10.61
Ursa Maj	NGC 3726	11^h33^m	47°01'	10.2
Ursa Maj	NGC 3810	11^h40^m	11°28'	10.6
Ursa Maj	NGC 3893	11^h48^m	48°42'	10.2
Ursa Maj	NGC 3898	11^h49^m	56°05'	11.7
Ursa Maj	NGC 3938	11^h52^m	44°07'	10.9
Ursa Maj	NGC 3941	11^h52^m	36°59'	10.3
Ursa Maj	NGC 3953	11^h53^m	52°19'	10.8
Ursa Maj	NGC 3992	11^h57^m	53°22'	10.6
Ursa Maj	NGC 4051	12^h03^m	44°31'	12.92
Ursa Maj	NGC 4088	12^h05^m	50°32'	11.2
Ursa Maj	NGC 4125	12^h08^m	65°10'	10.7

Ursa Maj	NGC 4605	12^h39^m	61°36’	10.9
Ursa Maj	NGC 5322	13^h49^m	60°11’	10.1
Ursa Maj	NGC 5457	14^h03^m	54°20’	7.86
Ursa Maj	NGC 5474	14^h05^m	53°39’	11.3
Ursa Maj	NGC 5585	14^h19^m	56°43’	11.2
Ursa Maj	NGC 5866	15^h06^m	55°45’	10.7
Ursa Maj	NGC 5907	15^h15^m	56°19’	11.1
Ursa Maj	NGC 6503	17^h49^m	70°09’	10.2
Ursa Maj	NGC 6946	20^h34^m	60°09’	9.6
Leo/Hyd	NGC 2775	09^h10^m	07°02’	11.03
Leo/Hyd	NGC 2903	09^h32^m	21°30’	9.7
Leo/Hyd	NGC 3115	10^h05^m	-07°43’	9.9
Leo/Hyd	NGC 3166	10^h14^m	03°27’	7.21
Leo/Hyd	NGC 3338	10^h42^m	13°44’	12.1
Leo/Hyd	NGC 3344	10^h43^m	24°55’	10.5
Leo/Hyd	NGC 3351	10^h43^m	11°42’	11.4
Leo/Hyd	NGC 3377	10^h47^m	13°59’	10.2
Leo/Hyd	NGC 3379	10^h47^m	12°34’	10.2
Leo/Hyd	NGC 3486	11^h00^m	28°58’	10.5
Leo/Hyd	NGC 3489	11^h00^m	13°54’	10.2
Leo/Hyd	NGC 3521	11^h05^m	-00°02’	11
Leo/Hyd	NGC 3627	11^h20^m	12°59’	8.9
Leo/Hyd	NGC 3628	11^h20^m	13°36’	6.07
Leo/Hyd	NGC 2613	08^h33^m	-22°58’	11.6
Leo/Hyd	NGC 2835	09^h17^m	-22°21’	10.3
Leo/Hyd	NGC 3109	10^h03^m	-26°09’	10.4
Leo/Hyd	NGC 3923	11^h51^m	-28°48’	9.6
Leo/Hyd	NGC 4038	12^h01^m	-18°52’	11.2
Leo/Hyd	NGC 5236	13^h37^m	-29°51’	7.54
Virgo	NGC 4030	12^h00^m	-01°05’	10.6
Virgo	NGC 4216	12^h15^m	13°08’	11
Virgo	NGC 4261	12^h19^m	05°49’	11.4
Virgo	NGC 4303	12^h21^m	04°28’	10.18
Virgo	NGC 4365	12^h24^m	07°19’	6.64
Virgo	NGC 4374	12^h25^m	12°53’	10.1
Virgo	NGC 4429	12^h27^m	11°06’	11.02

Virgo	NGC 4438	12^h27^m	13°00’	10
Virgo	NGC 4442	12^h15^m	13°08’	11.2
Virgo	NGC 4472	12^h29^m	08°00’	9.4
Virgo	NGC 4477	12^h30^m	13°38’	11.38
Virgo	NGC 4486	12^h30^m	12°23’	9.59
Virgo	NGC 4517	12^h32^m	00°06’	10.6
Virgo	NGC 4526	12^h34^m	07°41’	10.7
Virgo	NGC 4527	12^h34^m	02°39’	11.4
Virgo	NGC 4535	12^h34^m	08°11’	7.38
Virgo	NGC 4536	12^h34^m	02°11’	11.1
Virgo	NGC 4552	12^h35^m	12°33’	10.73
Virgo	NGC 4569	12^h36^m	13°09’	10.26
Virgo	NGC 4579	12^h54^m	-10°14’	10.5
Virgo	NGC 4594	12^h39^m	-11°37’	8.98
Virgo	NGC 4621	12^h42^m	11°38’	10.6
Virgo	NGC 4636	12^h42^m	02°41’	9.4
Virgo	NGC 4649	12^h43^m	11°33’	9.8
Virgo	NGC 4654	12^h43^m	13°07’	12
Virgo	NGC 4665	12^h45^m	03°03’	10.3
Virgo	NGC 4666	12^h42^m	-00°11’	10.8
Virgo	NGC 4697	12^h48^m	-05°48’	9.2
Virgo	NGC 4699	12^h49^m	-08°39’	9.6
Virgo	NGC 4731	12^h48^m	-06°23’	10.5
Virgo	NGC 4753	12^h52^m	-01°11’	10.85
Virgo	NGC 4762	12^h52^m	11°13’	11.12
Virgo	NGC 4856	12^h54^m	-10°14’	10.72
Virgo	NGC 4939	13^h04^m	-10°20’	11.3
Virgo	NGC 5054	13^h16^m	-16°38’	10.36
Virgo	NGC 5068	13^h18^m	-21°02’	10.5
Virgo	NGC 5247	13^h38^m	-17°53’	10.5
Virgo	NGC 5248	13^h37^m	08°53’	10.97
Virgo	NGC 5364	13^h56^m	05°00’	11.2
Virgo	NGC 5566	14^h20^m	03°56’	11.1
Virgo	NGC 5746	14^h44^m	01°57’	11
Virgo	NGC 5846	15^h06^m	01°36’	10.1
CB/CV	NGC 4192	12^h13^m	14°54’	11

CB/CV	NGC 4254	12^h18^m	14°24’	10.4
CB/CV	NGC 4274	12^h29^m	29°36’	10.4
CB/CV	NGC 4293	12^h21^m	18°22’	10.4
CB/CV	NGC 4314	12^h22^m	29°53’	11.4
CB/CV	NGC 4321	12^h22^m	15°49’	9.5
CB/CV	NGC 4382	12^h25^m	18°11’	10
CB/CV	NGC 4414	12^h26^m	31°13’	11
CB/CV	NGC 4450	12^h28^m	17°05’	10.9
CB/CV	NGC 4459	12^h29^m	13°58’	11.32
CB/CV	NGC 4494	12^h31^m	25°46’	9.7
CB/CV	NGC 4501	12^h31^m	14°25’	10.4
CB/CV	NGC 4548	12^h35^m	14°29’	11
CB/CV	NGC 4559	12^h35^m	27°57’	10.4
CB/CV	NGC 4565	12^h36^m	25°59’	10.42
CB/CV	NGC 4725	12^h50^m	25°30’	10.1
CB/CV	NGC 4826	12^h56^m	21°40’	9.36
CB/CV	NGC 4145	12^h10^m	39°53’	11.3
CB/CV	NGC 4151	12^h10^m	39°24’	11.5
CB/CV	NGC 4214	12^h15^m	36°19’	10.2
CB/CV	NGC 4236	12^h16^m	69°27’	10.5
CB/CV	NGC 4242	12^h17^m	45°37’	11.37
CB/CV	NGC 4244	12^h17^m	37°48’	7.72
CB/CV	NGC 4258	12^h19^m	47°18’	8.4
CB/CV	NGC 4395	12^h25^m	33°32’	10.6
CB/CV	NGC 4395	12^h25^m	33°32’	10.6
CB/CV	NGC 4449	12^h28^m	44°05’	10
CB/CV	NGC 4490	12^h30^m	41°38’	9.8
CB/CV	NGC 4618	12^h41^m	41°09’	11.2
CB/CV	NGC 4656	12^h43^m	32°10’	11
CB/CV	NGC 4736	12^h50^m	41°07’	8.99
CB/CV	NGC 5005	13^h10^m	37°03’	10.6
CB/CV	NGC 5033	13^h13^m	36°35’	10.8
CB/CV	NGC 5055	13^h15^m	42°01’	9.3
CB/CV	NGC 5194	13^h29^m	47°11’	8.4
CB/CV	NGC 5371	13^h55^m	40°27’	11.3

*Region refers to the area of the sky as defined in the program

* RA = right ascension

*Dec = Declination

*Cam/Eri = Camelopardus/Eridanus

*Ursa Maj = Ursa Major

*Leo/Hyd = Leo/Hydra

*CB/CV = Coma Berenices/Canes Venatici

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Conflicts of Interest

Preliminary reports of this project were made at the AAS Meeting 233 in January 8, 2019 and presented at the 70^{th} International Astronautical Congress, 21-25 October 2019, Washington, D.C., United States. A preliminary report of the project was published in the IAC proceedings, reference number IAC-19, E1,3,11,x54118

Could Redefining U.S. Space Power Mitigate the Risk of Space Logistics Degradation by the Threat of Space Weaponization?

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American Public University System

Abstract

This research article aims to assess U.S. space logistics and the threat of space weapons through the lens of proposed theories and concepts of space power. This analysis will begin with a brief introduction to space logistics, followed by the threat of space weapons, address concepts of space power, and end with recommendations and a new theory of space power. To this day, more states are gaining access to the space domain and challenging U.S. space dominance. As Smith suggests, the U.S. has been more focused on tracking objects in orbit instead of protecting space assets and deterring adversaries (M. V. Smith 2002). While the space treaties of the 1960s and 1970s attempted to establish the peaceful use of the space domain, preventing outer space's weaponization, its effectiveness has slowly declined over the decades with changes to global, national security objectives and technology advancements.

Advanced societies rely on the critical space infrastructure (CSI) for daily life to include supporting economies and government systems. From the day CSI's were established in the space domain, their technology has vastly improved to provide better services. Even though the expansion and reliance have enhanced technological capabilities with communications, remote sensing, global positioning/navigation, broadband, and entertainment, it has also exposed vulnerabilities. In 2016 the U.S. had 576 satellites in orbit while China had 181, and Russia had 140 (Johnson-Freese, 2016). A space-faring nation with significantly more satellites in orbit than other states could be viewed as threatening space dominance. As Georgescu et al. explain, "this dependency breeds vulnerability, both to natural and man-made risks arising from the specific environment in which space systems operate, as well as to deliberate attacks seeking to destabilize societies" (Georgescu et al. 2019).

Keywords: U.S. space power, risk, space logistics, degradation, threat, space weaponization

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¿Podría la redefinición del poder espacial estadounidense mitigar el riesgo de degradación de la logística espacial por la amenaza del uso de armas espaciales?

Resumen

Este artículo de investigación tiene como objetivo evaluar la logística espacial de Estados Unidos y la amenaza de las armas espaciales a través de la lente de las teorías y conceptos propuestos del poder espacial. Este análisis comenzará con una breve introducción a la logística espacial, seguida de la amenaza de las armas espaciales, abordará los conceptos del poder espacial y finalizará con recomendaciones y una nueva teoría del poder espacial. Hasta el día de hoy, más estados están obteniendo acceso al dominio espacial y desafiando el dominio espacial de EE. UU. Como sugiere Smith, Estados Unidos se ha centrado más en rastrear objetos en órbita en lugar de proteger los activos espaciales y disuadir a los adversarios (M. V. Smith 2002). Si bien los tratados espaciales de las décadas de 1960 y 1970 intentaron establecer el uso pacífico del dominio espacial, evitando el uso de armas en el espacio ultraterrestre, su eficacia ha disminuido lentamente a lo largo de las décadas con los cambios en los objetivos de seguridad nacional y mundial y los avances tecnológicos.

Las sociedades avanzadas dependen de la infraestructura espacial crítica (CSI) para la vida diaria para incluir economías de apoyo y sistemas gubernamentales. Desde el día en que se establecieron los CSI en el dominio espacial, su tecnología ha mejorado enormemente para brindar mejores servicios. Aunque la expansión y la dependencia han mejorado las capacidades tecnológicas con comunicaciones, teledetección, posicionamiento / navegación global, banda ancha y entretenimiento, también ha expuesto vulnerabilidades. En 2016, Estados Unidos tenía 576 satélites en órbita, mientras que China tenía 181 y Rusia tenía 140 (Johnson-Freese, 2016). Una nación espacial con significativamente más satélites en órbita que otros estados podría verse como una amenaza para el dominio del espacio. Como Georgescu et al. explican, “esta dependencia genera vulnerabilidad, tanto a los riesgos naturales como provocados por el hombre que surgen del entorno específico en el que operan los sistemas espaciales, así como a los ataques deliberados que buscan desestabilizar las sociedades” (Georgescu et al. 2019).

Palabras clave: Poder espacial estadounidense, riesgo, logística espacial, degradación, amenaza, armamento espacial

重新定义美国太空实力能缓解由太空武器化威胁造成的太空后勤弱化风险吗？

摘要

该研究文章旨在透过所提理论和太空实力概念视角，评估美国太空后勤和太空武器威胁。本篇分析将首先简要介绍太空后勤、太空武器威胁，接着研究太空实力的概念，最后提出建议和关于太空实力的新理论。目前，更多的国家正在进入太空领域，挑战美国的太空主导权。正如学者Smith所暗示的那样，美国一直更多地聚焦于追踪轨道上的物体，而不是保护太空资产和威慑对手（M. V. Smith 2002）。尽管20世纪60年代和70年代的空间条约试图建立对太空领域的和平使用、防止外层空间的武器化，但随着全球、国家安全目标的改变和技术提升，条约的有效性在几十年里缓慢下降。

高等社会依赖关键空间基础设施（CSI）以供每日生活，把支持经济和政府系统包括在内。自CSI在太空领域建立之日起，相关技术已获得巨大提升，以期提供更好的服务。尽管CSI的扩张和依赖通过各方面提升了技术能力，包括传播、遥感、全球定位/导航、宽带、娱乐，但也暴露了弱点。2016年，美国在轨道中拥有576颗卫星、中国拥有181颗、俄罗斯拥有140颗（Johnson-Freese，2016）。一个在轨道上拥有的卫星数量远超过其他国家的太空强国能被视为对太空主导权造成威胁。学者Georgescu等人解释道，"这种依赖性会在两方面催生脆弱性，一是空间系统所运作的特定环境中产生的自然风险和人为风险，二是企图混乱社会的蓄意攻击"（Georgescu et al. 2019）。

关键词：美国太空实力，风险，太空后勤，退化，威胁，太空武器化

Introduction

Unlike terrestrial logistics, space operations and the space environment's intricacies make logistics much more complex and demanding on supply chain management. In 2011 alone, 25 tons of supplies and equipment were transported to the ISS consisting of propellant, oxygen, water, food, spare parts, and medical equipment (Johnson 2011). By understanding this logistical complexity, vulnerabilities could be more easily evaluated to mitigate future space weapon attacks' damage. Johnson explains space logistics as (1, 2011) "the theory and practice of driving space system design for operability, and of managing the flow of material, services, and information needed throughout a space life cycle." Within this concept are multiple factors that could lead space logistics to become vulnerable to adversaries and hinder space logistics' effectiveness. For example, the logistics involved with the Shuttle and ISS have demonstrated multiple areas that could improve current space logistics' efficiency.

Five key areas of contemporary space flight logistics could be improved. These areas include fragmented databases, storage problems on the ISS, real-time awareness of system health and logistics inventory levels, overly complicated and bureaucratic processes, and costly NASA logistic practices designed in program/project lines (Andy, Evans, and Laufer 2006). Each one of these critical areas contributes to inefficiencies that affect space logistics in one way or another. In addition to these vital elements, space logistics must also consider ground operations and the supplier network. While Laufer et al. explain each of these critical elements must be considered, the most significant inefficiency does not come from any technical aspects of space logistics but the administrative and managerial processes (Andy, Evans, and Laufer 2006). For example, the DoD Logistics Transformation Study identified a lack of perspectives being shared within engineers and logisticians to determine issues and improve many of the critical areas previously mentioned. While each key area has a specific function, the managerial aspect plays a significant role in space logistics efficiency. Each key area requiring improvement also exposed vulnerabilities.

The lack of security measures increases vulnerability. Security measures could be introduced in many forms. The Rumsfeld Commission was assigned in 2001 to review all U.S. space activities as they related to national security. After a thorough review, what they determined was two significant recommendations were required for all U.S. space activities:

1. A centralized management of space programs and overall acquisition of space platforms for national security.
2. Creation of a military space department when conditions allow.

Without these recommendations, the 2001 commission argued that the U.S. would risk an inventible conflict in space. The vulnerability of space weapons to space launch could range anywhere from the ground site, throughout the launch process up to 62 miles to space and continue in orbit. Augustyn explains how space logistics' safety and security are dependent on terrestrial network connections required for business and government agencies (Augustyn 2020). For example, space launch operations alone require the deployment of payloads into space, the sustainment, augmentation, or reconstituting satellite constellations for military or commercial uses (DIA 2019). The risk of conflict did not end in 2001 with the Rumsfeld Commission.

In fact, it continued, and in 2017 General Hyten suggested to Congress that the space domain required oversight of the acquisition, deployment of strategic ground control segments, oversight of the enterprise-wide defense system, the development of rapid space capabilities for experimental technology, the appointment of an oversight executive agent for the Joint Requirements Oversight Council, and the development of a national space security executive committee (Whitney, Thompson, and Park 2019). The oversight committee was the first step that later led to the development of the U.S. Space Force.

The Threat of Space Weapons to Space Logistics

The security of space logistics is dependent on the vigor and efficiency of the supply chain. The key to this dependency is the satellite command and control architecture (C2). The C2 is the primary control to uplink communication and downlink data to ground stations through antennas, transmitters, and receivers (DIA 2019). In addition to the C2, there are many variables associated with the supply chain and the space environment that can transport logistics very difficult, leading to costly mistakes. As Andy et al. explain (35, 2006), "we have also come to learn that the path to optimizing operability and sustainability is by consideration of the entire supply chain." The strength of the supply chain directly relates to the success of space logistics and space operations in general.

According to the U.S. Space Policy, the space infrastructure is considered a vital national interest and must be protected (Weston 2009). The U.S. national interest in space has grown with the reliance and dependence on technological capabilities regarding communications, remote sensing, global positioning/navigation, broadband, and entertainment. As Georgescu et al. state, 90% of military communications are transmitted and routed through civilian satellite systems (Georgescu et al., 2019). This reliance by the U.S. military on civilian communication satellites and the U.S. infrastructure consisting of more satellites than any other state inevitably increases vulnerability. In 2009, the U.S.-owned 400 satellites worth over $123 billion out of the 900 active satellites in orbit (Weston 2009). However, an adversary could expose those vulnerabilities and render U.S. satellites or their associated space logistics useless or incapacitated by other means.

Space weapons could threaten space logistics in many ways—from an operational standpoint to administrative burdens. Logistical operations could be affected by the administrative burdens due to the internet-of-things that link humans to intelligent machines and robotics in space logistics (Augustyn 2020). The autonomous operations of satellite systems, as well as the logistics, expose valuable space assets to adversaries. To fully understand how a threat of space weapons could be possible, we must first define what space weapons are. Weidenheimer elaborates on the definition of space weapons that has also been accepted by the

United Nations. Weidenheimer states (16, 1998) "a space weapon is a device, located in space at the time of its attack, that is designed to damage or harmfully interfere with the normal operation of a target located anywhere (in space, in the air, on the ground, underground, on the sea, or under the sea); or a device, located anywhere, designed to damage or interfere with the normal operation of a target in space (where space means the volume 90 kilometers or more above the earth's surface)" (Weidenheimer 1998). While Weidenheimer's definition seems to encompass all space weapons, it fails to address or articulate an ever-growing and often concealed space weapon—cyberweapons. Weidenheimer implies cyberwarfare as a means of information warfare (IW). Cyberweapons have wreaked havoc among many industries to date and have already infiltrated the space domain as well. Knowing the space infrastructure depends on space logistics, vulnerabilities, and space weapons' threat should be clearly understood.

New space weapons include nuclear, kinetic energy, radio frequency (RF), high power microwave (HPM), laser, particle beam (PB), and information warfare (IW) (Weidenheimer 1998). In the United States, the Defense Intelligence Agency (DIA) categorizes these weapons. The DIA considers any weapon used to (9, 2019) "disrupt, damage, or destroy enemy equipment and facilities" a direct energy weapon and any weapon designed to "jam, spoof or control the electromagnetic spectrum" a weapon of electronic warfare (EW). However, for this analysis, more specific weapon terminology will be used for clarity and understanding. Each space weapon could be leveraged by adversaries knowing their effects on operations if a satellite or logistical system could be rendered inefficient. These weapons could be used as a means of kinetic attack, direct energy, or cyber-attack (information warfare) (Handberg 2019). What makes these weapons more difficult to detect in modern satellite technology is their inconspicuous use. For example, advanced satellites used various systems to operate. The various communications satellites used and relied on by societies worldwide include voice communications, television broadband internet, mobile services, and civilian and military data transfer services (DIA 2019). Unbeknownst to the U.S., an adversary's communication satellites could be orbiting with added ASAT (anti-satellite) technology (Johnson-Freese 2016). A commercial satellite could easily have concealed ASAT technology. Listed below are concise explanations of each space weapon with the anticipated effect on space assets or operations.

Nuclear Weapons

Even though the definition of a nuclear space weapon has not been clearly defined, what is clearly defined is fitting the category of weapons of mass destruction (Ferreira-Snyman 2015). A weapon of mass destruction would destroy space assets and be used as a significant deterrent for an adversary. Handberg explains how (299, 2019) "nuclear weapons provide a bigger bang for the buck which attacks support among weaker states for their development and possible use, increasing the probability of use when threatened." However, nuclear weapons were specifically mentioned in the Outer Space Treaty because of this reason—the bigger bang. In addition to the gravity of the explosion itself (that would be damaging but much different in the space environment), a primary concern is a radioactive fallout (Ferreira-Snyman 2015). The radioactive fallout could affect critical space-based assets damaging them or rendering them completely useless. Nuclear space weapons could come in various methods depending on the intended target. The majorly of these developed are projectile type weapons. Once they are detonated in the space atmosphere, they emit electromagnetic pulses. Emitting electromagnetic pulses could be used to deter an adversary elsewhere or distract them all together. One type of projectile is a nuclear-tipped intercontinental ballistic missile (ICBM) that could be used purposely as a space weapon because of its timing and accuracy. The U.S. alone can launch an ICBM within 30 minutes to any location on earth (Varni et al. 1996). Given this precision and timing, not only would space-based assets be threatened but also launch and landing platforms as well as ground operation centers.

Kinetic Weapons

There are two types of kinetic space weapons—A kinetic space energy weapon is known as a "hit and kill" weapon and generally does not carry explosives. In contrast, a kinetic weapon system could be designed with robotic ASAT mechanisms. The high speed at the impact on their designated target is designed to be enough for a kinetic space energy weapon's intended purpose. In 1983, the Strategic Defense Initiative (Star Wars) planned to use kinetic energy weapons in the form of missiles that could be used to destroy other missiles in the launch stages (M. S. S. Smith 2003). Even though the concept of Star Wars was developed in 1983, this method could very well be applied to modern-day kinetic energy weapons in space. As Vari explains, kinetic weapons could be used to reach small satellites in low earth orbit (LEO) containing storage containers within minutes (Varni et al. 1996). Kinetic space weapons could also be used to destroy or disable critical satellites intended for communications or navigation.

One example of this was on January 11th, 2007, when China intentionally collided with two objects in space to destroy an old weather satellite (Gubrud 2011). Even though the Chinese government denied this was any form of ASAT, it demonstrated Chinese space capabilities. They were able to deploy accurately and collided with another object for their intended purpose. An unintentional or intentional collision with space assets would hinder not only objectives but also introduce more problems. One example could have come from the HTV2 flight. The HTV2 was deployed in 2011 to deliver necessary spare parts in orbit to another shuttle using a Japanese robotic arm (Johnson 2011). If an adversary were to destroy the robotic arm using a kinetic weapon, critical parts would have never reached their destination. Whitney et al. explain how both China and Russia have prioritized the development of kinetic space weapons to counter U.S. Space Dominance (Whitney, Thompson, and Park 2019).

Radio Frequency Weapons

Radiofrequency weapons can be used primarily to disrupt communication and navigation systems. Radiofrequency weapons are a means of electronic warfare that encompass jamming and spoofing. Jamming can be accomplished by either downlink jamming where the damage is centralized to ground operators or uplink jamming where the satellite systems are affected.

Weidenheimer provides an example of uplink and downlink jamming. One is terminal guidance jamming, where a ground transmitter becomes inoperable, and another is terminal guidance jamming from a space-based system where communications cease completely (Weidenheimer 1998). Terminal guidance jamming could affect satellite systems in various ways and is not a new technology. As Howard explains, the Chinese government had developed jamming satellite technology in 2001. The Rumsfeld Commission report revealed that Iran and North Korea had also achieved similar advancements in technology (Howard 2010). Such advancements in radio frequency weapon technology could be devastating to space assets or operations.

A significant advancement in radio frequency weapons is the use of spoofing techniques. Spoofing can be used to compromise the entire electromagnetic spectrum by simulating fake signals or spreading erroneous information. Developing space logistics continue introducing more advanced technology such as autonomous UAV, e-mobility vehicles, and intelligent containers (Augustyn 2020). Many of these systems rely heavily on artificial intelligence. As Augustyn explains (361, 2020), "innovation machines join the logistics workforce not only through self-driving vehicles and IoT but also Augmented Reality (AR) in the environmental area of machine-human (anthropo-technical system) interaction and collaboration in space logistics systems." While the AR provides a whole picture using only a snapshot or small portion the environment area of machine-human provides the "human reasoning" to the machine. The Internet of Things (IoT) combines each computing device to work seamlessly and effectively together. Erroneous data introduced by spoofing could be devastating to space logistics causing excessive re-work and costs and ultimately not meeting logistical obligations.

High Power Microwave Weapons

High power microwave space weapons are only an orbital threat because current technology limits their capability solely from space-based satellites. The Soviets first introduced high power microwave space weapons in the mid-1980s by testing them on ballistic missile systems (Weidenheimer 1998). Not only did the Soviets take advantage of this technology, but the Chinese government did as well. As Blazejewski explains, intending to develop a strong space program, the Chinese have conducted space-based testing jamming their satellites with high-power microwave technology (Blazejewski 2008). These weapons have continued to improve over the decades, becoming a more significant threat to satellite infrastructures to this day. According to the Defense Intelligence Agency, high power microwaves are considered a directed energy weapon that can be very difficult to detect where the attack came from (DIA 2019). High power microwave weapons can be used for jamming communication between satellite systems.

Leveraging electromagnetic radiation, these weapons do not require accurate pinpointing; instead, they are transmitted with an array of high-energy pulses between tens of megahertz to tens of gigahertz to broadener targets (Varni et al. 1996). Once the high-power microwaves hit their intended target, all electronics are either permanently or temporarily disabled. Like radiofrequency weapons, these weapons can easily disrupt space logistics or operations in general. Besides the benefit of not requiring pinpoint accuracy, high-power microwaves could also be a preferred weapon because they can operate in any weather atmospheric condition. Most electronics are vulnerable to damage (Varni et al. 1996). With modern technology relying on an abundance of electronics to operate, high energy weapons could be one of the greatest threats posed by an adversary.

Laser Weapons

Laser space weapons can be developed and designed from either ground operations or space-based platforms. According to Possel, laser weapons are the most technologically advanced and cost-effective weapon that could be used (Possel 1998). However, to be most cost-effective, the entire laser weapon must be space-based. The laser weapons would operate on either platform (land or space) using large mirrors to transmit the laser beam to its intended location. The laser weapons generally target sensors on satellite systems to either disrupt, degrade, or damage them (DIA 2019). The targeted sensors would most likely be the most vital to space-based assets. In space logistics, smart sensors are used and relied upon to make critical decisions based on timing and passion (Augustyn 2020). If these sensors are targeted, spare parts or supplies may not reach their intended destination.

The last shuttle flight of the STS-134 Endeavour is one example of how critical sensors are to space logistics. The last STS 134 Endeavour flight's impact was significant because it was one of the only STS with such a large payload capacity. The large payload capacity of STS 134 Endeavor's had previously been used to transport a 1,400-pound ammonia pump module back to earth from the ISS (Johnson 2011). This was a significant event in space logistics because, following STS 134 Endeavor's flight, the U.S. had to rely on the Soyuz (Soviet Space Program) for large transports. Knowing the U.S. only had one STS capable at the time of large transport capacity, its sensors could have easily become a laser weapon target from an adversary.

Theory & Concepts

While there is no universally accepted theory of Space Power, many concepts attempt to define and address space power. While Smith explains space power as (7, 2020) “the ability to use spacecraft to create military and political effects,” the scope of this description seems broad and missing critical elements about the space environment. For example, the word “spacecraft” could easily be replaced with the word “aircraft” and then define air power. However, a much more comprehensive doctrine of space power was introduced by Lupton in 1988. Lupton explains how four schools of thought must be considered for space power—the sanctuary school is the ability for a state to oversee states from orbit. The survivability school considers the space environment and its vulnerability. The control school argues space should be a controlled environment, and the school of high ground implies the purview of space provides an advantage over adversaries (M. V. Smith 2002). Given current space operations, Lupton’s four tenants could easily be applied to a space-faring state to determine their extent of space power. Below are a few key concepts of space power from various known authors on the topic to provide a better understanding. Each author varies in experience and profession. Some are from military occupations (USAF), others are experts in the field, or scholars. The differences, similarities, and perspectives could shed light on familiar themes and gaps in the theory itself.

U.S. Space Dominance Through the Lens of Space Power

Even though each Space Power definition is different, they each imply a sense of control and deterrence in support of national interests. While Varni et al., Smith and the USAF Doctrine imply conflict or war is a cornerstone of Space Power, Lupton and Oberg see it differently. A significant factor that may have contributed to this difference could have been the timing of these definitions and the global events affecting U.S. national interests at the time. In 1996 the U.S. was involved in Operation Desert Strike in Iraq, and on September 11, 2001, the U.S. experienced one of the worst combined terrorist attacks to date. However, regardless of the timeframe, these concepts were developed. They all had a clear understanding of our growing reliance on U.S. space infrastructures and the necessity to ensure their functionality, seamless operations, and security.

In 1997 General Estes explained (23, 1998), “To begin with, it must be made clear that space is becoming, or some would say, space has become the 4th medium in which the military operates in the protection of our national security interests.” Unfortunately, it would take nearly two decades for the U.S. to establish a Space Force for General Estes's intended purpose. Along with U.S. Air Force leadership, General Estes understood the gravity of not having a specific U.S. armed service for the space domain. After all, the U.S. has a long history of displaying air and sea

Table 1. Concepts of Space Power by Various Authors

Author	Definition of Space Power
Oberg, Jim	(9, 2010) "Space power is the combination of technology, demographics, economic, industrial, military, national will, and other factors to contribute to the coercive and persuasive ability of a country to politically influence the actions of other states and other kinds of players, or to otherwise achieve national goals through space activity."
Varni, Jamie et al.	(73, 1996) "Global space power involves the application of the full spectrum of force, physical and virtual, from space on demand to an adversary's means of pursuing the conflict."
Smith, M. V	(49, 2002) "Space power is not composed alone of the war-making component of space. It is the total space activity; civil, commercial, defense, and intelligence, potential as well as existing.
October 1999 USAF Doctrine Center Publication	(7, 2002) "Space power, like airpower, can place an adversary at a disadvantage. Space Power is a subset of aerospace power."
Lupton, D	(141, 2013) "space power is the ability of a nation to exploit the space environment in pursuit of national goals and purposes and includes the entire astronautical capabilities of the nation."
Swilley, S	(146, 2013) "space exploration, commercial space endeavors, and space enablers serve as the core space activities associated with space power. These three core space power activities serve three distinct national processes: innovation, prosperity, and security"

superiority to ensure freedom of navigation and ensure national objectives are met with an assumption that conflict may be inevitable. However, to establish Space Power, the medium of the space domain where conflict could occur must be clearly understood.

Unlike other air and sea domains, where conflict has already taken place, the space domain is relatively new to conflict. As previously discussed, space weapons are vastly different to ensure functionality and effectiveness in the space environment. The key to achieving U.S. space superiority through Space power could be investing in space situational awareness networks. Situational awareness networks encompass radar, optical, and intelligence for ground and space operations as a means of anticipating conflicts (Szymanski 2019). Space situational awareness networks could not only monitor an adversary's terrestrial activity but also in space leveraging on space technology. As Robinson explains, to successfully ensure the principle of force employment is met, Space Power must leverage the space medium as an advantage over adversaries while remaining flexible during operations (Robinson 1998).

The U.S. Space Command (USSPACECOM) seems to have accepted Lupton's understanding of space power by prioritizing certain aspects of its vision for 2020. As Steele explains, four central tenants of USSPACECOM's vision: the control of space, global engagement, full force integration, and global partnerships (Steele 2001). The aspect that pertains most to Lupton's doctrine is the first aspect of USSPACECOM's vision. USSPACECOM's control aspects include surveillance as well as protection that are both vital elements of space power. However, should "control" be prioritized over other tenants of USSPACECOM? As Klien suggests, presence, coercion, and force should be prioritized as a means of commanding space (Townsend 2019). One of the primary reasons for this suggestion is leveraging the limited space-faring states. In other words, by the U.S. having the most space assets, it not only "controls" the space domain but also "commands" the space domain by its operational behavior.

While USSPACECOM appears to have adopted some of Lupton's space power concepts, there are many others. One gap that is unclear to have been adopted is Oberg's definition of space power in leveraging technology to achieve national security objectives. A common gap throughout the U.S.-centric space power literature is cybersecurity. This could be partly due to national security objectives and the clandestine nature of cybersecurity strategies. On the other hand, the Russian government (29, 2019) "considers the information sphere to be strategically decisive and has taken steps to modernize its military's information attack and defense organizations and capabilities." Russia's prioritization in this area of cyberspace has been ongoing contemporary cyber-attacks on U.S. systems.

Cyber Security and U.S. Space Power

To fully understand how the threat of cyber-attacks could limit U.S. space power, we must begin with a clear understanding of U.S. cybersecurity. In 2015 Astronaut Peake made an honest mistake. Using Skype, Astronaut Peake misdialed a call to a wrong number on the earth and established a data transfer connection to an unknown source for several minutes (Hannan 2018). While this breach in cybersecurity proved to be a low-level threat, it also raised awareness of cybersecurity vulnerabilities. As Nye states (45, 2017), "as recently as 2007, malicious cyber activities did not register on the director of national intelligence list of major threats to national security. In 2015 they ranked first." The United States relies on cyber capabilities in various aspects of space and critical terrestrial infrastructures. A significant threat was explained in 2012 by Defense Secretary Leon Panetta. He described how Russia and China have hacked into our electrical grid and can take it down at any moment (Nye 2017). While the act of taking down the United States power grid might expose a vulnerability, it would also demonstrate a failure of U.S. deterrence and offensive capabilities.

The nature of American cyber dominance in many ways is different than other states worldwide. First, the United States government continues developing new technology to maintain strong offensive and defensive cyber capabilities. This continued development appears to some as (48, 2016) a “cyber arms race” with China. This perception of a “cyber arms race,” as Mazanec explains, drives the development of new technology in cyber warfare (Mazanec, n.d.). Unlike the Space Domain with the Outer Space Treaty as a means of mitigating an arms race in space, the cyber domain has no such treaty. Each world superpower's unspoken objective is to dominate another state's technology in the best methods of offensive and defensive cyber capabilities. In other words, China, Russia, and the United States continue striving for better cyber warfare technology in a perceived “arms race.” Coincidentally, China and Russia are also two of the space-faring states with the most space weapon capability. In 2007 alone, China successfully launched an ASAT missile exposing vulnerabilities to the U.S. satellite infrastructure (Weston 2009). Had a space-faring adversary infiltrated the Chinese cybersecurity systems, the ASAT missile launch could have been compromised and deemed unsuccessful.

A significant threat to U.S. cyber dominance that also affects U.S. space power is communication and transmissions in U.S. society. As Andres explains (96, 2017), “The United States is an open society, which means even adversaries are allowed to attempt to influence or compromise the integrity of U.S. policymaking institutions.” While the United States might aim to achieve cyber dominance through different aspects, its open society will still introduce a means of vulnerability. In addition to the cyberspace vulnerability of an open society, the United States also relies heavily on cyberspace as a means of critical space and terrestrial infrastructures for electricity, water, banking, communication, transportation, and command and control military systems (Nye 2017). However, as Weston explains, the U.S. does have space-based electronic countermeasure capabilities that can render adversary satellite communication and transmissions useless (Weston 2009). While the United States' open society may expose vulnerability, the U.S. electronic countermeasures may minimize or deter the threat.

Before establishing the U.S. Space Force, the Global Space Coordinating Authority identified several command-and-control issues in the space domain. As Brown explains through the C2 Air Mobility lessons learned, the fragmented coordination of on-orbit assets created more problems and compounded inefficiencies (Brown 2006). By introducing improvements in C2, all space assets eventually fell under one commander—the Joint Functional Component

Commander-Space and Global Strike. This may improve inefficiencies in C2 but also unintentionally introduce vulnerabilities to cyber-attacks focused on a single commander instead of fragmented management of the past.

Proposed Theory and Concept of Space Power

Considering the contemporary threat of space weapons from space-faring states, space operations and logistics in the space environment, the importance of cybersecurity, and the primary objective of protecting space assets through space dominance, I propose a new theory as follows. *Space power is the command and control of the space domain, leveraging sea and air power, ensuring national objectives are met while continually adapting and improving technological advancements. Space power is also dependent on the strength of cybersecurity measures because of the inherent and ever-increasing risks associated with cyber-attacks.* Even though space power is superior to sea and air power in many ways because of its global access and presence, there are many contributing factors associated with the sea and air. Mahan's theory of sea power intended to ruin an adversary's economy by denying them opportunities to trade, commerce, and sea access (France 2000). This concept relates to space power because space is a controlled environment in several ways. For one, only limited states have the capability to reach LOE and deploy a satellite successfully. Another reason is due to the growing global reliance on space-based systems such as communication and navigation. Sea Power could also benefit space operations by providing launching or recovery platforms like SpaceX.

The application of Air Power to Space Power is more concise. Robinson defines Air Power as (51, 1998) "the use of or denial of the air medium for military value." This aspect could be simply applied to space power because to reach the space domain (at a minimum altitude of 62 miles), any object must pass through the atmosphere—the airpower domain. Leveraging U.S. airpower capabilities, the U.S. could use this as an advantage against adversaries while maintaining space dominance. C2 of this definition is a foundational concept that directly contributes to the effectiveness of Space Power. As Robinson suggests, command and control are where optimum situational awareness exists to direct space force actions (Robinson 1998). Whatever becomes an action or event in the space domain is determined at the command-and-control sector.

Recommendations

The threat of space weapons on the U.S. space logistics must be considered a top national security priority, not only because of societal reliance on critical systems but also because of military dependence. As Pfaltzgraff explains (147, 2013), "space power enables and enhances a state's ability to achieve national security." Analyzing the space power of our adversaries could be key to determine and anticipate threats to space-critical infrastructure. With several variations of space power concepts, the risk of space weapons on critical space logistical and operations, a common theme emerged—a space-faring nation's behavior in the space domain. As Lefebvre explained 2019), "the key to space power is acquiring the human and technical resources to increase one's freedom of action while aiming to reduce an opponent's." This definition suggests a continuous adaptation to technological changes to improve space operation and the associated logistical challenges. By the U.S. having the most space assets, it inevitably becomes the most vulnerable to adversaries and sets a standard of acceptable behavior.

A vital approach that has been introduced by the U.S. Air Force's space doctrine center that could be considered for other national and commercial space applications has been the Agile Combat Support (ACS). The ACS consists of essential areas of logistics to include civil engineering, maintenance, supply, transportation, logistics plans, and force protection (Hall 2003). The ACS incorporates essential areas of logistics to provide the necessary oversight to ensure efficiency. While the ACS was designed for anticipating war for the U.S. Air Force, it also ensures support systems within logistics to work more efficiently by less maintenance and more productivity. As Bruce DeBlois explained (80, 2009), "the decision to weaponize space does not lie within the military-seeking short-term military advantage in support of national security but at the higher level of national policy-seeking long-term national security, economic well-being, and world-wide legitimacy of U.S. constitutional values." Given the understanding that space weaponization may be unavoidable, lacking cybersecurity would compound any threat of conflict in the space domain.

In conclusion, due to the risk of vulnerability and civil and military reliance associated with the CSI, the United States must continually improve both its offensive and defensive cyber capabilities and never expose their shortcomings. Goines (1, 2017) states, "the Department of Defense reported in 2008 that it was probed hundreds of thousands of times each day, and the problem has only grown." By not maintaining a strong defensive posture could introduce an unnecessary vulnerability. Saxon explains how once and vulnerable individual is targeted, exploiting malware can be introduced, the individual is then attacked and covered up by obfuscating malware (Saxon 2016). This is just one example of what could happen with inadequate offensive or defensive cyber capabilities. One weakness in cyber defense could introduce "botnet" attacks. Botnet cyber-attacks are coordinated and strictly designed to gain command and control of computer servers (Saxon 2016). Any botnet cyber-attack on space logistics or operations would have devastating and costly effects. As Wang Xushing proclaimed in 1999, *"a 1-ounce integrated-circuit chip in a computer will perhaps be much more useful than a ton of uranium"* (Gauthier 1999). A nation once considered a space superpower might one day find themselves on their knees, rendered helpless and ineffective by a mere cyber-attack that they had not anticipated.

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Book Review: Reaching for the Moon: The Autobiography of NASA Mathematician Katherine Johnson

Title: *Reaching for the Moon: The Autobiography of NASA Mathematician Katherine Johnson*

Author: Roger D. Launius

Publisher: Simon and Schuster, New York (2019)

Language: English

Pages: 249

ISBN-10: 978-1-5344-4084-5

Price: USD 7.99

Reviewer: Dr. Kandis Y. Boyd Wyatt, PMP
Professor, Transportation and Logistics,
American Public University

The 2016 movie *Hidden Figures* defied box office estimates and made over $200 million both abroad and in the United States. While Hollywood would argue that where multi-million-dollar action films filled with violence, profanity, and strife raked in the most profit, this movie proved that audiences revealed at a refreshing film about the academic mathematical and scientific achievements of black women. The movie is loosely based on the book of the same name, which highlighted the story of a team of female African-American mathematicians who served a vital role in NASA during the early years of the space program. The main character, Katherine Johnson, was urged to publish her autobiography after the movie was published, and this book review highlights her autobiography: *Reaching for the Moon: The Autobiography of NASA Mathematician Katherine Johnson*.

> "You are no better than anyone else, but nobody else is better than you."
>
> ~ *Katherine Johnson*

Reaching for the Moon is an easy-to-read book targeted for youth, but her message is resounding for all ages. The book begins by highlighting Katherine's humble beginnings as the youngest of four. Her love of math came naturally to her and she counted everything—stairs, flatware, and steps to and from a destination. While the term 'gifted' was not common during her upbringing, it was clear that

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academics came easy to Katherine. She could read and write at age 4, and was promoted several grades. Katherine graduated high school at age 13 and entered college at age 14. She highlighted how her father, with a 6th grade education, was very intelligent and insisted on all four of his children attending college. With his foresight and wisdom, Katherine became a Mathematician with the highest GPA to date and entered West Virginia University to pursue graduate school. She then became a teacher at a segregated school in Virginia.

Katherine emphasized the phrase her father told her at a young age, "You are no better than anyone else, but nobody else is better than you," several times in the book while she highlighted the ageism, classism, colorism, racism, wage discrimination, and sexism, she encountered both in the workplace and in the world during her 36-year career at the Langley Research center. This is NASA's oldest field center in Hampton, Virginia.

Katherine was one of the first 'computers' at Langley, which was a term coined for African-American women who computed calculations for space experiments. Katherine's autobiography highlights how she was instrumental in the success of several space programs; putting a man in orbit, putting a man on the moon, the Space Shuttle Program, the 1981 launch of Space Shuttle Columbia, and the first Earth Resources Satellite. Through the seven chapters, it is fascinating to follow the evolution of the space program through Katherine's eyes.

Katherine showed that space is more than just science. She is a well-qualified expert to critically evaluate NASA's influence on society, policy, politics, and sociocultural evolution. She emphasized the importance of making NASA's work relevant to American citizens—calculators, radios, and TVs were all invented in the NASA space program, not to mention improving pacemakers and weather forecasts. She emphasized to remain curious and to ask questions: "But if you want to know the answer to something, you have to ask the question. Always remember that there's no such thing as a dub question except if it goes unasked. Girls and women are capable of doing everything that boys and men are capable of doing."

Katherine's story is not without heartache. She became a single mother of three girls at age 34 when her husband died of complications related to a brain tumor. She had relatives drafted to the Korean and Vietnam wars, and lost an adult daughter. She highlights that despite her intelligence and potential, there were limited opportunities for her. She often assumed extra jobs to make ends meet because her income was a fraction of her white, male counterparts. As she said in the book, "Bad things happen, then life goes on."

> [Tutoring], "speaks life into a young person's spirit and helps expand the vision of what's possible for his or her future, especially as it involves math and science."
>
> ~ *Katherine Johnson*

Through all of her triumphs and setbacks she emphasized that her greatest joy was tutoring and encouraging children. She emphasized that teaching was more than getting to the right answer, but rather, "helping students understand the background of what they were working on, how to figure out what the problem was, and then how to attack it. If you approach any problem properly, you'll get the answer."

In this easy-to-read book, she emphasizes that tutoring, "speaks life into a young person's spirit and helps expand the vision of what's possible for his or her future, especially as it involves math and science." **This book is a valuable resource for students, experts, and teachers of the space sciences and engineering. It will provide readers of all ages an invaluable understanding of the exciting human exploration of space at a time of significant societal and cultural evolution.**

Dr. Kandis Y. Boyd Wyatt, PMP

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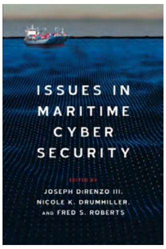
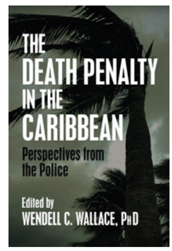


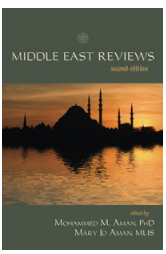
Issues in Maritime Cyber Security Edited by Nicole K. Drumhiller, Fred S. Roberts, Joseph DiRenzo III and Fred S. Roberts

While there is literature about the maritime transportation system, and about cyber security, to date there is very little literature on this converging area. This pioneering book is beneficial to a variety of audiences looking at risk analysis, national security, cyber threats, or maritime policy.

The Death Penalty in the Caribbean: Perspectives from the Police Edited by Wendell C. Wallace PhD

Two controversial topics, policing and the death penalty, are skillfully interwoven into one book in order to respond to this lacuna in the region. The book carries you through a disparate range of emotions, thoughts, frustrations, successes and views as espoused by police leaders throughout the Caribbean





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Edited by Mohammed M. Aman PhD and Mary Jo Aman MLIS

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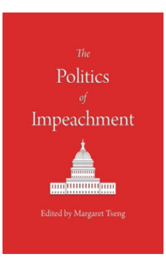
Unworkable Conservatism looks at what passes these days for "conservative" principles—small government, low taxes, minimal regulation—and demonstrates that they are not feasible under modern conditions.



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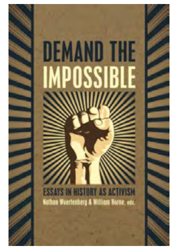
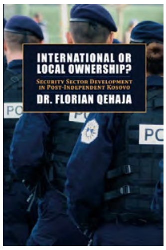
Edited by Margaret Tseng

This edited volume addresses the increased political nature of impeachment. It is meant to be a wide overview of impeachment on the federal and state level, including: the politics of bringing impeachment articles forward, the politicized impeachment proceedings, the political nature of how one conducts oneself during the proceedings and the political fallout afterwards.

Demand the Impossible: Essays in History as Activism
Edited by Nathan Wuertenberg and William Horne



Demand the Impossible asks scholars what they can do to help solve present-day crises. The twelve essays in this volume draw inspiration from present-day activists. They examine the role of history in shaping ongoing debates over monuments, racism, clean energy, health care, poverty, and the Democratic Party.



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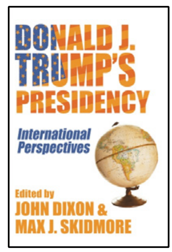
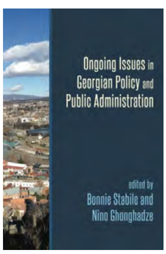


President Donald J. Trump's foreign policy rhetoric and actions become more understandable by reference to his personality traits, his worldview, and his view of the world. As such, his foreign policy emphasis was on American isolationism and economic nationalism.



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