The Next Generation of Advanced High Strength Steels– Computation, Product Design and Performance

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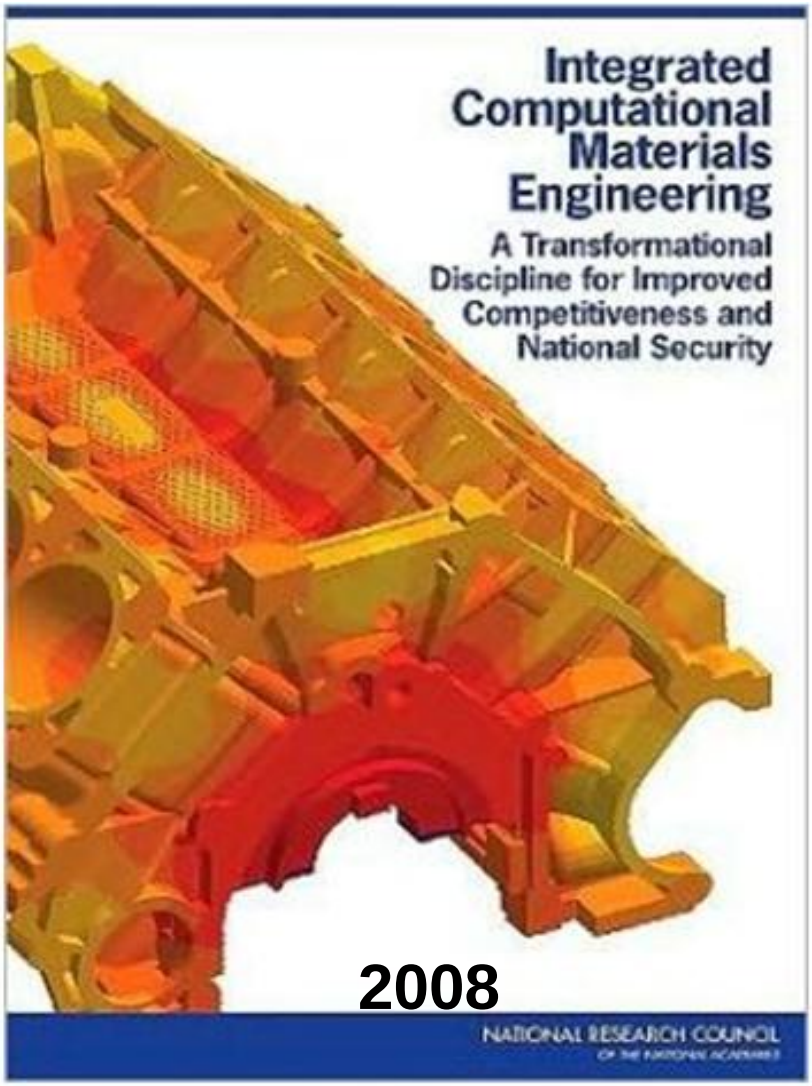
Auto/Steel Partnership

USAMP
UNITED STATES AUTOMOTIVE MATERIALS PARTNERSHIP LLC

INTEGRATED COMPUTATIONAL MATERIALS ENGINEERING (ICME)



What is ICME?

- an emerging discipline aimed at

  *- linking materials models across multiple length scales to tailor materials for application-dependent performance requirements**

  *- capturing, curating, and archiving the critical information needed to facilitate ICME in materials databases **

What is Required?

- *high level of technical maturity for the computational tools,*
- *education of science and engineering practitioners in ICME capabilities,*
- *customers and regulatory entity confidence in the outcomes of ICME implementations.*

*Panchal, et al. Key Computational Modeling Issues in Integrated Computational Materials Engineering," Computer-Aided Design 45 (2013) 4–25.

INTEGRATED COMPUTATIONAL MATERIALS ENGINEERING (ICME)

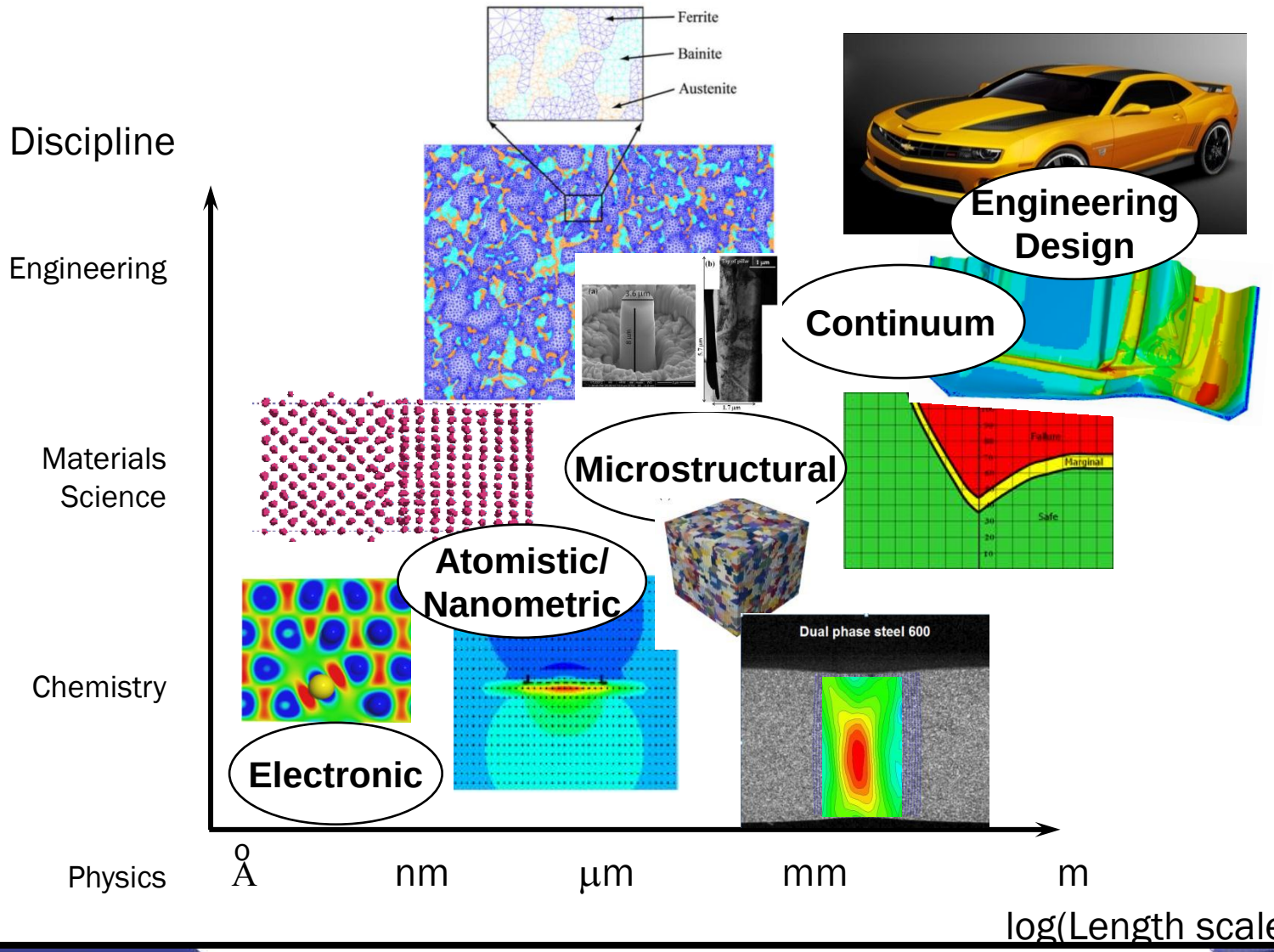
Advantages for Steels?

- ***Provide:*** new predictive modeling approaches aimed at linking microstructure to product performance,
- ***Accelerate:*** usage of steel as the "material of choice" in numerous industries,
- ***Increase:*** emphasis on ferrous metallurgy in U.S. universities,
- ***Foster:*** greater U.S. funding agency emphasis of steels as "cutting edge" materials,
- ***Refocus:*** professional materials societies on steels (e.g. ferrous metallurgy committee in TMS)

Steel ICME Projects in the U.S.?

- up to March 12, 2013, *no steel ICME program in the U.S.,*
- much emphasis on non-ferrous alloys (***aluminum*** and ***magnesium***),
- many in the computational materials science community consider steels a formidable challenge,
- steels are looked upon as "mature," "not-in-vogue," "not nano" – just plain "*not cool*" compared to other materials,
- only 8 accredited university metallurgy programs in U.S. (currently)

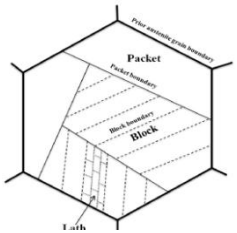
The Multi-scale Nature of Steel Alloys and Linkage with Alloy Design for Performance

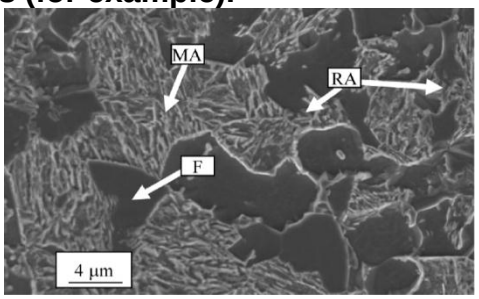


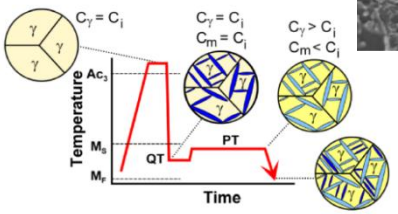
ICME FOR STEEL ALLOYS

Think of the possibilities if we could…

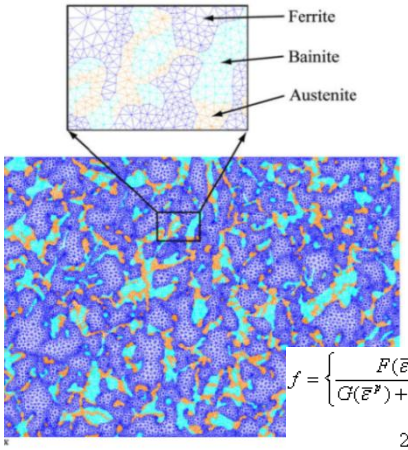
(a) *…use computers* (with minimal experimental inputs) to "design" multi-phase steel microstructures that achieve desired strength and ductility targets (for example).







(b) *…generate constitutive models* that accurately account for the multi-scale physical phenomena in an advanced steel under an arbitrary strain path.



$$\sigma_0 = \sigma_{y,F} + K_F \varepsilon_{ep}^{n_F}$$

$$\sigma_0 = \sigma_{y,B} + K_B \varepsilon_{ep}$$

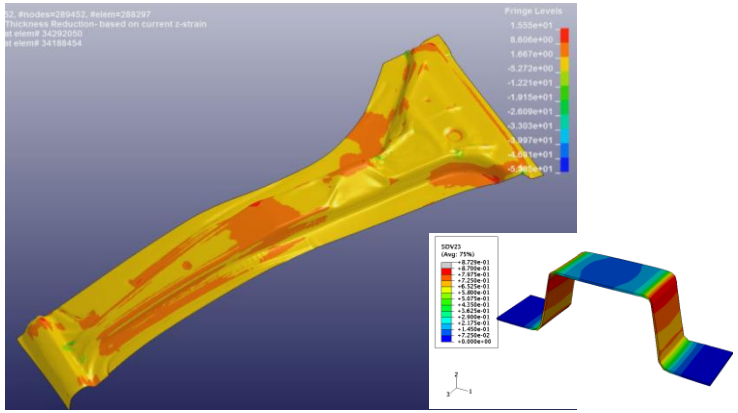
$$\sigma_0 = \sigma_{y,A} + K_A \varepsilon_{ep}^{n_A}$$

$$\sigma_0 = \sigma_{y,M} + K_M \varepsilon_{ep}$$

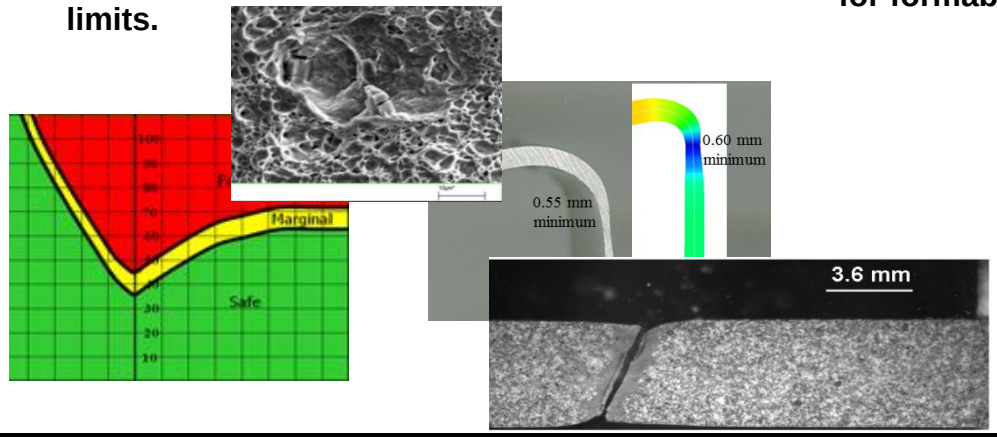
$$\Pi = R\sqrt{3J_2}\left[1 + k\frac{J_3}{J_2^{3/2}}\right] + \frac{\alpha I_1}{3}$$

$$f = \left\{ \frac{F(\bar{\varepsilon}^p)}{G(\bar{\varepsilon}^p)+H(\bar{\varepsilon}^p)}|\sigma_y|^a + \frac{G(\bar{\varepsilon}^p)}{G(\bar{\varepsilon}^p)+H(\bar{\varepsilon}^p)}|\sigma_x|^a + \frac{H(\bar{\varepsilon}^p)}{G(\bar{\varepsilon}^p)+H(\bar{\varepsilon}^p)}|\sigma_x-\sigma_y|^a + \frac{2N(\bar{\varepsilon}^p)}{G(\bar{\varepsilon}^p)+H(\bar{\varepsilon}^p)}|\sigma_{xy}|^a \right\}^{\frac{1}{a}} - X(\bar{\varepsilon}^p)$$

(c) *…pass* models onto metal forming and CAE engineers for formability and performance predictions in commercial FE codes.



(d) *…predict* formability and failure limits.



New ICME Project on Third Generation Advanced High Strength Steels (3GAHSS)

FINANCIAL ASSISTANCE
FUNDING OPPORTUNITY ANNOUNCEMENT

U. S. Department of Energy

Issuing Office
National Energy Technology Laboratory

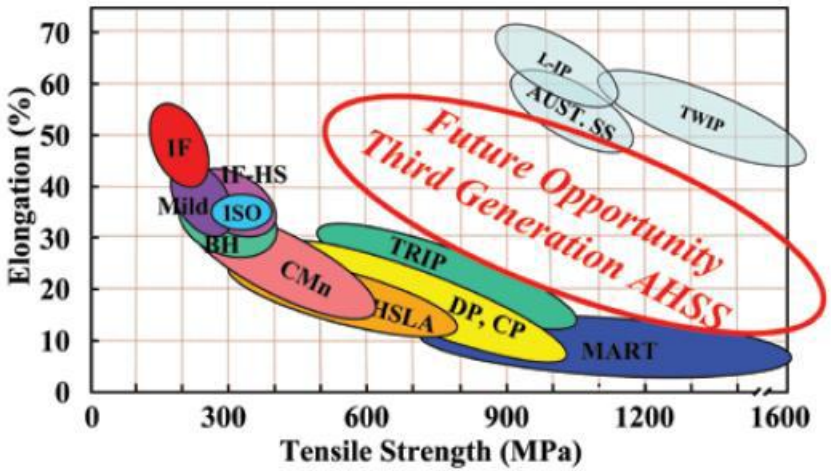
Funding Opportunity Number: DE-FOA-0000648

"Predictive Modeling for Automotive Lightweighting Applications and Advanced Alloy Development for Automotive and Heavy-Duty Engines"

Announcement Type: Initial

CFDA Number: 81.086 Conservation Research and Development

Issue Date: **03/22/2012**



Area of Interest 2: Integrated Computational Materials Engineering (ICME) Development of Advanced Steel for Lightweight Vehicles

New ICME Project on Third Generation Advanced High Strength Steels (3GAHSS)

Award to USAMP through Sec. Chu's Office (DOE): February 1, 2013

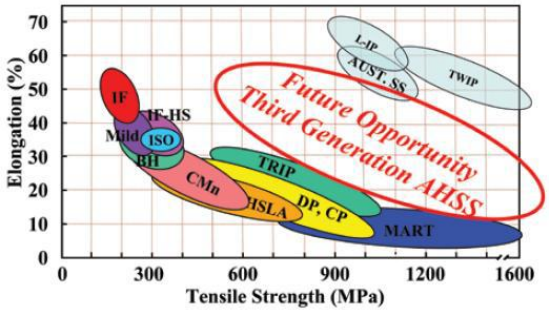
- http://energy.gov/articles/energy-department-investments-develop-lighter-stronger-materials-greater-vehicle-fuel

DOE Funding: $6,000,000 with 30% in-kind match

Duration: Four Years, starting 1Q 2013 (kick-off March 12, 2013)

Recipients, Sub-recipients, and Key Contractors

- **USAMP** – Chrysler, Ford, General Motors
- **A/SP - SMDI** (AAC Steel Companies): AK Steel, ArcelorMittal, Nucor Steel, Severstal North America, ThyssenKrupp USA, U. S. Steel
- **Universities**: Brown University, Clemson University, Colorado School of Mines. Michigan State University, University of Illinois
- **National Lab**: PNNL
- **Engineering Companies**: EDAG, LSTC



3GAHSS ICME Project Goal

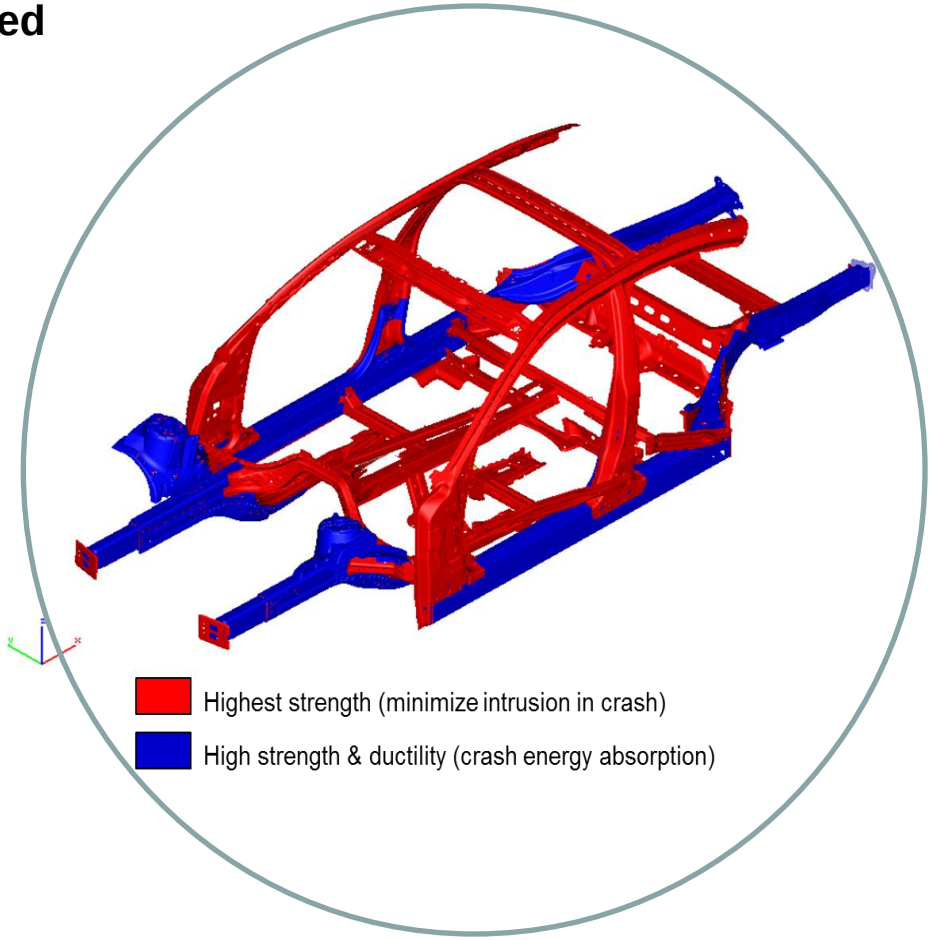
- **The goal of this project is to develop computational tools that will enable improved steels for lighter weight, safe and more fuel efficient vehicles.**

***For this purpose, we will*:**

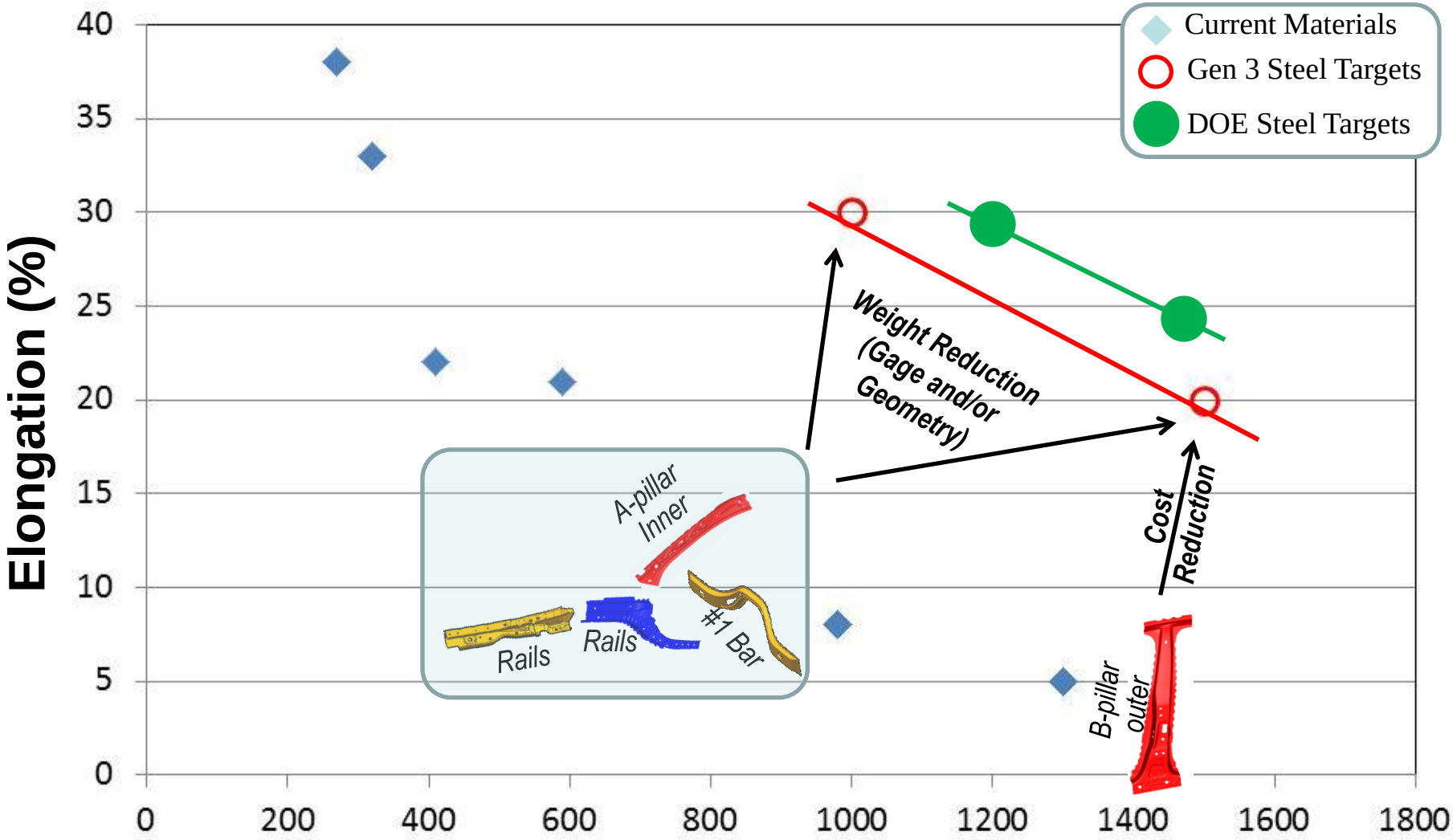
- ***Bring together…***the best minds in U.S. academia, industry, and national labs.

- ***Integrate…***state-of-the-art, multi-scale computational and experimental tools to produce a single ICME model to facilitate design of lightweight automotive components.

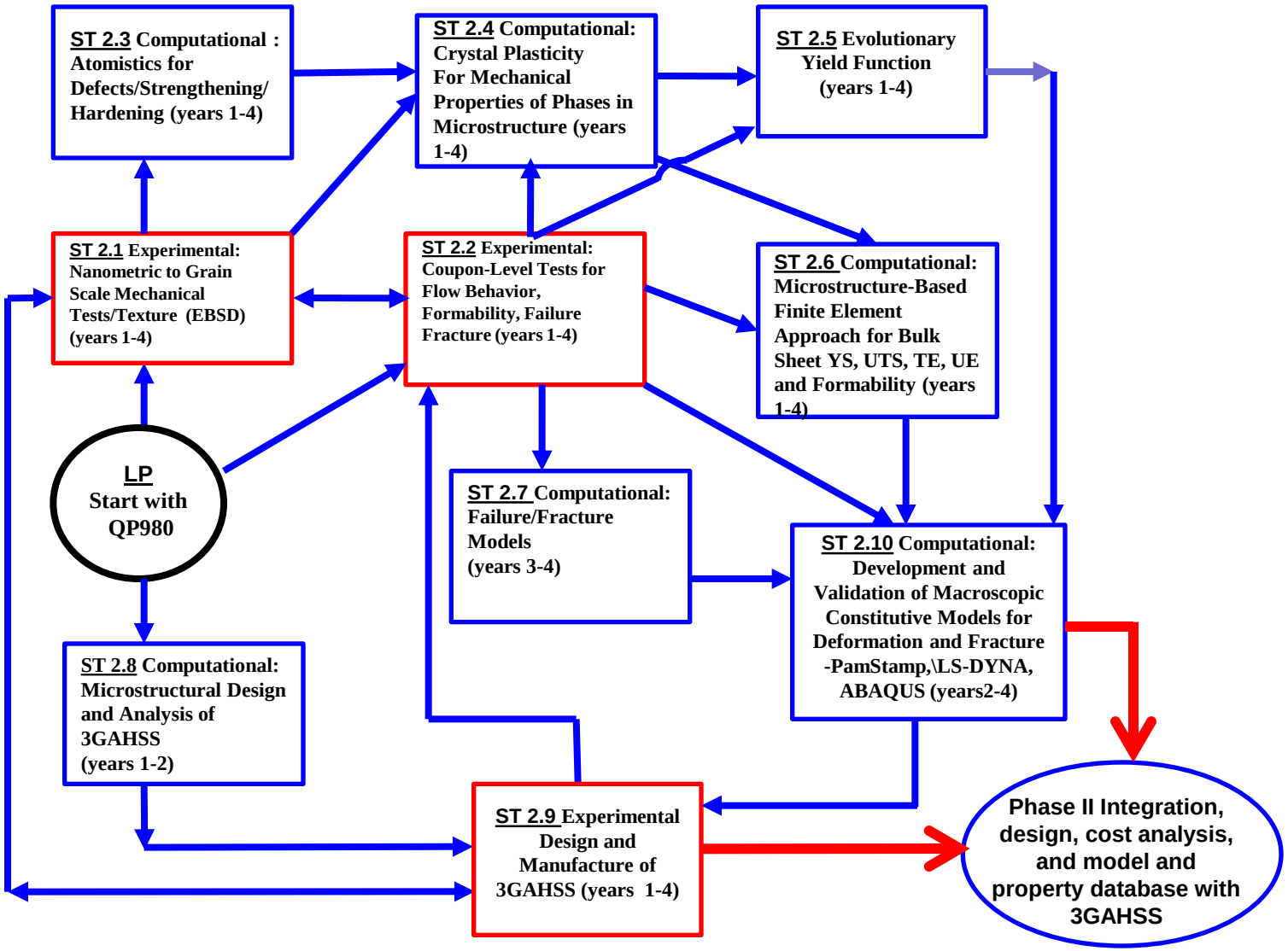
- ***Validate…***ICME model on actual vehicle components.



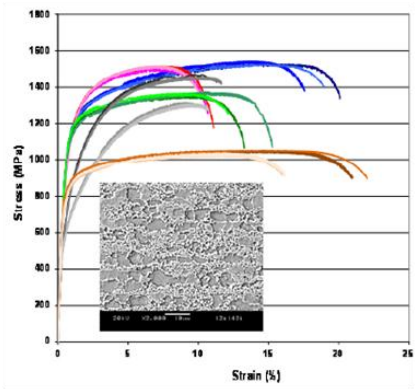
Representative Automotive Components for 3GAHSS ICME Project



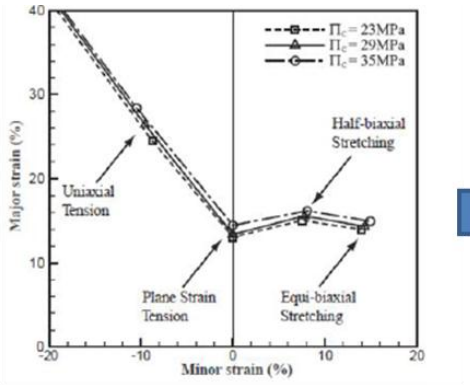
Phase I – Constitutive Model Development



Phase II. Forming, Assembly, Design Optimization, ICME Integration, Technical Cost Modeling



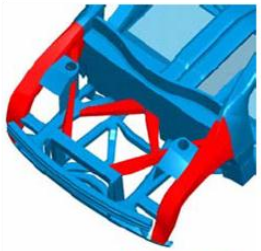
Bulk Properties from ICME

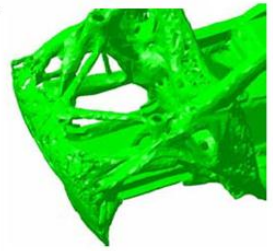


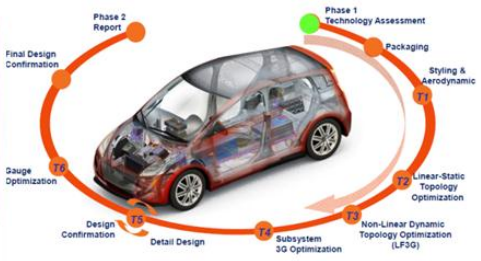
Task 3. Forming and Fracture and Validation

Task 4. State-of-Art Joining Technology from Prior Data

Task 5. Design Optimization







Task 6. Integration

Task 7. Technical Cost Modeling

Acknowledgement

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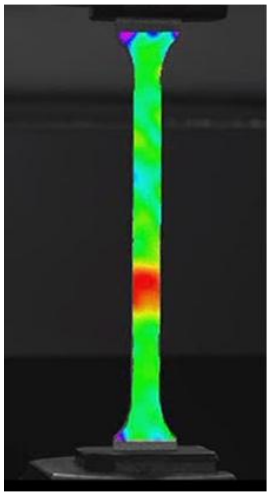
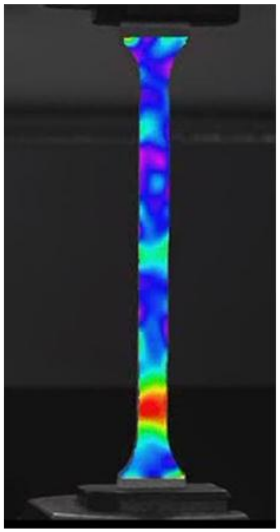
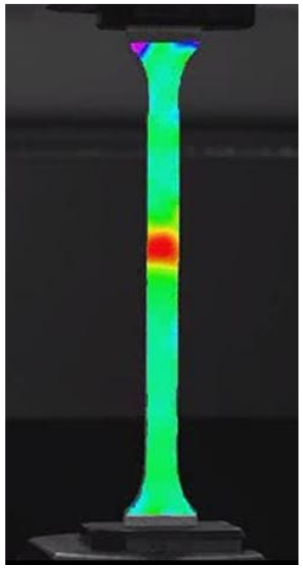
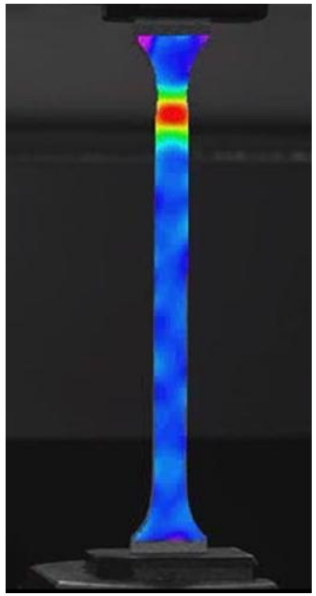
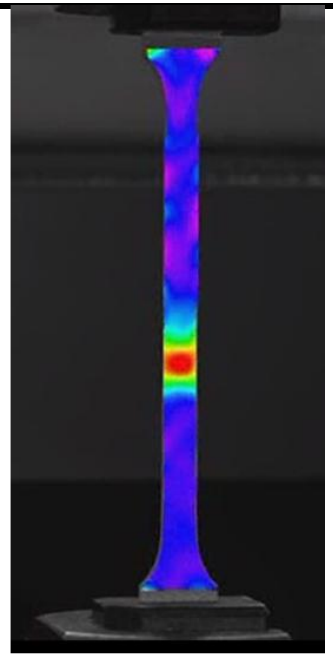

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