AVIATION WEEK NETWORK

2020 Program Excellence Awards

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Gregory Hamilton
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Acknowledged, agreed, and submitted by

Nominee's Signature ____________ Date 6/25/20

Nominee's Name (please print): Greg T. Stonesifer

Title (please print): Program Director, EVA Space Operations Contract

Company (please print): Collins Aerospace

AVIATION WEEK NETWORK 2020 Program Excellence Awards

## NOMINATION FORM

Name of Program: Extravehicular Mobility Unit (EMU) for the NASA Space Shuttle and International Space Station Programs

Name of Program Leader: Greg Stonesifer

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☒ Customer Approved

- Date: June 24, 2020
- Contact (name/title/organization/phone): Matt Bordelon/NASA/Contract Office Representative/281-483-7096

☐ Supplier Approved (if named in this nomination form)

- Date: ____________________________________________
- Contact (name/title/organization/phone): ______________________________

## CATEGORY ENTERED

Refer to definitions in the document "2020 Program Excellence Directions." 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**

☐ 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

## Point Distribution

| Executive Summary: Make the Case for Excellence (15 pts) | | |
|---|---|---|
| **Metrics**<br><br>**10 pts**<br><br>Predictive Metrics (10) | **Program Volatility/ Uncertainty/Complexity/ Ambiguity**<br>**25 pts**<br><br>Describe overall VUCA (10)<br><br>Cite examples of team response (15) | **Organizational Best Practices & Team Leadership**<br>**40 pts**<br><br>Innovative Tools and Systems (15)<br><br>Unique Innovative Processes for People Development/Knowledge Transfer (15)<br><br>Unique Practice es for Customer Engagement (10) |
| **Value Creation (10 pts)** | | |

## Abstract

In 150 words or less, why is this program excellent in terms of execution?

*(12 pt. Times Roman)*

Through the sustainment of the Extravehicular Mobility Unit (EMU), or spacesuit, Collins Aerospace engineers have enabled NASA astronauts to leave the safety of the Shuttle or International Space Station (ISS) to venture into the vacuum of space more than 200 times – flawlessly. Excellence in execution is a defining factor of this program where human life is at stake.

The sustainment program includes the maintenance, refurbishment, hardware development, logistics and real-time mission expertise for the compliment of EMU flight and training hardware. This program has extended four-fold the anticipated 10-year life of the EMU during the initial years of the Shuttle program, and saved NASA and taxpayers more than $56M in cost avoidance (2015-2019) through rigorous adaptation and evolution of systems and hardware. Collins engineers have afforded NASA the continued use of the EMU for human space exploration for more than 40 years.

## Purpose

Provide a 150-word description of the purpose of this program, spelling out all acronyms and correct acronyms

*(12 pt. Times Roman)*

The EMU (Extravehicular Mobility Unit, or "spacesuit") Sustainment program provides NASA with the ability to pursue human exploration of space.

The EVA (Extravehicular Activity) Space Operations Contract with NASA is the mechanism by which Collins Aerospace ("Collins") provides the hardware, facilities and expertise to sustain the EMU. The Collins team is an integral part of Mission Support during each EVA (or "spacewalk"), monitoring the performance of the EMU in real-time as the astronauts step into space, and during all training activities on the ground. Collins builds, refurbishes, assembles and extensively tests the EMU hardware when it is brought back to Earth, ensuring mission-ready systems are available for each flight. The sustainment of the EMU through this systematic and rigorous process has extended the use of the EMU to four times its original 10-year life expectancy.

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

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

*(12 pt. Times New Roman)*

Known as the world's smallest spacecraft, the Extravehicular Mobility Unit (EMU) provides everything an astronaut needs to survive in the vacuum of space – oxygen, water, ventilation, thermal control, CO2 removal and communications. When an astronaut steps out of the International Space Station (ISS) during an EVA ("Extra-Vehicular Activity," or spacewalk) they are trusting their survival to the development and sustainment efforts of the Collins engineers.

Made of more than 18,000 parts, the EMU was designed in the 1970s for the Shuttle program. NASA's vision was to create an exploration suit that would allow mobility outside of the Shuttle, enabling exterior experiments and repair work on the vehicle during flight. An outgrowth of the Apollo suits, the Shuttle EMU suits advanced the technology developed a decade earlier and adapted it for zero gravity, protected it from micrometeor penetration, and gave the astronaut up to seven hours of life support. The EMU suits enabled the building of the ISS on spacewalks from the Shuttle, and have been used continuously on the ISS for repair work.

New suits have not been manufactured since those first years of the Shuttle program. As the designer and prime integrator for the original EMU suits, Collins was awarded the first EMU contract in 1976 for the maintenance, refurbishment, hardware development, logistics and real-time expertise for the EMU flight and training hardware. Our current contract, the EVA Space Operations Contract (ESOC), was awarded in 2004.

Over the course of 40 years and more than 200 EVAs from the Shuttle and the ISS, Collins engineers have been dedicated to extending and adapting the use of the EMU to meet NASA's goals for human exploration. This includes ensuring hardware availability for nominal and contingency operations; conducting rigorous evaluation processes for the hardware and systems; ensuring suppliers and their products are available for refurbishments or manufacturing; and the employing processes and skills to certify new products or suppliers to maintain EMU operations.

Performing these tasks at a level of excellence has supported human exploration of space, enabled the building and maintenance of the International Space Station, saved NASA more than $56M (2015 – 2019) of cost avoidance and, most importantly, kept humans safe while operating in the harsh environment of space.

(Do not exceed 10 pages in responding to the following four descriptions; allocate those 10 pages as you deem appropriate, but it is important that you respond to all four sections.)

**VALUE CREATION** *(Value: 10 pts)*
**Please respond to the following prompt:**

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

At Collins Aerospace, we never forget who we are working for and are proud of our role in supporting human exploration of space. We know that the EMU is not just a piece of hardware, it is a life support system for an astronaut who is putting his/her life in our hands in the name of advancing science and our understanding of space. Being part of such important missions is a defining aspect of the Collins culture, and what motivates our engineers every day.

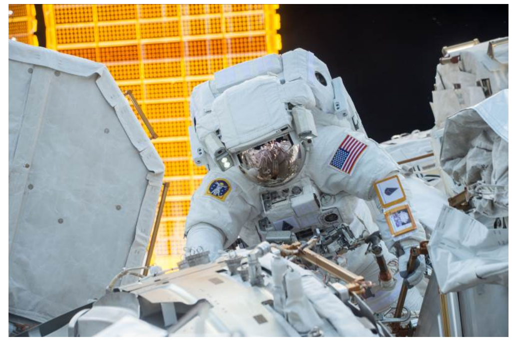
Meeting the challenges of the EMU Sustainment Program has expanded our understanding of the operations of hardware in space, which informs our future development activities. Through continuous data collection we have identified critical sense data (additional sensors or unnecessary measurements) that can give insight into both suit performance and crew health. For example, the EMU uses only one CO2 sensor in the ventilation loop at the inlet to the helmet. We used to determine the rate at which CO2 is being removed to understand the crew member's true metabolic output. Currently that is calculated by O2 consumption, but that data can be skewed by suit lead rate, CO2 removal system rate fluctuations, or other variables that cannot be determined with only an inlet CO2 sensor. Thus, a second CO2 sensor and its data can be very useful in the next suit design.

We've also learned how to expand the margins of the hardware. The EMU has encountered several scenarios where it has been used that were not part of the original design parameters and may not occur to new suit designers. One instance was a work site where high-intensity motions were needed to assemble a piece of hardware in a cold environment. This occurred prior to a low-intensity task in a warmer environment. These short duration, large changes in temperature and extreme fluctuations in crew metabolic rate identified transient cooling concerns. When this was modeled, we realized these parameters were outside the envelope of the design of the suit, which explained the suit's reactions. This resulted in procedure updates to slow the transitions in cases like this as well as updates in design criteria for new space suits.

We've been able to use our work on the EMU as a platform to establish best practices for long-term sustainment of complex systems. Some of these systems are currently in the Environmental Control and Life Support System (ECLSS) of the International Space Station (ISS), such as the Oxygen Generation Assembly, the Water Processor Assembly, Thermal Amine system and the Sabatier reactor. Other systems exist on the CST-100 and Orion spacecrafts to be launched in the future. This experience in long term sustainment has parlayed into other applications and long term use on submarines and other defense platforms.

The EMU Sustainment Program is a high-profile contract, serving to attract new talent to the business. The corporation has been the beneficiary of highly skilled young engineers eager to put their skills to work on complex systems that further space exploration.

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



The EMU Sustainment Program has been integral to the operation of the Space Shuttle and the ISS. NASA has relied on this program to provide the ability to venture into space to build and maintain the ISS, to advance the science conducted and the information collected, and to continuously improve the experience of humans working in space.

Through the innovations and management of the Collins team, NASA has been able to dramatically extend the life of the suit, saving the agency and the taxpayer millions in new suit development costs over the life of the program. The EMU was developed for a ten year lifespan to support the Space Shuttle. That ten year program turned into a 20-year mission on the Shuttle, and this year marks 20 years on the ISS.

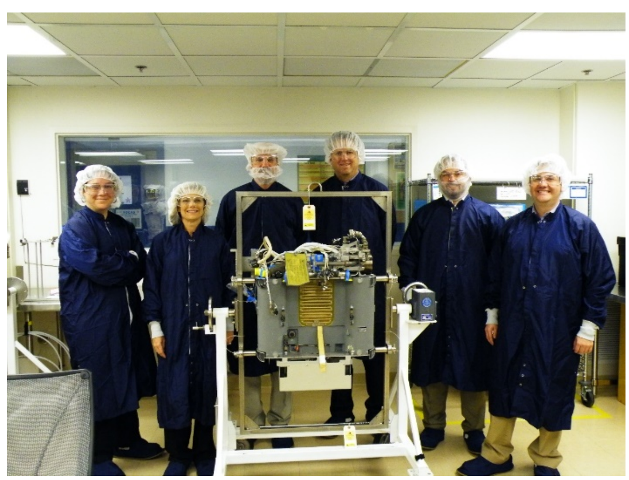
Transitioning the EMU from the Shuttle to the ISS program required certification of the hardware for long-term storage and multiple uses on the ISS. During the Shuttle years, the suit was returned for inspections and testing following each mission, spending no more than three weeks in orbit. Without this option on the ISS, the team developed a test protocol to run the hardware through 25 EVAs on the ground. This would represent the maximum number of EVAs a suit would see during its stay on the ISS. In addition, the team reviewed hardware fleet leader reports on each component to determine what minimum test and/or maintenance would be required during its stay. As each suit came back, inspections and testing were done in order to lengthen the duration from two, to four, to six years on the ISS.

This continuous maintenance and refurbishment of the suit has not only saved money on production of new suits over the past four decades, but it has provided a platform to test new suit enhancements and technology for next-generationsuit applications – to the Moon and Mars.

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

Being part of the EMU Sustainment team is a sought-after assignment within Collins Aerospace, attracting those who realize the importance and criticality of protecting a person's life for the harsh environment of space exploration.

The program offers team members the unique ability to develop spacesuit expertise and experience. The global community of experts in space suit hardware is small, so the opportunity to develop expertise in this area is very attractive. This project has been, and still is, instrumental in training the next generation of suit designers, operations personnel, technicians, trainers and reliability and safety engineers. Several of these talented people have begun work on the transition to new technology designs of the next generation suit. When a transition from the old to the newly-designed space suits begins, there can be a seamless switch to the operations and sustainment of the hardware because the basic knowledge of the space suit team will be in place.



*NASA observing EMU Primary Life Support System Refurbisment with Collins Aerospace*

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

Human space travel has captivated Americans since John Glenn first orbited the earth in 1962. The EMU Sustainment Program keeps that fascination alive by enabling every U.S. spacewalk from the ISS. Each time a spacewalk is streamed into a classroom, this program contributes to enthusiasm of budding scientists, engineers and mathematicians, helping them see a world beyond their own and a future bigger than themselves.

Without the EMU Sustainment Program, the ISS could not have been assembled. The benefits of having a continuously-inhabited orbiting platform for science and exploration, and international cooperation, would not have been realized. Even after its completion, the maintenance of the ISS for research and discovery has been dependent upon the availability and sustainment of the EMU. Not all situations can be done using robots, and it takes a human to assess and reason where robots cannot. One example of this need for a human assistance occurred during ISS assembly when a bolt was getting stuck during installation and the crew saw that it was galling and generating metal particles. The procedure was stopped and the next day the crew went back out on a spacewalk with a tool fashioned from a toothbrush on the end of a drill to remedy the issue. The brush was used to clean the threaded hole of its metal particles, then with lubrication applied, used to lubricate the hole's threads. Without a human in a space suit, these types of assembly issues could end the entire space station's mission.

The EMU was also integral to the performance of other space platforms and satellites. For example, it was astronauts wearing the EMU who repaired the Hubble Space Telescope in-flight, enabling the breath-taking images of our galaxy it has been sending back since.

With each step out into the vacuum of space in the EMU, we learn more about human survival in space – lessons that will take us back to the Moon and onward to Mars.

**METRICS** *(Value: 10 pts)*
**Please respond to the following prompt:**

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

*(12 t. Times Roman)*

To the team charged with sustaining a human life in space, every aspect of the effort is critical and excellence must continually be demonstrated. A failure of any part of the EMU that would force a termination of the EVA or put the astronaut's life at risk is unacceptable.

Thus, the use of typical sustaining program metrics, such as mean time between failures (MTBF), are not applicable. The program is necessarily designed to plan ahead and understand and predict when or where a failure will occur before it ever happens. By using an interval-based approach to evaluate hardware life, the program can make a fleet-wide assessment of hardware life expectancy. During the period of 2015-2018, Collins life extensions have saved NASA over $56M by extending the life of hardware rather than replacing it.

The metrics for this process include: usage times (which is made up of operation times in the environment, ground operation time and testing operation times); operating environmental conditions; configuration of the system while operating; and parametric test results against the specification values.

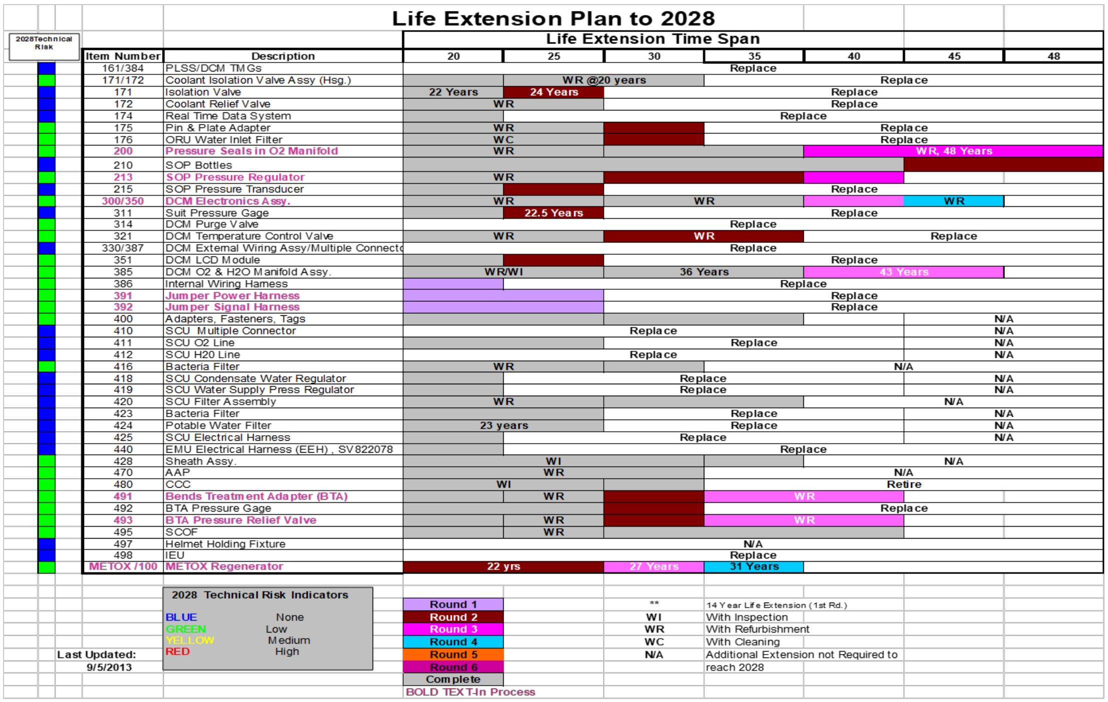
There is an incremental approach to the original design where it is considered more cost effective to review certain hardware for varying lengths of life extension in relation to the known qualities and experienced history with the component or subassemblies. For example, a metal plate that experiences minimal mechanical loads could be reviewed and extended for 10-20 years at a time, whereas a complex assembly that includes age sensitive materials may require more frequent reviews. This approach is used to save cost versus an entire EMU review every two years.

The process is formalized with these steps:

1. Determine the start date for the next life extension at least three years ahead of the first expiring serial number of that component. This allows for recovery of all possible outcomes, with the exception of designing hardware for replacement (if this outcome has a high probability the process would start even earlier).
2. Determine an interval duration for the next life extension goal (e.g. 2, 5 or 10 years)
3. Establish a component fleet leader serial number candidate based off of operational time, age of hardware, and other conditions.
4. Develop a Fleet Leader Plan that describes, inspections, testing, evaluations (destructive and no destructive), literature searches, etc. for that specific serial number item, and document for peer review and approval
5. Execute plan
6. Document the results, analysis and recommendation
7. Present findings and obtain approval from peers and the program.

The outcomes of these evaluations can determine the life extension interval and could change that interval from the initial plan based on the results. Typically, the outcome falls into these categories:

- Straight life extension – no further work required to set a new life date
- Refurbishment – e.g., replace softgoods at a specified duration, implement a test after a certain period within the interval, reset a control, etc.
- Replace – build to print new hardware
- Replace – design new hardware (usually due to materials or supplier obsolescence)




*Sample of Life Extension Plan for the EMU's Portable Life Support System (PLSS) sub components*

**DEALING WITH PROGRAM CHALLENGES (VOLATILITY, UNCERTAINTY, COMPLEXITY, AMBIGUITY, OR VUCA)**
*(Value: 25 pts)*
**Please respond to the following prompts:**

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

The VUCA that the program has faced over the years is diverse.

**Volatility.** The ability to maintain technologies, parts and raw material formulations for a system that was designed and qualified in the late 1970s is extremely challenging. Any change in these parameters forces a new qualification process that can be as simple documenting literature rationale, up to developing a new design and performing an extensive qualification program. As the design ages the latter tends to be the norm. The importance of being able to life-extend as much hardware as possible is critical to keeping costs down; however, the emphasis on safety cannot be compromised.

**Uncertainty.** In addition to obsolescence, the program is unsure how long NASA will want to continue to operate the EMU. This means that lifetime purchases to secure replacement parts from vendors may be for an uncertain lifetime of the EMU, forcing additional vendor purchases of old technologies or product lines no longer in production. This uncertainty of the EMU's use also pushes limits of hardware that has no analog in industry. For example, the use of electronic components beyond 25 years has very little data available in commercial applications. In some cases the US military has similar usage, but they don't always operate in the same environment, or they stockpile old stock replacement parts if failures occur. Some items will deteriorate with age even if they are stored in controlled environments, so this methods is not always successful.

**Complexity**. No one subsystem of the EMU is overly complex, but the integration of all the subsystems is very complex. Understanding reactions outside of design parameters in adapting the hardware to new tasks has been challenging. Many times this requires additional testing to validate the ability to successfully and safely perform the tasks. This evolution has shown us that the EMU does have margin beyond its original design, but we are still learning its full capabilities.

Any potential upgrades in data transmission sensor feedback, materials, etc. have been difficult to implement as any change can impact other older subsystems within the EMU. For example, a material must be nonflammable in 100% oxygen environment, and it must not leach out chemicals that can foul the sublimation process used for cooling. Without testing each change of material in the EMU's system, there is no way to truly know if it will affect the EMU. It was learned over time that some materials used on ISS outgas chemicals that end up in the air condensate of the ISS ventilations system. That chemical then is introduced into the EMU water system, either by the recycled ISS water used to provide cooling in the EMU or by the ventilation condensate that enters the EMU water system. Some of the chemicals can "foul" the sublimation process, which will cause the crewmember to get too hot. Continual water testing to determine the root cause chemical fouling and ensure these chemicals are not introduced on the ISS products is a constant task for Collins to protect the success of an EVA.

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

*(12 t. Times Roman)*

**Volatility.** The team proactively surveys all suppliers of commonly replaced parts or raw materials, as well as those items that may need replacement as a part of an upcoming life extension process. This survey asks many questions related to their product such as: are there plans to change a process or product chemical or material formulation? Is the manufacturing facility going to move, and is the vendor planning any new products that could discontinue current product lines? In addition, the team works closely with vendors if a supplier has a change or anticipates a change, to help them in minimizing the recertification process, such as identifying testing which could eliminate recertification.

For example, when it was determined that the EMU would be servicing the ISS beyond the anticipated 2010 end-date, we prepared by purchasing of many pieces of hardware that were needed to replace aging items. To minimize costs, Collins went back to the original manufactures of the hardware. Many had been sold or no longer produced the specific items. In one case Collins was able to purchase the component design and have another company fabricate and test it. With some detailed analysis and focused testing, Collins was able to reduce the cost of an otherwise costly and lengthy certification program for a new design from a different manufacturer.

**Uncertainty.** The team has developed a process to use when purchasing replacement hardware to try and anticipate the extended use of the EMU. It involves understanding the usage model of the EMU over the last several years, along with the individual life of all the components. Taking that data and then extrapolating forward to a point in time, the team has been able to accurately predict the additional hardware along with spares that can keep the inventory of hardware right sized, but cover EMU usage beyond published dates.

Collins has worked to develop long range logistics planning factoring in hardware life expectancy, life extension efforts, inventory assessments, crew usage rates, and failure histories to predict when a specific component needs stock replenishment. This is a continual process as any of these parameters can change. With this data, informed decision packages with risk assessments can be provided to the customer to proactively meet upcoming hardware needs.

These risks are captured in a risk register early on and tracked on a monthly basis through our One EVA Risk Board (ORB) and then presented to NASA. Below is an example of some risks and our risk register. Many risks that are tracked are in the supportability category. These are tracked even with low likelihood scores (low overall risk scores) to ensure we continue to survey and communicate with the vendors years before we need additional supplies.

| Risk Title | Cause (IF) | Effect (THEN) | Likelihood | Consequence | Risk Score | Category | Risk Mitigation | Risk Response | Status & Comments |
|---|---|---|---|---|---|---|---|---|---|
| SS: LCVG Liner Fabric | Supplier unwilling to provide material | Inability to support flight needs for LCVGs | 3 | 4 | **12** | Supportability | Amass inventory<br>Extend shelf life of inventory | Perform replacement task if liner is needed | 1) Task has been intiated.<br>2) The linerless evaluation has demonstrated the need for a liner<br>3) Scope and schedule have been developed and kick off has been scheduled |
| SS: Vectran Knit | Supplier removing knitting capability | Inabiity to support flight needs for Glove TMGs | 3 | 4 | **12** | Supportability | Amass inventory | Perform replacement task | 1) Last buy (received) supports glove production through 2021 with increased build and tasks support<br>2) Task has been initiated. Scope and schedule has been generated<br>3) Material on order |
| METOX Regenerator | Prime ISS METOX Regenerator failure and backup regenerator malfunction | Possibility of increased crew time and decreased EVA capability due to METOX Regenerator workarounds | 3 | 4 | **12** | Mission Success | Perform reassembly of cert regenerator (s/n 00001) in FY17, facilitating availability of chamber regenerator (s/n 00004) as a temporary LON early in FY18 and as a permanent LON unit post-AEA life extension efforts scheduled to be complete by FY19. This facilitates full LON capability for ISS METOX regeneration prior to current prime and backup units end of life (and future continued use via waiver) in FY20. | Response plan approved via ISS Sparing Review and SSCN funding in FY16. See detailed mitigation plan for s/n 00001 reassembly, FY18 s/n 00004 replacement as chamber prime unit, s/n 00004 AEA LE support, and eventual s/n 00004 availability in FY19/20 as a dedicated LON unit (or as an ISS backup unit if launched to orbit). | Back up METOX regenerator may not perform due to Torlon ball valve sticking after many years on orbit of unit non-activation.<br>S/N 00001 delivered. S/N 0004 FY18/19 AEA efforts beginning. |
| Chamber Umbilical Inventory | SCUs/IEUs are not replaced or life extended | EMU Vacuum runs (MEGA unit man rating) cannot be performed in the 11 Foot and SSATA Chambers | 3 | 3 | **9** | Mission Success | 1) Refurbish/deliver 7 SCU CMCs and 3 IEU CMCs<br>2) Build 7 new DCM CMCs and 7 I-330s<br>3) Refurbish/ship replacement hoses for s/n 1007, 11ft. Chamber SCU spare<br>4) Refurbish/test IEU s/n 1004 as SSATA prime<br>5) Refurbish/test IEUs s/n 1003 & 1005<br>6) Return IEU s/n 1008 on SpX-22 for LON chamber umbilical spare | TBD | Recharacterized risk |
| Loss of METOX Canister Extra CO2 Removal Capacity | Sorbent degradation | Loss of EVA time margin in CO2 removal capacity above 1.48 lbs of CO2 | 4 | 2 | **8** | Mission Success | Perform Teflon Film Evaluation study<br>Perform Teflon certification<br>Build 4 METOX cans with new sorbent, new Teflon Film, and Seals<br>Refurbish METOX cans with new sorbent, new Teflon Film, and Seals | Build and deliver new and refurbished METOX canisters. | Can S/N 0005 Partial AT: Can was shipped to NASA/JSC on 4/24. CR to FEMU-R-001 & EC for no JSC regeneration are in process<br>Can S/N 0003: Can is 95% refurbished<br>Qty 3 METOX Canister Refurbs: procurement of details continues |

*Example of the ESOC Risk Register*

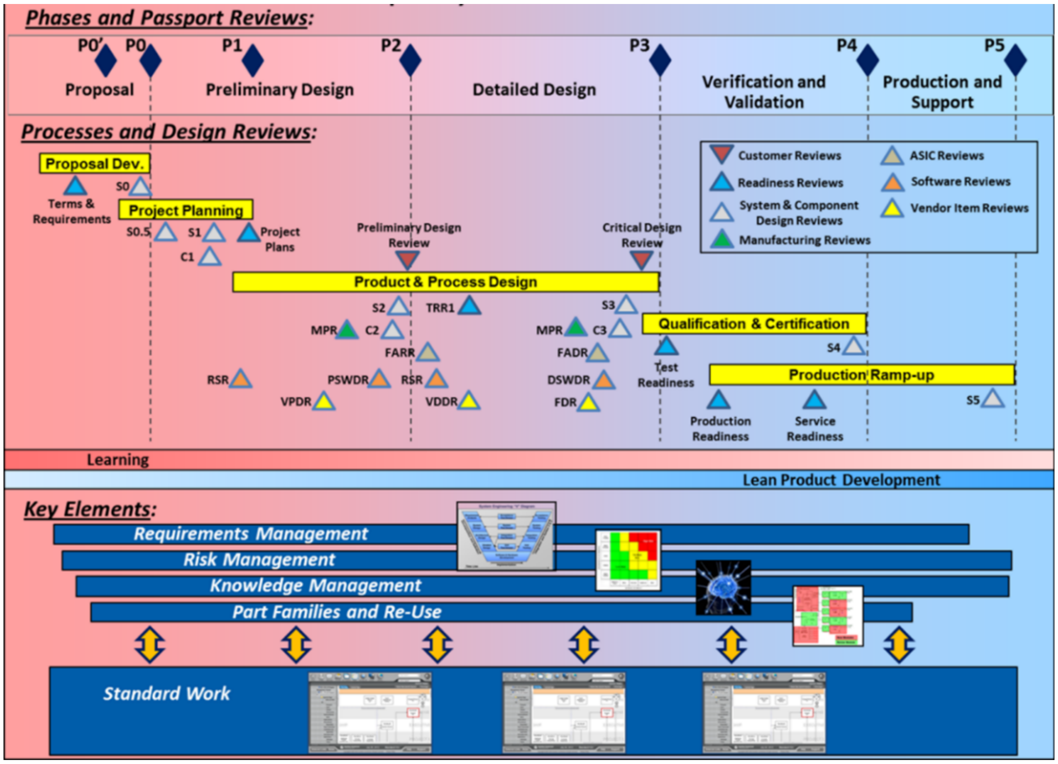
**Complexity.** When required to expand the boundaries of the EMU's design the team has a process to determine the analysis and evaluation methods to provide the necessary data for recommendations. This can involve multiple disciplines that provide input and also review data. This is then peer-reviewed and provided to NASA. Some of these evaluations can result in certification changes for an added capability or increase the EMU's boundaries.

One constant example of this is the addition of new vehicles to launch hardware to the ISS. The EMU was designed for the Space Shuttle and its loads. Each vehicle in use now or in the future has a different set of vibration loads that have to be assessed based on the hardware design. The EMU has many sub-components that can be launched as spare items or the entire unit can be launched. The Collins team has performed detailed structural analysis and testing to prove that the launch environments that exceed the original design are compatible and allow the EMU to perform once it arrives on the ISS. In addition to launch loads, the EMU has to survive the landing loads when it returns to Earth. All of these new load profiles have proven that the EMU has additional margin in its design to be able to meet these ever-changing operational environments as its mission changes.

**ORGANIZATIONAL BEST PRACTICES AND TEAM LEADERSHIP** *(Value: 40 pts)*
**Please respond to the following prompts:**

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

With the EMU Sustainment Program we utilize an Integrated Product Development (IPD) structure and a gated design review process. These integrated product teams consist of multiple disciplines that are either stake holders or experts in their field that can provide advocacy reviews. Each phase of a project is subjected to a gate or passport review at a major phase. Examples of phases include systems requirements development, preliminary design, critical design, and qualification/verification.



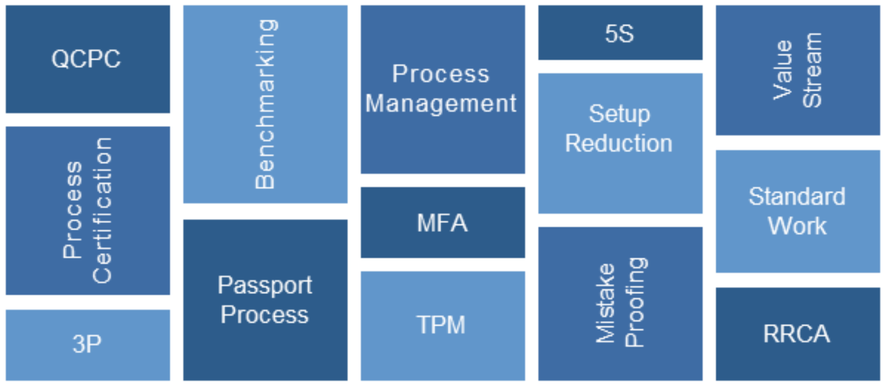

*Example of a project life cycle showing reviews*

A project must receive a gate review approval from the board prior to proceeding to the next milestone. In all cases these reviews are held prior to the customer mandated reviews (typically at the completion of these same phases) to ensure internal and customer requirements have been met.

We manage our programs with the Collins Management System (CMS), a life-cycle value stream system-based decision-making framework. The system focusing on empowerment, alignment and accountability to maximize customer value. Following this system helps us to demonstrate strong performance in all phases of the life cycle - from requirements capture to product retirement, and ensures that the teams who design, build and support our products are aligned.

The Collins Management System is applied to the ESOC program for the development programs as well as new builds of hardware. Even though hardware designs are certified, they may have not been produced for several years. The ESOC team then views those almost with the same rigor of a new design. The design documentation is reviewed to ensure the hardware can be manufactured with today's technologies. In some cases 3D models have to be generated because the designs are on paper. Then the IPD process is invoked to ensure all stakeholders and participants understand the production and testing requirements.

For continuous process improvement, we use the tools of our company's ACE (Achieving Competitive Excellence) system. Many of the tools that comprise the ACE system are in practice as a normal course of




*Achieving Competitive Excellence (ACE) Tools*

sustaining the EMU and its systems. Through Kaizen events for process improvements or value stream adjustments; , Relentless Root Cause Analysis (RRCA) for hardware failures, Benchmarking other best practices from within our company or others who share processes, Quality Clinic Process Charts (QCPC) to investigate trends using Turn backs for quality improvements, and other ACE Tools, we are able to quickly and accurately address any gaps in program execution before they become risks for the customer.

For highly complex technical products like the EMU, these tools and systems allow for the creation of robust technical solutions which meet challenging customer requirements.

➢ *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?**

Our ability to execute on customer's expectations requires us to attract, retain, engage and develop talent. The EMU Sustainment Program takes advantage of the Collins internship programs, bringing in college students to learn about and support the EMU. Interns are hired from a variety of disciplines, including engineers, finance and applied sciences. Many of these interns are given the opportunity to work at subcontractors' facilities, allowing them exposure to many aspects of our NASA contract. Our goal is to expose the interns to an exciting field in which to apply their skills, give them real-world experiences and develop them into future employee.

We have a program to connect retirees to our interns and early career employees. Periodically we invite our former employees to address this group and discuss how their careers developed over time, the mistakes they made and what they learned from them, and how they navigated the unique world of space exploration. We have also brought in former customers for this program. In one case, we had a retired NASA manager conduct bi-annual seminars for our interns to discuss his career and philosophies on NASA and career success.

Our team participates in Brown Bag lunch seminars presented by subject matter experts from our program and others. Some topics that have been presented included Failure Investigation process, Assured EMU Availability (AEA) program, and Space Hardware Logistics. We have found this method of supplemental learning to be successful and in fact many of the "students" at the seminars later volunteer to present topics they are experts in.

Collins Aerospace has a program to fast-track emerging leaders which takes high potential, early and mid-career personnel and provides an 18-month mentorship rotation. Each participant is assigned three mentors whom they shadow both virtually and in person for six months each. These mentors are leaders in different functions that will help provide a breadth of knowledge to expose the participants to many leadership styles and disciplines. In addition, each participant is assigned a general program management leader for coaching and guidance. There are15-20 participants in each cohort and they meet periodically to discuss their experiences among themselves and with their mentors.

During the FUEL participants' rotation through the ESOC program, they are provided mentorship via many of the Integrated Product Team (IPT) leads such as Engineering, Logistics and Program Management. With these disciplines they are exposed to interactions with the customer on a daily basis and also present to the customer on various topics associated with the program. In addition they are able to participate in real-time mission support during a spacewalk, providing assistance to the technical teams overseeing the activities and monitoring hardware health. This experience is invaluable to any area in which they want to pursue and isn't just for the technical side of the program. Exposure to the scheduling and finances of the project are also a part of the curriculum.

The use of a matrix organization supports knowledge transfer across programs, and allows associates to build experience on multiple product lines within his or her functional discipline. Best practices can be implemented across the business unit, as lessons learned are communicated to functional leads who are integrated across multiple programs. Well-established training system allows for core knowledge to be shared with new associates.

- *10 pts:* **What unique practices are you using to engage customers and how do you know?** *(12 pt. Times Roman)*

The EMU Sustainment Program is unique in that we are literally in the room and at the table with our customers every time our product is used. We are at Mission Control during every EVA. We are alongside the astronauts when they are fitted for the EMU, and we are team members for each of their training sessions.

Collins has a unique opportunity to engage the customer on a daily, even hourly basis. With ESOC (EVA Space Operations Contract) Collins has established transparency in almost every aspect of the operation of the contract. This is performed not only with standard monthly and weekly status reviews, but with participation in detailed weekly project specific meetings. In many of these meetings we also bring in our subcontractors to provide up-to-the minute statuses and assessments and answer specific questions.

We often have the NASA customer visit our facilities during testing and fabrication. Many times we plan the events around the customer's schedule to ensure they are present to witness the results. On occasion Collins will schedule events at our sub-tier vendors during critical test of fabrication to allow NASA to better understand risks and opportunities that we are managing throughout the life-cycle of the hardware. This helps NASA to make more informed risk-based decisions when dealing with critical schedules or cost decisions.

The ESOC also plays a significant role in decision-making for NASA regarding EVA and ISS operations readiness. Because the EMU is critical in the ISS operational plan, Collins is a voting board member of several NASA boards and panels. This wide membership is due to the trust the customer has in the ESOC team to bring technical and operational experience, as well as readiness approvals for critical ISS operations. Collins plays a role in approval for vehicle launch readiness, EVA Configuration Control Board decisions, as well as working-level panel decisions.


*Real-Time Mission Support with NASA, JAXA, and Collins Aerospace during US EVA 57*