Extending Product Lifetimes as an Approach to Material Efficiency

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Topics

- Approaches to extend materials / products / systems lifetimes
- Highlight coatings as an enabler for lifetime extension - focus on lifetime assessment issues
- Data management – issue and opportunity
  - The Materials Genome Initiative
- Decision framework

Approaches to Extend Lifetime

1	**DESIGN**	• Select durable systems / materials • Avoid / improve endurance through damage events [Surface protection (e.g., coatings); System design for impact / crash]
2	**MAINTAIN**	Improve maintenance tools and processes to track in-service performance and recommend intervention points (e.g., Non-destructive testing. Sensors and smart coatings.), supported by risk management
3	**REPAIR**	Provide repair technologies with improved efficacy, endurance, application robustness, supported by risk management
4	**TEST & SPECIFY / MODELS**	• Improve lifetime assessment protocols and specifications • Harmonize lifetime assessment protocols for efficiency • Leverage data for models
5	**RE-USE**	Enable second life in primary functional service (e.g., Recycle. Design for disassembly.)
6	**CONSUMER HABITS**	• Encourage longer use of functional products.

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Coatings Enable Longer Lifetimes








1806

Clipper ships strengthen international trade thanks to wood varnish

1920s

Beer available in coated cans

The Spirit of St. Louis first non-stop cross-Atlantic flight

1940s

Water-based paints

1960s

Automotive and heavy machinery powder coatings

1990s

Cathodic epoxy electro-coat

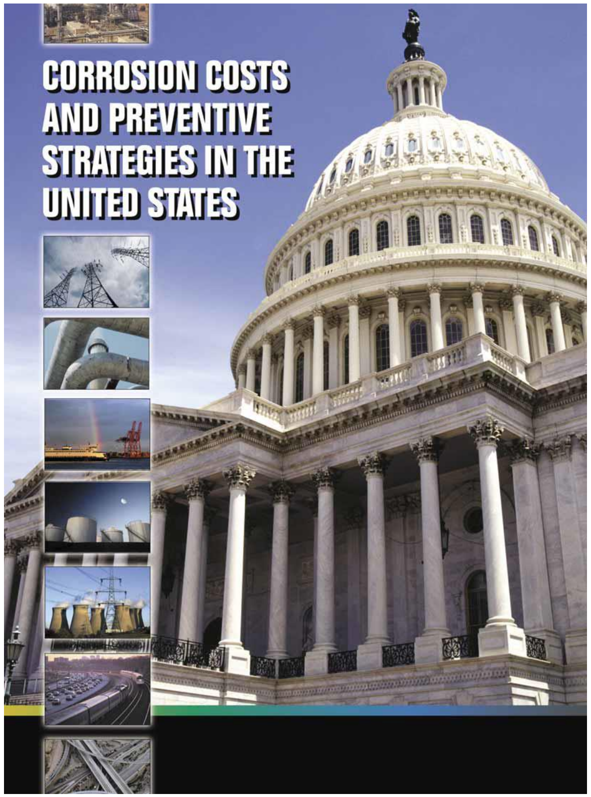
Highly durable coatings

Lower film weights

2000s

Smart and environmentally favorable coatings

Corrosion Limits Lifetimes



PUBLICATION NO. FHWA-RD-01-156, 2002

"… the total annual estimated direct cost of corrosion in the U.S. is a staggering $276 B — approximately 3.1% of the nation's GDP."

…. 25 to 30% of annual corrosion costs … could be saved if optimum corrosion management practices were employed."

In 2012, the U.S. Department of Defense estimated that corrosion costs for the military were $20.9 billion annually.

Ted Bates, a technical Fellow at Boeing, says corrosion has become more of a problem because of the military's decision to <u>extend the life of aging aircraft</u>.

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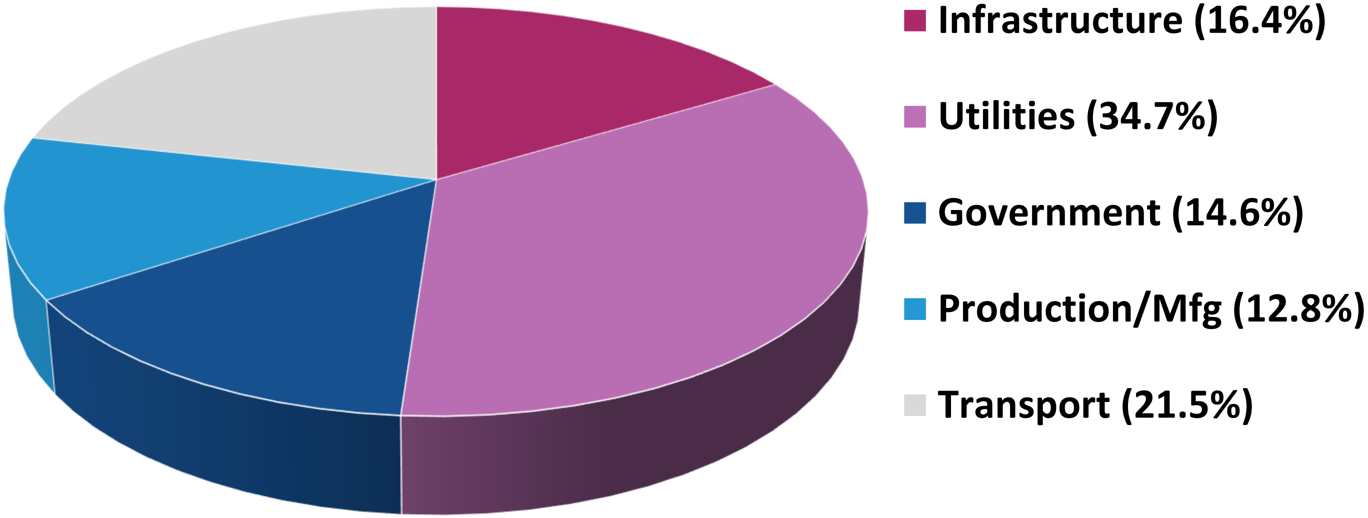
$276 B Cost of Corrosion in US



Conclusions

- Implement advanced **design** practices for better corrosion management
- Develop advanced **life-prediction** and performance-assessment methods
- Improve corrosion **technology** through research, development, and implementation

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Lifetime Prediction Challenges

- OEM specification tests are a critical part of materials development
  - Based on long-standing conventions with historical experience
  - Designed to replicate actual service environment
- The test protocols present challenges
  - Widely different test conditions
  - Time consuming and expensive test equipment
  - Highly variable test results
- Results do not correlate with real world results
  - Based on worst case scenarios (extreme versus actual conditions) therefore actual lifetimes are likely longer than estimated
- Vast amount of data not statistically analyzed -> few robust models

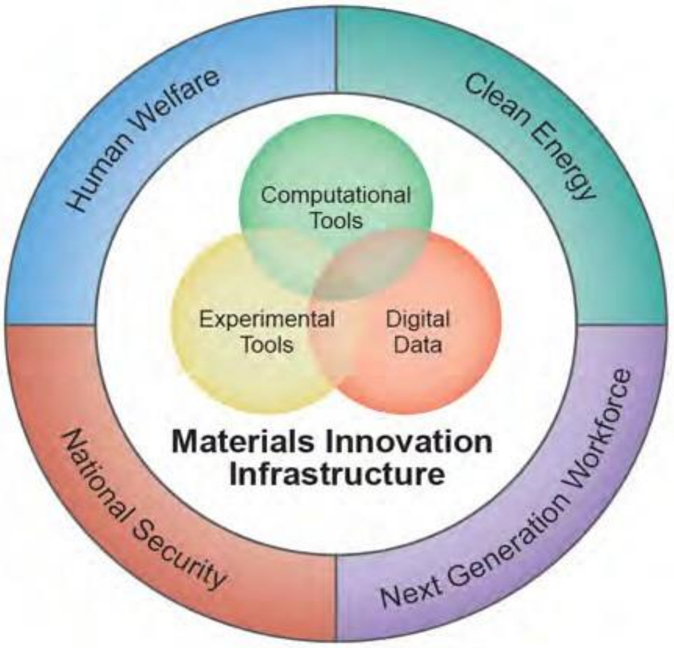
Implications

- Current coatings technologies can likely be used longer to safely protect from corrosion ... but how much longer?
- Value of improvements can be assessed by relative comparisions to historical results from existing test protocols
- Longer lifetime requirements, extreme service conditions and new technologies pose serious risks
  - Options to reduce risk are to evaluate in (simulated) service long term and / or develop new accelerated protocols and / or models

Improved protocols and models would accelerate product development time, guide lifetime improvements and reduce risk of using new technologies

Materials Genome Initiative

- An approach to leverage very large amount of materials data
- Initiated in 2011 by President Obama
- Mission to decrease time to market by 50% and << $$.
- Similar recommendations by European Science Foundation.



From James Warren, National Institute of Standards & Technology

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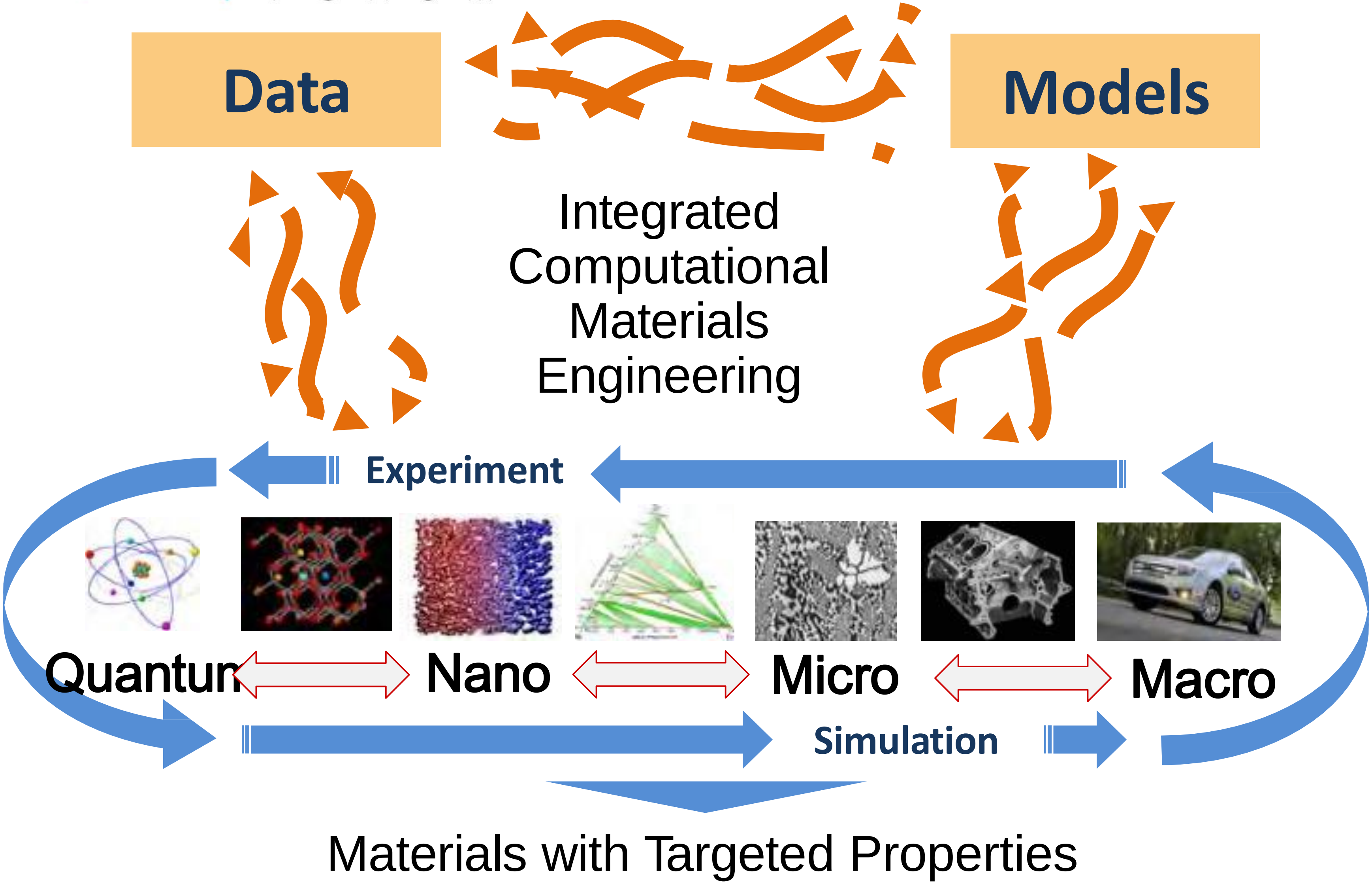


From James Warren, NIST

- TAKE THE LHC AS AN EXAMPLE
- DATA PRODUCED AT 1PB per SEC!
- REDUCED DATA SAVED ~ GB/S
- THAT'S A GOOD MODEL
- OTHER END - BIOLOGY?
- MATERIALS - IN THE MIDDLE

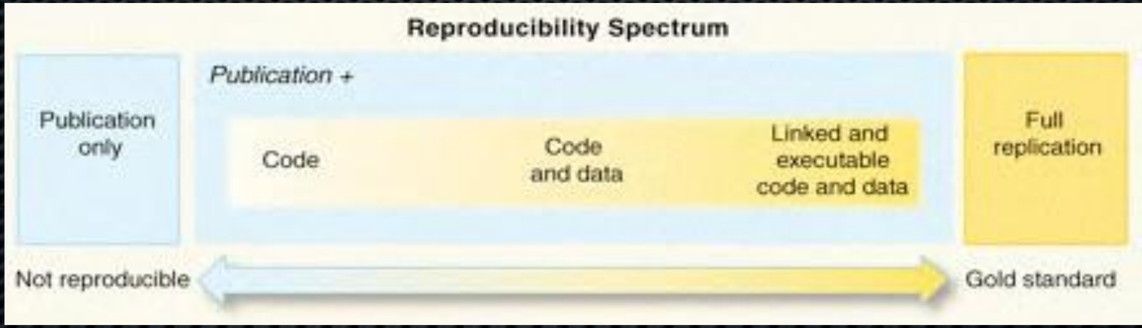
BETTER MODELS = LESS DATA

From James Warren, NIST

What should we be doing?

Science is characterized by the iteration of experiment and models, yielding higher fidelity with higher certainty.

- The measurement or computation of a quantity (data) is generally *meaningless* without the associated quantifying model that defines both the data and its uncertainties.
- Thus dissemination of data is ideally the dissemination of the following information:
  1. Measured quantities
  2. Associated quantifying models and
  3. *Raw data, including protocols (and equipment) by which it was obtained*



From James Warren, NIST

Refer to: R. Peng *Science* 2 Dec 2011: 1226-1227

Materials Genome Initiative:
Validated Integration

Computational Tools

What?
- Data dissemination
- Data capture
- Insights

How to achieve:
- Materials data repository
- Shared knowledge representation
- Workflow tools
- Metadata standards

Capture & Analysis

Experimental Tools

What?
- Analysis
- Data infrastructure
- Methods & Measurements

How to achieve:
- Automated capture
- Computational quality metrics & data-driven materials science
- Machine learning
- Exp design: new models best practice guides

Experimental Tools

What?
- Software
- Data infrastructure
- Hardware

How to achieve:
- Software catalogs & workflow tools
- Computational quality metrics & data-driven materials science
- Ingest & auto capture
- Best practices

Co-Deign

Capture & Analysis

from from James Warren, NIST

Decision Framework

- Goals and approach of Materials Genome Initiative compelling
  - Data type and structure not prescribed and voluntary vs structured, agreed data taxonomy … how to get stakeholder buy-in?
- Use lifetime assessment protocols and models in framework to decide upon best options for materials efficiency
  - Examples of trade-offs to extend lifetime
    A. More durable materials vs increase cost, e.g., civil infrastructure
    B. Materials of concern vs longer lifetime, e.g., metal packaging BPA-containing epoxy coatings, chrome-based anti-corrosion coatings
    C. Use of different / new materials vs long term service history and / or validated qualification protocols, e.g., new alloys and composites
  - Evaluate against other options to improve materials efficiency, e.g., lifetime extension vs. recycling
- Proposed framework: Residence time in economy / cost to replace, cost and risk of new approaches to improve materials efficiency

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Residence Time in Economy







SHORT LIFETIME — **MEDIUM LIFETIME** — **LONG LIFETIME**

Months — ***Years*** — ***Decades***

- Packaging: short residence time and low cost to replace
- Little value to improve lifetime
- Recycle options critical
- Recent improvements to remove materials of concern

- Industrial equipment & infrastructure: longer residence, high cost to replace, greater risk
- More value for lifetime extension options, cost
- Risk reduction through good protocols and models – can't practically test new technologies over a lifetime