So, What is CEDAR?

Georges M. Fadel, Prof. of Mechanical Engr. (fgeorge@clemson.edu)
Gregory M. Mocko, Assoc. Prof. of Mechanical Engr. (gmocko@clemson.edu)
Joshua D. Summers, Prof. of Mechanical Engr. (jsummer@clemson.edu)
Cameron Turner, Assoc. Prof. of Mechanical Engineering (cturne9@Clemson.edu)

Clemson Engineering Design Applications and Research

- Objective Today
  - Introduce you to Engineering Design Research
  - Introduce you to the CEDAR research group
  - Explain our expectations of students
  - Begin a dialog

What we are not doing today:

Hiring students

A Bit of History and Organization

- Formed in 2009 to create an INTEGRATED thriving research lab
  - 1992 CREDO (Dr. Fadel)
  - 2002 AID (Dr. Summers)
  - 2006 EIML (Dr. Mocko)
  - 2016 DICE (Dr. Turner)
  - Facts
    - CEDAR Alumni >> 170 students (faculty, industry, government)
    - Current CEDAR members ~35 students (MS, PHD, UG)
    - Publications >> 500
- Goal:
  - Our group's philosophy is to push the state of the art in design while graduating design practitioners, design researchers, and design tool developers. We realize that our main contribution in moving the field of design forward does not come from commercialization of our published research. Rather, our most important impact, our most valuable product, is our students.

We are one lab with four faculty mentors

(Janus^2)

Purpose of the Lab (Students' View)

- Help each other out
- Talking to each other
- Someone in the lab took the class before
- Pilot studies
- Write week – publications…
- Share technical skills – software,
- Feedback on research – bouncing ideas or reviewing
- Leadership opportunities
- Community service – future engineers,
- Social events –
- Presentation practice: -
- Design projects/testing project –
- Motivation
- More productive

Roots of CEDAR

- Scholarship
  - Knowledge
  - Courses
  - Feedback
- Professionalism
  - Respect
  - Communication
  - Feedback
  - Behavior
  - Leadership
- Community
  - Support
  - Collaboration
- Service
  - Outreach
  - Education
  - Participation

General Information

- Research Meetings
  - Weekly group meetings
  - Monthly Design Meetings
- Activities
  - Attend conferences (New York, Orlando, Montreal, Seoul, Las Vegas, Vancouver, Milan, Quebec City, Ancona, etc.)
  - Social functions (pool parties, bar-b-ques, happy hour, float trips)
  - Service/Outreach (elementary education, tutoring, workshops)
- Facilities
  - Lab/Office space in EIB **134, 135, 136, 253**, Ravenel, Assembly Center @ CMI
  - Computers, software, machining, testing, measurement, fabrication
- Different Advising Approaches
  - You must see the students and faculty to find out how we work with our students and groups

FADEL

CEDAR ACCOMPLISHMENTS

- Currently 4 professors, 30+ graduate students, impacting undergraduate education with projects and CI
- I graduated 19PhDs (with 2 current), 115 MS (3 current), 26 Honors students (1 current), CI (3 current)
- My students worked on:
  - Developing first “grammar” to describe functions
  - Developing Affordance Based Design
  - Making lasting contributions in Rapid Prototyping and pioneering of multi-material design and manufacturing
  - Solving the 3D layout optimization problem subject to multiple objectives
  - Developing approaches for meta-material design
  - Developing approaches for complex systems optimization – NTC and AMGA

CURRENT RESEARCH

- Current students work on:
  - Design Theory:
    - Design Evolution using Affordances (Honors student ongoing)
  - Design Automation: Additive Manufacturing
    - Imbedding Sensors in AM parts to affect the design (MS ongoing)
  - Design Automation: Metamaterials:
    - Designing metamaterial for Damping purposes (Ph.D. ongoing)
    - Designing a metamaterial track pad for Army Tanks (2 MS completed, 1 ongoing)
    - Designing Metamaterials for combined loading (MS ongoing)
  - Design Automation: Optimization:)
    - Optimal layout of hoses and wires in a 3D environment (Ph.D. ongoing)

Affordance Based Design

- Based on theory of affordances from perceptual psychology
  - “The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill” (Gibson)
- Why design? To change and create affordances
- Design is specifying an artifact that possesses certain positive affordances and does not possess certain negative affordances
- Designers must determine (as informed by users) what the desired and undesired affordances are

Observations

- Affordances do not surface until users experience the artifacts
- Virtual prototyping, physical prototyping are critical to evaluate the product affordances
- Designers attempt to eliminate negative affordances, and increase positive affordances
- Overall positive trend as a product evolves

- We have designed a web site for users to provide input and evolve a design: http://lateral-ceiling-648.appspot.com/
- Considering now cultural and social impacts on product evolution

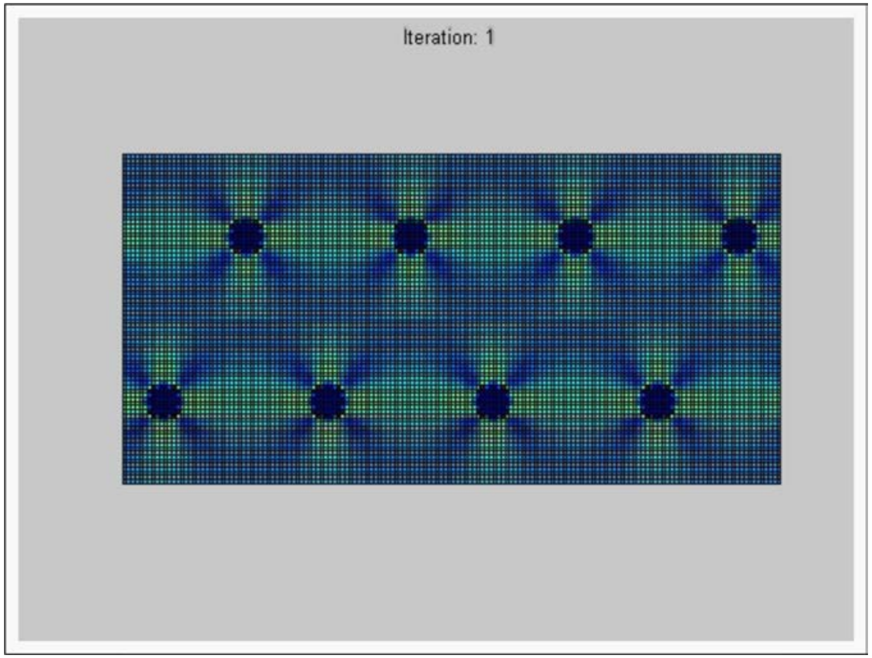
Meta- and Multi-Materials

- Meta-materials – designing and manufacturing an artifacts that has specific properties different from the properties of the base material it is made out of.
  - Uses topology optimization, finite elements, and additive manufacturing. Designed a shear band for Michelin Tweel, and a tank track pads for the US Army.
- Multi-materials – Designing and manufacturing artifacts whose functionalities are enhanced by placing materials at appropriate locations. (functionally gradients)
  - Uses topology optimization, finite elements, and additive manufacturing. Designed and built a flywheel using LENS process. Designed molds using multiple materials, and worked on several research topics: Multi-material representation, process modeling, and material characterization.

Shear Layer Metamaterial

Designing a shear layer made of an elastic material (PVC, Aluminum or steel), that has the same shear stiffness as rubber.

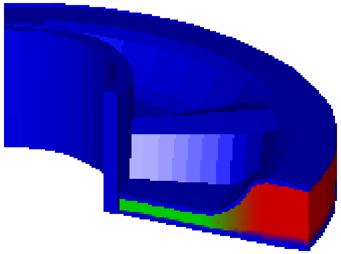
Purpose is to not lose heat due to hysteretic behavior when the object is under repeated deformation



Multimaterial Modeling

❑ Heterogeneous Objects (HO)

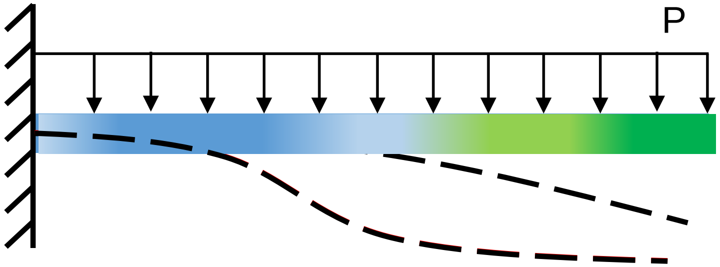
- Also called functionally graded materials or FGM



Heterogeneous flywheel [Morvan2001]

❑ Advantages of HO

- Mechanical properties (hardness, strength, …)
- Chemical properties (corrosion resistance, …)
- Biocompatibility
- Appearance
- Others



Projects for students

- **Metamaterial** design for tank track pads – Abaqus - (Army) (MS, Ph.D.)
- **Multimaterial** representation – Voxels, Octrees, Voronoi, … (Ph.D.)
- Boundary conditions resolution for snap through composites (mathematics, Ph.D.)
- Snap-through composites design (MS, PhD)
- Innovation trigger (MS)
- Extracting Affordances from Amazon reviews (w French team) (MS)
- Prioritizing **Affordances** – Does it affect design results? (MS)
- Use of Virtual Reality for **Affordances** elicitation – with IE - (MS)
- **Multi-criteria** Network Target Coordination optimization (Ph.D.)
- **Packaging** optimization for shipping.(MS)

What am I looking for?

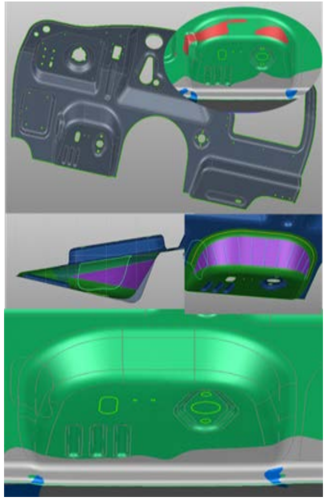
- Students eager to contribute to the field
- Motivation, curiosity, thirst to learn
- Dedication, hard work
- Goal driven, will publish, go to conferences
- Students who will eventually teach me

MOCKO

Research Topics

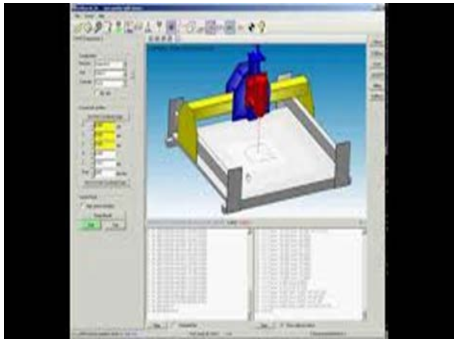
- Model-based systems engineering
- Digital thread of design information/knowledge
- Product life-cycle management
- Sustainability in manufacturing
- Representation of requirements knowledge and mining of information
- Early stage design creativity
- Distributed realization of complex systems
- Large data mining and crowdsourcing for requirements and functional analysis
- Energy expenditure and recovery during physical activity
- Modeling and simulation of single point incremental forming

Single Point Incremental Forming



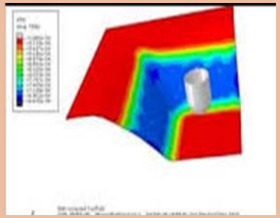
Generate SPIF CAD Model

1. Generate G-code

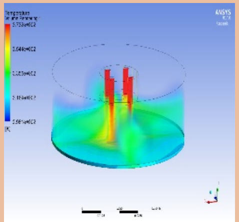


G-code

2. Use G-code tool path to generate simulation path



Transient Structural



Transient Thermal

ANSYS Simulation

3. Use simulation results to modify G-code toolpath and obtain desired shape

4. Once desired tool path is determined and verified by simulation part can be formed

Part Formation

Real Time Power Monitoring

Mocko Research Approach

- Students must
  - be inquisitive and explorative
  - take ownership for their research
  - must collaborate, argue, discuss, and defend
  - Be ethical
  - be passionate and excited about research

1. Slowly read current research.
   - Literature review
   - Know the current lit
2. Develop a research focus.
3. Develop a research plan.
4. Execute the plan.
5. Defend!

- Expect iterations

I will provide opportunities – students must seek and leverage those opportunities

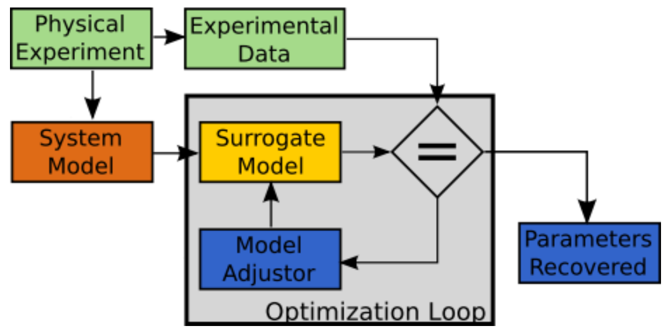
I would like to learn from you OR I would expect that you teach me

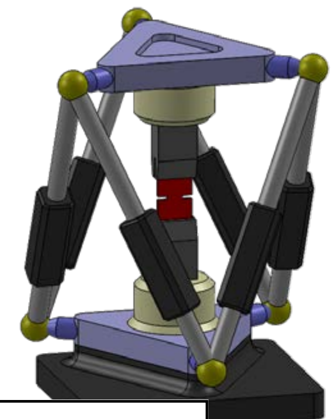
TURNER

Additive Material Testbed

NRL 66.3 Testbed

- Design and Build a desktop version of the NRL 66.3 6-DOF testbed specifically for additive material testing using surrogate modeling to enhance processing



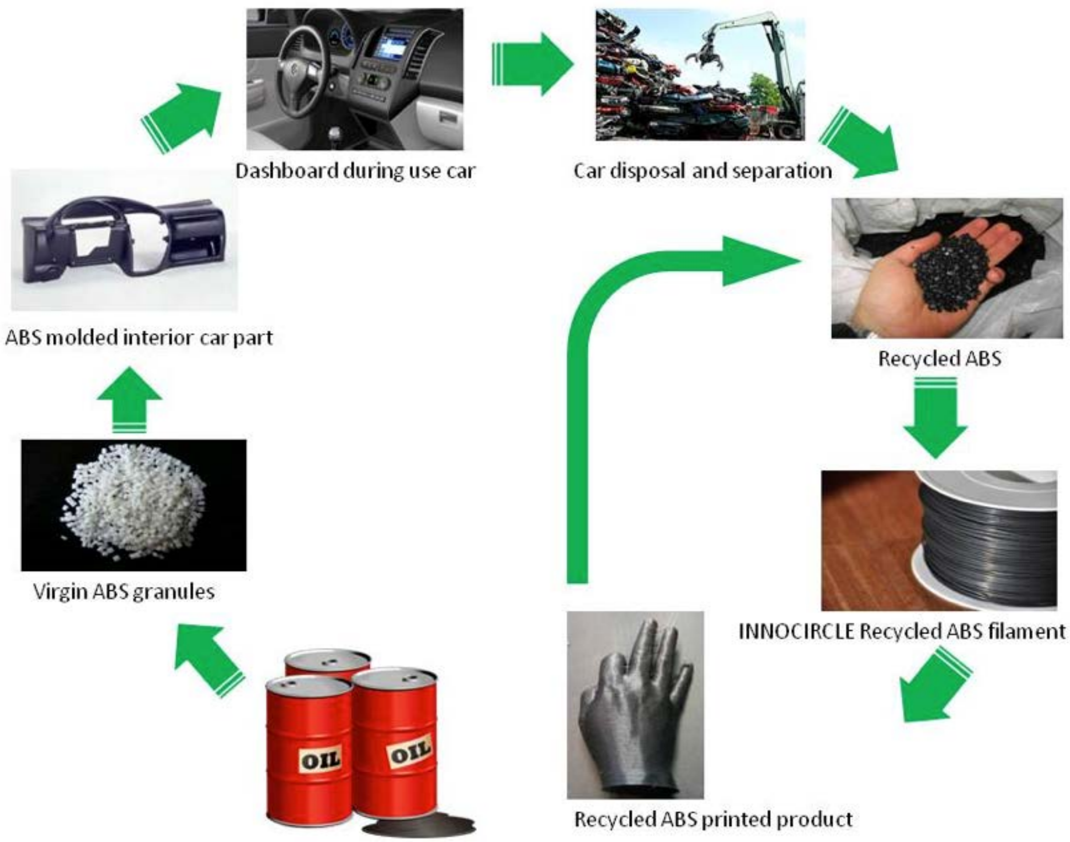


Advanced Material Modeling

- Current Material Models may not be adequate for modeling the meso- and microstructures in AM, therefore we are designing new modeling architectures.

AM Recycling / Doping Effects

- We make a lot of AM Parts, so…
- What is the impact on recycling some of the materials on the print properties?

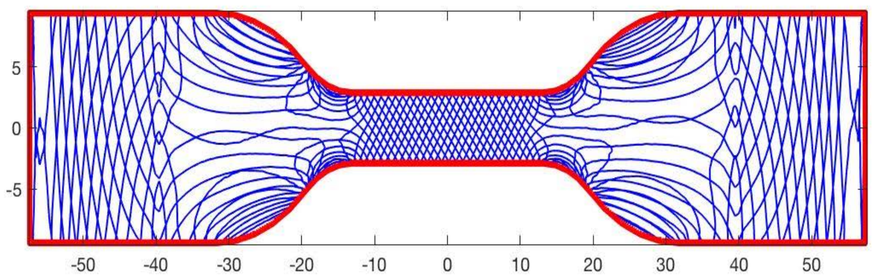


- While recycling fiber, we have the opportunity to introduce dopants, such as:
  - Virgin ABS/PLA
  - Color Agents
  - Nonpolymers
  - Carbon Black
  - Boron
  - Ferrous Materials
  - Nanoparticulates…
- These dopants may
  - Restore/Maintain mat'l properties
  - Introduce new desirable properties

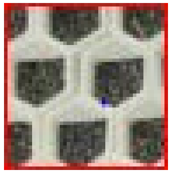
Advanced Material Modeling

- FEA may not be a suitable constitutive model for AM
- Typically composite materials are represented as homogeneous solid elements with differing stiffness along major and minor axes
  - The internal structure of 3D printed parts may not be well suited to this homogenization
- Other constitutive models, particularly DEM or hybrid FEM-DEM methods may be superior choices
  - Model can be constructed directly fr 3D printer's G-code
  - Superior computational performanc in domains exhibiting fracture or delamination

Implicit Infill Patterns and Mesostructures

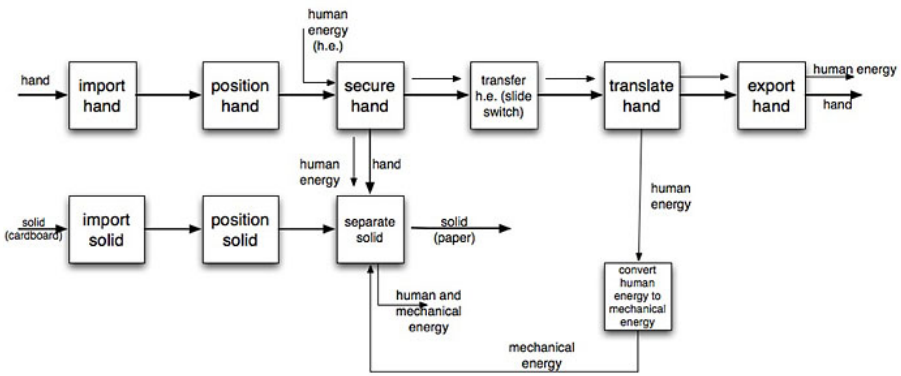


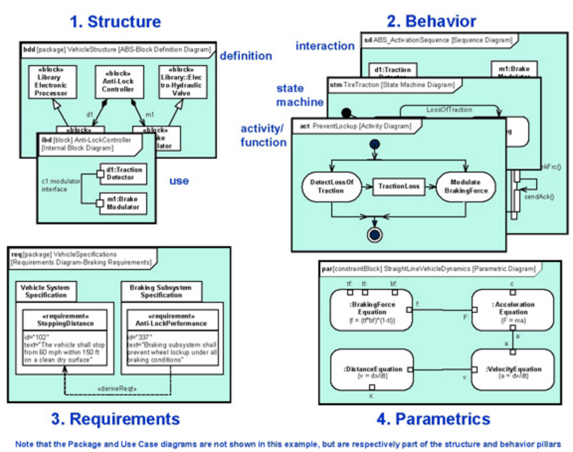
- We can build an implicit model of a part, and use that to apply virtually any functional infill pattern to customize the part properties by controlling the infill and mesostructures

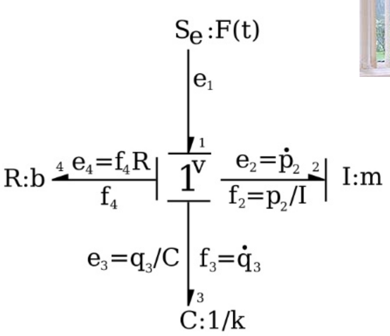


- Just need to figure out how to solve the inverse problem going from desired properties to correct infill and mesostructure

Abstraction in Design-by-Analogy



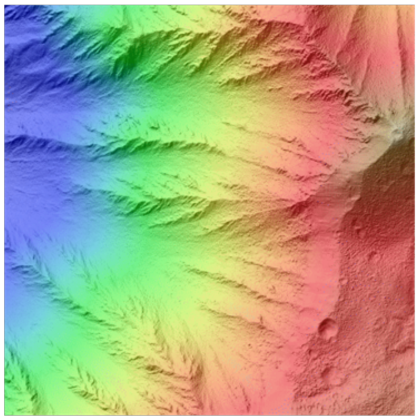




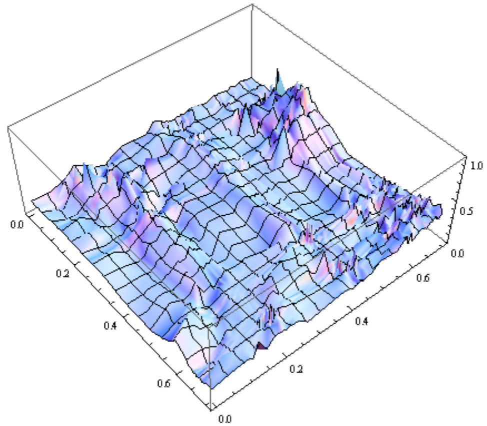
- Can we find design analogies with a computer?

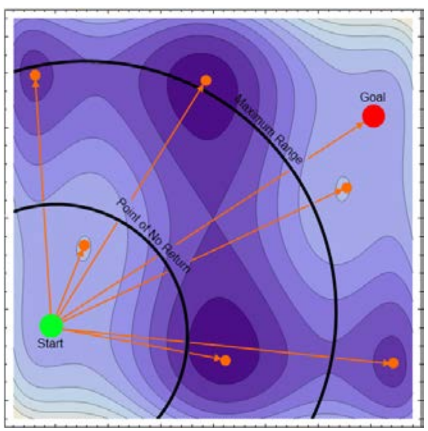
Heterogeneous Robotics

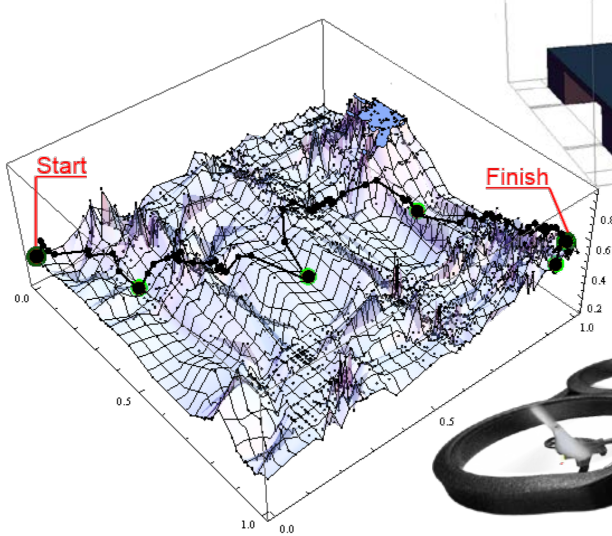
Original NASA Image



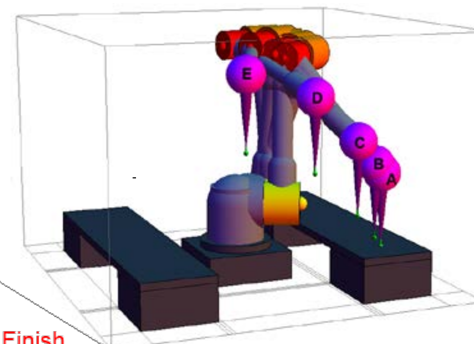
Metamodel

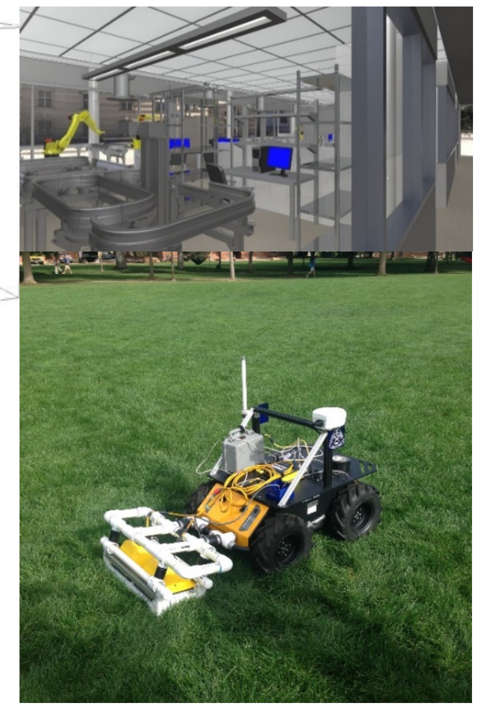






- Use Surrogate Model based optimization and Decision Making algorithms to make intelligent decisions

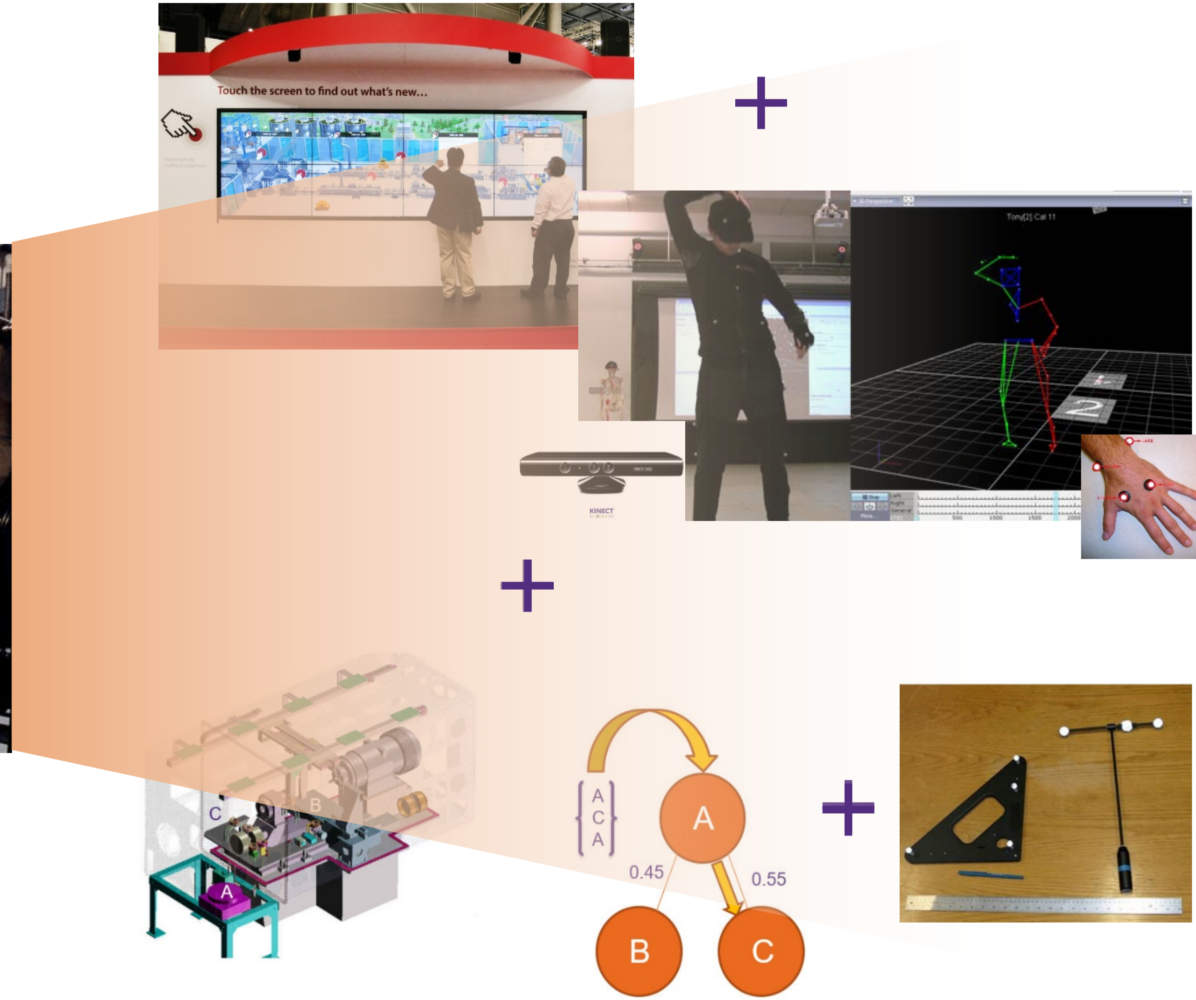




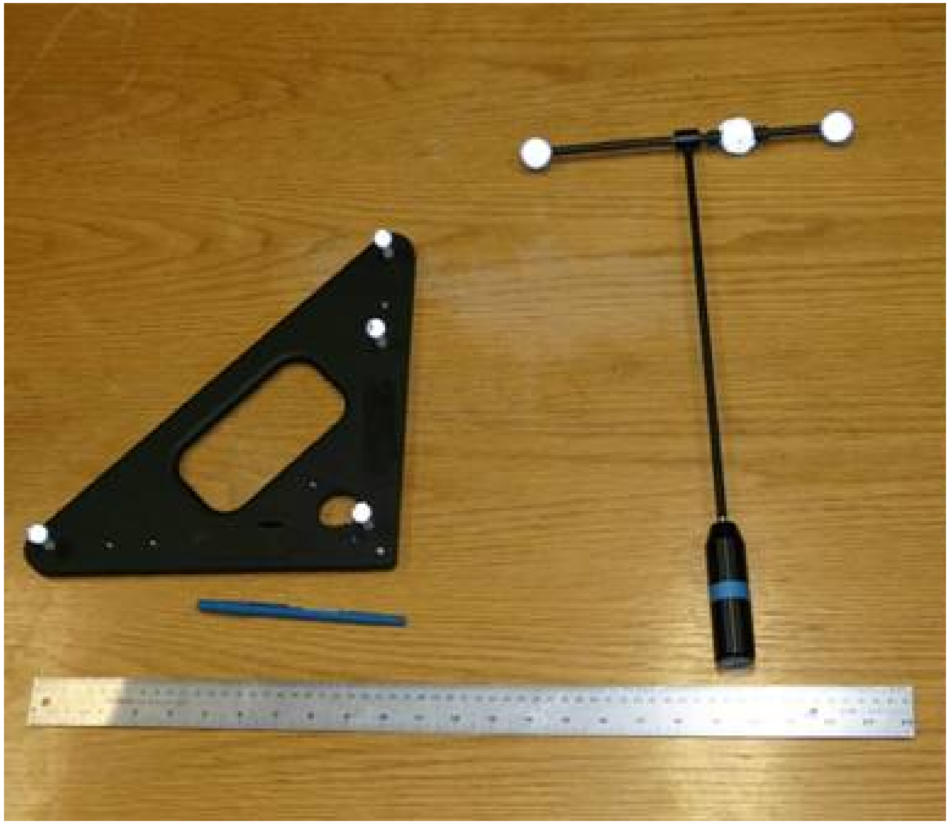
RAMR – Robotics And Mixed Reality Interface

- DOE Proposal with UT-Austin and UCLA (Pending)

Now

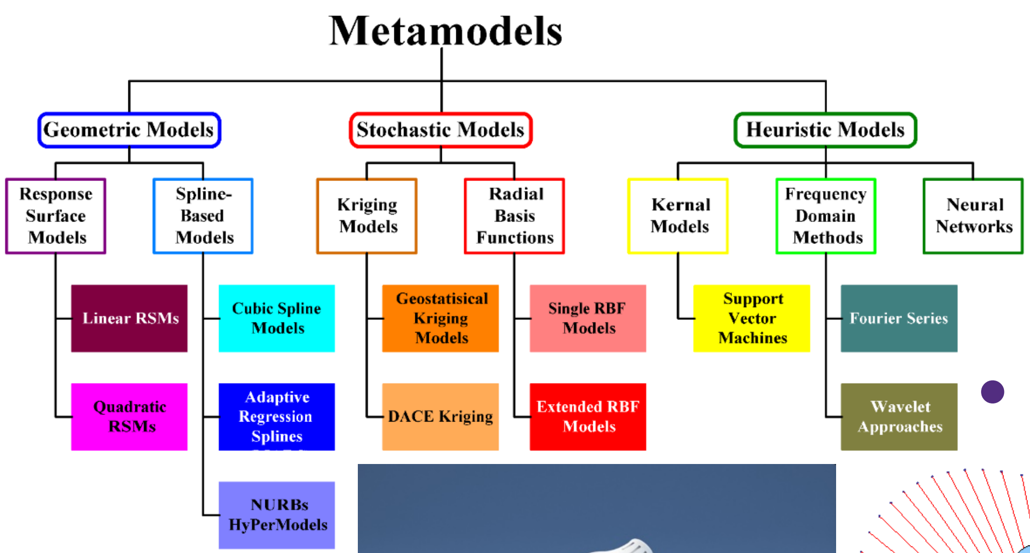


The Clemson Part – Virtual Props

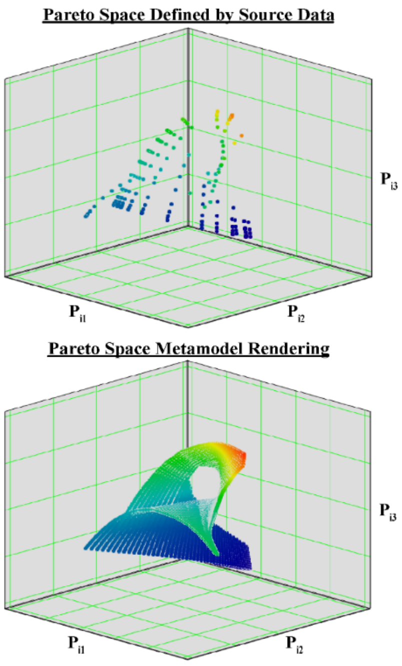


Surrogate Models

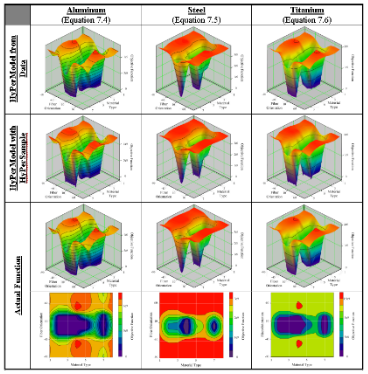
- Surrogate Models
  - Models of Models
  - Metamodels
  - If you cannot model the exact "thing" – model something *close*



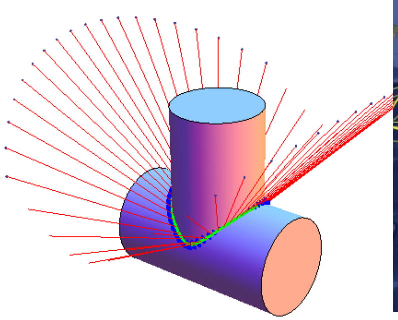
- Data Acquisition & Model Fitting

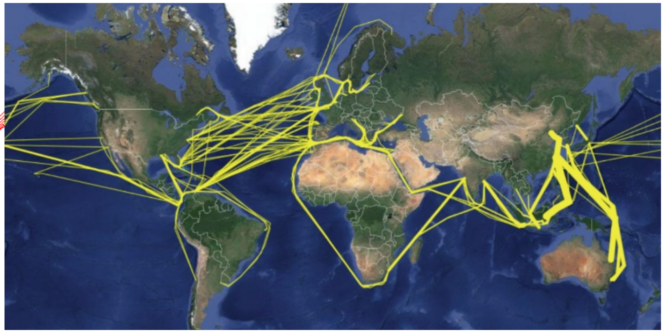


- Model Analysis



- Optimization via Surrogates





Collaboration

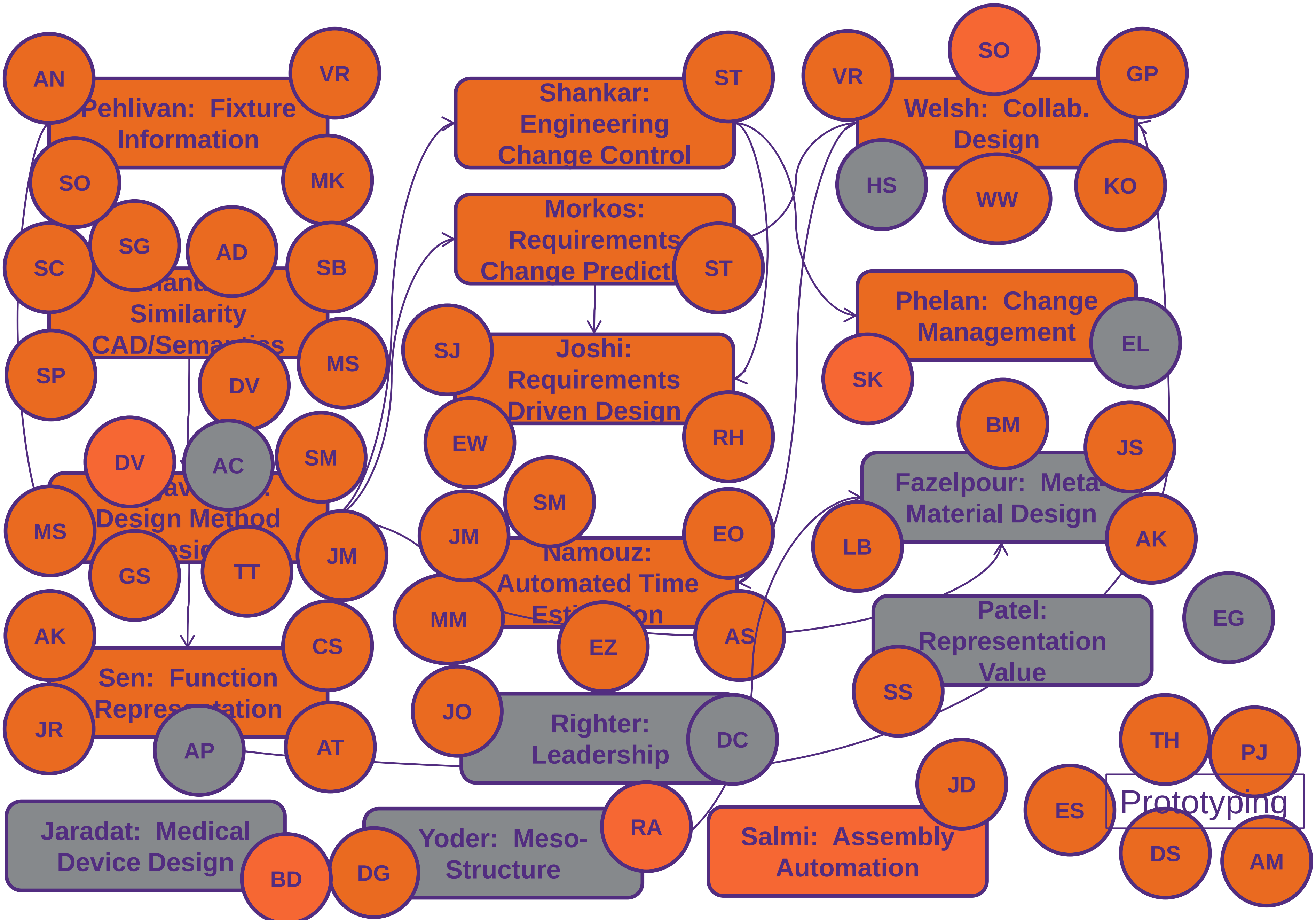
- Students must be inquisitive and explorative
- Students should take ownership for their research
- Students must collaborate, argue, discuss, and defend
- Approach
  - Design studies of users and tools
  - Development of tools (software, methods, etc.)
  - Must be practically rooted in engineering and science
  - Simulate – but demonstrate via application
- Students must be passionate and excited about research
- I will provide opportunities – students must seek and leverage those opportunities

SUMMERS

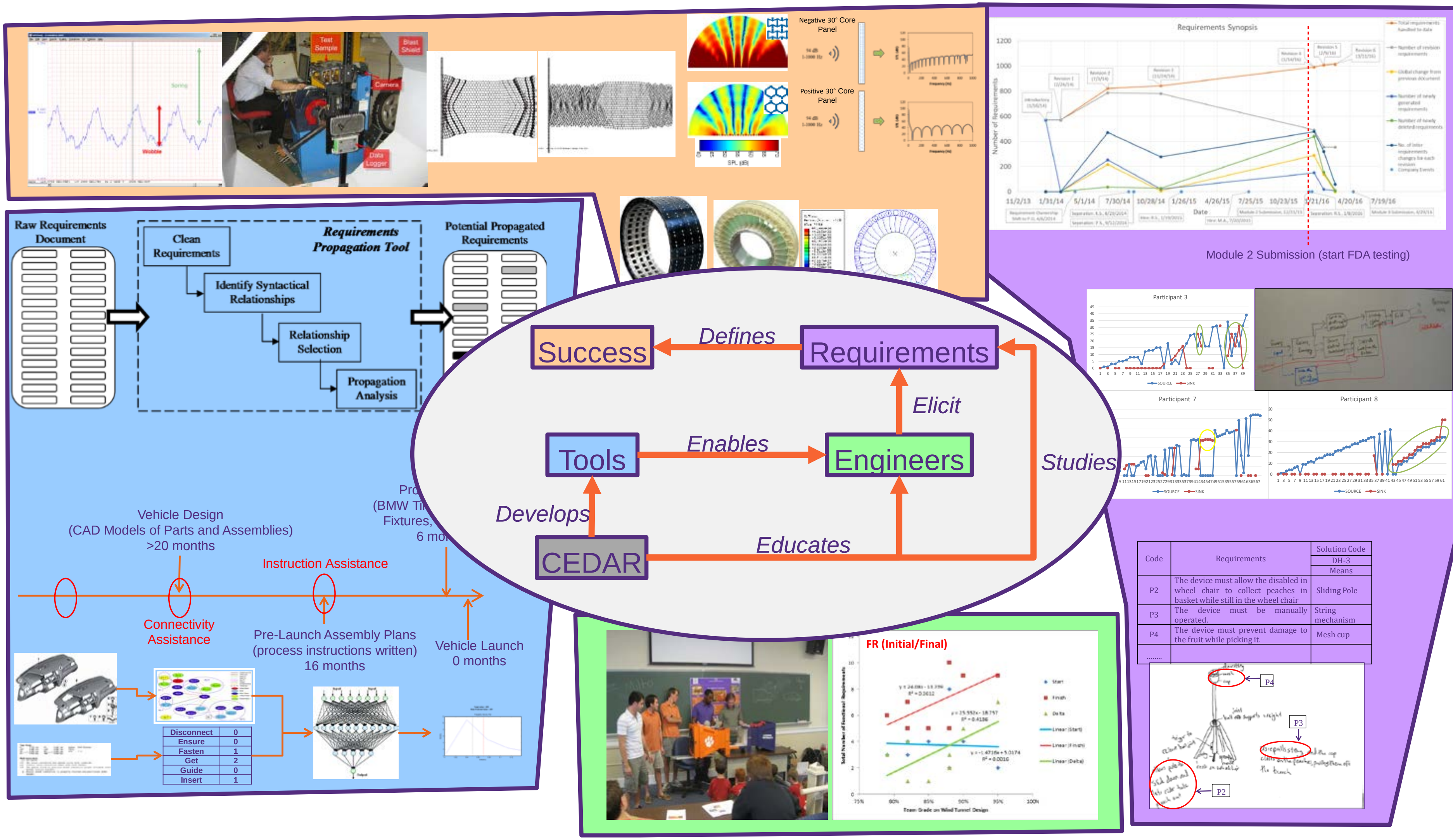
Micro CV

- PHD from Arizona State University (Prof. Jami J. Shah)
  - Design Automation Support for Embodiment (parametric/geometric)
  - Design Exemplar (next evolution of features; CAD Query Language)
- MS from University of Missouri (Prof. Alley C. Butler)
  - Feature Based Design of Submarines in VR (conceptual design)
  - Interned at Naval Research Lab (VR Lab)
- Clemson University
  - Assistant (2002-2008), Associate (2008-2012), Professor (2012-present)
  - Director of Graduate Studies (2014-); Assistant to the Dean for Minority/Academic Initiatives (2016-)
  - Graduated Students: 11 PHD, 51 MS, 4 Post-Doc
  - Current Students: 5 PHD, 9 MS, 1 PHD jointly advised in INP-Grenoble
  - Publications: 95 journals, 223 reviewed conferences, 4 patents
  - Funding: $8.9M (Summers' Portion: $3.7M) (57 proj.); **Active: $1.4M (Summers' Portion: $0.6M)**
    - **SC DOC – Augmented Reality**
    - **BMW – Cognitive Load Measurement**
    - **IFAI – Meta-modeling of Tent Loads**
    - **Honda – DFM Joining Advisory System (pending)**
    - **NSF – Function Modeling**
    - **NSF – Requirements Change Propagation**
  - Student projects: >> 400 teams on > 100 industry sponsored projects
  - 2 international awards, 4 regional awards, 4 University awards

Research Defined by Students*



Design Research



Current Projects/Research

- Funded Projects
  1. NSF: Requirements Evolution (student: A. Patel; collab with FIT)
  2. NSF: Function Modeling (student: H. Stidham; collab with Psychology)
  3. BMW: Cognitive Load Measurement during assembly (student: **pending**; collab with G. Mocko)
  4. IFAI: Meta-Modeling of Non-Certified Tents by Design of Experiments (students: MSE; collab with V. Blouin)
  5. Honda: Joining Advisory System (student: **pending**; collab with L. Mears)
  6. Department of Commerce: Augmented Reality Based Vehicle Inspection (student: **pending**; collab with L. Mears)
- Student defined research
  1. PHD: Leadership in Design Teams (**J. Righter**)
  2. MS/PHD: Function Modeling Behavior Patterns (**A. Patel**)
  3. MS: Collaboration in Design (**D. Chickarello**)
  4. MS: Personality Convergence in Design Teams (**H. Stidham**)
  5. MS: Morphological Charts (**A. Chawal**)
  6. MS: Design Enablers in Industry (**E. Gendreau**)
  7. MS: Designing Excess (**E. Lambert**)
  8. PHD: Modeling of Meso Structures with Micro Polar Theory (**M. Yoder** w/ L. Thompson)
  9. PHD: Spinal Injury Modeling (**M. Jaradat** w/ M. Harman)

Summers Research

- Approach
  - Empirical Designer Studies
  - Protocol Studies
  - Case Studies
  - Tool Development
- Practice of Design is Central
  - Will work on multiple projects, including industry sponsored
- Diversity of Experiences is Developed
  - Want more items for your resume
  - I encourage volunteer activities
  - I encourage social activities
  - You will work with other students on their research and projects
- Student Owned Research
  - Students drive the research
  - Summers mentors
    - I will teach you how to do research by guiding, cajoling, pushing, questioning, joking, encouraging, prodding, showing, doing, correcting, …

NEXT STEPS

Next Steps

- Joining CEDAR depends on you
  - Speak with current students
  - Attend weekly meetings
  - Participate in activities
  - Understand yourself and your needs

- Will not consider new students who have not succeeded in all FOUR first semester classes
- Will not consider new students who are not proactive (this is YOUR research)