

ACCELERATING TECHNOLOGY TRANSITION:
Bridging the Valley of Death for
Materials & Processes
in Defense Systems

National Research Council
National Academies

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE MAY 2006		2. REPORT TYPE		3. DATES COVERED 00-00-2006 to 00-00-2006	
4. TITLE AND SUBTITLE Accelerating Technology Transition: Bridging the Valley of Death for Materials & Processes in Defense Systems				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) National Research Council, The National Academies, 500 Fifth Street, NW, Washington, DC, 20001				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES SERDP/ESTCP Metal Finishing Workshop, May 22 - 23, 2006, Washington, DC. Sponsored by SERDP/ESTCP.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 49	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

COMMITTEE ON ACCELERATING TECHNOLOGY TRANSITION

DIRAN APELIAN

ANDREW ALLEYNE

CAROL A. HANDWERKER

DEBORAH HOPKINS

JACQUELINE A. ISAACS

GREGORY B. OLSON

RANJI VAIDYANATHAN

SANDRA DeVINCENT WOLF

WPI, *Chair*

University of Illinois, Urbana

NIST

Lawrence Berkeley National Laboratory

Northeastern University

Northwestern University

Advanced Ceramics Research, Inc.

MRS

Liaisons to the Department of Defense

JULIE CHRISTODOULOU, Office of Naval Research

WILLIAM COBLENTZ, Defense Advanced Research Projects Agency

BRUCE K. FINK, U.S. Army Research Laboratory, Aberdeen Proving Ground

MARY ANN PHILLIPS, U.S. Air Force Research Laboratory, WPAFB

CHARGE

Examine how new high-risk materials and production technologies are quickly adopted by successful integrated design/manufacturing groups.

(such as Boeing's Phantom Works and Lockheed Martin's Skunk Works; and racing sport industries such as America's Cup sailboats).

Develop the lessons learned from these materials and production technology applications including computational research and development, design and validation methodologies, collaborative tools, and others.

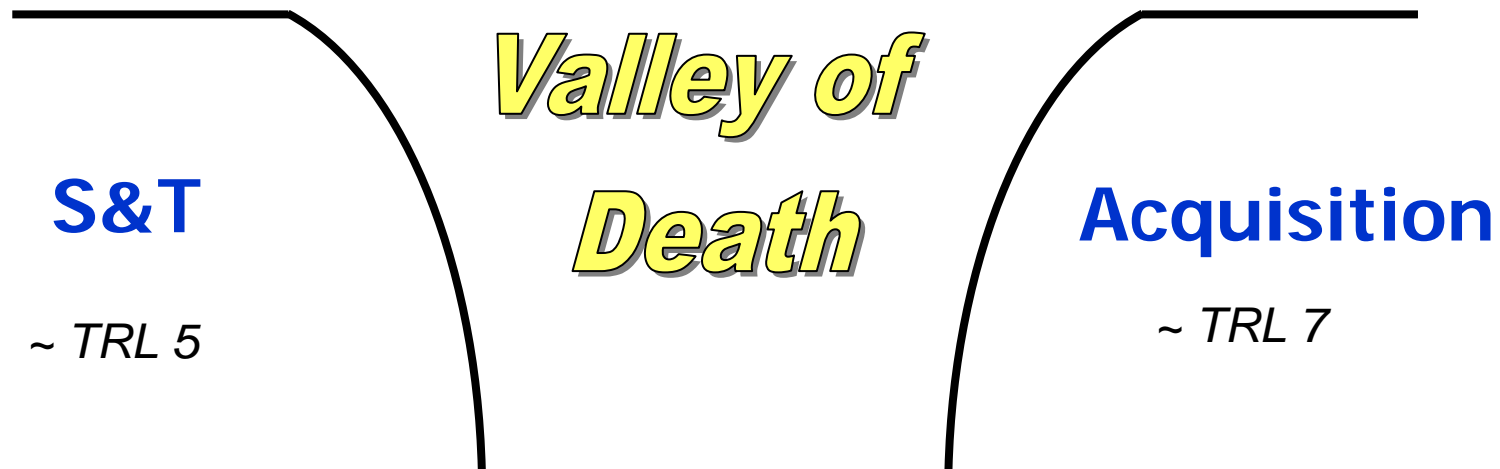
Identify approaches and candidate tool sets that could accelerate the use of new materials and production technologies in defense systems-both for the case of future systems and for improvements to deployed systems.

Prepare a workshop report.

PREFACE

- *DoD is in the process of a transformation from a Cold War-era fighting force to one that is lighter, more flexible, and more reliant on technology.*
- *Needs to respond to a wide range of asymmetric threats with speed and efficiency.*
- *Accelerating the transition of new technologies into defense systems critical and crucial.*
- *The typical time for moving new materials and processing technologies from research to application is at least 10 years and longer.*
- *Historical precedents for the transition of new technologies into defense systems have been neither fast nor efficient.*

Tech Transition Challenge



Ultimately, each transition is a “deal” that makes sense to all parties



Workshop on Accelerating Technology Transition

24-25 November 2003

National Academy of Sciences

- I. Technology Transition Overviews
- II. Integrated Design/Manufacturing Groups
 - *Case Studies*
- III. Computational and Collaborative Tools
 - *Lessons Learned*
- IV. Design and Validation Methodologies
 - *Lessons Learned*
- V. Approaches/Tools for Accelerated Technology Transition
- VI. Lessons Learned from Other Industries

Three specific areas emerged :

- **Creating a culture for innovation and rapid technology transition**
- Methodologies and approaches
- Enabling tools and databases.

Cultural Differences*

Complicating deal-making ...

IDEATION PEOPLE

- Have a special form of attention-deficit-disorder
- Are prototype-driven ("frog kissing")
- Learn by doing
- Say 'What if'?
- Nurture infant technology
- Figure out: *can it be done?*
- Fill the funnel: create new options
- Objective: Understanding

EXECUTION PEOPLE

- Are boring and narrow-minded
- Are requirements-driven (define the problem)
- "Do it right the first time"
- Say "prove it"
- Kill the weak and move on
- Decide: *should we do it?*
- Narrow the funnel: increase focus
- Objective: Delivery

**With apologies to all those who hate labels ... (J. Douglas Field, DEKA)*

SPECIFIC Cultural CHARACTERISTICS:

The culture must accept risk, anticipate failure and plan for alternatives;

A flexible environment with the ability to accommodate change during the development process;

Communication in all directions without regard to hierarchy;

A widespread sense of responsibility and commitment to success that goes beyond defined functional roles;

A culture that values innovation over short-term economic efficiency; and

A passionate focus on the end user's needs.

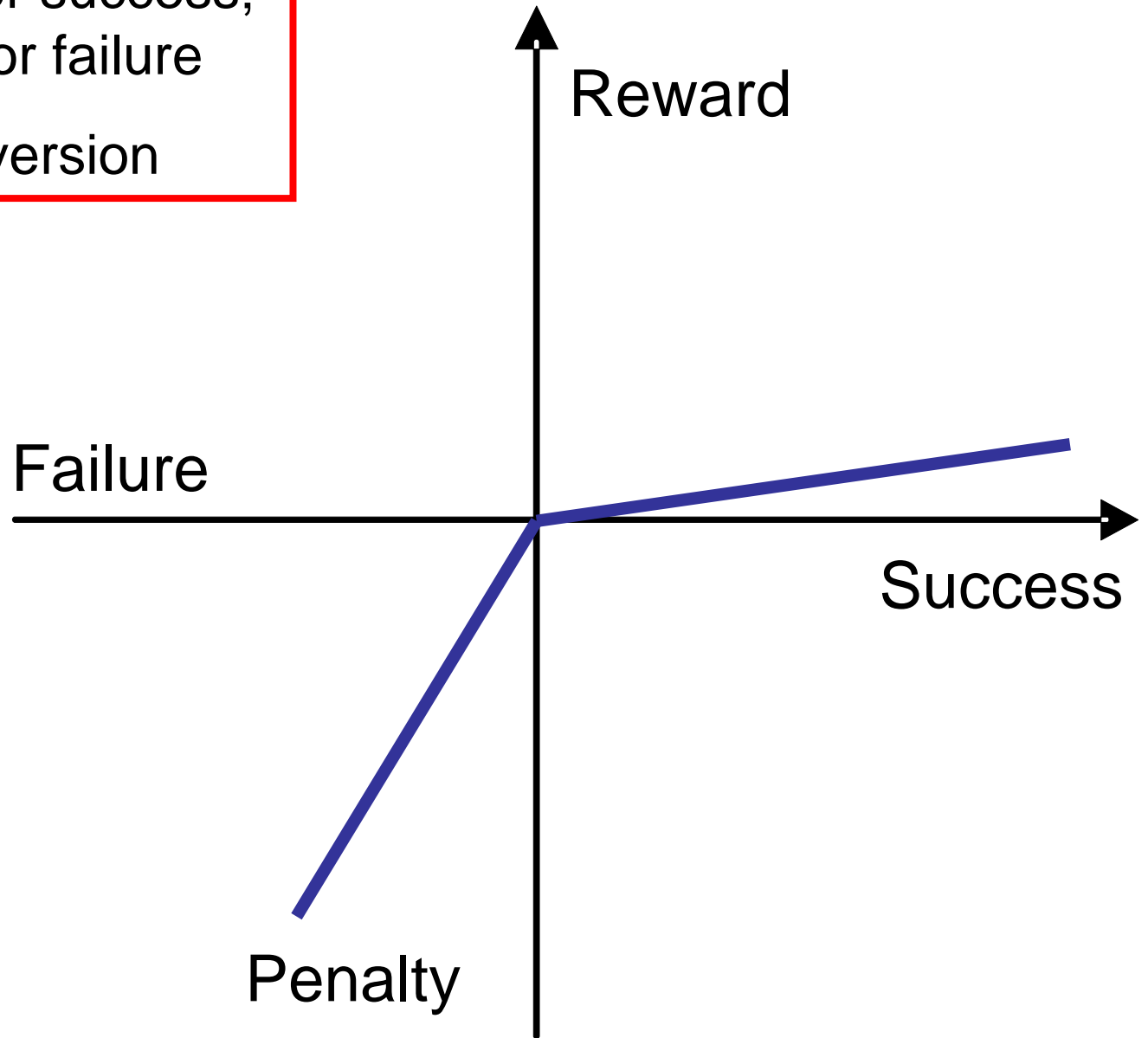
Cultural Issue # 1

a willingness to take risks

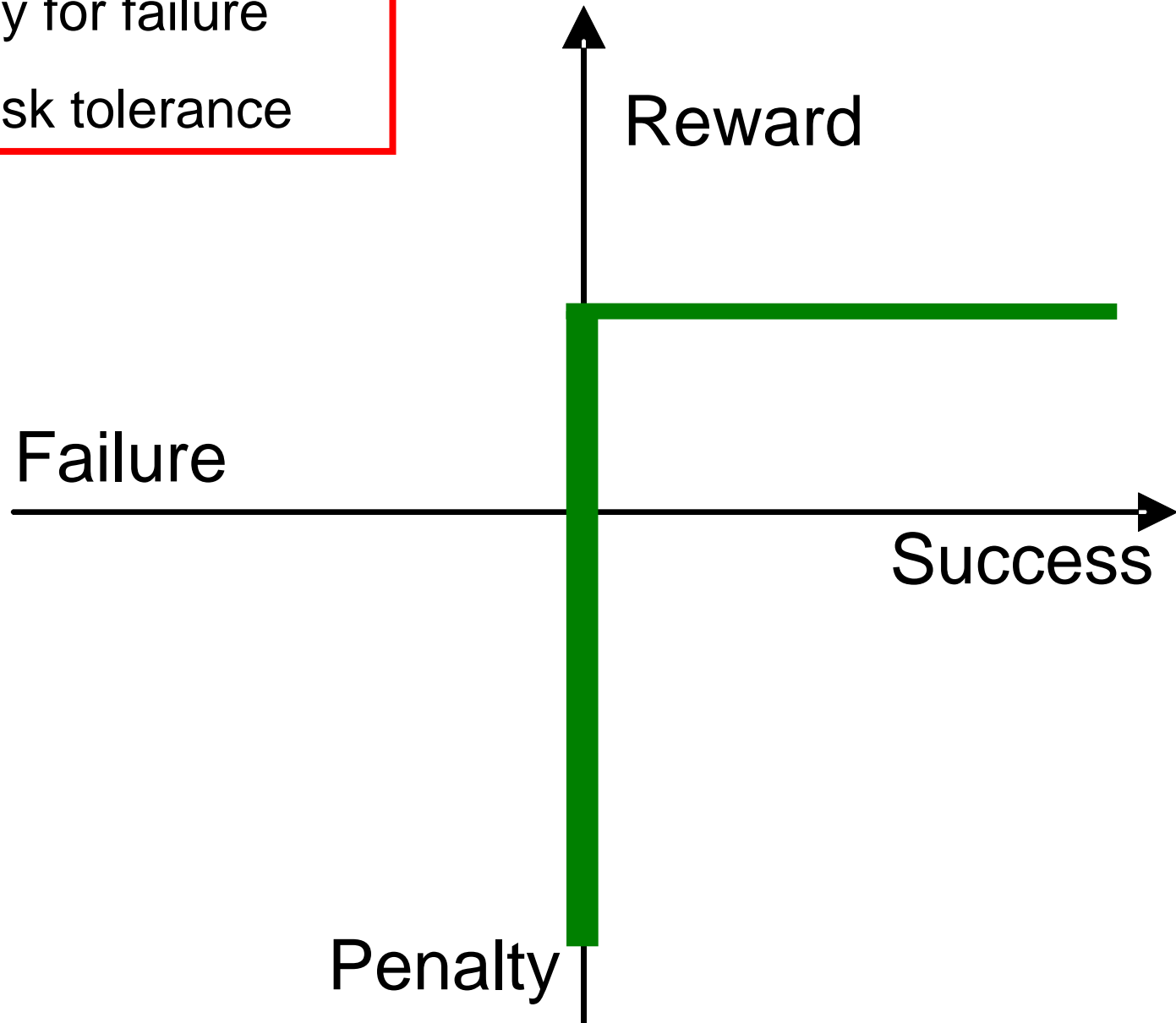
- there must be a clear understanding of the relationship between potential risks and rewards

- Is the technology needed?*
- What are the ramifications of not having the technology available?*
- What is the outcome if the technology fails in service?*

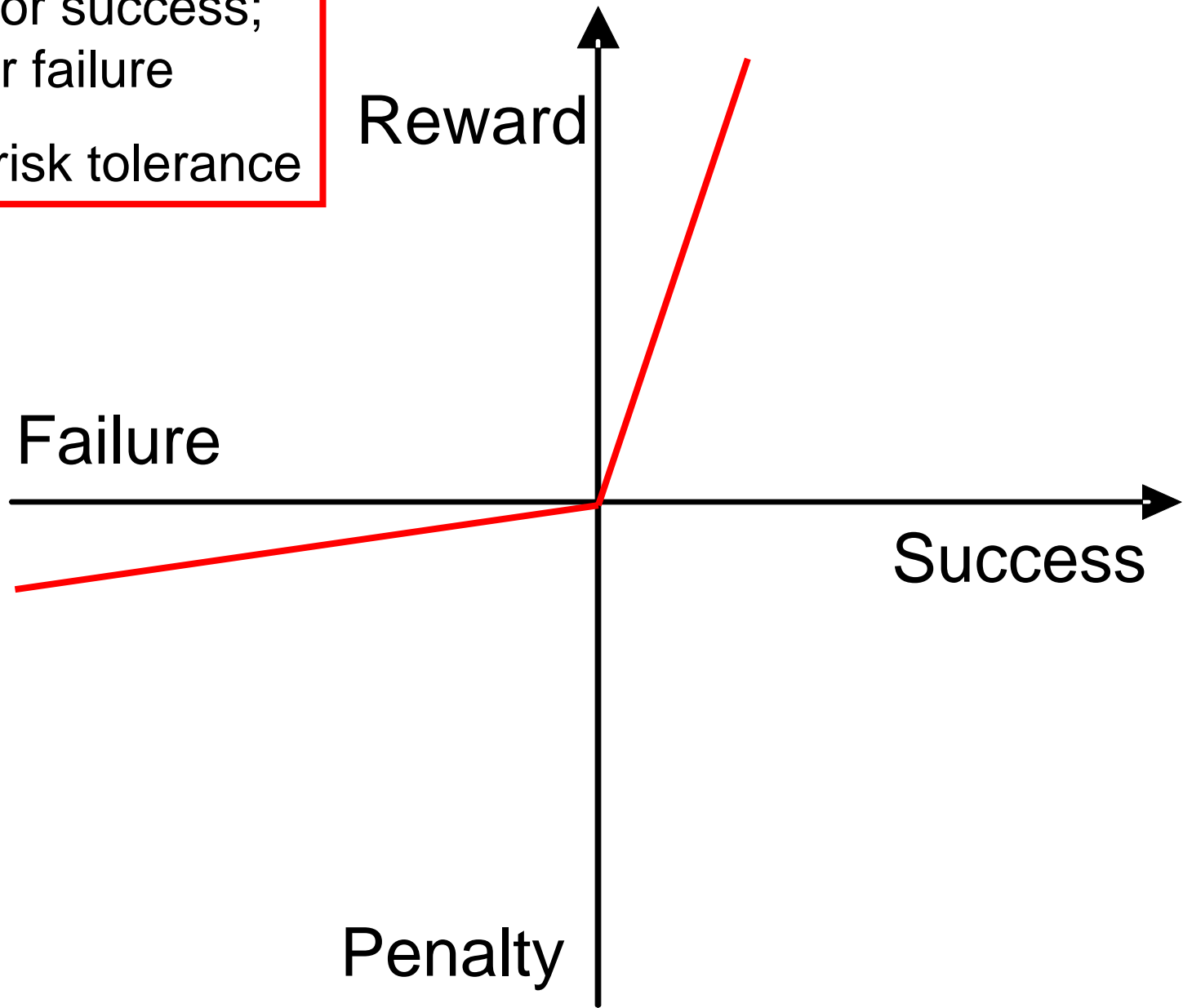
Small reward for success;
Large penalty for failure
Leads to risk aversion



Small reward for success;
Absolute penalty for failure
Leads to zero risk tolerance



Large reward for success;
Low penalty for failure
Leads to high risk tolerance



Summary Presentation

Design and Validation Methodologies – Lessons Learned

Three examples of successful, and sometimes rapid insertion of new materials and processes into military applications

- **Single Process Initiative for Technology Change in Existing Military Systems - Joe Felty, Raytheon Systems**
- **Accelerated Insertion of AerMet 100 into F-18 Landing Gears – K. K. Sankaran, Boeing**
- **Lessons from Kinetic Energy Tank Projectile Applications – Chris Hoppel, U.S. Army Research Lab**

Summary

Design and Validation Methodologies – Lessons Learned

Common characteristics for projects leading to rapid insertion of new materials and processes into military applications

- **Customer and OEM pull**
- **Clear chain for decision making**
- **Clear criteria for validating materials and processes for a particular application or range of applications**
- **Well-functioning military, OEM, supplier teams**
- **Continuity in project teams accelerates transitions**
- **Practice at insertion process (even for different materials, processes, and applications) lowers perceived risk**

COMMON CHARACTERISTICS....

The establishment of enterprises similar to “Skunkworks”. These are committed, **multidisciplinary teams** led by **champions** who inspire and motivate the team towards a specific goal.

The use of expanded mechanisms of open and free communication. This especially means the **ability to communicate awareness of problems** that will affect process goals.

The willingness of the champion to take personal risk. This kind of leadership results in a willingness of the organization to **take risks at the enterprise level.**

Adopting such a culture has several fundamental implications:

- Individuals must ***feel empowered to take risks***
- Management must anticipate and ***plan for failure***
- Everyone must champion ***teamwork and collaboration*** over individual accomplishments.
- Engineers and scientists responsible for innovation and development must be ***allowed to experiment, to think freely, to follow their nose, and to fail.***
- To encourage innovation, “failure is not an option” is replaced by ***“failure provides lessons learned in an innovative environment.”***

"Culture"



"... it needs to be cultivated;
you grow the Culture..."

Three specific areas emerged :

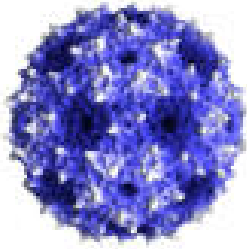
- Creating a culture for innovation and rapid technology transition
- **Methodologies and approaches**
- Enabling tools and databases.

*The primary method is
to work to technology function
rather than specification by better quantifying
the rewards associated with success and by
mitigating the risk of failure.*

**Three corporate best practices
that are effective**

Best Practice 1:

**Developing a "Viral" Process for
Technology Development**



“Viral” ... ??

“Viral” means the process

- provides a seemingly effortless transfer of information and products to others in the team,*
- exploits common motivations and behaviors that are reinforced by the team members' behaviors,*
- takes advantages of other team members' resources and knowledge to find solutions, and*
- scales easily from small to large scale implementation.*

Viral Processing...

- This entails quick, iterative development cycles and prototyping
- Effective modeling of materials and processes is a critical part of viral development

Best Practice 2:

**Increased Reliance on
Functional Requirements
Rather than Specifications**

Functional Requirements Rather than Specifications

- *One key limitation to rapid insertion of new technology is the lack of information given to vendors about the functional and technological needs.*
- *The increased reliance on functionality rather than specifications can only be implemented by having all stakeholders involved and sharing information.*



*Comparison of **Formula 1 Race Car** Technology Insertion Teams and **Military Aerospace** Market*

Formula 1	Military / Aerospace
Open specifications	Ultimate in detail specifications
Open processes	Use only our qualified processes
Constant improvement	Prove it will work
Rapid design cycles	New vehicle every 10 years

Best Practice 3:



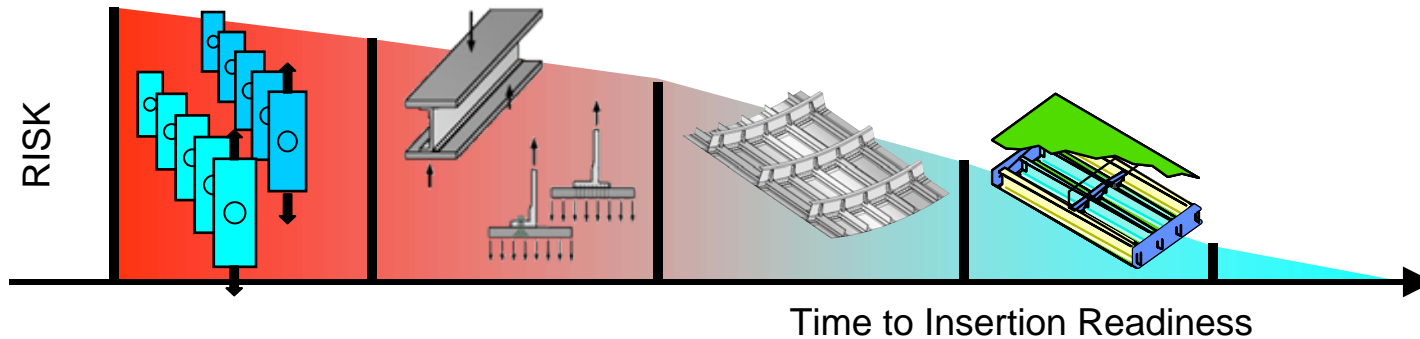
**Developing a Mechanism for
Creating Successful Teams as New
Systems are Envisioned**

Three specific areas emerged :

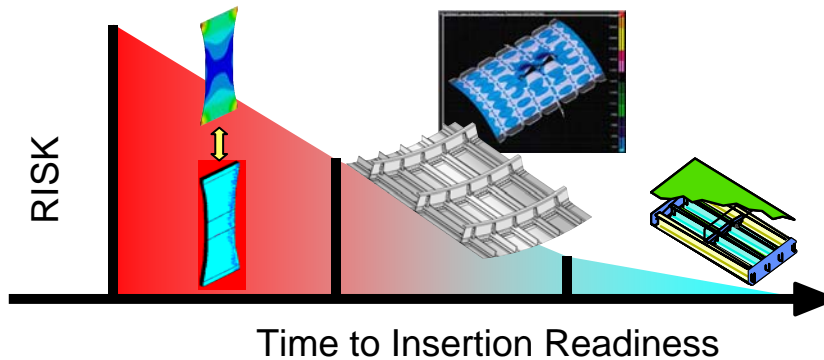
- Creating a culture for innovation and rapid technology transition
- Methodologies and approaches
- **Enabling tools and databases.**

DARPA Program on Accelerated Insertion of Materials

Traditional test supported by analysis approach

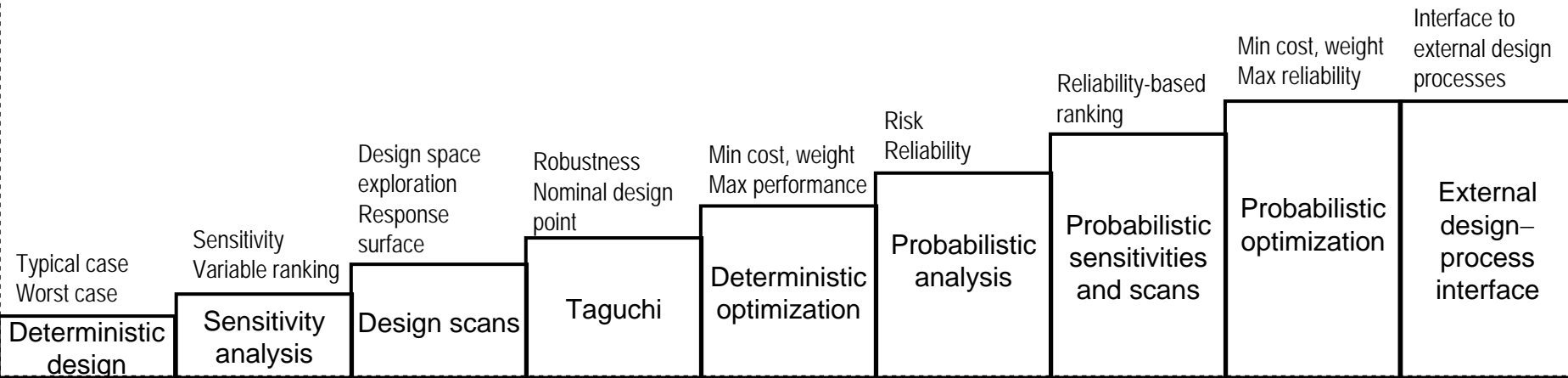


AIM provided an analysis approach supported by experience, test and demonstration

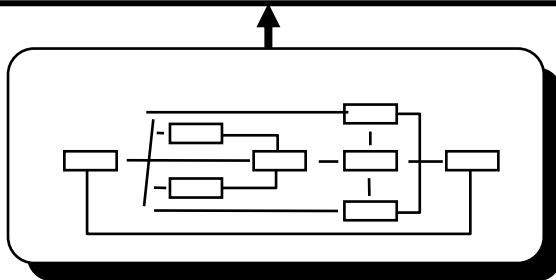


- COMPRO in RDCS – 6 month Taguchi versus weekend full factorial
- Processing cycle matched on first process attempt versus 6 panels by empirical tests
- SIFT analysis within RDCS – 3 days vs 6 months

Design and Analysis Approaches

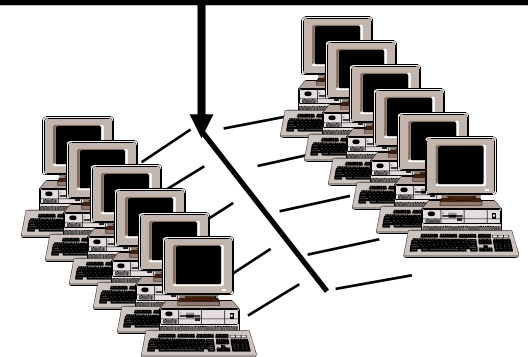


Real-Time Distributed Computing Systems



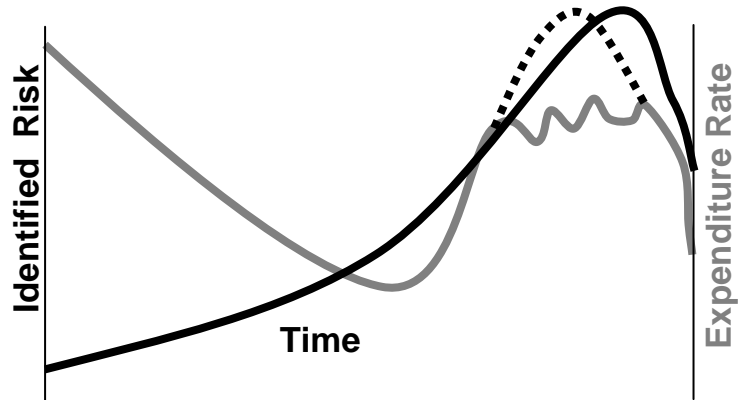
Linked models

Parametric analysis of a set of multidisciplinary codes connected together

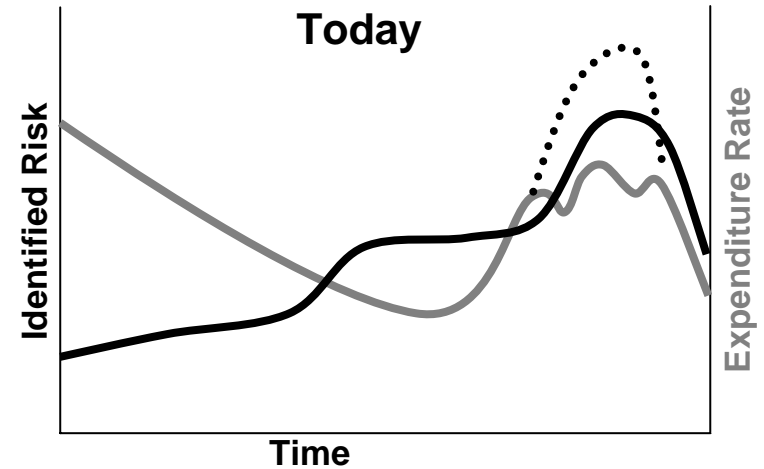


Distributed computing leads to timely results

Yesterday

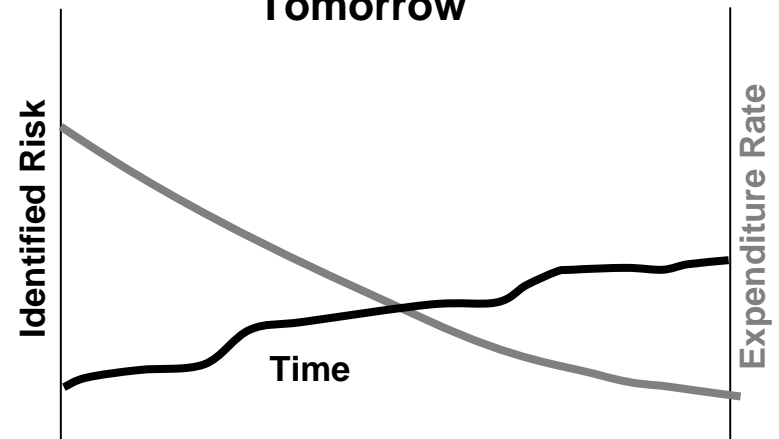


Today



Provides a framework for measuring progress in accelerating technology transfer

Tomorrow



Bob Schafrik, GE Aircraft Engines

The Office of Science and Technology Policy should lead a national multi-agency initiative in Computational Materials Engineering to address three broad areas:

- *Methods and Tools*
- *Databases*
- *Dissemination and Infrastructure*

DoD should adopt :

Develop a viral process for technology development through quick, iterative prototyping of materials and products, with facile, open communication; agile manufacturing processes; and effective modeling of materials and processes, system performance, and cost.

Work to functional requirements rather than specifications.

Develop a flexible mechanism for creating and recreating successful teams as new systems are envisioned.

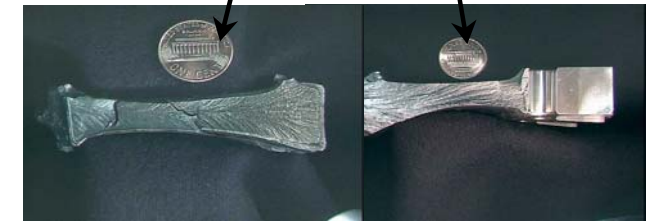
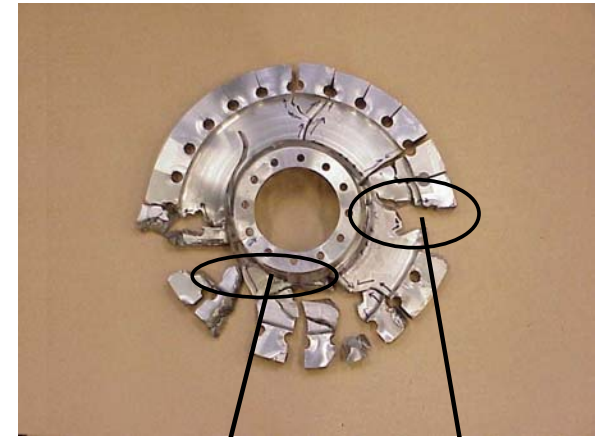
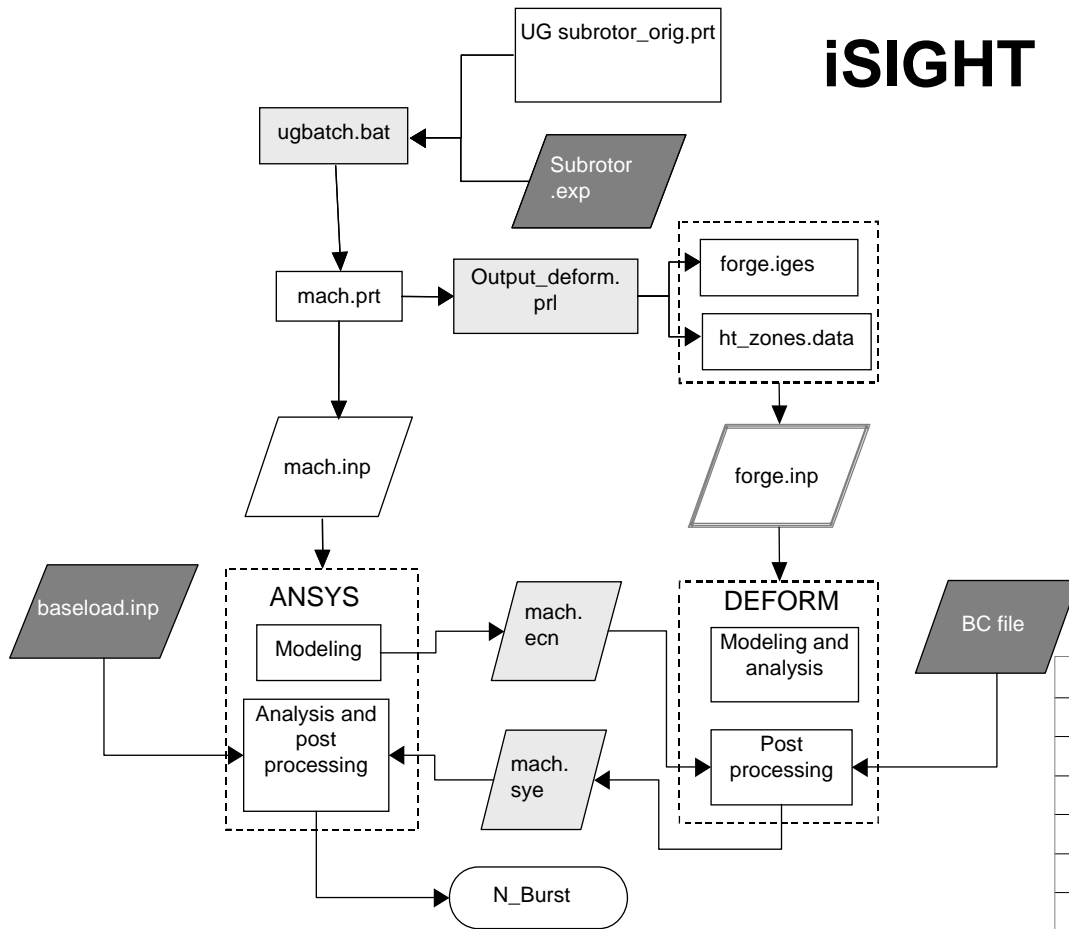
Methods and Tools:

An academe/industry collaboration built on such models as the DARPA-AIM should focus on the rapid transformation of existing fundamental materials numerical modeling capabilities into purposeful engineering tools on a pre-competitive basis. The scope should encompass all classes of materials and the full range of materials design, development, qualification, and life-cycle, while integrating economic analysis with materials and process selection systems.

Dissemination and Infrastructure:

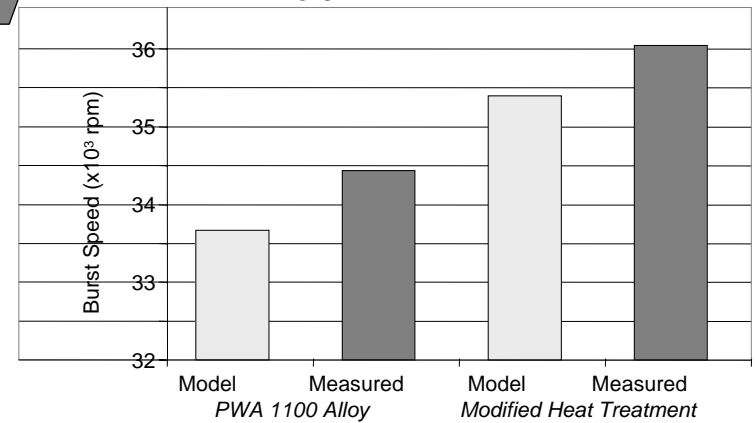
A dissemination initiative should provide ready access to a web-based source of pre-competitive databases and freeware tools as well as accurate information on the range of existing commercial software products and services.

iSIGHT

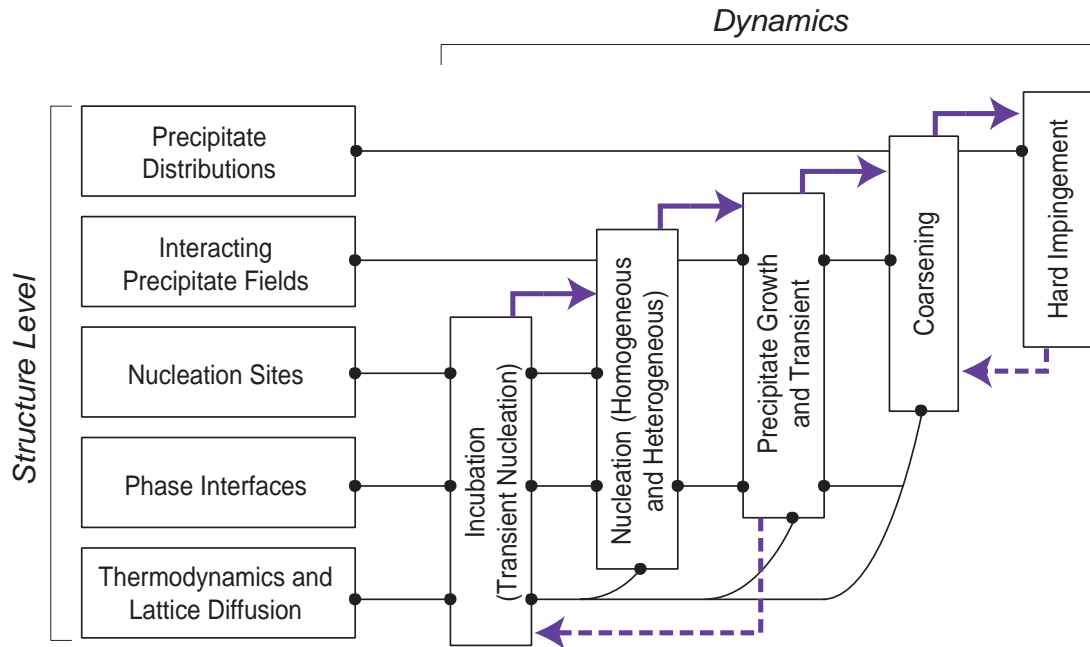


Rim hole

Bore



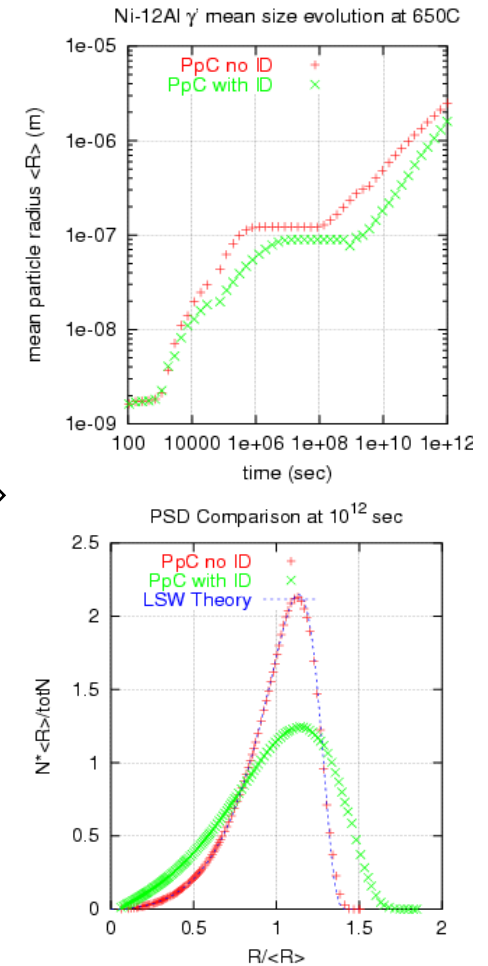
Mechanistic Basis



Input

Thermodynamics, Surface Energy, Mobility
Thermal History and Numerical Parameters

Output



It is more important to work on the *right* projects than it is even to do the work right.

Good work on the wrong projects cause many problems...

The overriding objective is to work on the right things

DoD should consider:

Introduce flexibility that reduces budget lead times and provides consistent funding during the development stage through full maturity;

Make better use of commercial off-the-shelf technology;

Implement shorter and more iterative design and manufacturing processes;

Simplify procurement and acquisition processes;

*Update standards and testing procedures to make it easier to introduce new materials and processes; and
Decentralize decision-making.*

CHANGING PARADIGM...

Changing such a culture may mean **decentralizing decision making, simplifying procurement and acquisition processes, reducing budget lead times,** providing consistent funding through development and maturation, making greater use of off-the-shelf technology, and valuing innovation over short-term economic efficiency.

Updating standards and testing procedures to make it easier to introduce new materials.

By better matching the **development and deployment time frames** in the venture capital industry, the military can leverage dual-use commercial development and billions of dollars in **private equity capital**.

Databases:



An initiative should focus on building the broad fundamental databases necessary to support mechanistic numerical modeling of materials processing, structure, and properties.

Cultural Issues

Successful technology transition is a long-term dialogue between the ***creators and end-users*** of new technologies.

Effective technology transition is a ***collaboration among all of these stakeholders*** that drives an iterative process of development, implementation, and acceptance.

A central theme ... the importance of creating a culture that fosters ***innovation***, rapid development, and accelerated technology transition

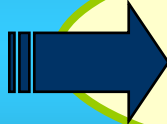
These elements include ***flexibility, a willingness to take risks, open communication without regard to hierarchy***, a sense of responsibility that replaces authority, and a commitment to success that goes beyond functional roles

Military, OEM, Supplier Teams

✓ Enabler:

Raytheon Corporate Management Council

- DOD representatives
- DCMA
- Raytheon Business leaders
- Raytheon Acquisition Reform Council



Technical Team

Air Force

Navy

Army

DCMA,
JG-PP

Programs

Engineering

EHS



Analysis

ARL
ARDEC
Primex / Alliant
Battelle
LLNL
Los Alamos

Materials

Amoco / Hexel / CytecFiberite
Primex / Alliant
ARL / ARDEC

Processing / Manufacturing

Primex / Alliant
Hexel / CytecFiberite
ARDEC / ARL
Univ. of DE
Stevens Tech

Validation / Testing

Aberdeen Test Center
Yuma Proving Grounds
Primex / Alliant
ARDEC
ARL

Feb 25

Boeing/CarTech
Coordination Meeting

Feb 28

Qualification Plan Developed

- Verify aging time
- Assess Durability/Damage Tolerance
- Validate protection Scheme

Apr 9

Brief F/A-18 E/F Program

May

Kickoff Cooperative Test Program

- CarTech
- Boeing (M&P, Structures, Landing Gear Design)
- NAVAIR (Materials and Structures)

Sep 4

F/A-18 E/F Design Decision
Selecting AerMet 100

Single Process Initiative Block Change Process

- ✓ The three-fold thrust of SPI is to:
 - 1) *consolidate processes and standards* in ongoing contracts,
 - 2) *modify contracts as a block* in a single facility rather than on a contract-by-contract basis, and
 - 3) *accomplish these changes in a streamlined, expedited manner* so that the Government can realize savings quickly.
- ✓ *Administrative phase of new technology insertion*

Summary of Benefits from Single Process Initiative

- ***Block modification of existing contracts for insertion of new technologies***
- ***Win-Win for DOD and contractor***
- ***Common process for technology insertion***
- ***Increase efficiency***
- ***Reduce costs***
- ***Improve quality***
- ***Minimize/Eliminate waste***
- ***Promote pollution prevention***
- ***Still viable process 7 yrs after inception***

Streamlined Acquisition Process; Best Customer Value

Demonstrated Success in Acquisition Reform

✓ Just a few of Raytheon's SPIs

- 1996 - Common Processes (1st DoD SPI)
- 1996 - Alternate coatings (1st EHS SPI)
- 1997 - Performance-based standards for top coats
- 1997 - Paint/Primer SPI-RES
- 1998 - Circuit Card Assembly Task Force
- 2000 - Performance-based Joint Test Protocol for paints/primers
- 2000 - Primers & Topcoats SPI expanded for enterprise-wide use
- 2003 - HMMP SPI



✓ SPI drives standardized processes across programs

✓ SPIs are well integrated and understood by Program Office

Builds Bridges to Customers, Programs, and Contracts



Summary – Kinetic Energy Munitions

- **Composite Materials were utilized in the M829A2 and M829A3 projectile programs to substantially decrease the sabot weights and increase the projectile lethality**
- **Composite materials were only used because it was critical to decrease sabot weight and increase projectile velocity**

New material was the only option for increasing lethality

- **Teaming with Government/Contractors/Sub-Contractors was essential to addressing material related issues during programs**

Chris Hoppel, ARL



Summary – Kinetic Energy Munitions

- **Transition in approach with each successive generation**
 - **M829A2 program focused on “system-level” qualification**
 - **Expensive projectile level tests required for evaluating changes**
 - **System level tests did not reveal all of the effects of material changes**
 - **M829A3 program utilized “material-level” evaluation with system-level validation**
 - **Requires more fundamental understanding of effects of material on system level performance**
 - **Allows material to be screened in sub-scale tests**
 - **Ultimately less expensive, as it reduces the needs for system level tests**

Chris Hoppel, ARL

SUMMARY AND LESSONS LEARNED

- ***Accelerated insertion of new steel AerMet 100 in landing gears for advanced version of F-18 enabled by***
 - ***OEM-determined general need in mid-1980's***
 - ***Strong customer pull for new material with same strength, higher fracture toughness***
 - ***Early designer/researcher communication***
 - ***Excellent Supplier/OEM/Customer cooperation***
 - ***Good metallurgical understanding of alloy family***
 - ***Sound technical judgment relative to technical risk/program benefits***

K. K. Sankaran, Boeing