TRAnsformative DESign (TRADES)
Industry Day

2016-05-13

TRADES Agenda

- 8:30 -9:00 Defense Sciences Office (DSO) Overview: Bill Regli, DSO Deputy Director
- 09:00-09:15 Contract Management Office Brief: TRADES BAA Process; Michael Mutty, TRADES Contracting Officer
- 09:15-10:00 TRADES Overview: Jan Vandenbrande; TRADES Program Manager
- 10:00-10:15 Break
- 10:15-12:00 Proposer Capabilities Session
- 10:15-12:00 Government breakout
- 12:00-12:30 FAQ Answer session with attendees and government

TRAnsformative DESign (TRADES) Overview

Jan Vandenbrande
PM/DSO

TRADES Industry Day
2016-05-13

TRADES Industry Day Objectives

- Present TRADES BAA to community – convey expectations for program
  - Final briefing to be posted to the TRADES BAA site
- Promote collaboration and team forming through performer presentations
- Answer questions from attendees
  - Note cards passed to attendees, please write any questions on note card
    - If participating online, please email questions to TRADES@darpa.mil
  - Questions collected at 10:15 am
  - Initial responses discussed at 12 pm
    - FAQs will be published to the TRADES BAA site
    - Additional can be submitted to TRADES@darpa.mil following industry day

Theme: **How to design & build better and faster**

Where I am coming from:

- **Undergrad:** Vrije Universiteit van Brussel
  - Electrical Engineering : F(x) → Embodiment
  - Mechanical Engineering: F(x) ↛ Embodiment
  - Math matters
- **Graduate:** University of Rochester
  - Solid modeling: Laying the foundations of CAD
  - Thesis: Automated machining feature recognition
- **Unigraphics** (Siemens NX)
  - Metal machining
  - Advanced concepts
- **Boeing** (Applied Math)
  - 90s: Automated machining planning
  - 00s: Improve Boeing's design methods
  - 10s: Composite manufacturing

What's New:

DARPA DSO PM

- Goal: Solve major gaps observed in design
- Initial effort: Transformative Design (TRADES) Program

TRADES Objective

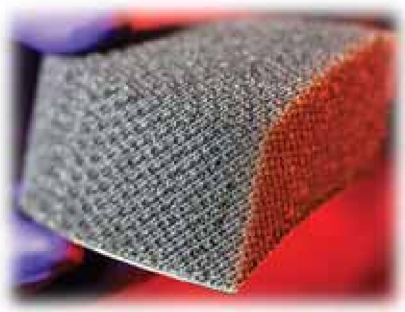
Transform design by exploring new math/algorithms to:

(1) Harness the tidal wave of new materials and fabrication methods that are coming our way, and
(2) Enable new designs that are unimaginable today.

Composites

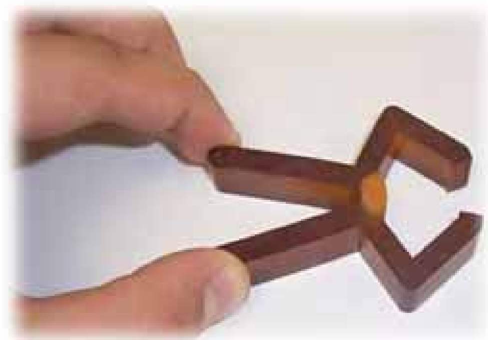
Personal picture

3D Printing

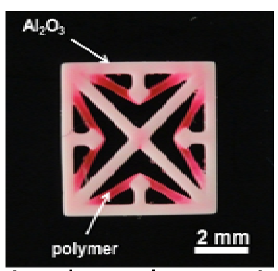


https://annual.llnl.gov/annual-2014/science

Multi-materials



Gupta@UMD
http://www.enme.umd.edu/~skgupta/InMoldAssembly.htm

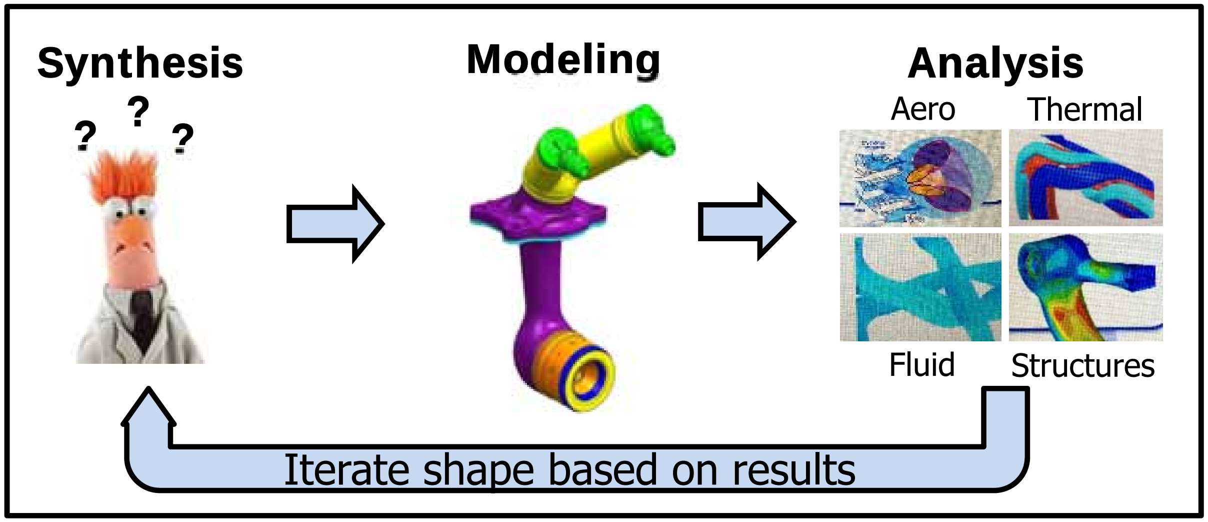


Negative thermal expansion

Super light weight structures

Conventional design processes are highly reliant on human expertise and legacy systems

Typical design process:

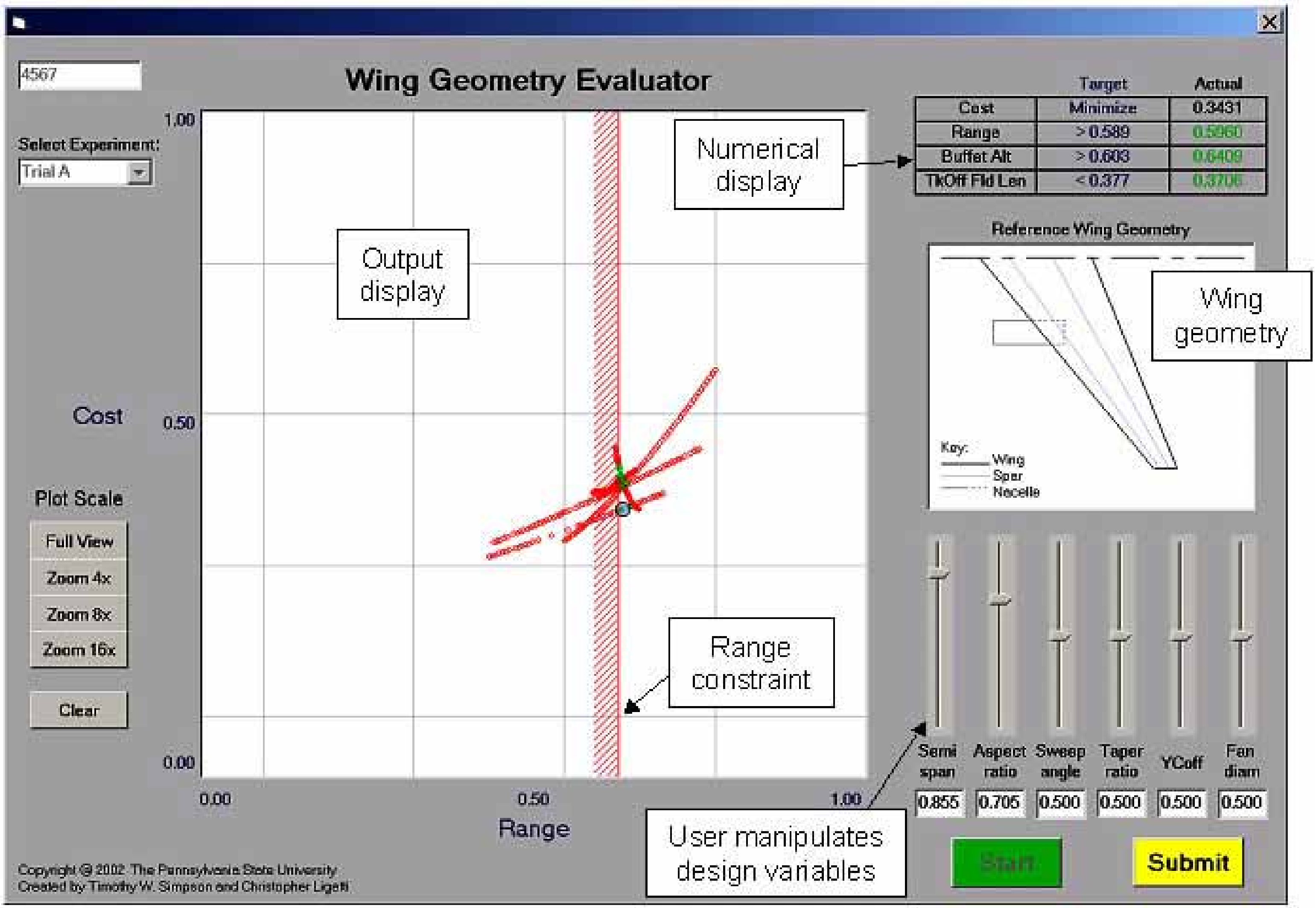


Challenges with advanced materials & manufacturing:

Synthesis	Design complexity exceeds human capacity
Modeling	Systems are not scalable to accommodate shapes with material
Analysis	Lack of interoperability and accuracy limits exploration

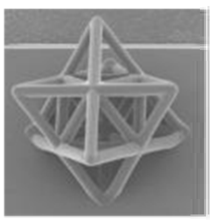
Design innovation is limited by human insight and lack of support from the design tools

Humans have limited capacity to reason in higher dimensions

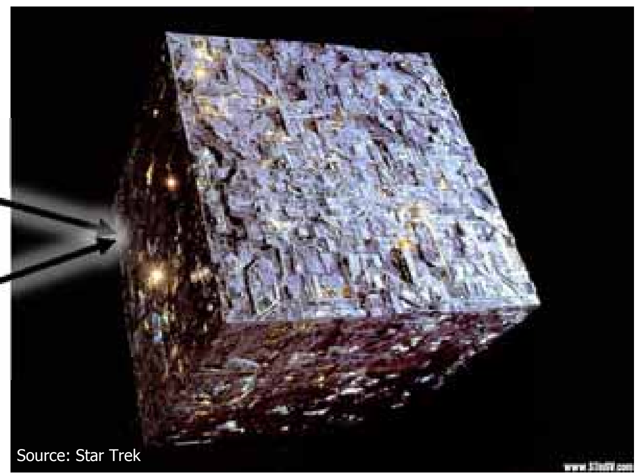


Source: Simpson, AIAA 2005-2060

We have reached the limits of our design tools



.01 mm



1 m

> 100,000 GBytes

RAM on most PCs: 8 GBytes

Interoperability hinders exploration

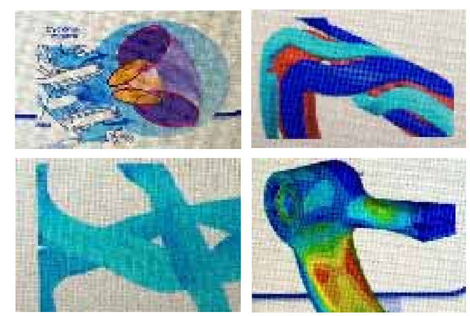
Notionally scaled by human effort

Modeling

30-70% of total effort[Sandia]

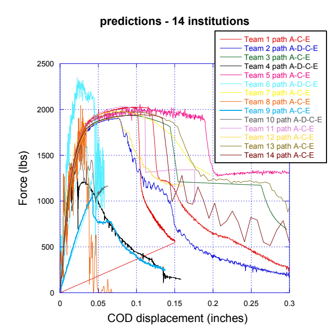
Analysis

Aero Thermal



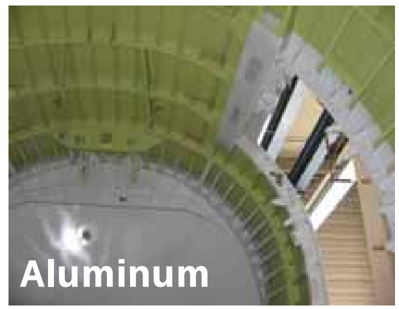
Fluid Structures

- Frequently requires human participation
- Conversion expert driven
- Results operator dependent



Consequence of limited human insight and lack of support from the design tools

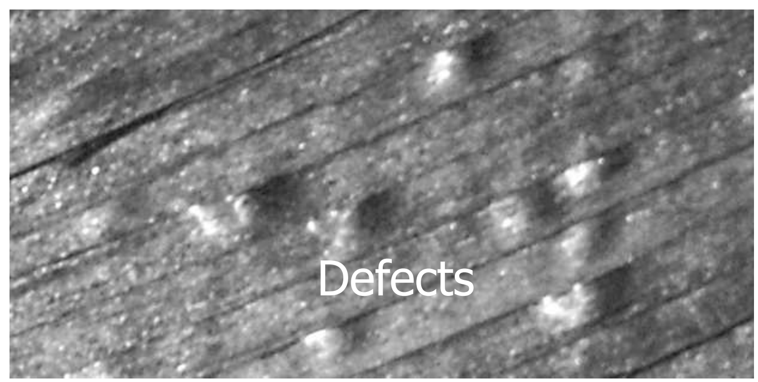
http://nautarch.tamu.edu/class/316/khufu/



https://commons.wikimedia.org/wiki/File:Airbus_A340_Int%C3%A9rieur_Fuselage_Arri%C3%A8re.JPG

http://www.airbus.com/newsevents/news-events-single/detail/the-first-a350-xwb-forward-fuselage-takes-shape/

http://www.compositesworld.com/articles/flying-high-on-composite-wings



Agnes Blom @ TU Delft

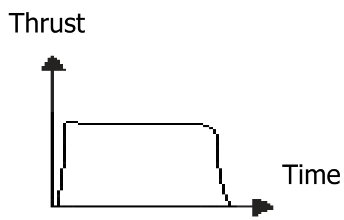
Enabling computers to manage the complexity that humans cannot

TRADES Vision: Computers are partners throughout the design process

Requirements →

Human

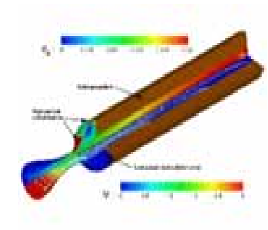
Describe the problem



Show me the options

Computer

Generate shape & material

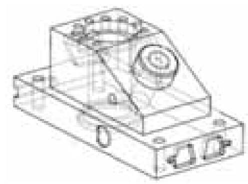


Find the best alternatives

TRADES will enable us to explore and discover entirely new designs

TRADES will explore and integrate new ideas

FA1: Modeling: Efficiently describe shape, material and their variations

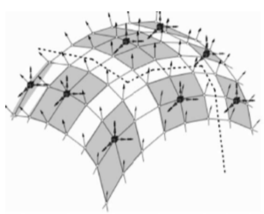


Explicit
Data centric
≤3D

→

Embedded physics?
Multi-resolution?
Functional/Generative?
≥3D?

FA2: Analysis: Compute physical properties directly & reliably



Discretization
Finite element analysis

→

Direct analysis?
Query based methods?

FA3: Synthesis: Generate and find the best designs

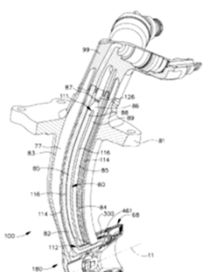


FIG. 3

Record

→

Optimization & Uncertainty?
Design as coding?
Evolutionary?
Machine learning?
Data analysis?

Seamless integration?

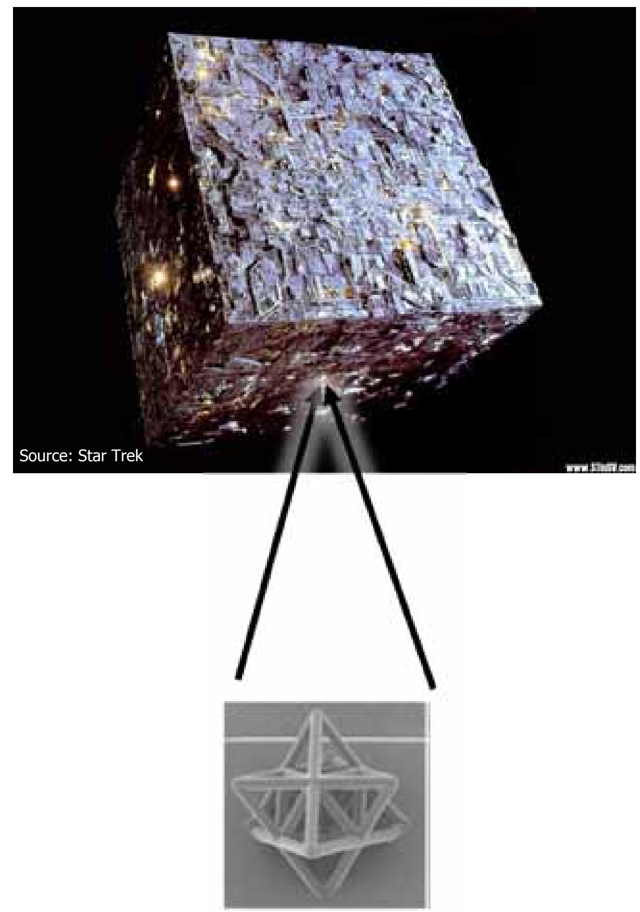
Focus Areas 1: Modeling

- Shape + topology + material + variability
- Scale span: ~0.01 mm to 100 m
- Support efficient computations
- Support modeling/editing operations
- Support generation of fabrication instructions
- Seamless interoperability with downstream processes

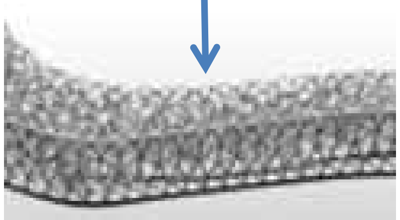
Focus Areas 2: Analysis/Computations

- Compute integral and differential properties of FA1
- Analyze/simulate with minimal or no conversion
- Propagate variability
- Maintain precision
- Speeds ≥ SOA
- Downstream needs: sensitivities

Mass? Thermal?



Focus Areas 3: Synthesis

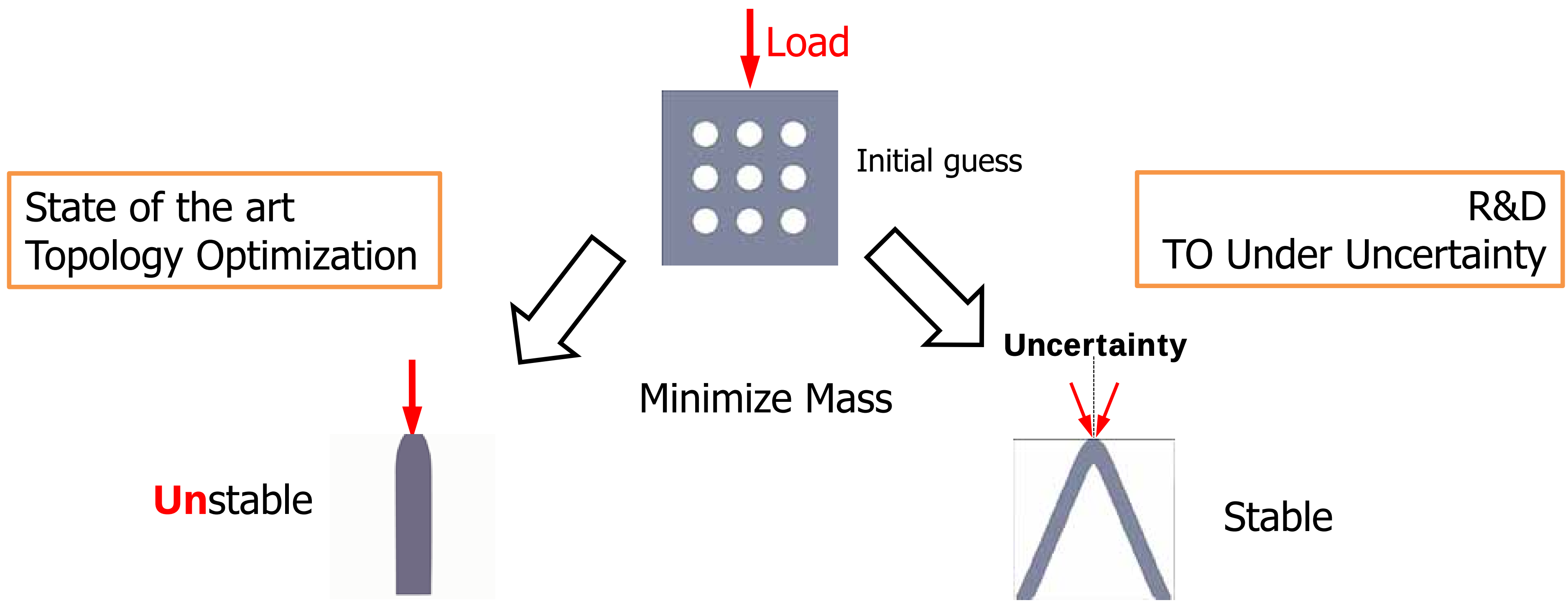


- Generate coupled shapes and materials given multi-physics and limits of fabrication technology
- Trade shape vs material variability
- Explore alternative design synthesis approaches
  - Generates optimized designs given requirements
  - Provide the seeds (species) for optimization (MDO)
- Find promising designs in complex design spaces
- Will it scale? How much?
- Leverage FA1 and FA2

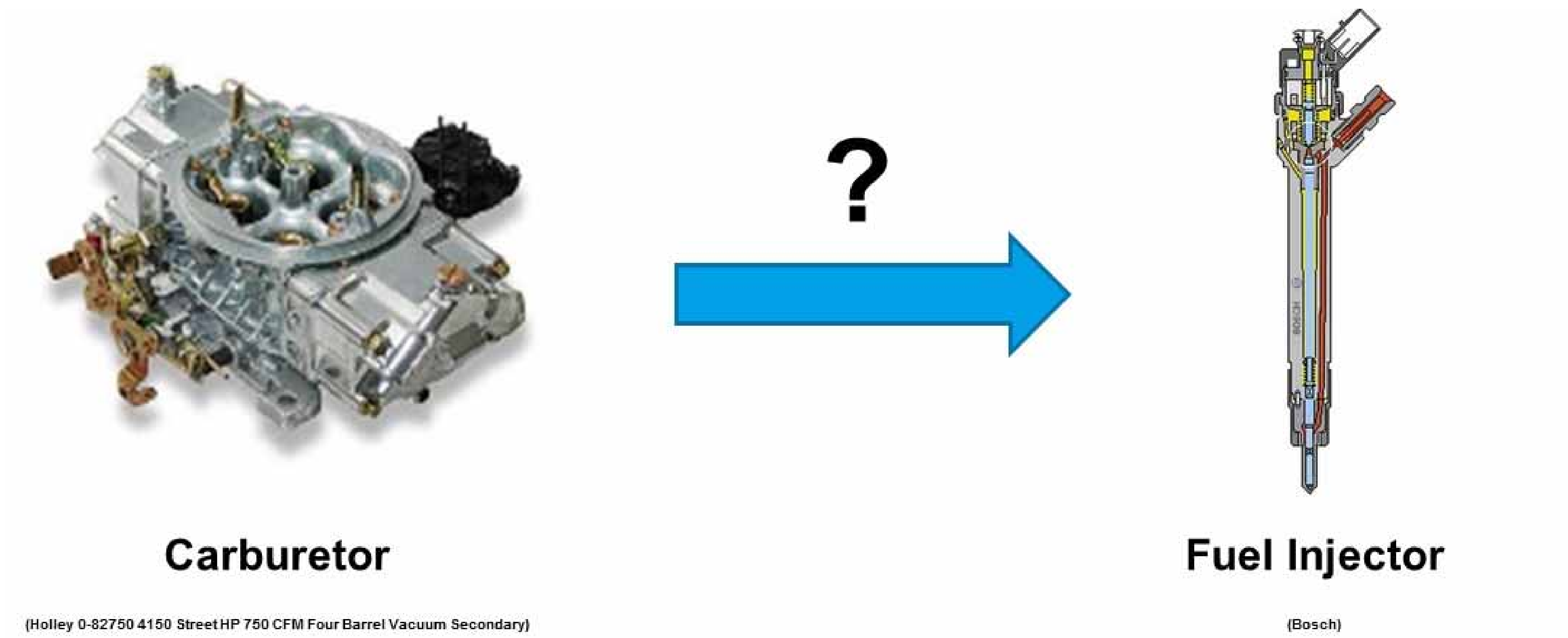
What can we learn from animation?

Animation provides some insight on how to deal with scale and complexity

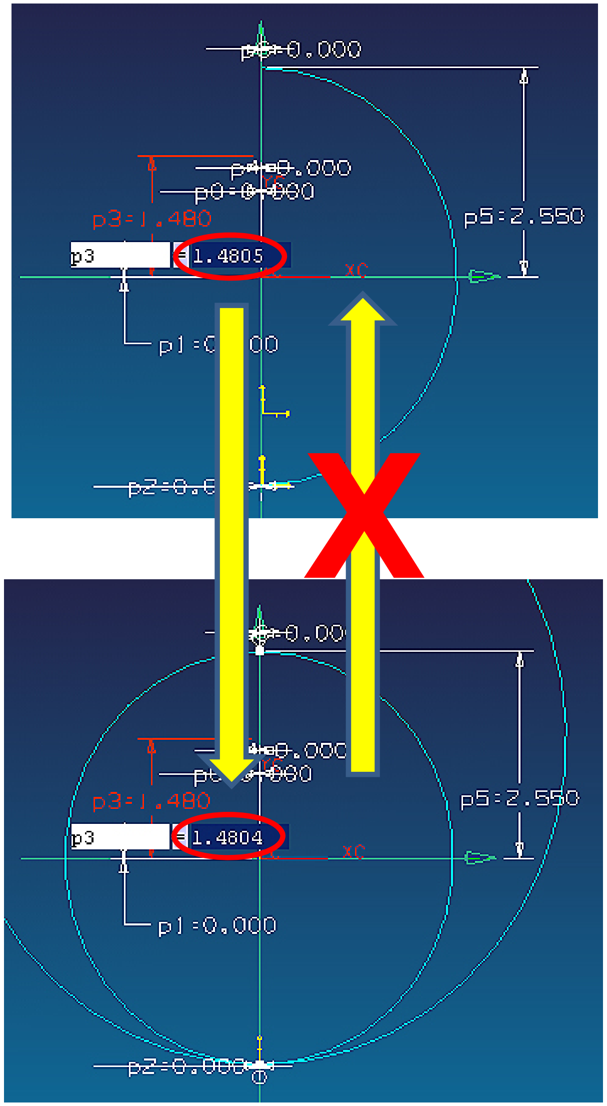
Can topology optimization (TO) under uncertainty (UU) compensate for variability?



How can we jump species to find radically new designs?



How do you debug a “design”?



How do you fix this?

- Debugging designs captured in a system is hard
- However, we have 60+ years experience debugging computer programs…

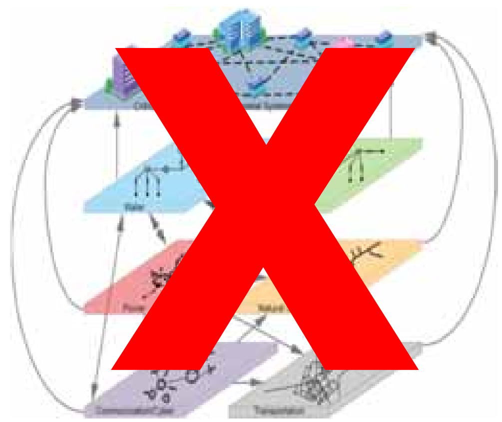
What can we learn from this?

GEODUCK

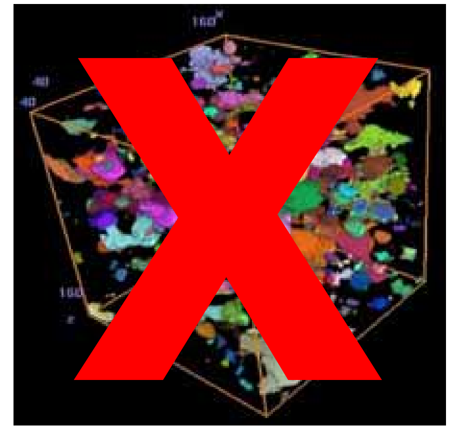
```
from Wing import WingClass, WingBox
from Cowl import CowlClass
from Fuse import Fuselage

class BCA797( Rules ):

    def __init__ (self, fuse_length = 2867.2):
        Rules.__init__ (self)

        self.fuse_length = fuse_length
        self.fuse_width = .1 * fuse_length
        self.fuse_height = .1 * fuse_length
        self.constant_length = .5 * fuse_length
        self.nose_sharpness = 1.0
        self.tail_sharpness = 1.0
        self.nose_length = .1 * fuse_length

        self.fuse_x_offset = .03 * fuse_length
        self.fuse_z_offset = .06 * fuse_length
```

What TRADES is not!

Computer graphics

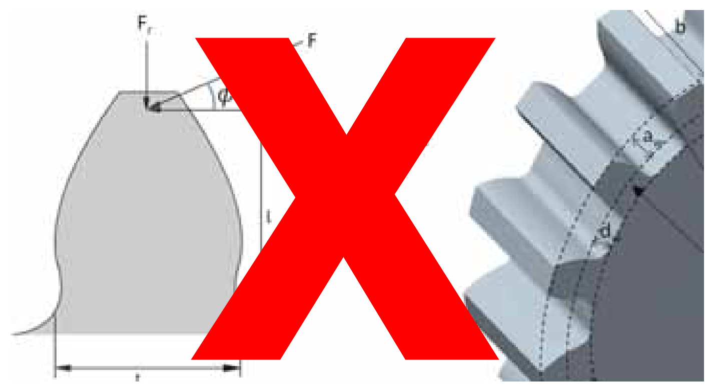


System of Systems



New materials development

New fabrication tools



Custom design processes

https://www.youtube.com/watch?v=8bml2pK6Ra0

Program structure

TA1: Design Technologies
- Multiple performers
- Teaming
- Focus areas:
    1. Modeling
    2. Analysis/Compute
    3. Synthesis
- Propose 1, 2 or all 3
    - Interoperate?
- Generality
    - If not: Interoperate?

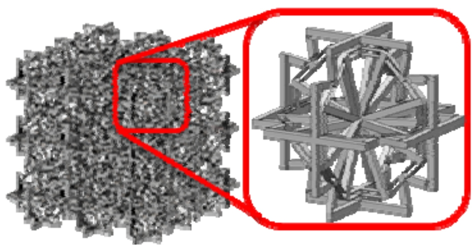
TA2: Design Testbed
- Single performer
- Common dev platform
- HPC/GPU
- Prototype ideas
- Collaborate/share
- Integration/interoperability
- Exemplar problems
- S/W Resources

- Explore alternative ideas, focus on the most promising methods
- Exemplar problems (EP) and metrics to evaluate progress
- Government partner to validate and verify performance

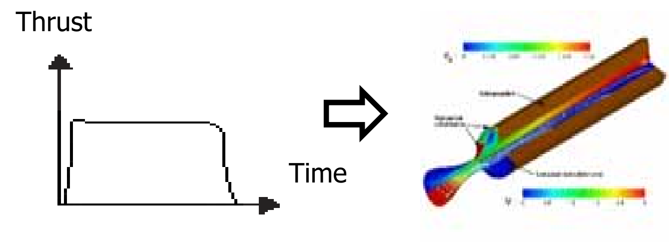
End goal is to enable designers to leverage investments in:
- Additive processes
- Weaving processes
- Layered structures
- Micro truss structures
- Graded materials
- Traditional materials

Draft exemplar problems

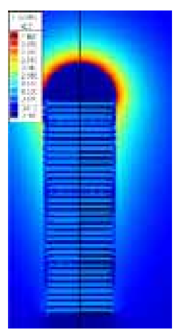
Aim is to exercise different aspects of TRADES, not get locked into 1 physics



Represent, manipulate, and compute properties of a 1 m^3 volume made of .01 mm micro-structures



Synthesize material composition and shape of solid rocket propellant to achieve a given thrust profile



Fit a 1MV voltage multiplier in a .1 m^3 space using graded materials to power the ICONS neutron generator

Example program metrics to measure success

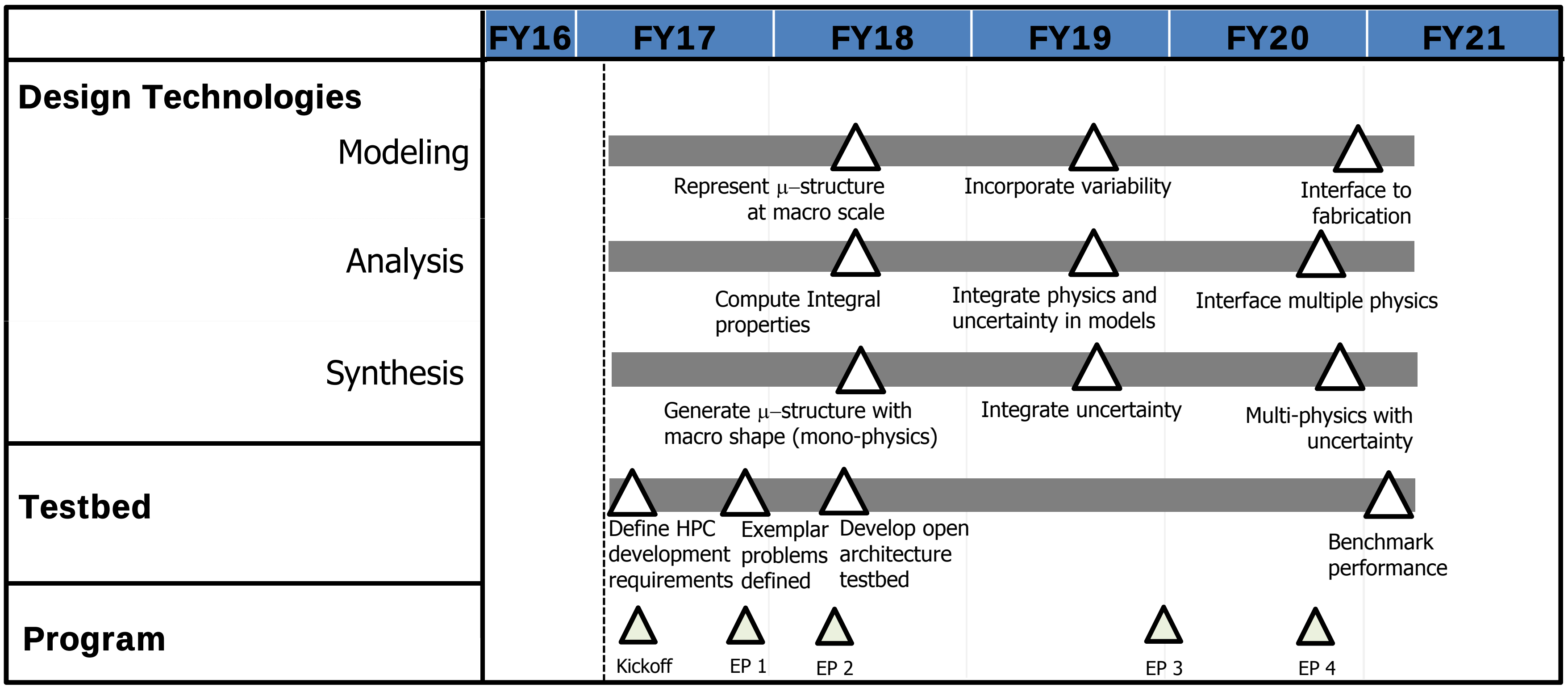
TRADES program metrics:

- Modeling, complexity, and response speed assessed against industry incumbents using nominal HPC cluster
- Multi-physics, interoperability and required computer-human interaction assessed against state of the art design tools

Program Metric	State of the Art	Threshold	Objective
Usable level of detail in physical scale difference	$\leq 10^5$	$>10^6$	$>10^8$
Object complexity (Shape + Material)	No material, 10^5 to 10^9	$>10^{12}$	$>10^{15}$
Computational efficiency (e.g., Simulating high fidelity physics)	Hours to weeks	minutes	seconds
Computer-human interaction	Experienced (> 10 yrs) professional required to generate and model non-trivial design solutions	Semi-professional required	Non-professional
Multi-physics design	Indirect through design-test	Sequential	Coupled
Material architecture and shape generation for multi-physics challenge problems	Does not exist	>2 Physics	>3 Physics, with uncertainty
Interoperability	Manual intervention	Automated	Direct

Schedule and structure

Single phase, 6.1, 48-month program



Deliverables:

- New math, algorithms and computer representations
- A testbed, community and collection of validated exemplar problems
- Novel techniques for interaction and design space exploration

TRADES Proposal Process

TRADES Key Dates

BAA Publish	5/11/16
Proposers' Day	5/13/16
Abstracts Due	6/1/16 4:00pm EST
Teaming Profile Due Date	5/16/16
Expected Abstract Responses	6/27/16
FAQ Submission Deadline	7/19/16 4:00pm EST
Proposals Due	7/26/16 4:00pm EST

How we think: The Heilmeier Catechism

Important questions to consider when approaching DARPA with ideas:

- What are we trying to do? (no jargon!)
- How does this get done today?
- What is new about your approach?
- If we succeed, what difference do we think it will make?
- How long do we think it will take?
- Can we transition (to the DoD or others)?
- How much will it cost?

LCD Pioneer

Heilmeier

Source: Wikipedia.

Regli's "DARPA 101"

Proposal Abstracts

- Proposers are strongly encouraged to submit an abstract in advance of a proposal
- Abstract provides a synopsis of the proposed project
- Abstract submission instructions can be found in BAA
- DARPA will respond to abstracts with a statement as to whether DARPA is interested in the idea
  - DARPA will attempt to reply to abstracts via email within thirty (30) calendar days of receipt.
  - If DARPA does not recommend the proposer submit a full proposal, DARPA will provide detailed feedback to the proposer regarding the rationale for this decision.
- Regardless of DARPA's response to an abstract, proposers may submit a full proposal
- Abstracts will be reviewed in the order they are received
- DARPA will review all full proposals submitted using the published evaluation criteria and without regard to any comments resulting from the review of an abstract

Full Proposals

Full proposals must include:

Volume 1: Technical and Management Proposal

- Maximum of 30 pages, including all figures, tables & charts but not the cover sheet or table of contents.
- Must include the following:
  - Cover Sheet
  - Official Transmittal Letter
  - Table of Contents
  - Executive Summary Slide
  - Goals and Impact
  - Technical Plan
  - Management Plan
  - Personnel, Qualifications, and Commitments
  - Capabilities
  - SOW & Schedule and Milestones
  - Cost Summary

Volume 2: Cost Proposal

- Mandatory with no page limit
- Should include an editable spreadsheet file that provides formula traceability among all components of the cost proposal
- Costs must be traceable between the prime and subcontractors/consultants, as well as between the cost proposal and the SOW
- Cost information must be substantiate proposed prices
- Pre-award costs will not be reimbursed unless a pre-award cost agreement is negotiated prior to award
- Must include:
  - Cover Sheet
  - Cost Summaries by Year, Month, and Task
  - Cost Details

Proposal submission instructions can be found in BAA

TRADES Review and Selection Process

- DARPA will conduct a scientific/technical review of each conforming proposal
- Proposals will not be evaluated against each other since they are not submitted in accordance with a common work statement
- TRADES proposals will be evaluated against three criteria
  - Overall Scientific and Technical Merit
  - Potential Contribution and Relevance to the DARPA Mission
  - Cost Realism
- Detailed description of each criteria can be found in the TRADES BAA

www.darpa.mil