*A NASA Approach to
"At-Risk Materials-Chemicals"

[~Mission Critical Materials-Chemicals]

By I. Sam Higuchi

NASA-HQ, Environmental Management Division

23 April 2008 Meeting

MERIT (Materials of Emerging Regulatory Interest Team)

***** **Disclaimer:** This presentation does not represent the official views or position of NASA, the presentation reflects only the personal views of the presenter.

THIS NOT “WHERE I AM,”

THIS IS “WHERE I WAS”

1) Invitation to you – within the next 45-days
2) My background

“STRATEGIC MATERIALS”

(“At-Risk Materials-Chemicals”) –

TWO COMMON ELEMENTS:*

1) Criticality of application (lack of substitutability)

2) Vulnerability of supply (domestic sufficiency)

*** Industrial College of the Armed Forces (National Defense University) (2007) “Industrial Study”**

NASA works with Space Exploration Equipment

DOD works with:

- **Weapons Systems and**
- **Weapons Platforms** – D. Dunn (AF Space Command)

Weapons Systems

http://mva.sd.gov/images%5Cmuseum%5Cmarch.jpg

Weapons Platform

http://www.msa.md.gov/msa/mdmanual/01glance/symbols/images/1198-1-542b.jpg

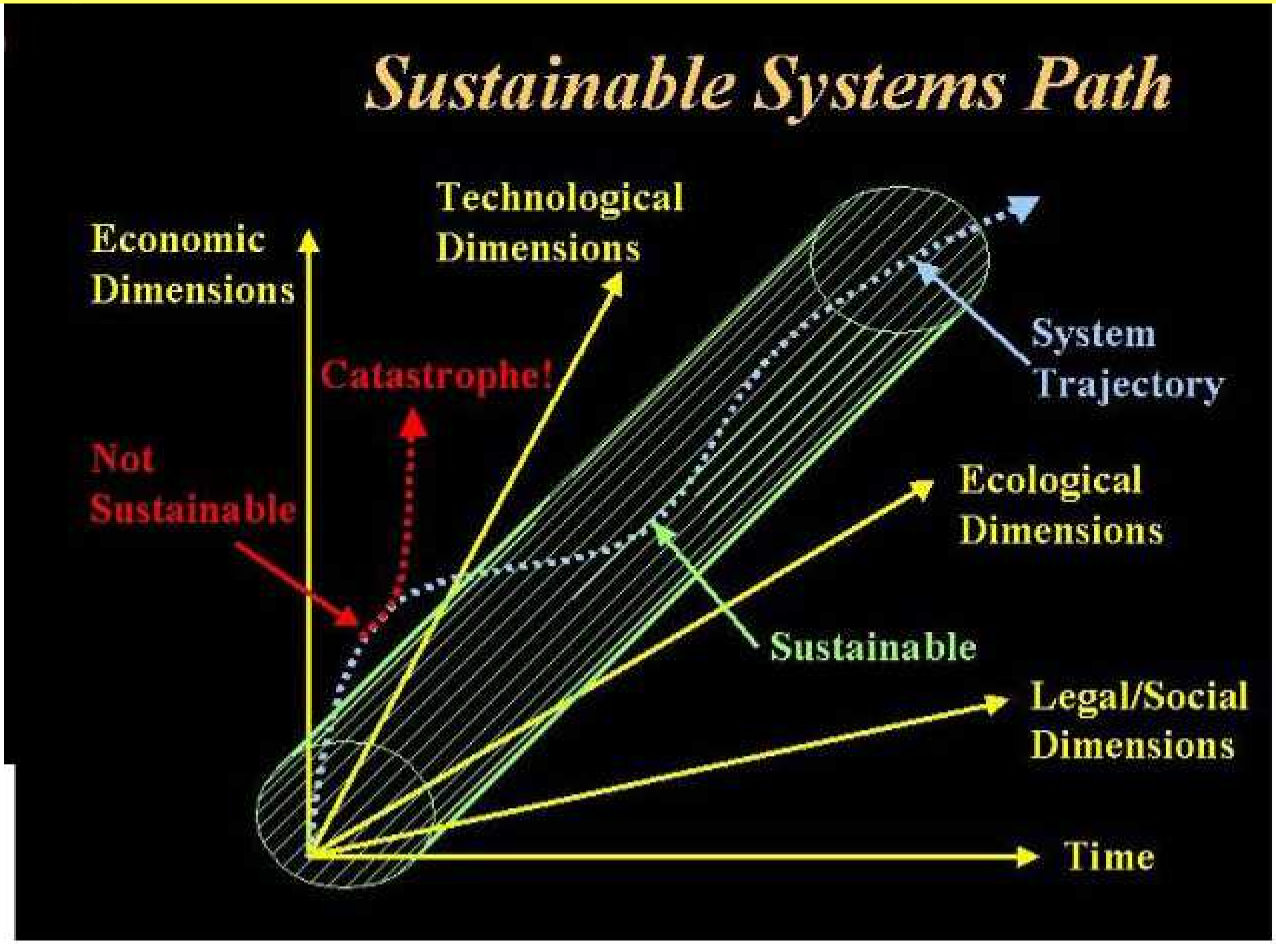
General Approach *[Sam's approach]*:
At-Risk Materials-Chemicals [~ mission critical materials]

Management Tool	***Choices and Selected Direction***	***Remarks***
I. Strategic Risk Management:	A) Accept, or B) Mitigate, or C) Monitor – watch list, or ***D) Investigate – Research Study***	NASA-wide Risk Management (ERM) using a Research Study Document with updates – new findings added
II. Programmatic Analysis and Evaluation:	Program phases -- ***A) Early: 1) who is being served; 2) what is going on*** ***B) Growth: 1) what are they doing; 2) what ought they be doing*** C) Mature: 1) did it work –desired outcome; 2) what would happen in absence of the program	**STUDY OUTLINE: 1) General Context: What is going on? 2) Technical Context: What is going on in the area of science and technology? 3) Environment, Safety and Health Context: What is going on to screen for ESH risks? 4) Sector Profiles (benchmarking & best practices): What are others doing? 5) What are some insights from Academia? 6) What is NASA doing? 7) What are some possibilities for NASA actions?**
III. Program Logic Model Design:	***A) Target Audience: Design-Engineers*** ***B) Objectives: 1) Influence design (DfESH), 2) data credibility in materials & materials processes, 3) data is user friendly, 4) compliance with Global restrictions, 5) options for substitutes, 6) include potential emerging restrictions, 7) additional enhancements (examples; cost, energy, performance), 8) promotes Sustainable Materials Management.***	Emphasis on: Keeping U.S. (domestic) aerospace industry as ***world class suppliers*** of aerospace products and services

“The Future isn’t what it used to be.” - - Yogi Berra

The “Global Materials-Chemicals Regulatory System” (part of the “Legal/ Social Dimensions”) is “dynamic”.

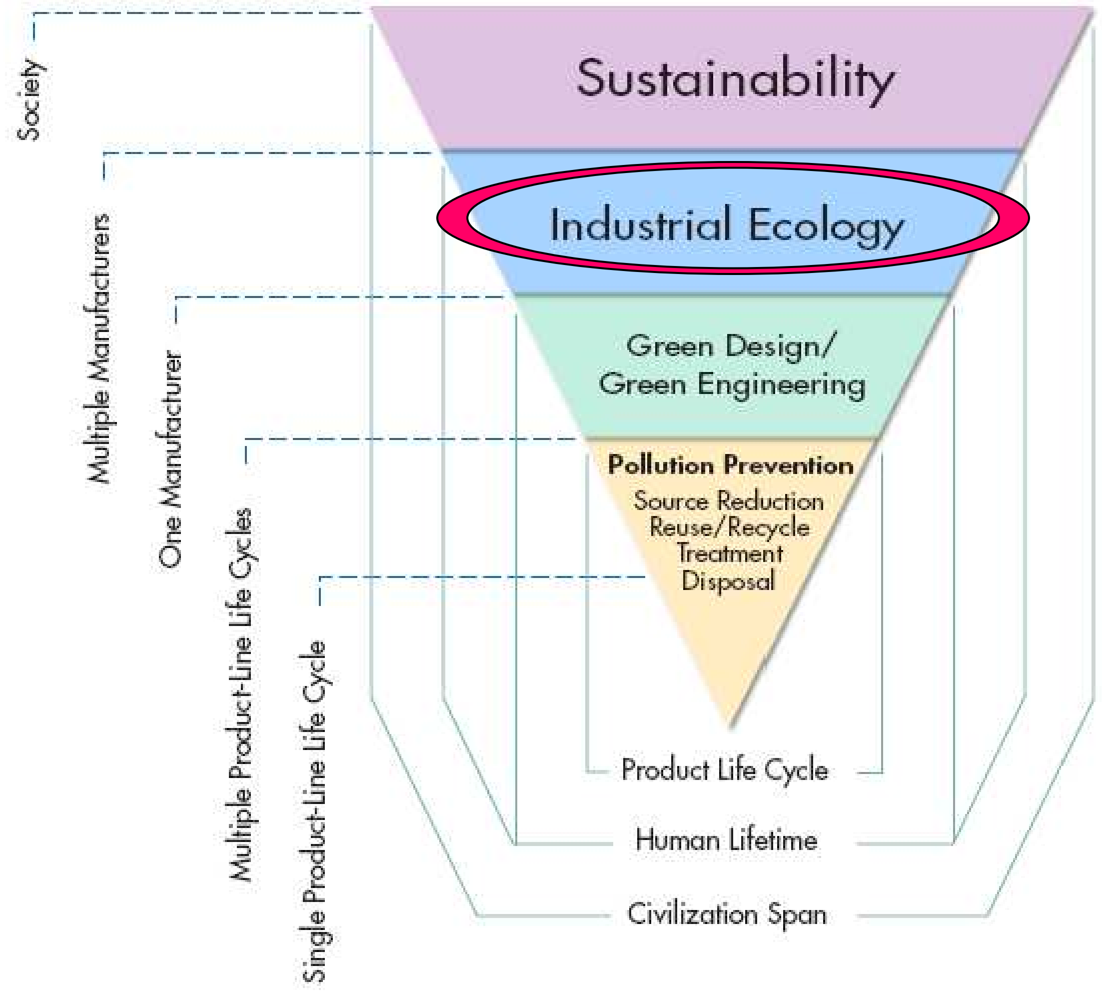
The “System” is not static.



www.epa.gov/ORD/NRMRL/Pubs/508NRMRLinterVIRT.pdf

Environmental Manager’s Perspective

Environmental and Organizational Scales of Environmental Impact Reduction Approaches



Modified by I. S. Higuchi & C. C. Hudson (2005) from Coulter, Bras et al. 1995.

Sustainability: ***Optimizes*** the following three items ***simultaneously (“Triple Bottom Line”)***:

1) Renewable over non-renewable resources,

2) Ecosystem health, ***and***

3) Human welfare.

Traditionally Pollution Prevention: ***Minimizes*** one ***or*** more of the following:

1) Non-renewable resources, ***or***

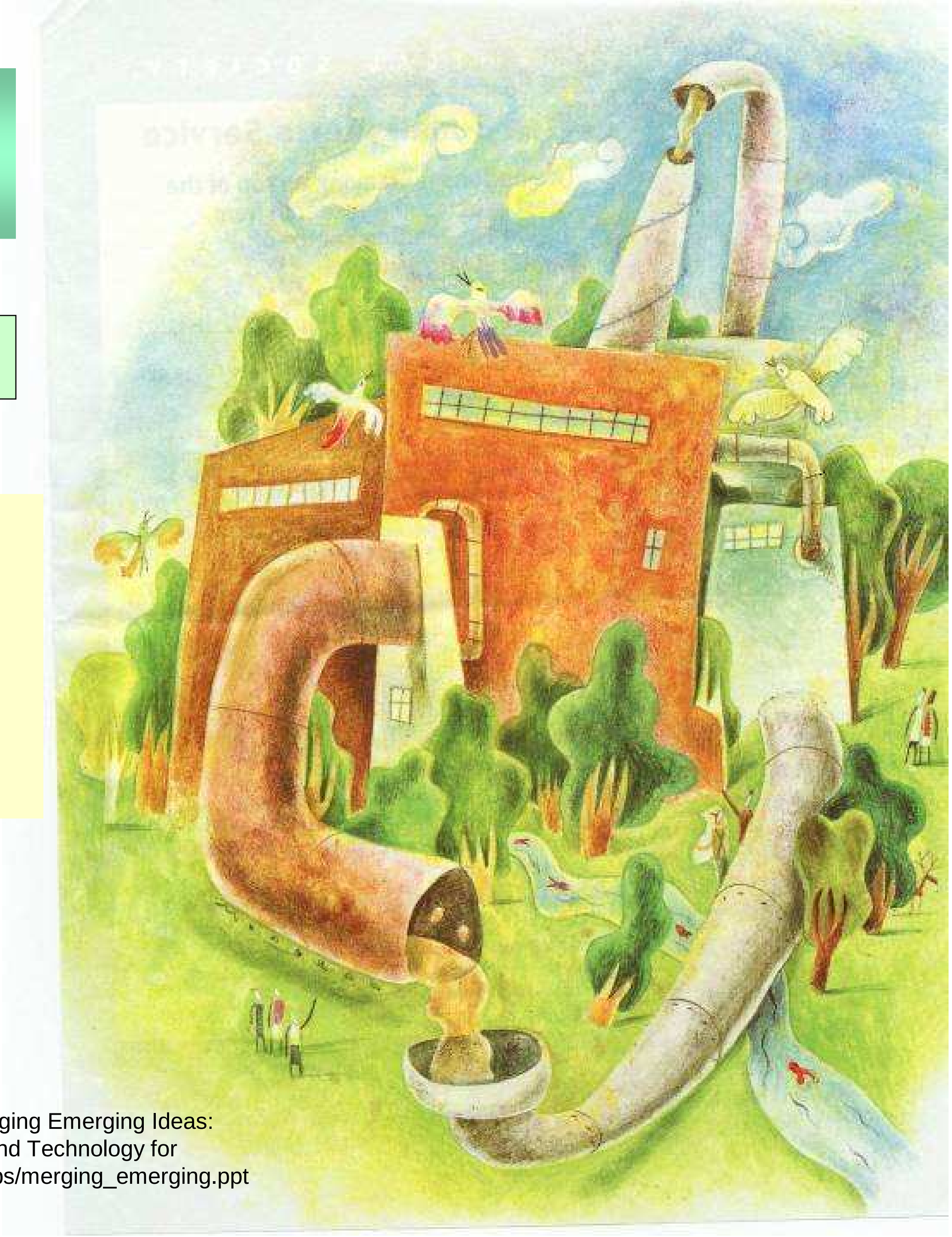
2) Environmental impact, ***or***

3) Safety & health hazards.

"THE SCIENCE OF SUSTAINABILITY"

INDUSTRIAL ECOLOGY

A SYSTEMS APPROACH TO ENVIRONMENTAL PROTECTION



B Karn, D. Bauer, D. Cash, R. Correll, T. Johnson 2003 “Merging Emerging Ideas: ‘Science of Sustainability’ (Industrial Ecology) and Science and Technology for Sustainablity” http://www.epa.gov/industrialecology/workshops/merging_emerging.ppt

REMOTE SITE RESEARCH:

“THE DREAM”

MOON BASE

MARS BASE

http://www.nasa.gov/centers/glenn/images/content/101885main_C91_08781_516x387.jpg

http://www.nasa.gov/centers/glenn/images/content/101903main_C88_11517_516x387.jpg

MATERIALS MANAGEMENT

REMOTE SITE RESEARCH: *"THE REALITY"*

ANTARCTIC BASE

[www.cep.aq/default. asp?casid=6896](www.cep.aq/default.asp?casid=6896)

http://web.archive.org/web/20051125095443/
www.antarctica.ac.uk/About_BAS/Cambridge
/Divisions/EID/Environment/fb_before.jpg

ARCTIC BASE

http://response.restoration.noaa.gov/pribilof/

Can NASA afford this?

- **LUNAR “MOUNT TRASH-MORE”**
- **MARTIAN “MOUNT TRASH-AND-SOME-MORE”**

Nucor -- http://www.nucor.com/indexstory.aspx?story=16

Lunar and Martian Research Bases: “Sustainment” –

AT WHAT COST TO TAXPAYERS?*

1) **$8,300** **(Titan IVB)** **to $8,500** **(space shuttle)** **per pound to LEO** **(in 2000 dollars)**
2) **$35,000 per pound to Saturn** **(Cassini probe)**

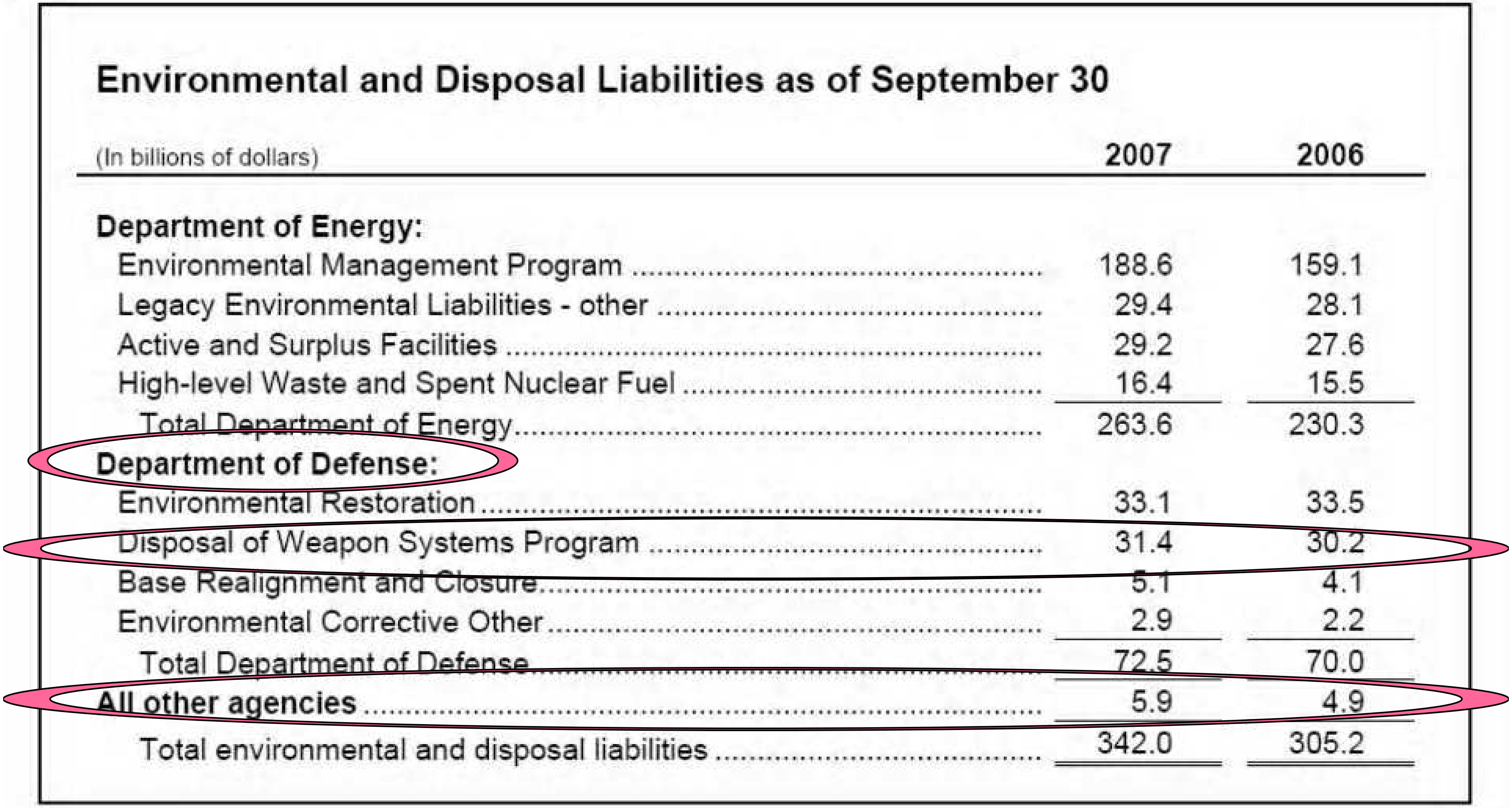
* H E McCurdy (2001) “Faster Better Cheaper: Low-Cost Innovation in the U.S. Space Progam”

AEROSPACE BONE-YARD

http://www.airfields-freeman.com/CA/ElMirage_CA_boneyard_03.jpg

Note 12. Environmental and Disposal Liabilities

U.S. Government – FY 2007 Financial. Report

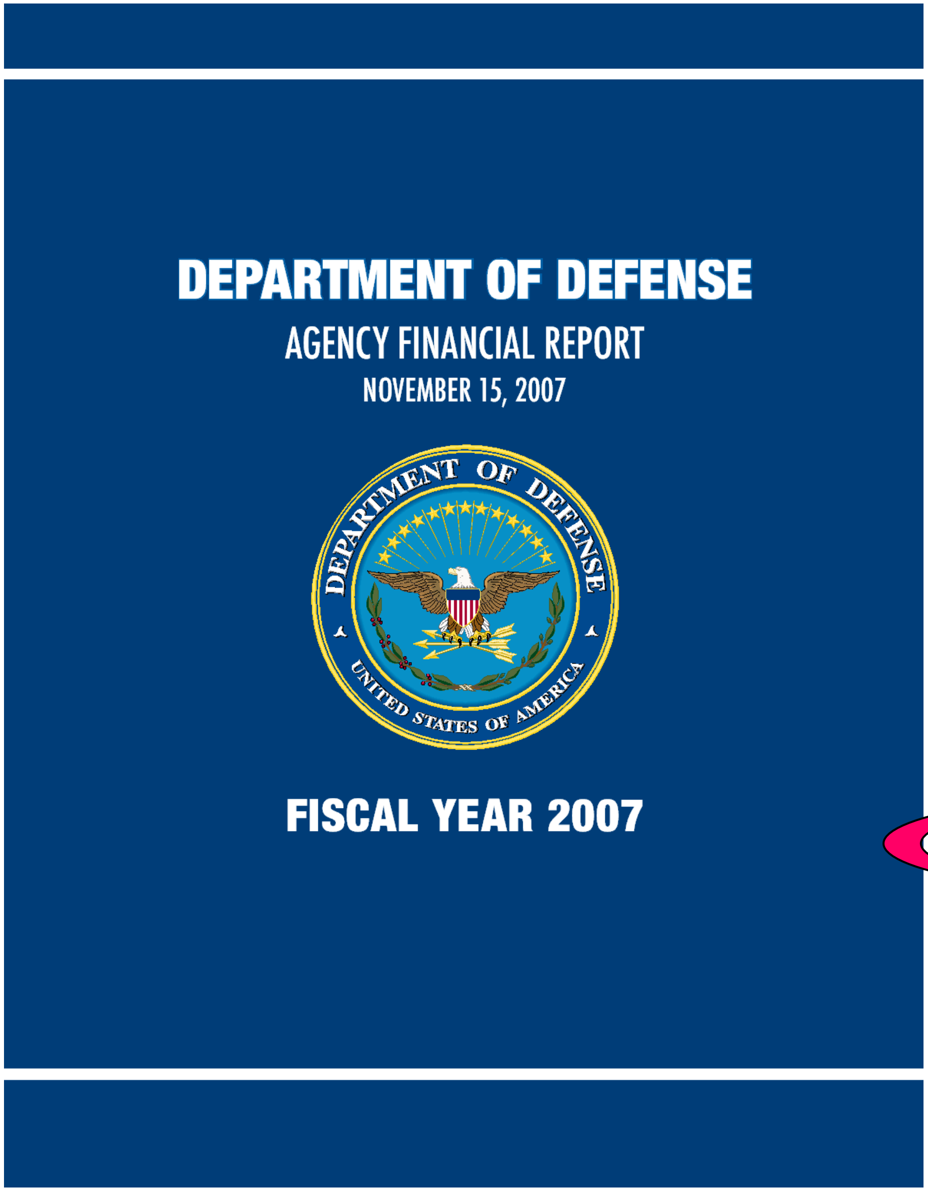


Environmental and Disposal Liabilities as of September 30

(In billions of dollars)	2007	2006
Department of Energy:		
Environmental Management Program	188.6	159.1
Legacy Environmental Liabilities - other	29.4	28.1
Active and Surplus Facilities	29.2	27.6
High-level Waste and Spent Nuclear Fuel	16.4	15.5
Total Department of Energy	263.6	230.3
Department of Defense:		
Environmental Restoration	33.1	33.5
Disposal of Weapon Systems Program	31.4	30.2
Base Realignment and Closure	5.1	4.1
Environmental Corrective Other	2.9	2.2
Total Department of Defense	72.5	70.0
All other agencies	5.9	4.9
Total environmental and disposal liabilities	342.0	305.2

“DOD also bears responsibility for disposal of chemical weapons and environmental costs associated with the disposal of weapons systems (primarily nuclear powered aircraft carriers and submarines).”

The FY 2007 Financial Report of the United States Government (Financial Report)
http://www.gao.gov/financial/fy2007/07frusg.pdf



DEPARTMENT OF DEFENSE
AGENCY FINANCIAL REPORT
NOVEMBER 15, 2007

FISCAL YEAR 2007

Note 14. Environmental and Disposal Liability

(Pages 65-68)

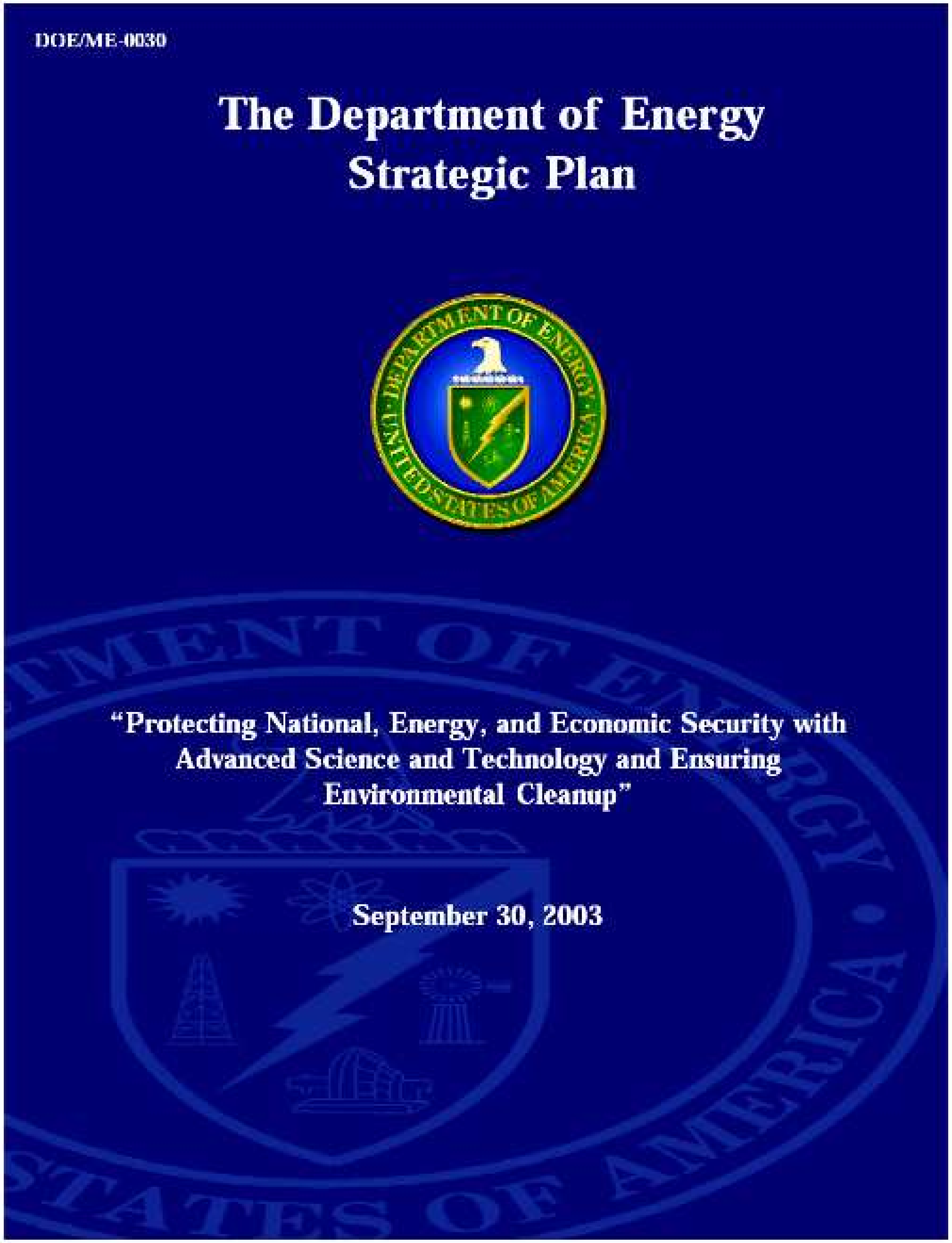
Environmental Disposal for Weapons Systems Programs

(Excluding Nuclear Ships and Chemical Weapons Disposal)**:**

Total = $3.44B*

**Other National Defense Weapons Systems = $0.20B plus Other = $3.24B*

http://www.defenselink.mil/comptroller/par/fy2007/Entire_Document_(5.1_KB).pdf



DOE/ME-0030

The Department of Energy
Strategic Plan

"Protecting National, Energy, and Economic Security with Advanced Science and Technology and Ensuring Environmental Cleanup"

September 30, 2003

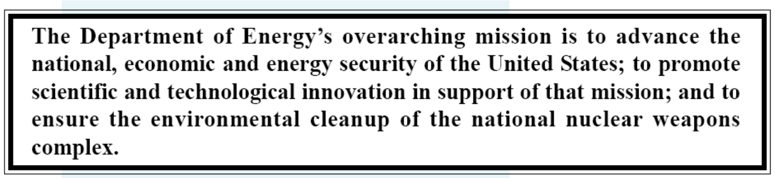
So, what will NASA's 2060 STRATEGIC PLAN be like?

Will "off earth" <u>Environmental Cleanup</u> be:

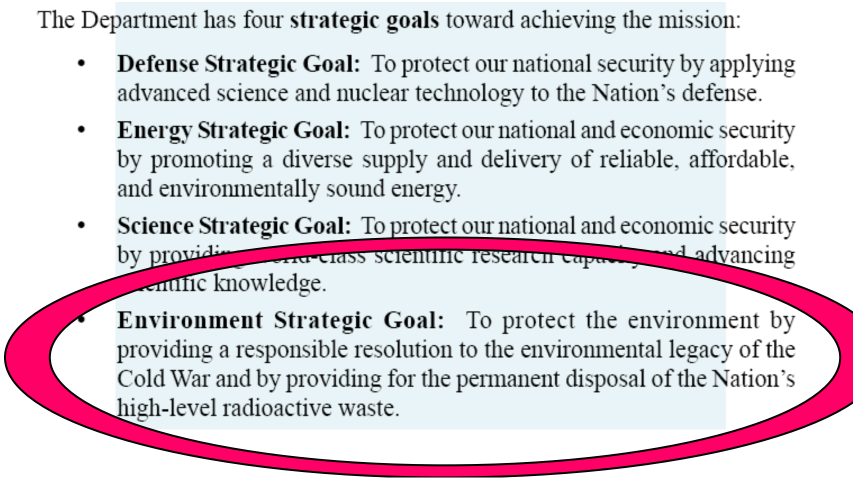
1) a part of NASA's mission, and

2) one of NASA's strategic goals?

--- <u>The choice is yours</u>.



The Department of Energy's overarching mission is to advance the national, economic and energy security of the United States; to promote scientific and technological innovation in support of that mission; and to ensure the environmental cleanup of the national nuclear weapons complex.



The Department has four **strategic goals** toward achieving the mission:

- **Defense Strategic Goal:** To protect our national security by applying advanced science and nuclear technology to the Nation's defense.
- **Energy Strategic Goal:** To protect our national and economic security by promoting a diverse supply and delivery of reliable, affordable, and environmentally sound energy.
- **Science Strategic Goal:** To protect our national and economic security by providing world-class scientific research capacity and advancing scientific knowledge.
- **Environment Strategic Goal:** To protect the environment by providing a responsible resolution to the environmental legacy of the Cold War and by providing for the permanent disposal of the Nation's high-level radioactive waste.

AEROSPACE SECTOR
MATERIAL INPUT AND POLLUTANT OUTPUT

INPUTS	**PROCESSES** (“middle-of-pipe” pollution prevention)	**OUTPUTS** (“end-of-pipe” compliance)		
		AIR EMISSIONS	**WASTEWATER**	**SOLID/ HAZARDOUS/ RESIDUAL WASTES**
Cutting oils, degreasing & cleaning solvents, acids, metals	Metal Shaping	Solvent wastes	Acid/ alkaline wastes	Scrap metal, waste solvents
Metals, abrasive materials, machining oils	Grinding/ Polishing	Metal shavings/ particulates, dust from abrasive materials	Wastewaters with oil, grease, and metal from machining	Abrasive waste, metal shavings, dust
Acid/ alkaline solutions, metal bearing & cyanide bearing solutions	Plating	Volatized solvents and cleaners	Waste rinse water containing acids/ alkalines cyanides, and solvents	Metal wastes, solvent wastes, filter sludges, wasted plating material
Solvent based or water based paints	Painting	Paint overspray, solvents	Cleaning water containing paint and stripping solutions	Waste paint, empty containers, spent paint application equipment
Acid/ alkaline cleaners and solvents	Cleaning, depainting, and vapor degreasing	Solvent wastes, acid aerosols, paint chips and particulates	Wastewater containing acids/ alkalines, spent solvents	Spent solvents, paint/ solvent sludges, equipment and abrasive materials, paint chips

From EPA’s Profile of the Aerospace Industry (November 1998) EPA/310-R-98-001

Alaskan Humor:

Which End Are You Dealing With?

http://apps.atlantaga.gov/citycouncil/Members/ctmartin/gallery_photos/images/YF-horse3_jpg.jpg

http://www.msa.md.gov/msa/mdmanual/01glance/symbols/images/1198-1-542b.jpg

http://www.ers.usda.gov/amberwaves/September06/DataFeature/Photo/datafeature.jpg

Design-Engineer’s Perspective

Learning to Speak the Jargon:
NEW TERMS

TERMS	MEANING
PRP	Product Realization Process
IPM	Integrated Project Management
PLM	Product Lifecycle Management
PDM	Product Data Management
PDE	Product Data Exchange
STEP	Standard for Exchange of Product model data
ISO 10303	ISO standard for STEP

Practical Engineering Questions About Selecting Materials*

* M. Kutz (2002) Handbook of Materials Selection

Set #1: What, Why, and How

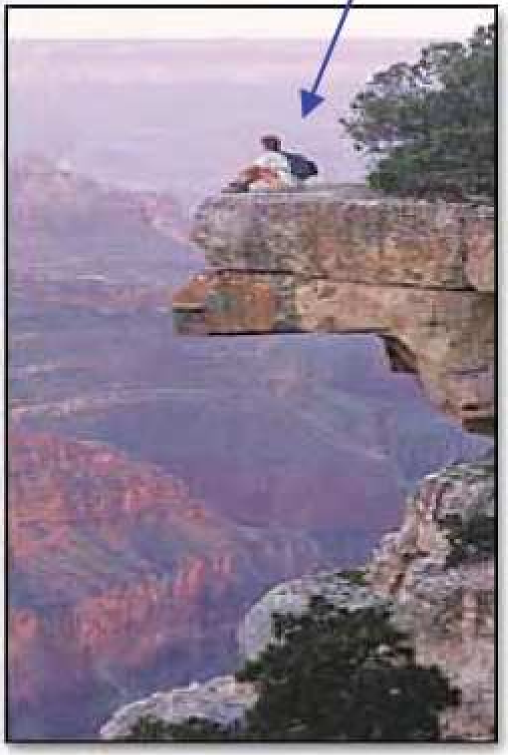
1) ***What materials have been used in particular industrial applications?***
2) ***Why were these materials selected?***
3) ***Were the materials processed in special ways?***
4) ***How did material properties relate to performance in service?***
5) ***Were there any problems initially, and did any develop later?***
6) ***What precautions are recommended?***
7) ***What were the key tradeoffs between properties and performance?***
8) ***What were the limitations imposed by the selected materials?***

Set #2: Specific Design Situation

1) ***What materials might have the characteristics that meet the needs of the application I'm working on?***
2) ***Where would I find information about such materials?***
3) ***What processing techniques might I use to create parts or components from these materials?***
4) ***How do I take into account properties and manufacturing processes in design process?***
5) ***How would I confirm that the materials I specify and purchase have the properties I'm looking for?***
6) ***How does the organization I'm working for go about supplying the materials required by the design I'm proposing, and what limitations may be imposed on my selection by such factors as cost, environmental degradation, etc.?***

What is the Problem?

Materials efforts (new compositions, processing, manufacturing) are not linked with the design process.

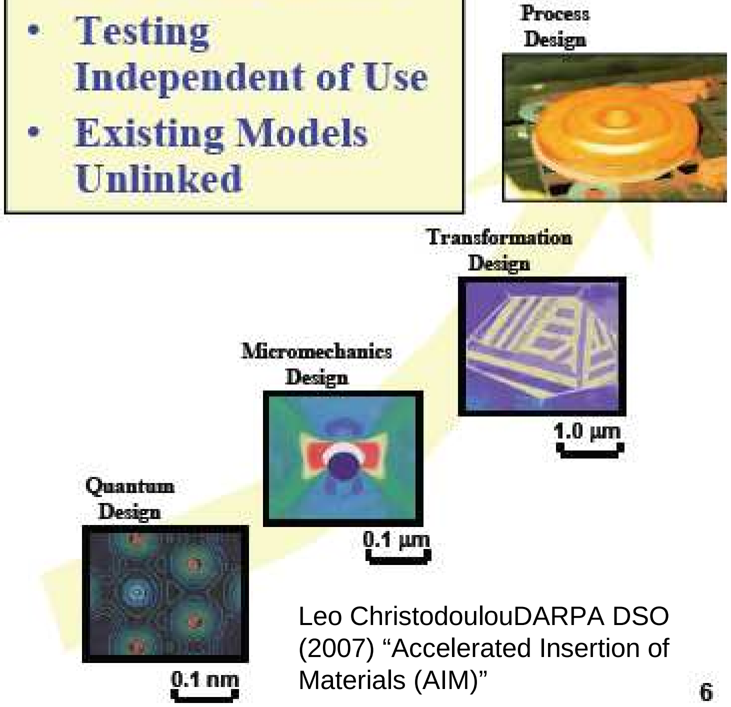


Materials Development

- **Highly Empirical**
- **Testing Independent of Use**
- **Existing Models Unlinked**

Systems Design

- **Materials Input from "Knowledge Base" of Data (Data Sheets, Graphs, Heuristics, Experience, etc.)**
- **System/Sub-System Design is Heavily Computational and Rapid**
- **Clean Sheet of Paper to Engine Design - 30 Months**
- **Well Established Testing Protocols**

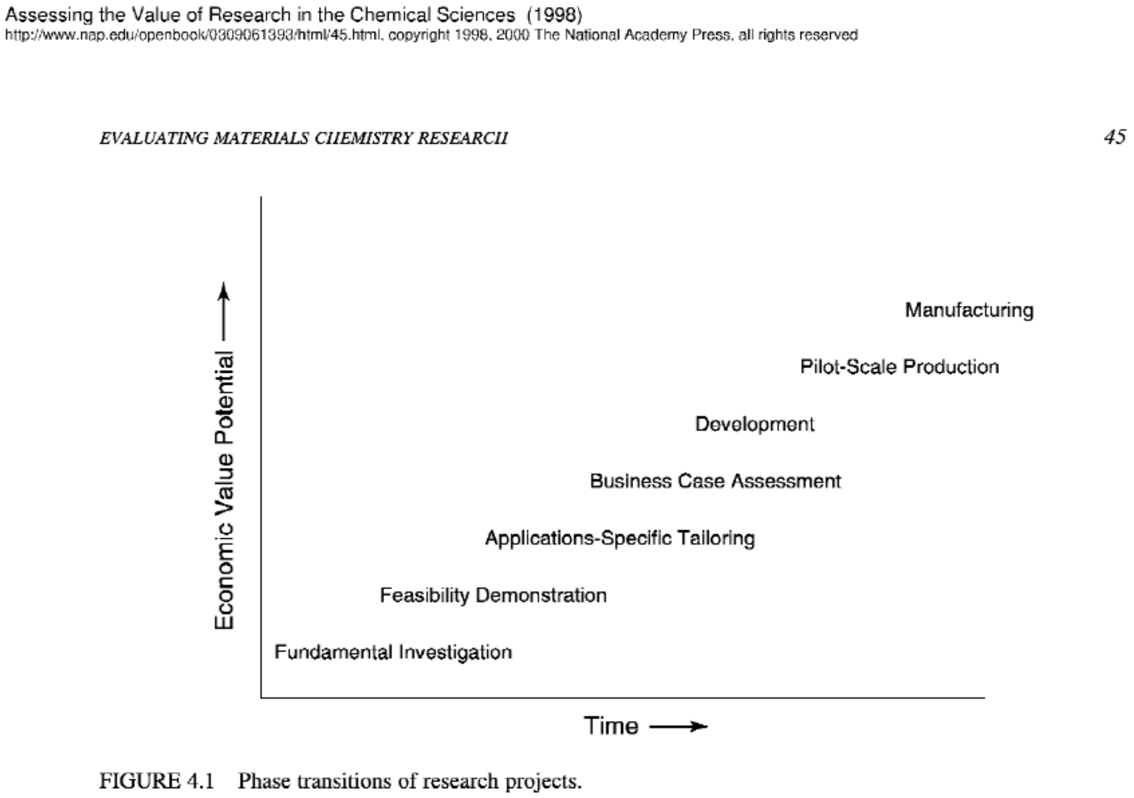


Leo ChristodoulouDARPA DSO (2007) "Accelerated Insertion of Materials (AIM)"

FILLING IN MATERIALS PROPERTIES GAP

In the Past, Design was limited by available Materials.

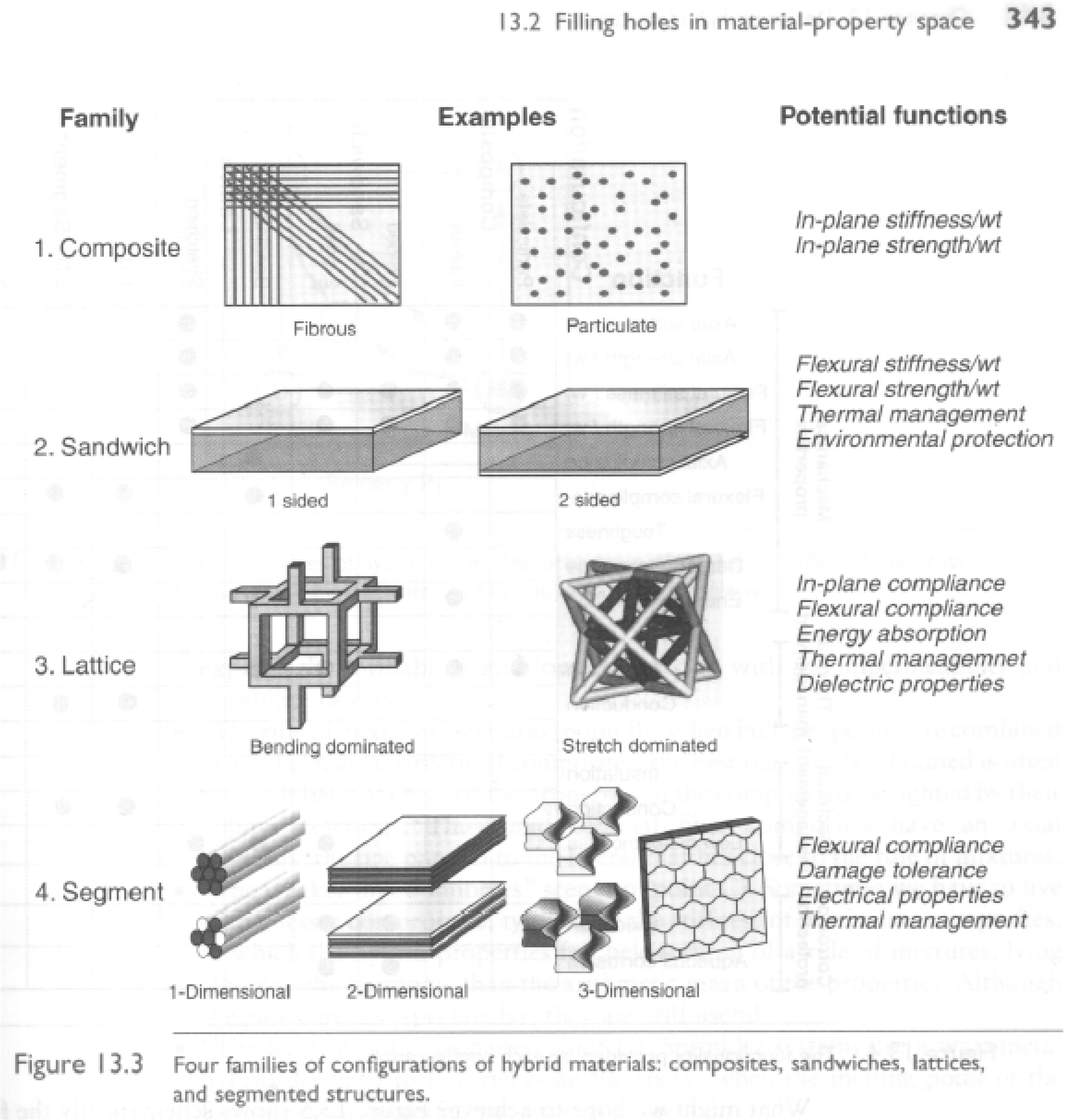
Today, it is becoming increasingly possible to make Materials to meet Design needs through <u>Materials Chemistry Research, Hybrids, and Nano-Technology</u>.



Assessing the Value of Research in the Chemical Sciences (1998)
http://www.nap.edu/openbook/0309061393/html/45.html, copyright 1998, 2000 The National Academy Press, all rights reserved

EVALUATING MATERIALS CHEMISTRY RESEARCH *45*

FIGURE 4.1 Phase transitions of research projects.



13.2 Filling holes in material-property space 343

Family	Examples	Potential functions
1. Composite	Fibrous Particulate	*In-plane stiffness/wt* *In-plane strength/wt*
2. Sandwich	1 sided 2 sided	*Flexural stiffness/wt* *Flexural strength/wt* *Thermal management* *Environmental protection*
3. Lattice	Bending dominated Stretch dominated	*In-plane compliance* *Flexural compliance* *Energy absorption* *Thermal managemnet* *Dielectric properties*
4. Segment	1-Dimensional 2-Dimensional 3-Dimensional	*Flexural compliance* *Damage tolerance* *Electrical properties* *Thermal management*

Figure 13.3 Four families of configurations of hybrid materials: composites, sandwiches, lattices, and segmented structures.

HYBRIDS

1.Composite

2.Sandwich

3.Lattice

4.Segment

M. F. Asby (2005) Materials Selection in Mechanical Design 3ed

“The Holy Grail for Materials Research

The ‘inverse problem’

Given a desired macroscopic property,

how do we design from first principles

the molecule or material possessing it?

Emily Carter, Princeton

And then, how do we make the material?”

Ex-metallurgist, NSF

D.W. Hess (November 30, 2006) Division of Materials Research, NSF
“Reverse Engineering a Possible Future”

NANOTECHNOLOGY

Gold (Au) a Nobel Metal

- **Its shape is flat in the nano-world;**
- **It is reactive in the nano-world.**

H. Ha1kkinen, B. Yoon, U. Landman, X. Li, H. Zhai, & L. Wang (2003) “On the Electronic and Atomic Structures of Small Au*N* - (*N*) 4-14) Clusters: A Photoelectron Spectroscopy and Density-Functional Study”; J. Phys. Chem. A 2003, 107, 6168-6175

J. Phys. Chem. A, Vol. 107, No. 32, 2003 **6171**

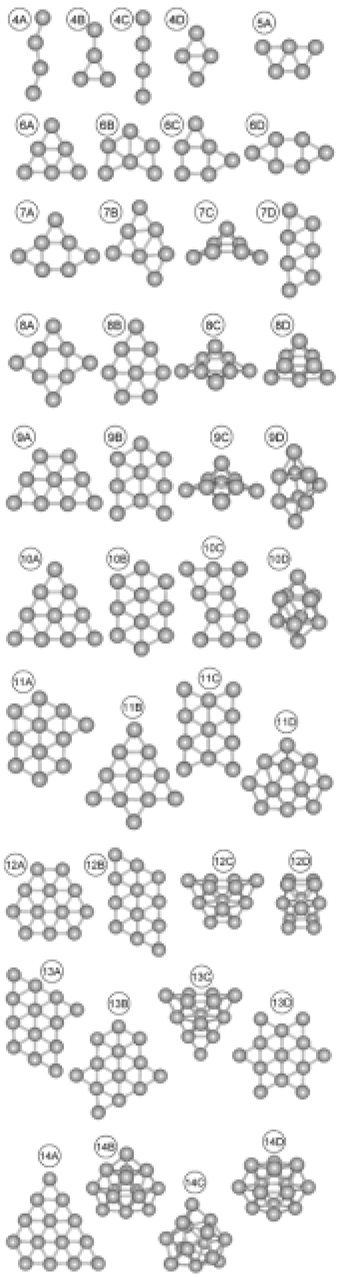
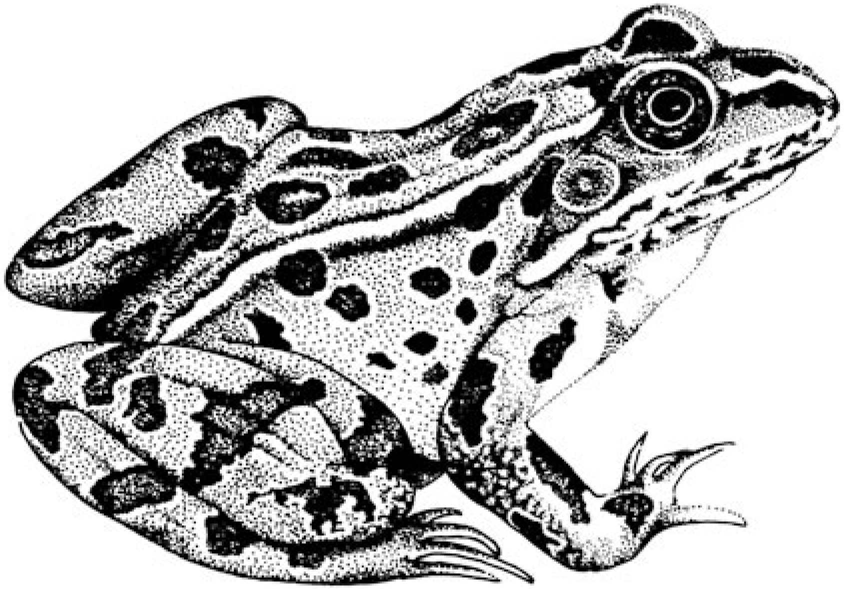
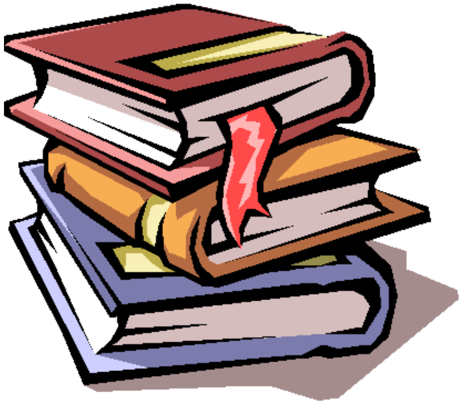


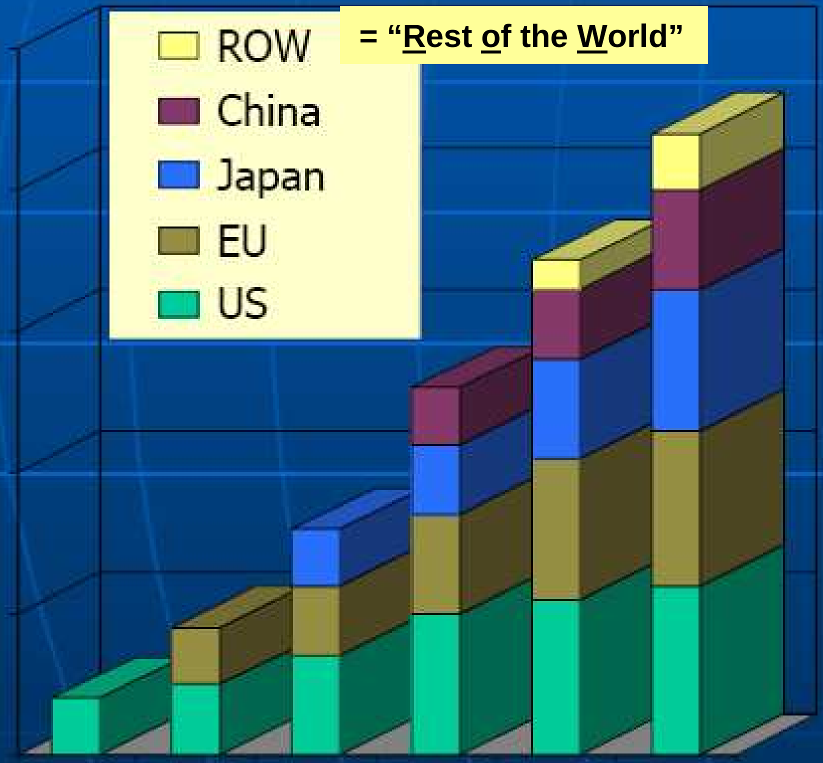
Figure 4. Optimized low-energy structures for Au_N^- clusters with *N* = 4−14. Several isomers are shown for each size, and the ground-state is labeled by "A" in each case. See Table 1 for the corresponding energetic and structural information.



“Leap-Frogging” Technology



Increasing Global Restrictions

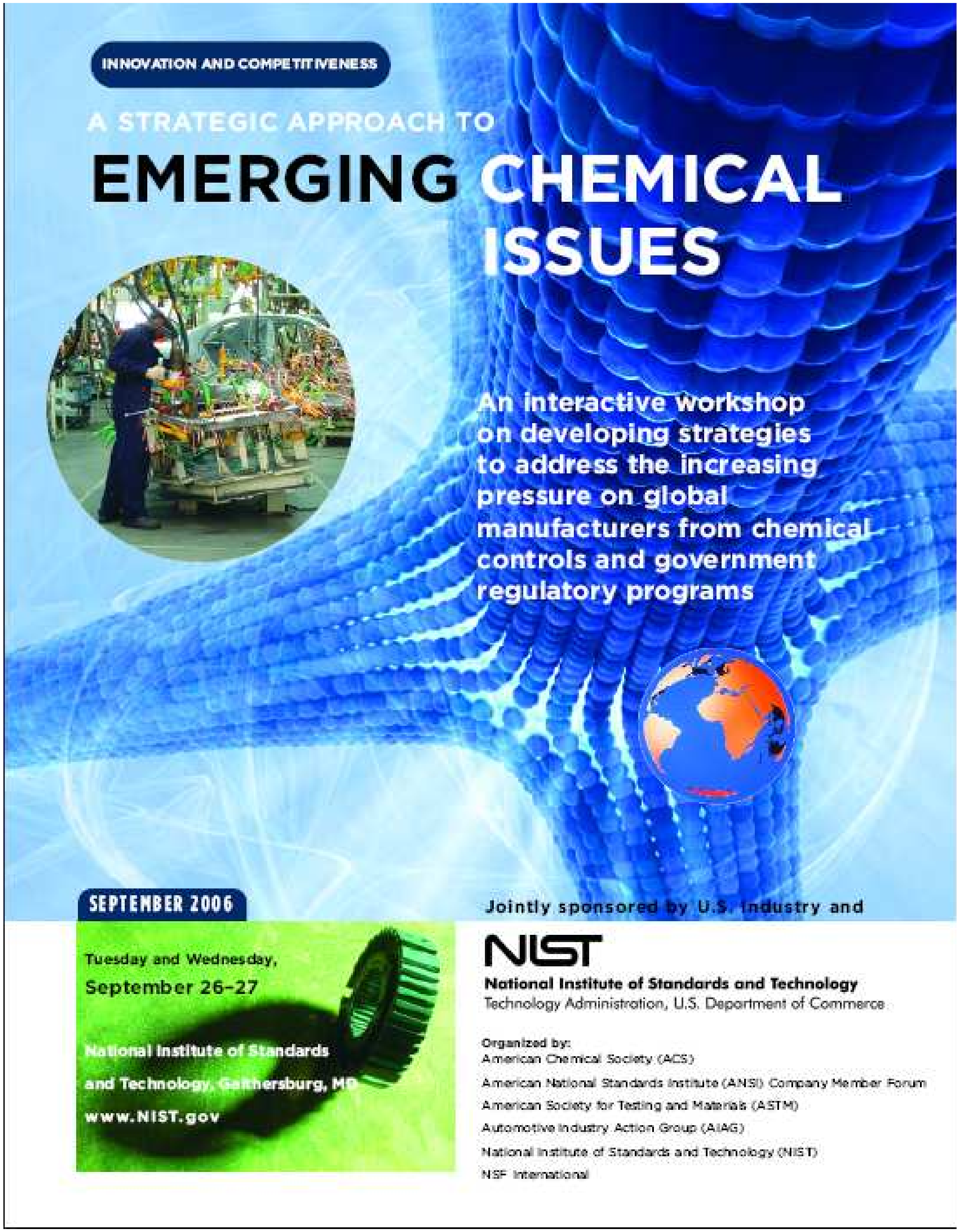


= “Rest of the World”

- Emerging Markets
  - Developing Countries
  - Increasing Regulations
  - Differing Requirements
- Customer Drivers
  - End-user ISO 14001 programs driving suppliers

Brian Sherin (CSP co-Founder, EORM / President, ESHconnect) & Jen Jeng (Associate EHS Consultant, EORM) (October 2001) “SESHA Academic Lecture Series: Design for Safety/ Design for the Environment in the Semiconductor Industry”

NIST – 2006 Workshop on Global Chemical Restrictions



INNOVATION AND COMPETITIVENESS

A STRATEGIC APPROACH TO

EMERGING CHEMICAL ISSUES

An interactive workshop on developing strategies to address the increasing pressure on global manufacturers from chemical controls and government regulatory programs

SEPTEMBER 2006

Tuesday and Wednesday,
September 26–27

National Institute of Standards
and Technology, Gaithersburg, MD
www.NIST.gov

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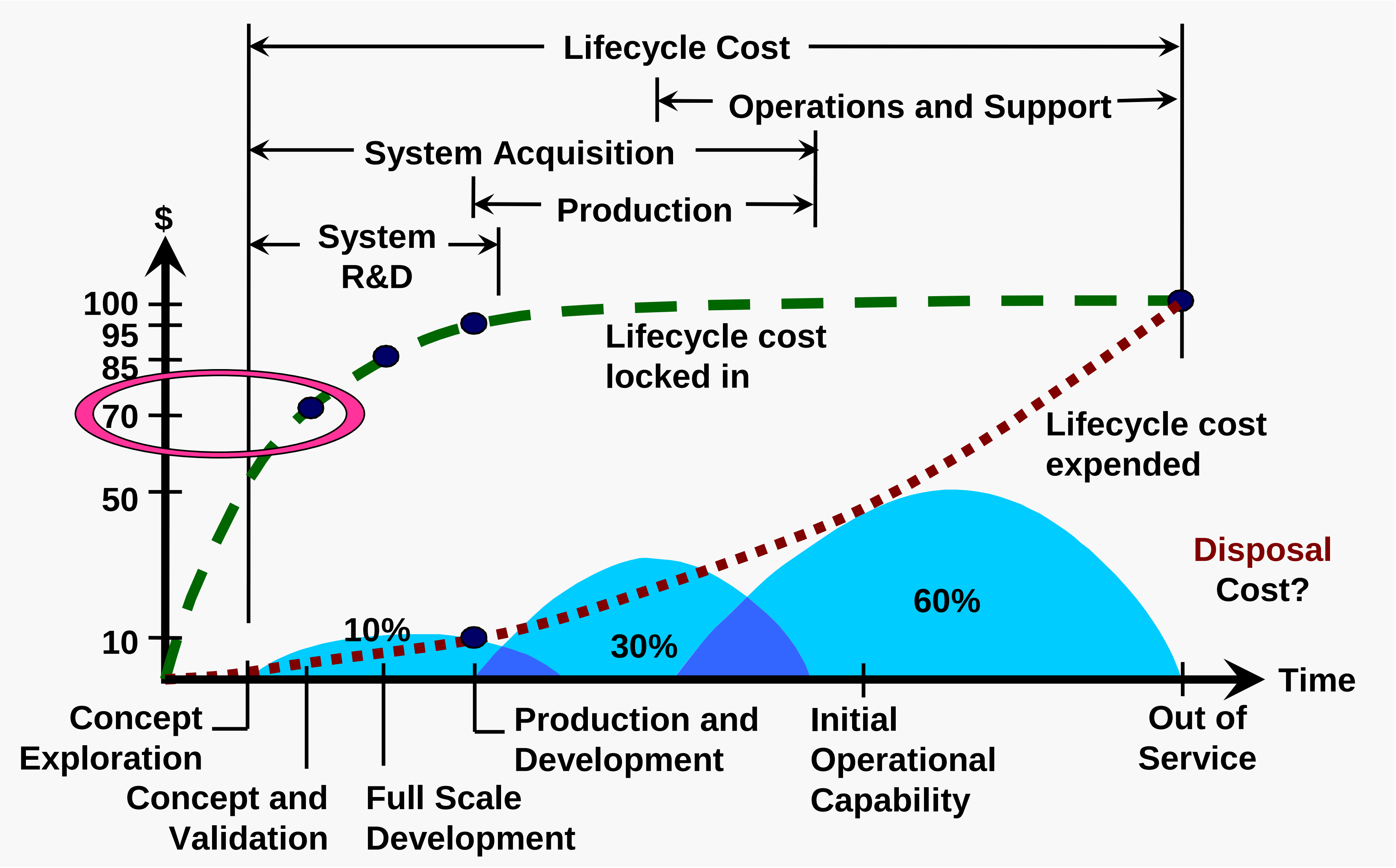
American Chemical Society (ACS)
American National Standards Institute (ANSI) Company Member Forum
American Society for Testing and Materials (ASTM)
Automotive Industry Action Group (AIAG)
National Institute of Standards and Technology (NIST)
NSF International

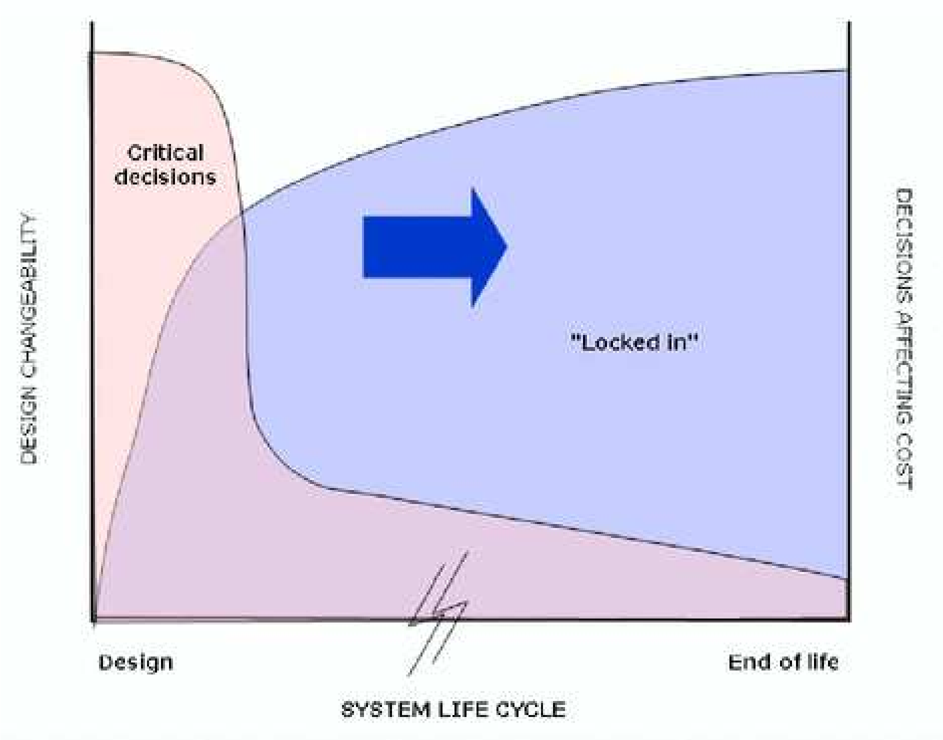
Percentage of Cost Locked In by Phase



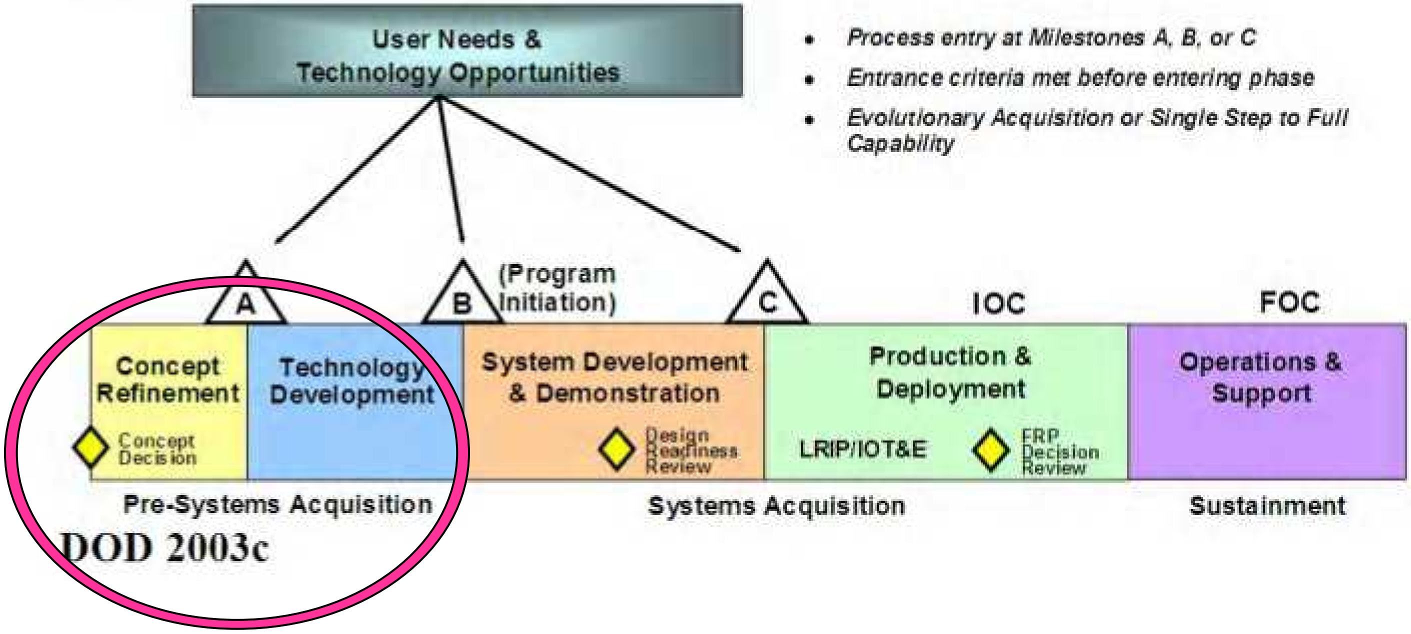
From W. J. Larson & L. K. Pranke (1999) Human Spaceflight: Mission Analysis and Design

NASA’s Approach -- in DOD Terminology:

“Technical Requirements, before Milestone B”



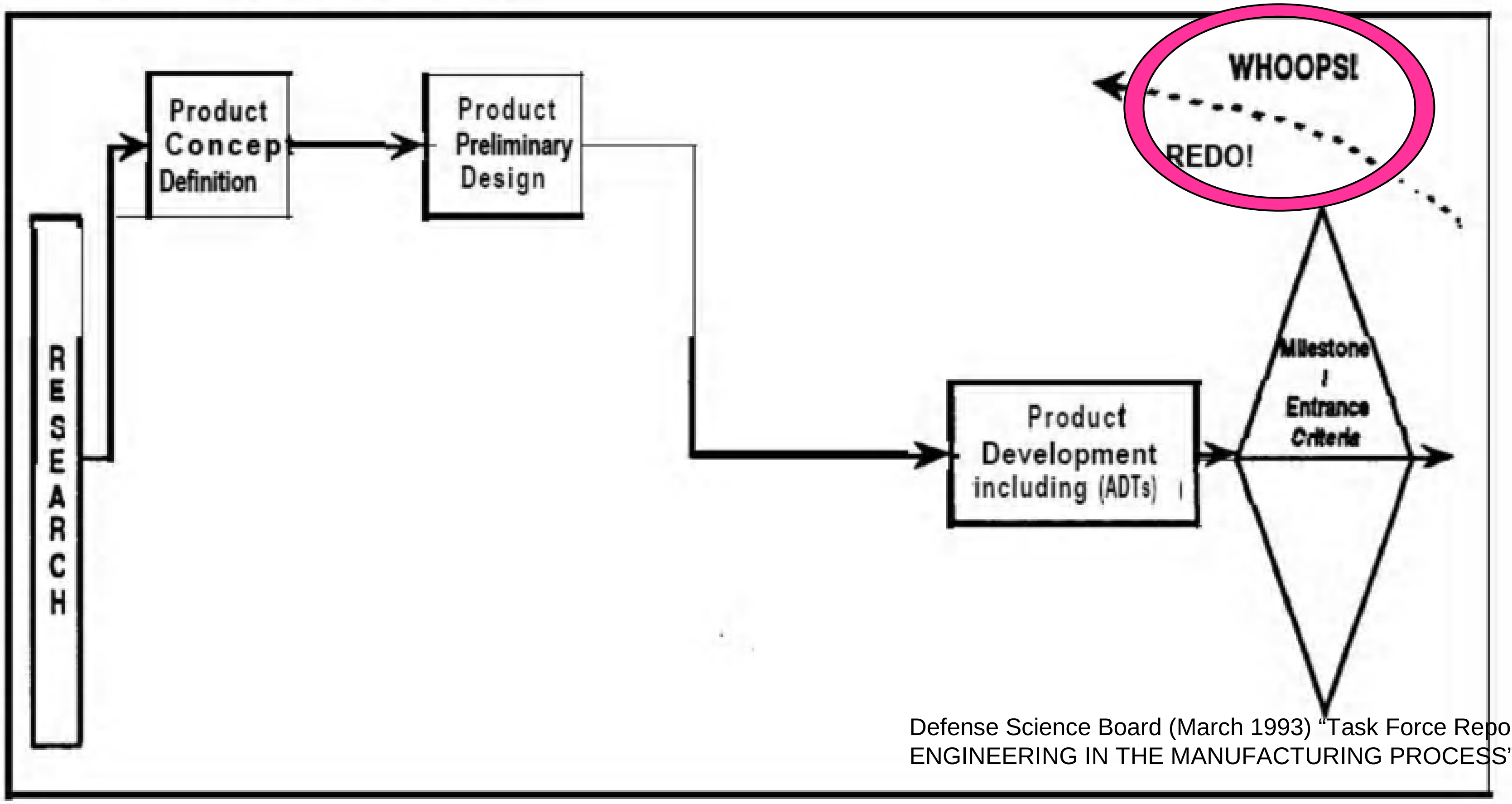
National Research Council (2004) “Retooling Manufacturing”



- *Process entry at Milestones A, B, or C*
- *Entrance criteria met before entering phase*
- *Evolutionary Acquisition or Single Step to Full Capability*

“WHOOPS -- WE DID IT AGAIN!”

Case #1	**Case #2**
We picked a Restricted Material!	***We got our “Exemption” -- but nobody wants to manufacture the stuff!***
Redo!	***Redo!***



Defense Science Board (March 1993) “Task Force Report: ENGINEERING IN THE MANUFACTURING PROCESS”

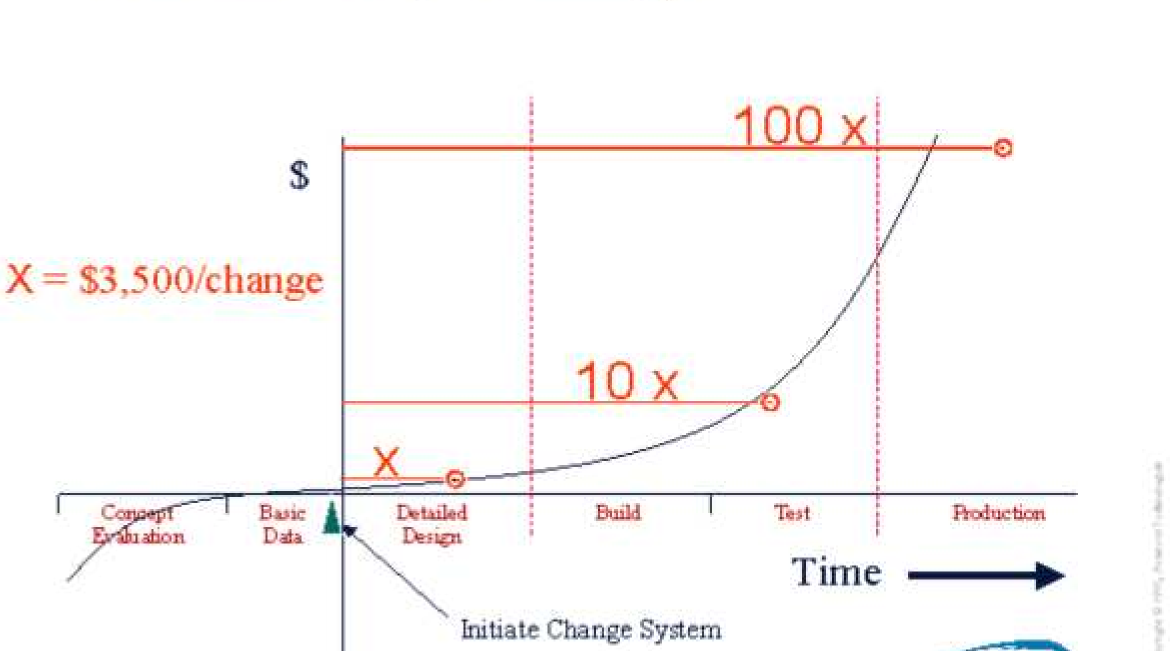
Aerospace Industry:

Change Order Cost

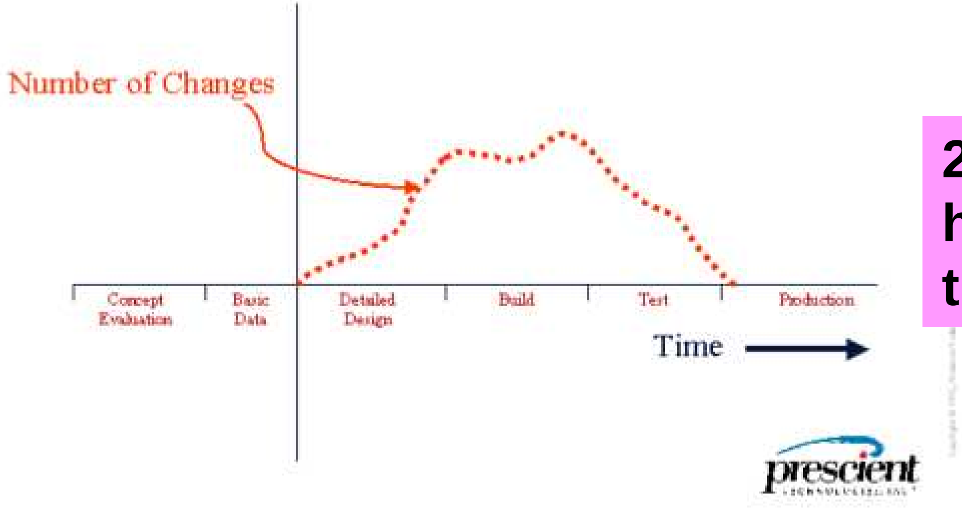
Gavin Finn

1) $350,000 per “Production Stage” Change Order!!

The Cost of Change



The Cost of Change



2) One material selection error, but how many change orders to correct the error?

Gavin A. Finn (Prescient Technologies) (1998) “Design Quality - A Prerequisite To Integration Of Design And Manufacturing” at the “NIST - Design/ Manufacturing Integration Workshop: Standards and Implementation Issues”

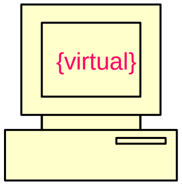
So, where do we start looking for some answers to these challenges?

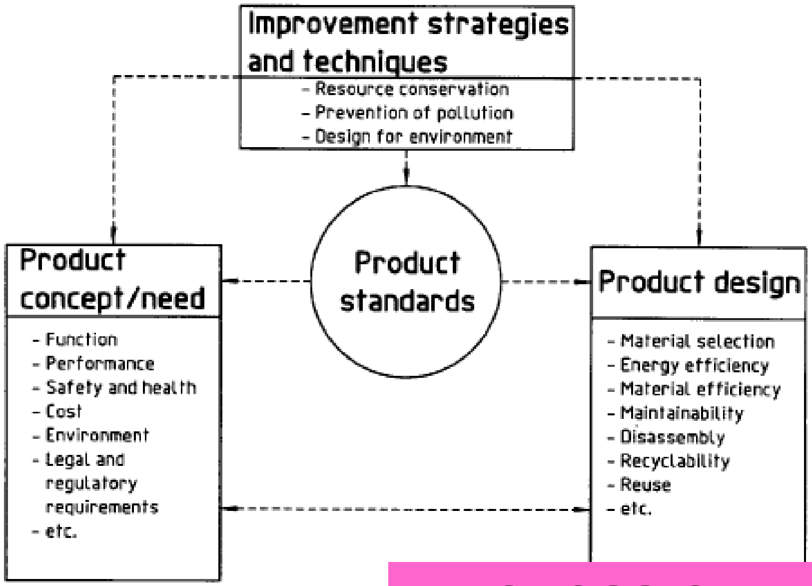
Product (Project, Program) Life-cycle Management (PLM)

NASA Life Cycle Phases	FORMULATION Pre-Systems	Acquisition		Approval for Implementation	IMPLEMENTATION Systems Acquisition	Operations	Decommissioning
Project Life Cycle Phases	**Pre-Phase A:** Concept Studies	**Phase A:** Concept & Technology Development	**Phase B:** Preliminary Design & Technology Completion	**Phase C:** Final Design & Fabrication	**Phase D:** System Assembly, Int & Test, Launch	**Phase E:** Operations & Sustainment	**Phase F:** Closeout

ISO/TR 14062

ISO Guide 64



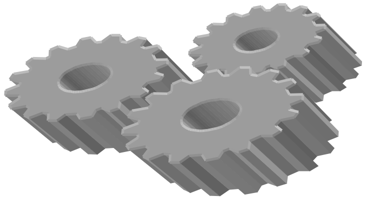


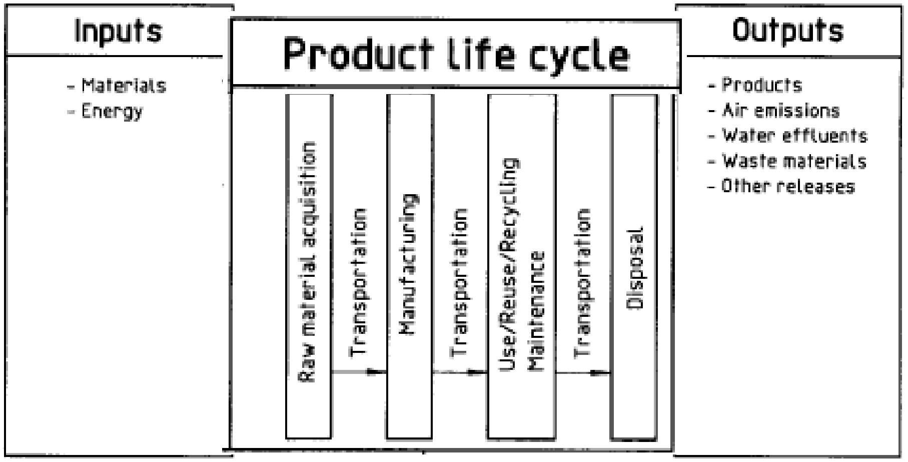
Improvement strategies and techniques
- Resource conservation
- Prevention of pollution
- Design for environment

Product concept/need
- Function
- Performance
- Safety and health
- Cost
- Environment
- Legal and regulatory requirements
- etc.

Product standards

Product design
- Material selection
- Energy efficiency
- Material efficiency
- Maintainability
- Disassembly
- Recyclability
- Reuse
- etc.





Inputs
- Materials
- Energy

Product life cycle

Raw material acquisition → Transportation → Manufacturing → Transportation → Use/Reuse/Recycling Maintenance → Transportation → Disposal

Outputs
- Products
- Air emissions
- Water effluents
- Waste materials
- Other releases

CROSS-CUTTING STRATEGIES*

* K. Geiser (2001) Materials Matter

- **Detoxification**
- **Dematerialization**
- **Decarbonization**

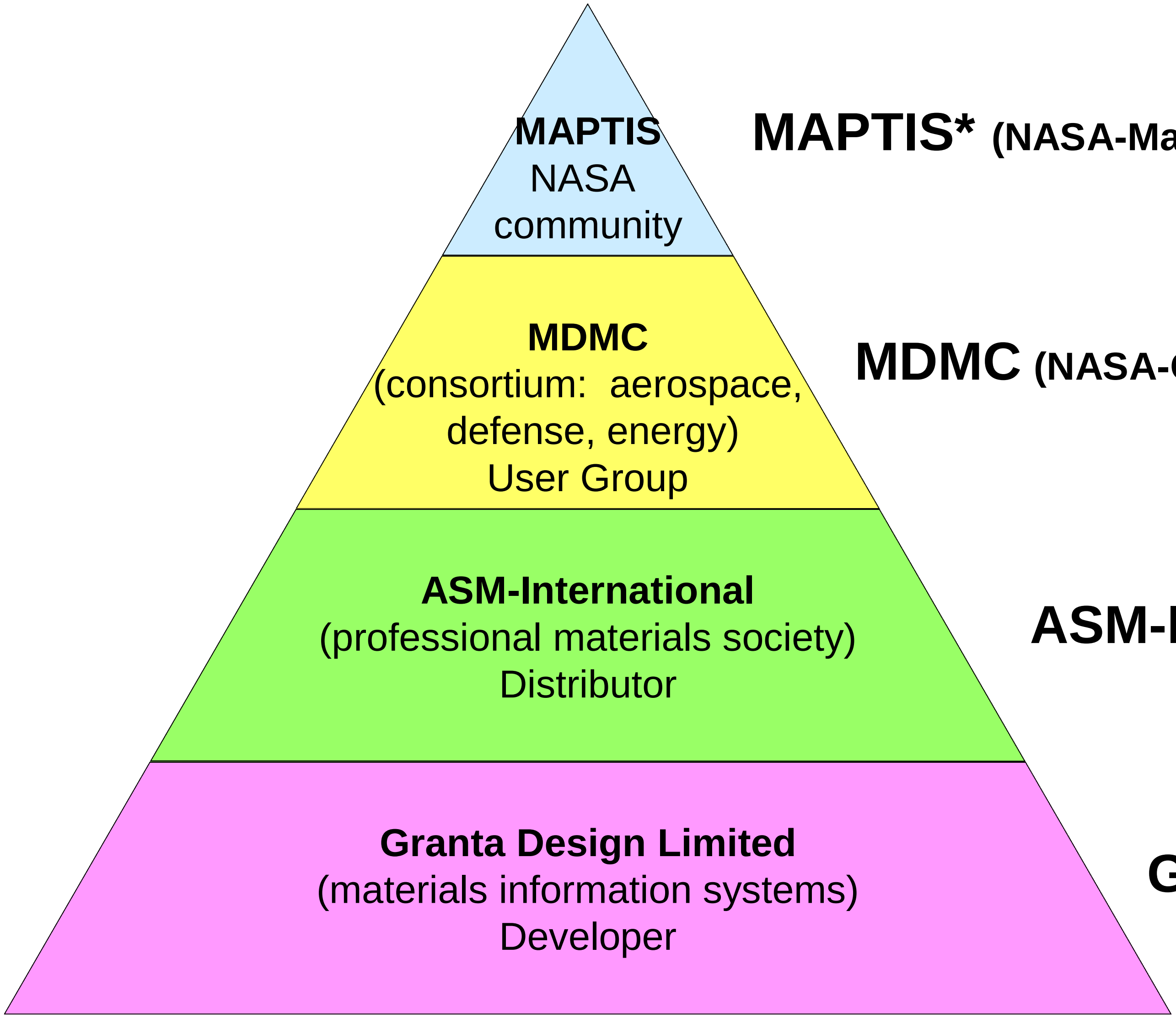
WHAT ARE THE NEEDS OF DESIGN-ENGINEERS?

"For information to contribute to knowledge, it NEEDS to be:

1. **Relevant,**
2. **Timely,**
3. **Accurate,**
4. **Comprehensible, and ideally**
5. ***In Useful form*."**

D. Darst (2007) Mastering the Art of Asset Allocation

<u>NASA's APPROACH: Engaging Others</u>



MAPTIS
NASA
community

MDMC
(consortium: aerospace, defense, energy)
User Group

ASM-International
(professional materials society)
Distributor

Granta Design Limited
(materials information systems)
Developer

MAPTIS* (NASA-Marshall Space Flight Center)

MDMC (NASA-Glenn Research Center)

ASM-International

Granta Design, Ltd

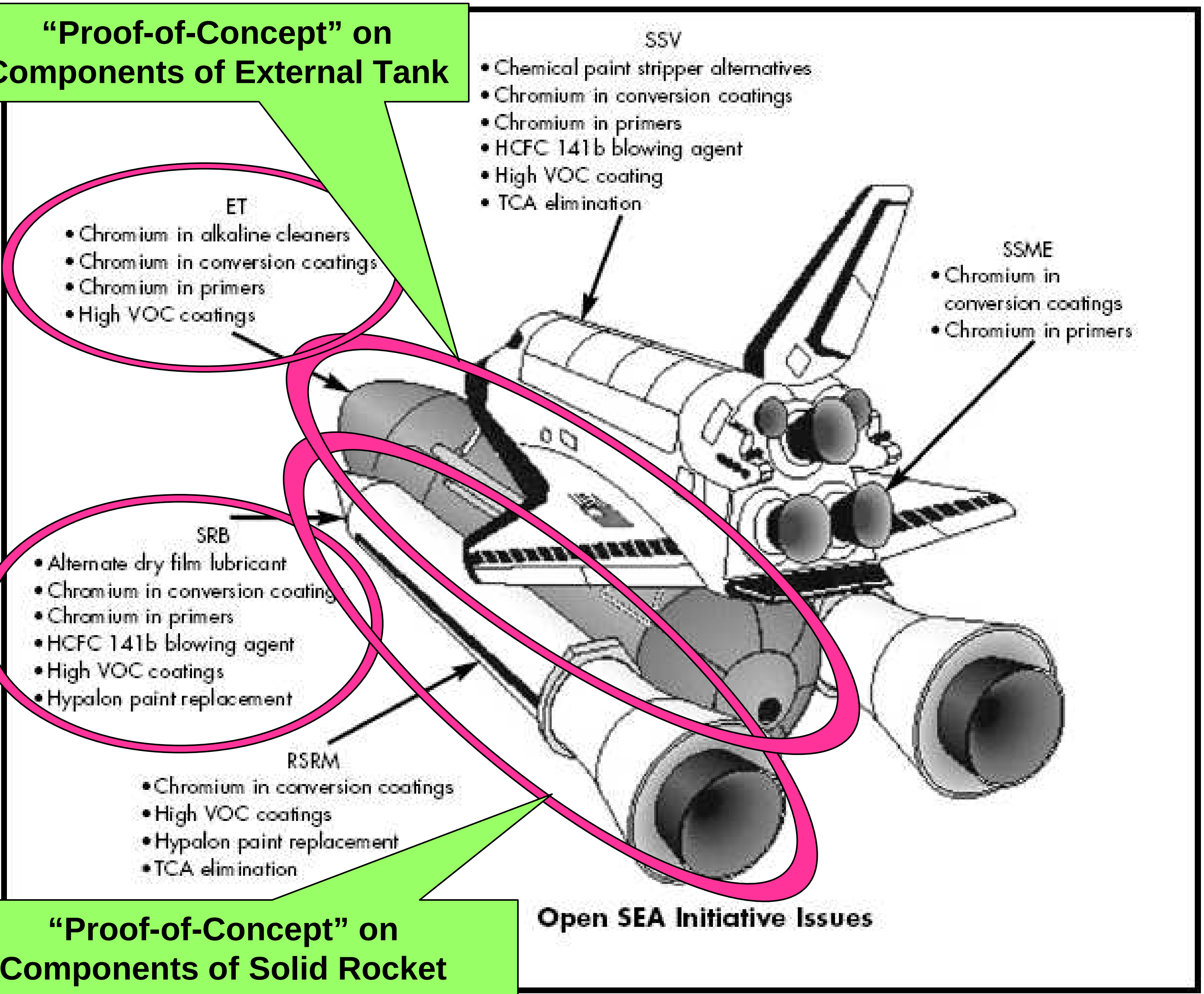
* *MAPTIS = Materials and Processes Technical Information System*

DEMONSTRATION PROJECT WITH INDIVIDUAL MEMBERS OF THE MDMC*

* Materials Data Management Consortium – Aerospace, Defense, Energy

MDMC Member?	Project Participant	Project Participant Expertise	Remarks
Yes	**Granta Design, Limited**	**1) Materials Science, 2) Materials Engineering, 3) Materials Information Systems**	http://www.grantadesign.com/ **1) Dr. M. Ashby: world renowned Materials expert ("bubble diagrams"), 2) Academia-Education: Materials Science, Materials Engineering, Design-Engineering, 3) Developer of Materials Information Systems for Project Life-cycle Management (PLM), 4) REACH**
Yes	**ASM-International**	**1) Materials Information, 2) Distribution of Materials Information**	http://asmcommunity.asminternational.org/portal/site/asm/ **1) Professional Society of Materials Scientists & Materials Engineers, 2) Distributes "Granta MI"**
Yes	**NASA-Glenn Research Center**	**NASA: 1) Materials Science, 2) Coordination through MDMC**	http://www.mdmc.net/ **Chair of the MDMC**
Yes	**NASA-Marshall Space Flight Center**	**NASA: 1) Materials Engineering, 2) Design-Engineers, 3) NASA Distribution of Materials Information**	http://maptis.nasa.gov/index.asp **Distribution of Materials information to the NASA community (including its OEMs) – MAPTIS-II**
Indirectly	**NASA-HQ (Environmental Management Division)**	**Liaison & Coordination**	**Mission Critical Materials-Chemicals [At-Risk Materials-Chemicals (including REACH and EPA "list of lists" plus)]**

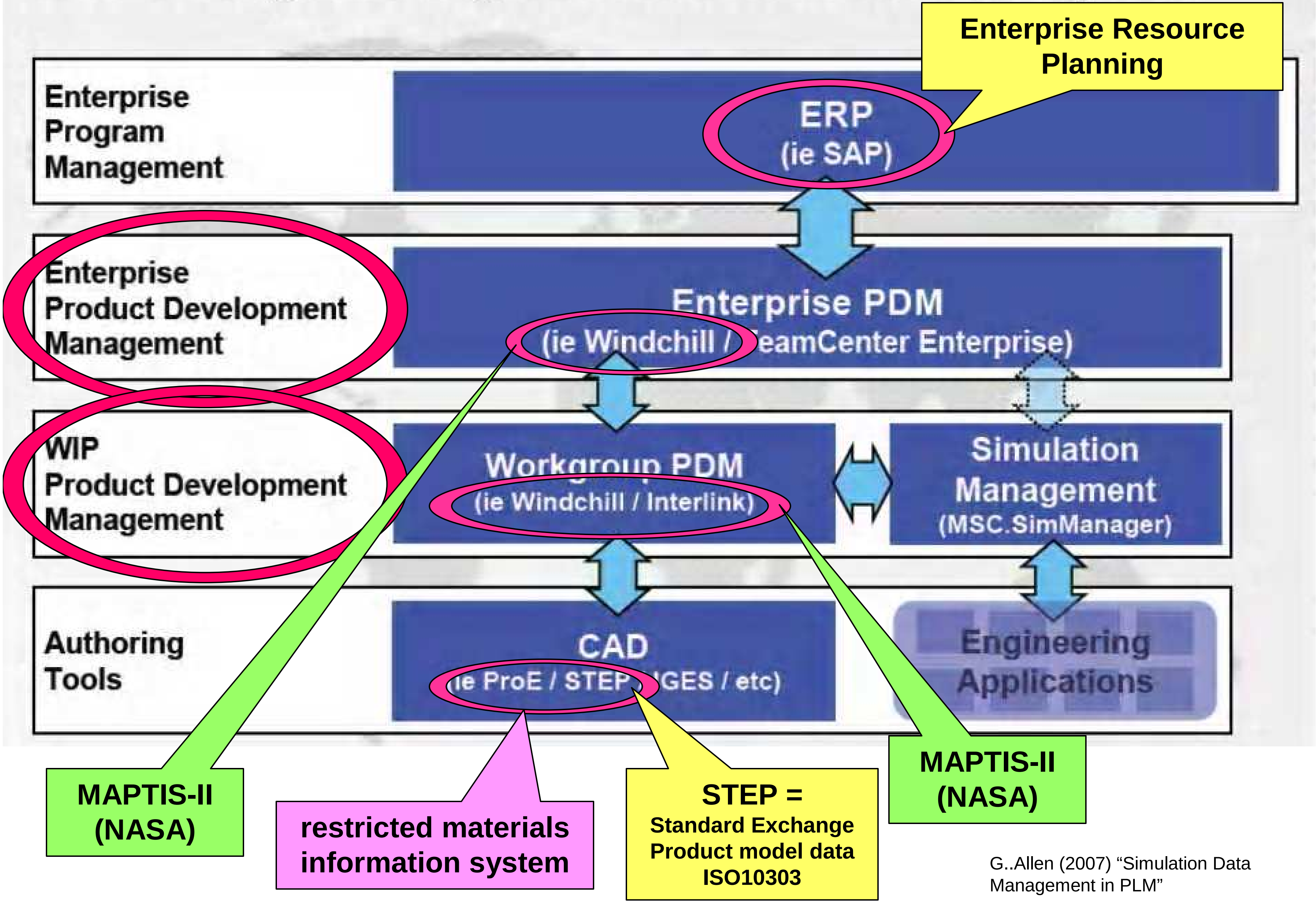
"Proof-of-Concept" on Components of External Tank



Open SEA Initiative Issues

"Proof-of-Concept" on Components of Solid Rocket Boosters

Role of Engineering Simulation in the Enterprise

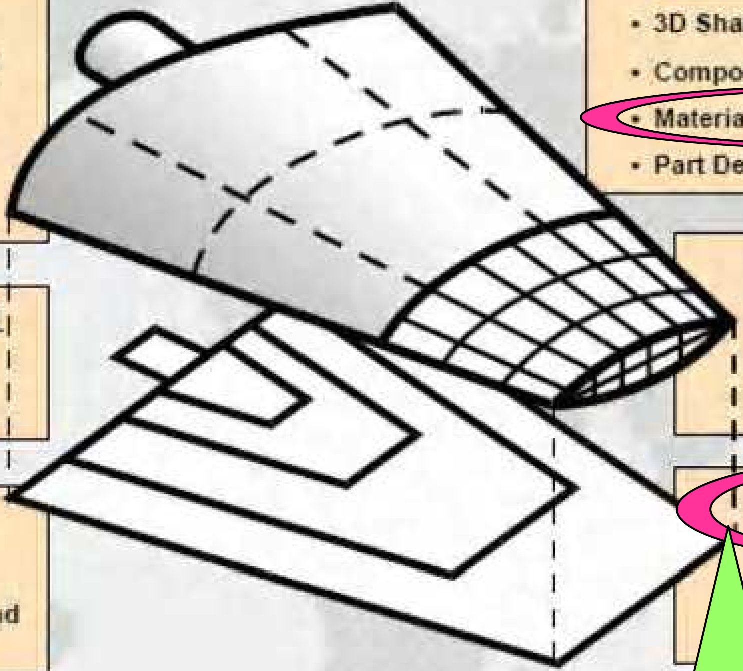


G..Allen (2007) “Simulation Data Management in PLM”

STEP AP209

STEP =
Standard Exchange Product model data
ISO 10303

MAPTIS-II (NASA)



Analysis Discipline Product Definitions

- Finite Element Analysis
  - –Model (Nodes, Elements, Properties,...)
  - –Controls (Loads, Boundary Constraints,...)
  - –Results (Displacements, Stresses,...)
- Analysis Report

Information Shared Between Analysis & Design

- 3D Shape Representations
- Composite Constituents
- Material Specifications & Properties
- Part Definitions

Design Discipline Product Definition

- Shape Representations
- Assemblies

Composite Constituents

- Ply Boundaries, Surfaces
- Laminate Stacking Tables
- Reinforcement Orientation

Configuration Control, Approvals

- Part, product definitions
- Finite element analysis model, controls, and results

Material Specifications & Properties

- Composites
- Homogeneous (metallics)

MAPTIS-II (NASA)

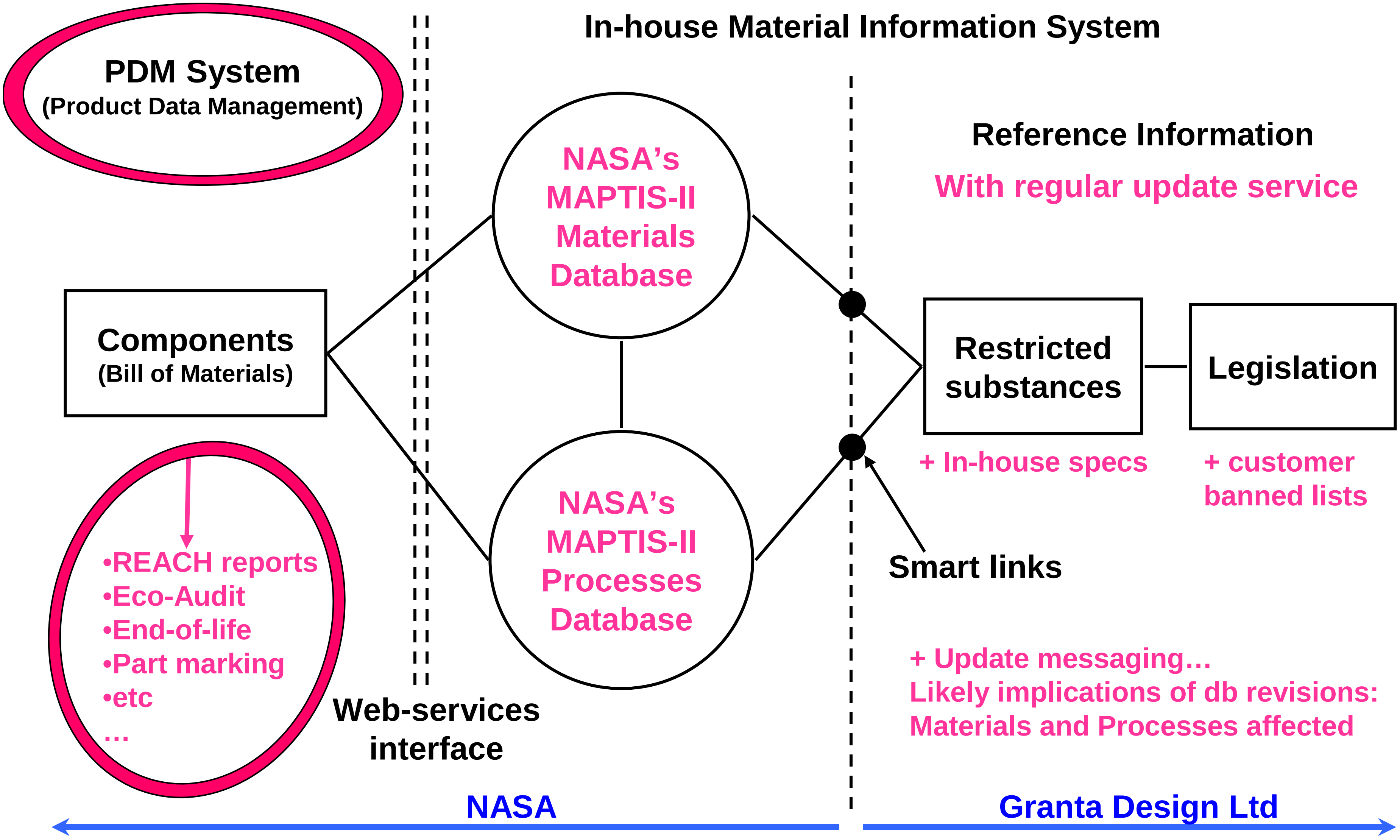
3D Shape Representation

- AP202/203 Commonality Plus Composite Specific 3D Shapes
  - – Advanced B-Representation
  - – Faceted B-Representation
  - – Manifold Surfaces With Topology
  - – Wireframe & Surface without Topology
  - – Wireframe Geometry with Topology
  - – Composite Constituent Shape Representation

restricted materials information system

G..Allen (2007) “Simulation Data Management in PLM”

Deployment Architecture



In-house Material Information System

PDM System
(Product Data Management)

Components
(Bill of Materials)

- REACH reports
- Eco-Audit
- End-of-life
- Part marking
- etc

…

NASA's MAPTIS-II Materials Database

NASA's MAPTIS-II Processes Database

Web-services interface

Reference Information

With regular update service

Restricted substances

Legislation

+ In-house specs

+ customer banned lists

Smart links

+ Update messaging…
Likely implications of db revisions:
Materials and Processes affected

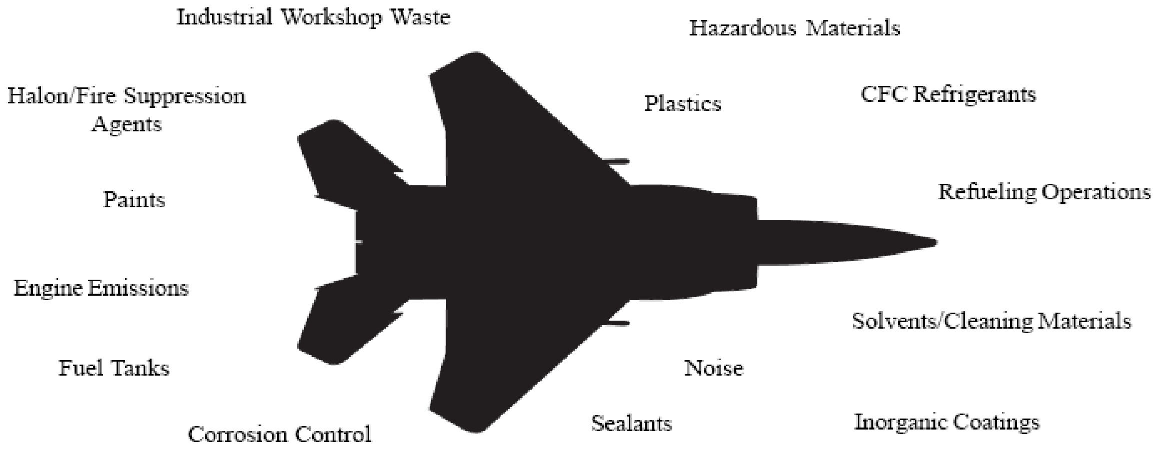
NASA

Granta Design Ltd

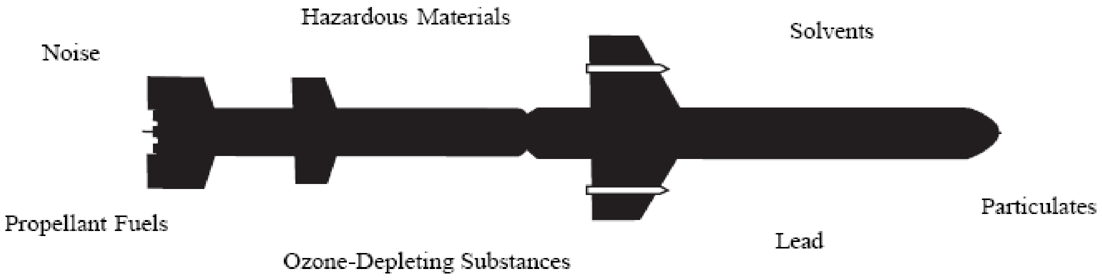
Environmental Considerations in Systems Acquisition Process: A Handbook for Program Managers*

*A joint publication of Sweden and the United States: U.S. Department of Defense and the Armed Forces for the Kingdom of Sweden (1999)

VARIETY OF AIRCRAFT WASTE STREAMS



VARIETY OF MUNITIONS WASTE STREAMS



Berry Amendment *(DOD Procurement Restriction)*:

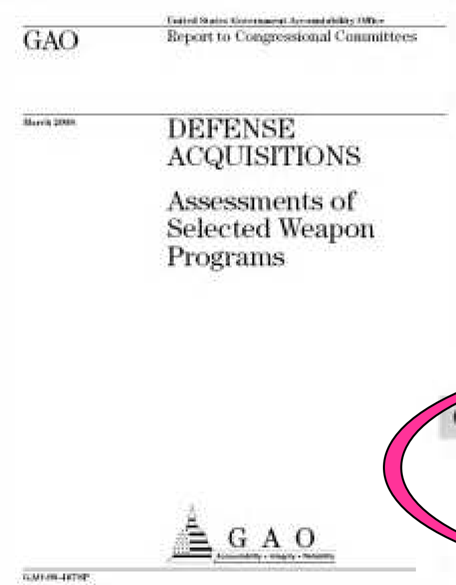
C-5 Reliability Enhancement & Reengineering Program (C-5 RERP)

"The program resolved *complications* related to a requirement that certain *specialty metals* be bought only from American sources.

* * *

[T]he Air Force granted a permanent *waiver* from the specialty metals provisions of the *Berry Amendment*, permitting the use of non-U.S. sources for certain *specialty materials*."

Source: Edwards AFB, CA. Photo taken by Air Force.



GAO

Report to Congressional Committees

DEFENSE ACQUISITIONS

Assessments of Selected Weapon Programs

G A O

Program Essentials

Prime contractor: Lockheed Martin

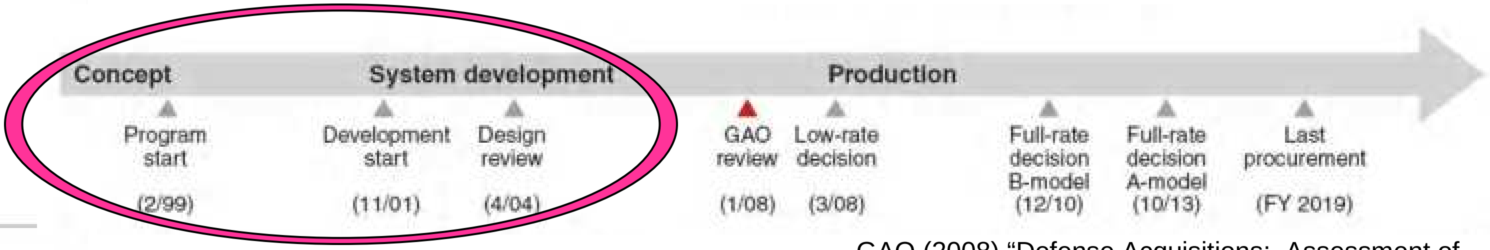
Program office: Wright-Patterson AFB, Ohio

Funding needed to complete:
- R&D: $403.6 million
- Procurement: $13,501.4 million
- Total funding: $13,905.0 million
- Procurement quantity: 108

Program Performance (fiscal year 2008 dollars in millions)

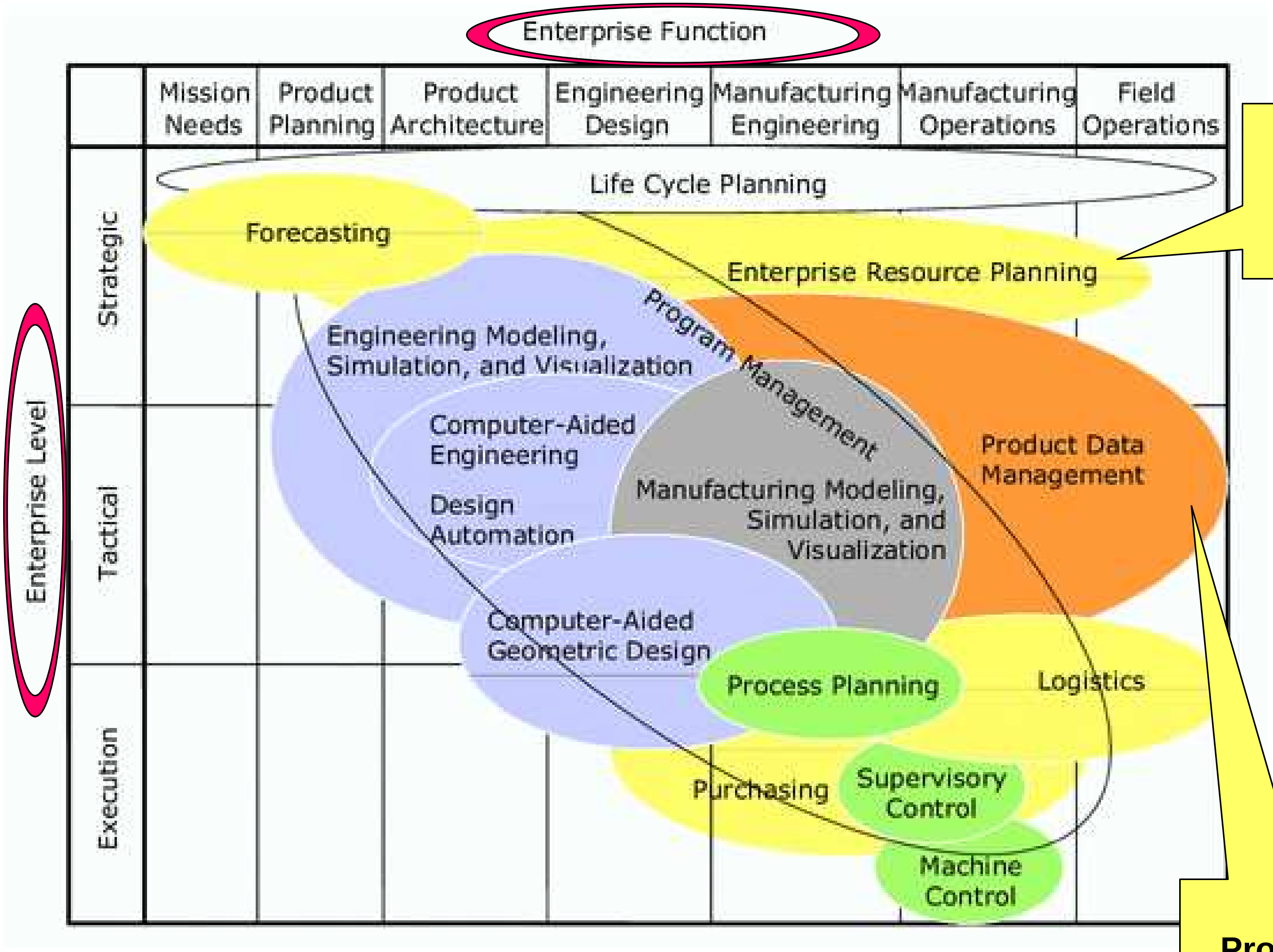
	As of 11/2001	Latest 09/2007	Percent change
Research and development cost	$1,664.4	$1,744.4	4.8
Procurement cost	$8,688.6	$13,531.6	55.7
Total program cost	$10,356.7	$15,283.9	47.9
Program unit cost	$82.196	$137.693	67.5
Total quantities	126	111	-11.9
Acquisition cycle time (months)	100	139	39.0

These numbers are expected to change after DOD completes its Nunn-McCurdy certification.



GAO (2008) "Defense Acquisitions: Assessment of Selected Weapon Programs"; GAO-08-467SP

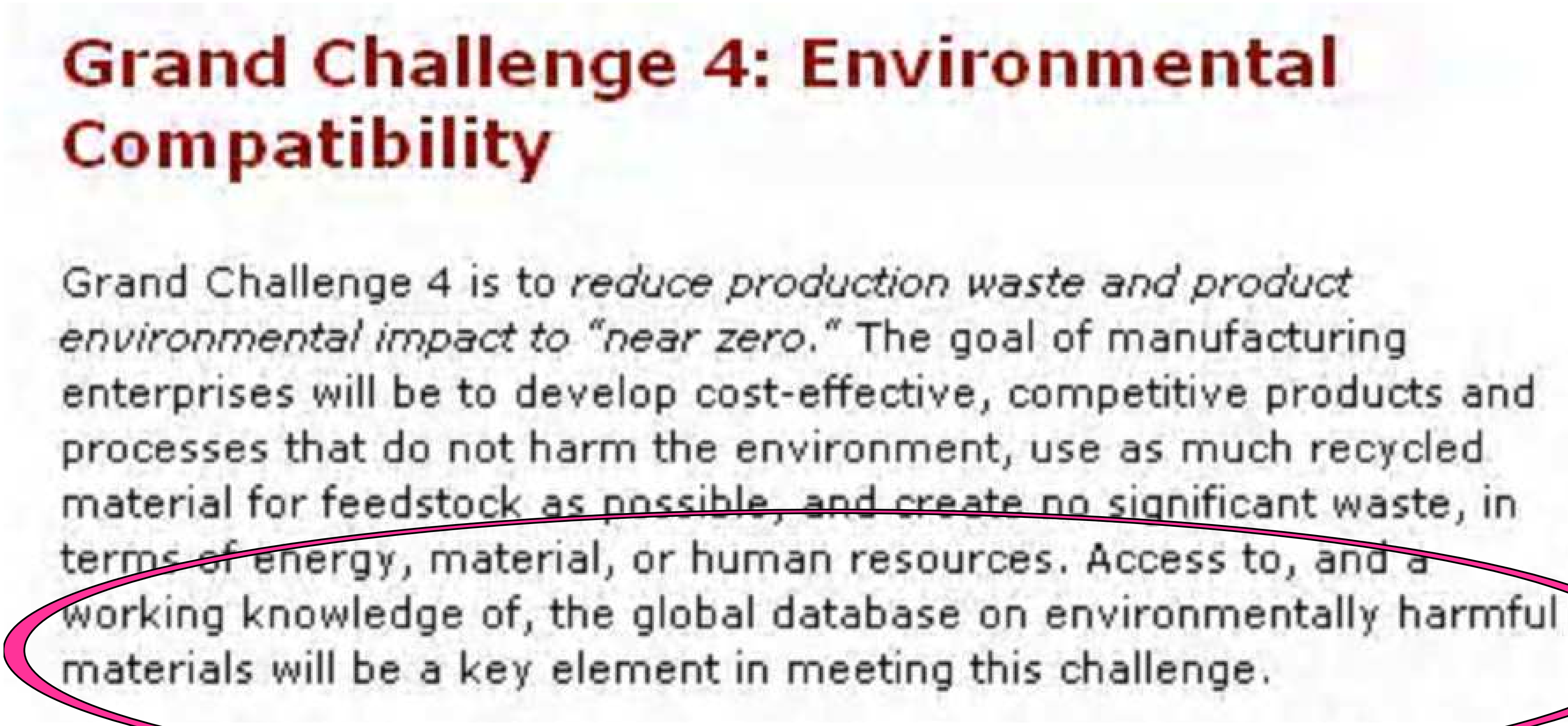
Manager’s Perspective



ERP = Enterprise Resource Planning

PDM = Product Data Management

National Research Council (2004) “Retooling Manufacturing”



Grand Challenge 4: Environmental Compatibility

Grand Challenge 4 is to *reduce production waste and product environmental impact to "near zero."* The goal of manufacturing enterprises will be to develop cost-effective, competitive products and processes that do not harm the environment, use as much recycled material for feedstock as possible, and create no significant waste, in terms of energy, material, or human resources. Access to, and a working knowledge of, the global database on environmentally harmful materials will be a key element in meeting this challenge.

Visionary Manufacturing Challenges for 2020
"Access to … [a] global database on environmentally harmful materials … [is] a key element …."

National Research Council
(1998) Visionary Manufacturing
Challenges for 2020

MATERIALS SCIENCE

Recommendation 3. Materials Science: The Department of Defense should create, manage, and maintain open-source, accessible, and peer-reviewed tools and databases of material properties to be used in product and process design simulations.

Integrated tools and databases for materials design, materials selection, process simulation, and process optimization are key to virtual manufacturing. Data gathered from manufacturing and materials processing using a variety of sensors can validate and improve design, modeling, simulation, and process control.

LIFE-CYCLE ASSESSMENT

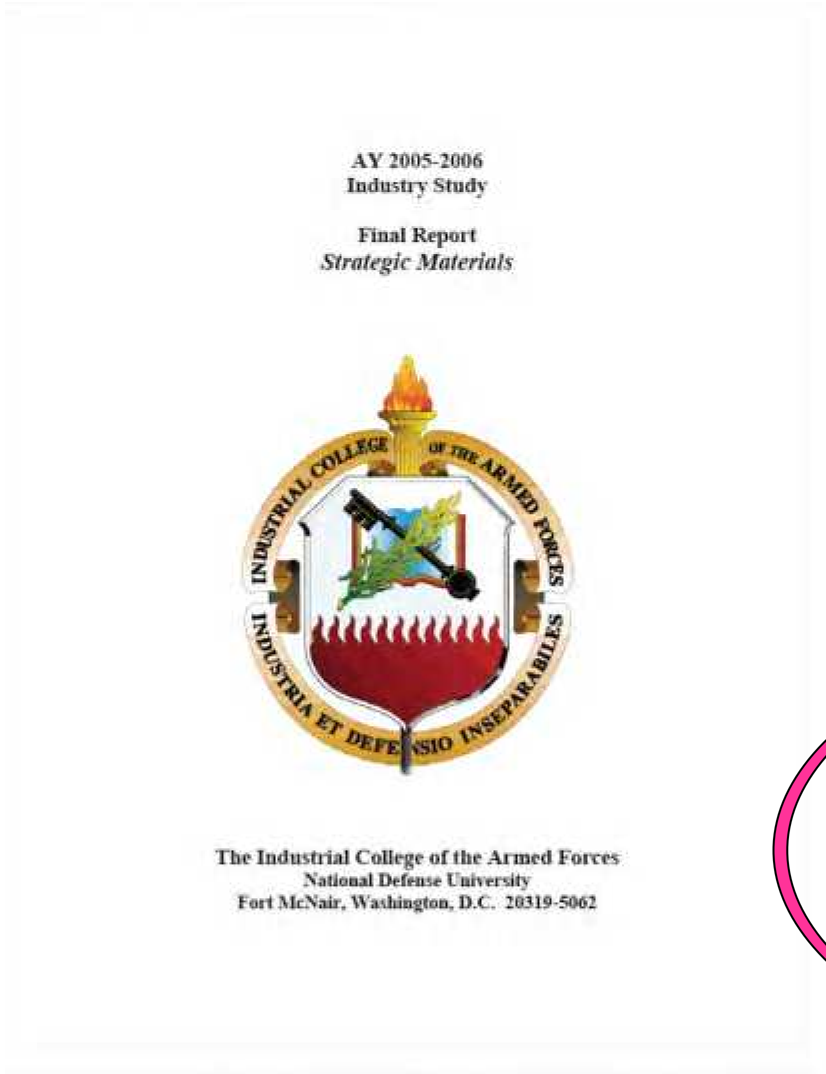
Recommendation 5. Life-Cycle Assessment: The Department of Defense should develop tools and databases that enable life-cycle costs and environmental impact to be quantified and integrated into design and manufacturing processes.

Establishing and maintaining peer-reviewed databases for environmental emissions and impacts of various materials and manufacturing processes will be critical for the government to integrate these factors into acquisition processes. Environmental performance metrics that combine multiple impacts are most useful for design decisions. The development of high-level optimization methods can allow analysis of the trade-offs between cost, performance, schedule, and environmental impact.

National Research Council (2004) “Retooling Manufacturing”

The Industrial College of the Armed Forces – AY 2005-2006 Industry Study: Final Report:

Strategic Materials


AY 2005-2006
Industry Study

Final Report
Strategic Materials

The Industrial College of the Armed Forces
National Defense University
Fort McNair, Washington, D.C. 20319-5062

Cultural Attachment to Traditional Materials

Efforts to transition new materials … face significant obstacles. *** [T]his tendency stems from difficulties engineers face … with [using] existing tools [such as handbooks and printed data sets].

***

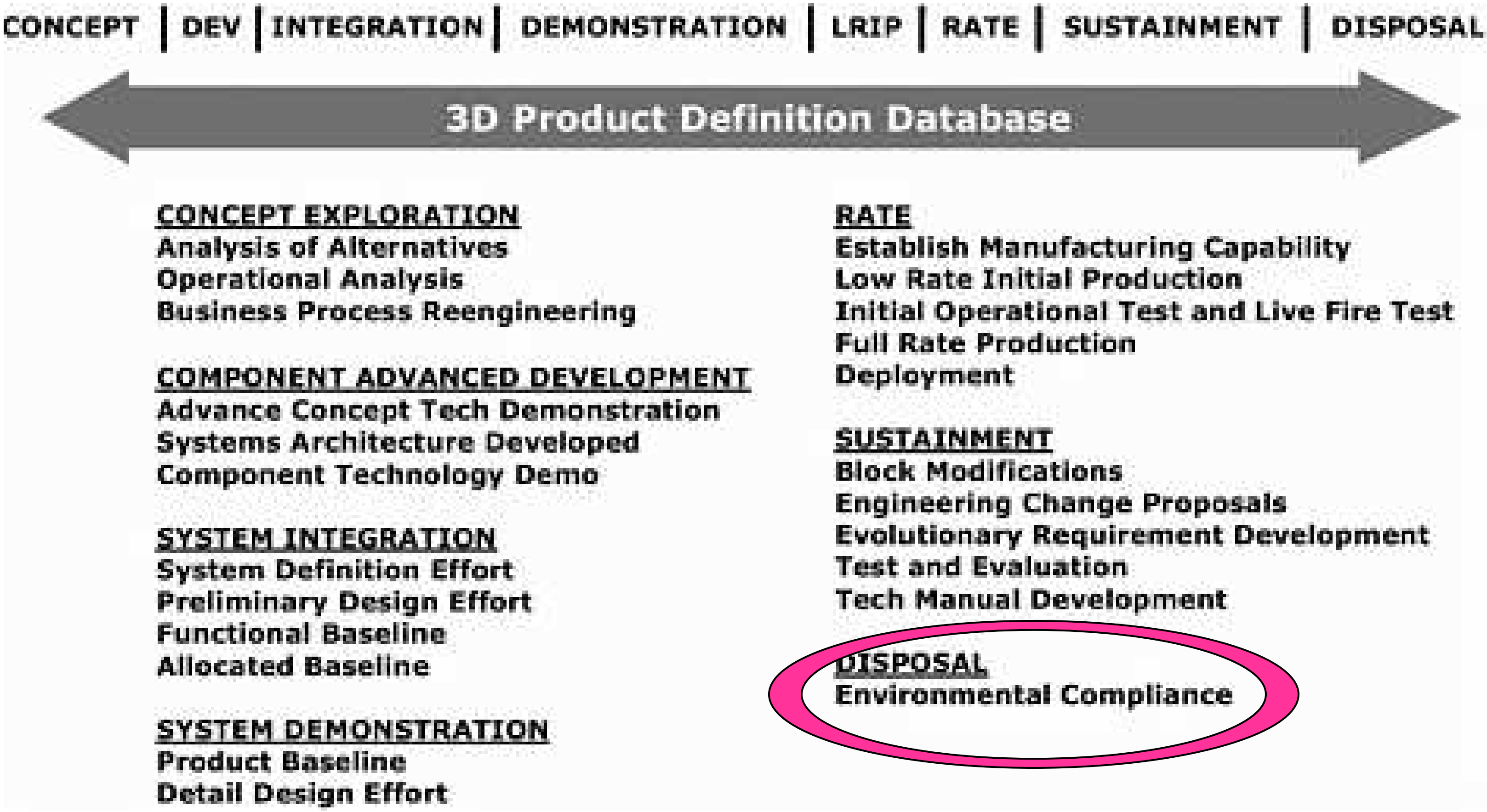
Improved databases … would help overcome this … resistance to new materials.

***

The government can play a significant role in … ***by supporting the development of [electronic versions] … of [new] engineering tools*** [such as, a comprehensive suite of materials software and verified data].

TOOLS FOR VIRTUAL DESIGN AND MANUFACTURING*

* From National Research Council (2004) Retooling Manufacturing: Bridging Design, Materials, and Production; Chapter 3.



CONCEPT EXPLORATION
Analysis of Alternatives
Operational Analysis
Business Process Reengineering

COMPONENT ADVANCED DEVELOPMENT
Advance Concept Tech Demonstration
Systems Architecture Developed
Component Technology Demo

SYSTEM INTEGRATION
System Definition Effort
Preliminary Design Effort
Functional Baseline
Allocated Baseline

SYSTEM DEMONSTRATION
Product Baseline
Detail Design Effort

RATE
Establish Manufacturing Capability
Low Rate Initial Production
Initial Operational Test and Live Fire Test
Full Rate Production
Deployment

SUSTAINMENT
Block Modifications
Engineering Change Proposals
Evolutionary Requirement Development
Test and Evaluation
Tech Manual Development

DISPOSAL
Environmental Compliance

Figure 3-4 Life-cycle phases expanded into the eight indicated at the top of the figure.

Computer-Aided Materials Selection During Structural Design*

*National Research Council (1995)

“Materials Selection Capabilities Required - Summary”*

“Routine Materials Selection -- … environmental impact considerations of material production, use, and disposal/ recycling, and suggestions for product improvements.”

*from ”Table 3-1 Summary of the Materials-Specific Information Technologies and Some Primary Computer Technologies Required ….”

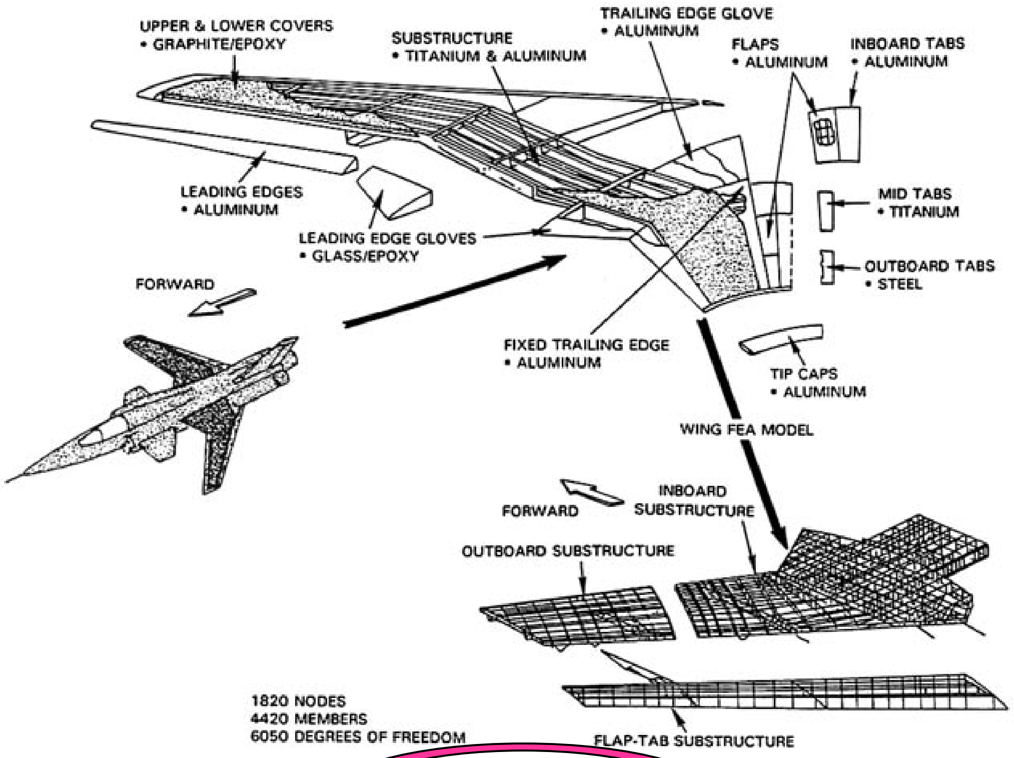


Figure 2-6 A model of the wing of the Grumman X-29 and associated FEA.

“Examples of Materials Information Required During Product Design”*

“Environmental stability

1)Toxicity (at all stages of production and operation)

2) Recyclability/ disposal.”

*from ”Table 2-1”

“Typical Product Design Requirements for Aircraft Structure Development*

“Cost …

- *Material handling*
- *Safety*
- *Environmental and waste disposal.”*

*from ”Table 2-2”

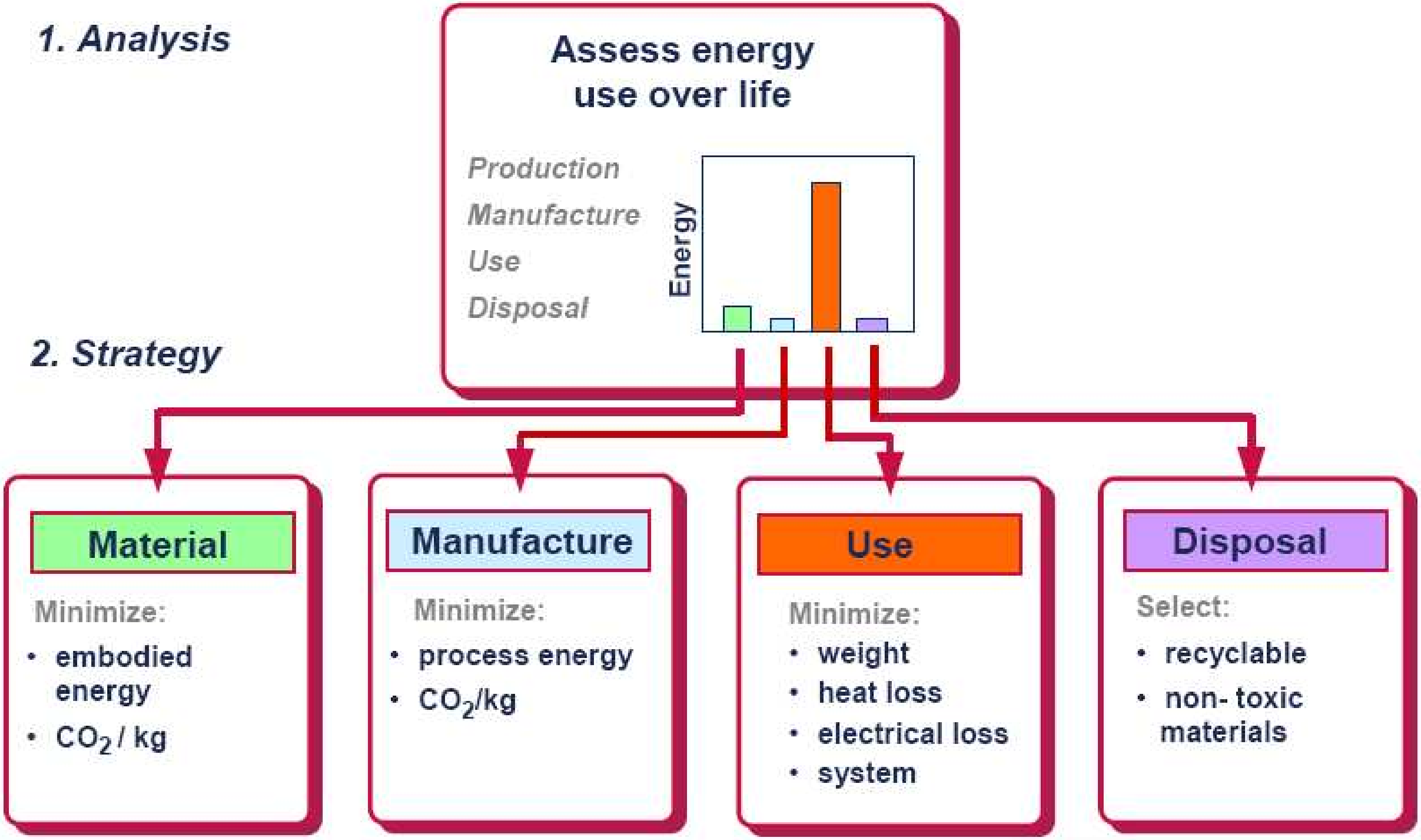
The Materials Strategy space

		Material Lifecycle Stages			
		Raw Material	Product Manufacture	Use	Disposal/ Recycling
Cost per Unit Function	$				
	Environmental				
	Weight or Volume				

Strategy for material selection

1. Analysis

2. Strategy



Assess energy use over life

Production

Manufacture

Use

Disposal

Material

Minimize:

- embodied energy
- CO_2 / kg

Manufacture

Minimize:

- process energy
- CO_2/kg

Use

Minimize:

- weight
- heat loss
- electrical loss
- system

Disposal

Select:

- recyclable
- non- toxic materials

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MATERIAL INTELLIGENCE