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2020 Program Excellence Awards

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Gregory Hamilton
President
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Acknowledged, agreed, and submitted by

Nominee's Signature _____ Date 10 June 2020

Nominee's Name (please print): JACK McAULEY

Title (please print): DIRECTOR, AIR TRAFFIC SYSTEMS AUTOMATION

Company (please print): RAYTHEON TECHNOLOGIES

NOMINATION FORM

Name of Program: Ground-Based Detect and Avoid (GBDAA) SkyVision Team _____

Name of Program Leader: Jack McAuley _____

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_____

[X] Customer Approved

- Date: 10 June 2020 _____
- Contact (name/title/organization/phone): Jason Glaneuski/Manager, Air Traffic Management Systems (V-343)/US Department of Transportation, John A. Volpe National Transportation Systems Center/ (office) 617-494-3769 (cell) 617-599-9913 _____

[ ] Supplier Approved (if named in this nomination form) - N/A

- Date: _____
- Contact (name/title/organization/phone): _____

CATEGORY ENTERED

Refer to definitions in the document "2020 Program Excellence Directons." You must choose one category that most accurately reflects the work described in this application**. The Evaluation Team reserves the right to move this program to a different category if your program better fits a different category.**

Check one

[X] Special Projects

[ ] OEM/Prime Contractor Systems Design and Development

[ ] OEM/Prime Contractor Production

[ ] OEM/Prime Contractor Sustainment

[ ] Supplier System Design and Development

[ ] Supplier System Production

[ ] Supplier System Sustainment

Abstract
In central Ohio, near the home of the Wright Brothers, a Government-Industry team came together with a common vision to provide and integrate, with FAA-certified capabilities and a decade of development, a solution enabling unprecedented safety of flight operations that resolved several technical, operational and regulatory challenges the Ohio Unmanned Aircraft Systems Center (Ohio UAS Center) was seeking. This team collaborated and developed SkyVision, the only mobile UAS ground-based detect and avoid (GBDAA), beyond visual line of sight (BVLOS) system certified by the Federal Aviation Administration (FAA) to provide drone operators with real-time aircraft display data, satisfying federal 'see and avoid' requirements. SkyVision provides UAS flight crews situational awareness while transiting civil airspace, and on April 3, 2019, the FAA issued a certificate of waiver or authorization (COA) to the Air Force Research Lab (AFRL) allowing defense-related UAS technology testing without relying on ground-based spotters or chase aircraft. Excellent execution!

Purpose
Ground-based detect and avoid (GBDAA) capabilities were developed in partnership with Raytheon, U.S. Air Force Research Lab (AFRL), USAF Material Command/Life Cycle Management Center, Department of Transportation (DOT) Volpe Center, Ohio DOT, MITRE Corporation and the FAA. The absence of on-board pilots creates challenges to airspace integration, most notably compliance with the regulations for pilots to "see and avoid" other aircraft. GBDAA displays airborne tracks, from a collection of sensors, for situational awareness and proximity alerts to crew and mission planners which allows the pilot to make decisions about flight maneuvers without using, mission limiting, ground observers or chase planes during day and night operations. These radar "enhanced-vision" information displays are synchronized with the Pilot-in-Command's and GBDAA Operator display to enable focus on piloting tasks and enable execution of pre-planned traffic avoidance maneuvers.

Executive Summary: Make the Case for Excellence *(Value: 15 pts)*

- **What is the Vision for this program/project?**

"It is an exciting time for the UAS industry, which is reflected in the sheer number of new technologies entering the market," said Brian Wynne, president and CEO of the Association for Unmanned Vehicle systems International (AUVSI). *"In order to harness this innovation and help keep the U.S. competitive as the global UAS market continues to emerge, we need a streamlined regulatory environment that allows for expanded operations and would enable even more transformative uses of this technology."*

The global Unmanned Aircraft Systems (UAS) market size is expected to gain market growth in the forecast period of 2020 to 2025, with a Consolidated Annual Growth Rate (CAGR) of 5.4%, and will reach USD $5.4 billion by 2025, up from USD $4.4 billion in 2019. While introduction of UAS in the National Airspace System (NAS) has opened up numerous possibilities with industry growth skyrocketing, it has brought operational challenges including safe integration into the NAS.

The SkyVision project was conceived with the purpose and vision to deliver a ground-based detect and avoid (GBDAA) capability that leveraged functionality from the NAS certified and operational Standard Terminal Automation Replacement System (STARS) equipment that enabled a remotely piloted aircraft (RPA), a.k.a. "drone", to operate in compliance with 14 CFR §91.113 without the use of either a ground-based visual observer or an observer onboard a chase aircraft, which over time becomes cost prohibitive. SkyVision's focus was to ensure safe unmanned aircraft (UA) operations in the NAS and to support unmanned aircraft system (UAS) operations for both military and civilian customers. This project is an example of agile development starting with NextGen operational research that includes industry,

academia and government along with cooperative research and development with the Department of Defense (DoD).

The body of work that evolved resulted in the first FAA approved system for beyond visual line of sight operations in the NAS through the issuance of a Certificate of Waiver or Authorization (COA). Typically, drones can only fly within the uninterrupted line of sight of the person operating the UAS, but this FAA COA allows both the Air Force Research Lab (AFRL) and the Ohio UAS Center, which is part of the Ohio Department of Transportation's DriveOhio Initiative, to use SkyVision to test drones beyond the visual line of sight within a 200-square-mile parcel of unrestricted airspace near the Springfield-Beckley Municipal Airport in central Ohio.

SkyVision "Splash" Event at Springfield-Beckley Airport OH, featuring Ohio Governor, Mike DeWine, Lt. Governor Jon Husted, U.S. Representatives Warren Davidson and Mike Turner, and AFRL Director, Jack Blackhurst

Delivered on-time and within budget, the SkyVision project placed Ohio, once again on the forefront of the aviation frontier with this technology and elevating Ohio as a critical national asset for the research and development of UAS technology. Quoting Ohio Governor, Mike DeWine, at SkyVision's commencement announcement on April 26, 2019, at Springfield-Beckley Airport, Ohio, *"This also opens the door for commercial companies to work with Ohio, AFRL, and the FAA to test their own UAS-related technology using our SkyVision detection system. This is a major step in revolutionizing the transportation industry, with Ohio leading the way for aerospace, defense, and aviation innovation."*

The SkyVision project demonstrates how a small team of dedicated individuals with a common vision can advance existing technologies in providing unfettered drone access safely in the NAS. The SkyVision mobile platform provides BVLOS detect and avoid capabilities that serve as the "eyeballs" of the drone flight crew to mitigate existing FAA requirements to "see and avoid" threats to safely carry out a UA operation. SkyVision allows ground-based flight crews to visualize the sensor data provided by ground radars to build an awareness of the relative locations of other airborne traffic near the drone aircraft.

The SkyVision team was assembled as a result of previous successes implementing a ground-based detect and avoid, BVLOS, solution for the United States Air Force at locations such as Cannon Air Force Base (AFB), NM. Although those solutions were installed, tested and operated as fixed assets in facilities such as air traffic control towers, the team was approached by AFRL and the Ohio UAS Center to leverage the technology. The result of this collaboration led to the creation of SkyVision as the first-ever mobile platform detect and avoid, BVLOS capability using NAS certified assets.

Typically, drones can only fly within the uninterrupted line of sight of the person operating the UAS, but this special waiver allows AFRL and the Ohio UAS Center, which is part of the Ohio Department of Transportation's DriveOhio Initiative, to use SkyVision to test drones using existing FAA surveillance radar and command and control assets. SkyVision provides the UAS flight crew with a display of cooperative and noncooperative flight tracks within the drone's operational airspace. This information allows the crew to safely navigate the NAS without using ground observers or chase planes during day and night BVLOS operations.

Realizing the future potential of this innovative technology the SkyVision Team established a "stretch" goal for this project to reach out to the entire UAS community and become an authoritative source of track and detect and avoid alert data for authorized users of this information. Data for decision making is provided visually using different flight crew situation displays, using web services or via direct LAN connections to the elements of the system. The vision was to leverage the same NAS certified tracking capabilities that have evolved over decades to support air traffic control (ATC) operations in the NAS and to guarantee unmanned aircraft system operations are synchronized with the track information shown to air traffic controllers.

And finally, SkyVision's success has been recognized by both the ATC and UAS communities through winning the Air Traffic Control Association (ATCA) Technical Symposium, 2019 Technical Paper Competition for their submission, "*Advances in the use of NAS Infrastructure and GBDAA for UAS Operations*", and also winning the 2019 ATCA Annual Team Award for Outstanding Achievement, and recently named a finalist for the 2020 Technology & Innovation Xcellence Award (Hardware-Platform category) by AUVSI. Vision dreamed, vision realized!

The SkyVision Team wins 2019 ATCA Annual Civilian Team Award for Outstanding Achievement with members from Raytheon Technologies, AFRL, DOT Volpe Transportation Center, Air Force Life Cycle Management Center, MITRE & FAA

- **What unique characteristics and properties qualify this program for consideration?**

This newest version of the project focused on SkyVision's mobile capabilities, highlighting aspects such as ingesting multiple FAA surveillance radar feeds into a certified terminal ATC automation system that performs multi-fusion tracking and providing the most accurate location of aircraft, both manned and unmanned. Coupled with radio and telecommunications gear, SkyVision creates a complete set of BVLOS services that can be installed and operated at or near any airport. Critical to this effort was the government and industry team that came together and collaborated in new ways to align necessary airport field work, surveillance integration, radio and phone connections, and the installation of a fully functional GBDAA system into a 36-foot modified recreational vehicle. This "GBDAA Bus" now known as SkyVision, provides a working environment to support operations for UAS stakeholders carrying out different missions for both Air Force Research Labs (ARFL) and the State of Ohio's UAS Center.

The SkyVision Team dedicated their efforts to develop a BVLOS capability that was platform agnostic and did not require system integration with UAS avionics. The system includes redundant computer, networking, and data recording hardware, GBDAA Version 2.0 software, site-specific adaptation and configuration data, surveillance and telecommunications feeds, and radio equipment. The system also displays weather and map data overlaid on a view of the local operational airspace environment. Alerts are displayed in the data block of tracks and are provided audibly over headsets or speakers to the GBDAA Operator (GO) or the Pilot In Command (PIC). Both visual line of sight (VLOS) and BVLOS operations are supported, but BVLOS requires SkyVision during flights which garnered the FAA COA.

To date there is no other capability to conduct UAS BVLOS operations in a mobile environment with NAS certified assets. The SkyVision team proved that through extraordinary collaboration, holding safety as sacrosanct, applying certified ground-based technology with innovative enhancements can empower government and industry's ability to move forward with efforts to embrace and safely integrate UAS during this newest and most exciting age of aviation in history.

VALUE CREATION *(Value: 10 pts)*

- **Clearly define the value of this program/project for the corporation beyond profit and revenue**

In 2018, the FAA predicted that the number of commercial small unmanned aircraft would reach 452,000 by 2022. But drone sales grew faster than expected, and the agency now expects that total to reach 1.66 million by 2023. According to an FAA report, commercial drones are regularly used to carry out research and development, execute training-education missions and film events, and conduct industrial and utility aerial inspections. There have been several highly publicized cases of unauthorized drones buzzing around major international airports, both in the U.S. and overseas.

According to the FAA UAS Sightings Report[1], reports of UA sightings from pilots, citizens and law enforcement have increased dramatically over the past two years. The FAA now receives more than 100 such reports each month and have logged in excess of 370 incidents in the first quarter of 2020. Many in the aviation safety community and beyond are asking the same question: Why are these incidents occurring and what can be done to prevent a potentially catastrophic accident?

The UAS industry has seen unprecedented levels of growth during the last decade in both military and civilian domains. However, there are still barriers to be overcome and technical challenges to be met. Many recent events have highlighted the potential safety impact of introducing drone operations into the nation's airspace. According to a congressionally mandated report by the National Academies of Sciences, Engineering, and Medicine, *"The safety issues may outweigh the expected substantial benefits to society, such as preventing derailments, inspecting cell phone towers, delivering medical devices to patients in cardiac distress, and assisting firefighters."* The key difference between manned and unmanned aviation is in the eyes of the pilot. Therefore to fully employ unmanned systems in the NAS, the ground-based pilot operator requires enhancements to their situational awareness provided by a variety of systems which provide them the same or greater awareness of the airspace they are operating in and the nonparticipant traffic they must see or "detect and avoid". The availability of this technology employed in more ways across the enterprise will enable full modernization of our national airspace system in ways that can support the safe integration of drones into everyday life.

Raytheon Technologies has been studying how to maintain aviation safety and developing capabilities as more drones fly in the NAS. Raytheon Technologies' Standard Terminal Automation Replacement System, or STARS, which is used by air traffic controllers across the United States for aircraft arriving and departing every airport, became the logical capability from which a ground-based detect and avoid (GBDAA) system could be developed. Using STARS software as the baseline, Raytheon in partnership with the DOT Volpe Center, the Air Force Life Cycle Management Center, the Air Force Research Lab, MITRE and in collaboration with the FAA, banded together to build a GBDAA capability that displays airborne tracks, provided by a collection of sensors, of large and small unmanned aircraft systems (sUAS) for operators and pilots to improve airspace/aircraft situational awareness and provide proximity alerts should drones encroach on manned cooperative air traffic.

The technology and capabilities derived from the GBDAA and SkyVision project has enabled Raytheon Technologies to invest further, creating an entire UAS Traffic Management (UTM) campaign to position as a leader in the creation of trajectory based operations (TBO) airspace management in the NAS, the provider to the FAA's Flight Information Management System (FIMS), perform as a UTM Supplemental Data Service Provider (SDSP), and continued growth in delivering "BVLOS with NAS assets" to customers both domestic and international, all while building an eco system of commercial partners including networks for to demonstrate those capabilities and shape future standards.

[1]https://www.faa.gov/uas/resources/public_records/uas_sightings_report/

➢ **Clearly define the value of this program/project to your customer**

Until now, one of the most pervasive limitations to the integration of UAS in the NAS is the inability of a UAS operator to "see and avoid" other aircraft as required by Title 14 of the Code of Federal Regulations (14CFR§91.113). According to FAA rules, UAS may only fly within the uninterrupted line of sight of the person operating the UAS under most circumstances, with chase planes or additional spotters in communication with the operator. SkyVision allows the pilot to make decisions about flight maneuvers without using ground observers or chase planes during day and night operations, providing drone operators with real-time display of aircraft position and altitude data to enable "enhanced vision" and thereby satisfy this key 'see and avoid' requirement.

Raytheon Technologies and DOT Volpe, building on previous Air Force GBDAA successes, partnered with the Ohio UAS Center, a division of the Ohio Department of Transportation (ODOT), and the Air Force Research Laboratory (AFRL) at Wright Patterson AFB, to design and deploy a mobile GBDAA system at Springfield-Beckley Municipal Airport (KSGH) in Springfield Ohio of establishing a test site within one hour of Wright-Patterson AFB from which AFRL researchers can fly unmanned aerial vehicles from beyond their visual line of sight while providing users with a variety of diverse, variable-altitude, over-land interactions to increase knowledge and confidence in UAS operations.

SkyVision in place at Springfield-Beckley Municipal Airport, Ohio

To meet specific mission needs of the Air Force at KSGH, Volpe and Raytheon Technologies experts engineered an innovative solution—a mobile command center outfitted with a full suite of GBDAA equipment and developed the SkyVision Project, a mobile automation and surveillance system designed specifically to support safe integration of drones within the airspace over Ohio. SkyVision allows drones to see and avoid other aircraft whether they are fellow drones or conventional aircraft. Based on the success of the program and satisfaction of required flight standards, the FAA accepted the safety case information presented by the team and granted an unprecedented Certificate of Waiver or Authorization to AFRL to operate drones beyond the visual line of sight for the Ohio UAS Center at the Springfield-Beckley Municipal Airport. Today any unmanned aircraft type is allowed to operate up to 10,000 feet above sea level and within a 200-square nautical mile section of unrestricted airspace near KSGH.

Advancing the development of drone technology in Ohio is one piece of the state's vision to serve as a destination for companies wanting to develop next generation transportation, whether it's connected autonomous autos or new forms of aviation. The result for civil aircraft is an increase in available airspace, enabling more direct routes and less time and distance flown while still maintaining critical safety standards for the flying public. An additional benefit is a reduction in overall aviation fuel emissions, as more direct routes typically use less fuel than longer routes. *"This also opens the door for commercial companies to work with Ohio, AFRL and the FAA to test their own UAS-related technology using our SkyVision detection system,"* said Gov. Mike DeWine, in a statement. *"This is a major step in revolutionizing the transportation industry, with Ohio leading the way in aerospace, defense and aviation innovation."*

➢ **Clearly define the value of this program/project to members of your team**

To meet the rapid and exponential growth in the UAS industry it is critical to approach this new set of aviation challenges with a new level of collaboration across the entire enterprise. In that light, to bring this GBDAA capability to life and employ it, in both fixed and mobile applications, was very much the result of a progressive level of Government-Industry collaboration and teaming. To meet this challenge, the GBDAA team(s) membership expanded and contracted as specific project needs required. These teams included the U.S. Air Force Life Cycle Management Center (AFLCMC), Air Force Research Labs (AFRL), DOT Volpe Transportation Center, Raytheon Technologies, the MITRE Corporation, the Ohio UAS Test Center, and various elements of the Federal Aviation Administration to name a few. These teams collaborated to develop and implement a ground-based Detect and Avoid (DAA) system to provide enhanced decision-making for unmanned aircraft operators conducting flight in the U.S. airspace.

This was never more evident than in central Ohio, near the birthplace of the Wright Brothers, during the development of SkyVision, the only mobile Beyond Visual Line of Sight (BVLOS) enabling DAA system. In this 18-month instance the team came together with a common vision and an innovative development to enable unprecedented safety of flight operations for unmanned aircraft. This effort, with FAA in synch with the team employed legacy FAA-certified capabilities to create this revolutionary capability which garnered FAA certification to provide drone operators with real-time aircraft display data, satisfying key 'see and avoid' requirements of FARs 91.111 and 91.113. This team secured an unparalleled Certificate of Authorization (COA) for any type unmanned aircraft to operate within 200NM of Springfield-Beckley Airport from surface to 10000 feet. The system, operational at Springfield-Beckley Municipal Airport, assists drone pilots in making safe decisions about flight maneuvers without using ground observers, temporary flight restrictions, or chase planes. A series of systems, procedures, and technologies were used to ensure safety of manned traffic operating near the Springfield airport. The system uses combined radar returns from nearby airports to provide comprehensive radar coverage of a 225 square-mile area. The fused radar data is routed to a mobile operations center, where it can be accessed and read by test center personnel and operators. The system is set up to enable BLOS flights throughout the 225 square-mile area, where test center personnel can manage mixed manned and unmanned operations.

"Much like the early days of manned flight, I think we are in a 'golden age' of rapid technological advancement. which today supports amazing new capabilities for unmanned aerial systems," said Art Huber, AFRL deputy director of operations. *"In this vein we see the SkyVision system as a remarkable achievement on the road to full integration of remotely piloted aircraft in the NAS system."* The team proved that through extraordinary collaboration, holding safety as sacrosanct, applying certified ground-based technology with innovative enhancements can empower government and industry's ability to move forward with efforts to embrace and safely integrate UAS during this newest and most exciting age of aviation in history. This level of teaming celebrates the close collaboration of in particular the SkyVision Team but builds on the proven certified technology, application of innovative enhancements, and hand in hand work with FAA, DOT at Federal and State levels and a myriad of technology experts and regulators to prove the safety case and implement in greater ways in the NAS.

- **Clearly define the contribution of this program/project to the greater good (society, security, etc.)**

According to a 2015 NASA Aviation Safety Reporting System Incident Report (a voluntary and confidential forum established to improve aviation safety), around noon on a clear February day, Delta Air Lines Flight 1559 was on the last leg of a six-hour flight to Los Angeles from Honolulu. Eight miles out from the airport, as the Boeing 757 jet descended out of 3,000 feet on final approach to runway 25 Left, the first officer prepared to radio the air traffic controllers at Los Angeles Tower for instructions. Before reporting in, however, an object in the distance caught the attention of the pilot. *"At first I thought it was a large bird soaring towards us,"* the first officer (FO) wrote in a report following the incident. *"But as it passed outside of the right forward first officer's window, I very clearly saw a large square-*

shaped bright red drone with black accents and black propellers." The drone flew by, passing 150 feet to the right of the jet. The FO radioed in to the tower, warning that a drone had been sighted within the final approach to LAX. The Delta pilot reporting the incident stated, *"I'm not sure there is anything we as pilots or the tower controller could have done to prevent this "uncomfortably close" encounter between a drone and a large passenger airplane unless these objects are made to be detectable on radar and/or TCAS and traceable to their extraordinarily irresponsible owners/operators."*

Unmanned Aircraft Systems (UAS) have seen unprecedented levels of growth during the last decade in both military and civilian domains. However, there are still barriers to be overcome and technical challenges to be met. Many recent events have highlighted the potential safety impact of introducing drone operations into the nation's airspace. According to a congressionally mandated report by the National Academies of Sciences, Engineering, and Medicine, "The safety issues may outweigh the expected substantial benefits to society, such as preventing derailments, inspecting cell phone towers, delivering medical devices to patients in cardiac distress, and assisting firefighters." The key difference between manned and unmanned aviation is in the eyes of the pilot. Therefore to fully employ unmanned systems in the NAS, the ground-based pilot operator requires enhancements to their situational awareness provided by a variety of systems which provide them the same or greater awareness of the airspace they are operating in and the nonparticipant traffic they must see or "detect and avoid"! The availability SkyVision's technology employed in more ways across the enterprise will enable full modernization of our national airspace system in ways that can support the safe integration of drones into everyday life.

METRICS *(Value: 10 pts)*

- **How do your predictive metrics drive action toward program excellence?**

All aspects of the SkyVision's project management and execution are guided by a corporate culture of standardized processes that help gauge program performance and examine predictive measures to determine the efficiency of the team's program execution. These institutionalized performance metrics provided the SkyVision team with consistent and effective program estimation and execution tools.

The organization's culture and common toolset support the collection of data that monitor performance metrics for items such as change management, requirements volatility, software size, milestone status, the status of deliverable data items, staffing, cost and schedule, defect containment (iTracker Mapping) and much more. Program management, project engineers and discipline leads access a central measurement repository to collect measurements tailored to the needs of the project.

Baseline data is established at program startup based on task order award and challenges from the program office plus any changes identified in formal "Gate Review meetings" with leadership. Changes follow an approved baseline change request or an engineering change proposal process in the month that the change is applicable, including software sizes and development hours for productivity calculations.

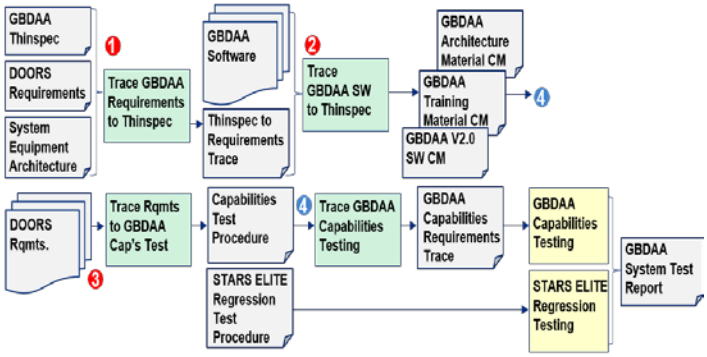
Performance tracking through performance measurements enabled quick decision-making by the project manager and aided in the resolution of risks and opportunities. Financial metrics were routinely reported and reviewed that enabled an ongoing engagement of senior leadership. This open dialogue provided a timely and accurate method for Raytheon Technologies and the SkyVision team to monitor, evaluate, and maintain the health of the program.

The SkyVision team integrated a tailored risk management (RM) process to track program performance risk. The performance metrics provided measured feedback that drove our mitigation plans for risk reduction. This integrated solution ensured the most current and accurate data was available in a timely fashion for proactive program analysis and subsequent actionable management decisions.

Our proactive RM process incorporated quality assurance into our issue resolution process enabling a continuous cycle of improvement. From day one, early involvement of key stakeholders in our integrated issue resolution process and frequent engagement with the process promoted rapid issue escalation and resolution.

Wherever possible, the SkyVision team built upon the successful performance achieved through using the STARS program RM process to implement a collaborative and open relationship with the project's stakeholders. This approach provided early identification of risks, proactive management of stakeholder dependencies, and a forum to discuss shared objectives.

The SkyVision team tailored processes to allow for efficient program execution within the bounds of this special program's budget and time constraints. The figure below illustrates the process used to support a formal Government audit of the operational software.



The SkyVision Project design, development, test and reporting process flow

Customer reviews of a "thinspec" design document along with the hardware architecture are traced to government requirements provided in a spreadsheet to determine that each has been addressed. Each requirement also maps to a section in the thinspec and a specific SkyVision GBDAA capabilities test procedure.

Thinspec sections describing what was being done were mapped the requirements, which included references to the software modules developed or modififed. Each requirement's test procedure was also stored in the dynamic object oriented requirements (DOORS) database. These capability tests were witnessed by government subject matter experts and with Raytheon Technologies quality assurance personnel during a compliance audit. Finally a regression test of the baseline STARS software was performed to validate that enhancements created for SkyVision software did not impact the NAS certified baseline STARS.

DEALING WITH PROGRAM CHALLENGES (VOLATILITY, UNCERTAINTY, COMPLEXITY, AMBIGUITY, OR VUCA) *(Value: 25 pts)*

- *10 pts:* **Describe overall VUCA faced by your project/program.**

Complex problems, such as the development of a first-of-a-kind GBDAA capability, often end up with a range of VUCA issues to resolve. The capacity of the GBDAA program and the SkyVision project to react to VUCA and provide strategic and tactical leadership depended greatly on our ability to leverage the Raytheon Technologies' culture of excellence. The mature engineering and management mindset helped the team respond to the divergent aspects of the environment we worked in.

One significant management challenge throughout the SkyVision Project was the execution tempo of the team as requirements evolved. What we were tasked to do and the timeline of important project milestones were often predicated on the alignment of decisions that had to be considered by management and stakeholders at all levels. This collaboration included the team members at MITRE, the United States Air Force (USAF) at both the Life Cycle Management Center (AFLCMC) and Air Force Research Labs (AFRL), the US Department of Transportation Volpe Transportation Center (DOT) and the Ohio Department of Transportation (ODOT) along with other subcontractors and governmental agencies.

Volatility in the response times of different organizations could impact execution progress and only by constant communication could these situations be mitigated. Throughout the early years of the GBDAA

program, differing organizations collaborated on the design of the system and how it would be applied to UAS BVLOS operations in the State of Ohio. Trade studies determined the feasibility of differing approaches to install these new GBDAA-provided detect and avoid and sensor capabilities for the state. Each instance required the development of complex program artifacts such as engineering drawings, equipment needed and its' pricing, site survey installation analysis and much more.

The uncertainty encountered is evidenced by the different site configurations that were analyzed before an eventual decision was made to produce a mobile GBDAA capability, now known as SkyVision. The differing venues and site configuration options that were considered included:

- Wilmington Air Park (KILN) operations in Ohio with local connections to on-site UAS Ground Control Systems (GCS) for the flight crew's GBDAA Operator (GO) and pilot-in-command (PIC).
- KILN operations with remote monitoring and control from a nearby ODOT UAS Test Center.
- ODOT UAS Test Center operations with a GO in the UAS Test Center and the PIC at KILN airpark.
- Connecting the different sites using the Ohio Advanced Research Network (OARnet)
- Connecting the different sites by extending the system's operational LAN or by using keyboard, video and mouse (KVM) extenders.
- Integration of an SRC Corp. LSTAR gap filler radar for radar surveillance
- Springfield-Beckley Airport (KSGH) GBDAA operations from their abandoned control tower
- ODOT UAS Test Center operations with a GO in the UAS Test Center and the PIC at KSGH airpark
- KSGH operations from a shelter at the adjacent Air National Guard Base

While design options were being considered, the project team had to ascertain the condition and attempt to repair an aging Airport Surveillance Radar – Model 9 (ASR-9) to determine its applicability to UAS BVLOS operations. Raytheon Technologies engineers were brought in to support these efforts while simultaneously developing and testing software and architecting the hardware solution for each possible location.

Ambiguity might be considered what the famed military theorist Carl von Clausewitz called "*the fog of war*." It's about those confusing situations in which multiple plausible interpretations exist about what's going on or what a different decision might mean to the project. It's about those times when a group of smart people are all looking at the same data yet coming to different conclusions about what it means—and here's the key—they all sound right.

Each of the options described were reviewed and analyzed before it was decided by the team to purchase a 36 foot used Winnebago Class A recreational vehicle to install the GBDAA system in. This decision to the uncertainty of finding a suitable venue turned out to be a mobile facility which then accelerated progress and provided options for the system's use that were impossible with a fixed installation.

Many at Raytheon Technologies, as well as within this project, have to manage challenging issues. For the SkyVision project these included responding to program funding lapses, marketplace competition, changes in leadership, site installation changes, and much more. The team continuously adjusted to adapt to these challenges and maintain a forward momentum.

Raytheon Technologies is particularly good at responding to these types of events due to our diverse organizational culture. We as a workforce were able to continuously meet, bring our blended Government, industry and academia partners together, and rise above a volatile evolving set of requirements because, in part, of our diversity. Each team member possessed unique experiences, perspectives, backgrounds, skills, and levels of education. The unique qualities that made us so different also made us stronger, smarter, more agile and adaptable as a unit. These characteristics equated to a more resilient workforce that could "take a punch and stay in the fight".

Our program management expertise helped organize a diverse workforce possessing several resilient attributes such as:

- Socially competent with the ability to elicit positive responses from others, thus establishing positive relationships.
- Highly skilled at problem-solving with the resourcefulness to seek help when needed.
- A sense of their own identity and the ability to act independently and exert some control over their local environment.
- Fostered a sense of purpose and future. The leadership's goals, focus areas, and strategies resonated with the team to help them maintain focus and morale throughout the project.

➢ *15 pts:* **Cite specific example(s) and how your team responded.**

Once the decision was made that a mobile facility would be constructed, trade studies were needed to identify an appropriate and affordable vehicle type. It would be safe to assume that large aerospace defense contractors like Raytheon Technologies do not routinely purchase used recreational vehicles outfitted with equipment for air traffic management, but this project team took on the challenge. Much work and mentoring was needed to develop the skill sets needed to make a correct vehicle purchase decision. With limited budget and time available to succeed, the resiliency of our team paid off. All involved stepped up to the tasks of identifying a vehicle, architecting the layout of equipment in the vehicle, purchasing the recreational vehicle (RV) and outfitting it for use as a GBDAA platform.

SkyVision's early construction at a Hanger at the Beverly Regional Airport in Massachusetts

After several collaborative iterations of alternative vehicle designs, a 36 ft. Winnebago was chosen by our team. Although the vehicle was initially intended to be purchased by the government, Raytheon Technologies was eventually given the task of procuring the vehicle. Only through close collaboration with the RV vendor could we convince them that it was worth their waiting for our organization to complete the corporate procurement process. Usually RV sales are done with private individuals who simply write a check to complete the process. The complexity of getting organizational approvals and following tailored procurement processes took more time than the RV vendor was accustomed to. On more than one occasion, management had to convince the RV sales team to not sell the vehicle to others who were willing to purchase it before we were. Our team's unique mission and enthusiasm for doing something good for the aviation community no doubt helped to convince the RV Sales Team to wait and work with us.

Once acquired, the SkyVision team collaborated to design the layout. As equipment had already been purchased based on the original requirements to install at a fixed location, the team had to re-engineer the system's architecture for this unique installation. After hiring the RV vendor to remove the interior bathroom and shower, master bedroom and kitchen tables, sink and stove the "GBDAA Bus" as it was called was moved to a hangar at an airport in the Boston area to complete the installation.

During a subsequent 45 day period, equipment was delivered and modified to provide a custom fit within the confines of the vehicle. As our Government partners installed lightning suppression and power

equipment the Raytheon Technologies team purchased and installed custom rack layouts and mounted desks with computer equipment for SkyVision users.

New half racks were designed for the system installed in the rear bedroom and bath of the vehicle as it was now modified to serve as the equipment room. The front kitchen area of the RV was transformed into dedicated GO and simulator positions, along with a visitor viewing area. A Federal Telecommunication Infrastructure (FTI) Service Delivery Point (SDP) was also installed to enable receipt of FAA surveillance radar data from any Airport Surveillance Radar (60 nautical mile range) or Air Route Surveillanc Radar source (200 nautical mile range).

Other non-standard installation tasks had to be managed. For example, to support field operations, a custom Ground Positioning System (GPS) antenna mount had to be designed and installed on the RV. The Raytheon Technologies team in this case used local lab facilities electricians to develop a mount that was permanently installed on the exterior of the RV.

As the GBDAA Bus was a one of a kind vehicle, no instructions for its construction were available beforehand. Management of the various teams involved (i.e. electrician, carpenters, engineers) was handled by constant on-site communications with full transparency of progress made and issures needing resolution. Many worked long hours and took great pride in the construction of what eventually was dressed up with blue vinyl wrapping and given the moniker "SkyVision" by AFRL.

Once SkyVision was shown off to the customer community at various conferences and demonstrations, it was requested to be made available for exhibitions at several locations. During the 2018 – 2019 season, the SkyVision vehicle travelled coast to coast from Washington DC to Edwards AFB in California to demonstrate its capabilities. A small team from the USAF, DOT Volpe Transportation Center and Raytheon Technologies travelled with the bus on several lengthy road trips to show off the capabilities of this new detect and avoid system. This challenged the SkyVision team to endure travel across lengthy stretches across the desert and throughout the country. The team was proud to say that the vehicle was always ready when needed just as it is today, again ready for both civilian and military BVLOS operations using drones of all size classes at the Springfield-Beckley Airport or at other locations to support BVLOS operations.

ORGANIZATIONAL BEST PRACTICES AND TEAM LEADERSHIP *(Value: 25 pts)*

- *15 pts:* **In executing the program, what unique and innovative practices, tools and systems frame your program and help you achieve program excellence**?

Program management used a standardized approach to effective program execution based on Project Management Institute (PMI) principles embodied in Raytheon's Integrated Product Development System (IPDS). These processes streamlined schedule development, reduced waste with repeatable processes, and supported the timely response to evolving project requirements. IPDS incorporated our Program Management Excellence (PMX) tool suite, best practices from our worldwide programs, and recent lessons learned from FAA and other programs. Raytheon's PMX tools supported the key activities on the program and provided tight integration and tracking of the functional and technical performance, including the performance of any subcontractors, against the project requirements, deliverables, and schedule. The processes and tools used were those recognized by the FAA's Air Traffic Organization (ATO) by a 2018 Award for Exemplary Program Management for its work on STARS/TAMR.

An Integrated Product Development Process (IPDS) identified methods for project stages including:

- Business strategy planning and execution - identifying viable business opportunities and using strategic planning to position the team early with the customer to strengthen team partnerships.

- Project leadership, management and control – identifying management and control tasks, award capture, program startup, execution and closure processes and reporting requirements.
- Requirement and architecture development – including requirements capture in a DOORS database and identifying site specific configuration needs, identifying interfaces and specifying appropriate data reference models, Concept of Operations and verification and validation requirements.
- Design and development – of the SkyVision system and all of its components including test equipment, facilities, supply chain support and initial program supportability preparations.
- Integration, verification and validation - where the system components are integrated, audited and tested. Independent testing was also carried out with the USAF and MITRE using test procedures mapped to each of the systems requirements. Testing included both lab work and flight testing.
- Production and deployment – including detailed production planning, material planning, improving / duplicating development equipment and tools for a production environment.
- Operations and support – which provided sustainment options following deployment with the goal of enabling operational availability and minimizing life cycle costs. These processes help anticipate changing logistics to allow continued operation and support within cost and schedule.

The SkyVision project used an iterative and incremental software and hardware development model to support multiple builds for integration and testing using a staged approach to system integration and verification. We employed an incremental approach using standardized Raytheon Technologies toolsets and processes for agile development. In fact, the GBDAA program and SkyVision project was one of the first adopters of these techniques in the organization. Within the process, we establish fixed deadlines for delivery at the start of the effort. The benefits of this approach was that it minimized risk through early discovery, and optimized value by prioritizing the work and deliveries in a predictable schedule.

Our development methodology adopted the low-risk agile concept of using scrums and sprints to incrementally build and test software in short iterations. A scrum is a practice to design, code, and test within short iterations, called sprints, each of a short duration. New capabilities, taken from a prioritized list are assigned to each sprint. The team collaborated to develop and verify capabilities conforming to authorized requirements. Using this development methodology, each scrum was limited to the team that is presented with a project plan and a set of requirements. The team incrementally delivers software to the integration and test teams that run their activities in accordance with the milestones that were identified in our Integrated Master Schedule (IMS) for the project.

As our work evolved, the SkyVision team integrated best practices from the organization's evolving Agile for Program Development (AFPD) processes and tools. AFPD represented a substantial internal investment in methodology that adapts agile frameworks to government programs so that modern efficiencies are realized while conforming to mandated government milestone activities. AFPD provided approaches for scaling agile development to multiple scrum teams working within the same-shared requirements. Throughout the GBDAA program, and the SkyVision project, JIRA[2] was used to manage problems found during the system and software development process. Problems were typically resolved in the same agile sprint or a subsequent sprint. Those unresolved were identified during post-development phases are tracked using JIRA.

Thinspec documents, written to share design and requirements information were reviewed internally and by the customer. These documents were linked to both the requirements and test procedures in our shared DOORS database as well as being documented as part of the overall set of JIRA epochs and stories developed. This insured the customer team and stakeholders had access to the information they needed to review our design progress and effect changes to the software as the system evolved.

[2]JIRA Software, development tool used by agile teams, from ATLASSIAN

Another approach to improving contract deliverable document production efficiency was used to reduce costs by shifting the production of training and technical documentation entirely to the engineering staff, reducing the need for separate technical writers who often needed the engineers to provide draft documentation to them anyway. Engineering staff were provided with the necessary image and document processing tools, along with multiple reviews with the customer to ensure satisfaction with the resulting program artifacts and their value to the flight and maintenance crews.

Documents provided included flight crew training course material as well as checklist and "quick reference" documents to assist with the system's operations. Maintenance staff training material was also provided along with a system architecture document and wiring diagrams that described the equipment and tasks relating to its upkeep. SkyVision and GBDAA training courses were also carried out by the engineering team.

Videos were also created and widely distributed to illustrate how the system worked. Readily available video processing software and capture technology allowed for rapid development. These short movies often captured the GBDAA situation display used by the flight crew to document both simulated and live flight operations. Appropriate captions were inserted to highlight important events and the resultant videos were extensively used at press events, presentations and conferences throughput the project. Often demonstrations of our BVLOS detect and avoid capabilities could be exhibited to interested parties without having to setup complex systems and simulators.

- *15 pts:* **What unique and innovative processes and practices are you using to develop people and transfer knowledge and how do you know they are working?**

Leadership and organizational processes guided the activities carried out across the SkyVision project team members as well as the company at large. With collaboration being a key to the project's success, all levels of each team member's organization needed to be able to communicate information and share resources for success. Part of the SkyVision team's culture was routine government-led meetings attended by all project participants. Monthly status reports were provided to the customer that described the technical and programmatic issues advancing or hindering execution. In addition, financial reports traced the costs spent vs. budgeted per the task order.

Raytheon Technologies has a long, proud tradition of employees helping employees. Mentoring employees at all levels of expertise played an important role in SkyVision's success through sharing the knowledge, experiences, and lessons learned. Team leaders mentored several employees using a well-defined process of informal meetings and tools to help bring up the level of expertise of the team. All employees were encouraged to explore the professional and personal benefits of being a mentor and mentoring others. The project also employed several new members of the workforce that participated in mentoring to foster their skillset and level of participation in the team's success.

Corporate, departmental, functional and lower level management meetings were venues used to present SkyVision to our workforce. Brown bag sessions, also a part of the Raytheon Technologies culture, allowed all facets of the workforce to learn about the system and its benefits to the future of aviation. These widely attended meetings served as a forum for questions from the entire Raytheon Technologies workforce and elicited interest from staff interested in the technologies presented.

The evidence in knowing our mentorship and knowledge transfer is beneficial, is in the number of requests from other Raytheon Technologies program managers for GBDAA and SkyVision's engineering resources. Programs such as STARS, NextGen Weather Processor, AutoTrac III, and SWIM Terminal Data Distribution System have all requested the skilled personnel from the GBDAA project.

- *10 pts:* **What unique practices are you using to engage customers and how do you know?**

The SkyVision project team engaged customers both nationally and internationally through exhibits, panel discussions, peer-review papers, presentations and demonstrations given at a diverse set of venues.

Two distinct Institute of Electrical and Electronics Engineers (IEEE) publications have been presented at both national and international conferences. The SkyVision Team was awarded the Air Traffic Control Associations (ATCA) 2019 Annual Civilian Team Award for Outstanding Achievement award, while also winning ATCA's Best Technical Paper Competition 2019 based on its publication, *"Advances in the Use of NAS Infrastructure and GBDAA for UAS Operations"*, authored by R.J. Stamm, J. Glaneuski, P. R. Kennett, J Belanger.

Raytheon Technologies' SkyVision Technical Director, Bob Stamm, presents "Advances in the Use of NAS Infrastructure and GBDAA for UAS Operations", at the FAA William J. Hughes Technical Center, May 2019

SkyVision has been exhibited at many trade shows including the 2018 and 2019 Air Traffic Control Association (ATCA) Annual Conferences, 2019 National Air Traffic Controllers Association (NATCA) Annual Communicating for Safety Conference, the Communications Navigation and Surveillance / Air Traffic Management (CNS/ATM) Conference, the IEEE Aerospace Conference and twice internationally at the IEEE/AIAA Digital Avionics Systems Conference. Additionally, the SkyVision team was invited to demonstrate SkyVision at Wright-Patterson AFB, OH, Edwards AFB, CA, and the State of Ohio Department of Transportation (ODOT) UAS Test Center.

Presentations were made at several Association of Unmanned Vehicle Systems International (AUVSI) conferences and at several press events such as those done with local Ohio television and press organizations. Recognition of our ground breaking work was acknowledged by the two most recent Ohio State Governors. The image to the right shows Governor Mike DeWine looking at one of our movies of routine Ohio GBDAA BVLOS operations at a large press event introducing the capabilities of our system to a statewide audience.

SkyVision during the NATCA Communicating for Safety Conference in Las Vegas, Nevada

Finally, less formal engagements fostered relationships between the people on both the government and industry team to align our goals and help us focus on critical challenges throughout the program. This team continues to remain intact and have received numerous inquiries from a multitude of customers, including the Northern Plains UAS Test Site through the University of North Dakota, Deseret UAS out of Utah, Northeast UAS Airspace Integration Research (NUAIR) from central New York, and even United Parcel Service in Louisville, KY. The SkyVision team continues to improve the product with plans to integrate Automatic Dependent Surveillance-Broadcast (ADS-B) as well as Raytheon Technologies active electronically scanned array (AESA) low-power radar that can surveil low-altitude flights of smaller aircraft and drones, thus increasing SkyVision's already high market interest in UAS Traffic Management.

The SkyVision project was an incredible example of program management excellence bringing team members with a common goal and vision to address the opportunities that UAS technologies will bring to the future of aviation and in creating capabilities for uses such as UAS testing, package delivery, agricultural uses, emergency management, protecting wildlife and even for weather predictability. The excellence delivered in program managing the SkyVision project enabled the opportunity to provide value-add to the future of UAS integration into the NAS.