Volume 2 / Issue 1 August 2019

Science & Engineering Vector

Senior Leadership Viewpoint

Your Vector to Air Force S&E Innovation and Insights

Mr. Jeff Stanley

To our readership, thanks for making VECTOR a part of your busy day. This quarter we present just a sampling of the exciting science and engineering innovations around the Air Force!

First, I am happy to announce late breaking news on the establishment of the Digital Engineering Enterprise Office and selection of its leader, Mr. Jeff Mayer. The Office is charged to help acquisition programs realize the benefits of Digital Engineering, many of which have been discussed on these pages over the past year. Jeff is the perfect person to lead this effort for the Air Force, and we'll have more details in our next issue.

The Air Force continues to provide dominant and war-winning products to warfighters through its innovative science and engineering workforce—YOU! In this issue we discuss Space and Missile Command's (SMC) utilization of Model-Based Systems Engineering (MBSE) in the acquisition of the Protected Tactical Enterprise Service (PTES). PTES is critical to ensuring communications in a complex environment and another example of how digital engineering improved requirements, ultimately increasing warfighter lethality.

As discussed in our last issue, technology and information protection is at the uppermost of our minds in the Department, and we need to ensure we have technical processes supporting that need. The Cyber Resiliency Office for Weapons Systems has successfully brought together historically disjointed systems to enhance Security Systems Engineering (SSE). Mr. William Meijas discusses the historical flaws needing corrections and how the CROWS office has led that effort. His article, with accompanying links to new Air Force guidebooks, is an essential read for anyone dealing with cyber security.

So much more and so little space! Please check out these articles as well: the A-10 System Program Office's (SPO) amazing job to digitize legacy Non-Destructive Inspection (NDI) data to quickly identify fleet damage "hot spots," and what the Air Force Nuclear Weapons Center (AFNWC) is doing to train over 400 military and civilian engineers in the use of MBSE to fulfill their mission of modernized nuclear deterrence. Following up from last issue, Air Force Life Cycle Management Center (AFLCMC) laid the groundwork to establish future partnerships at the 4th Annual Life Cycle Industry Days (LCID) Convention, a tremendous turnout in Dayton, OH—start planning LCID2020 now! And, Air Force Research Laboratory (AFRL) recently launched new technologies to space aboard the SpaceX Falcon Heavy Rocket to demonstrate safer propellants, increase worldwide understanding of the environment space vehicles operate in, and build more resilient space systems.

Finally, I want to personally thank Mr. Jeff Havelick, our VECTOR 1st line editor who helped envision and launch this product. Jeff has taken a position with AFLCMC as the Chief, Aerospace Systems Design & Analysis Engineering Branch. Jeff's passion for the Air Force and writing have been critical to our success! Mr. Dave Penaloza (Hanscom AFB) will be taking over Jeff's duties, and you can to submit stories of Air Force Science and Engineering excellence for our fall issue to Dave.

Inside This Issue

Digital Engineering at your Service

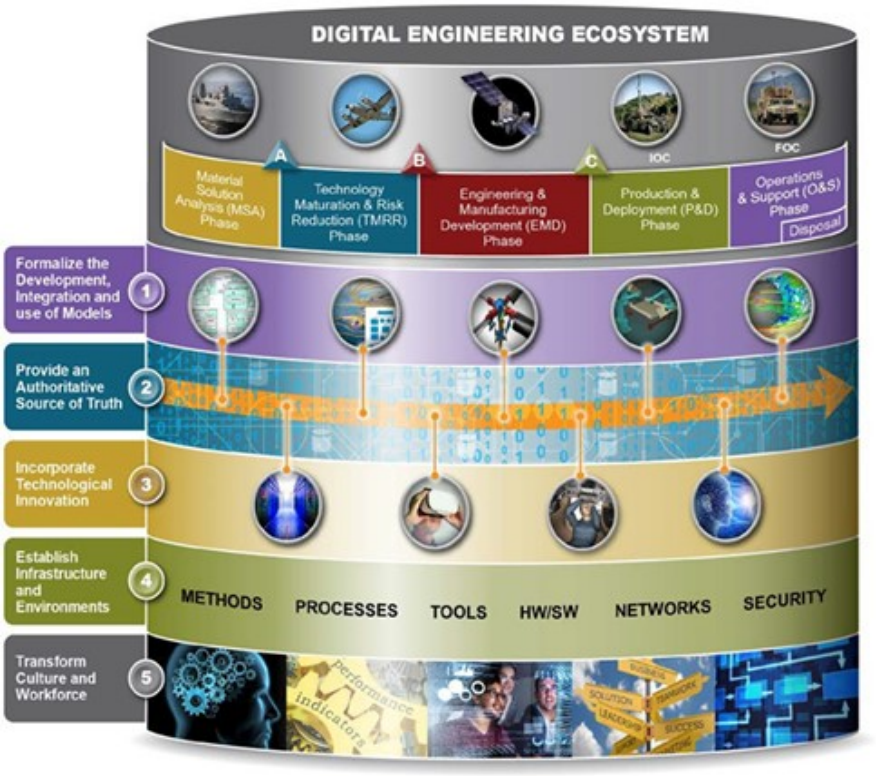
By Ms. Tevonya Garland, AFLCMC/EZC

Mr. Jeffrey Mayer, Director, Air Force, DEEO

The Digital Engineering Executive Steering Group is proud to announce the establishment of the Digital Engineering Enterprise Office (DEEO). The DEEO, led by Mr. Jeffrey Mayer, was formed to implement the Air Force's Digital Engineering vision and objectives.

Digital Engineering is a continuous way of doing system engineering related activities using technology. The benefits of Digital Engineering range from faster source selections and technical reviews with the use of models to reduced lifecycle costs for sustainment and operations.

The DEEO is tasked to help programs realize these benefits by:



- Developing a Digital Enterprise Environment within which the workforce can perform acquisition activities, collaborate, and communicate across stakeholders
- Providing the workforce with the right digital engineering tools, training, and infrastructure for modeling, simulation, and analysis
- Establishing secure, authoritative sources of digital engineering data available across the system lifecycle
- Creating and modifying policies, contracts, and processes to integrate digital engineering into decision making processes
- Aiding programs in utilizing digital engineering to support rapid implementations of innovation
- Transforming Air Force culture to have a digital engineering mindset throughout the system lifecycle

Stay tuned for future articles, podcast, and milSuite communities of interest on the DEEO and its efforts with Digital Engineering. For additional information related to the DEEO and digital engineering, feel free contact Mr. Jeffery Mayer at jeffrey.mayer@us.af.mil.

Protected Tactical Enterprise Service (PTES): *Employing Digital Engineering in Space and Missile Systems Center (SMC) Acquisition*

By Lt Col Patrick Little (SMC/MCD) PTES Program Office and Mr. Guy Varland, LinQuest

PTES is a National Security System which will provide an enabling component of the ground system for the DoD Protected Anti-jam Tactical SATCOM (PATS) capability that encompasses DoD Protected Tactical Waveform (PTW) systems. The Space and Missile Systems Center (SMC) PTES acquisition team employs Model Based Systems Engineering (MBSE) and Digital Engineering principles throughout the acquisition process and program life cycle.

To support the PTES Request for Proposal (RFP) process, the PTES team developed an integrated Sparx Enterprise Architect/Dynamic Object Oriented Requirements System (DOORS) MBSE model of the PTES system. This model contains all of the PTES requirements, as well as detailed technical structural/data/and activity models, to detail PTES employment. The team developed custom scripting to autogenerate the PTES System Technical Requirements Document (TRD) from the model.

The MBSE model (provided as part of the Bidder's Library) serves as the foundation for the development contractor to further refine the PTES Solution Architecture. This methodology provides traceability of Key Performance Parameter requirements; from the PTES Capabilities Development Document, to the System TRD, to the development contractor system specification, in a single integrated model.

Prior to RFP release, LinQuest, as part of the PTES team, used 3DataLinQ, a custom application, to develop a dynamic Digital Thread of the PTES mission planning process. This approach couples "static" activity diagrams from the MBSE model to a 3 Dimensional dynamic visualization of the planning process. The team utilized the combined PTES Digital Thread and MBSE model to refine PTES mission planning requirements and to articulate the planned employment of PTES to Combatant Commanders.

LinQuest, as the PTES Systems Engineering & Integration (SE&I), employed 3DataLinQ technology to develop a pre-RFP Risk Reduction Digital Twin of the PTES Mission Management System.

Figure 1 provides a screenshot of the PTES Digital Twin. This Digital Twin enables operators at the future PATS Operation Center to get an early "look and feel" of the new features/capabilities that will be provided by the PTES Mission Management System, prior to RFP release to industry. As a result of this process, operators provided invaluable feedback to the PTES team.

The PTES team refined or completely rewrote 140 of the 320 PTES Mission Management System requirements, based upon the Digital Twin enabled feedback.

After Boeing was awarded the development contractor award in 2018, the PTES government team used the Risk Reduction Digital Twin to assist Boeing with the development of the actual PTES system.

In addition to clear and concise elaboration of PTES requirements, this Risk Reduction Digital Twin methodology integrates with the development contractor agile method, to support the development and assessment of user stories, enabling superb collaboration between the PTES government team and industry.

Figure 1 PTES Digital Twin

Integrating Systems Security Engineering into Systems Engineering

By Mr. William Mejias, Air Force Lifecycle Management Center, Engineering Directorate

Systems Security Engineering (SSE) has over the years been executed through a number of disjointed activities that were not fully integrated into Systems Engineering (SE). These approaches were either compliance or checklist based. Figure 1 shows a graphical depiction of the legacy approach to SSE that illustrates the overlaps and discontinuities between existing security processes. In the below approach, programs often duplicate similar analyses for different purposes, or else are met with conflicting policy guidance and controls. Given today's emphasis on cybersecurity and cyber resiliency, it is important to emphasize that robust SSE accounts for both activities.

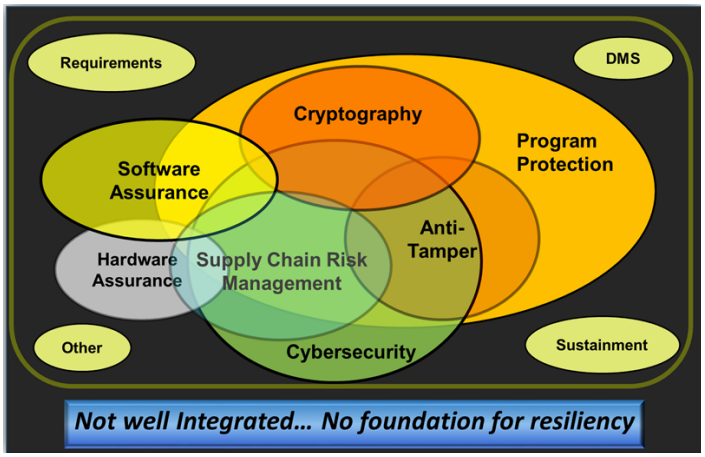


Figure 1 SSE Legacy Approach

Given that the Department of Defense (DOD) and the Air Force are moving towards a more holistic approach to SSE and mission assurance, it is critically important to transition towards a construct that incorporates existing acquisition SE analysis, products, and artifacts to promote a disciplined engineering approach to SSE. Ultimately, disciplined SSE builds from core SE processes and applies security processes as part of the existing SE framework, which in turn applies well-defined processes and tools in a disciplined, rigorous, and integrated manner.

Such an approach achieves an adequately secure and resilient system solution that complies with performance, cost, schedule, and risk parameters.

Ultimately, the desired end state is for SSE to be fully integrated into SE technical management processes, technical processes, and technical reviews, which is illustrated in Figure 2. DoD Instruction (DODI) 5200.44 defines SSE as an element of SE that applies scientific and engineering principles to identify security vulnerabilities and minimize or contain risks associated with these vulnerabilities.

The outcome will be systems with security and resilience "baked in" alongside the necessary evidence to support risk management decisions by governance authorities.

In response to the FY14 National Defense Authorization Act (NDAA) Section 939, calling for all of the Services to develop plans to increase cyber security and resiliency of weapon systems, the Air Force developed the Air Force Cyber Campaign Plan and stood-up the Cyber Resiliency Office for Weapon Systems (CROWS) to execute its acquisition portion. CROWS is focused on the acquisition community and Air Force culture to design cyber resiliency into new and existing weapon systems, assessing and protecting the fielded fleet, while increasing weapon system cyber resiliency and mission assurance.

To facilitate "baking" cyber resiliency into new and existing weapon systems, CROWS has developed the Weapon System Program Protection (PP)/Systems Security Engineering (SSE) Process Guidebook. The guidebook distills all the processes and activities associated with various SSE policies into an SSE integrated process guidance addressing *WHAT* to do and *WHEN* to bake cyber resiliency in. In addition to the time saved by systems security engineers and cyber professionals by not having to rifle through various SSE policies to discern the SSE processes, the guidebook also offers the following benefits:

- It integrates all SSE relevant processes into the SE process
- Links to other tools, aids, and resources
- Avoids duplication of analyses and creates efficiencies/synergies
- Artifacts (i.e., byproducts of processes) that support policy stakeholders
- Supports a balanced set of SSE requirements

CROWS has also developed an Air Force SSE Acquisition Guidebook. This Guidebook captures tailorable acquisition security-related contractual language and security-related system requirements to execute the various SSE policies into one document that addresses *WHAT* to do in more detail and *HOW* to perform the SSE activities articulated in the Weapon System PP/SSE Process Guidebook. Ultimately, this guidebook will save significant time upfront for systems security engineers and cyber professionals because it reduces the need to search through a list of SSE polices and other resources to determine the appropriate contract language.

The Acquisition Guidebook includes the following:

- Tailorable requirements for the Request for Proposal (RFP) section C (Description/specifications/ statement of work) that includes the Statement of Objectives, Statement of Work, and Systems Requirement Document

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- Recommended clauses for RFP section I (Contract Clauses), to include Federal Acquisition Regulation (FAR), DOD FAR Supplement, and Air Force FAR Supplement clauses
- Tailorable language for RFP section L (Instructions, Conditions, and Notices to Offerors)
- Tailorable language for RFP section M (Evaluation Factors for Award)
- Recommended SSE entry criteria for the ten SE Technical Reviews
- Recommended Contract Data Requirements Lists with associated Data Item Descriptions and delivery schedules that are traceable to the specific SOO/SOW requirements.

As stated above, the Acquisition Guidebook contains tailorable security requirements appropriate for incorporation into program requirement documents, such as a System Requirements Document or System Specifications. The next several subparagraphs address existing policies regarding requirements and security controls as they pertain to cyber.

DODI 5000.02 Enclosure 11 states, "Cybersecurity Risk Management Framework (RMF) steps and activities should be initiated as early as possible and fully integrated into the DoD acquisition process, including requirements management, system engineering, and test and evaluation. Integration of the RMF in acquisition processes reduces required effort to achieve authorization to operate and subsequent management of security controls throughout the system life cycle."

Enclosure 14, states, "Derive requirements and others system requirements into systems performance specifications and product support needs."

DODI 8510.01 states, "Mission owner(s) must translate security controls into system specifications into the system design, and ensure security engineering trades do not impact the ability of the system to meet the fundamental mission requirements. This includes ensuring that technical and performance requirements derived from the assigned security controls are included in request for proposals and subsequent contract documents for design, development, production, and maintenance."

Further, AFI 63-101/20-101 states, "Security-related system requirements are fully derived and integrated into overall system requirements, incorporated into the system's design through systems' security engineering (SSE), and thoroughly tested from a mission perspective."

The Office of the Under Secretary of Defense for Systems Engineering (ODASD (SE)) provided an engineering perspective on requirements and security controls. Their summary, which follows, should not come as a surprise: a) Requirements are the formal form of expression for systems engineering, and subjected to analysis, validation, and configuration control; they may be transformed, where justified, into other forms of expression; b) Security controls are an informal form of expression that may be used to inform engineering analysis (expression of design-independent capability need and expression of design-dependent derived and decomposed system requirements) and cannot be used as replacement for requirements; and c) Security controls must be traceable to their derivation source.

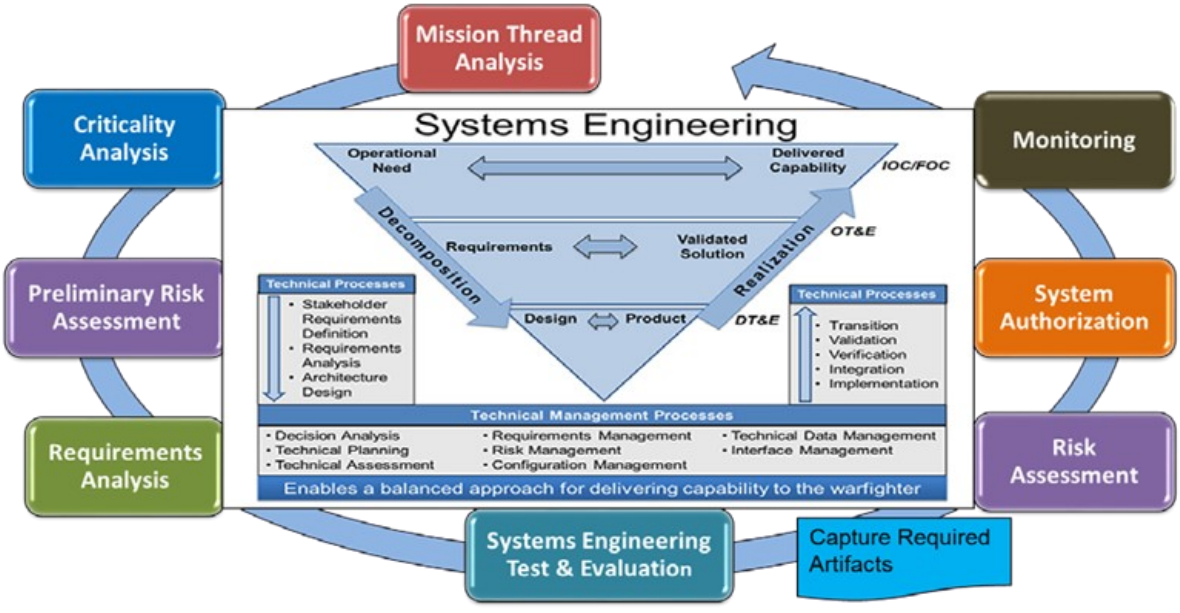

Figure 2 SSE Tasks Integrated into SE Technical & Technical Management Processes

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CROWS examined all of the security controls in the National Institute of Standards and Technology, Special Publication 800-53 r4, *Security and Privacy Controls for Federal Information Systems and Organizations,* which were written mostly from an Information Technology system/network perspective. Then CROWS translated the controls applicable to weapon systems, into system requirements. The set of weapon system, domain-agnostic, tailorable cyber security and resiliency system-level requirements are captured in Section 2.2 and Attachment 1 of the Air Force SSE Acquisition Guidebook. Requirements are also traceable to the 10 Cyber Survivability Attributes, published in the Joint Chiefs of Staff Cyber Survivability Endorsement Implementation Guide and other requirements sources. The effort required by systems security engineers and cyber professionals to translate security controls into requirements can be avoided by leveraging the results of this effort.

In summary, these guidebooks are essential tools for building a strong foundation for cyber resiliency because they move us away from an after-the-fact compliance-centric approach and towards a rigorous engineering-based, risk informed one. At this point, Systems Security Engineering activities are integrated into Systems Engineering and all conversations about risk, cyber or otherwise, can begin with basic Systems Engineering, something already ingrained in Air Force culture. This makes perfect sense, which begs the question, what took us this long?

Documents referenced in this article are available at the CROWS Air Force Portal site. To access them, navigate to the Air Force Portal (https://www.my.af.mil) and search "Cyber Resiliency Office for Weapons Systems (CROWS)."

Engineering Enterprise Leadership Moves

Organization	Leader	Job/Position/Duty
SAF/AQ	Dr. Yvette Weber	Associate Deputy Assistant Secretary for Science, Technology, and Engineering
Air Force Lifecycle Management Center	Dr. Keith Numbers	Technical Advisor (Propulsion, Engineering and Technical Services Directorate)
Air Force Sustainment Center	Mr. Michael Jennings	Technical Advisor (Weapon Systems Software Sustainment)
Air Force Research Laboratory	Dr. Qing Wu	Senior Scientist, Processing and Exploitation (Information Directorate)
Air Force Research Laboratory	Dr. Herbert Carlson	Retired (Air Force Office of Scientific Research)

AFRL puts new technologies into space aboard world's most powerful launch vehicle

By Mr. Bryan Ripple, 88th Air Base Wing Public Affairs

The Air Force Research Laboratory successfully put new technologies into space early in the morning June 25 as part of the Department of Defense Space Test Program (STP-2) mission, managed by the Air Force Space and Missile Systems Center, Los Angeles AFB, California.

A SpaceX Falcon Heavy rocket, the most powerful launch vehicle in the world, blasted off from Launch Pad 39A at Kennedy Space Center at 2:30 a.m. EDT. It was the Falcon Heavy's first night flight and just its third launch overall. It was also the first Falcon Heavy to fly using reused boosters.

The rocket carried 24 experimental satellites into space, including the Green Propellant Infusion Mission (GPIM) spacecraft, which enables the first ever on-orbit demonstration of the AFRL developed Advanced Spacecraft Energetic Non-toxic Propellant (ASCENT).

A SpaceX Falcon Heavy rocket carrying 24 satellites as part of the Department of Defense's Space Test Program-2 (STP-2) mission launches from Launch Complex 39A, Tuesday, June 25, 2019 at NASA's Kennedy Space Center in Florida. Four NASA technology and science payloads which will study non-toxic spacecraft fuel, deep space navigation, "bubbles" in the electrically-charged layers of Earth's upper atmosphere, and radiation protection for satellites are among the two dozen satellites that will be put into orbit. Photo Credit: (NASA/Joel Kowsky)

Space demonstration of this new propellant, ASCENT, formerly known as AF-M315E, marks a major milestone in a national effort to develop new energetic propellants to replace hydrazine, the current established chemical propellant of choice for nearly all current satellite propulsion. Not only is ASCENT 50 percent higher performing than hydrazine, it is also a vastly safer alternative, allowing for streamlined ground operations relative to legacy propellants. While hydrazine is flammable, toxic, and requires use of Self Contained Atmospheric Protective Ensemble (SCAPE) suits for handling operations, ASCENT propellant requires minimal Personal Protective Equipment (PPE) such as a lab coat and a splashguard for the face.

"The demonstration of a revolutionary green propellant for spacecraft propulsion is critical as we move toward space operations being the new normal," said Dr. Shawn Phillips, chief of AFRL's Rocket Propulsion Division at Edwards Air Force Base, California.

Also part of the STP-2 mission was AFRL's Demonstration and Science Experiments (DSX) spacecraft. The first of its kind globally, the DSX flight experiment will conduct new research to advance DOD's understanding of the processes governing the Van Allen radiation belts and the effect they have on spacecraft components. DSX's elliptical path in medium Earth orbit (MEO) will increase understanding of this orbital regime, and advance understanding of the interplay between waves and particles that underlie radiation belt dynamics, enabling better specification, forecasting and mitigation. This will ultimately enhance the nation's capability to field resilient space systems, AFRL officials say.

DSX's mission is different from most other Air Force flight experiments as it is a purely scientific mission. The spacecraft is equipped with a unique suite of technologies such as space weather sensors and graphite antenna booms used to conduct experiments with very-low frequency (VLF) radio waves. DSX has two sets of immense deployable booms due to the large antenna requirements of these experiments. One set extends 80 meters tip-to-tip and the other extends 16 meters tip-to-tip, making the DSX spacecraft one of the largest deployable structures in orbit.

"The space domain has never been more important to our nation than it is today," said Maj. Gen. William Cooley, AFRL commander. "The DSX satellite experiment will greatly increase our understanding of the environment spacecraft operate in and will give us the knowledge to build even better satellites to protect and defend our space assets. I am immensely proud of the AFRL scientists, engineers, and technicians that conceived and built the DSX satellite."

The DSX program is led by the AFRL Space Vehicles Directorate at Kirtland AFB, New Mexico, with key team members from the Air Force Space and Missile Systems Center.

DSX will conduct on-orbit experiments for at least a year.

LCID industry engagement on growth curve

By Mr. John Van Winkle, 88th Air Base Wing Public Affairs

Industry engagement is on a growth curve for the Air Force Life Cycle Management Center, drawing more people and needing more space to build stronger alliances to improve warfighter readiness.

That growth curve was evident during AFLCMC's 4th Annual Life Cycle Industry Days June 19-21 at the Dayton Convention Center.

LCID draws Air Force and Department of Defense acquisition leaders, major industry defense contractors and prospective suppliers together to discuss the Air Force's hot topics in acquisitions and challenges of today and tomorrow.

The event grew so popular that it needed more elbow room.

"It's little different venue than what we had last year," said Lt. Gen. Robert McMurry, AFLCMC commander. "The reason is we had too many attendees, and I like that. That's a good problem to have. I appreciate the fact that we have such a well-attended event."

LCID brought together more than 1,000 government and industry partners to build and strengthen alliances between government and industry. The event featured keynote presentations from top military acquisition leaders and weapon systems forecast briefings from Program Executive Officers, discussing the status of numerous programs, including future needs and current challenges.

"If you look around you at the folks who are sitting in this room – and you've got a problem somewhere in your portfolio -- the solution is in this room. There's somebody here at LCID who knows how to solve that problem. The key is to make that connection to make it work," the General said.

Robert Balserak, lead executive, Air Superiority Programs, Lockheed Martin Corporation (left) and Brett Stolle, curator, National Museum of the U.S. Air Force try out a F-35 simulator during the Air Force Life Cycle Management Center's Life Cycle Industry Days held at the Dayton Convention Center in Dayton, Ohio June 19-21. (U.S. Air Force photo / Michelle Gigante)

The three days of LCID featured keynote speeches with question-and-answer sessions, including the Honorable Robert McMahon, Assistant Secretary of Defense for Sustainment, Gen. Arnold Bunch, the Commander of Air Force Materiel Command, and Gen. Mike Holmes, the Commander of Air Combat Command, as well as Lt. Gen. Duke Richardson, the future military deputy for the Office of the Assistant Secretary of the Air Force for Acquisition. Other heavily-attended events included panel discussions featuring Program Executive Officers, as well as a panel with defense industry executives. A host of concurrent sessions also competed for attendees' time and attention, with forecast reviews by separate AFLCMC directorates, and discussions on rapid acquisitions, supply chain readiness and strategic capabilities.

Between sessions, the tempo only picked up for attendees, as the essential elements of business ruled the day. Attendees launched into side conversations tackling topics of existing technologies and future capabilities in depth, learning what potential needs and opportunities exist, then set to work establishing mutual interest to make contacts and lay the groundwork for future partnerships.

This too, was among the goals for LCID.

"It is more important than ever to focus our efforts on strengthening our alliances and partnerships. It is my hope that this gathering will provide a forum for both large and small business to discuss opportunities to partner with government agencies on near and long-term capabilities," said McMurry.

About one-fourth of the tracks at LCID concentrated on small business. This included panels on opportunities, portfolios, past and future Pitch Days, and readily-available Air Force Intellectual Property that can be licensed for use. Extra attention was also given to explaining Education Partnership Agreements, Patent Licensing Agreements, Information Transfer Agreements and Cooperative Research and Development Agreements, all of which are mechanisms enabling public-private partnerships between Air Force and industry or education to drive research and production activities. AFLCMC and AFRL Small Business Offices were on site in force throughout the event, available to discuss navigating the contracting process with small business attendees.

The marketing side of industry has also put LCID on their respective "to-do" lists, with 27 separate contractors manning booth space to increase their brand awareness and showcase their goods and services to government and

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industry attendees. Attracting attention is a key element when managing a booth at events like LCID, and industry vendors, the National Museum of the U.S. Air Force, Air Force Institute of Technology and Air Force Research Laboratory all met that challenge. One of the most popular was a corporate booth which demonstrated the potential applications of virtual reality systems. The vendor was able to discuss practical applications ranging from virtual training to computer-assisted maintenance and combat operations. Vendors also distributed a host of small items adorned with company logos and even distributed information on future defense industry conventions.

The third day of the event went even deeper into specific specialties and weapons systems by dedicating the entire day to one-on-one sessions for attendees to meet with Program Executive Officers and their staffs.

Each of the LCID events demonstrated the government and the defense sector have recognized the value of LCID, and that it serves as an opportunity for increased partnerships between government and industry, as well as for smaller vendors to market their goods and services to larger defense contractors. AFLCMC is looking forward to continued growth in LCID 2020 and is planning to offer even more compelling partnership and collaboration opportunities.

Digital Engineering Training at Air Force Nuclear Weapons Center

By Mr. Ernest David Herrera, Air Force Nuclear Weapons Center (AFNWC/EN)

The modernization of nuclear deterrence is the focus of the Air Force Nuclear Weapons Center (AFNWC), consisting of 400 military and civilian engineers who are scattered across five states. To accomplish this responsibility, they will need to prevail over the demands of technical and program complexity, along with cost, schedule, and performance. Meeting these challenges require a workforce trained to "Own the Technical Baseline," with the knowledge to answer the technical questions of "what, how" and "why," for increasingly complex systems. The solution for these questions reside within Digital Engineering and its focus on model-centric processes, known as Model-Based System Engineering (MBSE), as opposed to document-centric processes.

Twelve students graduated from the inaugural introductory course on Model-Based System Engineering in June 2019 at Hill AFB.

In order to train all 400 military and civilian engineers in MBSE, an inaugural 20 hour introductory course was held in Albuquerque on April 16-18, 2019, applying practical hands-on experience using Systems Modeling Language (SysML) and Cameo Modeler. This course, which started with a limited class size of twelve participants, in order to ensure course instructor attention to all students, was also presented to ICBM engineers at Hill AFB on June 25-27. Next, it will be presented to sustainment engineers (Cruise Missile) at Tinker AFB on August 19-21, and then at Hill AFB, in September. Our approach is to assure basic literacy in MBSE and to complete this introduction by the end of FY20.

We will offer three other types of MBSE classes in FY19. First, *Introduction to the Digital Enterprise*, a class that introduces digital engineering, the digital enterprise, product life-cycle management, and program/ project management software to all personnel. We also will establish an *Advanced MBSE Course* to develop fluency for 5% of our workforce, to work with industry modelers. For development of MBSE applications in test and evaluation, product life cycle management, system of systems, vulnerability and fault analysis, a *Workshops/laboratory* is in planning.

In addition to training, the Engineering directorate (AFNWC/EN) has initiated pilot programs for the virtualization of systems, vulnerability analysis, for cyber applications, and a joint project with the Department of Energy's Sandia National Laboratory, for re-entry vehicle subsystems. The objectives are to gain experience with MBSE.

In FY20, we will complete training for all AFNWC personnel, to include eight introductory MBSE classes, two modeler's classes, and two applications workshops. In addition, we will develop MBSE applications for test and evaluation, product lifecycle management, vulnerability analysis, system of systems, and areas in a virtual laboratory environment.

Our training initiative is addressing the culture/ workforce development challenge, by introducing the paradigm shift through guided introduction and practical, important applications. For this writer, who began his 50-year work life with a slide rule, a drafting table, and paper, this is the future—for now.

Defining and Developing the Digital Groundwork to Realize Tangible Tactical Advantages

By Mr. Hazen Sedgwick, Chief, A-10 ASIP Engineering, AFLCMC

The term 'NLign' was a play on words to bring aircraft damage data 'in-line' with aircraft integrity requirements. Since the software's beginnings as a Small Business Innovative Research project in 2007, NLign has quickly become an essential tool for the A-10 in maintaining an aging fleet. NLign has the capability to spatially locate data on a two or three dimensional model, and provides means to be able to search and trend that information.

The A-10 engineers within the System Program Office (SPO) first used this program as a way to document discrepancies and their associated analyses to speed future support requests. Eventually, additional forms of data began to be recorded into the system: Non-Destructive Inspections (NDI), test and teardown, non-conformance records, flight histories, serialized component historical records, and discrepancy data. The engineers currently have access to over 42,000 spatially defined records, providing at-a-glance communication of emerging fleet damage hot spots.

An A-10 Thunderbolt II from the 122nd Fighter Wing, Indiana Air National Guard, sits on the flight line at Alpena Combat Readiness Training Center, Mich., July 22, 2019, during exercise Northern Strike 19. (U.S. Air National Guard photo by Master Sgt. Scott Thompson)

One of the largest areas of improvement has been in the realm of the acquiring NDI data. For years the aircraft maintenance shops captured NDI data on hand written forms. These records remained with the aircraft component until it left the depot. The inspection findings are the main purpose for depot maintenance and are essential to predicting aircraft fatigue to manage the fleet. It took several months for the hand written forms to arrive in the Aircraft Structural Integrity Program's (ASIP) office for processing. That time gap made it very difficult to find errors and correct them before the aircraft left the depot.

Due to the critical nature of the inspection data and the challenge of managing a fleet beyond its original design life, it became necessary to change how inspection data was collected. NLign was organically configured by the SPO engineers, sheet metal Mechanics, and NDI Technicians to effectively capture inspection data. The process used to collect data with NLign was validated on the shop floor, technical order requirements changed, and a training program was implemented to ensure success. Now, data is controlled, digitally captured, and available in real time.

The results of this are no less than astounding. What used to take seven to nine months can be completed in weeks. Additionally, the increased collaboration between the A-10 maintenance groups and the engineers has led to a dramatic increase in the quality of data. The quality of inspection records went from 17% good in 2017 to a current 95% in 2019.

With the proven efficiencies had at the Hill depot to capture maintenance data, the A-10 SPO is deploying NLign and training the field units on how to benefit from this system. The intent is to develop and implement processes to collapse engineering response times, collect prognostic indicators, and forecast individual aircraft maintenance based on condition and need.