Integrated Computational Materials Engineering: A Study on Implementing ICME in the Aerospace, Automotive & Maritime Industries

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The Minerals, Metals & Materials Society

MANUFACTURING
TMS
ICME IMPLEMENTATION STUDY
DESIGN
MATERIALS

UCSB TMS

Full Project Team

- TMS Staff: Project lead, facilitate project team work, final report, dissemination and promotion

- Nexight Group (LLC): Facilitate project team work, work with TMS on final report

- ICME Implementation Teams (IITs): Subject matter experts
  - Responsible for the content of this work
  - The "brains" & experience behind this study

Team Leaders

Tresa Pollock (U. of California - S.B.)
John Allison (U. of Michigan)
John Deloach (Naval Surface Warfare Center)
Brad Cowles (Pratt & Witney - retired)
Justin Scott (TMS)

TMS Leads

Project Leader (PI): George Spanos
Project Coordinator: David Howe

Funding Support

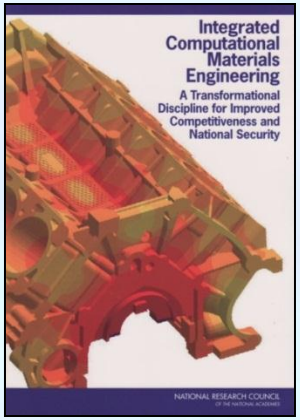
DoD (ONR, AFRL), DOE, NSF

Motivation

- **Support ICME & MGI goals of accelerating development (at reduced cost) of advanced materials and manufacturing processes: from discovery to deployment**

- **ICME recognized as new discipline & awareness growing worldwide**
  - **2008 National Academies report established ICME as a discipline, overall vision, discussed broad cultural & technical issues**
  - **ICME World Congress(es), Journal issues, books, courses/workshops, etc.)**

- **Although some ICME case studies to date, to realize this vision more extensively, and rapidly, a focused study was undertaken to define the frameworks and pathways to *ICME <u>implementation</u> in the near term (≤ 3 yrs.)***



Some Background

- **14 Month Study: June, 2012 - July, 2013**

- **Centered predominantly on lightweighting (and propulsion) applications in three industrial sectors**

- **Final Report: “A ‘Field Manual’ for Implementing ICME in the Aerospace, Automotive & Maritime Industries”**

- **Study results and report will be rolled out at “The 2nd World Congress on ICME” July 7, 2013 in Salt Lake City, Utah**

Overall Project Goals/Tasks

- **Recommendations for ICME *implementation* in aerospace, automotive, and maritime industrial sectors**
  - **"Field manual" for practitioners to implement ICME**
- **Develop "Frameworks" for ICME Implementation**
  - **Steps, computational tools, experiments, people, flow of information/data - across product development cycle**
- **Implementation time frame: next 1-3 years to *begin* an ICME-accelerated product development program**
- **Report could nucleate self-assembly of ICME teams and/or programs**

Project Overview

- **Five ICME Implementation Teams**
  - **3 teams, each associated with a <u>specific industry</u>**
  - **4th team - pervasive cross cutting issues**
    - **e.g.: verification/validation, uncertainty quantification, integrating design ….**
  - **5th team: review panel for final report**
- **1st three teams:**
  - **Aerospace industry**
  - **Automotive industry**
  - **Maritime industry**

ICME Implementation Teams

- **Composition of each team:**
  - **Team leader**
  - **~ 10 top technical experts:**
    - **ICME, materials, design, engineering, applications**
    - **variety of materials types (metals, composites, ceramics)**
    - **majority industry; key academics and gov. as well**

- **Team mechanics:**
  - **Series of on-line meetings**
  - **“Homework” assignments to support meetings**
  - **Two-day in-person facilitated working sessions for each of four teams**
  - **Iterative editing on final report**

Team Leaders

- Aerospace: Tresa Pollock
  - Univ. of Cal. at Santa Barbara - Dept. head
  - Chair of 2008 National Academies study on ICME

- Automotive: John Allison
  - Univ. of Michigan Professor (much of career at Ford)
  - Co-Chair of 2008 National Academies study

- Maritime: John Deloach
  - Naval Surface Warfare Ctr - Welding Branch Head (& ONR)
  - Handles many materials issues for Navy platforms

- Crosscutting: Brad Cowles
  - Consultant - retired Pratt & Whitney (37 years)
  - Oversaw tech. projects & technology development programs

- Report Review: Justin Scott
  - TMS Technical Project Leader
  - Worked on ICME-related studies at Inst. for Defense Analysis

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ICME Implementation Teams
By Affiliations

Aerospace
University of California - S. B.
Cowles Consulting /Pratt&Whitney
GE-GRC
GE Aviation
AFRL
Lockheed Martin
Pratt & Whitney
Boeing
Boeing

Automotive
University of Michigan
Timken
Hydro Aluminum
Ford
GM
University of British Columbia
Pacific Northwest National Lab.
Ford
Consultant
Alcoa

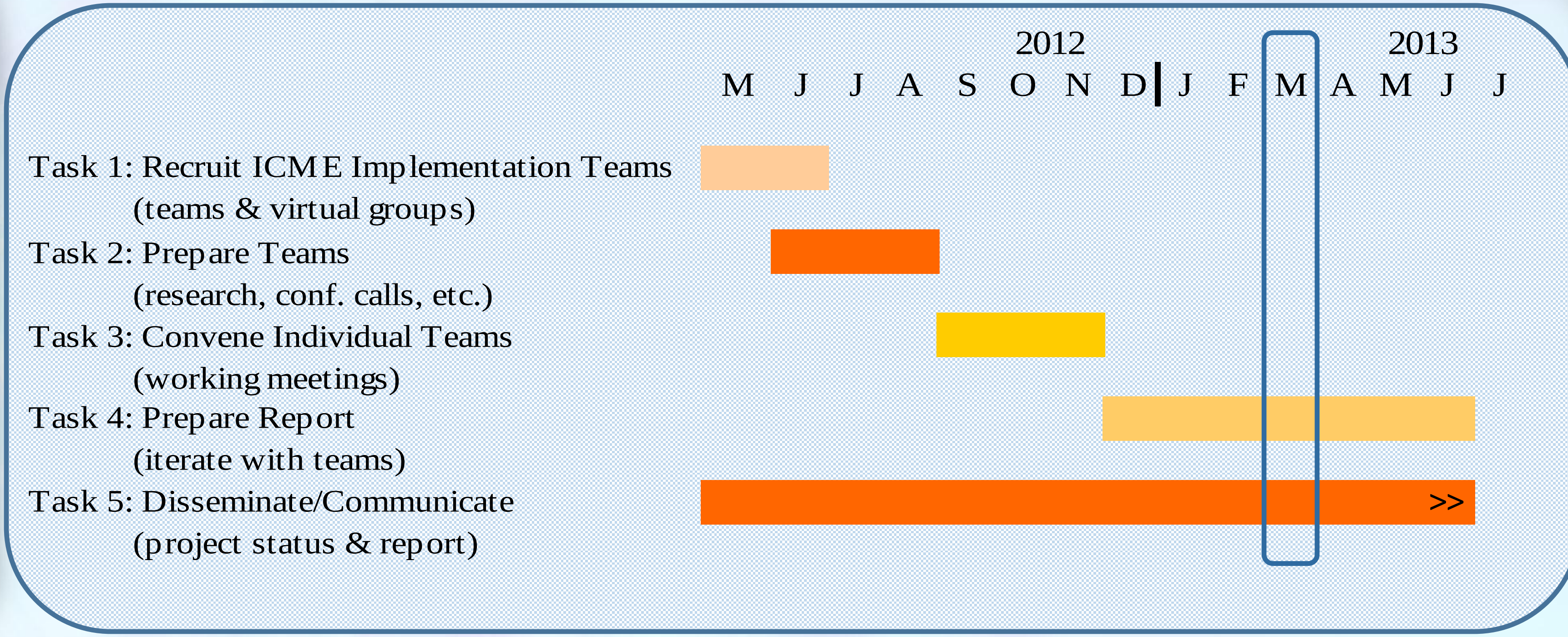
Maritime
Naval Surface Warfare Center
EWI
Ingalls Shipbuilding
Naval Surface Warfare Center
Arcelor Mittal
Naval Research Laboratory
Office of the Secretary of Defense (OSD)
HII-Newport News
NAVSEA

Cross-Cutting
Cowles Consulting /Pratt&Whitney
Thermocalc
Georgia Tech.
Pratt & Whitney
Alcoa
Purdue
ESI
University of Oklahoma
Northwestern University/Questek

Review
TMS
Naval Research Laboratory
University of North Texas
NIST
General Electric (retired)
General Motors
Oak Ridge National Lab.
University of Michigan
Tinken Steel

- **Mixture of Big Industry, Smaller Companies, Academia, Government**

ICME Implementation Study
Status Update



Task 1 - complete

Task 2 - complete

Task 3 - complete

Task 4 - in progress (draft in review)

Task 5 - in progress (press releases, TMS e-news, JOM, etc. to date)

- ❖ **On course for release at ICME 2nd World Congress in July**

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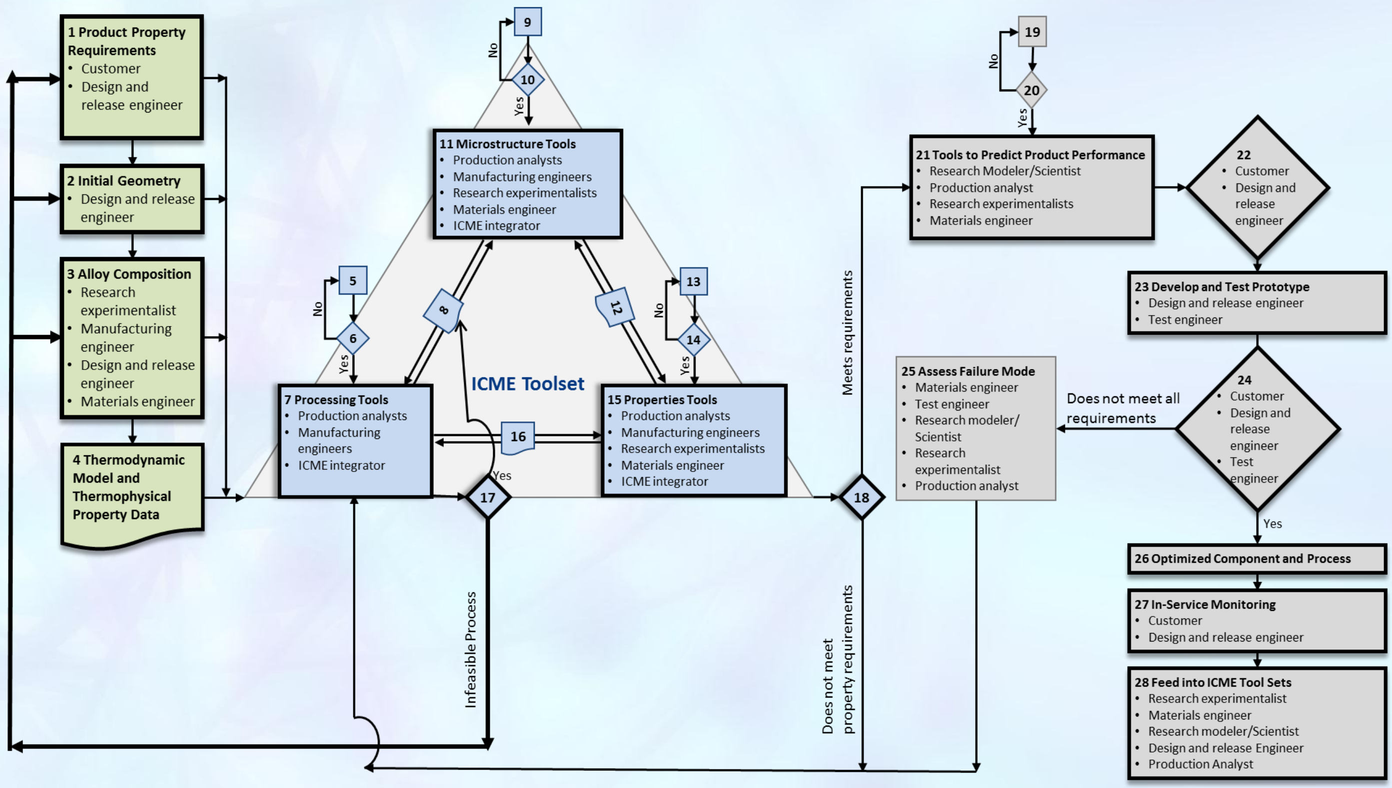
Study Outputs (For Report)

- "Frameworks" detailing steps needed to execute an ICME-Accelerated Product Development Program (IAPDP) in each industrial sector
- Current state of ICME Implementation
- Detailed actions at each step within IAPDPs, for each of the three frameworks
- Descriptions of personnel needed for each step in an IAPDP
- Detailed strategies for addressing needs & barriers to ICME implementation in near term (1 - 3 yrs.)
- Recommendations for more than 50 application opportunities for Implementing ICME in near term
- Critical pervasive, crosscutting issues and recommendations

Study Outputs - Some "Previews"

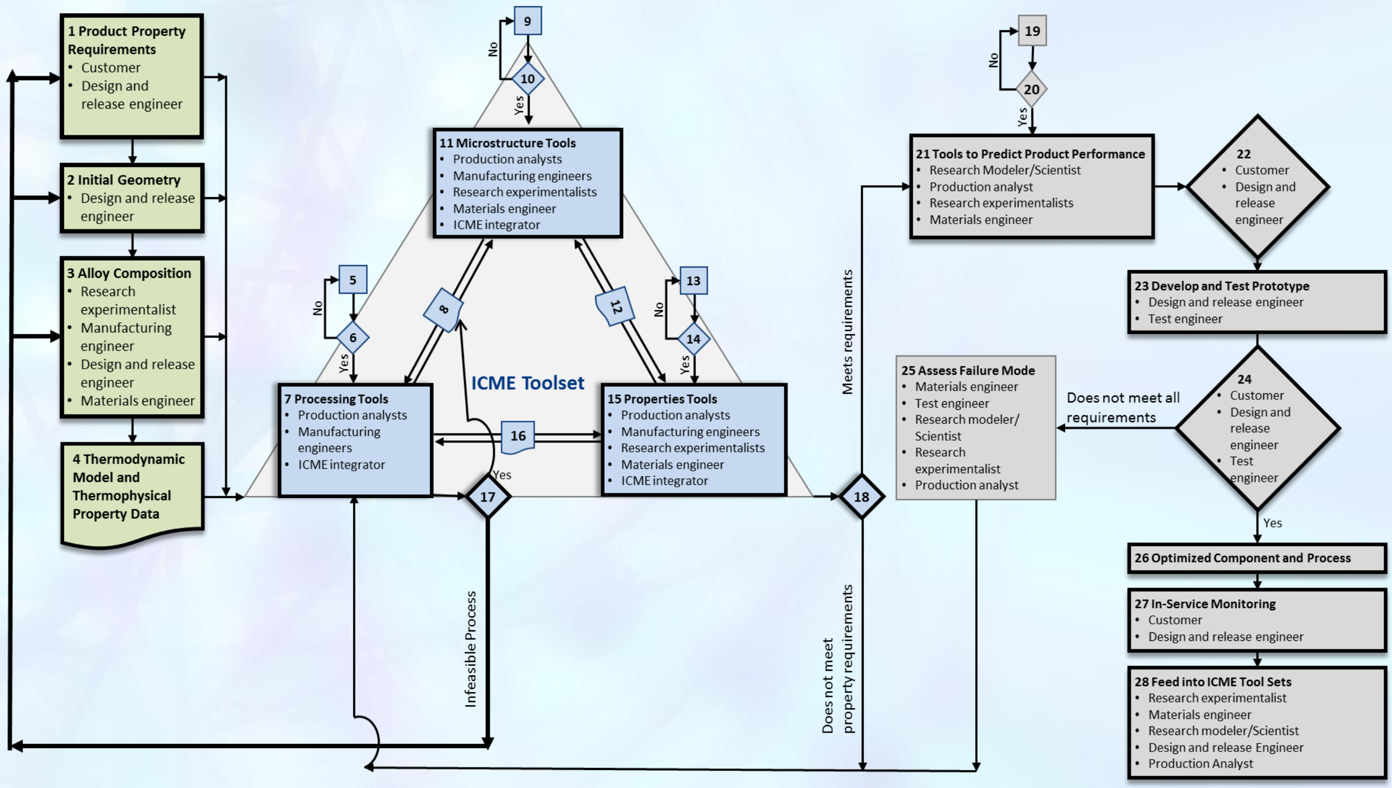
A Sample "Framework" (see details below)



ICME Models and Toolsets: Key for shapes in blue above	
	• Suites of models are identified or developed (8, 12, 16)
	• Models are validated and verified [V&V'd] in iterative processes (9,13, 17)
	• Linking tools transmit data between models (11, 15, 19)
	• Suites of V&V'd computational tools are applied to the specific product development (10, 14, 18)

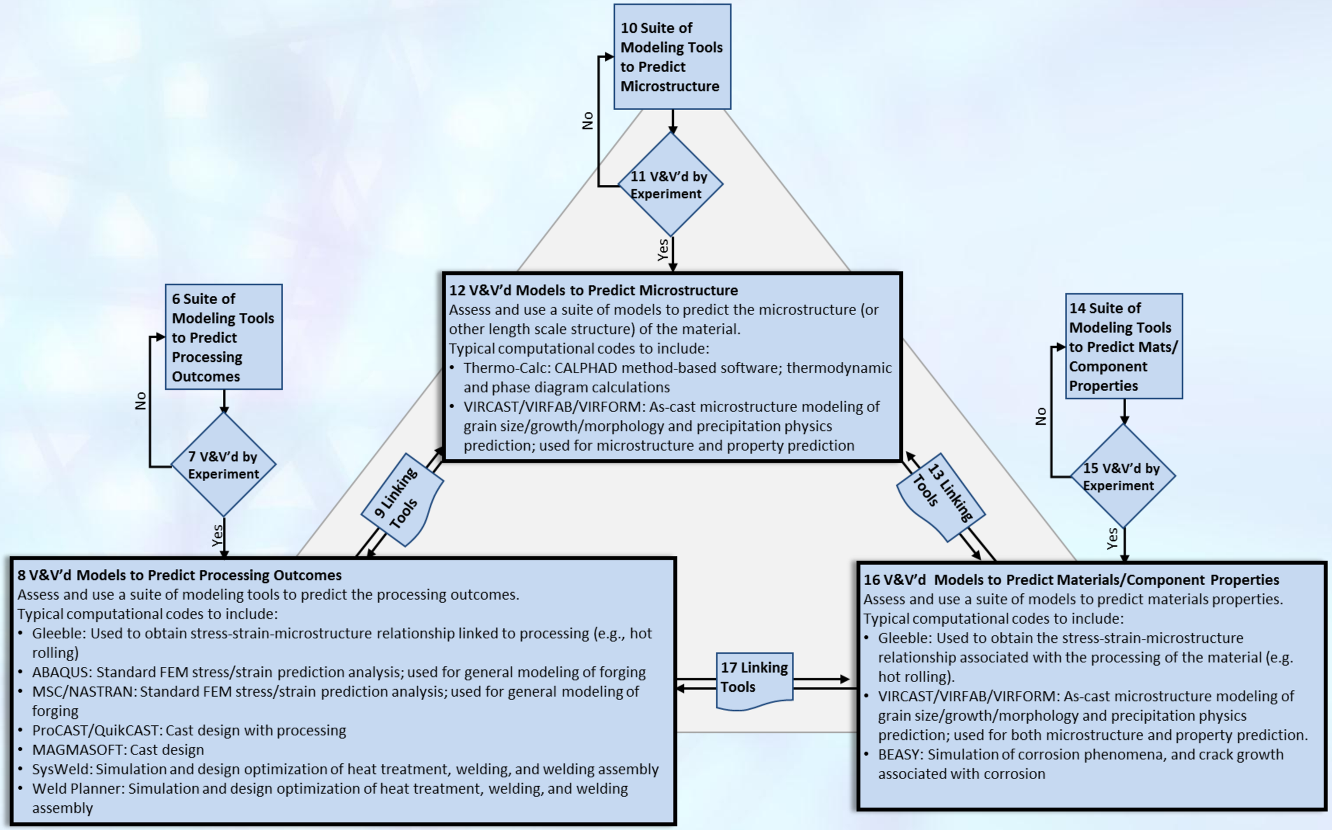
Study Outputs - Some "Previews"

A Sample "Framework"



- This specific framework is for **Automotive** industry
- This particular overlay includes types of *personnel* needed at each step
- Highlight: provides location and interactions of various personnel types at various steps in the Integrated Product Development Cycle
  - E.g., design & release engineer, manufacturing engineer, research experimentalist, materials engineer, production analyst, ICME expert/integrator…..

ICME Toolset Portion of Framework



- This specific ICME toolset portion of a framework is from Maritime industry chapter
- Overlay here highlights examples of some of the computational & experimental tools employed at each step in the ICME toolset
- E.g., ABAQUAS, ThermoCalc, ProCAST, SysWeld, Gleeble …..

ICME Implementation Study Report

A Field Manual for Implementing ICME in the Aerospace, Automotive, and Maritime Industries

- **Detailed table entries corresponding to different steps in the frameworks – one example from Aerospace chapter draft**

Step	Actions and Tools

17. Decision Point: Verify and validate models using experimental tools	• Conduct series of experiments to validate that the modeling results are representative of real-world conditions and design experiments specifically to work within the bounds of the model to confirm validity. Experimental tests could include:
	− *Experiments to validate the thermodynamics (phase diagram) results, which could include:*
	    o Heat treatments (isothermal and/or continuous cooling)
	    o Microscopy: Optical microscopy, SEM/EBSD, and/or TEM to characterize microconstituents resulting from the heat treatments.
	    o Differential Thermal Analysis (DTA)
	− *Experiments to measure mechanical or other physical or thermo-physical properties (including output of ANSYS), which could include:*
	    o Neutron diffraction (residual stress)
	    o X-ray diffraction techniques
	    o Creep testing (engine components)
	    o Corrosion testing
	    o Tensile tests (yield and ultimate strength, ductility – elongation/reduction in area).
	• Conduct series of tests to verify the computational accuracy of the modeling software and confirm that any physics-based codes are correctly executed.
	− Note: This may require several iterations of experiments or adjustments to the modeling tools ensure validity.

- **See next two slides for some details >>>>>**

ICME Implementation Study Report

A Field Manual for Implementing ICME in the Aerospace, Automotive, and Maritime Industries

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	− *Experiments to validate the thermodynamics (phase diagram) results, could include:*
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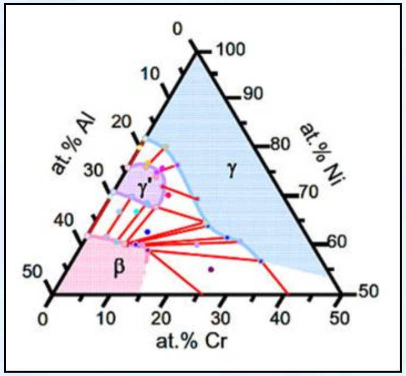
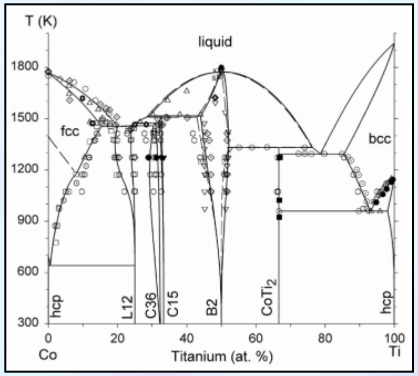
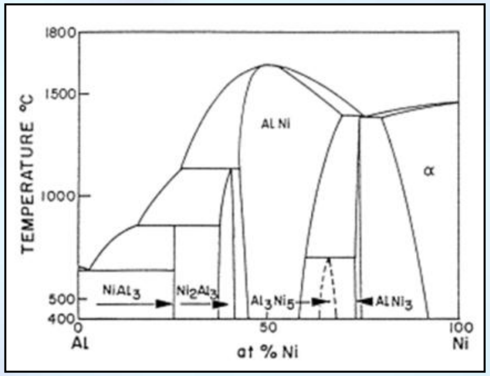
	  ○ Optical microscopy, SEM/EBSD, and TEM to characterize microconstituents resulting from the heat treatments
	  ○ Differential Thermal Analysis (DTA)



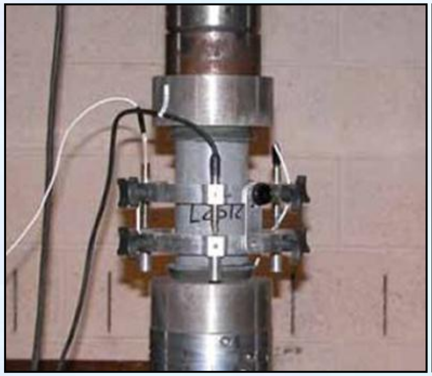


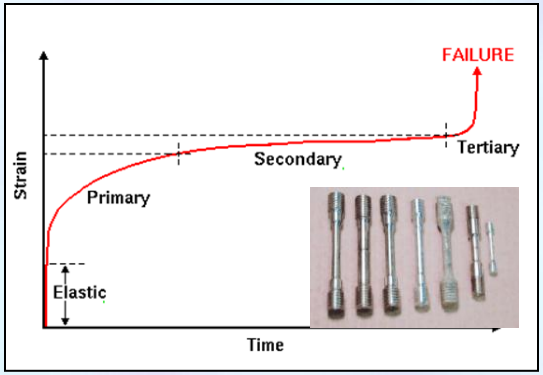


ICME Implementation Study Report

A Field Manual for Implementing ICME in the Aerospace, Automotive, and Maritime Industries

Step	Actions and Tools
17. Decision Point: Verify and validate models using experimental tools	– *Experiments to measure mechanical, physical, properties (including output of ANSYS); could include:* ○ Neutron diffraction (residual stress) ○ X-ray diffraction ○ Creep testing (engine components) ○ Corrosion testing ○ Tensile tests (yield and ultimate strength, ductility – elongation/reduction in area)





Excerpts from Maritime chapter draft

Step	Actions and Tools
5. Material Composition	• Conduct research to investigate materials candidates and alloy compositions…. include extensive literature review • Utilize computational codes such as Thermocalc or Pandat to help determine *potential* materials compositions • Examine compositional design options using set of trials and screening options on small-scale components (e.g., plates or filler wire).

Excerpts from Maritime chapter draft

Step	Actions and Tools
5. Material Composition	• Define and complete experimental test matrix to down-select to preferred materials compositions and processing approach • Make changes/additions to fabrication specifications using performance requirements, geometry, matls. composition – *Note: From this point through step 26, the materials suppliers are driving the process with metallurgical knowledge, etc.*

Who Should Read This Report and Why?

- A variety of stakeholders (or potential stakeholders) throughout various organizations, including:
  - Professionals in aerospace, automotive, & maritime industries
  - People in other materials-intensive industries
  - University professionals and students
  - Government scientists and engineers, program officers, and policy makers
- Report discusses not only who should read it, but:
  - Why, and what benefits they will receive
  - What actions they might take after reading this report
  - Can be read at different "resolutions", depending on level of previous involvement in ICME or product development
    - Some take a deep, full read
    - Others - executive summary (~8 pages), final comments, and skim text

Creating a Business Case for ICME

- **Need: convincing stakeholders to adopt ICME methods:**
  - Modeling software, supporting databases, and qualified personnel are significant investments
  - Often viewed as a substantial business risk from perspective of management
  - Want to ensure they achieve their expected return on investment (ROI)
  - Others……
- **Recommended Actions**
  - Develop a quantitative economic case
  - Document case studies and lessons learned
  - Address risk and uncertainty quantification and mitigation
  - Others……..

One Example

Detailed Tactics for one of these recommended actions

- ***Develop a Quantitative Economic Case***
  - Provide a sound *quantitative analysis* that details the benefits
  - Specifically, define how an ICME-accelerated product development cycle can reduce risks, costs, and/or time expenditures
  - Contributions to such reductions include decreased testing requirements; reduced risk, time, and iterations for materials and process development
  - Elimination or reduction of costly traditional product iterations
  - Consider the *complete manufacturing chain* of a particular material or component rather than just the cost of the raw material, and demonstrate reduced cost or time expenditures
  - Etc….

Strategies for addressing needs & barriers to ICME implementation in the near term (1 - 3 yrs.) – one example from the draft report

- **Needs**
  - **Improved Quantitative Modeling Tools, Including:**
    - **Microstructure model tools for high-pressure die casting aluminum & magnesium alloys**
    - **Tools to predict forming/welding induced property changes in subsequent crash and noise-vibration-harshness simulation**
    - **Others….**
- **Recommended Actions**
  - **Two-day workshop with representatives from industry and academia (and publish results)**
  - **Establish best practices for evaluating maturity and predictive capability of different software tools and models**
  - **Others….**

Concluding Remarks - 1

- It is a very exciting time in Matls. Sci. & Engineering
- In large part due to application of MS&E innovations into industry to develop advanced new products – ICME
- ICME now recognized as a discipline, worldwide awareness is growing rapidly, leveraged with MGI
- Great potential for ICME to reduce significantly time & cost of developing materials, components, and manufacturing processes
- But we stand at a critical juncture or “tipping point”

Concluding Remarks - 2

- **To realize this vision, we need detailed pathways to rapid implementation**
- **We all have some part to play in the success of ICME**
- **This study considered a “field manual” for near term ICME implementation**
- **Provides practioners with**
  - **frameworks, recommended actions & personnel, near term opportunities to imbed ICME into product development cycles within ~ 3 years**
- **Final report to be first published and distributed on July 7, 2013 (at 2nd World Congress on ICME)**

Thank You!`

Questions