



Materials and Manufacturing Capabilities for Sustaining Defense Systems: Summary of a Workshop

ISBN
978-0-309-26757-1

75 pages
7 x 10
PAPERBACK (2012)

Robert J. Katt, Rapporteur; Defense Materials Manufacturing and Infrastructure Standing Committee; Division on Engineering and Physical Sciences; National Research Council

 Add book to cart

 Find similar titles

 Share this PDF



Visit the National Academies Press online and register for...

- ✓ Instant access to free PDF downloads of titles from the
 - NATIONAL ACADEMY OF SCIENCES
 - NATIONAL ACADEMY OF ENGINEERING
 - INSTITUTE OF MEDICINE
 - NATIONAL RESEARCH COUNCIL
- ✓ 10% off print titles
- ✓ Custom notification of new releases in your field of interest
- ✓ Special offers and discounts

Distribution, posting, or copying of this PDF is strictly prohibited without written permission of the National Academies Press. Unless otherwise indicated, all materials in this PDF are copyrighted by the National Academy of Sciences. Request reprint permission for this book

Materials and Manufacturing Capabilities for Sustaining Defense Systems

S U M M A R Y O F A W O R K S H O P

Robert J. Katt, *Rapporteur*

Defense Materials Manufacturing and Infrastructure
Standing Committee

Division on Engineering and Physical Sciences

NATIONAL RESEARCH COUNCIL
OF THE NATIONAL ACADEMIES

THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, NW Washington, DC 20001

NOTICE: The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This study was supported by Contract No. W911NF-10-C-0098 between the National Academy of Sciences and the Department of Defense. Any views expressed in this publication are those of the author(s) and do not necessarily reflect the views of the organizations or agencies that provided support for the project.

International Standard Book Number-13: 978-0-309-26757-1

International Standard Book Number-10: 0-309-26757-9

Cover: Image of a three-dimensional fractal. Although highly complex it shows self similarity at every length scale, mimicking the capabilities needed to sustain today's intricate defense systems. The two glowing focal points represent the materials and manufacturing required to reach those capabilities. By looking closely at the image it is possible to see the pattern of the two focal points repeated in the structure at many length scales, both large and small, just as materials and manufacturing have to reach every level of the system to create the capabilities needed to sustain our defense systems. Artist: Erik Svedberg, image generated mathematically on a dual core cpu.

This report is available in limited quantities from:

National Materials and Manufacturing Board
500 Fifth Street, NW
Washington, DC 20001
nmmb@nas.edu
<http://www.nationalacademies.edu/nmmb>

Additional copies of this report are available from the National Academies Press, 500 Fifth Street, NW, Keck 360, Washington, DC 20001; (800) 624-6242 or (202) 334-3313; <http://www.nap.edu>.

Copyright 2013 by the National Academy of Sciences. All rights reserved.

Printed in the United States of America

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Ralph J. Cicerone is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Charles M. Vest is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Ralph J. Cicerone and Dr. Charles M. Vest are chair and vice chair, respectively, of the National Research Council.

www.national-academies.org

WORKSHOP PLANNING GROUP

ROBERT H. LATIFF, *Chair*, U.S. Air Force (ret.) and R. Latiff Associates

W. DALE COMPTON, Purdue University

ALAN C. ECKBRETH, Eckbreth Consulting

JESUS M. DE LA GARZA, Virginia Polytechnic Institute and State University

ROSARIO A. GERHARDT, Georgia Institute of Technology

GEORGE T. GRAY III, Los Alamos National Laboratory

THOM J. HODGSON (NAE), North Carolina State University

MICHAEL F. McGRATH, Analytic Services, Inc.

STEPHEN M. POLLOCK (NAE), University of Michigan

ROBERT E. SCHAFRIK (NAE), GE Aviation

DENISE F. SWINK, Private consultant

STEVEN G. WAX, Private consultant¹

¹ Resigned October 8, 2012.

**DEFENSE MATERIALS MANUFACTURING AND INFRASTRUCTURE
STANDING COMMITTEE**

ROBERT H. LATIFF, *Chair*, U.S. Air Force (ret.) and R. Latiff Associates
ROBERT E. SCHAFRIK (NAE), *Vice-Chair*, GE Aviation
VALERIE BROWNING, ValTech Solutions, LLC
JESUS M. DE LA GARZA, Virginia Polytechnic Institute and State University
GEORGE T. GRAY III, Los Alamos National Laboratory
MICHAEL F. McGRATH, Analytic Services, Inc.
E. SARAH SLAUGHTER, Built Environment Coalition
DENISE F. SWINK, Private consultant
A. GALIP ULSOY (NAE), University of Michigan
HAYDN N.G. WADLEY, University of Virginia
STEVEN G. WAX, Private consultant

Workshop Staff

DENNIS I. CHAMOT, Acting Director
ERIK B. SVEDBERG, Senior Program Officer
ROBERT J. KATT, Rapporteur/technical writer
RICKY D. WASHINGTON, Administrative Coordinator (until August 2012)
TERI G. THOROWGOOD, Administrative Coordinator (effective August 2012)
HEATHER LOZOWSKI, Financial Associate
ANN F. LARROW, Program Associate (effective August 2012)

Acknowledgment of Reviewers

This report has been reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise, in accordance with procedures approved by the National Research Council's Report Review Committee. The purpose of this independent review is to provide candid and critical comments that will assist the institution in making its published report as sound as possible and to ensure that the report meets institutional standards for objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process. We wish to thank the following individuals for their review of this report:

Thom J. Hodgson (NAE), North Carolina State University,
David W. Johnson, Jr. (NAE), Stevens Institute,
Gerald Mahan (NAS), Pennsylvania State University, and
Galip Ulsoy (NAE), University of Michigan.

Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the views presented at the workshop, nor did they see the final draft of the workshop summary before its release. The review of this workshop summary was overseen by Lyle Schwartz, University of Maryland. Appointed by the NRC, he was responsible for making certain that an independent examination of this workshop summary was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this summary rests entirely with the author and the institution.

Contents

OVERVIEW	1
Unresolved Large Issues, 2	
Theme 1 Parts Obsolescence: Dealing with Diminishing Manufacturing Sources for Parts and Components, 5	
Theme 2 Counterfeit Parts and Nonconforming Materials: Issues and Potential Solutions, 6	
Theme 3 Strategies to Deal with Materials Shortages, 8	
Theme 4 Easing the Transition from System Acquisition to System Sustainment, 10	
Theme 5 Enabling the Cradle-to-Grave Digital Thread for Materials, Parts, and Components of Systems, 11	
Theme 6 Transitioning to Condition-Based Maintenance, 12	
Theme 7 Government–Industry Information Sharing and Partnering to Sustain Defense Systems, 13	
Theme 8 Research Topics for Sustainment Science and Technology, 14	
Theme 9 Policy Obstacles to and Enablers for Meeting System Sustainment Challenges, 14	
WORKSHOP PRESENTATIONS AND DISCUSSIONS	16
Welcome: What Is DMMI? and Meeting Objectives, 16	
DOD and Materials Issues, 17	
The Air Force Research Laboratory and Materials Issues, 18	
The Army and Materials Issues, 24	

Open Discussion: Materials Issues and Programs to Mitigate Shortages, 27	
Materials Shortages and Strategies to Counter Them, 31	
Sustaining Air Force Aging Aircraft into the Twenty-first Century, 34	
The Air Force Diminishing Manufacturing Sources and Materials Shortages Program Office, 37	
Open Discussion: Problems Related to the Supply Chain, Parts Obsolescence, Certification, and Sustainment, 40	
Senate Armed Services Committee Report on Counterfeit Electronic Parts in the DOD Supply Chain, 43	
Counterfeit Parts and Parts Obsolescence, 45	
DARPA's TRUST and IRIS Programs, 50	
Open Discussion Related to Counterfeit Problems, Substandard Parts, and Substandard Materials, 54	
Current Issues at the Defense Microelectronics Activity, 55	
Issues at the Office of Compliance of the Center for Devices and Radiological Health, 58	
Open Discussion, 61	
References, 61	

APPENDIXES

A Statement of Task	65
B Workshop Participants	66
C Workshop Agenda	70
D Acronyms	73

Overview

The Standing Committee on Defense Materials Manufacturing and Infrastructure (DMMI) conducted a workshop on July 23 and 24, 2012, to share information and gather perspectives on issues concerning materials and manufacturing capabilities for sustaining defense systems. This workshop, held at the headquarters building of the National Academies on Constitution Avenue in Washington, D.C., was conducted according to the procedures of the National Research Council (NRC) for convening such an activity. By these procedures, all workshop participants—including presenters, members of the DMMI standing committee, Reliance 21, invited guests, and visitors—spoke as individuals, and no overall findings, conclusions, or recommendations were developed during or as a result of the workshop. All statements and views summarized in this publication are attributable only to the individuals who expressed them. It is worthwhile noting that the sponsor, Reliance 21, is a Department of Defense (DOD) group of professionals that was established to enable the DOD science and technology (S&T) community to work together to enhance DOD S&T programs, eliminate unwarranted duplication, and strengthen cooperation among the military services and other DOD agencies.

The DMMI appointed a workshop planning group to develop the workshop agenda and decide on invited guests and presenters, in accordance with the statement of task approved by the Governing Board of the NRC (Appendix A). The planning group also consulted with the Reliance 21 materials and processing community of interest. The workshop participants, who included a number of members of this Reliance 21 community of interest, are listed in Appendix B. Appendix C is the workshop agenda and Appendix D spells out the acronyms used here.

The planning group's role was limited to planning the workshop, and the workshop summary was prepared by the workshop rapporteur as a factual summary of what occurred at the workshop.

The presentations and discussions during the workshop are summarized sequentially in the main part of this report as "Workshop Presentations and Discussions." As an aid to readers, the rapporteur has identified nine themes that recurred in multiple presentations and discussions:

1. Parts Obsolescence: Dealing with Diminishing Manufacturing Sources for Parts and Components
2. Counterfeit Parts and Nonconforming Materials: Issues and Potential Solutions
3. Strategies to Deal with Materials Shortages
4. Easing the Transition from System Acquisition to System Sustainment
5. Enabling the Cradle-to-Grave Digital Thread for Materials, Parts, and Components of Systems
6. Transitioning to Condition-Based Maintenance
7. Government–Industry Information Sharing and Partnering to Sustain Defense Systems
8. Research Topics for Sustainment Science and Technology
9. Policy Obstacles to and Enablers for Meeting System Sustainment Challenges

These themes were also described in the open discussion before the close of the workshop, when discussion leader Steven Wax asked the participants for comments, in light of all the presentations and discussions, on unmet needs and unresolved big issues in the areas of sustainment, replication/obsolescence, and counterfeits. The discussion resulted in the following outline of needs and issues suggested by one or more participants. The individual items in this outline were not discussed in depth during the session and do not reflect any consensus among the workshop participants but can serve the reader as another source of material from the workshop.

UNRESOLVED LARGE ISSUES

Sustainment

- From cost curves for sustainment, it appears that savings from implementation of improved sustainment could be used to move new sustainment technologies from TRL/MRL 6 to TRL/MRL 9.¹ However, use of such

¹ MRL, Manufacturing Readiness Level. Nine MRLs are defined in AFSAB, 2011, p. 152.

- savings has to be consistent with DOD business practices and culture, including financial management practices.
- The transition from initial design and production to depot and field maintainers is difficult and needs attention.
 - What is lacking for accurate forecasts of maintenance/sustainment needs?
 - Tools to do assessment in the field; one example is handheld tools to facilitate capture of status data at the time that maintenance is done.
 - Better tools to provide more complete data that could reduce mission-incapable (MICAP) hours and time in depot.
 - Remote inspection technologies that do not require dismantling platforms to get access.
 - Means to address the cost of getting nondestructive evaluation technologies through engineering development.
 - Which data should be captured to have a digital data thread adequate for life-cycle sustainment?
 - What policy and implementation can be considered for DOD purchase of data rights?
 - Sustainment (maintenance) S&T in areas such as corrosion and inspection:
 - What is it? How should sustainment S&T be defined?
 - Not all sustainment S&T is maintenance-oriented. It should also include upgrading as part of sustainment.
 - Improved fundamental understanding of corrosion (6.1 research) could enable design to mitigate corrosion rather than the trial-and-error approach of screening coatings. The problem is similar for cracking.
 - Value of doing S&T—why is funding for sustainment S&T hard to get? What are incentives for doing it?
 - Improve transitioning of S&T results to practice (e.g., make better engineering trade-offs using existing technology).
 - Distinguish between funding to develop new technologies for sustainment and funding the application of existing and new technologies to real-world problems.
 - Cost/benefit models to explore policy and technology alternatives:
 - Issue: DOD systems are not bought on the basis of their life-cycle cost.
 - Need technology solutions that are consistent with how DOD does business and how programs are funded.
 - Proposed solutions need to be viable in the current system.
 - How much culture change is necessary to transition from current practice to better sustainment methodology? What can the military services and DOD do to change the culture?

—Are issues with sustainment more often leadership issues than technical or materiel issues?

Replication/Obsolescence

- Vulnerability assessment methodology.
- Institute for Defense Analyses (IDA) models and war games.
- Possible solution: replace worn parts with substitute parts instead of hard-to-find or manufacturer-original parts.
- Need for rapid, low-cost certification of replacement material and parts.
- Integrated computational materials for engineering (ICME).
- Trusted production—for example, the Trusted Supplier Program of the Defense Microelectronics Activity (DMEA) and in-house production options.

Counterfeit Parts and Materials

- The problem of nonconforming parts is growing rapidly. Do we know enough to put disincentives in place to limit deliberate introduction or acceptance of nonconforming materials and parts?
- Policy, regulation, risk analytics (e.g., U.S. Food and Drug Administration). Down to which level in the supply chain? What are or should be the disincentives for counterfeiting or misrepresenting materials or parts?
- Trusted sources
 - Even with trusted sources, DOD will still need validation for malicious components.
 - Availability of trusted foundry/supplier participants to support commercial users as well as DOD?
 - Trusted sources and verification/validation testing need to go deeper than Tier 1 suppliers.
- Low-cost, more effective testing (electrical, mechanical?) needed to do a better job of catching counterfeits.
 - Technical means are needed for validation/verification of parts. Defense Advanced Research Projects Agency (DARPA) programs—Trust in Integrated Circuits (TRUST) and Integrity and Reliability of Integrated Circuits (IRIS)—can demonstrate proof of concept, but their products face a “valley of death” and many will not transition to implementation.
 - Risk analytics might help with decisions on which technology developments (such as the DARPA TRUST and IRIS results) are worth implementation.

- A stronger procedural response is needed for the detection of counterfeits—reporting to community, forward and backward tracking through the supply chain.
- System-level testing methods are needed, including boards and lower-level components (resistors, diodes).

Highlights of participants' comments during the workshop on these themes are presented below; these highlights should not be interpreted as consensus statements from the workshop or the DMMI standing committee.

THEME 1

PARTS OBSOLESCENCE: DEALING WITH DIMINISHING MANUFACTURING SOURCES FOR PARTS AND COMPONENTS

Parts obsolescence is an issue when the lifetime of a system is much longer than the availability of spare components for that system. This can occur when either the manufacturer of the component no longer exists or when the components are frequently updated or changed by the manufacturer such as in the electronics industry. Today, not many solutions exist for solving this problem. Some efforts involve buying the last parts before they no longer are available, while other efforts seek to replace the part with other similar parts.

Currently, using a part, component, or subsystem in a system (such as an aircraft or other weapons platform) different from the one for which it was qualified or certified requires requalifying/recertifying it for the system(s) of potential use. Similarly, materials and parts/components need requalification or recertification when the raw materials used in them or their manufacturing processes change. While workshop participants understood the rationale for this requirement, which is necessary to ensure that functionality and reliability are not affected by such substitutions and changes, a number of participants saw it as an R&D challenge to find ways to decrease the cost and time required for appropriate qualification/certification of substitutes.

One participant, who is a materials scientist, said that even the smallest changes in material composition from what was used in a part originally could, in principle, drastically change structure at some scale, which in turn could alter properties that affect the function of that part.

One suggestion was to pursue new approaches to standardization of specifications. Dianne Chong of Boeing noted that variability in specifications for very similar applications of what seem to be identical parts is a problem for commercial-sector manufacturers that have merged operations or have acquired other companies, not just a problem for DOD. She suggested that a single system for recording and main-

taining parts specifications could help with this aspect of the obsolescence problem. The goal would be to share (across DOD or a commercial enterprise, or even more widely across the aerospace community) a common set of qualification and certification requirements for the same physical part in essentially similar applications.

Royce Smith of the 448th Supply Chain Management Wing, U.S. Air Force, made the case for proactively managing diminishing manufacturing sources and materials shortages rather than reactively addressing shortages after they occur. He described how the Air Force is using the Advanced Component Obsolescence Management (AVCOM) system to monitor and plan for parts obsolescence in Air Force legacy systems. A key step is loading complete parts information for an aircraft subsystem into AVCOM. Once that relatively complex step is complete, AVCOM can produce alerts on impending obsolescence, analyses of possible form/fit/function replacements for an obsolescent part, analyses for all end items in the inventory that are affected by an obsolete part, and other kinds of reports. For parts with no current manufacturers and no logistics solution established yet, the next step is an analysis and resolution process. Unfortunately, the process of loading subsystem information into AVCOM has to be prioritized because of funding constraints, so not all subsystems of all legacy aircraft have so far been represented.

Dr. Chong said that, in her experience at Boeing, the time required to find another supplier of a discontinued part depends on many factors, but often identifying a potential supplier is fairly quick; it takes longer to certify the supplier and/or the replacement product. Boeing is actively investigating computation-based tools that would lessen the amount of testing required to certify a replacement; most of these tools and the development of associated testing techniques are intended for certifying structural materials rather than electronic parts.

The workshop participants briefly discussed the potential for three-dimensional printing technology to provide critical parts when the normal supply pipeline is disrupted. Among the several challenges that some participants saw in this as a solution to parts obsolescence were that (1) a part produced this way would still need to be qualified or certified and (2) the appropriately qualified raw material has to be available.

THEME 2

COUNTERFEIT PARTS AND NONCONFORMING MATERIALS: ISSUES AND POTENTIAL SOLUTIONS

Most of the presentations and discussion at the workshop used the term “counterfeit part” in a sense consistent with the definition used by the industry consensus standard (SAE AS 5553), which includes used parts sold as new, as well as parts that had part numbers changed and unauthorized copies of the authentic

part. Carl McCants from DARPA said that he preferred the term “nonconforming part,” which he understood to include both counterfeit parts as defined by the industry standard and imperfectly fabricated parts from a licensed manufacturer. Bryan Benesch told the workshop that, for the FDA, a counterfeit product is defined more narrowly and requires that the counterfeit item use the brand name or other trademark/service mark identifiers owned by the makers of authentic items.

None of the participants spoke of known cases of counterfeit parts where the motivation of the counterfeiter was “malicious” in the sense of deliberately seeking to cause system performance failure or to infiltrate the system to obtain information or control in some way. Several participants who had dealt with cases of counterfeit parts said the motivation seemed to be the economic value of supplying the demand for an otherwise hard-to-find part. However, the prospect and feasibility of malicious intent were raised by many of the participants at various times during the workshop. Dr. McCants made a general argument for careful consideration of malicious intent in counterfeit hardware parts because of the increasing integration of hardware systems into all kinds of networks, many of which are known to have experienced cyberattacks or have been shown to be vulnerable to such attacks.

Joseph Bryan, who was the lead staff member on the investigation by the Senate Armed Services Committee of counterfeit electronic parts in the DOD supply chain, summarized the investigation and its major findings and recommendations (Committee on Armed Services, 2012). The investigation identified about 1,800 cases of suspect counterfeits involving more than a million counterfeit parts. Most of the counterfeits identified by the committee were previously used parts that had been removed from assemblies and circuit boards and resold as new parts. The investigators found that DOD lacked knowledge of the scope and impact of counterfeit parts on critical defense systems. The investigation also revealed that DOD and large defense contractors were not keeping track of counterfeit parts they found. The committee relied on testing companies used by defense contractors and their suppliers for much of their information. Neither commercial users nor DOD agencies were routinely reporting instances of counterfeiting found by their independent testers.

In all four cases of counterfeit microprocessor chips described by Scott Fish (Army chief scientist), the routine performance tests performed at several points in the supply chain failed to detect the anomalies. This makes the problem of identifying and dealing with counterfeits very tricky, he said.

Several participants discussed recent cases of nonconforming materials (materials that did not meet the composition, formulation, or processing specifications under which they were acquired by the purchaser), such as the titanium used to fabricate certain aircraft parts. Katherine Stevens of the Air Force Research Laboratory (AFRL) and other participants noted the importance of building and maintaining

a system of trusted suppliers as one approach for dealing with nonconforming materials, as well as for avoiding counterfeit parts.

Dr. Fish described proactive actions the Army is taking to address the counterfeit parts problem (in addition to the remedial actions taken when a counterfeit part is identified and has been used in fielded systems). An initial risk management capability for supply chain issues includes increased attention on the government side and increased diligence on the part of prime contractors and their suppliers in testing parts for performance compliance. The Army is also working with the Office of the Secretary of Defense (OSD) on a Trusted Supplier Standard.

As one participant noted, the issues with counterfeit parts and materials discussed at this workshop seemed to fall into two categories: (1) the quality of the counterfeit part and the risk of negative performance consequences resulting from poor quality relative to an authentic part and (2) the risk of malicious intent, including the addition of functionality to a counterfeit part or deliberate alteration to remove or compromise functionality. This participant added that solutions useful for the first category might be inadequate for the second category. A second participant agreed with the difficulty of addressing malicious addition or changes to functionality, adding that overreliance on standards and on testing to those standards could create complacency about the security of the supply chain.

Another participant thought that the alternative to having an error-proof way to detect functionality that has been added to a counterfeit part, which seems extremely difficult to guarantee against, is to have a trusted network of suppliers. But, this participant added, a trusted supplier network probably requires a combination of technology and policy approaches (see Theme 9). Robert Schafrik described the intensive information-sharing and partnering process GE uses to establish and maintain its trusted supplier relationships. Daniel Marrujo described the role of DMEA as the accreditation authority for DOD's Trusted Foundry Initiative and responded to numerous questions from other participants about the initiative and how it might be expanded to deal with sustainment issues including parts obsolescence as well as counterfeit parts.

The status of testing for "added functionality" in electronic parts was raised early in the workshop. The only presentation that addressed current capability or current R&D for such testing was Dr. McCants's account of DARPA's TRUST and IRIS programs.

THEME 3

STRATEGIES TO DEAL WITH MATERIALS SHORTAGES

Robert Schafrik summarized the technical argument, as reported in the peer-reviewed literature, that upward trends in the global demand for metals, combined

with downward trends in the quality of metal ores, support the conclusion that users in both defense and commercial applications should anticipate increased cost, decreased availability, and increased risks of supply disruptions.

Dr. Schafrik believes an analogous argument can be made for other, nonmetal raw materials and agrees with the position that reactive responses, after a materials supply threat occurs, should be replaced by a proactive strategy.

A proactive strategy can begin by anticipating the risk of a shortage. It would apply a staged approach to responding, starting with identifying alternative sourcing solutions but continuing with increasing manufacturing efficiencies (less waste of the raw material), recycling, substituting alternative material(s), and substituting alternative technologies (systems) that do not require the material. Dr. Schafrik then moved from the general concept of a proactive strategy to describe the particular approach used by his company, GE, to develop technical risk reduction programs for materials with high criticality for the company.

Dr. Chong described processes used at Boeing for managing materials shortage and parts obsolescence risks that were broadly similar to the proactive strategy Dr. Schafrik described.

Dr. Fish gave examples of recent Army experiences with material shortages that were significant enough to come to his attention at Army Headquarters. In some instances, limited-duration shortages due to unexpected production losses were handled by drawing down reserve stocks. Other cases involved major price increases from the single domestic supplier, no domestic supplier, or a supplier base that was unable to meet demand. He said the Army does not presume that all production of a defense-critical chemical or material must be domestic, but there have to be adequate controls in place on both production and supply to ensure that requirements are met. He also suggested that relying on a sole source for a critical material must be paired with a program to stockpile sufficient reserves to cover an interim supply shortage.

Temporary material shortages can also occur when production capability is transferred from one supplier to another, either because the original supplier sells a product line to another company or because the customer initiates a change in supplier. To address this cause of temporary shortages, one participant suggested that a best practice would be for any supplier to notify customers when it was initiating any disruption in supply capability. This prior notice would allow customers to increase inventory in advance of the potential disruption.

The participants discussed whether the new Sector by Sector, Tier by Tier (S2T2) program in DOD will provide a tool for assessing the services' supply vulnerabilities. A participant familiar with the program noted that there are policy constraints on how the database can be accessed, to protect a supplier's competitive position and proprietary information.

THEME 4

EASING THE TRANSITION FROM SYSTEM ACQUISITION TO SYSTEM SUSTAINMENT

System acquisition and the process of designing, developing, and putting some new asset into use are very different from system sustainment, where maintenance and service of the asset is the main focus. It is clear that with sustainment also come issues related to parts obsolescence and an increased risk of counterfeit parts, as well as potential materials shortages. One of the most demanding challenges, according to Dr. Stevens of AFRL, is transitioning technology from the system development and acquisition world to the sustainment world.

In the first open discussion session, this challenge was articulated by one participant in the following questions: Are there materials or manufacturing technologies that inherently make parts more transferable between systems and applications? What can be done on the production or processing side to make long-term sustainment easier, including easing the problems that occur when an original manufacturer goes out of business or can no longer supply parts? Without exposing proprietary information, what processing information would help a subsequent manufacturer?

Another comment during the same discussion was that sustainment contractors often do not have the resource base, including personnel with appropriate expertise, to provide the level of problem analysis and resolution that original equipment manufacturers (OEMs) provide. Maintenance depot personnel—both government personnel and contractors—prefer to work from technical orders that are written like step-by-step recipes.

Alan Eckbreth noted that the study team for the advisory report *Sustaining Air Force Aging Aircraft into the 21st Century* had defined “sustainment” as the combination of operations and maintenance (O&M) and modifications for upgraded performance (AFSAB, 2011, p. vi). He explained the significance of that definition with respect to applying new technology approaches in the context of how Congress appropriates funding for O&M separately from funding for modernization. Both Dr. Eckbreth and Dr. Stevens used data from that study showing that O&M costs for the Air Force fleet have nearly doubled in the past 14 years, even though total aircraft inventory has continued to decline. The study also argued for use of key sustainment effectiveness metrics other than cost alone, such as aircraft availability divided by cost (AA/\$). Dr. Eckbreth described a number of findings and concomitant recommendations from the AFSAB study that could help ease the transition to sustainment.

Dr. Stevens said that AFRL’s vision for the future is to move from the current linear paradigm for the material life cycle—in which materials and processes

research leads sequentially through materials development, component design, component testing, certification/qualification, manufacturing, and sustainment—to an integrated sustainment paradigm in which all these stages in the life cycle are being examined interactively and in parallel. The manufacturing portion of this integrated life-cycle approach includes a concept called “moving manufacturing to the left” (addressing manufacturing issues early in the R&D process) and a digital data collection and archiving component called the “cradle-to-grave digital thread.” The objective of the former is to enable earlier development of game-changing products and manufacturing process technologies. The objective of the cradle-to-grave digital thread is to develop and employ digital environments and tools that increase efficiencies in all stages of the life cycle.

THEME 5

ENABLING THE CRADLE-TO-GRAVE DIGITAL THREAD FOR MATERIALS, PARTS, AND COMPONENTS OF SYSTEMS

As noted under Theme 4, the digital data collection portion of AFRL’s integrated life-cycle approach to sustainment is called the “cradle-to-grave digital thread.” But beyond this particular AFRL initiative, a number of workshop participants were interested in and commented on both the challenges of and the potential approaches for implementing a digital data environment that would capture relevant data throughout the system life cycle and make it available for sustainment activities.

Several participants noted the challenge of capturing adequate design and manufacturing data and documentation from the OEMs during system development and acquisition so that they will remain available even after a part or component goes out of production. Information on the manufacturing process, not just CAD/CAM designs, is being lost. Some participants noted that this challenge is not unique to the Air Force. A problem raised several times in different ways by various participants was knowing what information from the initial development and production phases needs to be captured to make downstream sustainment easier. One participant noted that much is still not understood about the knowledge, as well as the data, necessary to replicate a part or provide for sustainment over an extended system life cycle. Dr. Stevens said that capturing nondestructive evaluation/inspection (NDE/I) data for individual systems as they go through maintenance during their operational lives is also an essential part of the cradle-to-grave digital thread concept.

During an open discussion session, one participant suggested that a relevant policy question is whether DOD should (1) attempt to buy the technical data sufficient to maintain a “digital data thread” and store those data in an engineering

data repository or (2) look to OEMs to maintain that information and buy it back as a service. Would a DOD data repository be as complete and accurate as the data OEMs would maintain? One response to this suggestion was that it is important for DOD to get the technical data rights up front because an OEM might not remain in business, or, if it is sold, it might not be bought by another DOD supplier that could retain the data to make it available.

Several participants also noted a number of current efforts, such as the ManTech programs in OSD and the Army, to overcome or at least ameliorate some of these problems for implementing the digital data thread vision.

THEME 6

TRANSITIONING TO CONDITION-BASED MAINTENANCE

Condition-based maintenance is maintenance where the traditional form of scheduled maintenance at regular intervals is replaced by maintenance when needed. To determine when maintenance is needed, an indicator such as declining performance is measured and maintenance is performed when a predetermined reduction in performance is reached. According to Dr. Stevens, moving to condition-based maintenance is one way to improve Air Force fleet health management. Currently, the Air Force depots are moving increasingly in the direction of high-velocity maintenance, which will allow flight systems to be turned around and returned to operational availability more rapidly. Inspection techniques, lifing methods, and data acquisition technology are being developed to enable condition-based maintenance rather than replacement based on time in use or the like. Data from the design, production, and operational maintenance phases of the system life cycle are necessary to enable condition-based maintenance, said Dr. Stevens. She later noted that having a digital representation of each physical system (e.g., each aircraft) would be very beneficial to condition-based life management.

The study that Dr. Eckbreth chaired found that lack of quality and consistency in parts replacement on the part of the Air Logistics Centers (ALCs) makes it difficult to accurately forecast supply chain needs. Some of the R&D recommendations from that study (see Theme 8) are relevant to paving the way for condition-based maintenance. It should be noted, however, that for some Air Force platforms deployed to remote locations, a proactive replacement approach where parts are regularly replaced according to a schedule might be more appropriate from both mission success and cost standpoints.

THEME 7

GOVERNMENT–INDUSTRY INFORMATION SHARING AND PARTNERING TO SUSTAIN DEFENSE SYSTEMS

Participants discussed the extent to which industry best practices for dealing with the problems reflected in Themes 1 through 6 could be shared across the defense supplier community and might be of value to DOD as well. Are there industry best practices in supplier management and manufacturing data capture that could be adopted or adapted by DOD as better ways to do business? Industry consensus standards, including the process by which such standards are developed, maintained, and revised as necessary, were one principal example used by several participants of a best practice to emulate in addressing sustainment problems.

Royce Smith described the Shared Data Warehouse (SDW), an information system supported by the Defense Logistics Agency to capture and share information about parts that are going out of stock from an established supplier. According to Mr. Smith, SDW allows the military services to buy extra inventory of a part before it goes out of production. The Air Force hub for the SDW, which is in Mr. Smith's organization, consolidates estimates of how many parts are nearing obsolescence at each ALC and sends one requisition to the Defense Logistics Agency. He sees tools like SDW as the principal way to avoid parts obsolescence by buying sufficient inventory before production of the part ends. Other participants suggested that the SDW concept could be expanded to include more of DOD, defense prime contractors, or even the wider aerospace industrial community.

Bringing government and industry together in partnerships such as the new Army Cooperative Research Alliances for multiscale and microstructured materials was suggested as a way to attack sustainment problems.

The Materials Genome Initiative (MGI) is a “multi-agency initiative designed to create a new era of policy, resources, and infrastructure that support U.S. institutions in the effort to discover, manufacture, and deploy advanced materials twice as fast, at a fraction of the cost” (NSTC, 2012). Even though MGI has focused on the program's objectives of using new materials in new applications, both Dr. Stevens (Air Force) and Dr. Fish (Army chief scientist) saw it as potentially having rich applications to sustainment issues such as those discussed at the workshop.

The trusted supplier relationships of companies like GE and Boeing should be partnerships between supplier and customer rather than adversarial relationships. Participants familiar with how industry handles these relationships noted that the military, as the customer, must follow through on protecting its suppliers' pro-

proprietary and competitive information. They thought that government customers would have a great deal of difficulty maintaining that kind of relationship because of acquisition requirements for competitive contracting. Participants brought up other similarities and differences between DOD–supplier relationships and commercial industry relationships.

THEME 8

RESEARCH TOPICS FOR SUSTAINMENT SCIENCE AND TECHNOLOGY

The study chaired by Dr. Eckbreth on sustaining the Air Force fleet recommended increased funding for sustainment S&T because those investments are critical to reducing maintenance costs. The increased funding would result from a rebalancing of the AFRL portfolio to better align it with the fleet composition in the near to mid future. Maintenance S&T requires increased emphasis in order to contribute to life extension, expedited inspections, and reduced touch labor (AFSAB, 2011). The recommended areas for fundamental research included (1) testing for corrosion, stress corrosion cracking, and accelerated aging; (2) fuel leak detection and prevention; (3) wiring fault detection; and (4) research in software verification and validation, self-describing code, software readability interoperability, and other software sustainment areas. The report also discussed specific maintenance technologies that the study team considered to have crosscutting benefits for improving fleet maintenance and sustainment. It argued that approaches to transition technologies with promising returns on investment need to be adopted to realize the benefits of S&T advances in these areas (AFSAB, 2011).

During the discussion following Dr. Eckbreth’s presentation, several participants described actions that AFRL is taking to address the recommendations of his study and others. They also noted that feasibility of the recommended maintenance and sustainment S&T in an era of constrained DOD and Air Force budgets is still being assessed.

THEME 9

POLICY OBSTACLES TO AND ENABLERS FOR MEETING SYSTEM SUSTAINMENT CHALLENGES

The participants discussed whether S&T solutions for the system sustainment challenges highlighted above could be separated from changes in current policy and DOD and military service culture. Many of them expressed skepticism that purely S&T approaches could in and of themselves effectively meet the challenge.

Several participants even noted that, based on past experience, advisory recommendations to DOD or individual services that addressed technology solutions only were highly unlikely to be implemented. Technology R&D recommendations, they argued, should instead be presented in the context of current business models and practices in DOD, including funding processes linked to congressional appropriations. Throughout the workshop, and particularly in the question and discussion periods, various participants commented on linkages between potential technology approaches and policy or culture issues that would have to be addressed to make the technology approach effective.

Several participants described how de facto responsibility for key decisions that affect downstream (after system acquisition) availability of parts and materials, environmental issues, and other sustainment challenges has shifted over time, from systems engineering offices within DOD and military service program offices to the prime contractors. One participant thought that the new Air Force Life Cycle Management Center (AFLCMC) could help bring some of that responsibility, as well as the engineering expertise to exercise it, back within the Air Force. However, other comments were more pessimistic about the likelihood of the trend reversing, given budget constraints and the necessity of finding acquisition cost savings.

In describing the challenge of transitioning systems from acquisition to sustainment (see Theme 4), Dr. Stevens said that different views on which organization is responsible for transitioning the technology into sustainment applications are part of the challenge, but problems related to how expenditures are categorized for appropriations (which costs can be covered out of which pot of money) are at least as important. Another participant suggested that Extended Availability of Funds Authority, if it could be applied to cost savings from improvements in sustainment practices and technology, might help ease funding constraints. Other participants remarked on the difficulty of planning and implementing a long-term program for more efficient and effective sustainment of legacy systems when the funding for such sustainment activities was short term (1-year funding for some types of sustainment activities).

In response to the discussion of recycling scarce material as one response to material shortages, one participant recounted how current DOD regulations led to abandonment of what had been a successful program for recycling the rhenium-containing alloys in replaced Air Force jet engines and engine parts. Another participant contrasted that policy constraint with commercial industry practices that enable the same parts to be fully recycled.

Workshop Presentations and Discussions

WELCOME: WHAT IS DMMI? AND MEETING OBJECTIVES

Robert H. Latiff, Chair, DMMI Standing Committee

Dr. Latiff welcomed the participants to this fifth meeting of the National Research Council's (NRC's) Standing Committee on Defense Materials, Manufacturing, and Infrastructure (DMMI). The DMMI, which is associated with the NRC's National Materials and Manufacturing Board (NMMB), was formed at the request of Reliance 21, a Department of Defense (DOD) group of professionals that was established to enable the DOD science and technology (S&T) community to work together to enhance Defense S&T programs, eliminate unwarranted duplication, and strengthen cooperation among the military services and other DOD agencies. As its name indicates, the focus of DMMI is on issues relevant to materials, manufacturing, and the infrastructure that sustains the materials and manufacturing enterprises essential to national defense.

Dr. Latiff noted that this workshop had originated in conversations with members of the Reliance 21 Materials and Processing community of interest on issues of parts obsolescence, diminishing sources for manufacturing, certification of spare parts, requalification of materials, counterfeiting, and other quality assurance and maintenance problems for DOD as defense systems are kept for longer and longer service lives. Dennis Chamot, associate executive director of the NRC's Division on Engineering and Physical Sciences and currently the acting director of the NMMB, reviewed the NRC procedures applicable to workshops. As such the workshop was

an open meeting, and any publication produced from it would be publicly available. No classified, proprietary, or for official use only (FOUO) information was presented or discussed during it. This workshop summary recounts the discussions and presents the views of individual participants; there are no conclusions or recommendations that reflect a corporate or consensus position of the DMMI, the NMMB, or any other entity of the NRC.

DOD AND MATERIALS ISSUES

Lewis Sloter, OSD Principal Reliance 21 Materials and Processes Community of Interest

Dr. Sloter described how the Reliance 21 Materials and Processes community of interest had worked with the DMMI to develop a workshop agenda covering the broad area of materials sustainability with respect to defense equipment, infrastructure, and recapitalization. Critical materials substitution and demand reduction were addressed at a previous DMMI meeting and remain a focus of DOD planning. Two weeks before this workshop, the Institute for Defense Analyses (IDA) held a workshop on issues related to specific materials and approaches to reduce vulnerabilities related to them. Sustaining adequate supplies of materiel, particularly with respect to equipment refurbishment and recapitalization, is currently important to planning for future utilization of the mine-resistant ambush protected (MRAP) vehicles fielded during Operation Iraqi Freedom. Normalization and global support for the F-35 Joint Strike Fighter aircraft is another highly topical issue, as is the broad subject of strategic manufacturing and local supply. Materials supply, utilization, certification, and substitution will be important aspects of Pentagon discussions on strategic sourcing, offshoring, and the control and prevention of counterfeit parts in the electronic and mechanical subsystems of critical defense systems. Dr. Sloter said these issues would provide grist for the materials research mill.

Dr. Sloter sees the twenty-first century as a time when material technologies will see significant advances. He expects rapid manufacturing in small volumes to be important in many areas, including pharmaceuticals, mechanical components, and electronic components. New manufacturing, printing, and templating technologies will be among the great opportunities to continue the advances reflected in Moore's law for microprocessor-based systems. The difficulty will be in making the best use of limited resources to pursue the applied research and development (R&D) opportunities with the greatest potential benefits, given the broad range of opportunities and challenges.

Dr. Sloter was asked for his perspective on how much further improvement can be expected in structural materials, such as materials for hypersonic flight or other cutting-edge applications where material properties are a constraint. Are DOD

priorities being focused more on near-term problems or far? He replied that fundamental, curiosity-driven research, which is long-range and opportunistic with respect to using new discoveries, is very healthy. Near-term sustaining research, broadly speaking, is also very healthy. It is coming out of a period that focused on multiple-point approaches to addressing solutions for specific operational, maintenance, and sustainability problems by the rapid application of relatively mature materials and processes to systems fielding and sustainment. The defense community is also coming out of a long period of ameliorating the environmental impact of materials processes such as plating and coating processes. He is concerned about the prospects for near-term maturation of materials and processes in areas such as hypersonics. Mechanical designs to provide thermal protection are probably ahead of the complementary development of specific materials. In areas like hypersonics, there may be a switch from technology push by innovative material solutions to requirements pull from prototype systems development.

Another participant suggested that some of the challenges appear to be in putting the right teams together to address, from a systems perspective, problems that are multidisciplinary. Is DOD moving toward that team-building approach in any of its programs? Dr. Slotter replied that he has seen a positive trend toward teaming during his 14 years in the Pentagon. He cited as an example the close interactions among Joint Staff, requirements developers in the services, acquisition managers, and industrial base policy staff within the Pentagon. He also sees some good examples of teaming in large integrated programs such as the F-35 Joint Strike Fighter and in some of the integrated teams at the Defense Advanced Research Projects Agency (DARPA). There have also been some lessons learned from programs that did not do as well. He agreed that there was still a long way to go before defense engineering and manufacturing achieve the level of integrated planning characteristic of the automobile industry, for instance.

Several other participants gave examples of defense industry companies that have initiated efforts in integrated computational materials engineering (ICME) in their DOD contract work, without being driven in that direction by DOD program management.

THE AIR FORCE RESEARCH LABORATORY AND MATERIALS ISSUES

Katherine A. Stevens, Director

Materials and Manufacturing Directorate, Air Force Research Laboratory

Dr. Stevens began by noting that the Air Force Research Laboratory (AFRL) is concerned about the sustainability of future weapon systems, as well as about technology for keeping the existing legacy systems flying. Some of the required technology is related to materials and processes. AFRL's Materials and Manufactur-

ing directorate has cradle-to-grave responsibilities for materials and manufacturing, which means it is involved in sustainability and cost of future materials and systems, as well as the life-cycle management problems associated with maintaining and sustaining the aircraft “on the ramp” today. In 2012 the new Air Force Life Cycle Management Center (AFLCMC) was created, replacing the Aeronautical Systems Center. The new center is responsible for supporting aircraft weapon systems through their entire life cycle.

As context for the Air Force’s problem of aging aircraft, Dr. Stevens showed a chart of the systems that had been introduced in each decade since the 1950s, with those still in the inventory shown in red, those out of the inventory in black, and systems in development shown in blue (Figure 1). The average aircraft has been in service for 23 years, with fighter aircraft averaging 22 years, tankers 35 years, and bombers 47 years. Even though the current fleet is the smallest in numbers of aircraft since the inception of the Air Force, the cost of sustaining the fleet continues to rise (Figure 2).

The AFRL sustainment investment is divided among three research thrusts:

- Supporting sustainment of the current fleet (field and depot sustainment);
- Improving fleet health management; and
- Enabling robust design of new systems through use of advanced tools, techniques, and processes.

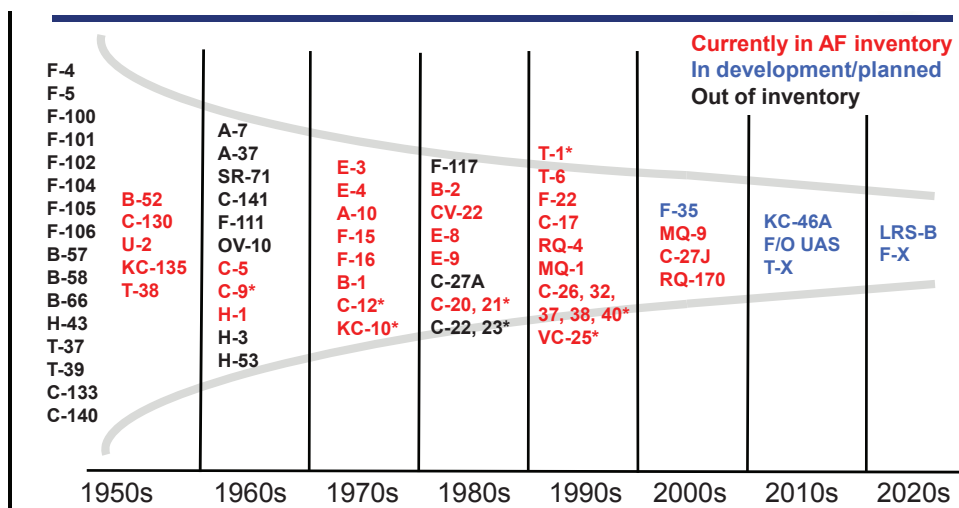


FIGURE 1 Air Force legacy and projected aircraft inventory. Year of first flight or, as denoted by an asterisk, first appearance of a commercial derivative in the Air Force inventory. SOURCE: AFSAB, 2011, p. 13.

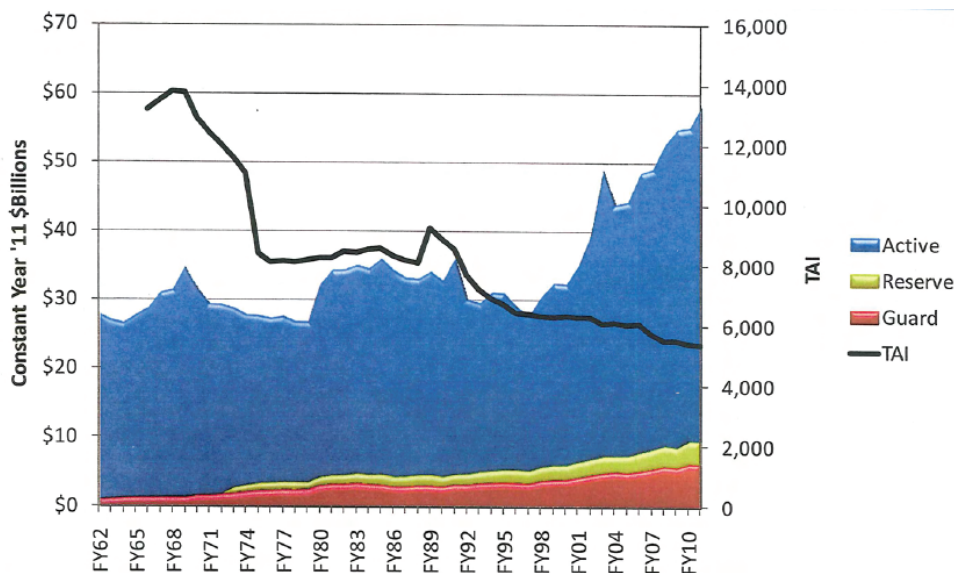


FIGURE 2 Size of total aircraft inventory (TAI) and cost of fleet operation and maintenance, FY 1962-2010. SOURCE: Katherine Stevens, AFRL, "AFRL and materials issues," presentation to the committee on July 23, 2012, Slide no. 7.

A recent example in the first research thrust was technical information provided to support risk-mitigation actions in response to the discovery that non-conforming titanium had been used to fabricate aircraft parts in the inventory. By identifying the impact of nonconforming material on the parts' properties to enable a component risk analysis for Air Force weapon systems, the Directorate was able to help limit the scope of the problem. Currently, using a part, component, or subsystem in a different system (aircraft) than the one for which it was qualified or certified requires requalifying or recertifying it for the system(s) of potential use. This pervasive qualification process demonstrates the challenge of ensuring system safety when common materials or components are not properly tracked.

With respect to improving fleet health management, Dr. Stevens said that the ultimate Air Force objective is to move to condition-based maintenance. The Materials and Manufacturing directorate's research in nondestructive evaluation and inspection (NDE/I), such as research in multilayer crack detection, advances the move toward this objective, as does development of the capability to capture, retain, and rapidly retrieve analyses of materials and component or subsystem health from NDE/I data. In the short term, Air Force depots have adopted high-velocity maintenance for rapid turnaround, and they need appropriate evaluation techniques to support knowledge of systems before the systems or components

reach the depot for maintenance and repair. Techniques for doing this are being developed.

Dr. Stevens remarked that sustainment is potentially a very rich application area for activities under the Materials Genome Initiative (MGI), even though the focus of attention has been on MGI objectives for new materials in new applications. For example, if a system in the fleet has a sustainment problem, reducing the time to fix the problem and certify a new material or new parts can go a long way to keeping aircraft flying. There was further discussion among the participants on the potential impact of MGI on sustainability. One participant said that the same tools needed to enable ICME would also enable more rapid qualification or certification of a replacement material or part. Dr. Stevens added that AFRL has projects and programs that support both ICME and MGI. AFRL's vision for the future is to move away from the current linear paradigm for the material life cycle—in which material and processes research leads sequentially through materials development, component design, component testing, certification/qualification, manufacturing, and sustainment—to an R&D paradigm in which all these stages in the life cycle are examined interactively and in parallel through an integrated approach.

The manufacturing portion of this integrated life-cycle approach includes a concept called “moving manufacturing to the left” (addressing manufacturing issues earlier in the R&D process) and a digital data collection and archiving component called the “cradle-to-grave digital thread.” While the objective of the former is to enable earlier development of game-changing products and manufacturing process technologies, the cradle-to-grave digital thread aims to develop and employ digital environments and tools that increase efficiencies in all stages of the life cycle. Participants noted that one of the challenges for the cradle-to-grave digital thread is capturing computer-aided design/computer-aided manufacturing (CAD/CAM) or computer augmented design and manufacturing (CADAM) materials from original equipment manufacturers (OEMs) when a product has gone out of production. The challenge is being made more difficult by cost-cutting decisions not to “buy” the data rights from the OEM contractor at the beginning of the acquisition process. This challenge is not unique to the Air Force.

In response to a question, Dr. Stevens said that much of the responsibility for downstream decisions related to materials availability, environmental issues, and so on appear to have been ceded to the OEMs. James Mattice added that responsibility for issues at a life-cycle level formerly resided in the systems engineering function within the cognizant Program Office for acquisition of a system. Under acquisition reforms dating back to the Goldwater-Nichols Act,¹ that responsibility has devolved to the OEM. He sees the new AFLCMC as having the potential to help bring some of that responsibility and engineering expertise back under Air Force

¹ Goldwater-Nichols Department of Defense Reorganization Act of 1986, Public Law 99-433.

control. Others commented that information on the manufacturing processes, not just the CAD/CAM designs, is being lost. Dr. Stevens added that a significant issue is that some portion of the data associated with the design of processes, specific configurations, and so on is not owned by the Air Force. There is growing recognition of the importance of capturing key design and production data for the long-term sustainment of aircraft and other complex defense systems.

Referring to the right-hand side of Figure 3, Dr. Stevens said that capturing NDE/I data for individual systems as they go through maintenance during their operational lives is also an essential part of the cradle-to-grave digital thread concept.

Data from all three phases represented in the figure—design, production, and operational maintenance—will be necessary to enable condition-based maintenance and to have a digital representation (digital twin) of each physical system (e.g., each aircraft). The Digital Thread Sustainment Focus at AFRL, which is aimed at integrating data, models, and simulations throughout the system life cycle, includes the following objectives:

- Extending configuration management to include material properties and dimensional variations from production, modifications, and repairs.

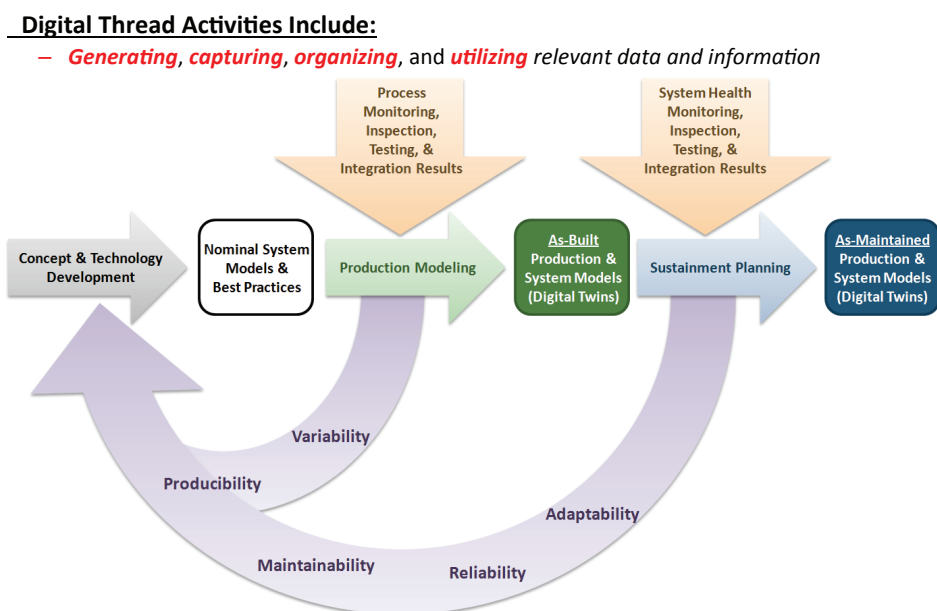


FIGURE 3 Air Force manufacturing technology concept of the cradle-to-grave digital thread. Digital thread activities include generating, capturing, organizing, and utilizing relevant data and information. SOURCE: Katherine Stevens, AFRL, “AFRL and materials issues,” presentation to the committee on July 23, 2012, Slide no. 21.

- Providing digital twins representing the current state of a physical component, system, or manufacturing enterprise for condition-based decision making.
- Integrating and visualizing as-maintained representations across the fleet and throughout the supply chain.
- Delivering individual and fleet life-cycle lessons learned back to designers and planners.

In response to a question about the one or two biggest areas where more needs to be done, Dr. Stevens cited the challenge of transitioning technology from the system development and acquisition world to the sustainment world. Different views on which organization has which responsibilities for preparing technology for implementation into sustainment applications are part of this challenge. At least as important are funding problems related to how expenditures are categorized for appropriations (which costs can be recovered from which pot of money). The business case for a sustainment application not only has to make sense on its own but also has to align with the available resources (the pots of money that are not empty).

A second question to Dr. Stevens and the workshop generally was this: What can be done to solve the problem of program-specific certification requirements for the same part or component used in different systems? Dr. Stevens replied that part of the problem could be addressed through new approaches to standardization of specifications. Dianne Chong added that the problem also exists for manufacturers who have merged the operations of multiple acquired companies. The solution there is seen as having a single system for recording and maintaining parts specifications. Corporate- or enterprise-wide initiatives are needed to address the problem of multiple distinct part numbers for what is in reality the same part.

A participant asked if it makes sense for DOD to emulate the best practices that industry has adopted to address problems such as those of multiple specifications for essentially the same part or of different part numbers/identifiers, each with its own specifications, for what is in reality the same physical part. Can the best industry-tested practices be moved into the defense establishment? The discussion of this question revolved around the difficulty of identifying and encouraging best practices across different organizations without becoming caught up in too-rigid specification of standards. Another question was how willing potential competitors might be to share approaches and practices that in some cases they might see as part of their competitive advantage.

On the problem of different OEM part numbers for the same physical part in different systems or in different subsystems or components of the same system, Royce Smith of the Air Force Diminishing Manufacturing Sources and Materiel Shortages (DMSMS) Program said that while it is important to retain the original OEM part numbers in the system used for sustainment, they need to be linked to

one stock number associated with the physical part. A given stock number may be identified by five or ten different OEM part numbers. This point led to clarification of the problem in terms of sharing a common set of qualification and certification requirements for the same physical part in essentially similar applications.

THE ARMY AND MATERIALS ISSUES

Scott Fish, Chief Scientist, U.S. Army

Dr. Fish began by emphasizing the commonality of the issues that the Army faces with those identified by Dr. Stevens. He first described Army S&T activities in materials and proceeded on to the issues of counterfeit parts, parts obsolescence, and materials shortages.

In addition to its role in the MGI, the Army's Multiscale Research on Materials focus includes two collaborative research alliances (CRAs): Materials in Extreme Dynamic Environments (MEDE) and Multiscale Modeling of Electronic Materials (MSME). Both CRAs, in which the Army partners with university investigators, involve fundamental research on applying multidomain modeling to investigate and develop multiscale materials. MEDE is aimed at fundamental research on new materials for armor and blast protection applications. MSME is focused on improved sensors and other electronics applications. The kickoff meetings for both CRAs were at the end of July 2012. Both CRAs are taking a materials-by-design approach, with the long-term goal of designing revolutionary materials—structural materials in the case of MEDE, electronic materials in that of MSME—for Army systems. The other military services have representatives monitoring both CRAs, and there have been routine conversations among representatives from the Army and the other services about the research.

In addition, the Army Research Laboratory (ARL) has its own strategic research initiatives, one called Materiel and Devices in Extreme Environments, another, Extreme Energy Science. Dr. Fish expects there will be interesting crosstalk between the CRA teams and the ARL activities because new approaches to modeling and to metrics for measuring materials performance are important for all parties.

Dr. Fish next gave four examples of recent Army experience with counterfeit parts. In these four cases, each of which involved a counterfeit microprocessor chip, the routine performance tests carried out at several points in the supply chain did not detect any anomalies. Nor have component or system failures so far been attributed to these four counterfeit parts. Dr. Fish described the corrective actions being taken to deal with the parts that were installed in fielded systems. In addition to remedial actions, the Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASAALT) is taking the following proactive steps to address the counterfeit parts problem:

- ASAALT has established an initial risk management capability for supply chain issues like this. The capability includes increased attention within the government and increased diligence on the part of Army prime contractors and associated intermediate providers in their supply chains to test for part performance compliance.
- ASAALT is continuing to work with the Office of the Secretary of Defense (OSD) to develop a Trusted Supplier standard.

Dr. Fish described the problem of counterfeit parts, particularly counterfeit microelectronic chips, as “very tricky,” given that many of them are passing current quality screening tests. From his understanding of the situation, the current testing requirements are not sufficient to ensure that counterfeit parts like these chips are not getting into fielded systems.

In response to a question, Dr. Fish said that evidence of malicious intent had not been found yet in the examples he described, but investigation of the sources of the counterfeit parts is ongoing. Dr. Fish stressed again that the parts distributor and the prime contractors affected by these counterfeit chips had been quick to notify their DOD customers of the problem, once it was discovered. Dr. Fish was asked if there were sufficient existing legal sanctions against a supplier that intentionally sells parts that it knows to be counterfeit. He said that he was unsure if sanctions might apply to the ultimate supplier or manufacturer of a counterfeit part, but there are statutes in place that apply to the prime contractors and their tier 2 and tier 3 subcontractors for properly qualifying their suppliers. This led to further discussion of issues surrounding the growing reliance on foreign manufacturers and suppliers located outside the United States and the likelihood that counterfeiting is motivated solely by the economic value of supplying demand for an otherwise hard-to-find authentic part. Also discussed was the type of testing available to detect “added functionality” or location- or target-specific alterations that might be present on counterfeit chips.

Dr. Fish concluded with a list of materials supply and shortage issues that were serious enough to be reported up to Army Headquarters from Army Program Executive Offices (PEOs) because they were viewed as having a significant impact on acquisition costs and schedules:

- *Strong nitric acid.* An explosion in May 2012 at a major domestic source for this chemical stock will require drawing down reserve stocks until production comes back on line in 12 to 18 months. There are alternative sources, but they do not produce enough to meet demand.
- *Aerospace castings.* Dr. Fish described the problems of long lead times and late deliveries of these castings as an across-the-board problem for DOD,

based on a recent OSD Industry Study. This is a supplier (capacity) issue rather a materials shortage issue.

- *Ammonium perchlorate*. The price per pound from the single U.S. supplier of this ingredient for rocket propellant is increasing significantly. Foreign sources exist but are not qualified for U.S. defense requirements. This is a DOD-wide industrial base issue.
- *Nitrocellulose and nitroglycerin*. Production volume will be reduced during the changeover to a new contractor at the government-owned, contractor-operated facility, which is the only one worldwide with sufficient capacity for nitrocellulose.
- *Butanetriol*. There is no existing U.S. supplier for this chemical used in rocket motor manufacture. A source is being developed in Memphis, Tennessee.

In response to a question, Dr. Fish agreed that the chemical supply issues in this list stem from the limited market for the chemicals in question, which makes the economic context analogous to that of therapeutics with small markets. Thus, there may be some commonality with the approaches being considered by pharmaceutical manufacturers for therapeutics with small markets but important niche uses. The Army does have authority to use foreign sources that are in NATO countries, and Dr. Fish thought that the butanetriol example was in that category.

Dr. Fish was asked to comment on the difference, from an Army acquisition perspective, between chemical shortages where U.S. industry still has the facility capacity to manufacture (perhaps with adaptation) and chemical shortages where a manufacturing capability no longer exists domestically and the only capacity is foreign-based. Dr. Fish replied that whether the lack of domestic capacity was a critical issue would probably be decided case by case. In general, though, the Army does not presume that all production of a defense-critical chemical or material must be domestic. But there would have to be adequate controls in place on both production and transport to ensure that supply requirements will be met. The overall protection mechanism must be adequate, as the line between domestic and foreign sourcing is not always distinct.

With respect to his examples of single-source specialty chemicals with supply issues, Dr. Fish said that reliance on a sole (domestic) source for a critical material must be paired with a program to stockpile sufficient reserves to carry through an interim supply shortage, as happened for strong nitric acid. That approach works, but it does stress the system.

A related question was whether the new Sector by Sector, Tier by Tier (S2T2) analysis of the defense industrial base provides the services with a tool for assessing their supply vulnerabilities, such as single-source vulnerabilities. Dr. Stevens replied that the Air Force Manufacturing Technology Program has plans to use the S2T2 database as a resource. Dr. McGrath added that there are policy constraints on how

the database will be accessible, given that some of the survey data being collected are business-sensitive and proprietary. This led to discussion among the participants on how PEOs in the DOD acquisition community could make effective use of the S2T2 information without directly accessing the restricted data.

OPEN DISCUSSION: MATERIALS ISSUES AND PROGRAMS TO MITIGATE SHORTAGES

Discussion Leaders:

Michael F. McGrath, Vice President, Analytic Services, Inc.
Rosario A. Gerhardt, Professor, Materials Science and Engineering
Georgia Institute of Technology

Dr. McGrath suggested that this discussion session should focus on how the prior presentations relate to the following five critical issues, which were called out in the prologue of the workshop's announcement-agenda document, and whether any additional critical issues have emerged:

- Are there ways to rapidly qualify materials or components when the raw materials or their manufacturing process has been changed?
- How does one economically replicate the production of a part that is no longer made?
- How does one rapidly assure that aftermarket parts have acceptable performance and have not been tampered with?
- How can ICME-like approaches (e.g., MGI) be applied to support the sustainment environment?
- What information from the initial development and production phase needs to be captured to make downstream sustainment easier?

Dr. McGrath suggested that the participants focus on the technology (and policy) issues that pertain to the materials and manufacturing infrastructure rather than more broadly taking on all sustainment issues. From this perspective, he offered the following themes from the prior presentations:

- Dr. Slotter had described DOD's concerns about supply and substitution, certification, and control of counterfeits. For the S&T community, there are both challenges and opportunities in responding to these concerns.
- Dr. Stevens had provided the sustainment context for these issues as they affect Air Force systems that will be operating for a long time. She described what AFRL—and particularly the Air Force's Materials and Manufacturing program—is doing about the issues.

- Dr. Fish had noted the commonality of the Air Force issues described by Dr. Stevens and those of the Army. (Dr. McGrath added that, from his experience, the issues also apply to the Navy.) Bringing government and industry together in partnerships such as the new CRAs in multiscale and microstructured materials may be one way to attack the problems. Several participants had suggested that industry best practices could be shared and could be of value to DOD as well.

Dr. Gerhardt added that another aspect of these problems is that they are extremely complex. It is necessary to find ways to repair and maintain complex systems with diverse subsystems, components, and parts, while also developing materials needed for future applications. From her perspective as a materials scientist, a difficulty is that even the smallest change in composition from that of the original part or component can drastically change structure at some scale, which in turn can alter properties that affect the function of that part or component. Solutions need to be worked on from the top down and from the bottom up. The presentations by Dr. Stevens and Dr. Fish illustrated the tremendous complexity of the problems. To make the discussions more fruitful, she suggested distinguishing the following topics:

- Development of new materials.
- How to deal with counterfeit parts.
- How to deal with replacement of parts that are no longer being made.
- Development of standards and, possibly, establishment of policies to guide how these complicated networks of systems can continue to perform adequately.

To elaborate on the last of these topics, Dr. Gerhardt used the example of the development of the IEEE-488 standard to guide the interfacing of computers with equipment.² All companies that need to provide that kind of interface must adhere to that standard.

In response to Dr. McGrath's request that participants name one or two issues on which more needs to be done, participants suggested the following issues:

- What can be done (in materials and manufacturing R&D) so that DOD is not facing the same problems 30 years from now that it faces today? Does this mainly involve making policy changes that facilitate the government's forming long-term relationships with suppliers as opposed to putting sup-

² IEEE-488 is a specification for a short-range digital communications bus and was created in the late 1960s for use with automated test equipment.

plier contracts out for bid every several years, with the new contract going to the lowest-cost bidder without accounting for transfer and start-up problems?

- Are there materials or manufacturing technologies that make parts that are inherently more transferable between systems and applications? What can be done on the production and processing side to make long-term sustainment easier, including easing the problems that occur when an original manufacturer goes out of business or can no longer supply parts? Without exposing proprietary information, what processing information would help a subsequent manufacturer?
- Are there industry best practices in supplier management and manufacturing data capture that could be adopted or adapted by DOD as better ways to do business? A first step would be to benchmark what companies do as best practices in supplier management—for instance, in building and maintaining a network of trusted suppliers. Another example is the commercial companies that remanufacture or salvage engines and other complex subsystems or components of legacy systems.
- The alternative to having an error-proof way to detect functionality that has been added to a counterfeit part, which seems extremely difficult to do, is to have a trusted network of suppliers. This probably requires a combination of technology and policy approaches.
- A participant from a major original equipment manufacturer (OEM) and prime contractor for defense systems said that his department's procedure for qualifying a supplier includes requiring that the supplier share with the prime all the details of its manufacturing processes. The prime even sends a process expert to the supplier to learn about the process. For this to work, the participant cautioned, there must be adequate trust that proprietary information will not be transferred to others and competitive advantages will not be lost. The continual stream of incremental changes to manufacturing processes is also reported up the chain to the prime. For a small supplier, there are provisions for the OEM to seek an alternative source if the supplier goes out of business or can no longer supply. A second participant from another major OEM said that similar procedures for supplier-partnering are used with their specialty chemicals and materials suppliers.
- The trusted supplier relationship in the preceding item requires a partnership between supplier and customer rather than an adversarial relationship. The customer must follow through on protecting suppliers' proprietary and competitive information. Government customers have a great deal of difficulty maintaining that kind of relationship because of acquisition requirements for competitive contracting. But for an OEM, these long-term partner relationships are a considerable advantage. The quality of the

technical data provided by a supplier is typically proportional to the level of protection that the supplier's intellectual property will receive.

- As Dr. Stevens noted in her presentation, transition from the initial acquisition/production environment to a sustainment environment is difficult. Sustainment contractors often do not have the resource base, including personnel with appropriate expertise, to apply the same level of problem analysis and resolution that OEMs provide. Maintenance depot personnel—both government personnel and contractors—prefer to work from technical orders that are written like step-by-step recipes.
- Transfers of production capability from one supplier to another often result in delivery delays that can cause temporary shortages. This can occur when the original supplier sells a product line to another company, as well as when the customer initiates a change in supplier. A good industry practice would be for a supplier to notify customers when any supplier-initiated disruption in supply capability is planned, so the customer can increase inventory to cover a potential delay in the delivery pipeline.

The last of these issues led to discussion of whether three-dimensional printing technology will be able to help provide critical parts whose normal supply pipeline has been disrupted. One challenge to such technologies is that, even when complete CAD/CAM data, including tooling data, are available, suppliers do not allow that information to be used for parts production until they can no longer deliver the parts themselves. A part produced using CAD/CAM data still needs to be qualified, whatever new production process is used, and the qualification process for aviation parts, for example, can take 2-3 years. Another challenge is whether the appropriately qualified material is available. A question arose as to whether there was a formal lessons-learned report from the Army's Mobile Parts Hospital program, which is basically a mobile machine shop transported on a tractor-trailer.

There may be two distinct categories of problems with counterfeit parts, one participant suggested, with different solutions for each category. The first category concerns the quality of counterfeit parts relative to that of valid, qualified parts. Potential solutions for ensuring parts quality include building trusted supplier relationships, having appropriate policies, and applying appropriate test procedures. The second category, which appears harder to address, concerns attempts, for any number of reasons, to hide some new functionality in the counterfeit part without altering the part's properties as measured by the quality standards. The part is designed to behave differently, long after it has been delivered, only after receiving an instruction from the originator or under particular predefined conditions. This type of counterfeiting, also called "additive manufacturing," could potentially be applied to mechanical parts and materials ("cyber-physical" systems), as well as

microelectronic parts and components. Solutions applicable to the quality problems may not solve this second category.

Another participant agreed about the difficulty of addressing the second category of counterfeit problems. Overreliance on standards and on testing to those standards can create a complacency about the security of the supply chain. In reality, this participant said, there is no way to build quality assurance systems that respond to everything that could potentially happen. As complete design and production-process data sets become a standard industry practice, the availability of those data also allows an intentional counterfeiter to know exactly what a counterfeit part should do to remain undetected. Different entities within customer organizations—such as the intellectual property group and the supply chain managers—have to work together.

MATERIALS SHORTAGES AND STRATEGIES TO COUNTER THEM

Robert E. Schafrik, Vice-Chair, General Manager Materials and Process Engineering Department, GE Aviation

Dr. Schafrik began by noting the substantial contribution to this presentation by his colleague, Steven Duclos, Chief Scientist and Leader for Material Systems and Nanotechnology, Advanced Technology Programs, GE Global Research.

His first point with respect to abrupt disruptions in material cost or availability is that users need to change from a reactive mode to an approach that uses early understanding of risk to inform early action. Graedel and Cao (2010) compared trends in global demand for metals with trends in ore quality to support their conclusion that users should anticipate increased cost, decreased availability, and increased risks of supply disruption. The typical response today to a materials “crisis”—whether the crisis stems from demand outstripping supply, a mining disruption, export curtailment, or an unforeseen “black swan” event—is to exercise alternative sourcing options while simultaneously pursuing manufacturing efficiencies, recycling, and materials substitution strategies, all in parallel. A strategic response to the crisis would instead rely on assessing the raw materials risk prior to the shortage and then acting to anticipate the risk by identifying alternative sourcing solutions and the serial application of efforts to increase manufacturing efficiencies, recycle, substitute alternative materials, and/or substitute alternative technologies (systems) that do not require the material (Graedel and Cao, 2010).

Dr. Schafrik described the risk assessment process that GE has adopted to be proactive in introducing technical risk reduction programs for materials with high criticality for the company. After a rhenium shortage several years ago, GE began the process of identifying the amount of each strategically important material it

uses per year through a detailed supply chain materials analysis. One risk reduction strategy is to improve the buy-fly ratio for high-risk materials (the amount of material acquired is typically a substantial multiple above the amount of that material in finished systems). Closed-loop recycling systems and materials substitution are also important risk reduction strategies. In addition, designs for engines and other highly complex systems and subsystems are now taking materials availability into account in design decisions. This materials sustainability risk management process is also used for nonmetal materials such as polymers and fibers.

Dr. Schafrik described the general approach to quantitative risk assessment that GE uses, which includes consideration of the total annual expenditure on a particular raw material and quantitative measures of market supply and price risk and the impact of supply restrictions on the company (industrial impact). The three factors are graphed in a criticality diagram for the materials of greatest concern, as shown in Figure 4.

Based on this criticality analysis, the company develops a material sustainability strategy that can include ensuring continued supply by having more than one sourcing option, by increasing manufacturing efficiency—that is, reducing the amount of the material required—by recycling, by reducing or eliminating reliance on a high-risk material by material redesign or substitution, or by substituting an alternative technology that does not use the high-risk material but still satisfies

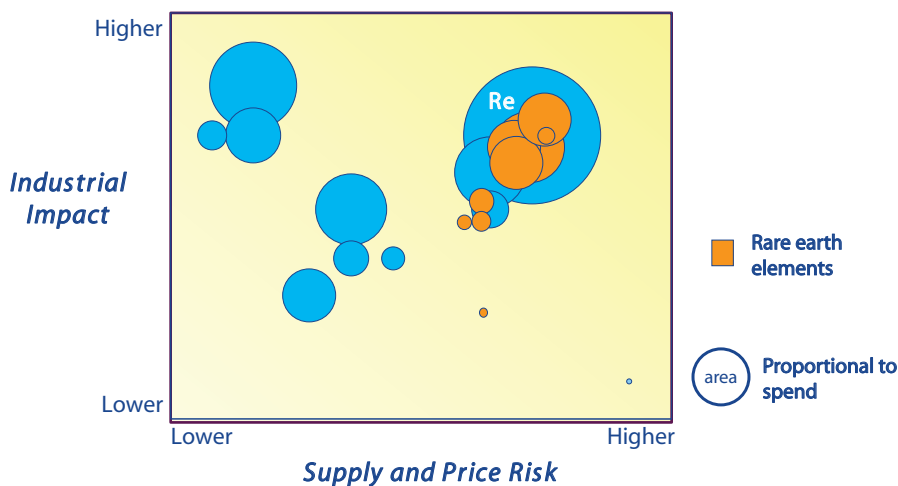


FIGURE 4 Notional example of a criticality diagram for materials shortage risk assessment. Each circle represents one of the raw materials selected for analysis. SOURCE: Robert Schafrik, GE Aviation, “Materials shortages and strategies to counter them,” presentation to the committee on July 23, 2012, slide no. 13.






	He ³	Rhenium	Rare Earths
 Sourcing	✓	✓	✓
 Manufacturing efficiency		✓	
 Recycle	✓	✓	✓
 Material re-design or substitution	✓	✓	✓
 System substitution			✓

FIGURE 5 Overview of sustainability strategies for three critical materials (elements). Each element and each application will use a unique mix of options. SOURCE: Robert Schafrik, GE Aviation, “Materials shortages and strategies to counter them,” presentation to the committee on July 23, 2012, slide no. 15.

customers’ needs. Figure 5 illustrates how the five approaches have been combined in sustainability strategies for three high-risk materials: helium-3 (He³) for neutron detection systems, rhenium, and rare earths. Dr. Schafrik described the details of each approach for these three materials, emphasizing ways in which each strategy requires cooperation among the sourcing, manufacturing, and engineering functions within the enterprise.

In response to a question on recent shortages of particular forms of titanium, Dr. Schafrik said the materials sustainability risk assessment he was describing applied only to the material and not to the availability of the end product. In his view, a shortage of processing capacity is in principle easier to manage than a raw material shortage, since investments can be made to find or create additional capacity. In addition, to avoid processing capacity constraints, the company works with key suppliers to arrive at capacity agreements that are mutually beneficial. In response to another question, Dr. Schafrik said that redesigned production processes do require requalification, but the company has adopted qualification procedures that shorten the time required. For example, ICME was applied to develop and qualify two low-rhenium alloys, reducing from 6 years to 2 the time from start of material

development to Federal Aviation Administration (FAA) qualification of the new materials in a jet engine.

The participants discussed the potential for government funding for recycling of engine and aircraft parts to conserve materials such as metal alloys containing rare earths. One participant noted that regulations requiring destruction of used parts before they could be removed from an Air Force maintenance depot had led to abandoning a program for recycling rhenium alloys from replaced engines and engine parts. Dr. Schafrik responded that, in the commercial aircraft industry, contrary to DOD experience, servicing contracts typically incentivize an airline to return a used turbine blade in exchange for a new one. Other differences between commercial airline and military practice include policies for inspection and replacement of turbine blades.

SUSTAINING AIR FORCE AGING AIRCRAFT INTO THE TWENTY-FIRST CENTURY

Alan C. Eckbreth, Eckbreth Consulting

Dr. Eckbreth chaired the study team that authored the Air Force Scientific Advisory Board (AFSAB) report *Sustaining Air Force Aging Aircraft into the 21st Century* (AFSAB, 2011). His presentation focused on two parts of the terms of reference for the study:

- Identify specific aircraft systems, in addition to structures and engines, that contribute to the safety, availability, and effectiveness of aging aircraft.
- Identify technology needs and technology approaches that can be applied or developed to extend the life or ease maintenance for these aircraft systems, while facilitating future adaptations and performance enhancements of the aircraft.

The study team defined “sustainment” as the combination of operations and maintenance (O&M) and modifications for upgraded performance (AFSAB, 2011, p. vi). This definition meant that sustainment requires consideration throughout the entire life cycle of the system (aircraft), including both O&M expenditures (Air Force appropriations code 3400) for repair, remanufacture, and replacement and modernization expenditures for research, development, test, and evaluation (RDT&E) (code 3600) and procurement (code 3010) of upgrades.

As context for the problem, the AFSAB report included Figure 1 (also used by Dr. Stevens), showing the diminishing recapitalization of the Air Force fleet over time. Remanufacturing has become increasingly important to the efforts to

keep this aging aircraft fleet flying, a point that Dr. Eckbreth illustrated with a diagram of remanufactured structural parts and subsystems of the KC-135 aircraft. Dr. Eckbreth discussed with several other participants the extent to which the funding of O&M, including remanufacturing and replacement, from one-year funds (code 3400) constrains the ability to plan for and execute a continuing and efficient long-term program for sustainment of aging aircraft. Dr. Eckbreth said the AFSAB study team was told of cases where opportunities to replace an aging part with an improved replacement had foundered because of the obstacles to combining modernization expenses with O&M expenses. He and other participants noted that multiple advisory bodies have recommended policy changes that would enable the military services to more easily access necessary funding, but to no avail.

After describing the various factors that contribute to the increase in programmed depot maintenance costs as the fleet ages, Dr. Eckbreth used the version of Figure 2 (also used by Dr. Stevens in her presentation) as it appeared in the AFSAB report to emphasize that O&M costs for the Air Force fleet have nearly doubled in the past 14 years, even as the total aircraft inventory has continued to decline. In short, as time passes, it is costing more to sustain fewer aircraft.

In addition to cost, other key sustainment effectiveness metrics are also being affected as the Air Force fleet ages. Dr. Eckbreth described how the aircraft availability metric is defined (roughly, the percentage of aircraft that are available and mission-capable at a given time)³ and how sustainment issues are making it unlikely that the aircraft availability goals set by combatant commanders can be achieved. Of particular relevance to this DMMI workshop, parts supply issues grow as a system ages:

- Diminishing manufacturing sources and materiel shortages (DMSMS) problems increase as weapon system lives are extended. When the study team met with the Air Force Global Logistics Support Center (AFGLSC), 80 percent of the center's systems engineering staff was working DMSMS issues.
- Subsystem product life cycles decrease with time, and increasing use of commercial-off-the-shelf (COTS) parts leads to more rapid parts obsolescence and increasing parts supply issues.
- Shortages impact both field level and depot performance.
- Lack of quality and consistency of reports from the Air Logistics Centers (ALCs) on parts replacement actions makes it difficult to forecast supply chain needs.

³ According to the AFSAB report, aircraft availability is defined as the percentage of a fleet's total aircraft inventory that is mission capable. "Mission capable" means that the aircraft is available to be scheduled for a mission. (AFSAB, 2011, p. 420).

The study team found that the Air force lacked depot maintenance efficiency metrics and proposed “cost of aircraft availability (AA)” as a measure of depot efficiency. In a resource-constrained environment where the combatant commanders’ AA targets are routinely not being met anyway, the Air Force should quantify AA/\$ as a function of programmed depot maintenance rate (e.g., aircraft per day) and use this efficiency model, as well as AA goals, to analyze and evaluate sustainment initiatives.

Accurate forecasting of parts replacement was identified as a key enabler for increased AA. The report’s second recommendation was to improve supply chain forecasting to minimize field-level maintenance and depot production delays due to parts shortages.

Because S&T investments are critical to reducing maintenance costs, the report recommended increased fundamental research efforts at AFRL oriented to legacy aircraft maintenance needs, a process for maturing promising hardware maintenance technologies to technology readiness level (TRL) 6, and full-scale demonstrations to take those new technologies with a high return on investment from TRL 6 to TRL 9 (implementation). The recommended areas for fundamental research included (1) testing for corrosion, stress corrosion cracking, and accelerated aging; (2) leak detection and prevention; (3) wiring fault detection; and (4) research in software verification and validation, self-describing code, software readability interoperability, and other software sustainment areas. The report also discusses specific maintenance technologies that the study team considered to have cross-cutting benefits for improving fleet maintenance and sustainment.

In closing, Dr. Eckbreth presented the following summary points as the bottom line from the AFSAB study:

- Aging legacy aircraft will drive sustainment costs ever higher in the coming years.
- Capability upgrades and sustainment of advanced technologies, especially software and avionics, will further stress budgets.
- Introducing AA/\$ efficiency metrics will allow the Air Force to gauge depot performance and explore efficacy of improvement programs.
- Commercial airline practices, enhanced supply chain forecasting, more accurate maintenance databases, and S&T maintenance advances will contribute to increasing AA and restraining cost growth.
- Strengthened integrity programs will ensure the airworthiness of aging legacy fleets.
- Maintenance S&T requires increased emphasis to contribute to life extension, expedited inspections, and reduced touch labor.
- Approaches to transition technologies with promising returns on investment need to be adopted to realize the benefits of S&T advances.

During the question and discussion period following Dr. Eckbreth's presentation, participants described actions that AFRL in particular has taken to address the recommendations of this and other advisory reports on fleet sustainment issues, including corrosion R&D activities currently under way at AFRL. Feasibility of the recommended maintenance and sustainment S&T in an era of declining DOD and Air Force budgets was cited as a key constraint that is still being assessed. Participants also referred to a 2011 report from the Government Accountability Office (GAO) on corrosion issues with the F-35 Joint Strike Fighter (GAO, 2011) and a study from the Center for Naval Analyses on maintenance issues with the KC-135 tanker aircraft fleet (Francis and Boning, 2005).

THE AIR FORCE DIMINISHING MANUFACTURING SOURCES AND MATERIALS SHORTAGES PROGRAM OFFICE

**Royce Smith, Lead Program Manager
448th Supply Chain Management Wing, Tinker Air Force Base**

Mr. Smith described the work of the 448th Supply Chain Management Wing as managing all the old systems that are being kept flying ("the tired iron"). The 448th Wing, which previously reported to the AFGLSC, is now part of the Air Force Sustainment Center (AFSC). The DMSMS Program Office supports parts supply management for all the older Air Force weapons systems.

A key information system for monitoring and planning for parts obsolescence in these older flight systems is the Advanced Component Obsolescence Management (AVCOM) system. Due to funding constraints, the process of loading parts information into AVCOM for aircraft subsystems has to be prioritized. The loading process includes data mining from technical orders, from design drawings, and, as a last resort, by going back to the OEM for parts specifications. One integrated circuit (IC), for example, may have more than 122 applications in different assemblies used on different Air Force systems (indicated by unique Weapons System Designator Codes). During each of the steps in the loading process, when mistakes are found in part numbers or specifications, the errors are sent back to the government engineers for correction approval. The AVCOM predictive tool produces reports on whether there is information on manufacturers of the part, how many manufacturers are actively producing a part (two or more, just one, or none), and whether there is a logistics solution for an obsolescent (not currently being manufactured) part. A logistics solution might be having sufficient inventory to meet all expected life-cycle demands. AVCOM can produce alerts on impending obsolescence, analyses of possible form/fit/function replacements for an obsolescent part, an impact analysis for all end items in the inventory that are affected by an obsolescent part, and other kinds of reports. For parts with no current manufacturers and no

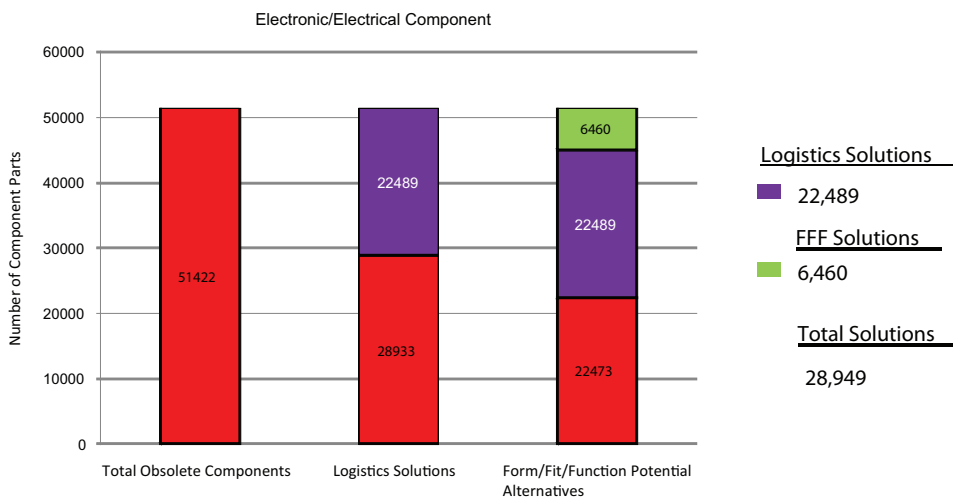


FIGURE 6 Status of obsolete parts for subsystems currently in AVCOM system. SOURCE: Royce Smith, 448th Supply Chain Management Wing, Air Force Sustainment Center, “The Air Force Diminishing Manufacturing Sources and Material Shortages Program,” presentation to the committee on July 23, 2012, slide no. 20.

logistics solution settled on yet, the next step is an analysis and resolution process. A joint government–contractor team works on resolving the obsolescence issues for subsystems, in priority order, typically several years before the inventory for the obsolete part is forecast to be exhausted. A final solution may involve a formal Technical Order change to allow use of a replacement part or a redesign package with complete specifications for recreating the part.

For the subsystems and components currently loaded into AVCOM, approximately 51,400 electronic/electrical parts are obsolete (Figure 6) out of a total of about 7 million parts in the system. Of these, logistics solutions have been identified for about 22,500, and form/fit/function replacements⁴ have been identified for an additional 6,460. Thus, there are, by coincidence, a similar number (about 22,500) of obsolete parts currently identified for which there is not yet a sustainment solution. This analysis takes into account parts that may have been assigned different part numbers over time but are functionally identical. Each year, roughly a million additional parts are added to the AVCOM system as additional subsystems are loaded and analyzed. Thus, the total number of obsolete parts without a solution

⁴ A form/fit/function replacement is considered a potential replacement until the cognizant engineering authority for the subsystem that uses it approves it as a replacement.

fluctuates as new parts are loaded while solutions are being found for the parts in priority subsystems.

The overall program objective is to reduce the mission-incapable (MICAP) hours for systems still in the inventory. Reducing MICAP increases AA. During FY 2011, the DMSMS program office resolved 18,482 individual obsolescence issues, valued at an estimated cost avoidance benefit of \$707 million. Most of these were for electronic, electrical, and electromechanical parts; some were for mechanical parts.

Next, Mr. Smith described the Air Force role in the Shared Data Warehouse (SDW) information system, which was undertaken several years ago by the Defense Logistics Agency (DLA) to capture and share information about parts that were going out of stock from an established supplier. The warehouse helps provide opportunity for the military services to buy extra inventory of a part before it goes out of production. To illustrate the extent of the problem, the Air Force module of the SDW identified 1,014 next-higher assemblies that were affected by the loss of part or component manufacture during FY 2011. The Air Force hub for the SDW consolidates estimates of the numbers of the part needed by each of the ALCs and sends one requisition request to DLA.

Mr. Smith said the principal way to avoid parts obsolescence in the future will be to use tools like the SDW to buy sufficient inventory before production of the part ends. A limitation, however, is that the manufacturer has to notify some participating part of DOD that it is planning to stop manufacture of particular parts or even to go out of business altogether. Mr. Smith discussed with other participants the problems of finding out when third- and fourth-tier vendors in the supply chain are discontinuing production of needed parts for whatever reason.

In response to a question, Mr. Smith said he could not see a reason, from his perspective, for assigning different degrees of criticality or overall mission impact to a particular part. This led to discussion of differences with commercial airline practice, where some parts are identified as fly-to-failure, meaning that flight safety would not be affected if the part were to fail while the aircraft was in flight. Mr. Smith said that decisions about subsystems or components that are more critical or have higher authority are made by the cognizant engineering authorities for purposes such as determining the priority of subsystems to go through the AVCOM data loading process.

To summarize his argument for the value of proactive DMSMS management by systems like AVCOM and SDW rather than reactive management of obsolescence issues, Mr. Smith characterized the two approaches as follows:

- Reactive DMSMS Management
 - Event driven—already behind the curve when notified that a part is not available for a repair;
 - Increased risk of impact on mission readiness; and

- Impacts compound as the system ages; cost increases and maintainability decreases.
- Proactive DMSMS Management
 - Requires up-front investment and planning;
 - Requires accurate and timely information to enable appropriate, efficient response;
 - Improves mission readiness by avoiding event-driven surprises without solutions; and
 - Facilitates enhancements to system capabilities.

DMSMS assessment needs to be done systemwide and throughout the life cycle, Mr. Smith concluded. During preacquisition planning, if the government is not going to buy all the technical data needed to remanufacture, then performance-based logistics contracts—for example, on contractor logistics support (CLS)—are needed to motivate OEMs to commit to maintaining the system throughout its life cycle.

During the question and discussion period after the presentation, Mr. Smith added that in only a few instances do acquisitions program managers consult with his organization about the potential obsolescence of parts for proposed designs of new systems. In those instances where there has been consultation before acquisition, systems like AVCOM have been useful in identifying obsolete parts in the design, or parts that could become prematurely obsolescent, resulting in recommendations to redesign subsystems to avoid these problems.

OPEN DISCUSSION: PROBLEMS RELATED TO THE SUPPLY CHAIN, PARTS OBSOLESCENCE, CERTIFICATION, AND SUSTAINMENT

Discussion Leaders: Robert E. Schafrik and Alan C. Eckbreth

Dr. Schafrik highlighted the following points for further discussion from the preceding three presentations:

- It is important to be proactive rather than reactive in response to supply chain shortages and parts obsolescence. Do DOD and/or the defense industry have the knowledge base tools to move from reactive responses to proactive ones?
- Separating S&T-based issues from policy issues. Assuming one cannot do much about the policy issues, what can be done within the current policy context to optimize the effectiveness of the S&T work that has been done?

- What are incentives for industry to help on the sustainment side of the systems life cycle, such as CLS?
- How can maintenance technology be transitioned to the ALCs?

With respect to the third point, a limitation of CLS under current Air Force policy is that 50 percent of the work has to be done within an Air Force ALC.

One participant disagreed with the assumption in the second point that policy issues should not be addressed. The participant suggested that the workshop should at least identify areas where policy changes could be made that would make a real difference in dealing with sustainment problems.

A fifth recurring theme noted by the participants was the importance of capturing and retaining the technical data about materials and parts for use during system sustainment. A relevant policy question is whether DOD should attempt to buy the technical data sufficient to maintain a digital data thread and store the data in an engineering data repository or instead look to OEMs to maintain the data and buy the information as a service. Would a DOD data repository be as complete and accurate and updated as the data OEMs would maintain? Another comment was that it would be important for government to get the technical data rights up front because OEMs might not remain in business and might not be acquired by another government supplier that could retain the data to make them available.

A serious technical question with respect to the digital data thread, however it is implemented, is deciding which data are useful for the long-term sustainment of systems. The participant who raised this point added that the Air Force does not have enough knowledge or data necessary to replicate a part or sustain it over an extended system life cycle. One ongoing effort to define standards for technical data packages, under the Army ManTech program, is Military Standard 31000. Another participant stressed that state-of-the-art technologies to support condition-based maintenance and other advanced sustainability approaches dependent on adequate status information are not being incorporated in new aircraft like the F-35 because of budgeting and contracting (low-bid competition) constraints.

Individual participants then identified the following additional barriers to successful implementation of the digital data thread vision:

- The military's operational requirements lead to an emphasis on preventive maintenance and replacement rather than the fly-to-failure standard applied to select components by commercial airlines (the difference arises from the operational context of commercial airlines).
- The unreliability of data in existing maintenance databases and the lack of integration and transparency undermine condition-based maintenance.

- Major gaps still exist in the archives of engineering design documentation (e.g., CAD records) for legacy systems.
- Much of the archived electronic documentation is stored in formats that are unreadable by the current generation of design software tools.
- Ongoing upgrades to CAD/CAM tools can lead to subtle differences in how specifications from an earlier generation of the tool software are interpreted on the current version of the tool.
- Changes in manufacturing processes over time can alter the condition of a part even when design and initial manufacturing process documentation are followed; remanufacture to achieve the same functionality can require modifying the design and process specifications.
- Maintenance databases that rely on maintenance technicians to fill out records are subject to human error; automated ways to capture maintenance data are necessary.

Some participants also noted a number of current efforts, such as the Army and OSD ManTech programs, to overcome or at least mitigate these obstacles to digital data thread implementation. As one participant summarized the situation, the vision for digital data thread applications is way ahead at the “run” stage of implementation, while the actual situation is only at a “walk” or even a “crawl” stage; many incremental steps will be needed to achieve the visionary objectives.

Dr. Sloter commented that several activities at the federal level are pursuing the kind of proactive strategy Dr. Schafrik presented for addressing shortages of critical materials. First, a recent IDA workshop conducted for the DLA Strategic Materials Directorate focused on criticality of materials; the next workshop will focus on vulnerability of materials to supply shortages and other disruptions. Second, a scenario-based planning methodology, which has been applied for more than a decade to the National Defense Stockpile, is being expanded for application to a broader range of materials and material applications. Third, the Department of Energy (DOE) has extensive planning for critical materials in the energy sector, similar to the approaches Dr. Schafrik described. It is soliciting for a critical materials hub that will establish a research capability for critical materials planning. Finally, there is an interagency working group on critical materials in the Office of Science and Technology Policy.

The participants discussed the impact on U.S. companies of the recent additions to the list of substances banned in the European Union by the European Union Registration, Evaluation, Authorisation, and Restriction of Chemical Substances (EU REACH) regulations. Some companies have worked at anticipating which substances would be banned, such as hexavalent chromium; they began R&D for process alternatives and substitutes before the substances to be banned were announced.

Another comment was that advisory studies that make technical recommendations to address materials and manufacturing issues are typically not implemented unless the study also addresses business practices (government, commercial sector, or both, depending on the recommendation) and sources of funding for implementing the recommendations. This participant suggested that any study making recommendations on the workshop's themes should be a joint study of policies, business practices, technical drivers, and how these factors interact. Recommendations that are perceived by DOD as addressing purely technical issues—even from NRC elite committees—are seldom fully implemented. A complete assessment of the relevant DOD business practices and the financial impact of a recommended change would, this participant suggested, be much more useful to decision makers than a purely technical assessment. While acknowledging that this suggestion would add to the challenge of preparing the study and would require adding people knowledgeable in DOD operations to the committee, the participant believed that the recommendations would be more likely acted upon.

SENATE ARMED SERVICES COMMITTEE REPORT ON COUNTERFEIT ELECTRONIC PARTS IN THE DOD SUPPLY CHAIN

**Joseph M. Bryan, Professional Staff Member
Senate Armed Services Committee**

Mr. Bryan was the lead staff member for an investigation by the Senate Armed Services Committee into the presence of counterfeit electronic parts in the DOD supply chain (Committee on Armed Services, 2012). The investigation was initiated in March 2011 and dealt primarily with counterfeit electronic parts and components.

An important early finding was that DOD and the large defense contractors were not keeping track of counterfeit parts. The Senate Armed Services Committee relied on testing companies used by DOD, the contractors, and their suppliers for information on counterfeits. The independent testing companies had relatively good records and had found a lot of counterfeit components.

The investigation identified about 1,800 suspect counterfeits, accounting for more than a million counterfeit parts in the defense supply chain. Information was gathered from 9 major contractors and 22 testing companies. Counterfeit parts were found in dozens of weapons systems, including military aircraft, Army thermal weapon sights, and mission computers for the Missile Defense Agency's Terminal High Altitude Area Defense missile (Committee on Armed Services, 2012, p. ii).

Most of the counterfeits identified in the investigation were previously used parts that had been removed from assemblies and circuit boards and sold as new

parts. The Senate committee traced about 125 counterfeit parts back through the supply chain. About 70 percent came from China. The Air Force reported that one Chinese supplier identified in the investigation had sold more than 84,000 suspect parts into the defense supply chain. Mr. Bryan gave an example of one counterfeit part traced back to a Chinese source through six intermediary purchasers, including the major defense contractor who supplied the part, which was integrated into a subsystem for a Navy helicopter.

As part of the investigation, the Armed Services committee asked GAO to set up a shell company to search the Internet for certain hard-to-find electronic parts, as well as parts marked with incorrect production dates (beyond the date of last actual production) and parts with bogus part numbers. The shell company purchased 16 parts. Every one of the parts that GAO purchased was determined to be counterfeit, and all of the suppliers were based in China.

The investigation found that DOD lacks knowledge of the scope and impact of counterfeit parts on critical defense systems. The overwhelming majority of counterfeit parts in the supply chain had not been reported at the time of the investigation. DLA, which supplies 80 percent of the spare parts used by DOD, neither consistently reported instances of counterfeit parts to the Government–Industry Data Exchange Program nor maintained an internal list of instances in which it had been supplied counterfeit electronic parts. Furthermore, DLA had repeatedly purchased counterfeit parts from the same distributors.

In response to a question on the definition of “counterfeit part” used by the investigators, Mr. Bryan explained that the term included used parts sold as new, parts whose numbers had been changed, and unauthorized copies of the authentic part. This is the same definition used by industry—SAE International Aerospace Standard (AS) 5553-2009. A participant noted that repackaging of commercial-grade parts as military-grade is also a problem, and the participants discussed the negative consequences of using non-military-grade parts or other kinds of counterfeits in military operations. When asked if the investigation had identified any instances of malicious intent beyond economic interest on the part of counterfeiters, Mr. Bryan said that the investigation was unclassified and so had not focused on that issue. Mr. Bryan said that economic interest appeared to be the motivation for most of the cases investigated by the Senate committee. In response to another question, he said that the investigation dealt only with electronic parts, but he was aware of a lot of interest in counterfeit structural parts as well. Other workshop participants described instances of materials substitution and structural parts that had been knowingly misrepresented by a prime contractor or supplier. Instances were discussed where domestic suppliers of counterfeit materials and structural parts simply closed down one shell company operating via the Internet when their counterfeiting was detected and set up another with a different name, often in a different city.

The Senate investigation found that weaknesses in testing practices increased the vulnerability of critical defense systems to counterfeit parts. It also found that neither DOD agencies nor defense contractors were routinely reporting instances of counterfeiting. Failure to report counterfeits when identified allows suspect parts and their suppliers to remain in the defense supply chain. In addition, the investigation found that contractors sometimes seek reimbursement from DOD for the cost of replacing identified counterfeit parts contained in systems they (the contractors) had supplied.

The National Defense Act Authorization for FY 2012 requires, among other things, that counterfeits be reported, that contractors use trusted suppliers, and that a tighter inspection regime for imported electronic parts be implemented. The NDAA also changed the law to prohibit defense contractors from charging the government for the cost of repairing or replacing systems they supply that contain counterfeit parts. Mr. Bryan said that these new statutory requirements will result in regulations requiring DOD and the defense contracting community to set up better systems to track testing and verification and to share that information on counterfeit parts.

After the presentation, the participants discussed weaknesses in the testing practices used by contractors and their suppliers, and the major changes in reliability of the global supply system for electronic parts stemming from used-component recycling activities in China, the rapid turnover in manufacturing lines for original, authentic parts, and the growth of Internet-based parts purchasing. There was extended discussion of potential performance-degrading effects of counterfeit parts that seem to work properly in routine testing or testing under unstressed conditions.

COUNTERFEIT PARTS AND PARTS OBSOLESCENCE

Dianne Chong, Vice President, Assembly, Factory, and Support Technologies Engineering, Operations and Technology, Boeing

To set the stage for her comments on how Boeing deals with parts obsolescence, counterfeit parts, shortages, and other issues raised at the workshop, Dr. Chong gave an overview of Boeing as a global commercial business and described where her organization fits within the company. She stressed that Boeing does not make most of the parts and components it uses: It is highly dependent on its supply chain, which includes 22,000 partners and suppliers. Her organization handles all of the materials R&D and process and manufacturing technology development for Boeing. This includes sustainment support for all Boeing production programs, as well as near-, mid-, and far-term technology R&D. The Boeing materials and parts management organization handles issues related to limited-life parts, COTS hardware, and environmental concerns, as well as obsolete and counterfeit parts.

Counterfeit electronic parts are particularly troublesome for aerospace electronics, Dr. Chong said, because of the wide range of risks they raise: not just system malfunction risk but also mission risk, safety risk, schedule risk, and economic risk. She agreed with comments of earlier participants about the importance of counterfeiting and misrepresentation of materials and structural parts. Sources of information for identifying counterfeits include whistleblowers internal and external to the supply chain intermediaries, as well as testing done by Boeing and its suppliers. When asked if she knew of any instances of industrial sabotage or malicious intent motivating an instance of counterfeiting, she replied that she did not personally know of any; typically it seems to be a case of someone not doing their job with respect to verifying, testing, and reporting. Mergers and acquisitions can also affect supplier processes, particularly for materials and structural parts manufacturing. Even a change from one facility to another within a company that is performing a production process can change product characteristics.

In response to a question about how far down the supply chain Boeing is vigilant about supplier quality assurance and testing, Dr. Chong said that it depends on the supplier and the part or material in question. For materials and structural parts, Boeing uses a system of ongoing audits and inspections. Beyond these internal practices, the company also participates in aerospace industry activities to set standards, including the Aerospace Industries Association Counterfeit Parts Integrated Process Team and the SAE G-19 Committee, which developed the SAE AS 5553 standard for counterfeit parts, which Mr. Bryan had referenced.

For materials shortages and parts obsolescence, Boeing has strategies to anticipate and plan for events in advance similar to those Dr. Schafrik described in his presentation. Figure 7 lists the approaches that are used in the DMSMS management strategy, while Figure 8 illustrates the steps in one of these approaches, the DMSMS Management Process. Dr. Chang sees counterfeiting as a harder problem to anticipate in advance and address with a standard process.

Sometimes an obsolescence problem comes to attention because a supplier tells Boeing it cannot make a component or part anymore because one of its materials or parts suppliers is no longer making a needed material or part. Later in her presentation, Dr. Chong listed and discussed three major drivers for DMSMS: diminished overall demand; green initiatives and moves to environmentally compliant parts; and extended support periods resulting in product supply–system life cycle mismatches. When a supply discontinuance notice is received, because a supplier is going out of business or is stopping a production line, multiple parts and even families of part types can be affected. The time required to find another supplier depends on many factors, but often identifying a potential supplier is fairly quick; it takes longer to certify the supplier and/or the replacement product. Boeing is actively investigating computation-based tools that would lessen the amount of testing required to certify a replacement;

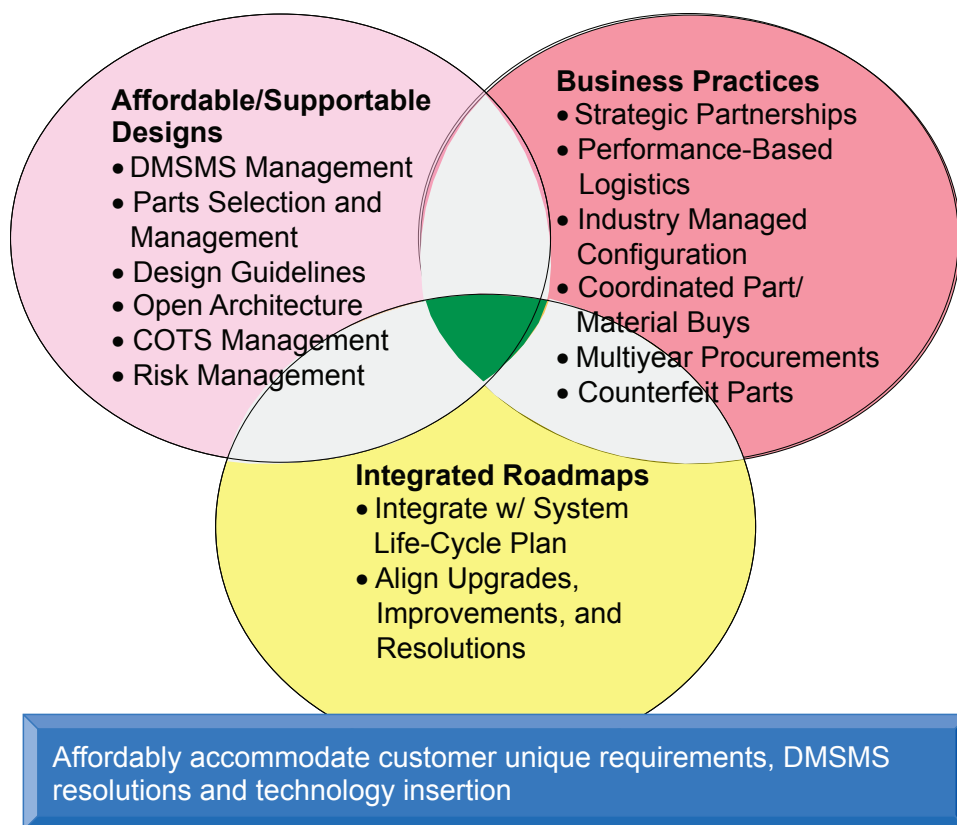


FIGURE 7 Elements of overall DMSMS strategy used by a major aerospace systems integrated manufacturer. SOURCE: Dianne Chong, Assembly, Factory, and Support Technologies; Engineering, Operations, and Technology, Boeing, “Counterfeit parts and parts obsolescence,” presentation to the committee on July 24, 2012, slide 13.

most of these tools and associated testing technique development are intended for structural materials certification.

Boeing has problems with parts and materials obsolescence because, even within its supply chain, it may be a relatively small customer for some suppliers, as Mr. Royce remarked with respect to Air Force purchases of electronic parts for legacy systems. Dr. Chong also noted that sometimes Boeing’s decisions to move to a new process may cause obsolescence because its suppliers cannot afford to keep manufacturing lines operating for replaced materials and parts that Boeing is no longer buying. Even the aerospace industry as a whole is often a relatively small part of the potential market for a parts or materials manufacturer. Dr. Chong presented a chart showing that the electronics share of the military/aerospace

Boeing DMSMS Management Process

Engineering, Operations & Technology | BR&T

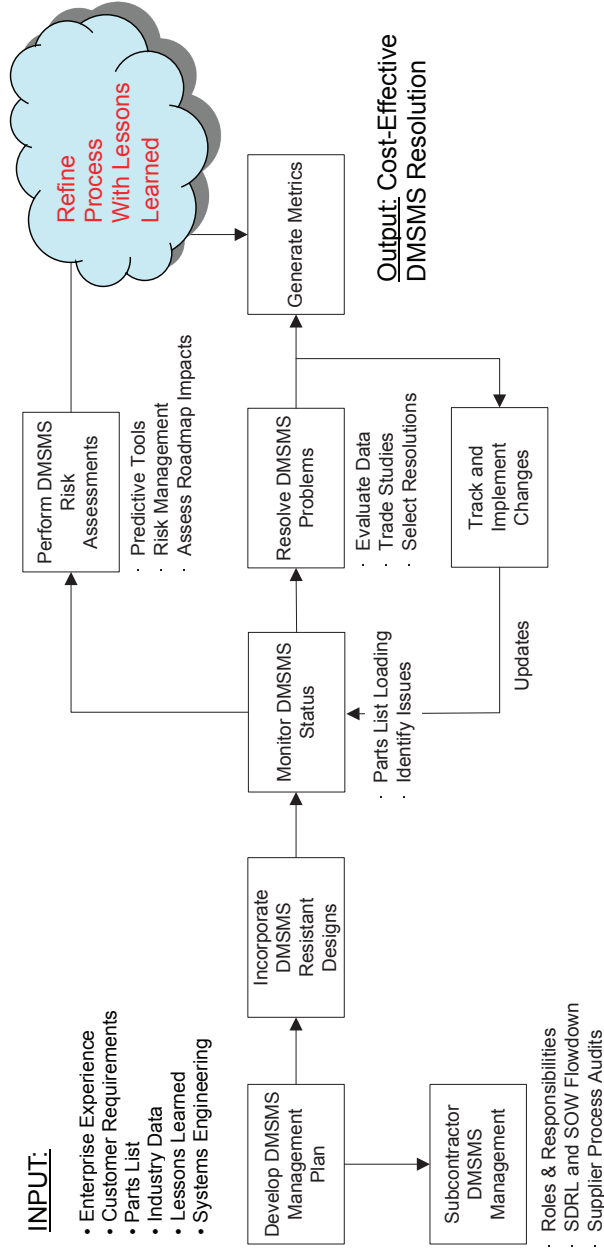


FIGURE 8 The DMSMS management process used by a major aerospace systems integrated manufacturer. SDRL, supplier data requirements list; SOW, statement of work. SOURCE: Dianne Chong, Assembly, Factory, and Support Technologies; Engineering, Operations and Technology, Boeing, “Counterfeit parts and parts obsolescence,” presentation to the committee July 24, 2012, slide 14.

market accounts for only about 1.9 percent of the global electronics market. As in dealing with counterfeit parts, Boeing is active in aerospace industry forums on DMSMS issues. Industry-wide approaches are seen as being more effective than going it alone.

In response to a question, Dr. Chong said that electronic parts become obsolete much more frequently than structural parts and materials. However, she agreed with a participant who suggested that obsolescence and shortages for polymers and other nonmetal materials were becoming more frequent. Environmental regulations are one factor in obsolescence, but changes in manufacturing demand are also important. In response to another question, she said that Boeing assigns a criticality rating to all parts of its systems, based on structural and/or mission requirements. Dr. Chong's responses to additional participant questions touched on the following points:

- The work at Boeing on computational tools to expedite certification has not yet explicitly addressed the problem of identifying counterfeit parts that pass conventional tests.
- Boeing uses warranty-servicing data and other field-servicing data as a source for lessons learned in its DMSMS management process.
- For the resolution to a DMSMS problem (see Figure 8), the first choice is to find a substitute supplier or material/product, but at other times the solution is to redesign the part. Redesign requires verification/certification of the entire system, so it is more costly and takes more time.
- The statutory changes noted by Mr. Bryan have led to differences in how Boeing defines a trusted supplier. What is required from the supplier depends in part on how much it supplies and its overall relationship with Boeing.
- When asked whether she thinks the counterfeit parts problem will stabilize or continue to grow, Dr. Chong said she expects that problem can be dealt with if the community acts jointly. In 30 years, she expects new problems to emerge.
- Most of Boeing's flight control software is developed in-house rather than contracted out. The trend over time has been to acquire really good software developers to become part of the in-house capability. Software certification is another area where R&D teams in the mission assurance groups are working to understand fundamentals and find ways to streamline the process.

DARPA'S TRUST AND IRIS PROGRAMS

**Carl E. McCants, Microsystems Technology Office
Defense Advanced Research Projects Agency**

As background to the DARPA Trust in Integrated Circuits (TRUST) and Integrity and Reliability of Integrated Circuits (IRIS) programs, Dr. McCants discussed the relationship between trusted hardware and cybersecurity. Address and Winterfeld (2011) identified corporate information, personal information, information technology (IT) infrastructure, and the national critical infrastructure as the main categories of targets for recent and future cyberattacks. The DARPA TRUST and IRIS programs are aimed at protecting the national critical infrastructure. As defenses against attacks on software systems and networks improve, Dr. McCants said, adversaries are attacking other vulnerable areas, including hardware.

Because any device that incorporates ICs with networking capability can be compromised, the diversity of networked devices in traditional IT and non-IT applications requires R&D on hardware robustness and trustworthiness. Bad hardware will win over good software, Dr. McCants said, because hardware vulnerabilities live at a much lower level in the operational environment than the software that runs on the hardware. Any device that is connected to a network and has compromised parts is a potential threat to that network, as well as to any system in which the device is physically incorporated. Nontraditional devices that are connected to the Internet include smartphones, netbooks, and tablets; inexpensive streaming-media players and electronic game controllers; smart meters used by utilities; automobile electronic control units and telematics; high-definition televisions and Blu-ray players; and smart appliances in the home.

Near the end of his presentation, Dr. McCants gave an unclassified example of how hardware networked into software-based information processing can cause systems failures. In October 2008, a significant commercial airline incident (more than 120 people injured) occurred because the Airbus A-330 aircraft's flight control computers received incorrect data from a sensor, causing the aircraft to unexpectedly dive twice. The Australian Transport Safety Bureau investigators concluded that a single faulty inertial reference unit (hardware) in this networked system initiated the chain of processing failures (which included software algorithm errors) that led to the dives.

For military systems, hardware vulnerability has increased over time because of historical trends in how ICs are manufactured. In the 1970s and 1980s, ICs for military weapons systems were designed, fabricated, assembled, and tested by integrated U.S. companies that supplied ICs to DOD. During the 1990s, the option for vertically integrated domestic production by a U.S. company remained, but there were more options for assembly and testing offshore. The military market

also began using more COTS ICs, which were increasingly fabricated in foreign foundries and assembled and tested offshore. COTS parts were initially used for non-mission-critical parts, but during the past decade or so that constraint has disappeared. The option for DOD trusted fabrication within the United States by a vertically integrated supplier remains, but the military market increasingly relies on COTS parts, including some that are foreign designed, for both mission-critical and non-mission-critical applications. Furthermore, DOD has decreasing control over the electronics supply chain as one moves further back in the chain from the major systems integrators to the suppliers of subsystems, then to board assemblers, and ultimately to the parts and materials suppliers.

Recognition of these hardware supply chain issues led DARPA to initiate the TRUST program in 2007; its aim was to ensure that ICs used in weapons systems must perform as designed—no more, no less. The program's initial objective was to develop techniques to find any changes to the physical design of an IC, assuming that the physical instantiation of the “golden design” was available.⁵ The initial challenges were to be able to (1) verify the design of a 90-nm digital complementary metal-oxide semiconductor IC against the golden design in less than 30 days, (2) verify that the verification tools used did not alter the original design of the inspected ICs, and (3) verify that the bitstream used to program field-programmable gate arrays (FPGAs) was not compromised. The program's technology performer teams included a metrics team, a test article team, and a red team, as well as three teams working on the verification technologies. The Information Sciences Institute at the University of Southern California developed a technique to reverse-engineer ICs nondestructively, using X-ray computed tomography.

Dr. McCants described the problems and approaches used for the “Trust in Design,” “Trust in Fabrication,” and “Trust in FPGAs” parts of the program. He then listed the following accomplishments of the TRUST program:

- Tools to verify the design integrity of application-specific integrated circuits (ASICs) with 50 million transistors.
- X-ray computed tomography system (30+ mm field of view, 30 nm resolution) for nondestructive reverse engineering.
- Automated FPGA tool suite to validate bitstreams and third-party intellectual property (IP) vendors.
- Test articles to evaluate the reverse engineering capabilities.
- Transitioning of these tools to government agencies.

⁵ By “golden design,” Dr. McCants meant a complete design specification for an IC as originally manufactured that could be trusted as an absolute reference—a gold standard for what that IC should be and should do.

In response to participants' questions, Dr. McCants made the following points:

- The ASIC verification process is very expensive. It would not be feasible as a routine testing process for multiple specimens in a shipment, for example. Some federal agencies have found it useful for examining items and articles of "great interest."
- While 90-nm circuit design was roughly the state of practice in 2007, now 60-nm and 45-nm designs are being produced. The X-ray imaging technology has been successful in imaging circuit features at 45 nm and 32 nm.
- Although the X-ray tomography does not change an inspected IC's physical structure, work is ongoing to assess whether the electrical properties of the IC are altered by the high-intensity, high-energy X-radiation used.
- The program did not undertake verification of larger assemblies on a chip such as video graphics arrays.
- Although TRUST examined only silicon-substrate ICs, much of the technology and analysis capability should be applicable to nonsilicon substrates.

DARPA initiated the IRIS program in September 2011 to address technical issues of functionality, integrity, and reliability in electronic and information processing systems. IRIS aimed to enable DOD to have confidence that such systems (1) function as intended and (2) are free of exploitable vulnerabilities, either intentionally or unintentionally designed or inserted as part of the system at any time during its life cycle.

Whereas TRUST focused on change detection in ICs, IRIS is looking at extracting information on an IC's functionality: What does this chip do, and what are all the things this chip can do? With respect to reliability, the IRIS goal was to quickly estimate, from a small number of samples (e.g., 10 ICs), the mean time to failure, based on applying physics of failure to the IC design. Another difference from TRUST is that analog and mixed-signal (analog and digital) designs are included in the goals for functionality and reliability analysis, as well as all-digital IC designs. Instead of assuming a golden design is available, the challenge is to conduct the full functionality and reliability analyses with just the standard information that would come with purchase of the IC. IRIS has the following specific goals:

- *Technical Area 1.* Determine the full functionality of a silicon digital IC when only a functional specification and limited test vectors for the IC's operation are given.
 - Use reverse engineering to determine the full flattened netlist—that is, how the IC is internally connected—by nondestructive methods.

- Derive a detailed specification of the IC’s functional capabilities from the flattened netlist; identify all logic blocks and primitive components of the IC and describe the functions represented.
- *Technical Area 2.* Determine the full functionality of a silicon mixed-signal or analog IC when only a functional specification and limited test vectors for the IC’s operation are given. Use reverse engineering of mixed-signal ICs to derive their functionality by either nondestructive or destructive methods.
- *Technical Area 3.* Determine the full functionality of a third-party IP block when only standard documentation is provided. For soft IP and for FPGA IP, identify all characteristics of the IP block and determine functional behavior, including any extraneous circuitry; determine whether extraneous circuitry is benign or malicious; and automate a significant portion of the process.
- *Technical Area 4.* Determine the reliability of a silicon IC (both digital and mixed-signal ICs are included) when only a few samples are available for accelerated life testing.

In concluding his presentation, Dr. McCants offered the following suggestions for moving forward in ensuring that DOD has trusted hardware in its critical defense systems:

- Integrate technologies such as those developed during the DARPA TRUST and IRIS programs to address hardware integrity concerns.
- Develop system-level technical and technology-informed policy approaches to supply chain risk management, trusted microelectronics, and non-conforming-part mitigation (includes both counterfeits and imperfectly fabricated authentic parts).
- Initiate further research into potential hardware exploits.
- Model and test conditions that place ICs in unusual operating modes to identify vulnerabilities.
 - Identify and harden data leakage paths.
 - Develop intelligent testing to explore the state space of digital and mixed-signal ICs. (Dr. McCants characterized “intelligent testing” as methods that add no more than 1 percent to the cost of an IC.)
- Continue development of the trusted onshore manufacturing ecosystem for specific requirements.
- Continue research to recharacterize the software/hardware boundary conditions—that is, understand the vulnerability space when “good” software meets “bad” hardware and when “bad” software meets “bad” hardware.

OPEN DISCUSSION RELATED TO COUNTERFEIT PROBLEMS, SUBSTANDARD PARTS, AND SUBSTANDARD MATERIALS

Discussion Leaders: Denise F. Swink and Robert Latiff

In response to questions from other workshop participants, Dr. McCants made the following points:

- Although the initial work specifications for IRIS technology developers only require them to assess reliability at an IC's specified operating conditions, DARPA is asking them to consider ways of exploring how an IC would respond to off-normal conditions.
- For radiation-hardened ICs (for example, in spacecraft), it may be reasonable to build a proof-of-concept prototype using an FPGA, then use the experience with that unit to design an ASIC.
- Funding for TRUST was \$80 million. Current funding for IRIS is \$75 million.
- For DOD to implement and sustain a sound "trust but verify" approach as a customer for electronics parts, given the risks discussed, the cost of adequate testing will need to decrease. Good risk analysis of the risks of testing versus not testing should drive decisions about when, how, and what to test.
- In Dr. McCants's opinion, malicious-intent alterations to hardware are more likely to target low-cost components such as resistors, diodes, or AC/DC transformers rather than microprocessors. Thus there needs to be more systems-level testing aimed at detecting nonconforming parts anywhere in an assembly or subsystem.
- DARPA is not currently working on "Trust at the PC Board Level," but there is a lot of work on "Trust in Software." A service laboratory that did a lot of board fabrication would be a good place to take on technology development to deal with the former.
- FPGAs are not yet able to cover fully the application space in which ASICs are used, particularly where non-silicon-substrate ASICs give a distinct performance advantage.
- Dr. McCants agreed with a comment that testing based on high-volume random inputs to compare the responses of two chips could in principle be a way to look for differences in chip function.

CURRENT ISSUES AT THE DEFENSE MICROELECTRONICS ACTIVITY

Daniel M. Marrujo, Lead Microelectronics Reliability Engineer Defense Microelectronics Activity

Mr. Marrujo's objectives for the presentation were to explain what DMEA does, for participants not familiar with it, and to show how DMEA is addressing some of the issues posed for discussion at this workshop. The new Systems Assurance and Security Division now includes DMEA's Trusted IC program and reverse engineering capability. The Microelectronics Design and Integration Division is able to design ICs from legacy technologies down to the state-of-the-art node sizes. The Microelectronics Development and Test Division includes the fabrication center, packaging capabilities, and testing capabilities.

Two major challenges for defense microelectronics are that (1) weapons systems have extended life cycles, from 20 to 40 years, and (2) commercial requirements, not military requirements, dictate the technology and market for new microelectronics. Mr. Marrujo contrasted the life cycle performance, reliability, and security demands of defense systems with conditions and functionality drivers in the market for commercial microelectronics applications. He noted the multisupplier and global nature of the commercial microelectronics supply chain, as discussed by previous speakers, and summarized the range of risks to reliable and secure operations. In addition to the increasingly sophisticated counterfeits being introduced into the supply chain, the growing use of COTS parts raises performance degradation issues stemming from the lower quality of commercial versus military-specified ICs and from unannounced changes by commercial-market vendors in IC design, processing, and packaging. Because military applications are such a small part of the IC market, loss of production capability occurs for a range of reasons, which Mr. Marrujo illustrated with recent examples.

To address these challenges, the DMEA mission is to provide all of DOD, as well as other federal entities and foreign allies, with microelectronics technology solutions by leveraging advanced microelectronics technologies:

- DMEA's Advanced Reconfigurable Manufacturing for Semiconductors (ARMS) program includes an adaptable, flexible IC foundry at the Sacramento facility. All the processes are under government-held licenses. ARMS is capable of prototype and low-volume production at this DMEA facility; any high-volume production runs are done by industry partners in the program.

- The Advanced Technology Support Program III (ATSP3) awards Indefinite Delivery/Indefinite Quantity contract vehicles with defense industry partners that give DMEA and all DOD program offices streamlined access to state-of-the-art technologies and engineering capability. DMEA engineers provide technical support to ATSP3 task orders. Contracts under ATSP3 are capped at \$4.7 billion.
- As the accreditation authority for the Trusted Foundry Initiative, DMEA evaluates security parameters, process controls, and the like for design houses, aggregation facilities, mask-making facilities, fabrication facilities, and test facilities throughout the supply chain to ensure they are abiding by security requirements. Every company in the program must renew its accreditation every 2 years, and DMEA audits the fabrication and mask-making facilities. There are currently 55 suppliers accredited under this initiative.

In response to questions about the Trusted Foundry Program, Mr. Marrujo gave the following responses:

- With respect to the balance between new production and sustainment capability among participants in the program, most of DMEA's sustainment production for older systems is done through its in-house fabrication capability rather than through new contracts with participants in this program.
- The program is set up to include facilities in the United States, United Kingdom, Canada, Australia, and New Zealand, but the only current non-U.S. participant is a semiconductor manufacturer in Australia. Other facilities located outside the United States are nearing completion of initial accreditation.
- Facilities that participate receive no guarantee of work; the amount of effort required of a facility to be accredited depends on case-specific circumstances.
- The Trusted Foundry designation does not remove all the risks of malicious activity and nonconforming parts discussed by Dr. McCants and others. It does help to minimize the risk of malicious intent by ensuring that certain security practices and conditions are in place.
- A trusted source of supply for a variety of microelectronics technologies, including FPGAs, is being looked at by a White House-led DPA cybersecurity group with the end goal of determining if Title III funding should

be applied. Aside from this relationship there seem to be no other ties between Title III and the Trusted IC program.

In response to participants' questions about other aspects of DMEA activities, Mr. Marrujo gave the following responses:

- As a recent example where DMEA had solved an obsolescence problem, he described the design and fabrication of a form/fit/function replacement ASIC used on SSN Virginia-class submarines, after the facility that had made the original ASICs burned down, destroying all the design and mask-making documentation as well as the production capability.
- DMEA's production activity can provide added (upgrade) capability in addition to meeting original form/fit/function requirements.
- With respect to how quickly the DMEA flexible foundry can change from one production run to another, he said the facility runs different processes for different substrates and device types every day.
- The replacement ASIC production for the Virginia-class submarines occurred before the Trusted Foundry Program was established, so doing that work through a Trusted Foundry participant was not an option. DMEA now provides broker services for program managers who are interested in contracting with participants in the Trusted Foundry initiative. In principle, a program office seeking a similar replacement device (e.g., an ASIC for another application where the original supplier had ended production) can have the fabrication done by a Trusted Foundry participant.

Workshop participants discussed the potential for expanding the relationship between DMEA and participants in the Trusted Foundry Initiative. Helping to direct DOD and other government customers to the Trusted Foundry participants was suggested as a way to sustain such foundries and stimulate the community's interest in participating in the program. Another suggestion was to market Trusted Foundry participants' high-value obsolete parts to commercial-sector OEMs and to encourage private industry customers generally to use Trusted Foundries. Participants favored these approaches for expanding the Trusted Foundry partnership because they thought it could help with the problems of electronic parts obsolescence and counterfeits.

ISSUES AT THE OFFICE OF COMPLIANCE OF THE CENTER FOR DEVICES AND RADIOLOGICAL HEALTH

Bryan H. Benesch, Special Assistant to the Director and CDRH Device Determination Expert, Food and Drug Administration

Mr. Benesch's responsibilities in the Office of Compliance in the CDRH include counterfeit products policy. The areas of the economy that FDA regulates account for 20-25 percent of consumer expenditures. Counterfeiting in these domains is primarily an issue in the area of drug products. Statistically, Mr. Benesch said, 5 to 8 percent of drugs sold globally are counterfeit.⁶ With the rise of drug marketing and sales via the Internet, shipment of counterfeit drugs into the United States from foreign sources has increased and is difficult to interdict.

The FDA was set up to deal with domestic production, Mr. Benesch said, but it has had to become global in reach to deal with counterfeit drug production. In July 2011, FDA published *Pathway to Global Product Safety and Quality*, which includes a section on counterfeiting.⁷ Work groups are being started to take into account all aspects of global counterfeiting of FDA-regulated products in developing a risk-based strategy to limit entry of counterfeit products into the United States. FDA is working with the World Health Organization, which is adding counterfeit medical devices to its long-standing concern with counterfeit drugs. It also works with the Office on Intellectual Property in the Executive Office of the President, which has issued several white papers on counterfeit pharmaceuticals.

Mr. Benesch also works with FDA's criminal investigators on their work in counterfeit device operations. FDA investigators typically team with enforcement officers from the U.S. Customs and Border Protection, Immigration and Compliance Enforcement in the Department of Homeland Security and with the Federal Bureau of Investigation to interdict illegal shipments at points of entry, including the large international mail facilities. Until recently, when President Obama signed the Food and Drug Administration Safety and Innovation Act of 2012 (FDASIA), these inspections did not have authority to seize and destroy the counterfeit drugs that were interdicted. Now they may be destroyed rather than returned to the

⁶ According to the FDA Web site, a U.S. law defines counterfeit drugs as those sold under a product name without proper authorization. Counterfeiting can apply to both brand name and generic products, where the identity of the source is mislabeled in a way that suggests that it is the authentic approved product. Counterfeit products may include products without the active ingredient, with an insufficient or excessive quantity of the active ingredient, with the wrong active ingredient, or with fake packaging. Available at <http://www.fda.gov/Drugs/DrugSafety/ucm169898.htm>. Accessed October 12, 2012.

⁷ This FDA special report is available online at <http://www.fda.gov/AboutFDA/CentersOffices/OfficeofGlobalRegulatoryOperationsandPolicy/GlobalProductPathway/default.htm>.

shipper. The inspectors use a drug-listing database system, which includes photographs of many drug products, to compare items visually with authentic products. Samples can be sent to FDA laboratories for analysis, and for large shipments, the manufacturer of the authentic drug may be contacted to help determine if the interdicted shipment is authentic or counterfeit. FDA is also doing some field testing of equipment for chemical characterization. The FDASIA requires that a trusted supply chain between authorized producers of licensed drugs and shippers of these products be developed. Those provisions currently apply only to pharmaceuticals, not to medical devices. However, FDA does have a regulation requiring a Unique Device Identifier on authentic medical devices, similar to the universal product code barcode used on retail sale items. Because FDA will have a database of the authentic identifiers from two trusted suppliers of the codes, counterfeiting should become more difficult. FDA also learns of counterfeiting operations from the large pharmaceutical manufacturers, which have their own operations to look for counterfeits of their products and identify the sources. FDA assigns criminal investigators if these corporate investigators find signs of counterfeiting.

Since 2001, the FDA has had only 16 cases of counterfeit medical devices. In 2010, DOD came to the FDA because it had found counterfeits of the combat application tourniquets included in soldiers' personal first aid packs. Other cases have involved surgical mesh, infusion pumps, glucose test strips for diabetics, condoms, dental filling material, and contact lenses. Reshipment back to the United States of devices originally distributed for sale in another country is illegal if the FDA-allowed medical indications for a device differ from those in the country of original distribution, because the item is considered to be misbranded and/or adulterated.

FDA is working with foreign regulators to (1) get intelligence on material coming out of China and other major sources of counterfeit drugs and devices, (2) develop a system of trusted suppliers and partners, and (3) find ways of identifying counterfeits. Mr. Benesch participates in a Department of Justice working group on microelectronics counterfeiting.

FDA can only examine 1 to 2 percent of the medical devices being shipped into the United States. To make this limited inspection effort more effective, FDA has a new software program that uses risk analytics applied to internal and open source intelligence, such as information on companies that other countries have taken actions against, to identify suspect importers and the products with the greatest safety and health risks to the American public.

In medical devices, obsolescence issues are encouraging counterfeiting just as they do in defense microelectronics and other parts of legacy systems. For example, refurbishing of older x-ray equipment, CAT scanners, etc., often requires electronic parts that are no longer being produced. This creates the same economic incentive for counterfeiting and the same types of problems as the workshop had already discussed in connection with sustainment of legacy defense systems. For FDA en-

forcement purposes, a counterfeit product has to carry the imitated brand name. If a substitute product works as intended, has no safety issues, and meets other FDA requirements, it is not considered a counterfeit; if it violates the original manufacturer's intellectual property rights, that is not an FDA issue. FDA requirements for a manufacturer of a look-alike product to prove that it has the same characteristics as the original vary greatly, depending on the regulatory class (Class 1, 2, or 3) into which the product falls. Class 3 products require clinical testing and higher manufacturing quality standards. Most of the device counterfeiting is at Class 1 and Class 2 levels, where the compliance requirements are less stringent.

In his summary, Mr. Benesch said that FDA is engaging with the World Health Organization and with other international entities such as the Asia-Pacific Economic Community to work on a global strategy for determining where counterfeiting is happening and ways to detect counterfeits. It is just beginning to work more with the device industry on trusted supply chain issues and reliability of microchips and other microelectronic parts.

In response to questions and comments from other workshop participants, Mr. Benesch made the following points:

- He characterized a “trusted supplier” in the medical device supply chain as starting with the manufacturer of the finished device. The trusted chain of custody goes from the manufacturer to a distributor, then a retailer. Third-party distributors are difficult for FDA to regulate, and it is not illegal to import gray market medical devices, although gray market drugs are illegal. FDA has limited regulatory authority to reach back to suppliers of parts and components used in finished medical devices. The device manufacturer has to have controls on its suppliers, such as inspection and testing of incoming parts, to ensure standards set by it have been met. Mr. Benesch said FDA would like to be able to push the requirements for trusted supplier status further back to the parts suppliers. FDA is interested in learning what kinds of on-site inspections of suppliers and other quality assurance measures the final device manufacturer is undertaking. Does it know the ultimate supplier of the parts and components it is using?
- With respect to the drug side, the new FDASIA gives FDA more legal authority to establish a Trusted Supplier program, such as registering facilities and knowing the source of the active ingredients, to make it harder to introduce counterfeit drugs into the supply chain. Those provisions make it harder for an entity in the supply chain to change the source of supply from one facility to another.
- As for devices imported into the United States, FDA can only use the existing legal authorities. All the companies that export products to the United States are supposed to register with FDA. The new screening software for

arriving shipments can determine if data are missing that would verify the shipper's registration. It is harder to go back to the suppliers of parts and components, although the existing law can be used when imported parts and components are exclusively for medical devices.

- Enforcement actions often take years to complete. If a seller has violated the law, it can be arrested and prosecuted for violations of Title 18, as well as violations of the Food and Drug Act. However, criminal investigations can take a long time. FDA can also take civil actions, which include seizing products and civil prosecution.

OPEN DISCUSSION

Discussion Leader: Steven G. Wax Private Consultant and Member, DMMI Standing Committee

Dr. Wax asked the participants for comments, in light of all the presentations and discussions, on unmet needs and unresolved big issues in the areas of sustainment, replication/obsolescence, and counterfeits. The discussion resulted in an outline of needs and issues suggested by one or more participants that can be found in the overview of this workshop summary report.

After all participants present for the final session had an opportunity to offer suggestions on unmet needs and unresolved issues, Dr. Latiff adjourned the workshop.

REFERENCES

- AFSAB (U.S. Air Force Scientific Advisory Board). 2011. *United States Air Force Scientific Advisory Board Report on Sustaining Air Force Aging Aircraft into the 21st Century*. SAB-TR-11-01. Washington, D.C.: Headquarters, Air Force, Science Advisory Board. Available online at [http://www.dre.vanderbilt.edu/~schmidt/PDF/USAF%20SAB%20Sustaining%20Aging%20Aircraft%20Study%20Final%20Report%20\(Public%20Release\).pdf](http://www.dre.vanderbilt.edu/~schmidt/PDF/USAF%20SAB%20Sustaining%20Aging%20Aircraft%20Study%20Final%20Report%20(Public%20Release).pdf). Accessed on October 5, 2012.
- Andress, J., and S. Winterfeld. 2011. *Cyber Warfare: Techniques, Tactics and Tools for Security Professionals*. Waltham, Mass.: Syngress.
- Committee on Armed Services. 2012. *Inquiry into Counterfeit Electronic Parts in the Department of Defense Supply Chain*. Report of Committee on Armed Services of the United States Senate. Report 112-157. May 12, 2012. Washington, D.C.: U.S. Government Printing Office. Available online at <http://www.armed-services.senate.gov/Publications/Counterfeit%20Electronic%20Parts.pdf>.
- Francis, P.J., and W.B. Boning. 2005. *Summary Analysis of the Material Condition of the KC-135 Aerial Refueling Fleet*. CRM D0010627.A4/1REV. Alexandria, Va.: Center for Naval Analyses. Available online at <http://www.cna.org/sites/default/files/research/D0010627.A4.pdf>.
- GAO (Government Accountability Office). 2010. *Defense Management: DOD Needs to Monitor and Assess Corrective Actions Resulting from Its Corrosion Study of the F-35 Joint Strike Fighter*. GAO-11-171R. Washington, D.C.: GAO. December. Available online at <http://www.gao.gov/new.items/d11171r.pdf>.
- Graedel, T.E., and J. Cao. 2010. Metal spectra as indicators of development. *Proceedings of the National Academy of Sciences of the United States of America* 107(49): 20905-20910.
- NSTC (National Science and Technology Council). 2012. Materials Genome Initiative. Office of Science and Technology Policy, <http://www.whitehouse.gov/mgi>. Accessed October 14, 2012.

Appendixes



Statement of Task

An ad hoc committee will convene a 2-day public workshop to discuss the issues around and potential solutions to:

1. DOD materials shortages/price instabilities (for materials such as rare earth elements, rhenium, and carbon fiber);
2. Parts obsolescence;
3. Part/component certification;
4. Domestic (DOD industrial base) processing and manufacturing capabilities; and
5. Identification of future issues.

The workshop might also consider additional topics close to and in line with the five mentioned above. The workshop will use a mix of individual presentations, panels, breakout discussions, and question-and-answer sessions to develop an understanding of the relevant issues. Key stakeholders would be identified and invited to participate. Approximately 10-12 speakers will make presentations. An individually authored Workshop Summary document will be prepared by a designated rapporteur.

B

Workshop Speakers and Other Participants

WORKSHOP SPEAKERS

Bryan H. Benesch
Special Assistant to the Director
Center for Devices and Radiological Health
Device Determination Expert
U.S. Food and Drug Administration

Joseph M. Bryan
Professional Staff Member
Senate Armed Services Committee

Dianne Chong
Vice President Assembly, Factory, and Support Technologies
Engineering, Operations and Technology
Boeing

Alan C. Eckbreth
Vice President
Eckbreth Consulting

NOTE: Workshop participants also included members of the Planning Group and the DMMI Standing Committee.

Scott Fish
Chief Scientist
Army

Daniel M. Marrujo
Lead Microelectronics Reliability Engineer, Defense Microelectronics Activity

Carl E. McCants
Microsystems Technology Office
Defense Advanced Projects Research Agency

Robert E. Schafrik
General Manager
GE Aviation

Royce Smith
Lead Program Manager
Diminishing Manufacturing Sources and Materiel Shortages Program
Tinker Air Force Base

Lewis Sloter
OSD Principal
Reliance 21 Materials and Processes Community of Interest
Office of the Assistant Secretary of Defense (Research and Engineering)/
Weapons Systems

Katherine A. Stevens
Director, Materials and Manufacturing Directorate
Air Force Research Laboratory
Wright-Patterson Air Force Base

OTHER PARTICIPANTS

Julie Christodoulou
Navy Principal
Reliance 21 Materials and Processes Community of Interest
Office of Naval Research

Michael Dunlevy
Air Force Acquisitions

Natalie Gluck
Institute for Defense Analyses
Support Contractor to Reliance 21 Materials and Processes Community of Interest

Warren Johnson
Universal Technology Corporation
Support Contractor to Reliance 21 Materials and Processes Community of Interest

Howard Last
Institute for Defense Analyses
Support Contractor to Reliance 21 Materials and Processes Community of Interest

Michael Maher
DARPA Principal
Reliance 21 Materials and Processes Community of Interest
Defense Sciences Office
DARPA

James Mattice
Universal Technology Corporation
Support Contractor to Reliance 21 Materials and Processes Community of Interest

Larry Perkins
Materials and Manufacturing Directorate
Air Force Research Laboratory

Michael Rigdon
Institute for Defense Analyses
Support Contractor to Reliance 21 Materials and Processes Community of Interest

Matt Trexler
Materials and Manufacturing Technologies Branch
Materials Division
Army Research Laboratory

Jennifer Wolk
Navy Member
Reliance 21 Materials and Processes Community of Interest
Carderock Division
Naval Surface Warfare Center

Eric Wuchina
Naval Materials
Office of Naval Research
Carderock Division
Naval Surface Warfare Center

Jeff Zabinski
Army Principal and Chair
Reliance 21 Materials and Processes Community of Interest
Army Research Laboratory



Workshop Agenda

NATIONAL ACADEMY OF SCIENCES BUILDING
2101 CONSTITUTION AVE., NW, WASHINGTON, D.C.
JULY 23 AND 24, 2012

Monday, July 23

- 8:30 a.m. **Welcome: What Is DMMI? and Meeting Objectives**
Robert Latiff, Chair, DMMI Standing Committee
- 9:00 **DOD and Materials Issues**
Speaker: Lewis Slotter, Office of the Assistant Secretary of Defense
(Research and Engineering)/Weapons Systems
- 9:30 **Q&A**
- 9:40 **The Air Force Research Laboratory and Materials Issues**
Speaker: Katherine A. Stevens, Director, Materials and Manufacturing
Directorate, AFRL
- 10:10 **Q&A**
- 10:20 Break
- 10:40 **The Army and Materials Issues**
Speaker: Scott Fish, Army Chief Scientist
- 11:10 **Q&A**
- 11:20 **Open Discussion: Materials Issues and Programs to Mitigate Shortages**
Discussion Leaders: Michael F. McGrath and Rosario A. Gerhardt

- 12:00 p.m. Lunch
- 1:00 **Materials Shortages and Strategies to Counter Them**
Speaker: Robert Schafrik, General Manager, GE Aviation
- 1:30 **Q&A**
- 1:40 **Sustaining Air Force Aging Aircraft into the Twenty-first Century**
Speaker: Alan Eckbreth, Eckbreth Consulting
- 2:10 **Q&A**
- 2:20 Break
- 2:40 **The Air Force Diminishing Manufacturing Sources and Material Shortages Program**
Speaker: Royce Smith, Tinker Air Force Base
- 3:10 **Q&A**
- 3:20 **Open Discussion: Problems Related to the Supply Chain, Parts Obsolescence, Certification, and Sustainment**
Discussion Leaders: Robert Schafrik and Alan Eckbreth
- 4:00 Adjourn for the day

Tuesday, July 24

- 8:30 a.m. **Welcome, What We Heard Yesterday**
Robert Latiff, Chair, DMMI Standing Committee
- 9:00 **Senate Armed Services Committee Report on Counterfeit Electronic Parts in the DOD Supply Chain**
Speaker: Joseph M. Bryan, Professional Staff Member, Senate Armed Services Committee
- 9:30 **Q&A**
- 9:40 **Counterfeit Parts and Parts Obsolescence**
Speaker: Dianne Chong, Vice President, Assembly, Factory, and Support Technologies; Engineering, Operations and Technology; Boeing
- 10:10 **Q&A**
- 10:20 Break
- 10:40 **DARPA's TRUST and IRIS Programs**
Speaker: Carl E. McCants, Microsystems Technology Office, DARPA
- 11:10 **Q&A**
- 11:20 **Open Discussion Related to Counterfeit Problems, Substandard Parts, and Substandard Materials**
Discussion Leaders: Denise F. Swink and Robert Latiff
- 12:00 p.m. Lunch
- 1:00 **Current Issues at the Defense Microelectronics Activity**
Speaker: Daniel M. Marrujo, Lead Microelectronics Reliability Engineer, DMEA

- 1:30 **Q&A**
- 1:40 **Issues at the Office of Compliance, Center for Devices and
Radiological Health**
Speaker: Bryan H. Benesch, Special Assistant to the Director and
CDRH Device Determination Expert, FDA
- 2:10 **Q&A**
- 2:20 Break
- 2:40 **Open Discussion**
Discussion Leader: Steven G. Wax
- 3:00 Adjourn Workshop

D

Acronyms

AA/\$	Aircraft Availability divided by cost
AFGLSC	Air Force Global Logistics Support Center
AFLCMC	Air Force Life Cycle Management Center
AFRL	Air Force Research Laboratory
AFSAB	Air Force Scientific Advisory Board
AFSC	Air Force Sustainment Center
ALC	Air Logistics Center
ARL	Army Research Laboratory
ARMS	Advanced Reconfigurable Manufacturing for Semiconductors (program) (DMEA)
AS	Aerospace Standard
ASAALT	Assistant Secretary of the Army for Acquisition, Logistics and Technology
ASIC	application-specific integrated circuit
ATSP3	Advanced Technology Support Program III
AVCOM	Advanced Component Obsolescence Management (system)
CADAM	Computer Augmented Design and Manufacturing
CAD/CAM	computer-aided design/computer-aided manufacturing
CAT	computer-aided tomography
CDRH	Center for Devices and Radiological Health (FDA)
CLS	Contractor Logistics Support
COTS	commercial off-the-shelf

CRA	collaborative research alliance
DARPA	Defense Advanced Research Projects Agency
DLA	Defense Logistics Agency
DMEA	Defense Microelectronics Activity
DMMI	Standing Committee on Defense Materials, Manufacturing, and Infrastructure
DMSMS	Diminishing Manufacturing Sources and Materiel Shortages (program)
DOD	Department of Defense
EU REACH	European Union Registration, Evaluation, Authorisation, and Restriction of Chemical Substances (regulations)
FAA	Federal Aviation Administration
FDA	Food and Drug Administration
FDASIA	Food and Drug Administration Safety and Innovation Act of 2012
FOUO	for official use only
FPGA	field-programmable gate array
GAO	Government Accountability Office
IC	integrated circuit
ICME	integrated computational materials engineering
IDA	Institute for Defense Analyses
IP	intellectual property
IRIS	Integrity and Reliability of Integrated Circuits (DARPA program)
IT	information technology
MEDE	Materials in Extreme Dynamic Environments (Army program)
MGI	Materials Genome Initiative
MICAP	mission impaired capability awaiting parts
MRAP	Mine-Resistant Ambush Protected (vehicle)
MRL	Manufacturing Readiness Level
MSME	Multiscale Modeling of Electronic Materials (Army program)
NDE/I	nondestructive evaluation/inspection
NMMB	National Materials and Manufacturing Board
NRC	National Research Council
NSF	National Science Foundation

O&M	operations and maintenance
OEM	original equipment manufacturer
OSD	Office of the Secretary of Defense
PEO	Program Executive Office, program executive officer
R&D	research and development
RDT&E	research, development, test, and evaluation
S2T2	Sector by Sector, Tier by Tier (DOD program)
S&T	science and technology
SDW	Shared Data Warehouse
TRL	Technology Readiness Level
TRUST	Trust in Integrated Circuits (DARPA program)

