AIR FORCE RESEARCH LABORATORY SUSTAINMENT SCIENCE AND TECHNOLOGY STRATEGY

Abstract

AFRL Sustainment Science and Technology Strategy

Viable United States Air Force (USAF) fleets of aerospace vehicles operating at peak performance are essential to US national security and that of its allies. The ability of the AF to project global force helps to keep rogue nations in check and sends a transparent message to other increasingly powerful nations that we have genuine strength to back up our force projection. Sustainment is a critical function to maintain performance legitimacy of USAF weapon systems. This document describes the Air Force Research Laboratory (AFRL) views on maintaining cutting edge technology from a broad range of technology areas, e.g., structural and functional materials and their fabrication processes, sensors and diagnostics, airframes, propulsion, space, manufacturing, etc. Key tenets to achieve available, safe and affordable aerospace systems are defined to guide the AFRL Science and Technology (S&T) Investment Strategy. An outline on fundamental problems associated with sustainment, particularly in regards to maintenance operations and supply is given and the strategic program priorities required to keep the fleets operating at peak performance are described. Annex 1.0 is provided for the strategic framework guiding the investment needs to mitigate pervasive corrosion problems across USAF aerospace fleets and systems.

Introduction

Joint Publication (JP) 3-0, Joint Operations, defines sustainment as "the provision of logistics and personnel services necessary to maintain and prolong operations through mission accomplishment and redeployment of the force" and defines the logistics core capabilities as "supply, maintenance operations, deployment and distribution, health service support (HSS), logistic services, engineering, and operational contract support."[1] Joint Publication 4-0, Joint Logistics, further defines maintenance operations functional capabilities as "depot maintenance operations, field maintenance operations and manage life cycle systems readiness" and the supply functional capabilities are "manage supplies and equipment, inventory management and manage supplier networks."[2]

The overall mission of the AFRL is stated as: *"Leading the discovery, development, and integration of affordable warfighting technologies for our air, space, and cyberspace force."* Supporting this mission, AFRL conducts sustainment science and technology (S&T) projects in the logistics core capabilities of supply, maintenance operations, HSS and engineering. For the purposes of this strategy, sustainment will consist of the supply and maintenance operations core capabilities. AFRL research strategy in HSS and engineering core capabilities will be detailed in other documents.

As of 30 September, 2012, the Air Force operates 95 aircraft model/design/series (MDS), from the venerable B-52 to the digital F-22 and MQ-9, a total of 5,551 aircraft using 38 different engines, 450 intercontinental ballistic missiles, 9 satellite constellations and 2,258 Air Force missiles (9 MDS) with both unique and common sustainment issues.[3] Maintenance of these aircraft, engines and missiles is accomplished on the flight line, in the backshop and at one of three depots by Airmen, civilian technicians and contractors.

Affordably maintaining safety, availability and mission capability of USAF systems is critical to sustaining our warfighting dominance. Identifying the readiness of aircraft, spacecraft, and missile systems by detecting damage and analyzing the condition of each system is critical to its mission effectiveness. The capability to rapidly repair and return these damaged systems to service is essential to maintain high sortie rates required during wartime. As the USAF becomes more technologically advanced, maintaining current and future weapon systems will be more challenging.

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[1] Joint Publication 3-0, Joint Operations, 2011
[2] Joint Publication 4-0, Joint Logistics, 2008
[3] Air Force Magazine, www.airforcemag.com, May 2013

Space sustainment is different but equally important. Sustainment poses a challenge unique to space: replacement is lower cost than on-orbit servicing of individual spacecraft and it is not cost-effective to bring a satellite back to the "hangar." Therefore the goal in spacecraft sustainment is to make the replacement spacecraft more affordable while at the same time increasing the service life of the spacecraft. The cost of launching a spacecraft to orbit is a significant affordability driver as well.

Weapon systems increasingly rely primarily on communications, sensors and information systems, which introduce significant sustainment challenges. Some of the key challenges are: reporting and diagnosing system health in structures with complex interactions between networks, hardware and software; sustaining complex software systems and containing maintenance costs; and managing information technology hardware in an environment with rapidly changing standards and technology.

To reduce the growing sustainment burden, AFRL's sustainment S&T vision is:

Sustainment Science and Technology Program Tenets

The AFRL sustainment S&T strategy is based on the following tenets:

- Research, develop and transition technology solutions to enable USAF weapon systems to meet or exceed safety, availability and/or affordability goals
- In partnership with the program offices at the Air Force Life Cycle Management Center (AFLCMC) and Space and Missile Center (SMC), support the major commands (MAJCOMs) by ensuring that the S&T strategy addresses the near-, mid- and far-term sustainment requirements and leads to successful transition and implementation
- Invest in developing sustainment technologies with favorable business case analyses, positive returns on investment and customer commitment to transition
- Partner with the Air Force Sustainment Center (AFSC) to develop science and technology solutions that will advance the Complex of the Future vision
- Leverage and collaborate with other services, agencies, academia and industry, both traditional defense suppliers and small business, to exploit sustainment technology developments
- Evaluate emerging technologies where the intent is not directly associated with sustainment issues, but where implementation could result in capabilities that improve weapon system safety, availability and affordability

Strategic Environment

The average aircraft in the USAF inventory is over 25 years old, the oldest fleet in Air Force history. The B-52 was introduced in 1955 and the C-130, KC-135 and U-2 were introduced in 1957. The Air Force weapon system sustainment budget for FY2012 is $9.7 billion, or 69.7 percent of the full requirement.[4] Weapons system support costs are going up 6-8% per year and aircraft maintenance cost per unit have risen 10% in the last three years.[5] Budget pressures are expected to reduce funds available for sustainment and delay recapitalization and modernization efforts. As the fleet continues to age, a greater share of the budget will be required to continue safe and effective operations, further delaying modernization plans and placing increased pressure on Maintenance, Repair and Overhaul accounts.

The Air Force is projecting that existing weapon systems must remain operational well beyond their design service life. Additionally, the requirements for the service life of new tactical and strategic platforms are projected to increase by a factor of 1.5 to 5. Critical enablers, such as stealth platforms and space and missile assets, have their own unique sustainment needs that vie for resources with sustainment of more traditional aeronautical systems. Balance must be struck to enable the Air Force to maintain not only the capability to fight today's fight but also plan for tomorrow's fleet.

Sustainment technology can enhance every life cycle phase of all Air Force systems as well as contribute capability to the worldwide infrastructure required to maintain fielded systems. Helping assure safety, contributing to maximize availability and providing technologies to reduce the maintenance burden are important measures of success. In addition technology to improve the efficiency and effectiveness of the sustainment processes can be introduced on the flight line or on the AFSC shop floor.

Sustainment Program Priorities

AFRL will prioritize resources for sustainment technologies as follows:

[4] National Research Council of The National Academies, *Examination of the U.S. Air Force's Aircraft Sustainment Needs in the Future and Its Strategy to Meet Those Needs*, 2011

[5] "The Air Force Faces Tough Decisions on Aging Fleet", Dayton Daily News, (March 24, 1213) and "Hiring Freeze Affects Fleet", Dayton Daily News, (March 26, 2013)

- **Priority 1: Partnering with stakeholders, ensure the safety of the current and future fleets. Conduct S&T to:**
  - Priority 1.1: Investigate the root cause of mishaps, failures and material/component degradation, recommend corrective actions and disseminate lessons learned
  - Priority 1.2: Improve understanding of the health of individual weapon systems and associated components
  - Priory 1.3: Improve the health of weapon systems and associated components
  - Priority 1.4: Improve tools used to calculate and manage operational risk
  - Priority 1.5: Provide an expanded technical basis for safe system service life extension

  Some of the products of Priority 1 tend to require short-term research efforts and include military handbooks and guides, government and non-government specifications and standards, improved inspection tools, Safety Inspection Board and Accident Investigation Board support and reports. Others require longer term efforts to improve the tools used.

- **Priority 2: Improve weapon system availability by conducting research providing technology solutions to:**
  - Priority 2.1: Reduce the maintenance man-hours per flight hour required to conduct inspection and maintenance tasks
  - Priority 2.2: Enable improved health assessment and condition-based maintenance on aircraft, spacecraft, and missile systems
  - Priority 2.3: Reduce hazardous materials and processes in USAF weapon systems and mitigate impacts to Airmen and the environment
  - Priority 2.4: Enable an efficient and responsive supply chain
  - Priority 2.5: Reduce the rate of spacecraft failure by extending the service life of spacecraft
  - Priority 2.6: Increase the technology refresh rate of ground mission systems

  Typical products of Priority 2 include next generation inspection tools and techniques enabling fundamental changes to Air Force maintenance practices, improved materials and processes that increase time between maintenance actions or reduce time to repair, knowledge to enable sound acquisition decisions and components with greater reliability.

- **Priority 3: Reduce the total ownership cost of USAF weapon systems by delivering technology options with a positive return on investment that:**
  - Priority 3.1: Mitigate or eliminate corrosion issues
  - Priority 3.2: Reduce the cost of replenishment spacecraft
  - Priority 3.3: Enable cost effective sustainment of low-observable systems
  - Priority 3.4: Reduce the materiel and labor costs to perform inspection and maintenance tasks
  - Priority 3.5: Reduce cost and complexity of weapon system software maintenance

- Priority 3.6: Reduce the impact to on-platform information systems when industry standards change or become obsolete
- Priority 3.7: Replace fixed function computational resources with general purpose COTS processing and industry-supported forward compatibility
- Priority 3.8: Reduce total system cost with open, extensible, multi-mission pod-based capability acquisition

Typical products of Priority 3 include lower life-cycle cost components that do not degrade mission capability, improved materials and processes, government and non-government specifications and standards, enhanced manufacturing capabilities and equipment and tooling enabling quicker and cost effective maintenance.

- **Priority 4: Improve sustainability of future weapon systems by conducting S&T to:**
  - Priority 4.1: Research and develop cross-domain design tools to incorporate sustainability needs early in the weapon system lifecycle
  - Priority 4.2: Incorporate technologies to assess and improve effectiveness of integrity programs
  - Priority 4.3: Include sustainability considerations during prototype design and development
  - Priority 4.4: Capture and formalize lessons learned in processes and documents useful in future procurements

  Typical products of Priority 4 include next generation maintenance and diagnostic tools embedded in weapon systems, models and software to inform acquisition decisions, military and commercial handbooks and guides.

Engagement Process

The AFRL Capability Lead (CL)[6] for Agile Combat Support (ACS) will be the AFRL lead for understanding the Air Force sustainment shortfalls and lead the development of appropriate research strategy plans to address the shortfalls. The CL will utilize existing Air Force planning processes to understand sustainment capability gaps.[7] Additionally, the CL will annually interface with the Program Executive Officers (PEOs), MAJCOMs, SMC and Air Force Materiel Command (AFMC) Centers to identify areas where S&T could help solve emerging or ongoing sustainment problems. AFRL will also receive inputs and provide subject matter expertise through various working level relationships. Subject matter experts (SME's) will develop projects for the CL to advocate. Using all information gathered, the CL will be responsible for the technical content and advocate

[6] The Capability Lead is an AFRL General Officer or Senior Executive appointed by the AFRL Commander to be AFRL's single point of contact for each of the 13 Service Core Functions. The CL for ACS is the Director of the Materials and Manufacturing Directorate. The Commander of Air Force Materiel Command is the Air Force's Lead Integrator for ACS.

[7] The current process used is the Core Function Master Plan (CFMP) process. Each Core Function Lead Integrator (AFMC for ACS) annually publishes a document that identifies risks and prioritizes capability gaps. AFRL utilizes information contained in the CFMP to develop and fund S&T programs.

for funding in the AFRL corporate processes. The CL will provide the PEOs, MAJCOMs, SMC and AFMC Centers' status of AFRL's technology programs.[8]

Funding

AFRL will target a minimum of 10% of its annual budget to resource this strategy. The desired allocation of funds to implement this strategy is:

- 20% supports Priority 1
- 35% supports Priority 2
- 30% supports Priority 3
- 15% supports Priority 4

However, AFRL will fund projects with the greatest impact to the Air Force for the weight of the effort.

Priority 1 does not receive the largest allocation of funding because many efforts are funded by organizations outside AFRL and the products do not typically require significant AFRL funded demonstration programs. Research efforts supporting this priority take advantage of a significant AFRL organic knowledge base and existing laboratory facilities, reducing the budget necessary for a healthy science and technology program. Research supporting Priority 2 and Priority 3 typically require significant industry development and manufacture of prototypes prior to technology transition, increasing the budget necessary to accomplish these priorities.

In the FY14 President's Budget, 9% of AFRL's budget supports this strategy. The current resource allocation is:

- 16% supports Priority 1
- 34% supports Priority 2
- 33% supports Priority 3
- 17% supports Priority 4

The CL for ACS will also recommend changes to the total budget committed to this strategy, budget allocation and prioritization to the AFRL Commander as necessary.[9] The CL will consider Air Force strategy and goals, AFRL core technical competencies and other national and international events when proposing changes. The CL is responsible for maintaining the strategy.

Summary

[8] These reviews will be through a number of existing processes. The Applied Technology Council, chaired by the MAJCOM Vice-Commander is the most visible process. AFRL also engages with the PEOs through an annual review chaired by AFRL/CC. The ACS CL should also engage through frequent informal discussions.

[9] AFRL's Corporate Board is comprised of all of the Directors or Commanders of the Technical Directorates plus Headquarters AFRL senior staff and will review any proposal prior to AFRL/CC approval.

AFRL has a vision and strategy for maximizing its contribution to the Air Force's ability to field, protect, support and sustain air, space, and cyberspace forces across the full range of military operations to achieve joint effects. Achieving that vision in a limited resource environment requires a carefully crafted strategy that balances the requirements of warfighter safety, warfighting effectiveness, and warfighting cost.

Paramount to that strategy is recognition that technology can significantly improve Air Force capabilities. This strategy provides a defined process to achieve balance between needs and resources to enable leadership to progress toward the development of the most beneficial technical opportunities for transition. The strategy begins with a set of guiding tenets, recognized priorities, and a defined engagement process.

There are significant opportunities in the mid- and far-term to develop technology options that will fundamentally change the Air Force sustainment philosophy and generate significant cost and availability improvements without sacrificing safety. AFRL will develop those options where customer support is offered to advance the technology from the lab to operational use.

Sustainment of the USAF fleet is vital to continue the tremendous airpower advantage the nation enjoys. AFRL, in partnership with key AFMC Center and Air Force MAJCOM stakeholders, will provide technology solutions to enhance the safety, availability and affordability of the current and future weapon systems.

The attached Annex 1.0 “Air Force Corrosion Science and Technology Strategy” provides a framework to mitigate pervasive corrosion problems across USAF aerospace fleets.

Annex 1.0

Air Force Corrosion Science and Technology Strategy

INTRODUCTION/BACKGROUND

The corrosion challenges facing the Air Force are[1]:

- Pervasive: Corrosion affects every Air Force weapon system, including our newest assets.
- Significant: In FY08-09 Air Force aviation and missiles corrosion costs were approximately $4.5B, or 24 % of total maintenance cost. Corrosion contributed to approximately 16% of system non-availability hours.
- Growing: Total maintenance costs are increasing; the proportion attributed to corrosion is increasing.

Upward USAF Cost Trend 2006-2009[2]

	Corrosion Cost (In millions)	Total maintenance (in millions)	As a percent of Maintenance
FY2006	3,105	$14,659	21.2%
FY2007	$3,537	$15,925	22.2%
FY2008	$3,908	$16,403	23.8%
FY2009	$4,485	$18657	24.0%

The Air Force-unique Integrity Program approach to fleet management drives Air Force-specific sustainment activities. This Corrosion S&T Strategy emphasizes those activities, while leveraging and tailoring Navy, Army, and other efforts.

Defined as "the deterioration of a material or its properties due to a reaction of that material with its chemical environment,"[3] corrosion is a well-documented sustainment challenge requiring a broad spectrum of solutions. In order to establish corrosion S&T activities commensurate with Air Force corrosion problems,[4] this working document outlines a comprehensive S&T Corrosion strategy to address near term challenges and provide long term solutions that allow the Air Force to better prevent, predict, detect and manage corrosion. The near term aim is to reduce the corrosion costs and impacts on availability to acceptable levels. A long term goal is to develop the design trade tools

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[1] *The Estimated Effect of Corrosion on the Cost and Availability of Air Force Aircraft and Missiles*, LMI Report, LMI, March 2012; the DoD Corrosion Policy and Oversight Office (CPO) sponsors corrosion cost and availability studies for the Army, Navy, and Air Force every two years. A common methodology is applied to enable valid comparison of trends and identify best practices.

[2] *Corrosion Overview and Need for a Strategy,* SAF/AQR-CCPE, August 2013

[3] *Department of Defense Instruction 5000.67, Prevention and Mitigation of Corrosion on DoD Military Equipment and Infrastructure,* 1 February 2010.

[4] The Independent Strategic Assessment Team (ISAT) Sustainment Panel Brief, 8 July 2013, stated: "Continue re-establishment of a research program for corrosion with scope consistent with the magnitude of USAF problem"

that will enable the acquisition community, to adequately account for and preemptively reduce corrosion impacts in future systems.

> "Science and Technology (S&T) investment in corrosion engineering is vital for the future safety, availability and affordability for Air Force systems and the health and safety of airmen. However, it is of critical importance to acknowledge S&T investment alone will not solve all corrosion-related issues. Air Force policy, organization, staffing and resource allocation decisions must coalesce to maximize the transition of corrosion-related technologies into a more efficient and effective acquisition and sustainment enterprise."[5]

VISION

The Air Force vision for Corrosion S&T is to provide full spectrum solutions addressing near term challenges and providing long term capabilities that allow the Air Force to better prevent, predict, detect and manage corrosion across the life cycles of AF weapon systems and facilities.

SCOPE

This Corrosion S&T Strategy augments the AFRL Sustainment S&T Strategy and establishes an initial framework for further definition over the next few months. The initial focus is on aircraft and subsystem corrosion, even though Corrosion S&T can also positively impact missiles, space assets, weapons, and facilities. Refinements of this strategy will address space and facilities after separate needs assessments have been conducted with the Space/Missile and Civil Engineering communities respectively.

CUSTOMERS & PARTNERS

The customers for this AF Corrosion S&T Strategy include the AF Corrosion Control and Prevention Executive (AF CCPE), Life Cycle Management Center (AFLCMC), Space and Missile Center (SMC) and Sustainment Center (AFSC). Engagements with MAJCOMs, DoD and other government entities, industry, and academia are necessary to properly identify stakeholders, deficiencies and opportunities to develop and transition technologies.

STRATEGY FRAMEWORK

Five essential elements required for AFRL and the AF to achieve the Corrosion S&T vision have been identified.

1. S&T Foundations
   - EXPERTISE: Further develop and sustain a cadre of dedicated SMEs with required education, training and experience to support the corrosion goals of AF acquisition and sustainment communities.

[5] *Corrosion Science and Technology Study,* AFRL-RX-WP-TR-2012-0498, May 2012

- PLANNING: Develop and maintain prioritized technology investment options.

2. S&T to Prevent Corrosion
   - Develop advanced corrosion resistant Materials and Processes (M&Ps).
   - Develop alternative M&Ps that provide equal/better performance to those that pose health and environmental risks.

3. S&T to Predict Corrosion
   - Develop technologies to better predict the corrosion performance consequences of alternate designs, materials, and operational environments to enable information-based decisions.
   - Build a science-based understanding in materials behavior for corrosion initiation and propagation enabling corrosion-based service life prediction.

4. S&T to Detect & Characterize Corrosion
   - Develop nondestructive tools that accurately detect the presence and severity of corrosion.
   - Develop accurate NDE/I (nondestructive evaluation/inspection) standards for use in corrosion assessments.[6]

5. S&T to Manage Corrosion
   - Develop capabilities enabling each of the AF Integrity Programs to better manage corrosion.
   - Partner with acquisition and sustainment communities to mature and transition new technologies for mitigating and controlling corrosion throughout current and future fleets.

IMPLEMENTATION

The AFRL/RX Director will be the AFRL lead for understanding the Air Force corrosion shortfalls and lead the development of prioritized research plans to address the shortfalls. The RX Director will ensure appropriate program balance and support for corrosion basic and applied science, development, and advanced technologies. The Agile Combat Support Capability Lead will periodically interface with the Program Executive Officers (PEOs), MAJCOMs, SMC and AFMC Centers to identify areas where S&T could help solve emerging ongoing sustainment problems. S&T roadmaps and budgets will be refined and inserted into the FY16 AFRL planning, programming and budgeting process to yield a comprehensive, integrated S&T corrosion program. “Bridge” programs will be expanded as resources are identified.

SUMMARY

Corrosion of Air Force weapons systems and facilities is having a serious negative impact on cost of ownership and availability. The Air Force-unique Integrity Program method of managing fleets drives the need for a stand-alone corrosion S&T capability in

[6] Includes improved approaches for hidden corrosion, multiple corrosion types, highly accurate probability of detection capabilities, reduced inspection time, and validated methods for determining whether maintenance actions must be performed immediately or may be delayed until later inspection cycles.

addition to collaboration with the other services. S&T alone will not solve all corrosion-related issues, however, investment in corrosion S&T is nonetheless vital for the future safety, availability and affordability for Air Force systems and the health and safety of airmen. The magnitude of corrosion costs, and their growing impact, necessitates an Air Force wide, collaborative strategy and resources commensurate with the magnitude of the problems.