AN ASSESSMENT OF THE VIABILITY OF DIRIGIBLES IN SUPPORT OF UNITED STATES MISSILE DEFENSE AND NATIONAL COMMUNICATIONS

A Capstone Research Project Submitted to the Missile Defense Advocacy Alliance and University of Southern California in Partial Fulfillment of the Requirements of the USC SHIELD Executive Program in Global Space and Deterrence

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ABSTRACT

Title: An Assessment of the viability of Dirigibles in support of United States Missile Defense and National Communications

Institution: University of Southern California (USC) in conjunction with the Missile Defense Advocacy Alliance (MDAA)

Program: USC SHIELD Executive Program in Global Space and Deterrence

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The United States lacks affordable and persistent surveillance capabilities to detect and track advanced adversary missile threats and rapidly augment national disaster relief efforts. Previously deployed elevated sensing capabilities experienced perceived challenges, undermining confidence among senior leaders within the Department of Defense and Congress. In March of 2022, Israel successfully deployed dirigibles as part of their multi-layered defense system to increase effectiveness against advanced and evolving adversary threats. This recent success, coupled with advancements in dirigible-related technologies, opens the aperture to revisit the value dirigibles may hold in support of U.S. missions.

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INTRODUCTION

Background of the Problem

"Adversaries are developing, fielding, and integrating more advanced air and missile capabilities into their strategies in order to favorably shape the course of a potential crisis or conflict. These air and missile capabilities pose an expanding and accelerating risk to the U.S. homeland, U.S. forces abroad, and our Allies and partners" (Department of Defense [DOD], 2022, p. 68). These advanced capabilities challenge even the most sophisticated missile defense systems and require a complex enterprise of sensing and shooting capabilities to defend the United States homeland and U.S. forces abroad. To address these challenges, the 2022 Missile Defense Review calls for "…persistent, resilient, and cost-effective joint IAMD sensor capabilities to detect, characterize, track, and engage current and emerging advanced air and missile threats regionally, and to improve early warning, identification, tracking, discrimination, and attribution for missile threats to the homeland" (DOD, 2022, p. 74).

The Commander of the United States Northern Command (USNORTHCOM) and North American Aerospace Defense Command (NORAD), General Glen VanHerck, laid out the problem clearly in his testimony before the House Armed Services Committee in March of 2022. "Russia has fielded a new family of advanced air-, sea-, and ground-based cruise missiles to threaten critical civilian and military infrastructure." He elaborated on the threat in his written testimony saying,

> the AS-23a air-launched cruise missile, for instance, features an extended range that enables Russian bombers flying well outside NORAD radar coverage — and in some cases from inside Russian airspace — to threaten targets throughout North America. This

> capability challenges my ability to detect an attack and mount an effective defense. In the maritime domain, Russia has fielded the first two of their nine planned Severodvinsk-class guided missile submarines, which are designed to deploy undetected within cruise missile range of our coastlines to threaten critical infrastructure during an escalating crisis. This challenge will be compounded in the next few years as the Russian Navy adds the Tsirkon hypersonic cruise missile to the Severodvinsk's arsenal (Eckstein, 2022, p. 1).

Gen. VanHerck called on the need for "…improved domain awareness to increase warning time and provide leaders at all levels with as many options as possible to deter or defend against an attack. Global all-domain awareness will generate a significant deterrent effect by making it clear that we can see potential aggressors wherever they are, which inherently casts doubt on their ability to achieve their objectives" (Eckstein, 2022, p. 2).

The threat picture does not get any better in the Pacific as China's rapid development of military capabilities is on a path to outpace U.S. capabilities to defend against them. According to Admiral (ADM) Aquilino, Commander of United States Indo-Pacific Command (USINDOPACOM), "in addition to an extensive arsenal of advanced ballistic missiles, the PLA Rocket Force is pursuing land-attack, supersonic cruise missiles and other advanced weapons. The PLA's new generation of mobile missiles uses multiple independently targeted reentry vehicles (MIRVs) and highly capable hypersonic glide vehicles (HGV) designed to evade U.S. missile defenses (Aquilino, 2022, p. 5).

In the 1940s and 1950s, the United States used balloons to surveil Soviet activity. As the demand for Intelligence, Surveillance, and Reconnaissance (ISR) increased and technologies advanced, the United States transitioned to highflying aircraft like the U-2 and ultimately to satellites flying in various orbital regimes. Although, technology and elevation are not the only attributes that increased. The cost of conducting ISR missions also increased with the U-2, as an example, averaging $38k per flying hour (Congressional Budget Office [CBO], 2021). Figure 1 from *Persistent Surveillance* (Gosnold, 2016) highlights the relationship between persistence and revisit rates for satellites at various altitudes (e.g., orbits like low-earth [LEO], medium-earth [MEO], geostationary [GEO], and highly elliptical [HEO]) and captures various ISR-related applications.

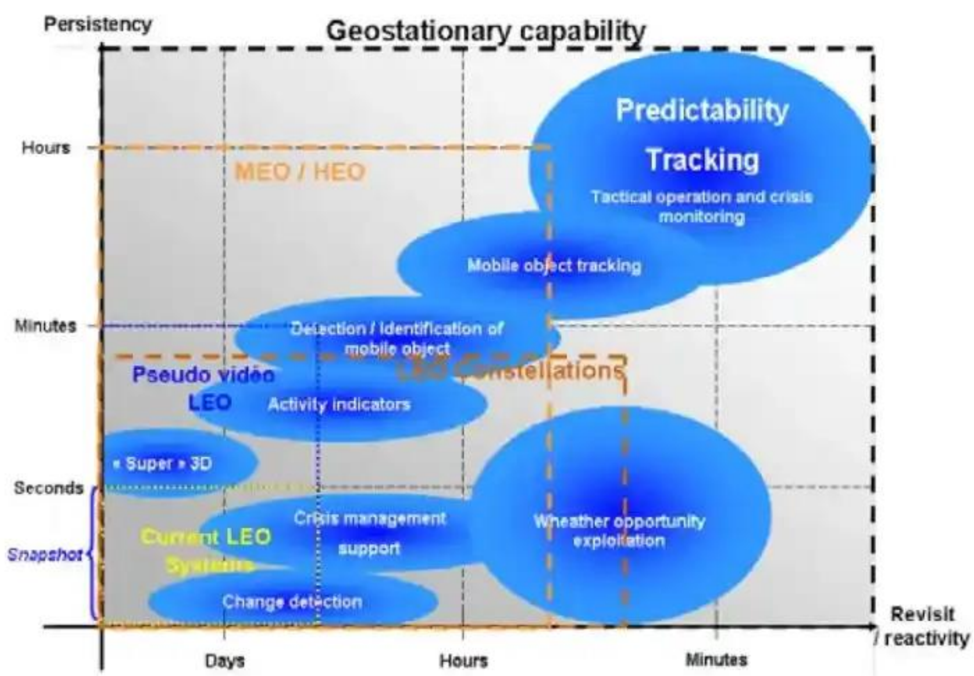

Figure 1. Persistency vs. Revisit

The Space Development Agency (SDA) seeks to leverage the expanding market in LEO satellite capabilities to field next generation space tracking and communications satellites. According to SDA Director, Derek Tournear, the cost of one of these satellite vehicles (SV) averages out to $14.1 million (Machi, 2021). Persistent 24/7 sensor coverage at LEO, even for regional areas of interest, would require approximately 150 satellites orbiting in multiple inclinations at a cost of $2.1 billion for the SVs, each with a design life of approximately three years. That price tag does not account for costs associated with launching the SVs into LEO or the cost of ground operations, which would add an estimated $2.5 billion. Dirigibles may offer a more affordable platform to conduct ISR-related missions in support of both regional and homeland missile defense capabilities.

Problem Statement

The United States lacks affordable and persistent surveillance capabilities to detect and track advanced adversary missile threats and rapidly augment national disaster relief efforts. Previously deployed elevated sensing capabilities experienced perceived challenges undermining confidence among senior leaders within the Department of Defense and Congress. In March of 2023, Israel successfully deployed dirigibles as part of their multi-layered defense system to increase effectiveness against advanced and evolving adversary threats (i.e., missile threats).

At the time of this writing, headlines around the globe reported a Chinese “spy” balloon transiting over the United States mainland to include sensitive military sites. Bryan Clark, director of the Hudson Institute’s Center for Defense Concepts and Technology, said the events of the last week highlight the disruption stratospheric balloons can cause to an adversary and predicted that it could trigger a larger discussion about the utility that balloons may have for military operations and whether the U.S. should invest more in the technology (Albon, 2023). This specific Chinese balloon is believed to have propulsion and steering capability, making it like a dirigible in function.

The Israeli’s successful deployment of dirigibles, coupled with recent events like the Chinese high-altitude balloon transiting over the U.S. mainland, open the aperture to revisit the value dirigibles may hold in support of U.S. missions.

Thesis

Dirigibles (aerostats, airships, blimps) provide an affordable and capable option to augment and enhance U.S. missile defense and national communications architectures.

Research Questions

Two primary and two secondary research questions bound the research and are listed below:

- Primary: What is the potential role of dirigibles in United States missile defense both domestically and abroad (i.e., in defense of Guam) to include employment considerations (e.g., weather, geography, safety, mission effectiveness, and cost of operations/sustainment)?
- Primary: What is the role of dirigibles in national communications supporting disaster relief?
- Secondary: What technology options, such as sensor/communications payloads, airship/aerostat design, and supporting ground infrastructure, are available?
- Secondary: Given previous challenges, what safety and policy considerations are necessary to increase confidence in deploying this capability?

Definition of Terms[1]

Airship: the generic term for any dirigible or powered lighter-than-air vehicle, including blimps and zeppelins. Until the 1930s, the word "airship" referred to craft that were both lighter-than-air (LTA) and heavier-than-air (HTA), but now its use generally implies only LTA craft.

Aerostat: a tethered, unmanned airship.

Balloon: an un-powered LTA vehicle. Balloons can derive their buoyancy from the confinement of hot air, hydrogen, helium, ammonia, or other gas. Balloons can be free (un-tethered and free to drift with the wind) or tethered to the ground (sometimes-called captive or kite balloons).

Ballonet: an air-filled bladder inside the envelope of a pressure airship used to regulate the gas

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[1] The definitions, terms, and acronyms identified in this section are not complete and will be expanded as the paper evolves. The definitions are from the Lighter-Than-Air-Society website. Glossary of Airship Terms | The Lighter-Than-Air Society (blimpinfo.com)

pressure and maintain the envelope shape.

Blimp: a synonym for a pressure airship.

Dirigible: a word that describes any steerable or directable airship, including blimps (pressure airships), semi-rigid airships and zeppelins (rigid airships). The term is often used to describe only rigid airships; however, it applies to both. Dirigible is synonym for airship.

Envelope: the gas bag of a pressure or semi-rigid airship. Unlike a rigid airship gas cell, an envelope forms an external barrier to the elements, and when pressurized, serves an integral role in maintaining the airship's shape. It also has fittings for attaching the fins, control car, and other structural components. The envelope is usually made of a high-strength fabric combined with a sufficiently impermeable barrier coating or film to minimize loss of the buoyant gas it contains. Formerly made of rubberized cotton, current envelopes are constructed mainly of synthetic materials with their seams cemented, glued, or sealed.

Heavier Than Air (HTA): the branch of aeronautics, which includes flight vehicles that require air passing over an airfoil (e.g., a wing) to generate aerodynamic lift. These vehicles include airplanes, gliders, helicopters, and kites, either piloted or un-piloted.

Hybrid Airship: an airship with features found in more than one type of dirigible construction, for example, an airship having both pressure airship and semi-rigid airship characteristics. The term also applies to "hybrid" vehicles that rely on a combination of LTA (a gas cell or envelope) and HTA (stationary or rotary wings) principles to achieve flight.

Lighter Than Air (LTA): the branch of aeronautics (sometimes further confined to aerostatics), which includes flight vehicles that depend upon buoyancy from the displacement of air for their lift. These vehicles include balloons and dirigibles of all types, piloted or un-piloted. LTA does not include kites (except when referring to tethered "kite" balloons or aerostats).

Non-Rigid Airship: another term for a pressure airship.

Pressure Airship: a term used to describe an airship whose shape is dependent on the gas inside its envelope having a higher pressure than is found in the atmosphere outside. With no lifting gas in its envelope, a pressure airship is merely an empty bag on the ground with its only rigid structures (control car, fins, and hardware fittings). It is also called a "non-rigid airship."

Rigid Airship: an airship whose shape is maintained by an internal framework and whose lifting gas is contained by a separate gas cell or cells within that structure. The external fabric covering on a rigid airship is not completely gas-tight, but it does protect the more delicate gas cells and other interior components from wind and weather, and it provides a degree of streamlining. Rigid airships include zeppelins and similar aircraft built by other companies. Even the metal skeleton of a "rigid" airship must flex somewhat under loads and stress, or it would break.

Semi-Rigid Airship: an airship with a rigid keel but whose envelope is maintained by gas pressure. The keel at the bottom of the envelope is used as a support for the control car, engines, ballast, and sometimes tail surfaces.

Zeppelin: The often-generic term for any rigid airship, derived from the name of its inventor and promoter, Ferdinand Graf von Zeppelin (1838-1917). The first aircraft of this type flew in 1900 near Friedrichshafen, Germany. After many trials and tribulations, Zeppelin was able to form a company, Luftschiffbau-Zeppelin, to manufacture this type of airship. The word is properly capitalized when referring to airships produced by the Zeppelin Company, but it may be shown in lowercase to describe generically any similar, cigar-shaped rigid airship.

Acronyms

AESA – Active Electronically Scanned Array

CAM – Criterion Alternative Matrix

DOD – Department of Defense

FEMA – Federal Emergency Management Agency

GEO – Geostationary (equatorial) Orbit

HEO – Highly Elliptical Orbit

HTA – Heavier Than Air

IAMD – Integrated Air and Missile Defense

ISIS – Integrated Sensor Is Structure

ISR – Intelligence, Surveillance, and Reconnaissance

JLENS – Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System

LEO – Low Earth Orbit

LTA – Lighter Than Air

MDA – Missile Defense Agency

MEO – Medium Earth Orbit

PLA – People's Liberation Army (China)

SDA – Space Development Agency

SMDC – U.S. Army Space and Missile Defense Command

SV – Satellite Vehicle

SWOT – Strengths, Weaknesses, Opportunities, and Threats

TARS – Tethered Aerostat Radar System

CHAPTER II

REVIEW OF RELEVANT LITERATURE AND RESEARCH

Introduction

To adequately assess the viability of dirigibles in support of United States missile defense and national communications, it is incumbent on the researcher to review as much relevant literature as possible. Conducting such an investigative endeavor allows the researcher to gain a deeper understanding of the subject matter. In this chapter, literature relevant to the core theme of the study is presented in a decomposed manner starting with the history of dirigibles and eventually leading to a review of technological advancements and opportunities for dirigibles in support of United States missile defense and national communications. Figure 2 highlights that decomposition.

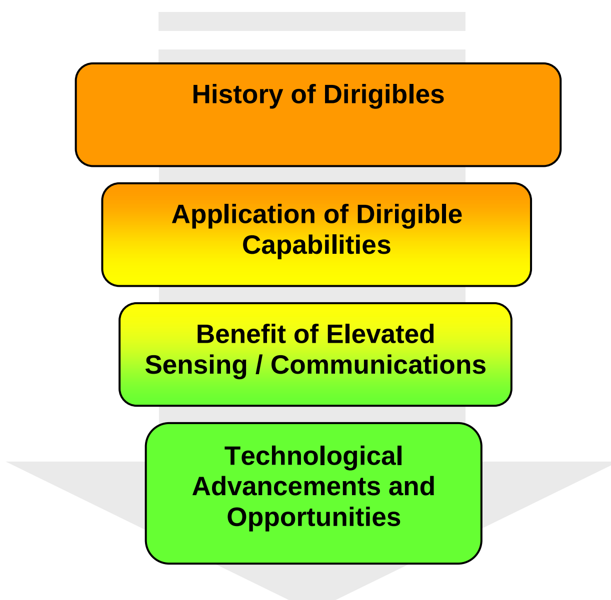

Figure 2. Focusing the Research

History of Dirigibles

This portion of the literature review captures a brief history of dirigibles. In the late 1700s, brothers Joseph and Jacques Montgolfier, paper mill owners in France, held a flame near the bottom opening of a paper bag, which expanded with hot air and floated upward (Bellis, 2019). Energized by their experiment, the Montgolfier brothers demonstrated one of the 1st known flights of an unmanned paper-lined silk balloon on June 4, 1783, in Annonay, France, with the balloon climbing to an altitude of 6,562 feet (Bellis, 2019). Only seven months later, a Montgolfier-designed hot air balloon carried seven passengers to a height of 3,000 feet over the city of Lyons (Bellis, 2019).

While the Montgolfier brothers focused on heating air to create buoyancy, a contemporary of theirs, Jacques Charles, and Nicolas Robert made the first untethered ascension with a gas hydrogen balloon on December 1, 1783 (Bellis, 2019). Jacques Charles combined his expertise in making hydrogen with Nicolas Robert's new method of coating silk with rubber, leading to the development of the Charlière hydrogen balloon (Bellis, 2019). The Charlière hydrogen balloon exceeded the earlier Montgolfier hot air balloon in time in the air and distance traveled, becoming the predominant form of the hydrogen balloon for the next 200 years (Bellis, 2019). The hydrogen balloon also overcame limitations of the hot air balloon, primarily uncontrolled descent when the hot air cools and sparks setting the balloon ablaze, which stemmed from using fire as the mechanism to keep the air hot (Bellis, 2019).

While Jacques Charles and Nicolas Robert advanced the state of the art with hydrogen-based balloons, a key limiting factor with their applicability was that they were not truly navigable. Attempts to improve maneuverability included elongating the balloon's shape and employing a powered propeller (see Figure 3) to move it through the air, and thus the airship (also known as a dirigible) was born (Bellis, 2019). French engineer Henri Giffard is credited with construction of the first navigable, full-sized airship. In 1852, Giffard attached a small, steam-powered engine to a propeller moving through the air for seventeen miles at a top speed of five miles per hour (Bellis, 2019).

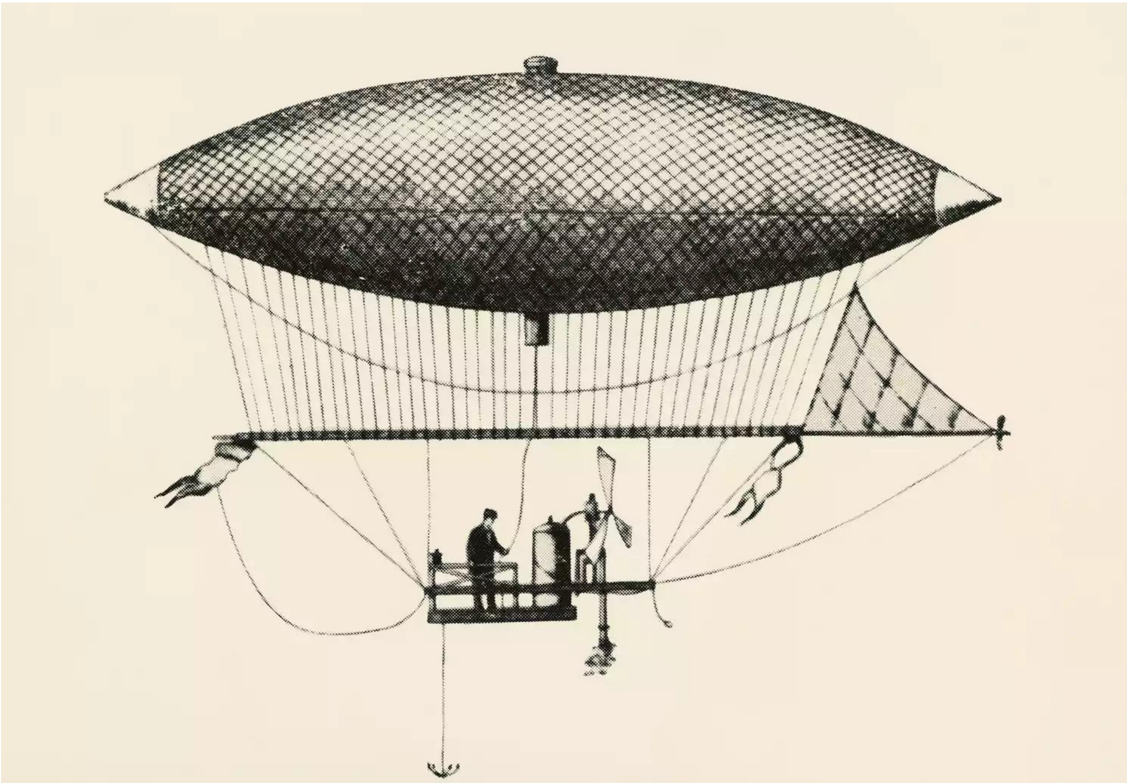

Figure 3. Henri Giffard and the Dirigible (De Agostini Picture Library / Getty Images)

“In 1898, the Brazilian Alberto Santos-Dumont was the first to construct and fly a gasoline-powered airship” (Bellis, 2019, p. 3). The innovation of the gas-powered airship laid the groundwork for airship development for the subsequent fifty years. In 1908, the United States Army Signal Corps acquired its first powered aircraft in the form of SC-1, a dirigible powered by a 20-horsepower Curtiss engine (Bellis, 2019). The United States Navy began acquiring non-rigid airships toward the end of the 1920s and during the 1930s and hired the Goodyear Tire and Rubber Company to build its new airships. After the attack on Pearl Harbor in 1941, the Navy asked the United States Congress for authorization to purchase an increased number of airships. "By June 1942, Congress had authorized the construction of 200 airships" (Rumerman, 2023, p. 2). The next twenty years would see changes in the size and types of airships (i.e., non-rigid, rigid, and blimps). In the mid-1990s, the Germany-based Zeppelin Luftschifftechnik built a prototype zeppelin, called the Zeppelin NT. In 2014, the Goodyear corporation decided to replace its aging fleet of blimps with the new Zeppelin NT semi-rigid airship (Moon, 2014).

Application of Dirigible Capability

There is a plethora of literature highlighting the wide-ranging application of dirigibles throughout history. Early application was primarily focused on passenger travel and surveillance. The elevation and dwell times create inherent advantages to those looking to employ this type of capability as evidenced by the United States Navy's use of airships during World War II (WWII). "The Navy used them for minesweeping, search and rescue, photographic reconnaissance, scouting, escorting convoys, and antisubmarine patrols. Airships accompanied many oceangoing ships, both military and civilian" (Rumerman, 2023, p. 1). It is interesting to note that of the 89,000 ships escorted by airships during WWII, only one was lost to enemy action (Rumerman, 2023). A Navy airship identified as K-74 was shot down by a German U-boat. During the battle, however, the K-74 damaged the German submarine significantly enough that it could not submerge and was subsequently sunk by British bombers in the North Sea while enroute to Germany for repairs (Rumerman, 2023).

In the early 2000s, the DOD flew large, tethered aerostats equipped with intelligence payloads over Iraq and Afghanistan to increase battlefield situational awareness. The U.S. Army also spent nearly $2.7 billion to develop the Joint Land Attack Cruise Missile Defense Elevated Netted Sensor System, or JLENS, which featured 70,000-pound tethered balloons used to warn against a missile attack on the United States homeland (Albon, 2023). "The JLENS program was canceled in 2017 after one of the aerostats broke free and floated from Maryland into Pennsylvania, causing power outages before it was downed in a field" (Albon, 2023, p. 2).

Recent innovations in Hybrid Airship design like Lockheed Martin's P-791 demonstrator, LTA Research's Pathfinder-1, and Hybrid Air Vehicles Limited's Airlander-10, open the aperture for additional applications. These airships can operate in austere locations and in many cases do not require airfield support. Applications for these types of airships range from humanitarian support, logistics and special cargo delivery (especially in austere locations like the Arctic), communications relay, remote sensing, and the potential to deliver kinetic effects in support of homeland missile defense.

The United States is not the only country to leverage dirigibles and/or balloons for military purposes. According to Judy Rumerman's article, "Airships and Balloons in the World War II Period:"

> From November 3, 1944 to April 1945, the Japanese launched 9,000 balloons carrying small 33-pound incendiary bombs over the Pacific Ocean in the hope that the winds would carry them to the United States. These were called the Fu-Go Weapon, and supposedly were a revenge bomb for the 1942 Doolittle raids on Tokyo. It is estimated that nearly 1,000 bomb-bearing balloons reached North America, landing in 16 U.S. States, Alaska, Canada, and Mexico. The last one found in North America was in Alaska

> in 1955—its payload still lethal. It was picked up by a 74th Air Rescue Squadron H-5 helicopter crew from Ladd Air Force Base near Fairbanks, Alaska. (Rumerman, 2023, p. 1)

The most recent application of dirigible-related capability grabbing attention in headlines around the world is China's high-altitude balloon, which crossed the Aleutian Islands, passed over Western Canada, and entered U.S. airspace over Idaho. On February 2, 2023, officials within United States DOD confirmed that the military was tracking the balloon, as it flew over the continental U.S. at an altitude of approximately 60,000 feet, including over Malmstrom Air Force Base in Montana, which houses the 341st Missile Wing, responsible for operating nuclear intercontinental ballistic missiles (Boyd, 2023).

Benefit of Elevated Sensing and Communications

As ballistic, hypersonic, and cruise missiles continue to evolve in both complexity and capacity, the age-old dichotomy in missile defense generally centers around a golden thread—detection and discrimination. Countries in competition continue to advance threats to avoid detection, either through reducing radar cross section or maneuvering in a way where the terrain masks their approach. Both strategies are an effort to minimize the time allocated for systems and missile defenders to successfully engage the target. Experts spend most of their time identifying terrain that optimizes the employment of their system in defense of a critical asset, also known as point defense. That optimization generally involves identifying a place that provides coverage of the asset you are trying to protect but extends the detection range to the maximum extent possible. Detection ranges quite simply equate to time, and time is fundamental to successfully engaging/defeating missile threats.

The United States has a very robust portfolio of systems tailored for defense against complex threats, both air breathing and ballistic. These systems are notoriously expensive, possess varying degrees of mobility, and have one singular trait in common—they are terrestrial-based and therefore have inherent limitations due to the curvature of Earth and terrain features. As ballistic, hypersonic, and cruise missiles continue to evolve, it is imperative the United States diversify its portfolio of sensors. "Countering these developments will require a sensor architecture rebalanced across multiple domains to provide resilient sensing options for both defensive systems and attack operations" (Karako & Rumbaugh, 2021, p. 2).

A compelling way to diversify the sensor architecture, while countering the inherent limitations of terrestrial-based sensors, is to elevate a robust sensor and communications architecture. There is certainly a balance when discussing elevation of sensors. Generally, space-based sensors are great for detection and early warning but lack the fidelity in energy returns to facilitate an intercept. It is a process of give-and-take when optimizing radar frequency or other energy toward a desired purpose. The higher the sensor, the less fidelity due to simple physics and distance. For this evaluation, research will centralize on dirigibles, both tethered and untethered, to extend detection ranges against cruise missiles and hypersonic/hyper glide vehicles, both of which stress the limitations of terrestrial-based sensors. There is a comprehensive sensing network of systems in both the terrestrial and space domain. However, to balance the architecture across all domains it is imperative to explore the domain in between terrestrial and space.

"Elevated sensors on a variety of platforms can fill critical capability gaps, enhance the U.S. sensor architecture, and make it more resilient to attack" (Karako & Rumbaugh, 2021, p. 2). There are several benefits in elevating sensing and communication packages. First, elevation increases the maximum distance of detection by eliminating limitations associated with the curvature of the earth and terrain features, both synthetic and natural. Directed energy must have a clear path, free of obstruction, to maximize its potential. Figure 4 shows detection ranges by elevation. The figure assumes the system used for detection remains the same with elevation as the only variance.

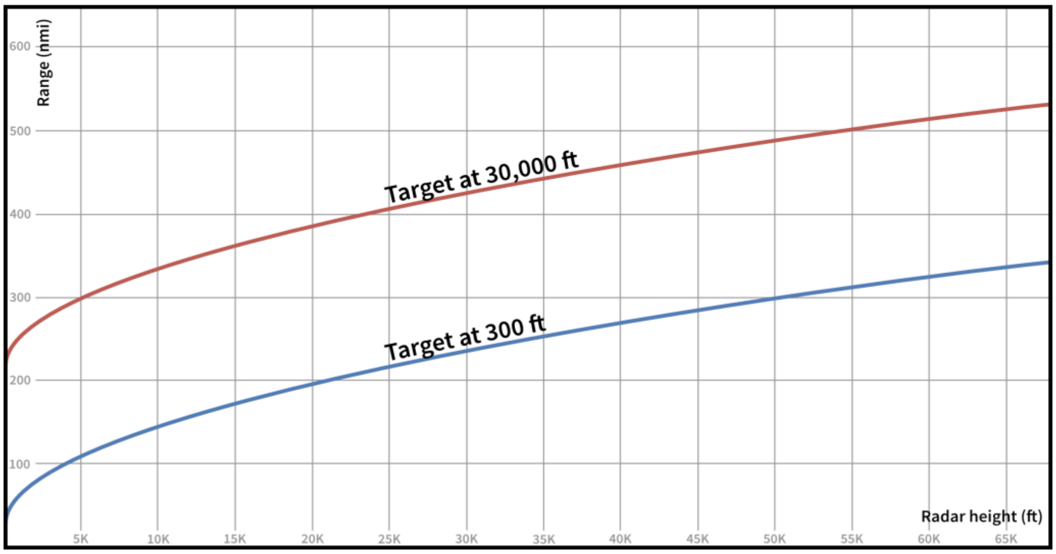

Figure 4. Relationship between Radar Height and Range

"If a target is flying at a 300-foot altitude, for instance, a sensor 10 feet off the ground would have a range of about 25 nautical miles. A sensor in a tethered aerostat 10,000 feet off the ground would have a range of 144 nautical miles, and a high-altitude aircraft operating at 60,000 feet would have a range of about 323 nautical miles" (Karako & Rumbaugh, 2021, p. 2).

Technological Advancements and Opportunities

Over the past few years, the commercial space industry has captured the imagination of many people, changing the idea of what is possible in terms of technology. The world is benefiting from competition between Elon Musk and Jeff Bezos, as Space X and Amazon proliferate Low Earth Orbit with thousands of communications satellites with the potential to enable the Internet of Things (IoT). Quietly, another revolution in technology is taking place.

As Lieutenant Commander Ryan P. Hilger writes in his Proceedings article entitled, "Airships? Yes, Really! Hybrid airships are not the blimps of years ago. They have the potential to transform military logistics, command and control, and surveillance and reconnaissance:"

> A new generation of hybrid airships are shaped like aerodynamic lifting bodies and have quietly been making tremendous technological strides that demand renewed attention. Advanced fabrics and ballasting systems, significant payload capacities, and more have brought the airship industry to a point where it will have a transformative impact in both the commercial and national security spaces. Combined with lightweight sensors and other systems, hybrid airships have the potential to be vital assets in executing both Navy distributed maritime operations and Marine Corps expeditionary advanced base operations. (Hilger, 2019, p. 1)

According to Hilger, the Defense Advanced Research Projects Agency in the past two decades has developed sensors that turn the entire skin of the airship into an active electronically scanned array (AESA) radar. At 60,000 feet, an AESA radar has a line-of-sight range of more than 300 miles making the radar extremely sensitive to small objects at very long ranges, which is a perfect application for missile point defense and communications applications. Hybrid airships have sufficient propulsive power to remain stationary within the jet stream, providing a stable antenna for long-range sensing. The long line-of-sight from the high-altitude platform can provide more secure point-to-point communications potentially augmenting national communications in support of disaster relief efforts and Arctic operations (Hilger, 2019).

Israel's newly deployed Sky Dew tethered blimp system provides them with a fixed airborne system that will hover at high altitudes and detect incoming long-range potential threats, like missiles. It compliments their already impressive, tried, and tested missile defense system that helped successfully defend the country during the 11-day Gaza war (McFadden, 2021).

Re-statement of the Problem

The United States lacks affordable persistent surveillance capabilities to detect and track advanced adversary missile threats and rapidly augment national disaster relief efforts. Previously deployed elevated sensing capabilities experienced perceived challenges undermining confidence amongst senior leaders within the Department of Defense and Congress. In March of this 2023, Israel successfully deployed dirigibles as part of their multi-layered defense system to increase effectiveness against advanced and evolving adversary threats. This recent success opens the aperture to revisit the value dirigibles may hold in support of U.S. missions.

CHAPTER III

RESEARCH METHDOLOGY

Research Approach

The research methodology used to support this study is the qualitative method. "Qualitative research is the collection, analysis, and interpretation of comprehensive narrative and visual data in order to gain insights into a particular phenomenon of interest" (Airasian, Gay, and Mills, 2006, p. 399). The specific approach used will be the case study. The case study is a "determination of characteristics of a particular entity, phenomenon, or person" (Airasian et al., 2006, p. 401). In this case, the phenomenon in question pertains to the rapidly evolving missile threats to the United States and advancement of dirigible-related technologies and capabilities.

Research Process

The research for this study employs the following six-step process:

1. Identify a research problem.
2. Review the literature.
3. Select participants/sample.
4. Collect data.
5. Analyze and interpret data.
6. Report and evaluate research.

To provide a reasonable level of rigor to the qualitative process, Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis, Criterion Alternative Matrix (CAM) analytics, and good practice criteria, identified by William Stiles (1999) in his article on evaluating qualitative research, will be used. The good practice criteria are described in the form of questions for the researcher. Those questions are as follows:

1. Are the study's questions or topics are clearly stated?
2. Is the selection of participants or materials clearly justified?
3. Are the methods for gathering and analyzing observations clearly described?
4. How in depth is the researcher's engagement with the material?
5. What was the researcher's iteration between interpretation and observation?
6. Were there systematic procedures for lining interpretations with observations?

Sources of Data

Key sources of data used to facilitate this study stem primarily from periodical reviews and online research. Interviews with key personnel in the United States Department of Defense and the commercial sector will be used to provide expertise and contextual insight. The personnel selected for interviews are comprised of senior-level stakeholders within the Department of Defense and subject matter experts from commercial companies advancing dirigible-related technologies. Cambridge Pixels Ltd's SPx Radar Coverage application was used to calculate radar coverage of sensors at various elevations in key geographic areas of interest.

CHAPTER IV

CONCLUSION

Dirigibles (aerostats, airships, blimps) have been used in the U.S. military since the early 1900s. With advancements in technology and evolving threats specifically designed to stress terrestrial based sensors, it is time to reconsider the viability of dirigibles from a whole-of-government approach. The Department of Defense continually scans the horizon for the next great capability or program of record to increase the competitive advantage of the U.S. against potential adversaries. Advancements in technology and associated concepts for employment posture dirigibles as a capability that may hold the key to closing the gap on complex and stressing threats, especially as an augmentation to terrestrial and space-based sensing capability.

Research suggests that dirigibles can provide an affordable and capable option to augment and enhance U.S. missile defense and national communications architectures. The Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis in Table 1 depicts external and internal factors as well as the strengths, weaknesses, opportunities, and threats for the value of dirigibles in support of missile defense and national communications. Dirigibles, in the form of tethered aerostats in the near term, and hybrid and stratospheric airships in the long term, can provide persistent sensor coverage over a wide area with fire control quality sensor fidelity to que missile defense effectors. The SWOT analysis highlights the dirigible’s persistent coverage, sensor range, and durability as its primary advantages with weather and institutional acceptance identified as its primary weaknesses.

<table>
<tr><th colspan="3">SWOT Analysis Matrix</th></tr>
<tr><td colspan="3">Assessment: Value of Dirigibles In Support of U.S. Missile Defense and National Communications</td></tr>
<tr><td rowspan="5">External Factors

• Technology innovations (new structure composites and payload miniaturization)
• Competition (competing platforms)
• Economic trends (fiscal uncertainty)
• Government policies and legislation
• Threats to homeland</td><td colspan="2">Internal Factors

• Previous challenges and lack of flash decrease institutional acceptability</td></tr>
<tr><td>Strengths</td><td>Weaknesses</td></tr>
<tr><td>• Persistence (24/7)
• ISR / Radar Range (Extends Horizon)
• Radar Sensitivity (Fire-Control Quality)
• Endurability (30 days)
• Survivability</td><td>• Weather
• Payload Capacity
• Slow Transit to Operating Area
• Institutional Acceptability</td></tr>
<tr><td>Opportunities</td><td>Threats</td></tr>
<tr><td>• Potential opening of “political window” given recent Chinese high altitude balloon surveillance (recognition of advantages)
• Success of recent Israeli Sky Dew
• Success of Persistent Threat Detection System (PTDS)
• Advancing technology</td><td>• Concern over Safety (ref: JLENS incident)
• Lack of Regulation for “Near Space”
• Budget for Point Defense Augmentation</td></tr>
</table>

Table 1. SWOT Analysis Matrix

The Criterion Alternative Matrix (CAM) in Table 2, compares four platforms against five key attributes to determine the most viable platform to augment missile defense and act as a communications relay. Information was collected from a variety of sources to include: the Office of the Assistant Secretary of Defense for Research and Engineering’s (OASD R&E) summary report of DOD-funded Lighter-Than-Air vehicles; an article from Elistair (2022) on the differences between captive aerostats and tethered drones and how they complement each other; and the United States Air Force (2020) MQ-9 Reaper fact sheet. The CAM analysis is weighted toward delivering capability sooner rather than later, favoring capability that is either currently in operation or can be quickly returned to operation. Each platform receives a score across each of the five attributes with the lowest score being the most favorable. The scores are then totaled up and averaged. Tethered Aerostat scores the best with an average of 2, followed by the Stratospheric Airship at 2.2, UAV at 2.8, and Tethered Drones at 3.

Missile Defense Augmentation and Comm Relay: Criterion Alternative Matrix Analysis					
Attribute / Platform	Coverage Area	Persistence (in targeted coverage area)	Payload Capacity	Near (0-2 yrs), Mid (2-5 yrs) or Long-Term (5-10 yrs) Availability	ROM Cost ($M)
Tethered Aerostat (e.g., TARS, JLENS-like)	200 nm (TARS) 340 nm (JLENS) 3	7 days (TARS) 30 days (JLENS) 2	1,000 kg (TARS) 3,175 kg (JLENS) 2	Near (in operations now) Near (leverage Sky Dew) 1	$9M sys (TARS) 2
Stratospheric Airship >20km altitude (e.g., ISIS)	500 nm 1	1 to 10 years 1	1,315 kg Threshold 17,599 kg Objective 1	Long Term 4	Unknown 4
Tethered Drones	5 nm 4	8 to 24 hours 4	~2 kg 4	Near Term 2	$125k per system 1
UAV (e.g., MQ-9 Reaper in ISR config) at 50k alt	~400 nm 2	15 hours per sortie; up to 27 hours 3	1,701 kg 3	Near Term 3	~$14M per unit ~$3.5k per flight hour 3

Table 2. Missile Defense Augmentation and Comm Relay CAM

Radar coverage area was further defined using Cambridge Pixels Ltd's SPx Radar Coverage application. Two key areas of interest were used to model what the radar coverage would look like over Guam (see Figure 5) and Washington D.C. (see Figure 6). Measurements included height of the radar sensor, anticipated range in nautical miles, and target altitudes at 300 feet, to simulate a cruise missile threat, and 30,000 feet to simulate aircraft. The application also considered the curvature of the Earth represented by the green shading at various distances.

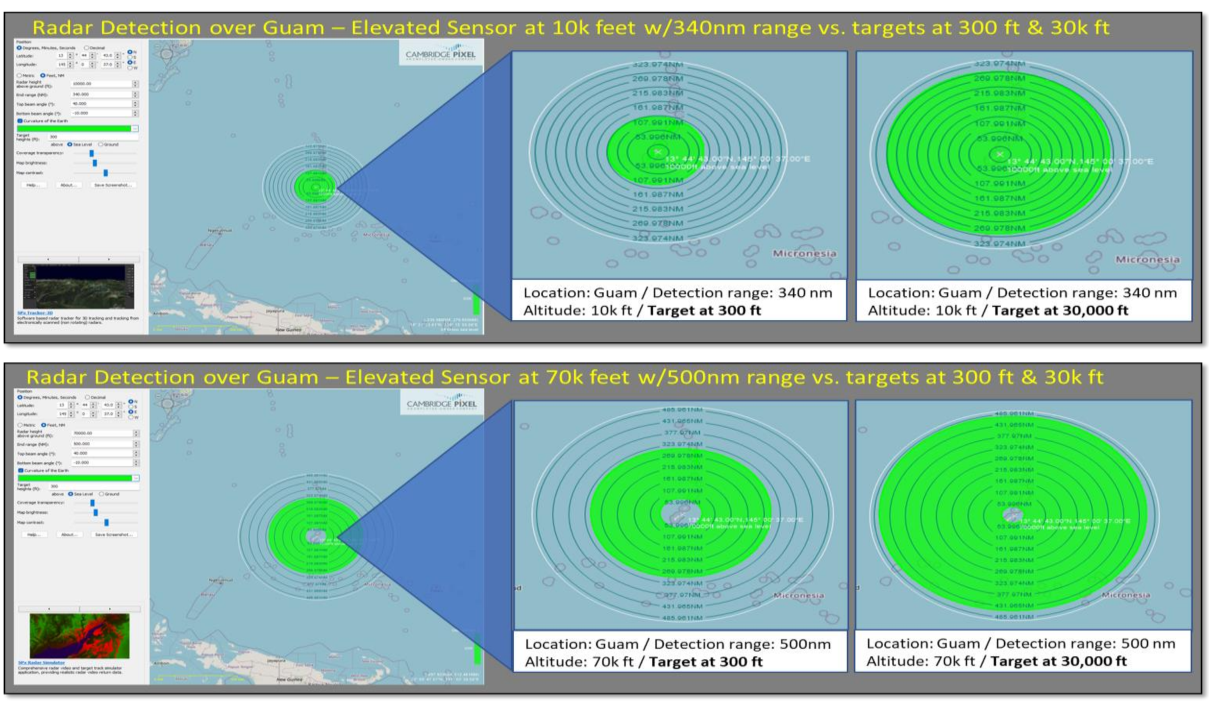

Figure 5. Radar Detection over Guam

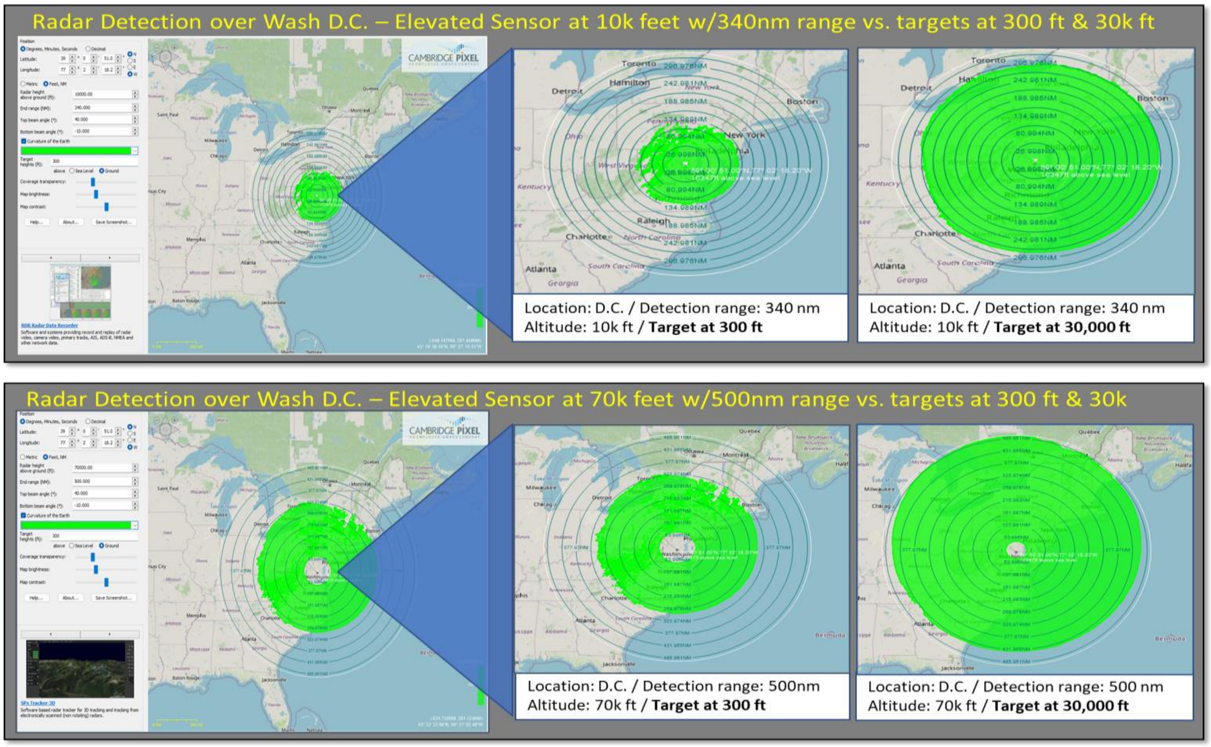

Figure 6. Radar Detection over Washington D.C.

Several senior leaders interviewed by the researchers expressed the continued need for elevated sensing platforms, in key areas, to mitigate a variety of missile threats posed by advancements in adversary capability, a role Army's JLENS was on a path to fulfill before "one of the two aerostats that make up the JLENS broke free Oct. 28 from its mooring station near Baltimore and took a three-hour jaunt through the skies of Pennsylvania, finally landing in a wooded area in the northeast portion of the state" (Judson, 2015, para. 2). Interviews with stakeholders from the Missile Defense Agency and National Guard Bureau recognized the value that a platform like dirigibles can provide, however, they expressed concern over operations and sustainment costs and the number of platforms needed to cover United States coastlines. It was recognized that increasing the altitude, to the stratospheric or "near-space" realm, could significantly reduce the numbers needed with each platform covering a much larger area. Stratospheric capability is not foreign to the DOD. "SMDC has been working on high-altitude balloons — basically dirigibles that can camp out roughly 60,000-90,000 feet in the air — for a long time, but recently the technology has improved, particularly through the commercial market. Google, for instance, used high-altitude balloons to help Puerto Rico after Hurricane Maria to help establish internet connectivity" (Judson, 2020, para. 8).

Advancements in Hybrid airships, like the Airlander 10 developed by Hybrid Air Vehicles in the United Kingdom and Pathfinder-1 developed by LTA Research, offer the potential to address challenges in key mission areas like Arctic Defense. LTA Research out of Moffett Field, CA, "believes that through a combination of new materials, better construction techniques, and technological advancements, airships are poised to—not reclaim the skies, certainly—but find a new niche" (Kozoil, 2022, para. 1).

It is important to note that research and development carries a significant burden of the cost associated with delivering a capability to our warfighters. Perhaps even more costly than the research and development is the time required from requirement identification, to testing and evaluation, and finally program delivery. That process alone can take five to ten years depending on the complexity of the program. Dirigibles, specifically Joint Land Attack Cruise Missile Defense Elevated Netted Sensor (JLENS), developed and tested by the U.S. Army, and capability like Israel's Sky Dew and U.S. Customs and Border Protection's Tethered Aerostat Radar System (TARS), have the potential to significantly reduce cost and time in delivering a proven capability to our warfighters. In the near-term, re-vitalizing JLENS, with a streamlined command and control structure and updated concept of employment, could augment point defense of critical assets in USNORTHCOM, USINDOPACOM, USEUCOM, and USCENTCOM's areas of operation, filling a critical window of vulnerability against cruise missiles and other advanced missile threats.

In the long-term, innovative endeavors like LTA Research's Pathfinder-1 Hybrid airship, and renewed investment in Stratospheric airship development would provide more flexibility, efficiency, and coverage against future threats to the United States homeland, territories, allies, and interests abroad.

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