



DIGITAL TRANSFORMS PHYSICAL

# GENERATIVE DESIGN CORE COMPETENCIES AND INDUSTRIAL APPLICATIONS

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*Product Management, Onshape  
Simulation & Generative Design*





AGENDA

# GENERATIVE DESIGN

## *CORE COMPETENCIES & INDUSTRIAL APPLICATIONS*

### AGENDA

- An Early Success Story
- Yesterday's Hands-On Experience
- Technical Underpinning
- Core Competencies
- (More) Industry Examples
- Questions & Answers

**Kevin McClintock & Volvo**

**Educational Implications**

**Implicit Geometry**

**Nuts, Bolts, and Tripwires**

**Jesse Craft & Jacobs Engineering**

**PTC & Technion**

**Jeff Olsen & Hiller Measurements**



WILL GENERATIVE DESIGN  
REPLACE ENGINEERS?



# VOLVO SUPERTRUCK 2

# KEVIN McCCLINTOCK & VOLVO

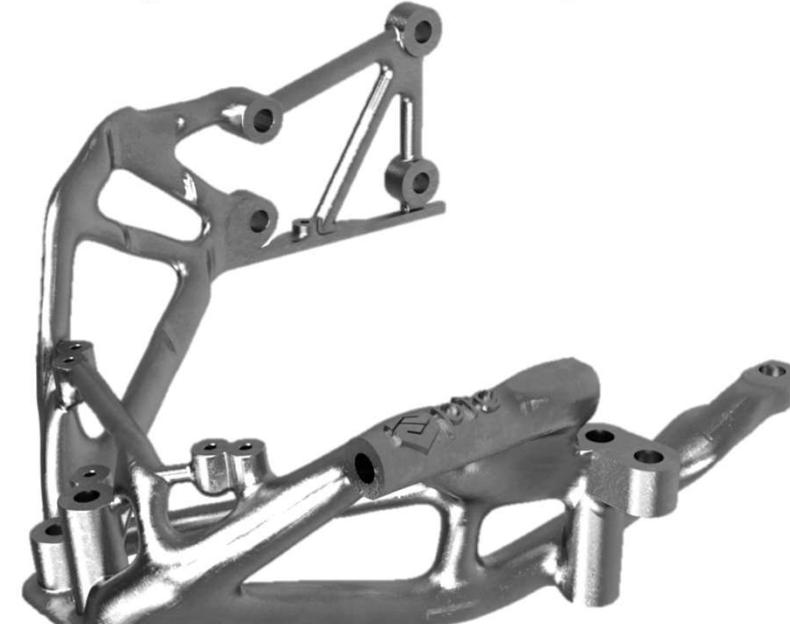
*UNBELIEVABLE PRODUCTIVITY*

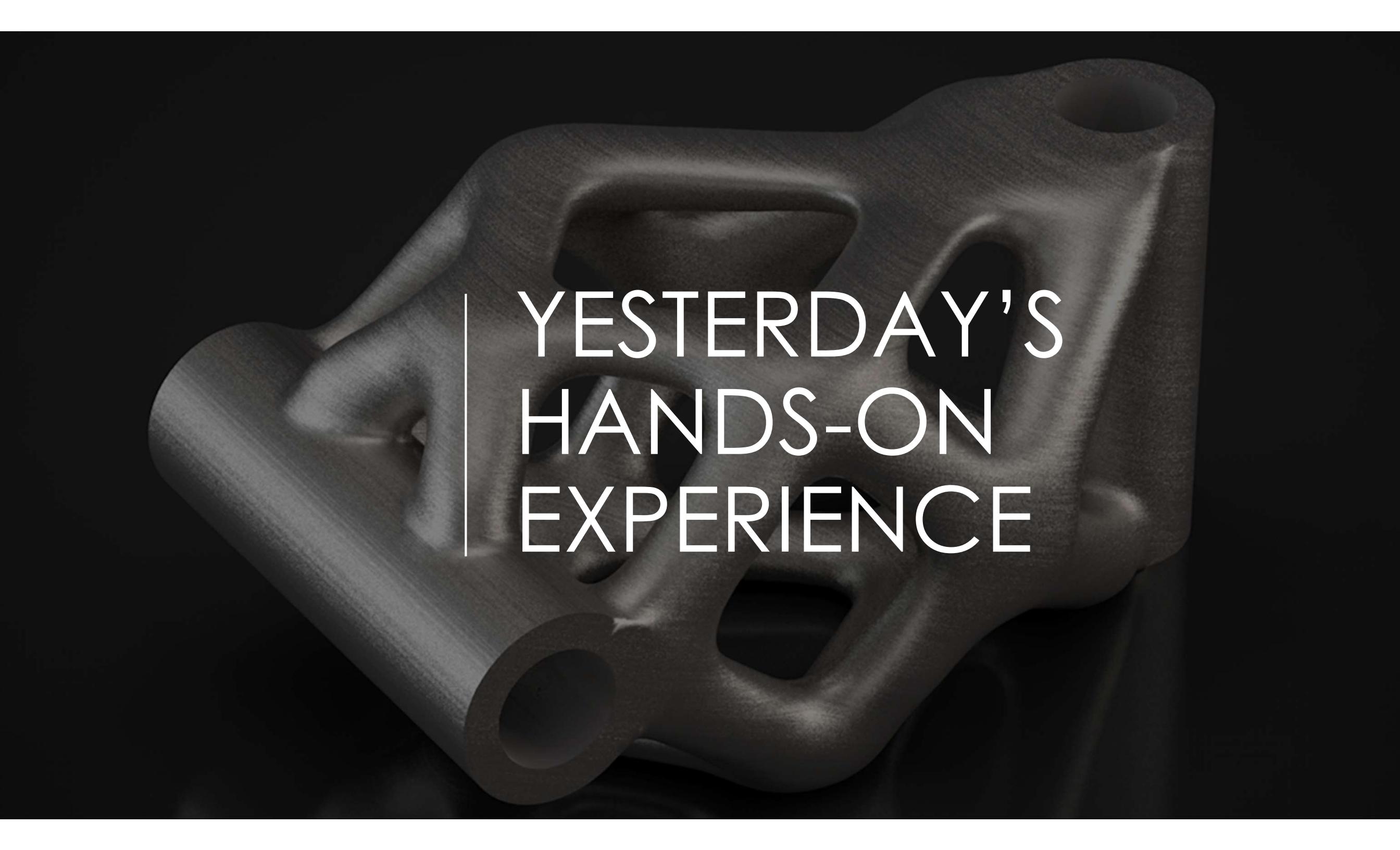
## WHAT DID HE ACHIEVE ON HIS OWN?

- Redesigned the entire powertrain installation systems
- Generatively designed a cast engine mount (below), a machined fan motor mount, and an additively manufactured bridge bracket
- Convinced Volvo executives to upgrade his workstation and expand generative design to his entire group



75% WEIGHT REDUCTION





YESTERDAY'S  
HANDS-ON  
EXPERIENCE

# ONSHAPE GENERATIVE WORKSHOP

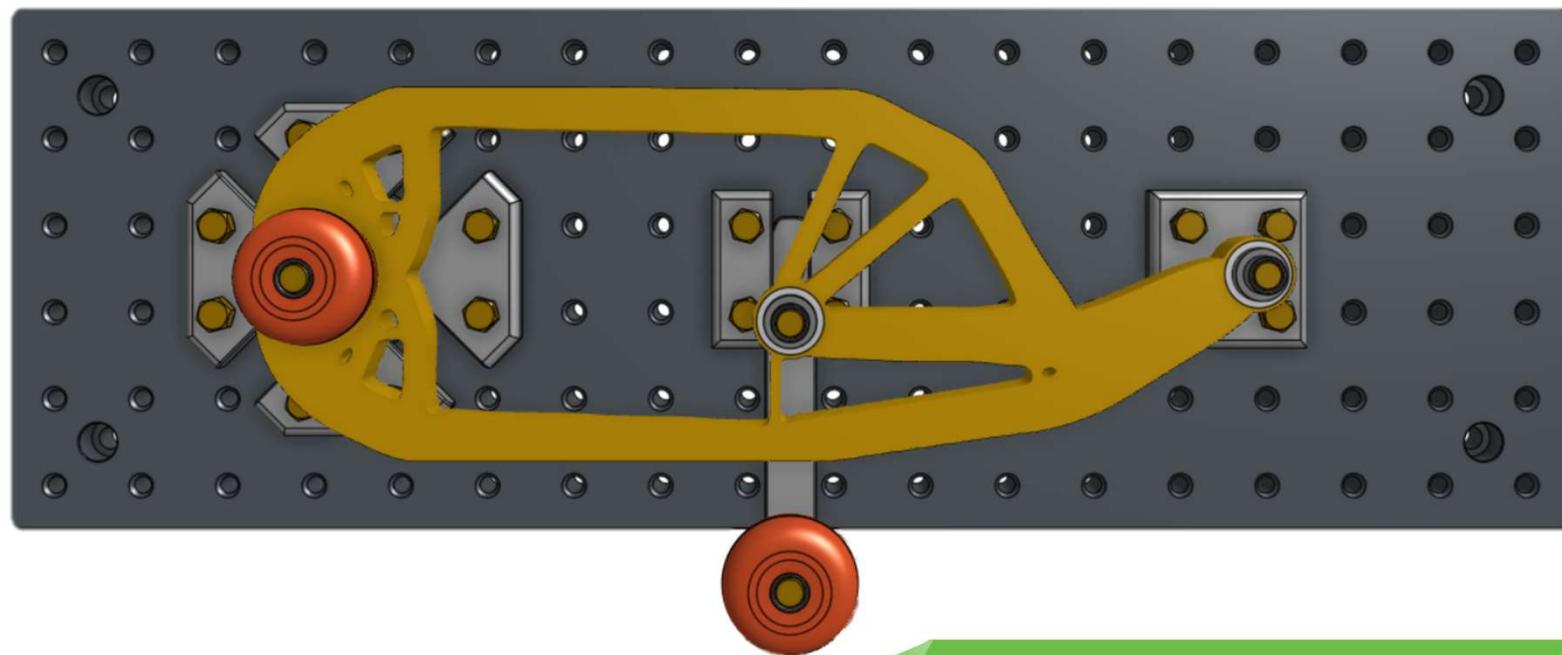
## *EDUCATIONAL IMPLICATIONS*

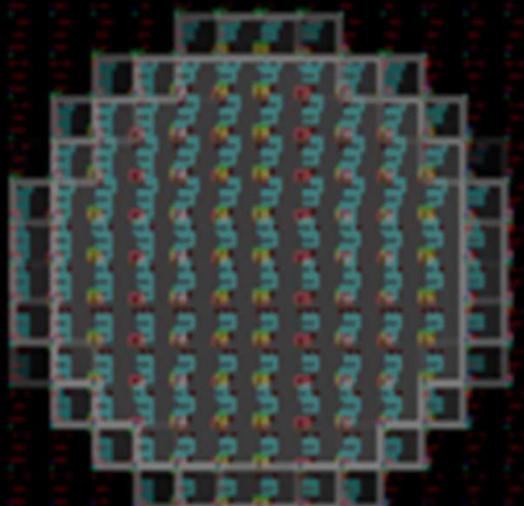
### WHAT MAKES THIS “WORK”

- Generative Design enables exploration – so explore the space
- The results can be felt – find ways to involve physical test specimens
- Generative Design builds (and tests) your intuition – leverage it as such

### SYSTEMS-LEVEL THINKING

- Establishing load cases is an exercise in itself
- Realize that every interface is a negotiation
- Measure the consequences of each decision
- Generate the pareto front of optimum designs





# TECHNICAL UNDERPINNING

# IMPLICIT GEOMETRY

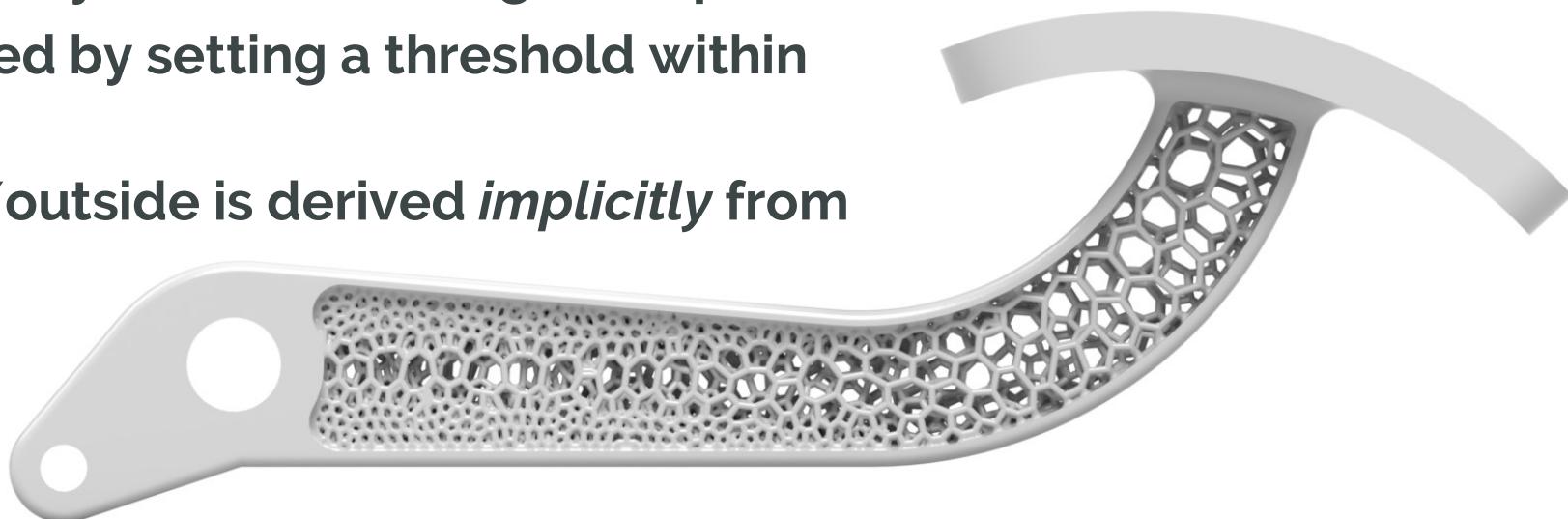
*DEFINING GEOMETRY FROM THE INSIDE-OUT, NOT THE OUTSIDE-IN*

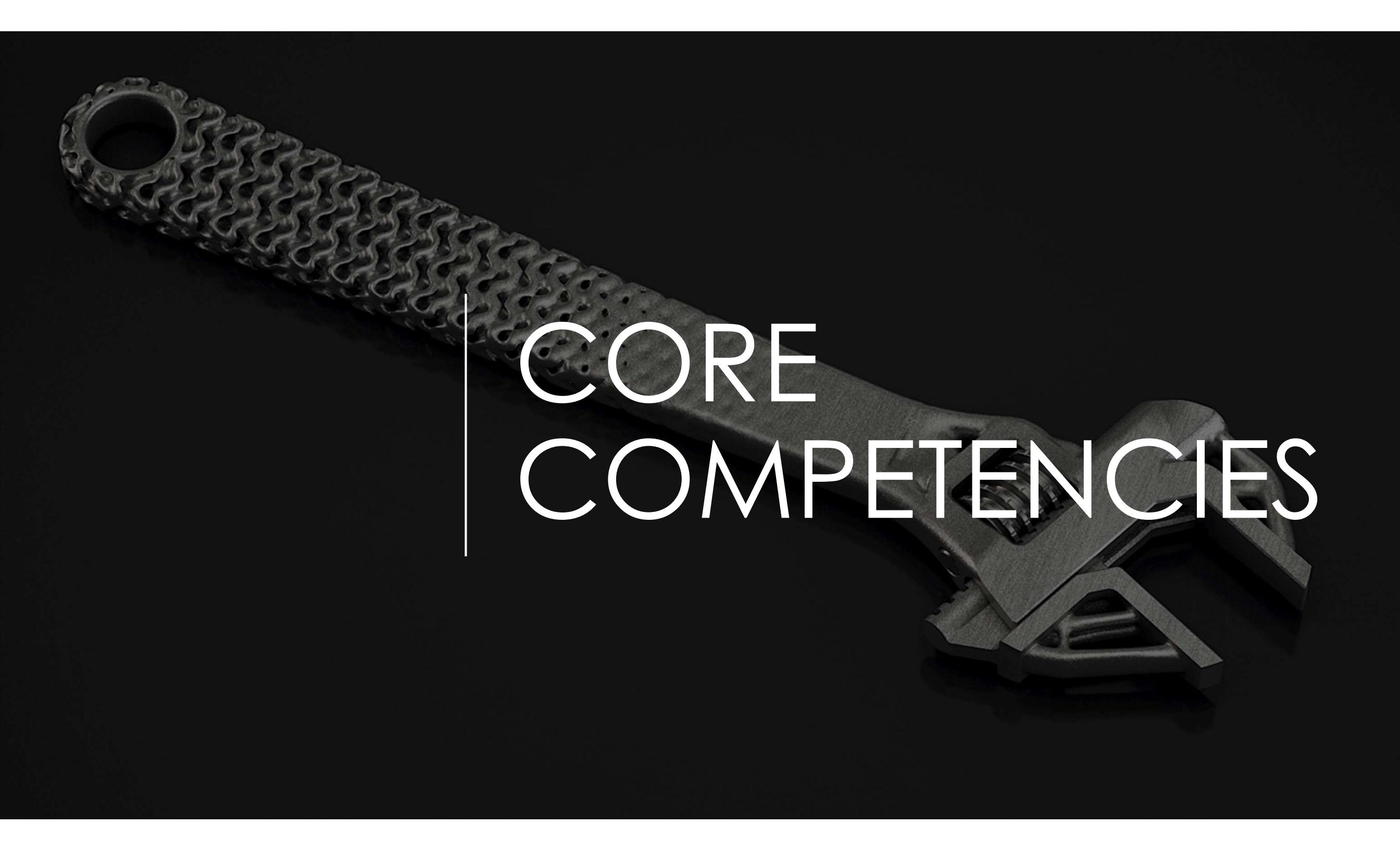
## WHAT IS “NORMAL” GEOMETRY?

- Conventionally, geometry is defined by a Boundary Representation (BREP)
- Solid parts are what lies within the explicitly defined surfaces.

## WHAT IS IMPLICIT GEOMETRY?

- Each Part is defined volumetrically as a field throughout space
- Part envelope is only determined by setting a threshold within that field
- The boundary between inside/outside is derived *implicitly* from that threshold
- One can superimpose fields to great effect





# CORE COMPETENCIES

# EXPERTLY ARTICULATE REQUIREMENTS

*SOMETIMES (NOT) EASIER SAID THAN DONE*

## WHAT YOU WANT

```
Factorial( int N ) {  
    for ( i : N-1 to 1 )  
        N = N*i  
    return N  
}
```

## WHAT WOULD BE REQUIRED

- One input N
- One output M
- N should be integral
- N should be greater than 0
- N will not be greater than 1,000,000
- Function should be  $\leq O(N)$  complexity
- Function should return N multiplied by each smaller non-zero integer
- Function should compile without warnings

Students must learn to be precise and unambiguous even in the “simple” things.

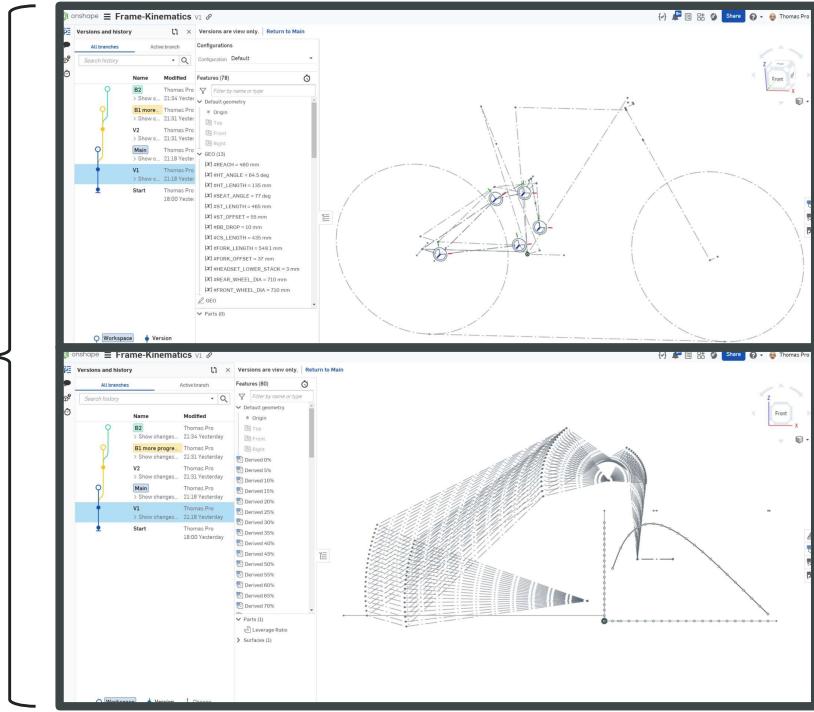
# THINK ABSTRACTLY

*OR AT LEAST KEEP IT IN MIND*

## MOTIVATION

- Generative Design encodes design intent, not just design features
- Most problems are not entirely new
- Demonstrate complete understanding of the problem
- Parametrically extend your investigation to any portion of the system

Abstracted Bicycle Frame Kinematics  
Courtesy of *Principia MBDS & OnCAD*



## FURTHER MOTIVATION

- Implicit geometry results are more robust if your generative model is properly abstracted

# BOUNDARY CONDITIONS, KEEP-INS, AND KEEP-OUTS

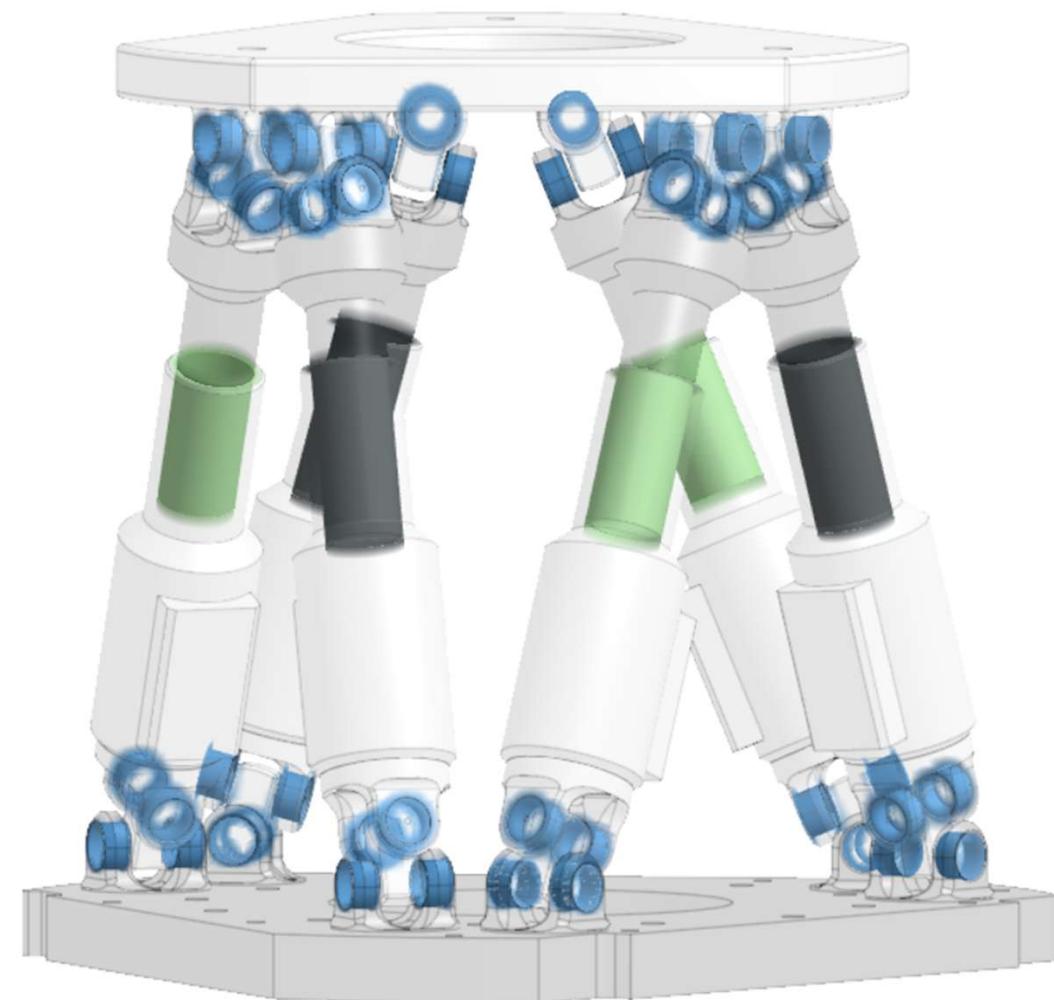
*NOT DIFFICULT, BUT DETAILED*

## NECESSARY CONSIDERATIONS

- Simulation is not reality  
Make intelligent approximations
- Mindfully consider each and every interaction
- Keep-ins are often best modeled by hand  
if you know what you want
- Keep-outs should consider assembly & installations  
requirements, not just obstacles and self-collision

## TYPICAL PAIN POINTS

- Improperly identifying Ground
- Under-constrained (linear-static) assemblies
- Under-specification of implicit offsets



# SIMULATION, LOADS, AND LOAD CASES

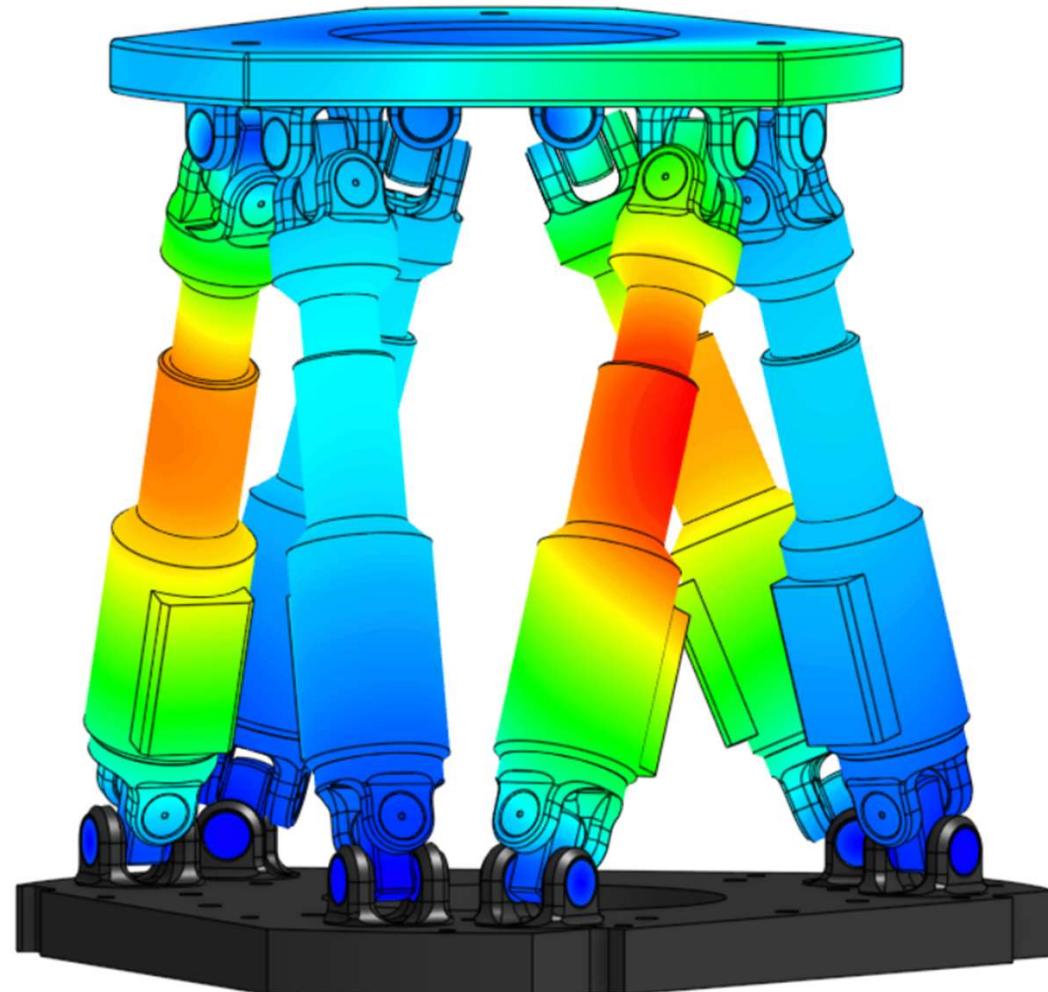
*THE “ACTION” COMPONENT OF GENERATIVE DESIGN*

## NECESSARY CONSIDERATIONS

- Simulation is not reality  
Make intelligent approximations
- Understand the simulation metrics you seek
- Construct load cases as close to your intended physical validation tests as possible
- Use multiple load cases  
...unless one is truly enough

## TYPICAL PAIN POINTS

- Not understanding simulation's limiting assumptions
- Not understanding intended operating conditions
- Improper element size



# OBJECTIVES, CONSTRAINTS, AND WEIGHTS

*KNOW YOUR LIMITS AND BE PREPARED TO HONOR THEM*

## BASIC

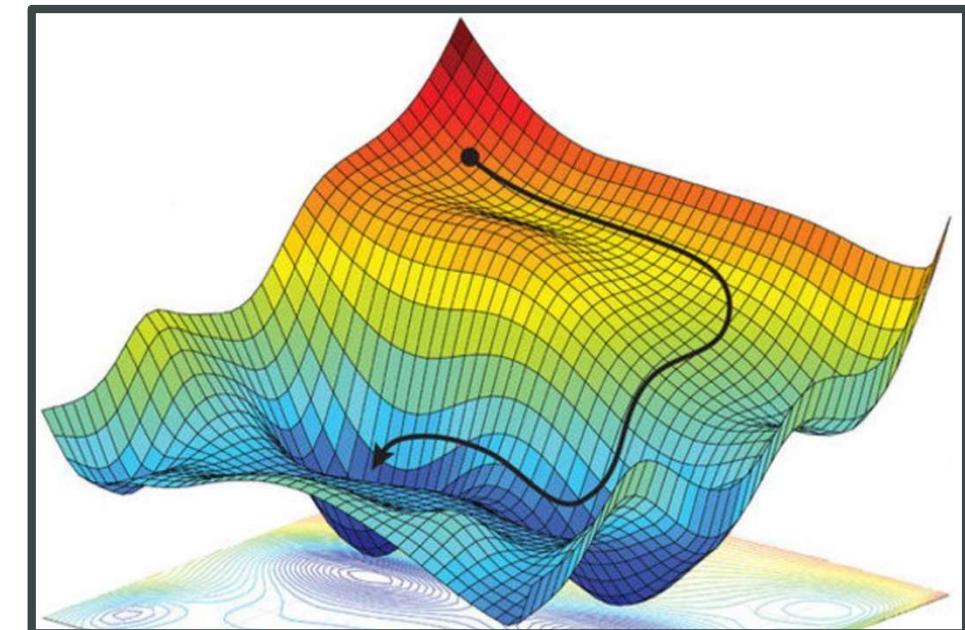
- Ceiling/Floor
- Minimize/Maximize
- Target... actually Minimize in disguise... actually Minimize(Maximize) in disguise

## MODERATE

- Geometric Constraints and Objective Weights
- Constraint-less aka Competing Objectives
- Different goals for different load cases
- Layered implicit fields

## ADVANCED

- Self-authored optimization functions



# COMPUTER AIDED DESIGN

*GEOMETRY IS THE LANGUAGE OF DESIGN*

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# INDUSTRY EXAMPLES

# JESSE CRAFT & JACOBS ENGINEERING

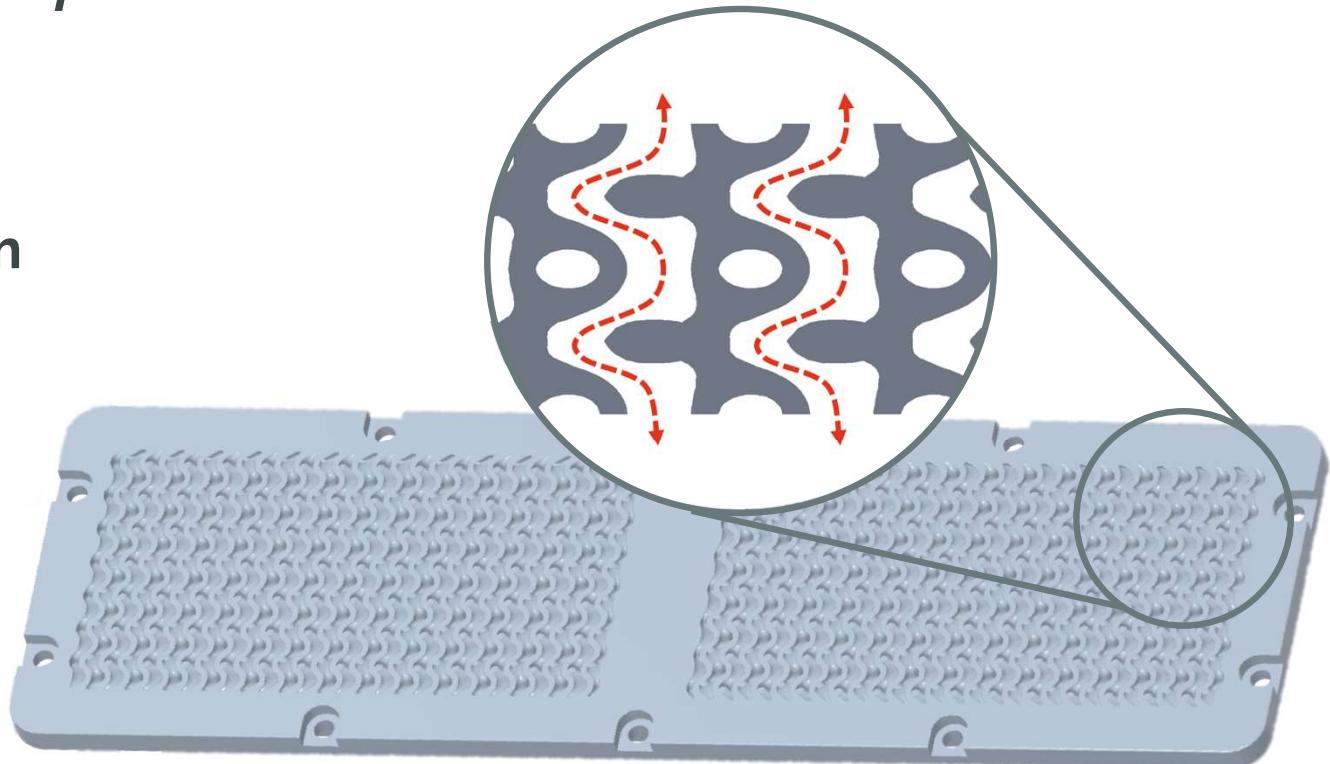
## PORTABLE LIFE SUPPORT SYSTEM FOR LUNAR MISSIONS

### IN HIS OWN WORDS

*As an engineer, I like right angles, flat surfaces and round dimensions, and generative design says that may not be the best solution. And so, if I want to be the best possible engineer at my job, I look to generative design to find those kinds of solutions.*

### GENERATIVE APPROACH

- CO<sub>2</sub> Exhaust Cover needed to shield from any direct micrometeoroid strike
- Periodic minimal surface structures provided guaranteed protection, ventilation, and additive manufacture
- Tortuous conventional geometry modeling becomes trivial with implicit geometry



# PTC & TECHNION

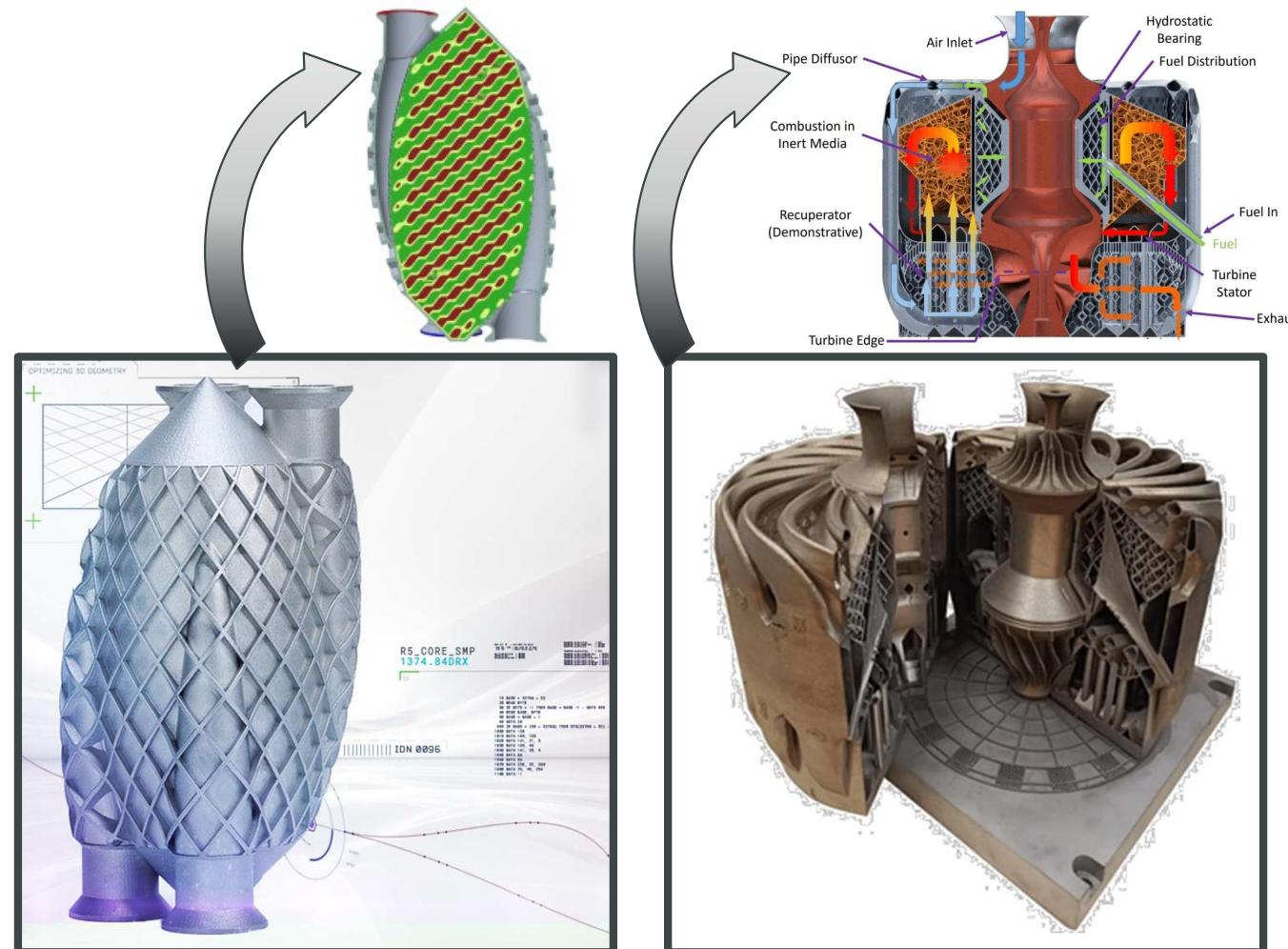
## THERMAL AND AEROSPACE APPLICATIONS

### GENERATIVE APPROACH

- Recognize that periodic minimal surface structures offer unprecedented heat transfer opportunity
- Recognize that lattice reinforcement could also serve as combustion chamber flame holder
- Leverage engineering insights and intuition with novel geometry

### FURTHER ENHANCEMENTS

- Optimize using simulation-driven implicit field



# JEFF OLSEN & HILLER MEASUREMENTS

## *HIGH VALUE CUSTOMIZATION – AT SCALE*

### IN HIS OWN WORDS

*It's not your job to design the product anymore. Your job is to design the constraints and allow software to design.*

*Quite frankly, even though you may or may not like the generative design aesthetics, from a business perspective and engineer perspective, it makes more sense.*

### FURTHER ENHANCEMENTS

- Incorporate generative solutions in other areas of design, starting with component placement and wire routing
- Integrate directly to online customer sales funnel for near-instant





Q&A

THANK YOU!