ICME Education at Northwestern

G.B. Olson

Northwestern University & QuesTek Innovations LLC

Evanston, Illinois

NORTHWESTERN UNIVERSITY

QUESTEK® INNOVATIONS LLC

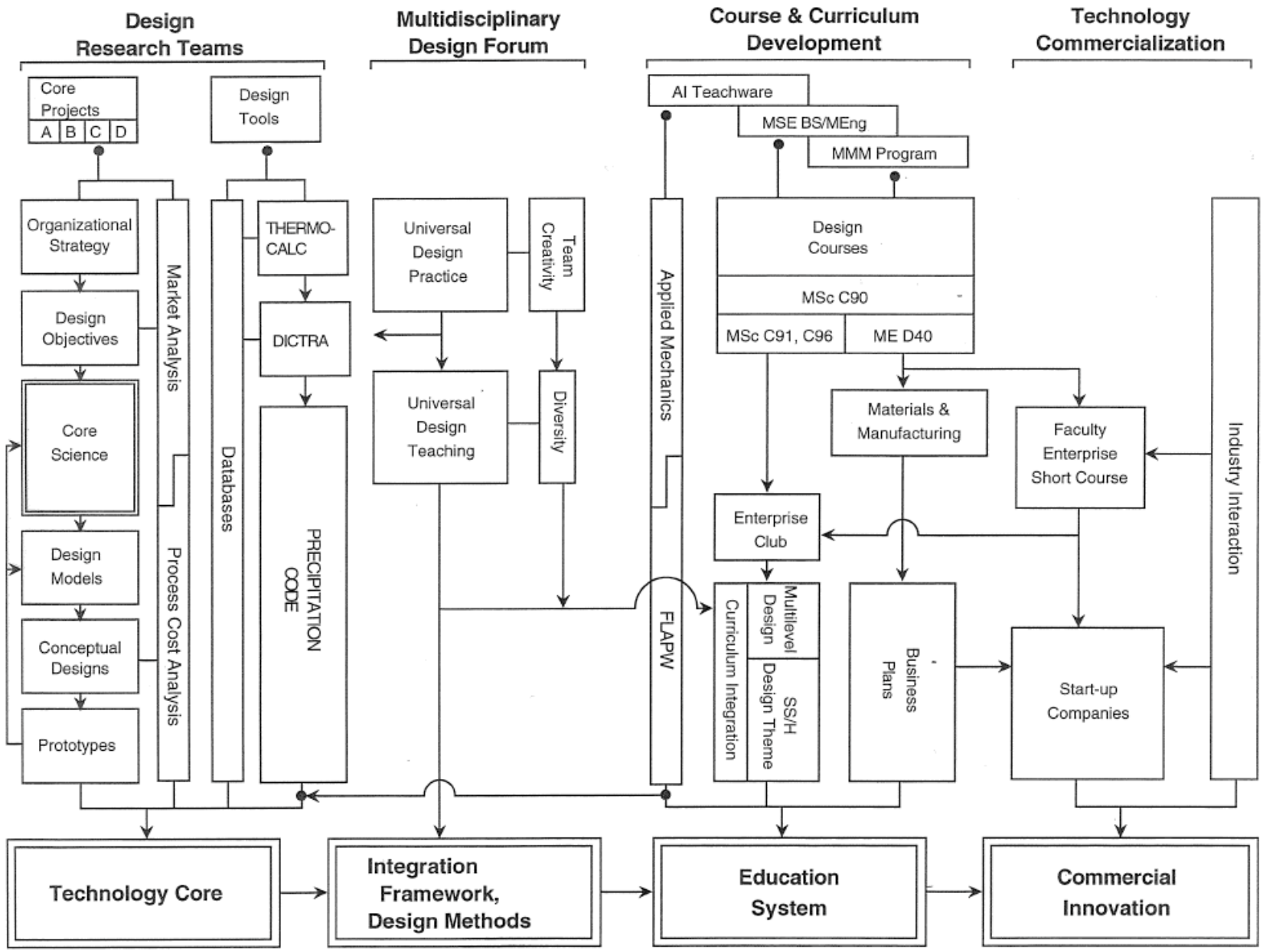
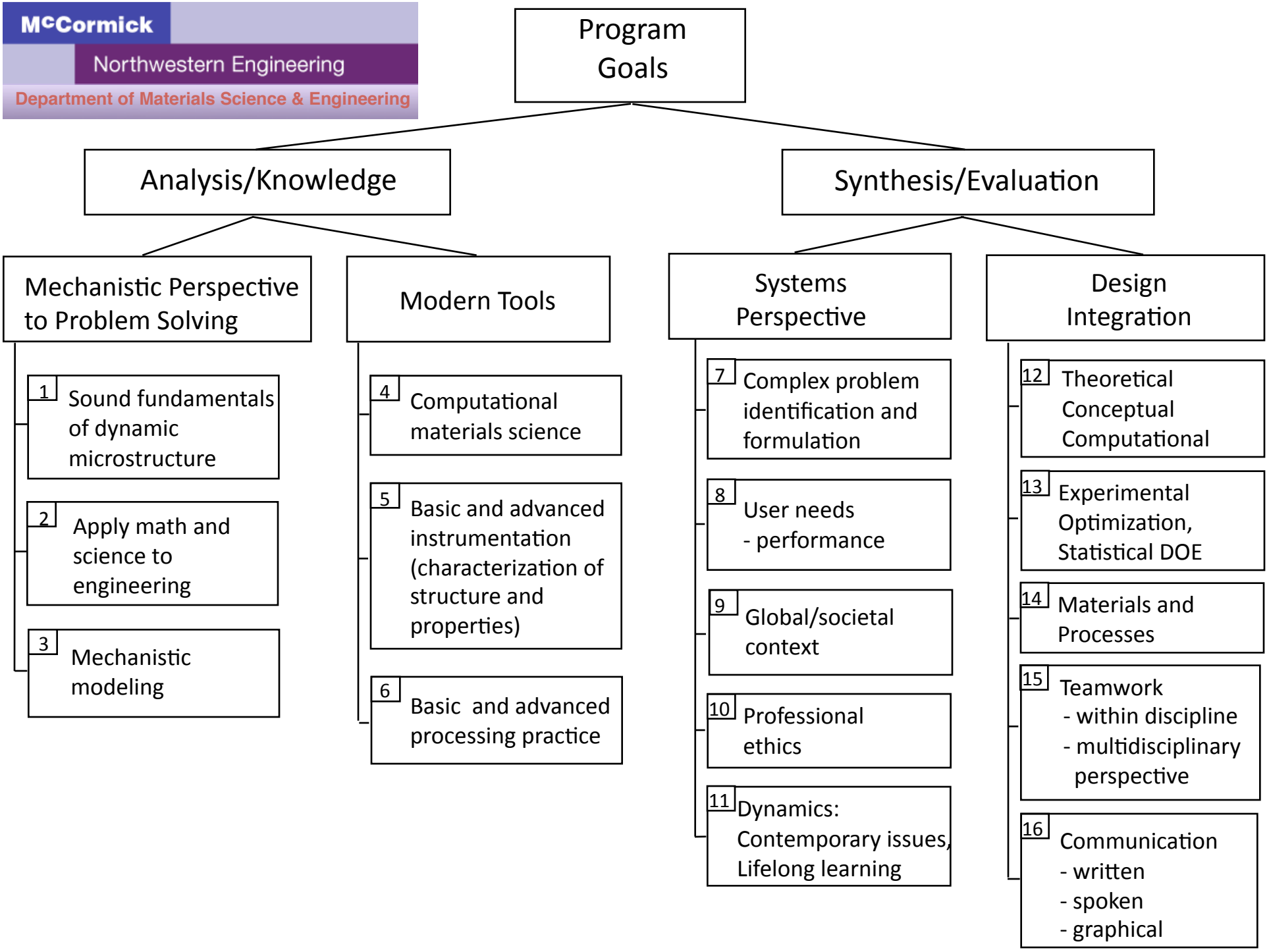

Design Research Teams
Multidisciplinary Design Forum
Course & Curriculum Development
Technology Commercialization
Core Projects
A
B
C
D
Design Tools
AI Teachware
MSE BS/MEng
MMM Program
Organizational Strategy
Market Analysis
Databases
THERMO-CALC
Universal Design Practice
Team Creativity
Applied Mechanics
Design Courses
MSc C90
MSc C91, C96
ME D40
Industry Interaction
Design Objectives
DICTRA
Universal Design Teaching
Diversity
Materials & Manufacturing
Faculty Enterprise Short Course
Core Science
PRECIPITATION CODE
Enterprise Club
Design Models
Process Cost Analysis
FLAPW
Multilevel Design
SS/H Design Theme
Curriculum Integration
Business Plans
Start-up Companies
Conceptual Designs
Prototypes
Technology Core
Integration Framework, Design Methods
Education System
Commercial Innovation

Table I. Bloom's Taxonomy of Educational Behavior (4)

Bloom proposed six classes of behavior, divided into two broad categories: (a) knowledge and (b) intellectual abilities and skills:

1. Knowledge. This class involves simple recall of the appropriate material, usually unaltered. The remaining five classes were categorized as intellectual abilities and skills.
2. Comprehension. In mastery of this, the lowest level of understanding, the student knows what is being communicated and can use the concept singly, without its full implications.
3. Application. This behavior requires the use of general principles, theories, or procedures in concrete situations.
4. Analysis. To exhibit analytical behavior, a student should be able to separate a complicated process, machine, or procedure and determine the inner workings of each portion.
5. Synthesis. This behavior class requires the student to assemble and arrange parts into a whole which was not previously apparent.
6. Evaluation. This behavior consists of judgments about the value of a material, method, or process, involving standards of acceptability.

McCormick
Northwestern Engineering
Department of Materials Science & Engineering



Curriculum Structure/Property Relations

	analysis/knowledge										synthesis/evaluation					
	mechanistic perspective to problem solving						modern tools				systems perspective				design integration	
	fund. dynamic microstructure	apply math & sci. to eng.	mechanisitc modeling	computational mat. sci.	instrumentation	processing practice	complex prob id & form	user needs - performance	global/societal context	prof. ethics	dynamics - environment	conceptual, computational	experimental, statistical	materials & processes	teamwork	communication
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
201 Princ & Prop Matls	X	X	X													
314/315 Thermo		X	X	X	X											
316-1,2 Micro Dynamics	X	X	X		X	X										
331 Intro Polymers	X	X	X		X	X										
332 Mech Behavior	X	X	X		X	X		X							X	X
351-1,2 Intro Physics Matls		X	X		X			X								
361 Cryst & Diffraction	X	X		X	X								X		X	
390 Materials Design	X	X	X	X			X	X	X	X	X	X		X	X	X
391 Process Design		X		X		X	X	X	X		X		X	X	X	X
396-1,2 Senior Project		X			X		X			X	X		X			X

MSE Design Curriculum

	F	W	S
1		**EDC 1**	**EDC 2**
2	**Thermo 1** **Intro MSE**	**Thermo 2** **Mechanics**	**Micro Dynamics 1**
3	**Micro Dynamics 2** **Mech Behavior**	**SS Physics 1**	**Materials Design** **SS Physics 2**
4	**Process Design**	**Senior Project**	**Senior Project**

Education: Multiyear Design Sequence

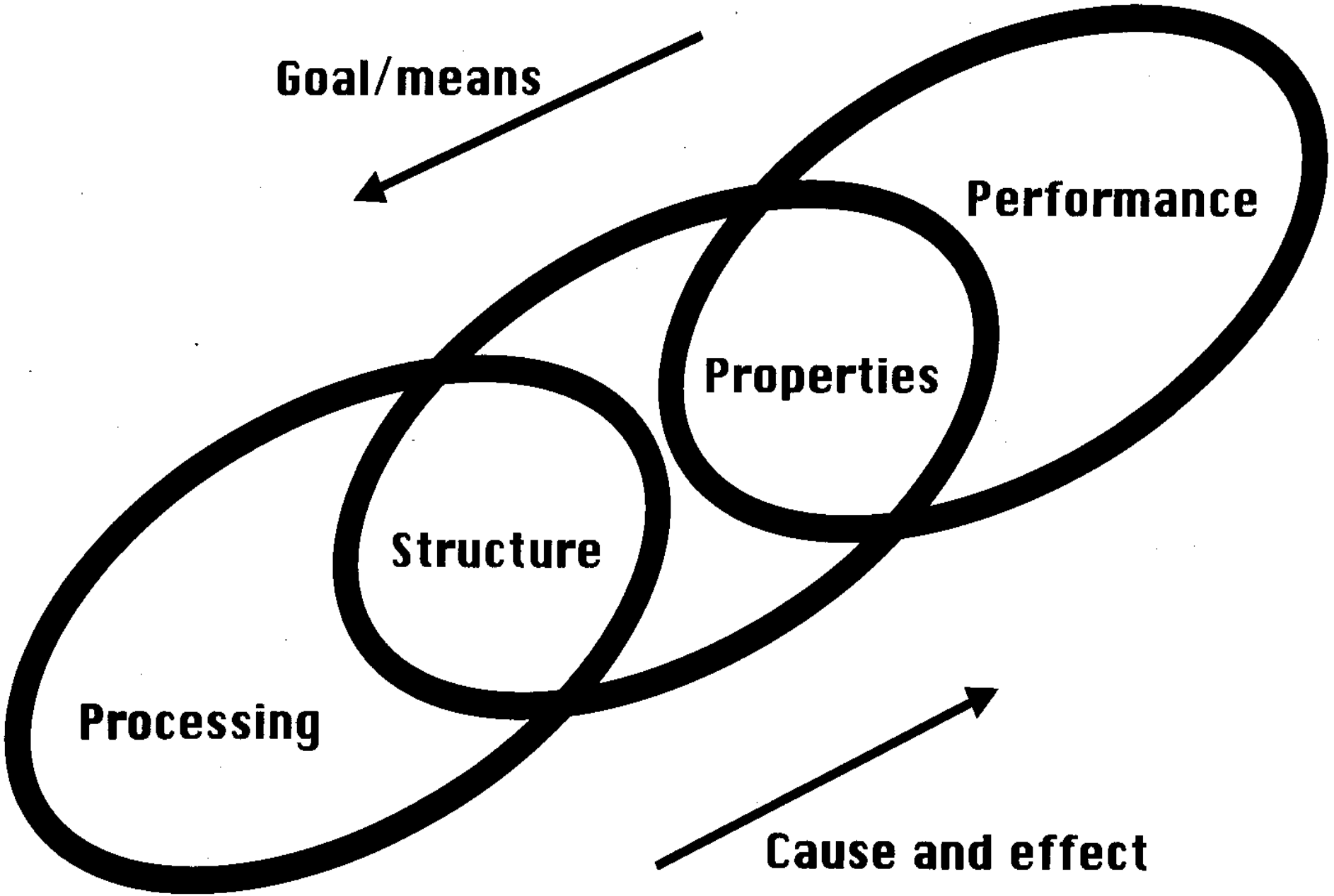
Bringing Modern Design to the Research University

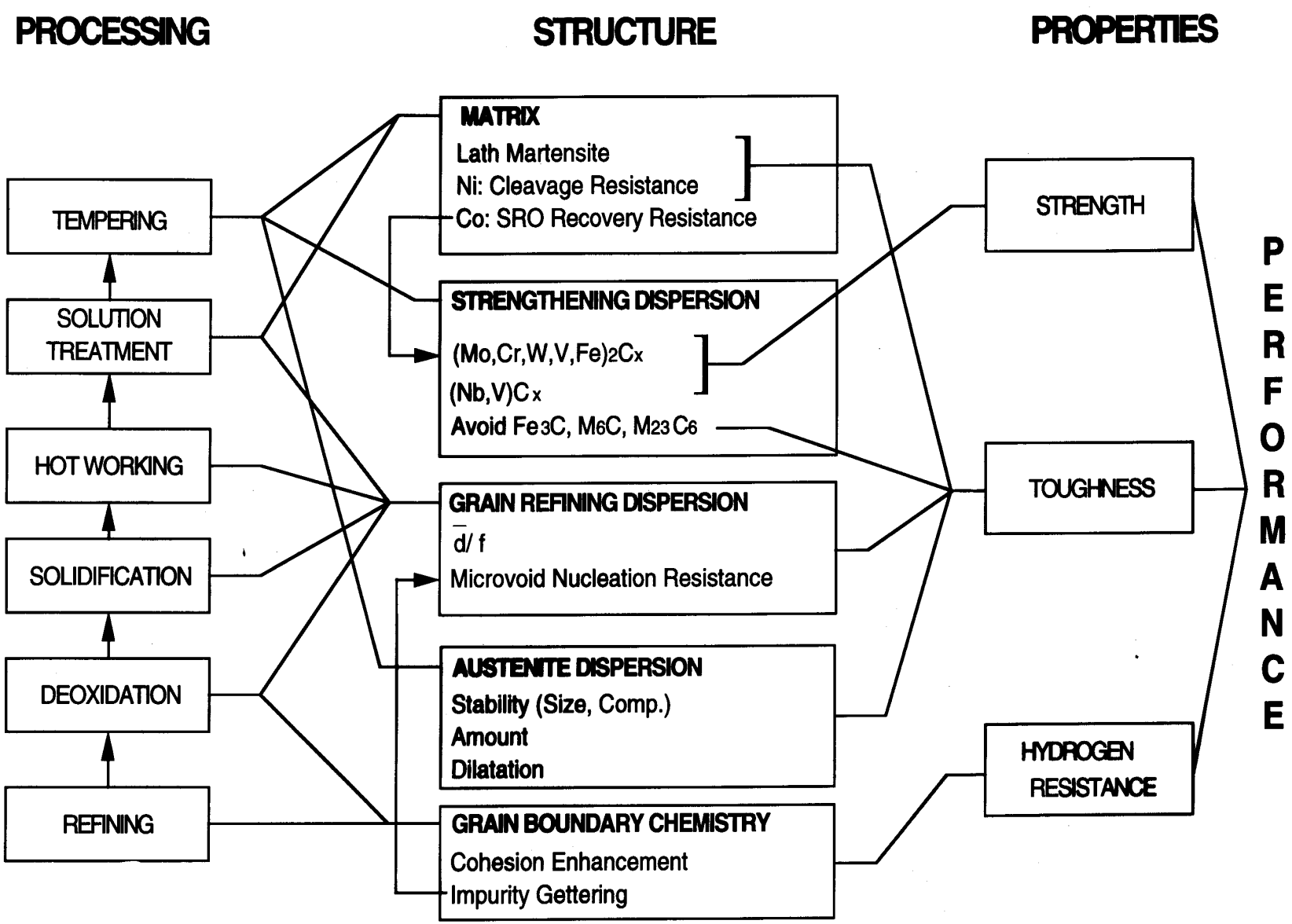
DSGN 106-1,2 **Freshman Engineering Design & Communication**
-- Cross-Cultural Teaching of Modern Product Design

Mat Sci 390 **Materials Design**
-- Computational Design of Dynamic Multiscale Materials

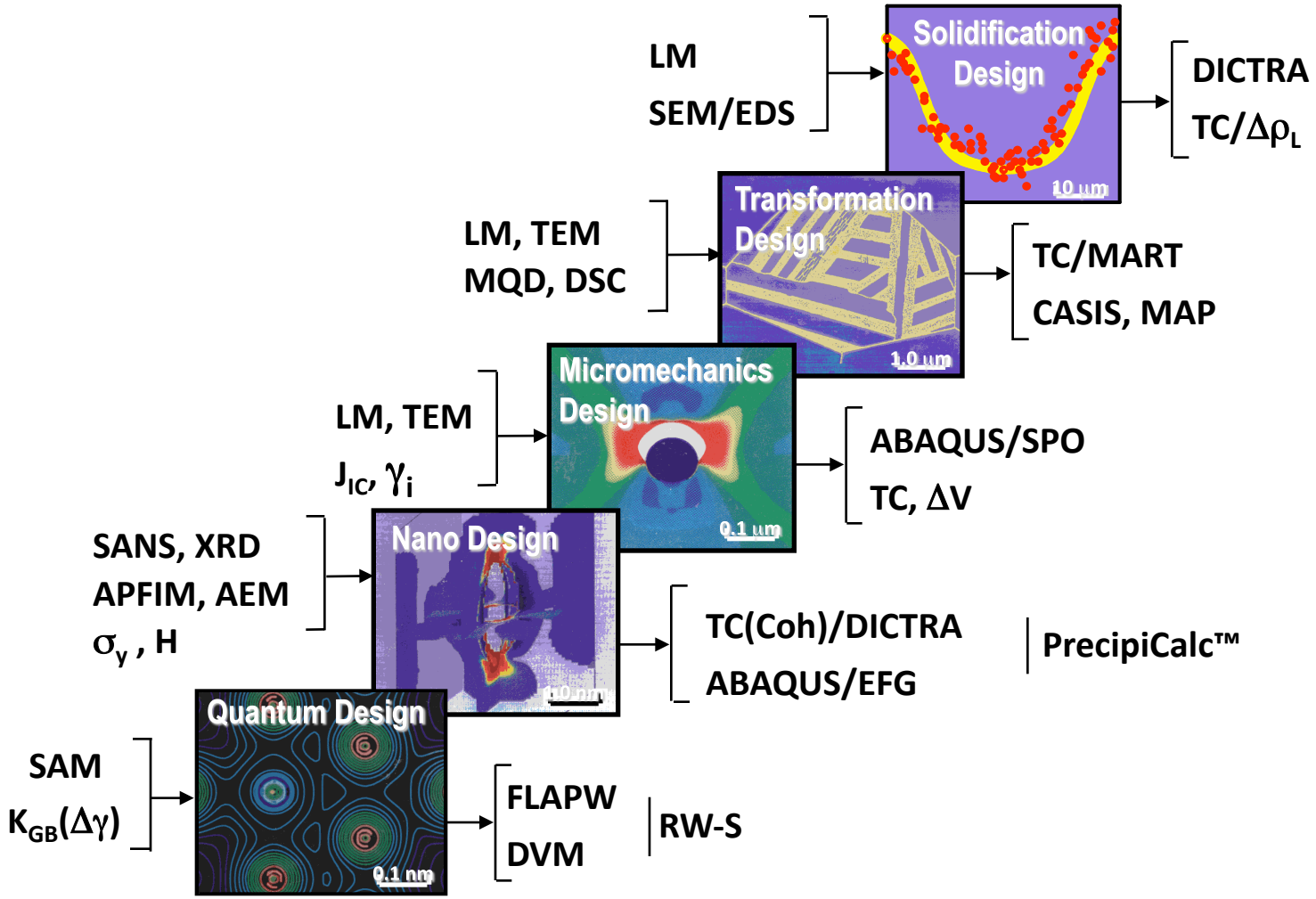
Mat Sci 391 **Process Design**
-- Statistical Methods of Experimental Process Optimization

Mat Sci 396-1,2 **Senior Project**
-- Experimental Research & Design Validation


Goal/means
Performance
Properties
Structure
Processing
Cause and effect


PROCESSING
STRUCTURE
PROPERTIES
TEMPERING
SOLUTION TREATMENT
HOT WORKING
SOLIDIFICATION
DEOXIDATION
REFINING
MATRIX
Lath Martensite
Ni: Cleavage Resistance
Co: SRO Recovery Resistance
STRENGTHENING DISPERSION
(Mo,Cr,W,V,Fe)2Cx
(Nb,V)Cx
Avoid Fe3C, M6C, M23C6
GRAIN REFINING DISPERSION
d/ f
Microvoid Nucleation Resistance
AUSTENITE DISPERSION
Stability (Size, Comp.)
Amount
Dilatation
GRAIN BOUNDARY CHEMISTRY
Cohesion Enhancement
Impurity Gettering
STRENGTH
TOUGHNESS
HYDROGEN RESISTANCE
PERFORMANCE

Hierarchy of Design Models



Computational Labs: MSc390 Materials Design

Lab 1. CES Ashby Materials Selection Software:
Formulating Design Objectives

Lab 2. TCW:
Basic CALPHAD Calculations

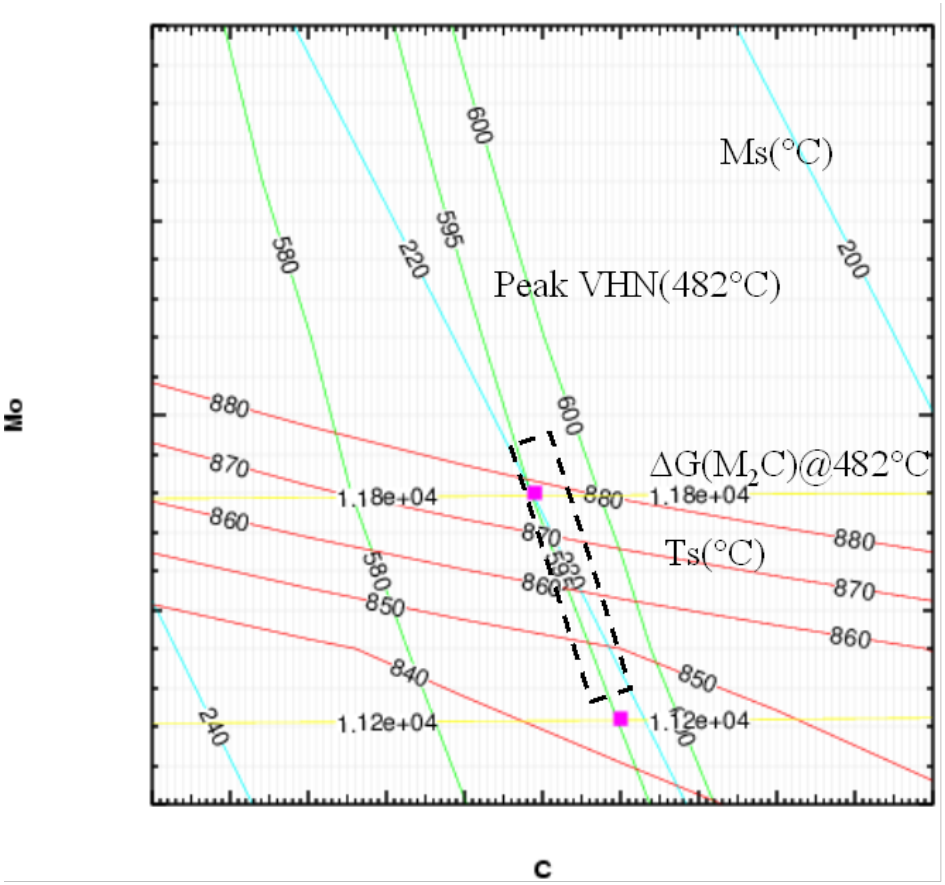
Lab 3. CMD1:
TCC-based Design Modeling

Lab 4. CMD2:
Model Integration in Parametric Design

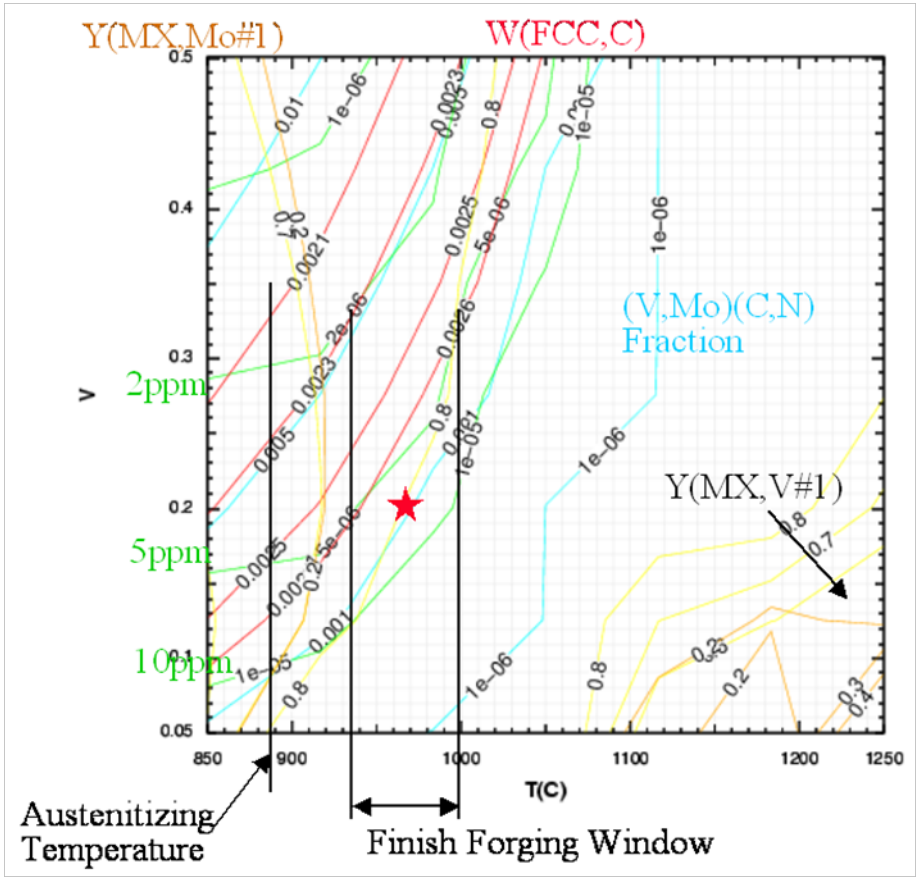
Lab 5. DICTRA/PrecipiCalc:
Dynamics Simulation

Example: Design Integration with CMD

Matrix + Strengthening Dispersion Design

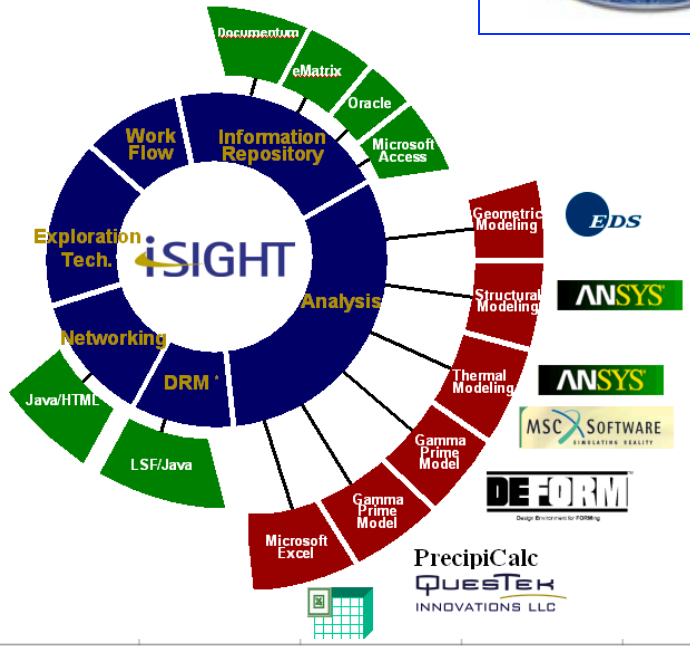


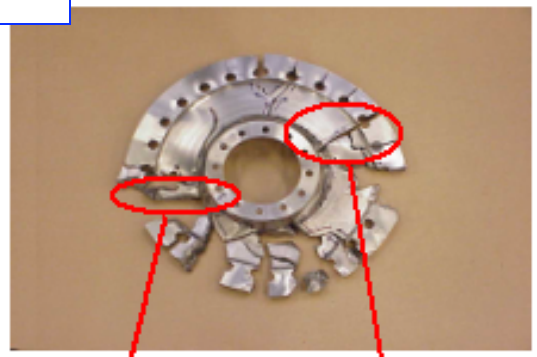
Grain Pinning Dispersion Design

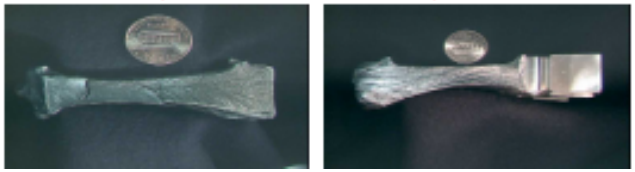


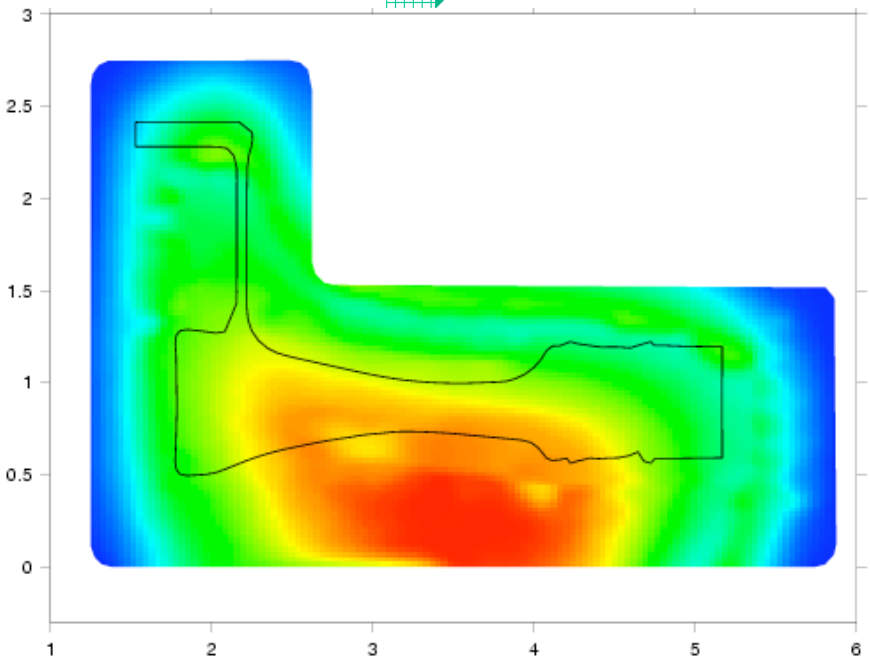
DARPA

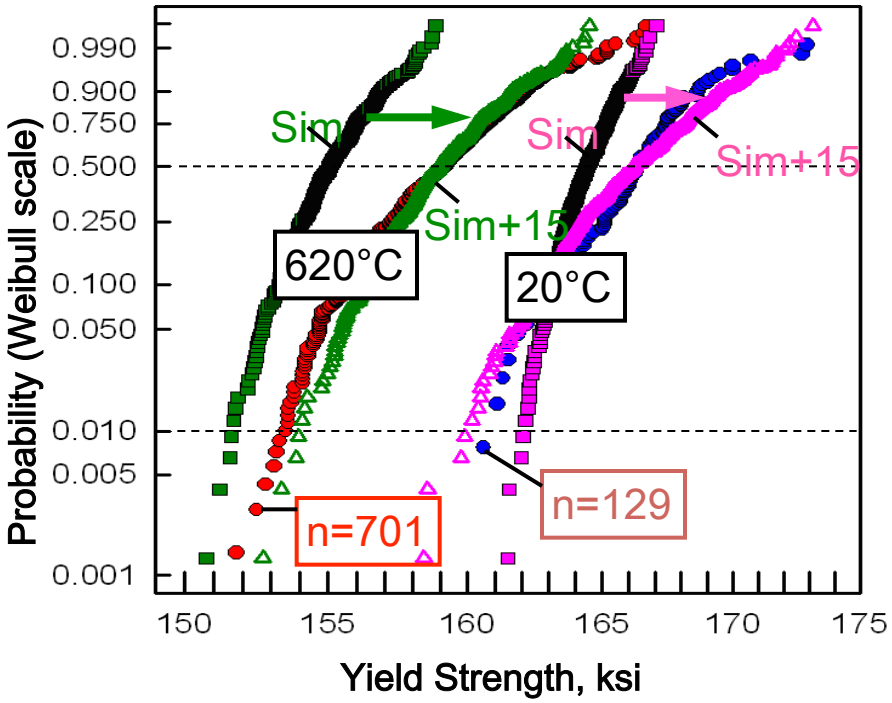
AIM
Accelerated Insertion of Materials



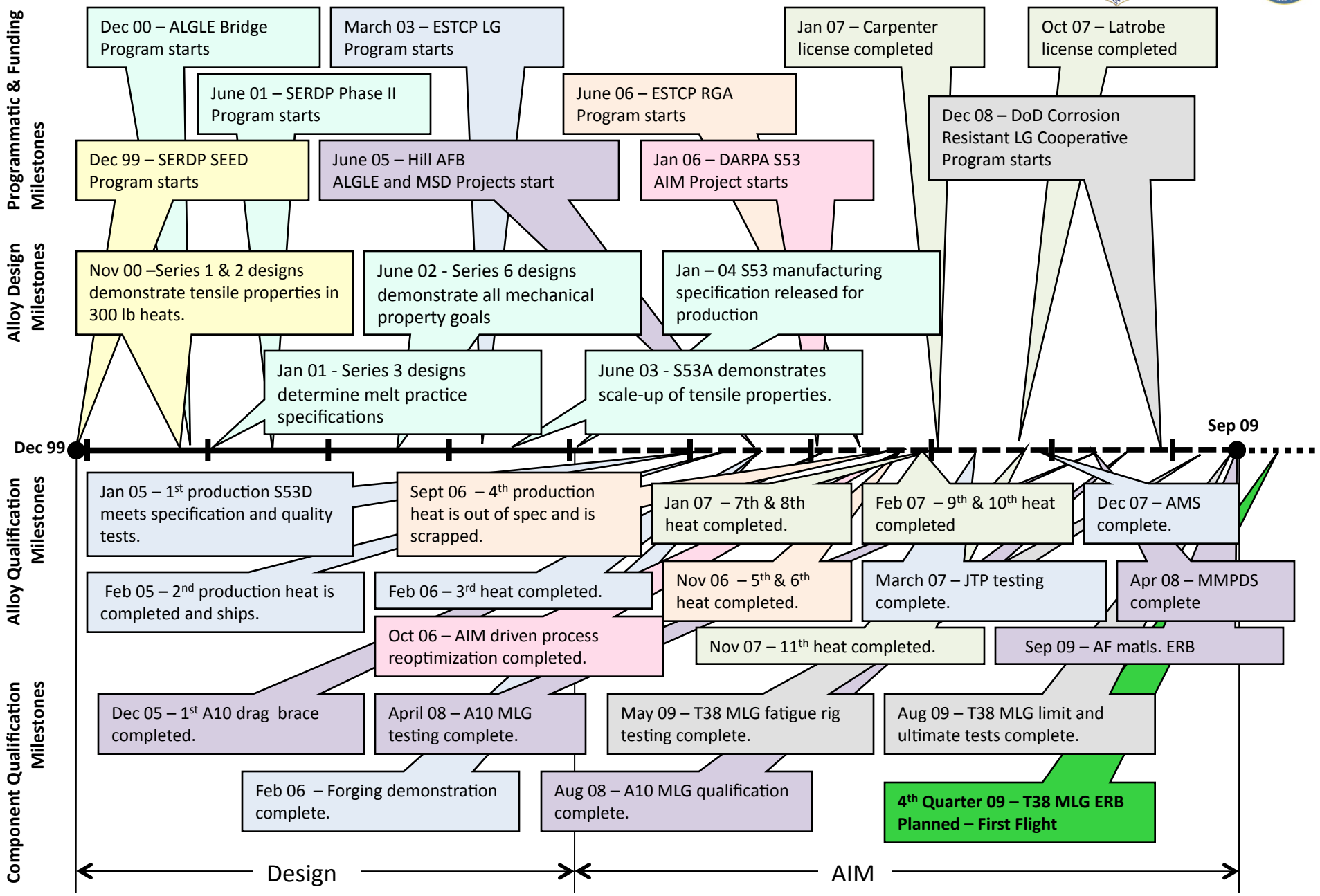








S53 Transition Milestones



MSc390 Materials Design

Spring 2010
Design Projects

I. **Civil Shield (EDC)**
Client: ONR, DHS, Trinity Rail
Advisor: Zack Feinberg

II. **Earthquake Steel (EDC)**
Client: ArcelorMittal
Advisor: George Fraley

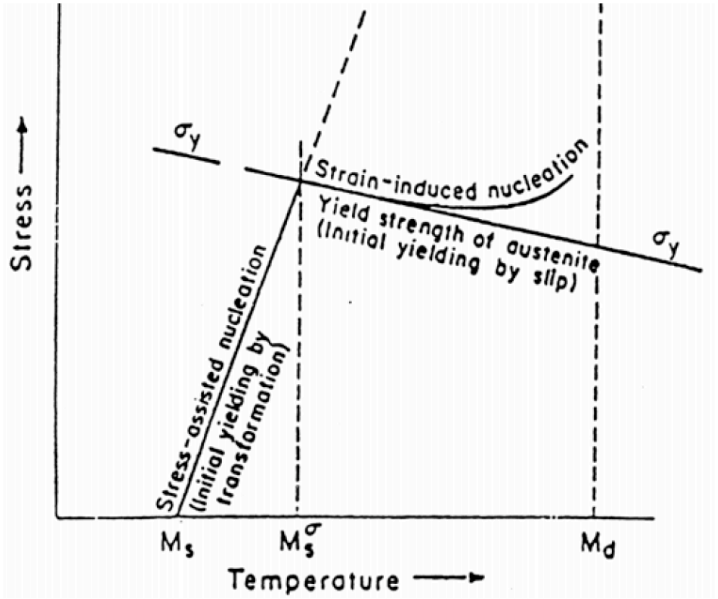
III. **TRIP800 Automotive Steel**
Client: ArcelorMittal, GM
Advisor: Jiadong Gong

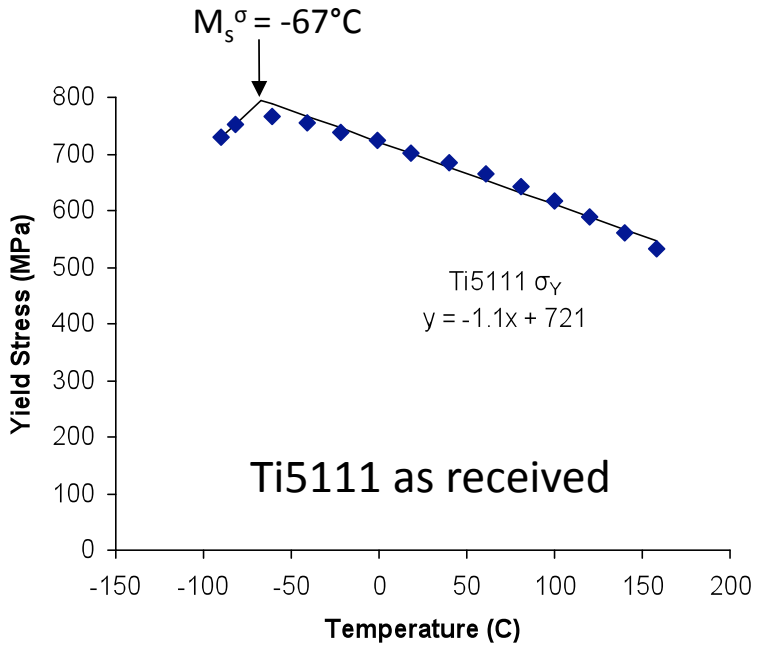
IV. **FSW Joinable Aluminum**
Client: Ford, Boeing
Advisor: Ryan Glamm

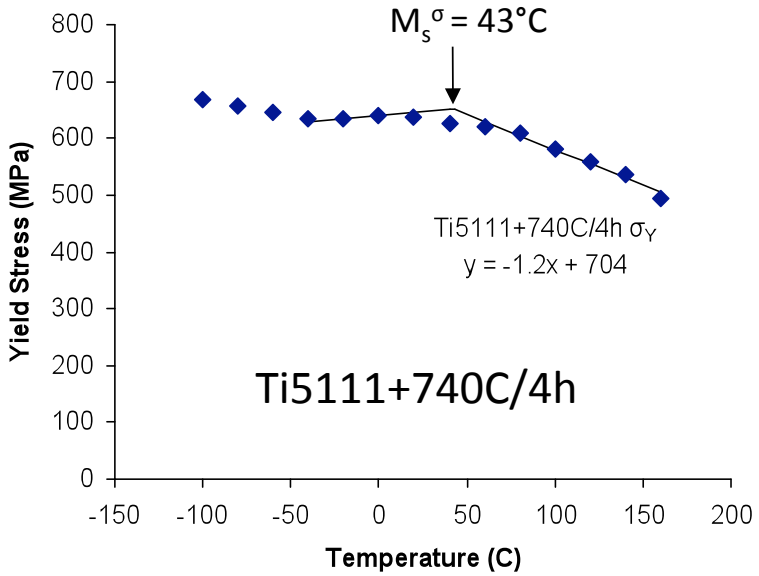
V. **HP Magnesium**
Client: ARL, GM, DOE
Advisors: Dr. Dennis Zhang
Stephanie Chan

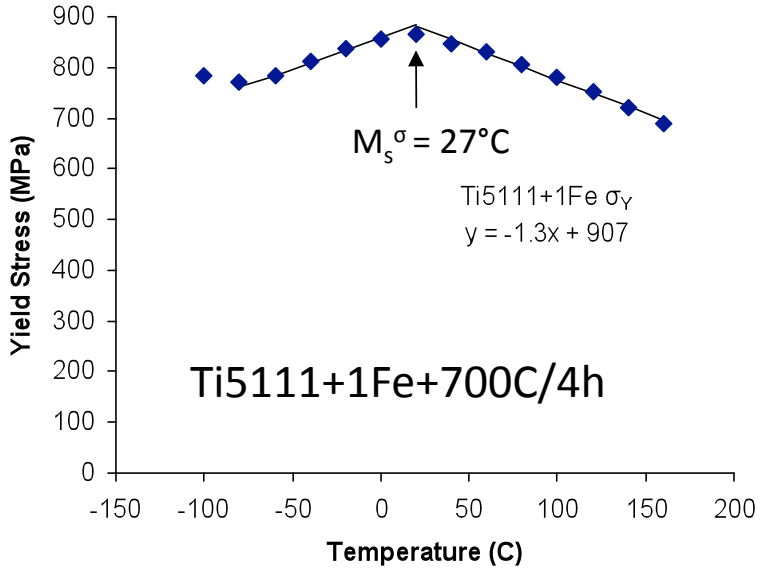
VI. **HP Shape Memory Alloy**
Client: GM, Medtronic
Advisor: Tengfei Jiang

TRIP Ti Experimental M_s^{σ} Calibration/Validation

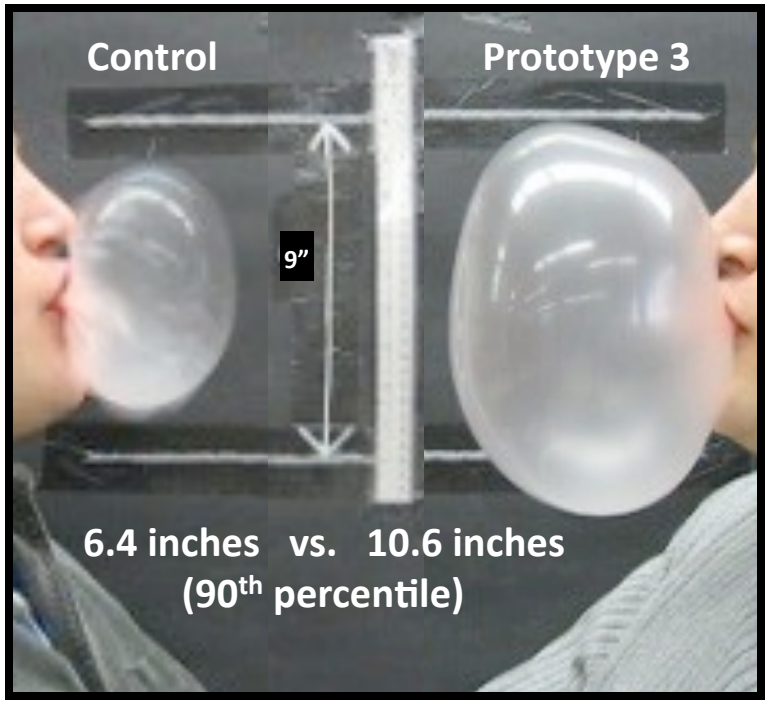


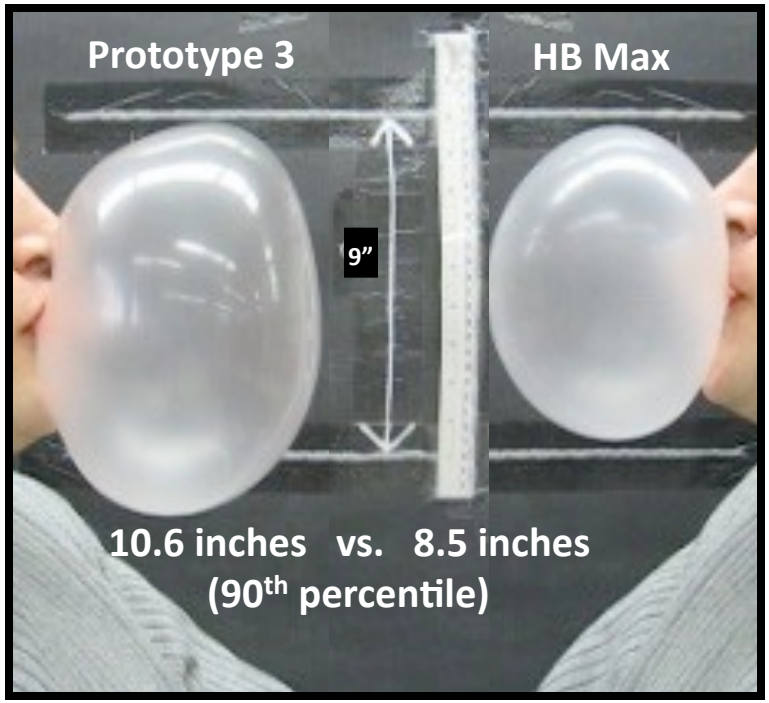






Applied Amorphensite: SuperGum (2008 Undergraduate Design Competition)



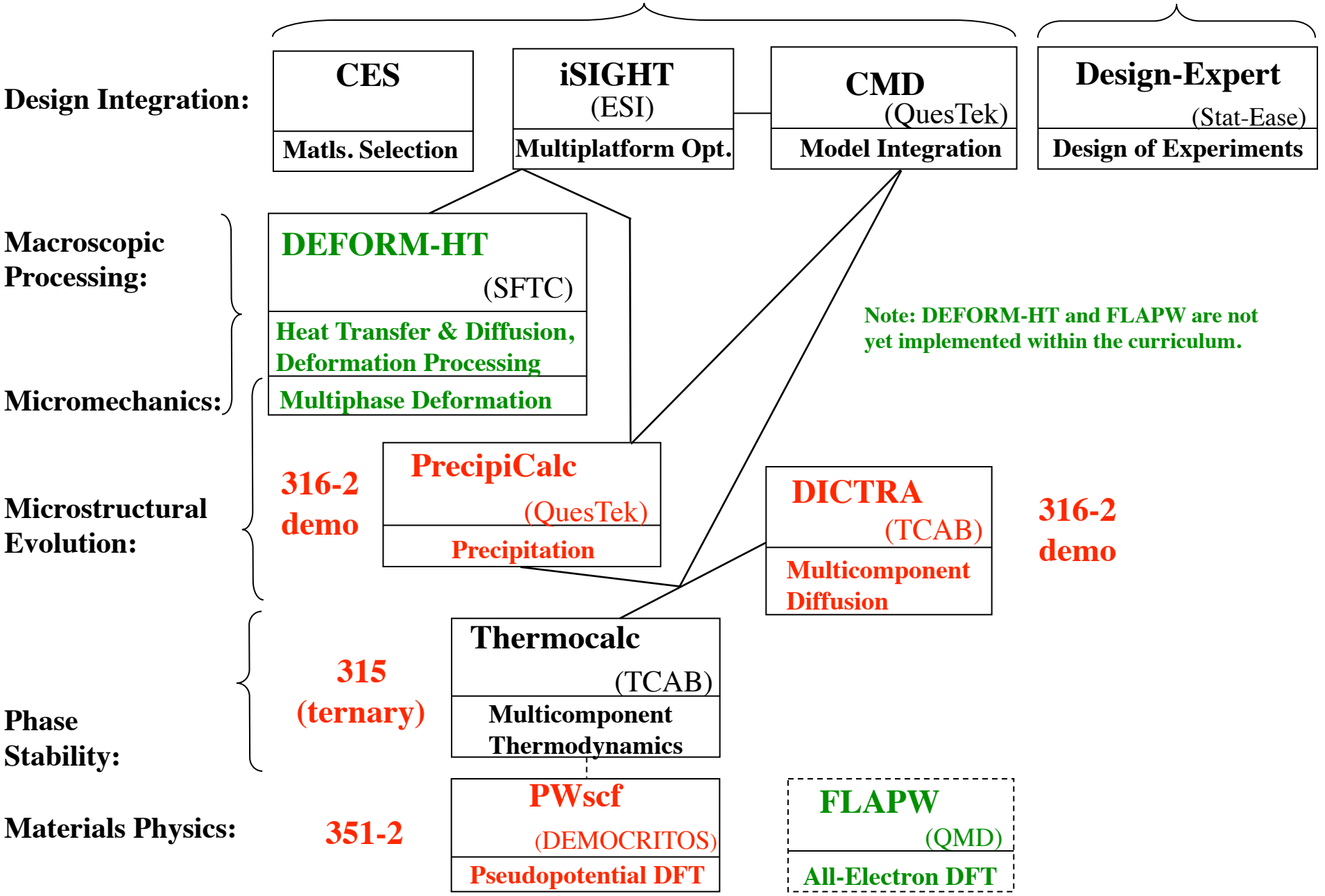


Computational Materials Science Tools

318 Mat Selection

390 Theoretical Design

391 Exptl Design



McCormick

Northwestern Engineering

NORTHWESTERN
UNIVERSITY

Our Vision: What an Engineer Should Be

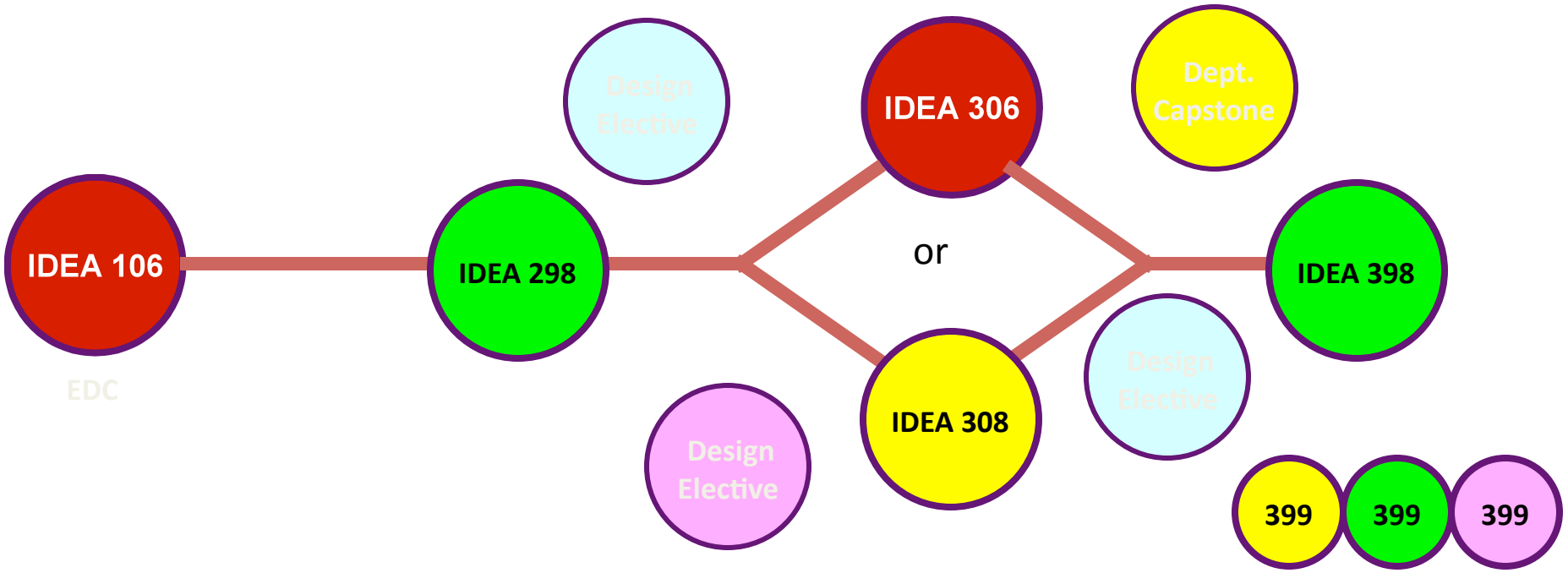
Technical checklist

- Gets the job done!
- Can understand and analyze the physical and mathematical underpinnings of his/her field
- Works effectively with both the abstract and the physical
- Works problems through to a complete and realistic solution

Creator of value

- Identifies and solves real problems within a social and economic context
- Works well in cross-disciplinary teams
- Adaptive learner
- Communicates effectively
- Responsible decision-maker

Design phases



CONCEPTUAL DESIGN

Needs discovery
Business planning
Concept generation
QFD
Prelim breadboard
Prelim vendor assess
Prelim specifications

EMBODIMENT DESIGN

User Feedback
Refine Specification
Alpha prototype
Design review
Vendor selection

DETAIL DESIGN

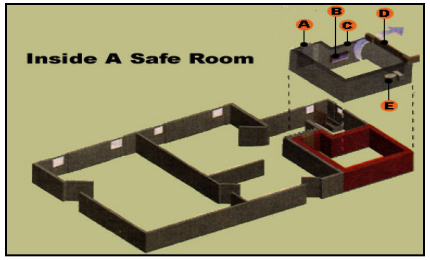
Working prototypes
User testing
Lab testing
Agency approval
Revisions
Vendor release

PRE-PRODUCTION

Tooling design
Tool revision
Pilot runs
Testing
Revision

Inspired by the HLB Process; courtesy Walter Herbst

Civil Shield Technologies



Affordable Civilian Anti-Terrorist Blast Mitigation

Team BlastTruss:

- Matthieu Chardon
- Michael McCarren
- Kelvin Chuu
- Stephanie Fruth
- Constance Lee
- Timothy Forbes
- Erick Haro
- Dennis Kouo

IDEA 298/398 WQ2004

Professors Olson and Herbst

Department of
Materials Science & Engineering
Robert R. McCormick School of Engineering and Applied Science
Northwestern University

idea

Terminator 4: Biomimetic Self-Healing Mg Composite

Team Members
Ben Mangrich
Charles Moore
Chiew Yen Thai
Kevin Lee
Mark Rocco

Team Advisor
Michele Manuel

Objectives:

- Design and test a magnesium-based alloy composite embedded with shape memory alloys that demonstrates crack closure and self-healing.
- Increase toughness of brittle materials through composite toughening: crack bridging and interfacial debonding.

Inspiration: To mimic both the structure-property relationship and spirit of biological materials to optimize composite design

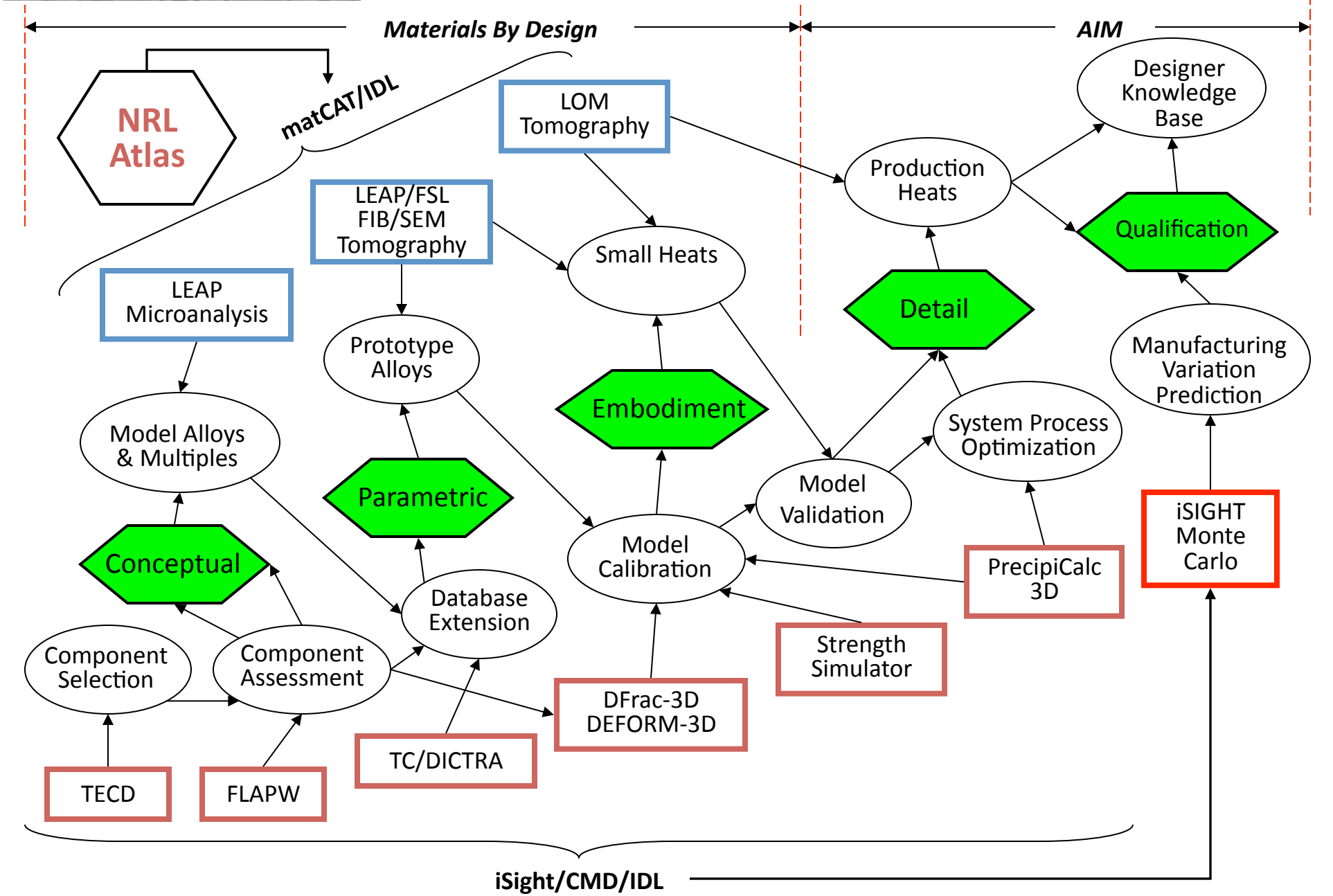
Predictive Science & Engineering Design (PS&ED)

Graduate Interdisciplinary Clusters in the Sciences and Engineering

Directors: Wei Chen, Greg Olson & Wing Kam Liu

- Discover, develop, and teach the common principles and techniques underlying PSED
- Engage faculty in collaborative, interdisciplinary research to pursue new funding opportunities
- Lay a foundation for future large-scale interdisciplinary research and education programs
- Provide an alternative intellectual community with "dual citizenship"
- Enhance the technical depth of design initiatives
- Attract gifted and talented students

Design Integration



The New Materiallurgy
- Shifting the Core

Descriptive Science	→	Predictive Science
Exploration for Discovery	→	Pioneering by Design
Empirical Measurement	→	Validated Simulation
Deterministic Science	→	Probabilistic Science
Reductionist Analysis	→	Systems Synthesis
Knowledge Generation	→	Value Creation
Materials	→	Concurrent Materials & Structures