20 YEARS

AVIATION WEEK

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Acknowledged, agreed, and submitted by

Thomas Coglitore Digitally signed by Thomas Coglitore
Date: 2024.07.12 11:54:34 -05'00'

12 July 2024

Nominee's Signature Date

Nominee's Name (please print): Tom Coglitore

Title (please print): General Manager, Collaborative Mission Autonomy

Company (please print): Collins Aerospace

NOMINATION FORM

Name of Program: Collaborative Mission Autonomy Program

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☒ Customer Approved

- Date: 8 July 2024
- Customer Contact (name/title/organization/phone): Don Endicott, Principal Systems Engineer (Senior), withheld, 703-526-6647

NA Supplier Approved (if named in this nomination form)

- Date: NA
- Supplier Contact (name/title/organization/phone): NA

PLEASE REFER TO PROGRAM EXCELLENCE DIRECTIONS AS YOU COMPLETE THIS FORM.

SECTION 1: EXECUTIVE SUMMARY: Make the Case for Excellence

Value: 10 points

Use 12 pt. Times Roman typeface.

What is the vision for this program/project? What unique characteristics and properties qualify this program for consideration?

The Department of Defense (DoD) has long-espoused the potential of advanced Artificial Intelligence (AI) and autonomy to enhance the reach, survivability, and lethality of the warfighter. During the award period, Collins Aerospace had the unique opportunity to develop a suite of *collaborative mission autonomy* technologies that finally realized this potential. Partnering with a DoD customer, the Collins team crafted a holistic, system-of-systems approach to design, develop, integrate, test, and deliver complex, platform-agnostic, combat-relevant autonomous technologies that support advanced Crewed/Uncrewed Teaming (C/U-T) operations. The task was not easy. Working alongside our government customer, the team overcame extreme adversity, including abrupt program pivots, unsteady funding streams, rapidly evolving requirements, significant technical complexity, and a corporate-level business reorganization. The team's success despite these challenges offers valuable lessons for government and industry alike.

Entering 2021, the team had just completed the first set of autonomous flight tests for Phase 2 of the program. Over the next eight months, the team completed two additional flight test series demonstrating combat-relevant, multi-ship, collaborative autonomy, but in doing so, the team also had to relocate their flight test operations to a new test range, adapt their autonomy to an updated aircraft interface, and integrate a new sensor. Despite these challenges, the August 2021 capstone Phase 2 flight test was a success.

The adversity the team overcame completing Phase 2 foreshadowed the complications they would encounter in the third and final phase of the program. Phase 3 started with a revamped Design Reference Mission (DRM), a new flight test vehicle, and a new set of communications requirements, all of which demanded creation of new autonomous behaviors. However, four months into Phase 3, the customer abruptly pivoted the program, twice. First, the team was directed to stop work on the original Phase 3 scope and instead develop capabilities for an entirely new and more complex autonomy mission using a new uncrewed aircraft. Then, only a few weeks later, the customer launched a separate and concurrent spin-off autonomy effort to deliver another set of autonomous capabilities for a different DoD stakeholder. Amidst these substantial changes, the team quickly regrouped and redistributed its resources to support the newly expanded scope. In Fall 2023, they successfully completed separate integration and demonstration events for both mission sets, plus a multi-ship flight test series, collectively demonstrating the viability of Collins' collaborative mission autonomy for complex C/U-T operations.

In addition to the "normal" volatility, uncertainty, complexity, and ambiguity (VUCA) that accompanies a cutting-edge R&D program, the team faced three systemic-level challenges: broad misunderstandings of AI and collaborative autonomy technologies; multiple competing and discordant autonomy-related programs; and evolving government contractual models intended to support the acquisition and sustainment of autonomy software. Because these challenges applied to both our internal team and our customer, overcoming them necessitated an extremely close and collaborative partnership.

The team also endured an RTX-level corporate reorganization in July 2023. The restructuring consolidated RTX's collaborative mission autonomy teams into a new, autonomy-focused organization within Collins. Despite the volatility that accompanied the business transition, which required harmonizing technologies, engineering resources, and business processes, the team soon realized the benefits of operating within a single, autonomy-focused business unit.

Embracing the flexibility inherent in agile development processes was paramount to the team's success. Fully implementing "agile" on a critical, high-visibility R&D effort required buy-in at all levels of the organization, as well as within the customer community. Typical business practices and long-favored metrics had to be tailored to ensure the team could deliver the desired capabilities on the necessary timelines. Clear, candid, and frequent dialog within the team and with the customer was also essential to building the necessary trust and collaborative partnership this complex program demanded.

SECTION 2: VALUE CREATION

Value: 15 points

Please respond to the following prompt:

- **Clearly define the value of this program/project for the corporation; quantify appropriately**

As an industry leader designing, developing, and fielding advanced mission systems, RTX and Collins have always endeavored to equip our nation's warfighters with the capabilities needed to prevail in conflict. Like the DoD, for the past several years we've been striving to harness the power of advanced AI and autonomy to enhance the reach, lethality, and survivability of the warfighter. Recognizing the criticality of advanced AI and autonomy to our nation, in July 2023 RTX consolidated its various autonomy efforts and teams into a new organization within Collins. This new organization is dedicated to accelerating the development and deployment of collaborative mission autonomy solutions. Indicative of our commitment to shaping future autonomy development, Collins leadership also allocated significant additional internal funds to expand classified laboratory space and infrastructure at multiple sites to better support the growing autonomy workforce, which has expanded to over 125 engineers spread across 14 states.

Prior to the RTX business reorganization, Collins had already made a significant multi-year commitment to accelerate the development and delivery of advanced, multi-ship collaborative mission autonomy solutions. Collins's RapidEdge™ initiative brings together a full suite of autonomy-enabling capabilities, including open reference architectures, DevSecOps pipelines, robust integration and demonstration environments, and governance processes. It also capitalizes on Collins's legacy developing and manufacturing safety-critical aviation hardware and software components using high-design-assurance processes to support the rapidly evolving autonomy market.

This program in particular provided Collins and RTX an opportunity to showcase the value of traditional defense firms in the fields of advanced AI and autonomy. While small, non-traditional defense start-ups may appear more agile and innovative in these fields, our exceptional performance on this program proves that large defense companies are capable of rapidly delivering advanced AI and autonomy solutions in support of the DoD's vision. Leveraging our operational analysis and mission engineering acumen that crosses multiple warfighting domains, our autonomy teams develop a holistic understanding of future combat operations in the contested battlespace. Applying those insights, our teams then employ a system-of-systems approach to precisely craft autonomous technologies that apply the power and speed of machine-to-machine collaboration to address critical tactical and operational-level deficiencies, delivering strategic-level results. Injecting direct, uniformed operator feedback into our autonomy design and development process reinforces this holistic approach and ensures that our autonomy solutions will be useful and impactful for the warfighter. This unique approach to autonomy development resulted in our team being the sole remaining performer at the end of the program.

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

This autonomy program represented the DoD's first significant effort to develop and flight-test collaborative mission autonomy optimized for C/U-T with fighter-type aircraft. While several DoD organizations had been experimenting with future iterations of autonomous aircraft, neither the DoD nor industry had yet developed and demonstrated a holistic solution using advanced AI and autonomy to effectively team autonomous, uncrewed aircraft with human fighter pilots for combat-relevant missions. The customer allocated over $300M to achieve the program's three primary goals: develop a flexible, modular, assured, open system architecture for C/U-T; demonstrate C/U-T across multiple operational missions through live flight test; and collaborate with and align to other government reference architectures.

Throughout the program, the customer stressed the necessity of remaining tightly focused on developing the core C/U-T autonomy framework and associated library of combat-relevant autonomous behaviors. The program's resulting collaborative mission autonomy software would ideally allow the DoD to use any aircraft and any sensor from a team of Uncrewed Aerial Systems (UASs) to seamlessly support a human fighter pilot during a dynamic combat mission. This approach differed significantly from prior DoD autonomy efforts, which had generally focused on building UAS aircraft and related hardware. By developing an open, modular, and platform-, mission-, sensor-, and communications-agnostic autonomy solution for C/U-T, the customer ensured the capability could be broadly adopted by any DoD service and easily applied to support a variety of C/U-T combat mission applications.

The customer also instituted a unique approach to requirements generation. Recognizing the novelty of the C/U-T concept and the nascent state of collaborative mission autonomy technologies, the customer did not specify any autonomy performance requirements in the Statement of Work. Instead, the customer only provided a high-level DRM and asked industry to derive potential system requirements and craft candidate C/U-T Concept of Operations (CONOPS). This approach unleashed industry's creativity and provided a path for mutual learning and discovery.

- **Clearly define the value of this program/project to members of your team; quantify if possible**

For members of our autonomy team, the program provided a unique ability to engage directly with warfighters and craft creative, technologically advanced solutions that would likely be deployed in only a few years. The speed of implementation was a stark contrast to the usual experience, typically characterized by several years spent developing technologies prior to user engagement and testing. The team used Cognitive Systems Engineering (CSE) and Pilot-in-the-Loop (PIL) events to connect our autonomy engineers with uniformed operators so they could jointly identify and prioritize critical autonomous capabilities for future C/U-T operations. Additionally, our engineers had the unique opportunity to fly aboard the UAS surrogate aircraft (Gulfstream G3s) that were being piloted by their autonomy algorithms.

The aggressive schedule and unique design requirements provided frequent opportunities for the team to engage with other engineers from across Collins and RTX. Even prior to the corporate reorganization, the team had been working closely with several sensor and communications hardware and software teams from across the organization to craft integrated mission system solutions that achieved the customer's ambitious requirements. The autonomy software and systems teams also partnered with flight test integration specialists and Modeling & Simulation (M&S) experts to develop a Live-Virtual-Constructive (LVC) environment capable of supporting the full range of developmental activities, from early benchtop experimentation through complex, multi-ship, live flight tests incorporating a mix of virtual and constructed assets and capabilities. This opportunity to span organizational boundaries helped pull the various teams together as they unlocked new synergies supporting a wide range of related pursuits and technologies.

Additionally, the fast-paced development environment and lean management structure provided individuals with occasions to hone their leadership skills. For several team members, their exceptional performance on this challenging program led to key roles on other critical programs and internal development projects. For example, the program's lead autonomy software engineer was selected as the lead software architect for our family of autonomy products; he is now applying the experience he gained on this program to guide the development and synchronization of multiple autonomy programs supporting a variety of DoD customers. Similarly, the program's lead flight test engineer is now leveraging the insights she gained executing the program's complicated test program, as well as establishing the critical collaborative partnerships with our government customer, in her new role as the deputy Chief Engineer for a high-priority, follow-on DoD autonomy effort. Several other individuals from the program are also now leading their own autonomy development and integration teams across the organization.

Finally, recognizing their outstanding contribution to the broader organization, the autonomy team received multiple business and corporate-level awards during program execution, including the prestigious Raytheon Intelligence & Space Excellence (RISE) award.

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

For more than a decade, the DoD has advertised its need for affordable combat mass and its desire to harness the power of advanced AI and autonomy to operate the new combat fleets. Collins's multi-ship collaborative mission autonomy promises to support these vital operational imperatives. However, simply developing AI and autonomy algorithms in isolation is insufficient. To be used within the context of military operations, and to potentially deliver lethal effects in the battlespace, the AI and autonomy must be developed systematically and holistically. They must be able to adapt to dynamic battlefield conditions while adhering to the ethical guidelines outlined in US government and DoD directives governing AI and autonomy. Consequently, our algorithms and associated autonomous capabilities are built around the core principles of explainability and resilience, and they incorporate validation and verification environments that support human trust, autonomy trustworthiness, and system-level risk assessment.

To support the DoD's requirements for affordable mass, Collins is also committed to helping the government reduce total lifecycle system costs by cultivating a robust marketplace for future autonomy providers. The C/U-T architecture developed during this program embraced openness, flexibility, and modularity. These architectural design principles encourage competition and provide future government customers with opportunities to integrate "best of breed" behaviors from a variety of autonomy providers. Additionally, the architecture, autonomous behaviors, and Software Development Kit (SDK) developed during this program were delivered to a central DoD repository established to encourage government-industry collaboration in the fields of AI and autonomy. Through this repository, several defense firms have already accessed and repurposed the capabilities we generated on this program to support their own products. We support this dissemination and proliferation of autonomous capabilities, and we actively participate in several government-sponsored Communities of Interest to better enhance industry collaboration and accelerate delivery of more useful and impactful autonomy to the warfighter.

Finally, based on our experience executing this program, our team gained unique insights into future autonomy development and sustainment requirements. While the development of advanced software-based autonomy capabilities does not require a total upheaval of traditional acquisition and sustainment processes, the existing processes require adjustment. Roles and responsibilities for industry suppliers, government acquirers, system integrators, data managers, tacticians, and front-line pilots and end-users must be updated to fully realize the DoD's vision for advanced AI and autonomy. Consequently, we launched an initiative to share our lessons learned regarding the future autonomy ecosystem with key DoD stakeholders.

SECTION 3: ORGANIZATIONAL BEST PRACTICES AND TEAM LEADERSHIP

Value: 35 points
Use 12 pt. Times Roman typeface
Please respond to the following prompts:

- ***15 points:*** **Describe the innovative tools and systems used by your team, how they contributed to performance and why**

Early in the program, the team realized they would need to adapt their standard engineering tools and business processes to achieve the customer's ambitious technical requirements and aggressive timelines. The team implemented a variety of digital solutions to help streamline their system design work, including Model-Based Systems Engineering (MBSE) tools, DevSecOps software pipelines, and advanced M&S. The team also looked outside traditional defense engineering disciplines for assistance, incorporating ethnography, cognitive systems engineering, and other human-centered design approaches into their processes to ensure the autonomy capabilities they were developing would seamlessly support warfighters.

Addressing the program's objective to develop a flexible, modular, assured, and open system architecture, while simultaneously deriving system-level requirements for C/U-T autonomy, required the team to implement robust MBSE practices. Using MBSE principles and tools, the team was able to easily categorize and trace the over 1,800 system requirements they derived, which spanned five hierarchical design levels and three architectural tiers. The team's early decision to develop and implement a three-tiered architecture model within the MBSE framework—consisting of reference, product family, and system architectures—paid dividends as the program responded to the multiple customer-directed pivots, each of which added new platforms and new DRMs. The team's novel MBSE architectural framework also helped them trace architectural decisions, system allocations, and individual requirements across the various solutions sets, enhancing consistency and supporting reuse when appropriate. For example, when the customer launched the separate, concurrent spin-off effort tackling another DRM, the team was able to identify portions of the existing architecture that could be reused or easily modified, greatly accelerating development.

The autonomy team also embraced software containerization and DevSecOps pipeline technologies as additional means to accelerate capability development. Containerization helped the geographically-dispersed team maximize their use of on-premises compute and allowed program leaders to quickly scale the number of supporting software developers as the program evolved. Containerization and DevSecOps also allowed the software developers to design, deploy, and test more complex, autonomous teaming behaviors across a variety of mission use cases. The flexibility of containerization and DevSecOps likewise supported the rapid adaptation and reuse of software developed on other Collins and RTX programs. For example, the team elected to repurpose a software planning tool originally developed for Electronic Warfare Battle Management to support their requirements for autonomy mission programming, execution monitoring, and post-mission analysis. Similarly, the team was able to pull from Collins's extensive library of flight managers and auto-router algorithms developed within an adjacent business unit and quickly integrate these core capabilities into the missionized autonomous behaviors they were creating.

The team worked hard to harness the power of advanced M&S to support rapid autonomy development and evaluation. Because the customer only provided a high-level DRM with genericized UAS platform capabilities, the team had to conduct early operational analysis to identify and evaluate potential C/U-T CONOPS, as well as the critical collaborative mission autonomy capabilities that would support successful DRM accomplishment. In several instances, the customer fed the insights generated by our team's M&S to their supporting Federally-Funded Research and Development Centers (FFRDCs) to help refine the DRM and guide future C/U-T studies. Working with our M&S and flight test integration specialists, the team also developed a Cognitive Netted Operations (COGNETO) plug-in to the government-standard Advanced Framework for Simulation (AFSIM) environment to support full-spectrum LVC autonomy testing. By linking our COGNETO autonomy-in-the-loop capability to the UAS aircraft's Hardware-in-the-Loop (HIL) testbed within an AFSIM environment, the team was able to validate the autonomy software in mission-relevant scenarios, including physical communications occurring within the vehicle's signal bus. This innovative testing environment proved invaluable when it uncovered a critical, undocumented interface discrepancy in the vehicle's flight control unit that would have been catastrophic in live flight test.

Recognizing autonomy development for C/U-T applications is a socio-technical engineering challenge, the team also opened their design aperture to incorporate a wider range of engineering disciplines and insights. For example, by working with the customer to gain access to uniformed pilots and operators, and then incorporating those aviators into the autonomy design and development process through our CSE and PIL events, our team was able to apply ethnographic and human-centered design approaches to craft more useful and impactful C/U-T autonomy solutions. Our recurring, multi-day CSE events brought our autonomy engineering team together with active fighter pilots and operators from across the services so they could collectively identify where and how advanced autonomy could function as a valued teammate to help the warfighters better accomplish their mission. The CSE process supported detailed examination of the pilots' current tactical and operational requirements, as well as their decision-making processes, identifying distinct mission-level, information-level, and presentation-level requirements. Using these insights, the autonomy team was then able to precisely craft autonomous capabilities that targeted critical deficiencies in mission execution, ensuring that the autonomy would seamlessly support the human operator's requirements rather than requiring the human operator adapt their practices to suit the autonomy. An added benefit of this approach was that it helped cultivate trust between the pilots and the autonomy system, which will be critical as the technology enters the force.

Fully implementing these innovative tools and processes was vital to accelerating development and delivery of useful, combat-relevant autonomous capabilities optimized for C/U-T. During the first phase of the program, it took approximately 12 months to address a specific DRM. During the final phase of the program, the team leveraged these new practices to design, develop, integrate, and test the full suite of autonomous behaviors for two separate DRMs in under nine months.

The accelerated pace of development and persistent changes in scope required the program management team adapt their standard business tools, too. Traditional detailed scheduling and reporting quickly gave way to simpler, higher-level, "agile" planning methods and products. This flexibility allowed the team to readily support the customer's abrupt program pivots. Implementing these new business processes demanded unprecedented levels of trust between the customer and program teams. Our team worked hard to cultivate and sustain these critical collaborative relationships from the outset through frequent and candid communications with our customer and associated DoD stakeholders. Without the flexibility these agile processes provided and the mutual trust they demanded, it is doubtful the program would have succeeded.

- ***10 points:* Define the unique practices and process you used to develop, lead and manage people?**

When the program began, autonomy was still an emerging area in Collins and RTX, just as it was in the DoD. There wasn't a large business organization dedicated to developing autonomy products or the associated workforce, which resulted in a leaner and flatter program organization during execution. Additionally, because the team was assembled from a variety of engineering disciplines, they were spread across the country—software developers in Indiana, Iowa, and Virgina; systems engineers in Indiana and Washington DC; flight test specialists in California and Iowa; and M&S personnel and program leadership in Texas. Despite their diverse engineering backgrounds and geographically-distributed makeup, the team quickly became a close-knit community as they routinely celebrated their ability to tackle the customer's most challenging problems while overcoming the program's significant VUCA.

Program leaders actively encouraged team-wide collaboration and creativity. Daily program meetings conducted over ZOOM provided an opportunity for any engineer to dial-in and learn about the most recent development activities and program challenges. The daily program meetings soon evolved to be more than just a status meeting; they became an open forum for active problem-solving. Project leaders also invited the broader team to attend and contribute during the customer's monthly Program Management Reviews (PMRs)—because the program requirements were constantly evolving, there were always ample opportunities for various team members to voice their potential solutions. Team members also participated in the recurring CSE and PIL events, which provided opportunities for the autonomy engineers to meet with and solicit feedback from uniformed operators on the autonomous behaviors they were creating. Empowering the team members to actively participate in these various meetings, even outside their assigned specialties, significantly enhanced the team's productivity and creativity.

The program also provided a unique opportunity for team members to do "something different." Pulled from classic engineering disciplines, including software, systems, M&S, and flight test, most engineers did not arrive on the program armed with a background in AI and autonomy, nor had they been exposed to the multi-disciplinary, socio-technical engineering approach critical to autonomy development. Engineering and program leaders therefore had to develop training materials to help educate the new team members on these fundamental concepts, and we frequently repurposed the training materials to support other customer and DoD stakeholder engagements. On several occasions, we were able to bring together members from our team and the customer's team for joint learning sessions, which helped foster additional collaboration, transparency, and trust.

Moreover, because autonomous behaviors are highly contextual, the team members also had to become exceptionally familiar with the mission use cases and current operational tactics. Absent this critical context, the engineering team could neither understand nor appreciate the operators' current challenges, and consequently they would be unable to develop the useful and impactful autonomy solutions the warfighters required to enable effective C/U-T. The requirement to ensure operational and tactical relevance materialized in the recurring CSE and PIL events that brought pilots and operators together with our autonomy engineers. An additional unique benefit for the team was the opportunity to learn current air combat tactics taught by both USAF Weapons School and USN Topgun instructor fighter pilots.

Throughout the program, management and engineering leaders made a concerted effort to reward stellar performers using a variety of mechanisms, including RTX-level "Rstars" performance awards. Program leaders also used key milestone activities, such as critical integration and flight test events, to identify superior performers for recognition by the customer and senior business leaders. Reflective of the rare and valuable experiences available to the team, and the team's collaborative and tight-knit community, the program witnessed historically low personnel attrition during the two-year award period. For example, the team had zero attrition among its software engineering personnel, a typically high-turnover skillset.

➢ ***10 points:* How did you leverage skills and technologies of your suppliers?**

Responding to the government's desire to develop and implement an open, flexible, and modular autonomy architecture, our team from the outset incorporated third-party partners and suppliers into our autonomy design and development process. To accelerate the integration and delivery of new autonomous capabilities, the team also developed a robust SDK and associated product documentation. Our industry partners, which included a mix of both large and small, classic and nontraditional defense suppliers, used the SDK to support their individual autonomy development activities. Additionally, to stimulate collaboration across a broader swath of the emerging autonomy ecosystem, we also supplied the SDK to our customer's partner-FFRDCs and other DoD stakeholders for independent review, as well as to the DoD's central autonomy repository. Whenever feedback was received from these various organizations, the team would quickly revise the SDK to enhance its usability.

Within the program execution team, members were always on the hunt for new opportunities to enhance collaboration and further accelerate capability development. Whereas the program initially relied on a traditional supplier model, the team quickly adapted the procedures. In place of the traditional model where a set of specific capability requirements was provided to a supplier along with preplanned delivery and integration milestones, our suppliers were instead invited to participate directly in our team's internal software scrums, identifying critical features and milestones and helping the team balance across the multiple competing program demands. Component and algorithm integration happened on a rolling basis as suppliers' capabilities were made available, helping uncover potential roadblocks earlier in the program. The suppliers were also invited to attend and participate in the program's PMRs, CSE and PIL events, and flight test activities. The additional open forums greatly enhanced collaboration across the effort.

The team established a similar, highly-collaborative partnership with a particular supplier charged with strengthening the team's understanding of current fighter tactics. This supplier helped facilitate the program's CSE events and guided the development of an operator-centric, tablet-based Human-Machine Interface (HMI) capable of supporting dynamic C/U-T operations. When discussing tactics, fighter pilots are apt to say, "it depends." Relying on the expertise embedded within its team, this supplier was able to coax the contextual "it depends" nuances from the uniformed pilots and then help steer our autonomy engineers as they crafted relevant, supporting autonomous capabilities. The supplier ensured that the capabilities we were developing would align to current tactics and fighter pilot decision-making processes, facilitating future pilots' trust in the autonomy and enhancing its usability. Similarly, the supplier was able to guide HMI development to ensure that critical information and formatting aligned to current fighter cockpit displays. The autonomy team's successful integration and demonstration event at the US Navy's Manned Flight Simulator (MFS) in September 2023 showcased this supplier's unique and valued contributions to the program. The day prior to the capstone event, Navy operational fighter aircrew received less than three hours total training on the autonomy tactics and the tablet-based HMI. The next day, the aircrew flew a set of complex C/U-T missions in the simulator in front of more than 80 distinguished visitors and DoD senior leaders. Because both the autonomy and the HMI had been crafted to support current fighter pilots, the human aircrew performed flawlessly, seamlessly teaming with their uncrewed, autonomous "little buddies" as they prevailed against an array of advanced enemy threats.

SECTION 4: DEALING WITH PROGRAM COMPLEXITY

(VOLATILITY, UNCERTAINTY, COMPLEXITY, AMBIGUITY, or VUCA)

Value: 25 points
Use 12 pt. Times Roman typeface
Please respond to the following prompts:

- ***10 points:*** **Describe UNIQUE areas of VUCA faced by your program and why. (Please avoid the issues surrounding Covid-19 pandemic, which was faced by all programs.)**

The team encountered significant VUCA, both internally and externally driven, during the period January 2021 through December 2023, as they raced to design, develop, integrate, test, and deliver the DoD's first collaborative mission autonomy solution for C/U-T. This included successfully navigating the volatility accompanying a massive corporate reorganization, uncertain and unsteady funding streams, complex and rapidly evolving technical objectives, and ambiguous program expectations and requirements.

• **Volatility.** On 1 July 2023, RTX announced a comprehensive corporate realignment, eliminating Raytheon Intelligence & Space (RIS) as a business and consolidating and optimizing several key mission areas from across the RTX businesses. Collaborative mission autonomy was a target for optimization, and the collaborative mission autonomy team within RIS merged into Collins under a new Battle Management, Command & Control and Autonomy (BMC2&A) business. The reorganization introduced significant volatility into the program. Legal disclosures, technology sharing agreements, information technology, charge numbers, and several other business processes all had to be updated and tailored. Additionally, there was a pressing need to identify immediate technology synergies and efficiency opportunities within the new business based on the reorganization. Amidst the multitude of challenges already inherent in the program, portions of the team had to suddenly divert their attention and resources to help stand-up the new business and familiarize the new leadership teams. Business cases justifying the collective program investments had to be refined and consolidated technology roadmaps had to be developed. Additionally, the new leadership teams had to re-establish the close, collaborative relationships with the customer.

• **Uncertainty.** Throughout execution, the program encountered significant funding uncertainty as the customer navigated looming government shutdowns, potential (and sometimes realized) reprioritization and reallocation of their earmarked program funds, and untimely delays in contract phase awards. The most significant funding challenges erupted in late 2022 when the DoD cancelled the customer's planned UAS vehicle. The subsequent pivot to a new UAS aircraft and a new DRM required the customer quickly reallocate program funding, and we received word that our individual allocation was being trimmed. Forced to minimize costs by either reducing personnel or reducing program duration, our program leaders elected to reschedule the program and use the existing staff to deliver the desired capabilities early. But then, several weeks later, the customer decided to instead terminate another performer's contract and allocate all remaining funds to our team. The newly realized funding allowed the team to return to its original schedule, but shortly thereafter the customer directed the additional funding also be used to support a separate, concurrent spin-off autonomy program. The abrupt changes in program funding rippled through the organization as the team's staffing profiles rapidly see-sawed between over- and under-staffed. Even once the staffing had stabilized, additional funding challenges remained. The multiple program excursions had complicated the customer's contract mechanism, and by March 2023, the promised funding increment still had not been executed. Moreover, the excessive delays had triggered additional, mandatory higher-level government reviews, which promised to defer the funding even longer. Program leaders were forced to issue formal stop-work orders to our suppliers, and the internal team was directed to immediately minimize program charges until further notice. Fortunately, a full internal stop-work never materialized. The contract modification was finally executed a few weeks later and the suppliers' contracts were quickly reactivated.

• **Complexity.** The complex, contextual nuances of AI and autonomous behaviors are typically underappreciated in government and industry. Autonomous behaviors built for one use case rarely directly apply to another use case, and open architectures do not necessarily offer true plug-and-play integration across autonomous system subcomponents. Underscoring this complexity with our customers, and then helping them educate their various stakeholders, was a persistent requirement throughout the program. Even then, pivots in program direction still occurred, forcing the team to adapt and adjust. For example, the DoD's abrupt termination of the intended integration platform mid-way through Phase 3 necessitated one such shift. The "Phase 3 Pivot," as the team called it, necessitated a new DRM, new autonomous behaviors, new HMI, and new integration and demonstration events—essentially an entirely new program with only ten months remaining in the final phase contract. The addition of the separate, concurrent autonomy spin-off program, involving yet another DRM and another target platform, added to the technical and programmatic complexity. Responding to these various changes, the team completely replanned the remaining program schedule three times over a four-week period. When the dust finally settled, the team was committed to supporting a capstone demonstration at the Navy's MFS the same week as the spin-off program final demonstration. Even then, additional integration complexity lurked, because the customer thereafter requested the team adjust their MFS demonstration plan to incorporate an additional platform. The additional MFS scope required partnering with another vendor and government program office on an already tight timeline to integrate our collaborative mission autonomy features into that platform's displays and communications systems. Moreover, the pair of integration and demonstration events were scheduled to take place only weeks before the final flight tests, which brought its own set of complex regulatory and range-safety requirements that govern multi-ship autonomous aircraft flight testing to the forefront.

• **Ambiguity.** As a cutting-edge R&D effort, the team was bound to suffer through some degree of ambiguity regarding program requirements and expectations. However, these ambiguities were amplified by the nature of the autonomy technology, the aggressiveness of the program schedule, and the desire of the government stakeholders to use the program to assert new roles, responsibilities, and contractual models for future DoD software acquisition efforts. Without customer-provided requirements for C/U-T autonomy, the team was expected to generate the autonomy requirements based solely off the high-level DRM. Given the aggressive timeline, that meant CONOPS development, requirements generation, software development, and aircraft modification processes all had to proceed concurrently. The ambiguity further cascaded into the test and evaluation events. Unlike traditional flight test programs, there was no exhaustive list of performance values and associated confidence levels that the autonomy technology was expected to achieve. Additionally, due to the nascent state of the technology, the various government stakeholders had not yet aligned on suitable Measures of Performance (MOPs) and Measures of Effectiveness (MOEs) to evaluate the autonomy's performance independent from the UAS platform in combat-relevant scenarios.

➢ ***15 points:* Explain how your team responded to these challenges. What changes did you make, what were the results?**

Despite these numerous VUCA challenges, the team excelled. They closed out Phase 2 with a successful flight demonstration in August 2021, and then again demonstrated robust collaborative mission autonomy solutions for two new combat-relevant DRMs during separate events in September 2023 before pivoting to a capstone live, multi-ship flight test series a few weeks later. Success on the program depended upon a strong, collaborative relationship with our government customer and our program partners, as well as open and candid dialog, frequent uniformed operator feedback, and agile processes flexible enough to rapidly respond to the evolving program requirements and expectations.

Frequent and transparent communications with the government at the program manager and chief engineer levels set the tone for the entire team. Through our ongoing dialog with the customer, our team discovered that both the government and industry were often confronting similar hardships, which typically could be traced to the three systemic challenges plaguing the current autonomy ecosystem—misunderstandings about AI and autonomous technologies; competing projects and programs vying for attention and funding; and evolving acquisition goals. Since the challenges often were similar, there were ample opportunities to collaborate to achieve a mutually-beneficial solution. For example, the customer frequently requested our team support their additional engagements with other key DoD stakeholders to help increase awareness of advanced AI and autonomy capabilities. The customer also directed more frequent PMRs and technical interchanges with supporting FFRDCs and other DoD agencies to better collaborate on the program's evolving requirements and expectations. The lack of clear autonomy-related MOPs and MOEs also became an area of robust collaboration between government and industry. Collectively, we were able to craft the first quantitative metrics that aided assessment of an autonomous systems' reliability and effectiveness within a complex, operationally-relevant environment.

As the partnership with our customer steadily grew through our frequent, focused, and transparent communications, program leaders became more willing to offer the customer additional visibility into their planning and execution processes. For example, the team regularly provided the customer with detailed reviews of their risk management watch items. These artifacts provided the customer with clear insights into how program-level VUCA was rippling through the project and impeding progress, and they helped facilitate candid conversations when evaluating potential changes in project scope and schedule. The nature of the contract, which limited financial risk to the company, also helped facilitate the open exchange of information, and the customer responded with a similar level of flexibility and pragmaticism when addressing any concerns that the team raised. The trust that extended between the two parties proved to be extremely beneficial to both throughout the program.

The team in-turn extended the principles of collaboration, open and candid communications, and trust to their suppliers. As mentioned previously, the team discarded the traditional supplier contractual processes in favor of a more integrated team-based approach, inviting the suppliers into the team's software scrums. Suppliers were also encouraged to actively participate in the customer's PMRs, interact with uniformed operators during the CSE and PIL events, and be front-and-center at demonstration and flight-test events. The partnerships that grew throughout the program were critical to program success. Leveraging the unique pockets of expertise among our suppliers, we were able to: deliver a broad set of documented requirements to support future autonomous system design; craft a practical and meaningful set of autonomy MOPs and MOEs; design and implement a useful, operator-centric HMI; and accelerate the development and delivery of autonomous C/U-T capabilities that will be immediately useful and impactful for the warfighter.

As the team confronted the numerous VUCA challenges during program execution, they also established a broad collaboration network across the various RTX businesses. Sharing lessons learned across the organizations, even if not directly applicable to collaborative mission autonomy technologies, was immensely helpful to program leaders as they tailored their processes to respond to the programmatic complexities. Despite the volatility that initially accompanied the RTX reorganization, the corporate realignment helped strengthen the teams' connections and collaboration with other related efforts.

Due to the ambiguous requirements and technical complexity within the program, obtaining early and frequent feedback from uniformed operators on the autonomous capabilities being developed was essential. The team's recurring CSE and PIL events offered the primary feedback opportunities. The team augmented these events with expertise from its various suppliers and additional engagements with other DoD stakeholders. Soliciting feedback was only half the battle though; the team then had to alter their development efforts accordingly based on the feedback.

Successfully implementing agile development and management processes proved invaluable in this regard. Agile provided the team with the programmatic and scheduling flexibility they required to adapt to customer and operator feedback, as well as overcome the significant VUCA challenges that frequently reverberated throughout the program. The benefit of agile was made most apparent during the "Phase 3 Pivot," when the entire existing program plan was instantly obliterated. Moreover, there was insufficient time remaining in the program to launch a comprehensive replan to support the two concurrent efforts. Using agile processes, the teams were able to quickly identify and prioritize critical tasks, monitor their progress toward completion, and assess the criticality of unfinished work. When new technical or scheduling difficulties emerged, agile processes helped the teams quickly reprioritize their tasks accordingly. As the two teams sprinted towards their separate final integration and demonstration events, tracking the critical dependencies between the efforts became especially challenging, and program leaders developed additional tools to help the teams better align their vital resources and personnel.

The value of an agile approach was also revealed in the final weeks of the program. Originally, the concurrent spin-off autonomy program was expected to culminate with a live flight test, but with only a few weeks left in the program, the customer's planned fleet of UASs were suddenly rendered unavailable. Because of the demonstrated success of our agile processes and our close relationship with the customer, in less than a week the team was able to propose additional, in-scope work that would apply the newly released flight test funds to critical backlog tasks. The customer approved the new plan almost immediately, resulting in a significant increase in delivered autonomous capability by program's end.

SECTION 5: METRICS

Value: 15 points
Use 12 pt. Times Roman typeface
Please respond to the following prompts, where predictive metrics indicate items that provide a view of how yesterday's actions and today's actions will affect the future timeline, cost or other requirement. Provide charts/graphs that illustrate performance to these metrics:

- **What are your predictive metrics?**

Appreciating the potential VUCA that might buffet this program during execution, program leaders determined that traditional program metrics and reports would likely be inadequate. Instead, they implemented an agile development and reporting model, and the primary predictive metric during program execution became sprint velocity. To help support evaluation of this critical metric, program leaders created graphical representations that illustrated each sub-team's sprint velocity and their predicted milestone closures. These results were frequently shared with both the team members and customer representatives.

Augmenting these engineering-focused predictive metrics, program managers also implemented their own metrics to help guide program execution. For example, given the dynamic nature of the program, cost data became a critical metric, and it was reviewed weekly to ensure functions were charging correctly and the contract would not overrun. Delayed supplier invoices and material receipts complicated the process.

Name runs and headcounts were also closely tracked to ensure the team had the right skill mix and appropriate staffing to successfully execute the program. The program management team augmented these reports with additional automated staffing tools to help highlight and communicate evolving personnel requirements to functional managers across the broader organization.

One metric that was not required by the contract and deliberately not collected was Earned Value (EV). Program leaders realized that attempting to track EV on this program, with all its uncertainty, would have saddled the team with endless replanning cycles for minimal value.

- **How did you perform against these metrics?**

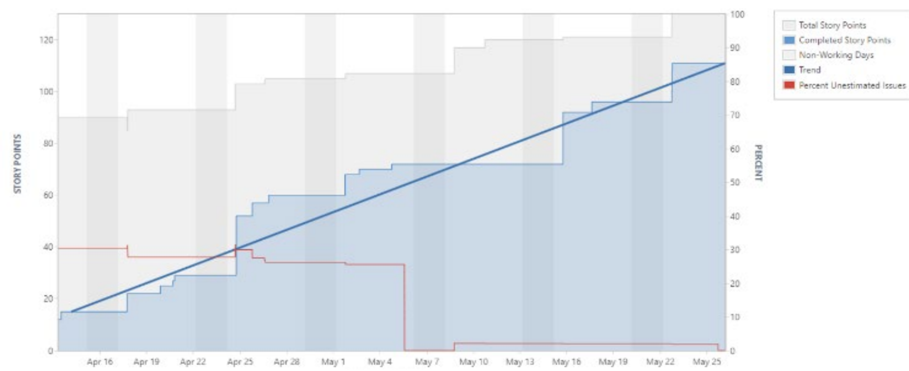
As the program adopted agile methods and processes, measured sprint velocity quickly became the best predictive indicator of program success. The team was fortunate that their historically low attrition translated to a relatively stable velocity metric during program execution. This allowed program leaders to craft realistic development plans, and then quickly adapt those plans in response to customer-directed adjustments in program scope and schedule. As a byproduct of the frequent program adjustments, the team became exceptionally adept at calculating agile story points for each task, as well as identifying and accounting for critical resource constraints that might affect the planned sprint velocity.

At the business execution-level, the scrutiny placed on program cost data helped ensure planned costs closely matched actual spending amounts.

- **How do your predictive metrics drive action toward program excellence? Please provide examples.**

Given the abrupt and frequent changes that occurred during program execution, evaluating and tracking sprint velocity became essential. Using the sprint velocity metric, program leaders could better prioritize and assign tasks to their various sub-teams, and then closely monitor progress and forecast eventual completion. Velocity reports and graphical displays also helped identify potential challenges earlier in the sprint, which allowed the teams to take corrective actions sooner and still achieve the desired milestones.

Sample Milestone Burndown Display



Version	Status	Progress	Start date	Release date	Description
Initial Test	RELEASED			14/Mar/23	
Baseline	RELEASED		13/Mar/23	15/May/23	Establish a basic runnable software baseline upon which to build capabilities fo[redacted]
Milestone 1	RELEASED		14/Apr/23	25/May/23	Basic ability to run software in such a way as to resemble the[redacted] DRM, but without hitting all requirements
MVP	UNRELEASED		01/May/23	16/Jun/23	Minimum viable product that meets the bare requirements of the DRM
[redacted] VC Demo 1	UNRELEASED		22/May/23	13/Jul/23	Additional fixes, integration, and improvements on MVP
[redacted] Flight Test Series 1	UNRELEASED		12/Jun/23	27/Oct/23	Ground test and execute flight test

The graphical displays of story point burn down also provided critical feedback on our engineering processes. During early program sprint reviews, leaders observed the majority of story points were being burned down immediately prior to the sprint's end. This indicated the stories likely needed to be further decomposed so that the teams could better monitor their progress during the sprint. Armed with this feedback, the teams steadily improved their story crafting and forecasting abilities to achieve a more stable burndown rate across the program.

When confronted with customer-directed changes in program execution or timing, these metrics helped the team quickly evaluate the repercussions across the program and then share their assessments with the customer. These tools also proved invaluable as the team balanced across the competing demands of the two separate DRM efforts during the final stages the program. Fortunately, confidence in the teams' sprint velocities and planning processes helped program leaders accurately forecast staffing requirements, task assignments, milestone completion dates, and capability completion criteria to better synchronize the development and integration activities between the two efforts.

Finally, although seemingly minor, the early focus placed on monitoring spend plans also contributed to program excellence. Because the forecast and actual spends were often closely aligned, the finance management team became more willing to trust program-generated financial data, eliminating the need for extensive financial reviews. This allowed program leaders to devote more of their contract dollars to accelerating autonomous capability development.