# On Bringing HPC Home For Growth

## Three Talks in One:

## Message from the Sponsor
## Who are the Missing Middle
## Making the Missing Middle not Missing


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Datacenter & Connected Systems Group (DCSG)

Intel Corporation

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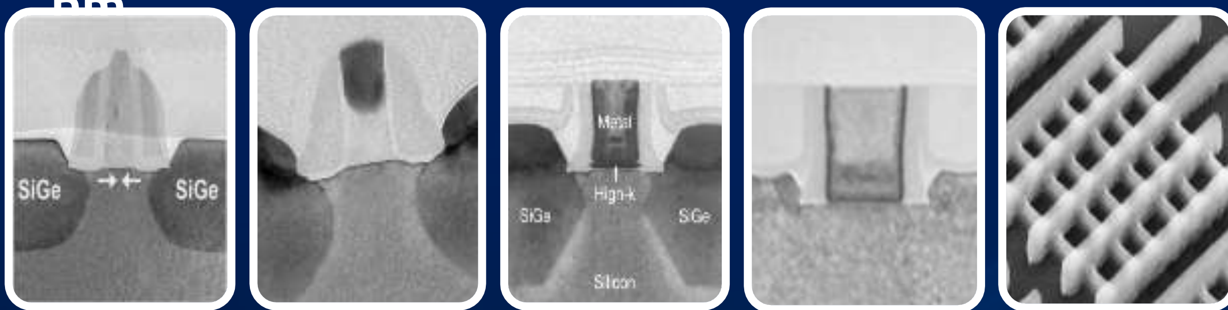
- 64-bit computing on Intel architecture requires a computer system with a processor, chipset, BIOS, operating system, device drivers and applications enabled for Intel® 64 architecture. Performance will vary depending on your hardware and software configurations. Consult with your system vendor for more information.

# Process Technology Leadership

| 2003 | 2005 | 2007 | 2009 | 2011 |
|---|---|---|---|---|
| **90 nm** | **65 nm** | **45 nm** | **32 nm** | **22** |




| Invented SiGe Strained Silicon | 2nd Gen. SiGe Strained Silicon | Invented Gate-Last High-k Metal Gate | 2nd Gen. Gate-Last High-k Metal Gate | First to Implement Tri-Gate |
|---|---|---|---|---|

*STRAINED SILICON*

*HIGH-k METAL GATE*

*TRI-GATE*

***The foundation for all computing***

## 22nm

A Revolutionary Leap in Process Technology

**37%**
Performance Gain at Low Voltage*

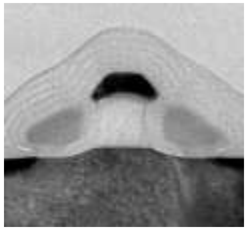
**>50%**
Active Power Reduction at Constant Performance*

Source: Intel
*Compared to Intel 32nm Technology

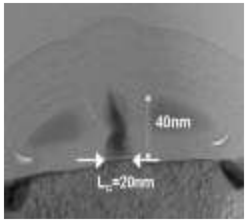
# Silicon Future

**90nm**
**2003**

**65nm**
**2005**

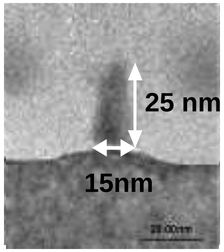


**45nm**
**2007**




**2005 – 2012**

**32nm**
**2009**




**22nm**
**2011**

**16nm**
**2013**

**11nm**
**2015**

**8nm**
**2017**

**2013 –2017**

New Intel technology generation every 2 years
Intel R&D technologies drive this pace well into the next decade

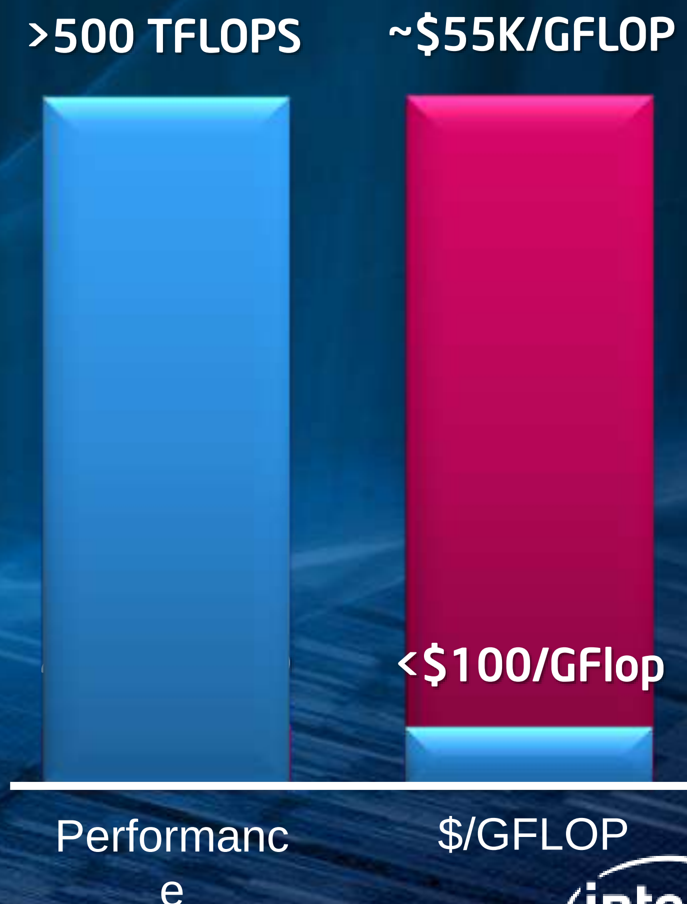
**Roadmap** ←→ **Research**

# We've Helped Transform Industries

Annual Server Processor Shipments

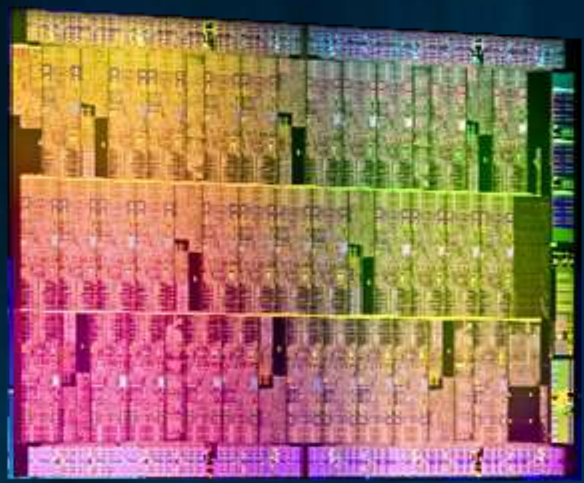

HPC in 1997

HPC in 2010

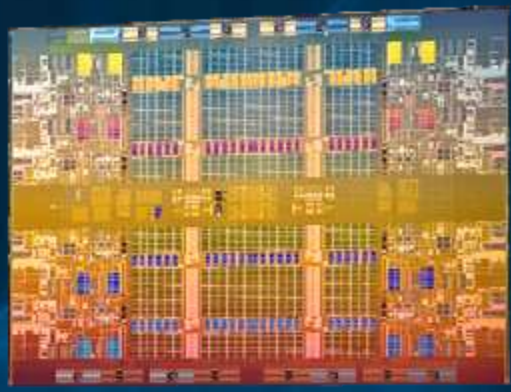


# Intel's Many Core and Multi-Core Engines

Many Integrated Cores at 1-1.2 GHz



Multi-core Intel® Xeon® processor at 2.26-3.5 GHz



Die Size not to scale

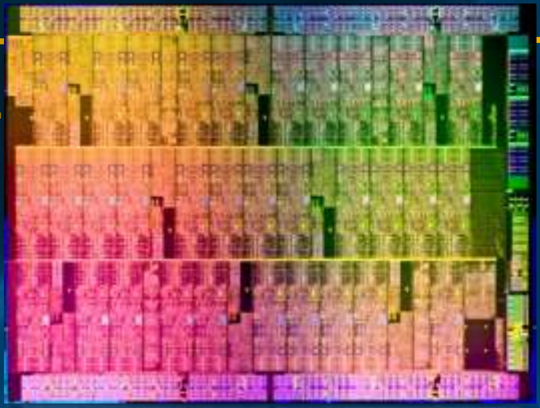
- The goals of Intel® architecture are to deliver:
  - Industry leading <u>performance/watt</u> for serial & highly parallel workloads.
  - <u>Optimized Efficiency*</u> for a Heterogeneous Solution in combination with Intel® Xeon® processors
  - Complete set of <u>software tools</u> to deploy scalable solutions efficiently

# Highly Parallel Performance

*Intel® Many Integrated Core (Intel® MIC) Architecture*

**Delivered Performance**

Launching on 22nm with >50 cores to provide outstanding performance for HPC users



**Performance Density**

The compute density associated with specialty accelerators for parallel workloads

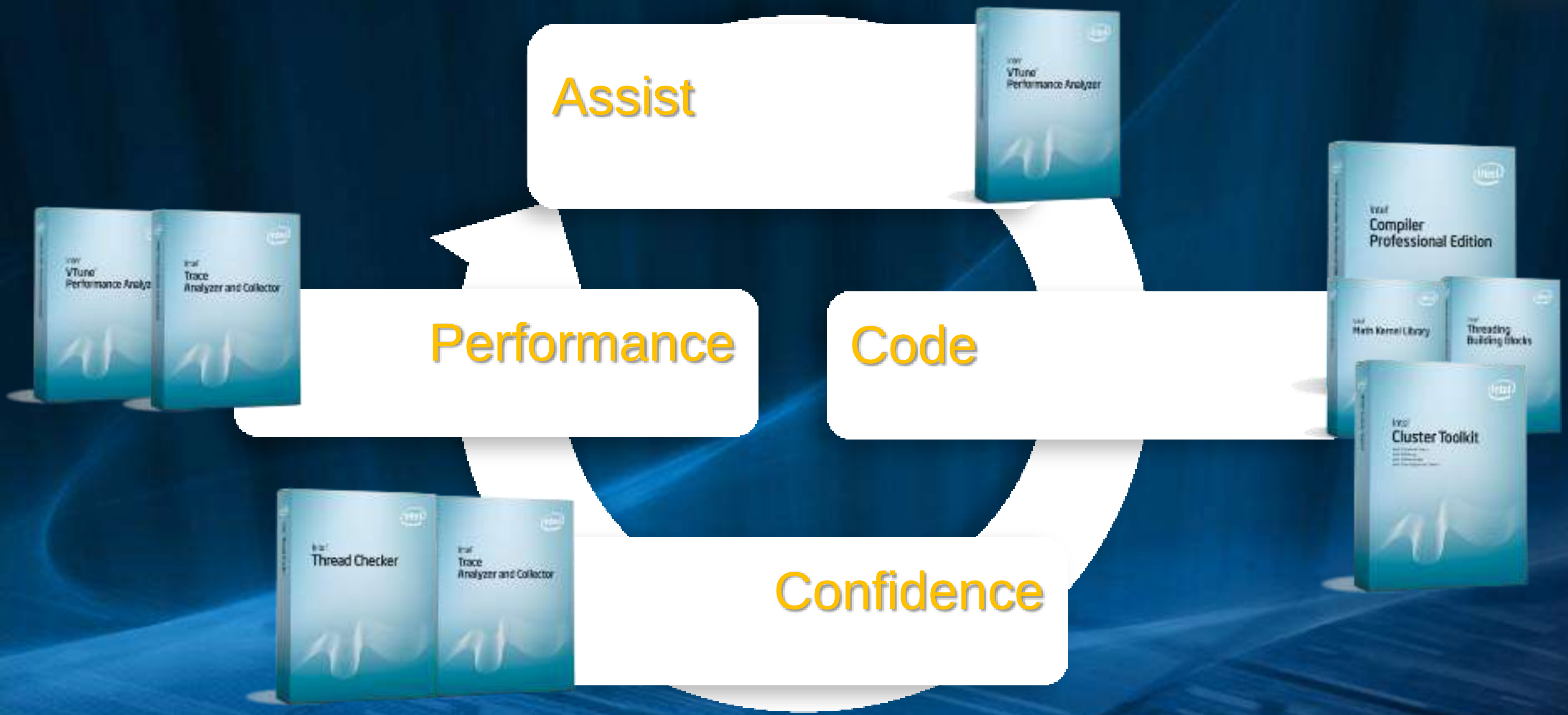
**Programmability**

The many benefits of broad Intel CPU programming models, techniques, and familiar x86 developer tools

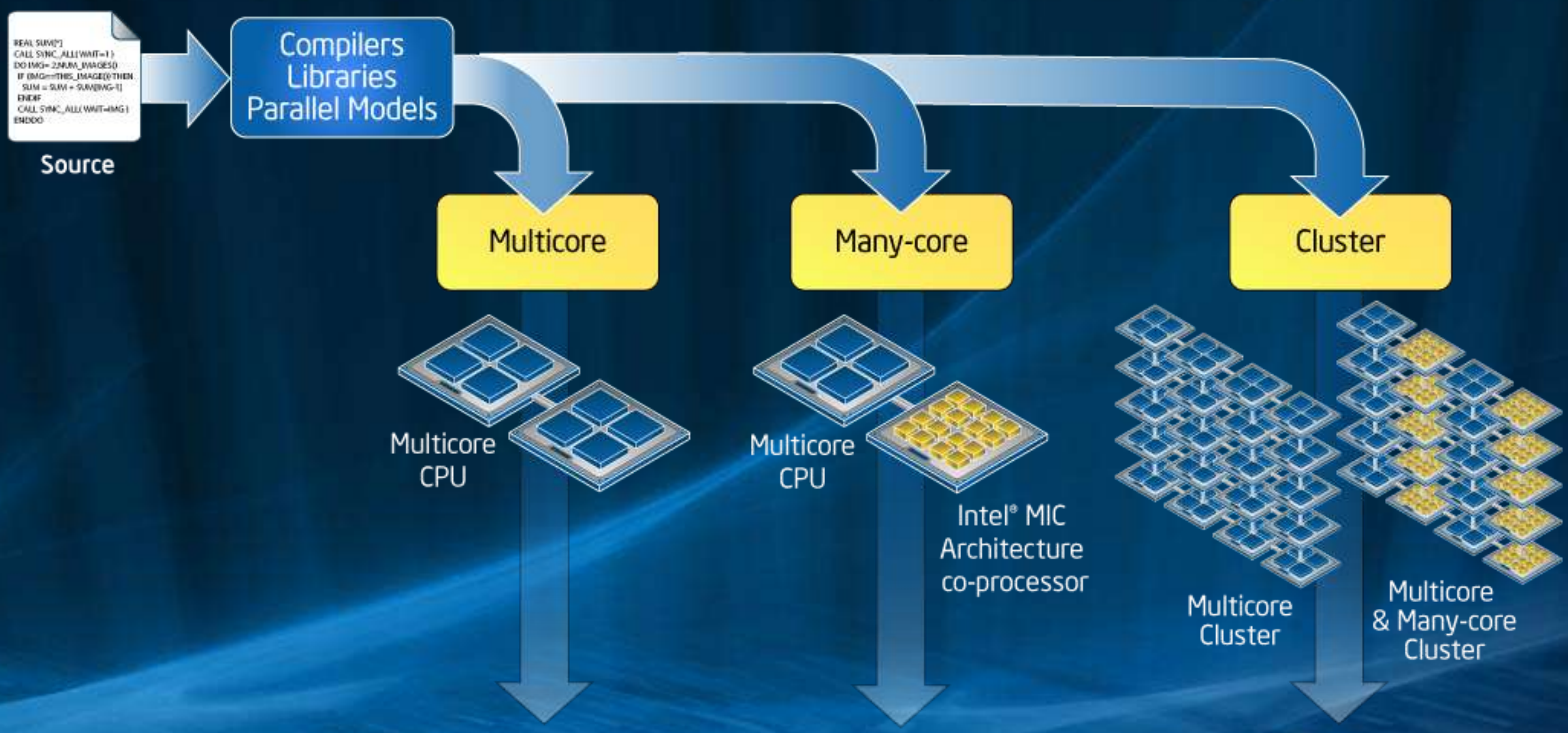
***A Step Forward In Dealing With Efficient Performance & Programmability***

# Optimization

*One Development Environment – Multi-Core to Many Core*



# Scaling Programmability




***Standard Programming Models Democratizes Usage***
***…Avoid Costly Detours***

# End-users Are Excited Too!

Programming models are the key to harness the computational power of massively parallel devices. Obviously, Intel has realized this trend and substantially supports open standards and invests in innovative programming models.
LRZ and TUM are using Intel hard- and software for many years and know the tool chain by heart.
MIC Execution: Straightforward. First version within a few hours, optimized version took 2 days

"By just utilizing standard programming on both Intel® Xeon processor and Intel® MIC architecture based platforms, the performance met multi-threading scalability expectations and we observed near-theoretical linear performance scaling with the number of threads."

"The CERN openlab team was able to migrate a complex C++ parallel benchmark to the Intel MIC software development platform in just a few days."

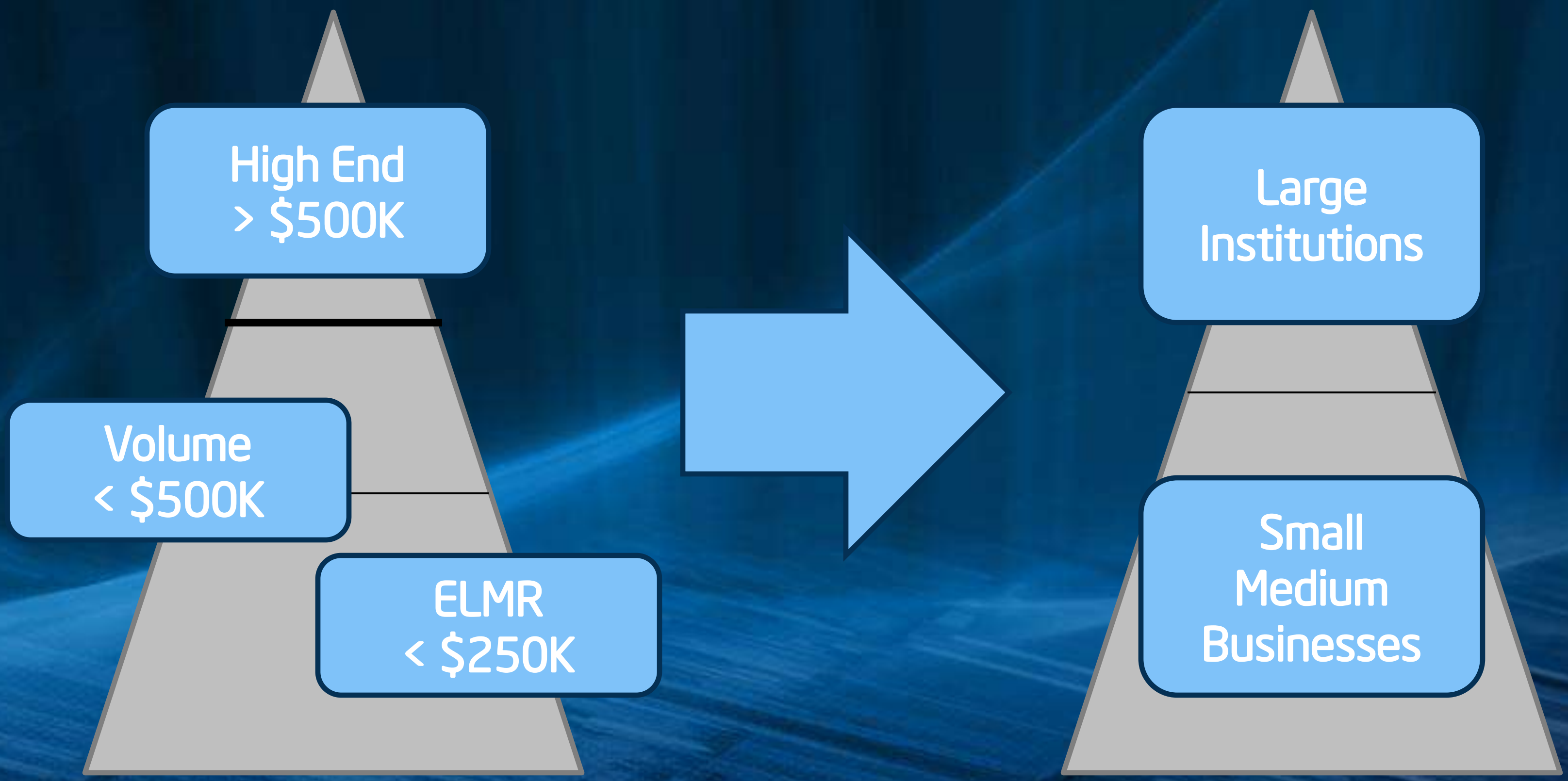
*"Moving a code to MIC might involve sitting down and adding a couple lines of directives that takes a few minutes. Moving a code to a GPU is a project" (4/21/11)*

*Dan Stanzione, Deputy Director at TACC*

# The Missing Middle

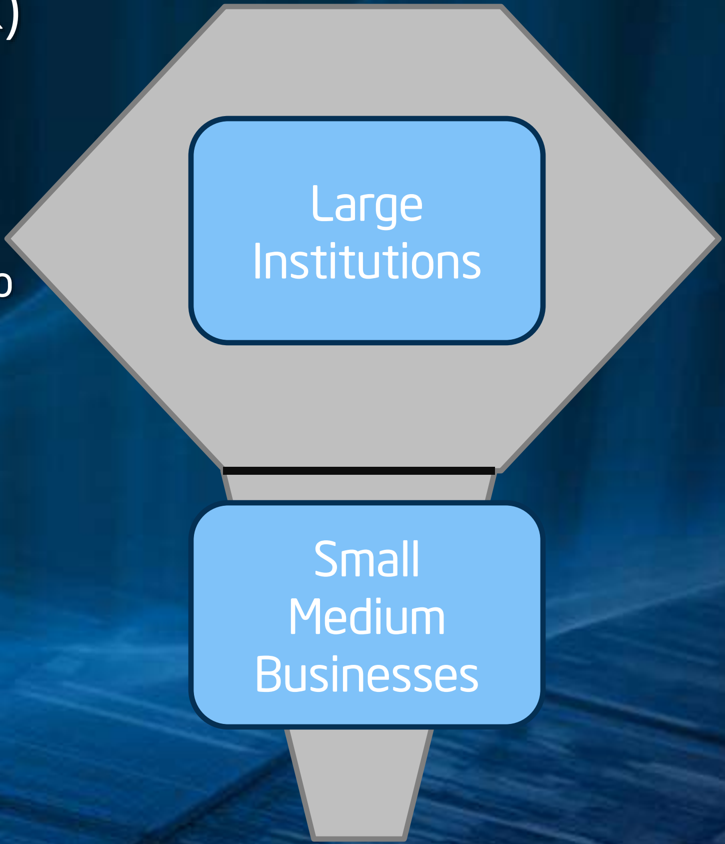

From ncms.org

# Implied Perspectives



# Reality?

- About two-thirds of ELMR-sized (<$250K) systems are upgrades or add-ons to larger systems[1]
- InterSect360 measures that:
  - Of true ELMR systems, 20-25% go to users who also have larger (high-end) systems.
  - so, only 10-15% of said systems go to ELMR users[2]
- IDC sees something similar, with 70%[3] of the <$500K going to the Workgroup, Department, Divisional segments.
  - Needs further visibility/corroboration




1 – Source: InterSect360 Research, HPC User Site Census: Lifecycles, 2009.
2 – Source: InterSect360 Research, custom user study, 2009.
3 – Source: IDC, personal comms, 2010

# Key Barriers

- The COC/IDC Reveal[1] report concluded that there are three major system barriers stalling HPC adoption:
  - Lack of Application Software
  - Lack of Sufficient Talent
  - Cost constraints

1 – Source: CoC/IDC Reveal report, 2008.

# Missing Middle Scope

## If Mfg is not for you, then …

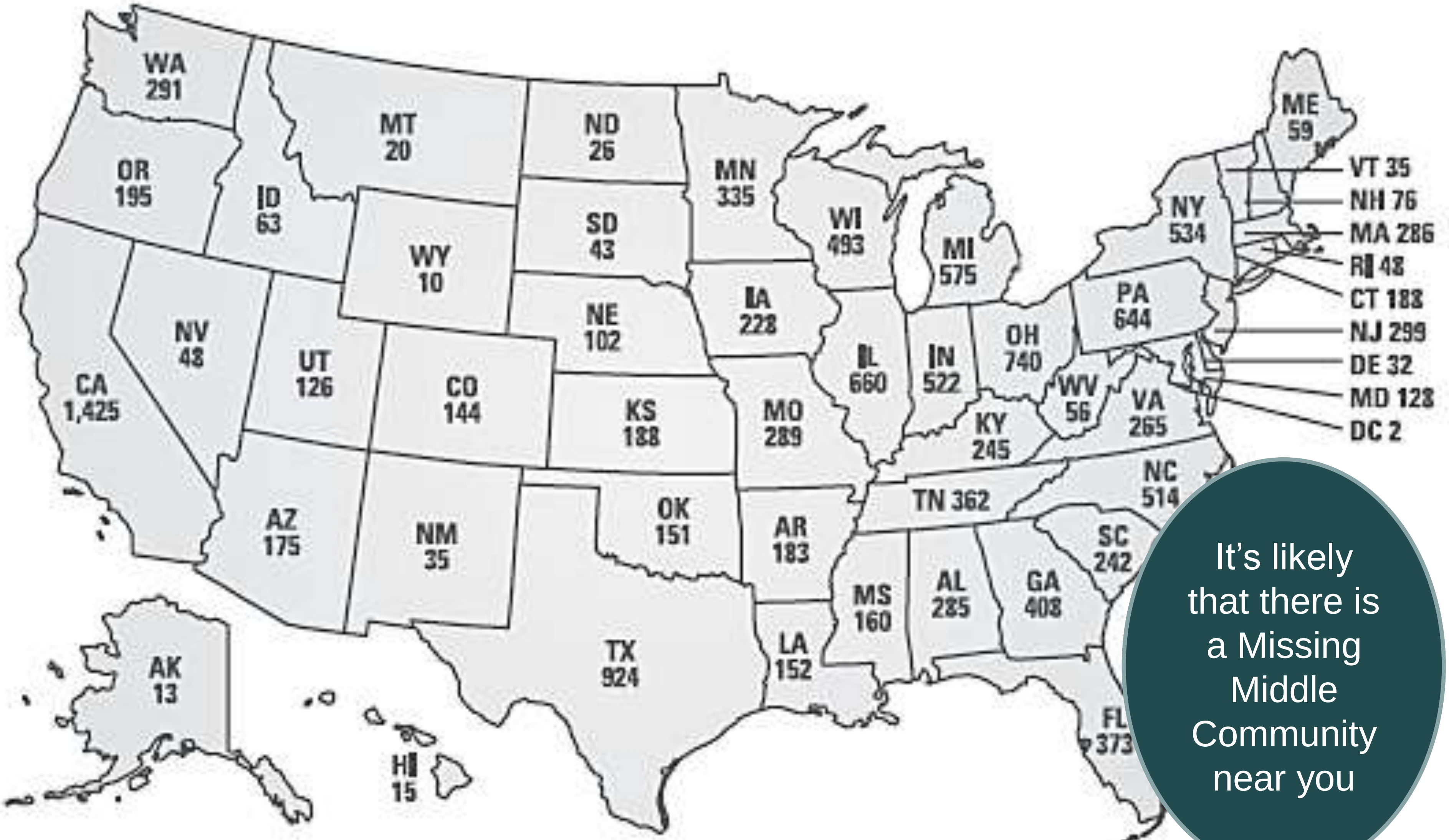
| Vertical | Relative Size to Overall Market Segment % | CAGR (IDC) | MM Affinity Judgment | Judged Latent Demand | Reachability |
|---|---|---|---|---|---|
| Manufacturing | 12.4 | High | High | 4x | High |
| Energy | 6.2 (just O&G) | Mid* | High | 4x*** | High |
| Life Sciences | 13.6 | Mid | High | 4x*** | Mid- disaggregated ecosystem |
| Weather | 4.4 | Low** | High** | 4x*** | Mid- disaggregated ecosystem |
| Gov/Defense | 26.2 | Mid | Mid | 2x*** | Mid- conservative entrenched players |
| Rest | 37.2 | Mixed | Mixed | 2x*** | Mixed |

*Just fossil; high for emerging/green
** Emerging micro-weather: high
*** Unmeasured SWAG

# Who Are the Missing Middle

http://www.youtube.com/watch?v=JqqsH4mgEYc

# Manufacturing Jobs (1000's of workers)




Source: U.S. Bureau of Labor Statistics, 2008

It's likely that there is a Missing Middle Community near you

# AHPDM
## Alliance for High Performance Digital Manufacturing

- Established to pursue solutions to the barriers facing the Missing Middle in US Manufacturing
  - "Transforming American Manufacturing for Economic Growth"
- Comprised of more than 45 entities, from:
  - Computer OEMs, ISVs, Academia, Manufacturing, National Labs
- Early results:
  - America COMPETES Renewal language for IAWG
  - Further analysis: results released via NCMS on 9/30/2010
  - Industry Recognition Initiative launched at IDC HPC User Forum on 9/14/2010

Intersect360
Intel
Ansys
Dell
Nimbis
R-Systems
Tabor Comms
Battelle
PSC
Polymer Ohio
Super Micro
Arista Networks
Microsoft
Univ Chicago
OSC
RMSC
HP

RPI
TACC
Bright Computing
IDC
Cray
ERDC
Appro
NCMS
Caterpillar
Accelrys
CD-Adapco
Platform
Brocade
3DS
NCSA
CUNY
ATK

SGI
Adaptive Computing
MSU
nVidia
RENCI
L&L
ORNL
GWU
PSU
GE
ACE Clearwater
LMCO
MAG

intel

# AHPDM Focus Areas

- Industry analytics: Nature of the MM and the key barriers
- Public Policy: Setting the national agenda for Transforming American Manufacturing
- Communications: Engaging with and about the MM
  - www.digitalmanufacturing.org
  - Major industry and government engagement: monthly cadence
- Solutions: How to resolve the "missing" element
  - Digital Supply Chain
  - PICs

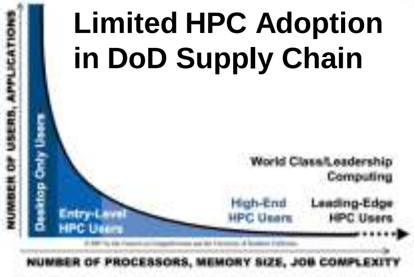
# Current Events

- America COMPETES Renewal Act of 2011
  - IAWG to pursue solutions space for the MM, led be DOC
- Launch of the *Advanced Manufacturing Initiative*
  - http://www.whitehouse.gov/sites/default/files/microsites/ostp/Advanced-manu.pdf
  - Noted among other things:
    - "A strong advanced manufacturing sector is essential to national security."
  - Proposed a budget of $500M spread across DOC, DOE, and DoD, growing to $1B in four years.
- NSF Launces the Innovation Corps – Oct, 2011

# HPC-ISP PILOTS: Case studies to evaluate whether manufacturing SMBs would see real benefits if they could obtain HPC access

**STATUS QUO**

### Limited HPC Adoption in DoD Supply Chain




- *The limited industrial user adoption of HPC is eroding the competitiveness of critical DoD suppliers and the country's industrial and military capability.*

**NEW INSIGHTS**

### Phase 1 Case Studies Found:

- *HPC is often **perceived** as an ultra high-end technology appropriate only for government or academia.*
- *There is a lack of understanding of the business value (**ROI**) of simulation and analysis with HPC.*
- *Access to talent, lack of software, and initial capital cost are all barriers.*

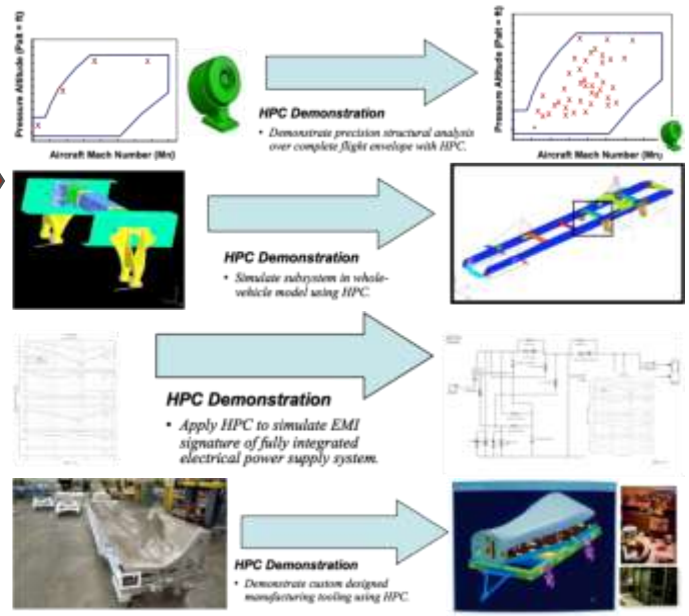


### Technical Approach:

- Demonstrate the business and competitive value of product simulation and analysis with HPC for U.S. manufacturing.
- Motivate usage of this innovation-accelerating technology throughout the DoD supply chain supplier base.
- Identify technologies and partners that can help support an HPC infrastructure for the DoD supply chain base.

### Deliverables

- Conduct four 12-month HPC pilot demonstrations with DoD supply chain "desktop-only" companies.
- The Council will deliver 10 HPC user case studies.




**QUANTITATIVE IMPACT**

### Success Stories:

- Successful examples of accelerated innovation, new discoveries, new product development, shortened time to market, cost savings.
- The Pratt & Whitney supply chain pilot will be measured in terms of value achieved/saved through a product value stream analysis.


**END-OF-PHASE GOAL**

### *Strengthen the DoD's Supply Chain*

- *Provide real world industry examples of the value of simulation and analysis with HPC that will stimulate usage through DoD's supply chain for greater supply chain reliability, product innovation, and cost savings.*

ISP=Innovation Service Portal

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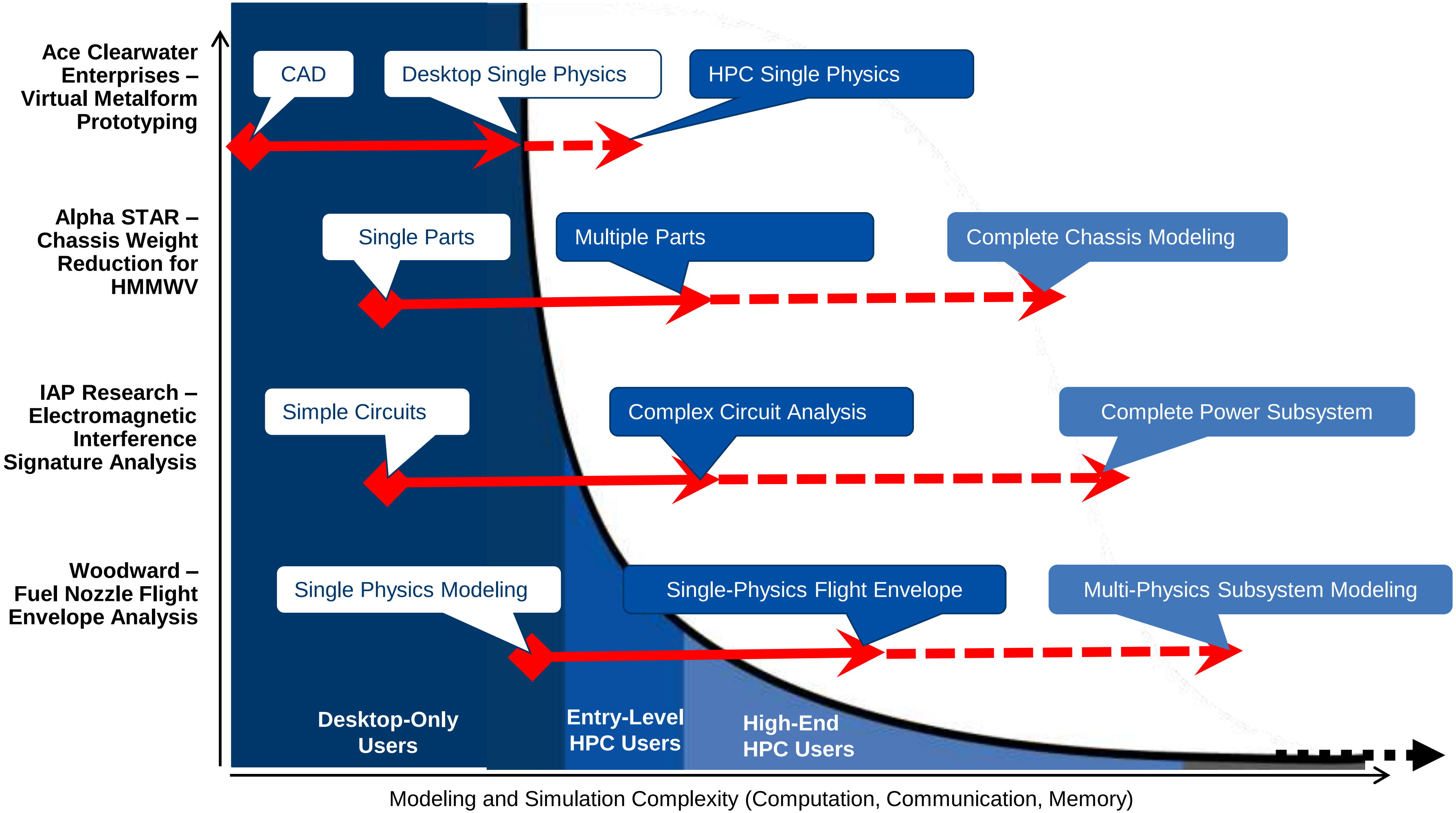
**Drive HPC Usage Throughout the DoD Supply Chain**

# Pilots intersecting different entry points



# ISI worked with an SMB engineering firm to leverage HPC

WOODWARD

**Fuel injection component supplier**

Information Sciences Institute

**HPC resource and expertise provider**

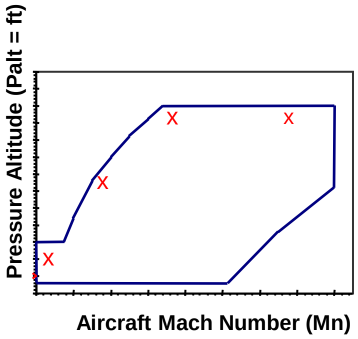
- 200 employees
- 3 computational engineers

**Jet engine supplier**

**Military aircraft**

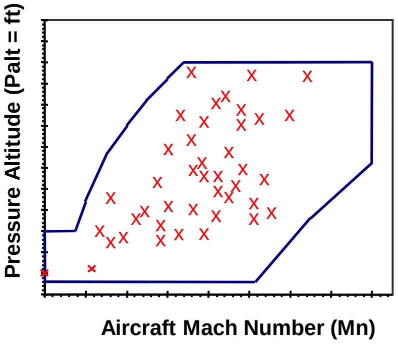
# Baseline goal: Simulate nozzle behavior at many more points within the flight envelope

**STATUS QUO**

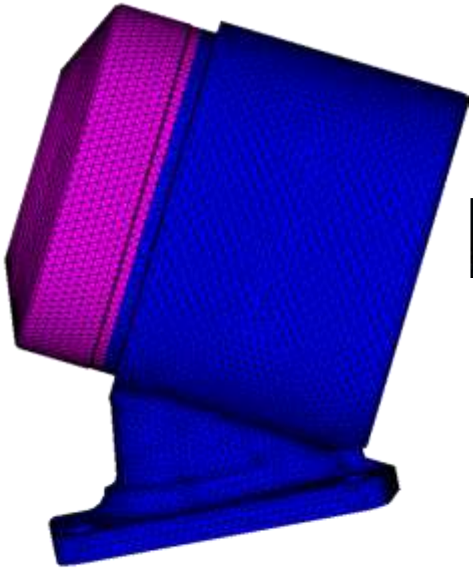



Eliminate the “desktop-only” bottleneck.

**GOAL**



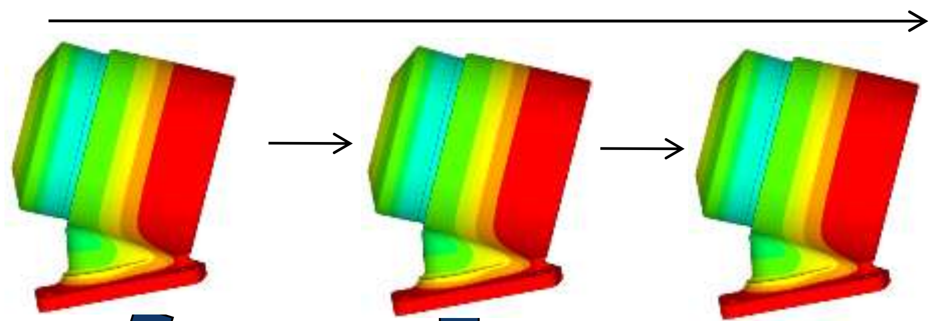
# Simulation problem: transient thermal + static structural analysis



**#1. Do thermal analysis to compute temperature using time-varying heat convection loads as inputs**

ANSYS

*Color shows temperature*

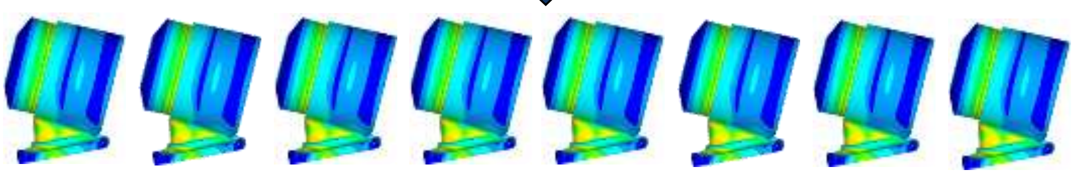



Model size increase: 4MDOF -> 6MDOF

**#2. Do structural analysis at different time points, using thermal loads calculated from thermal analysis**

…   …

# of points increase: 4 -> 81



*Color shows first principal stress*

**~480 MDOF total: 120X increase**

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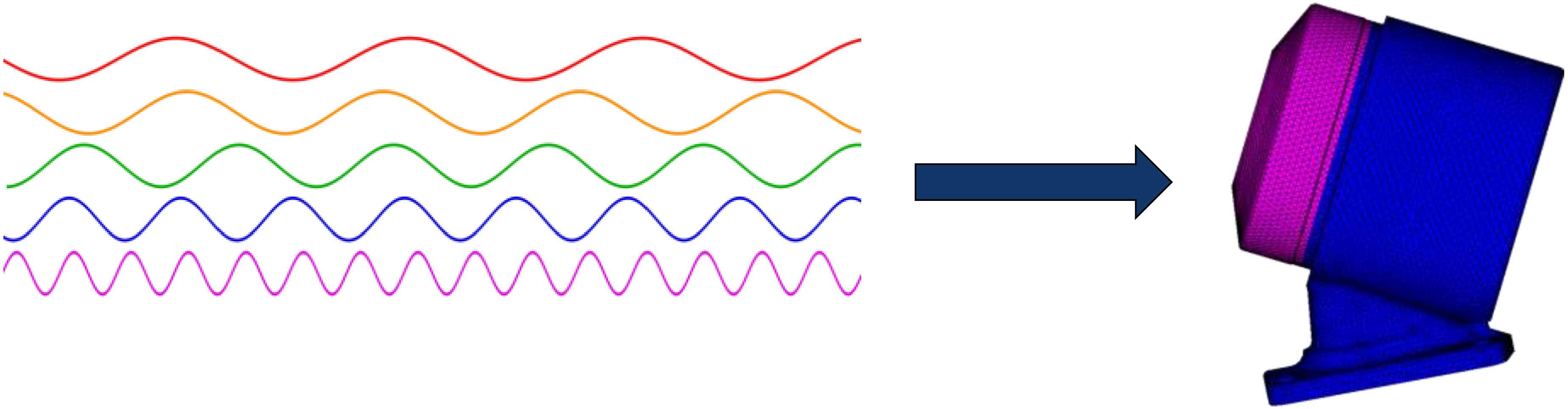
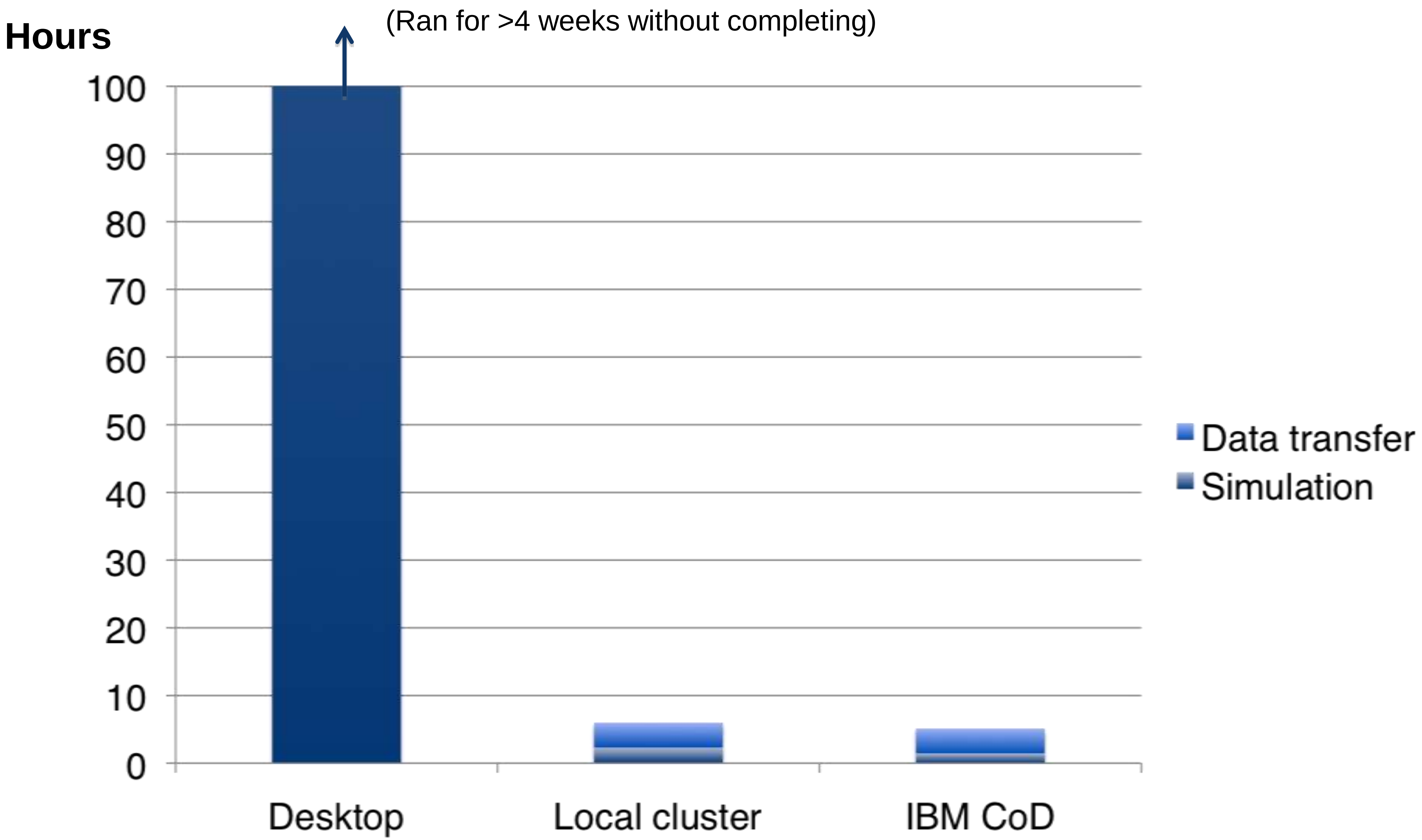
# Stretch goal: Harmonic analysis, would never attempt on desktop with large model



# Harmonic analysis ran only on HPC

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# Background

- **Power switching device for next generation US Navy ships**
- **New technology provides miniaturization**
  - **Increased power density**
  - **Increased *<u>conductive</u>* EMI**
- **Traditional EMI solution is ~30% over target cost and weight**
- **Current solution uses experience and iterative testing/evaluation**


ALTASIM TECHNOLOGIES
REALIZING TOMORROW'S TECHNOLOGY

# Future Business Impact

- **NGIPS roadmap indicates 60MW required for future "all electric" ship**
- **Power processed by solid state power switching devices**
- **For 60MW power output:**
  - **Development saving: ~$105M <u>per platform</u>**
  - **Development time saving: Decades**
  - **Procurement saving : ~$34M-3M <u>per ship</u>**
  - **Associated structure saving: ~$3.5M-600K <u>per ship</u>**

**Total cost saving: >$100M per platform**
**Total cost saving: >$30M per ship**

ALTASIM TECHNOLOGIES
REALIZING TOMORROW'S TECHNOLOGY

# HPC-ISP-PILOTS: Summary of results

STATUS QUO

**Limited HPC Adoption in DoD Supply Chain**

- *The limited industrial user adoption of HPC is eroding the competitiveness of critical DoD suppliers and the country's industrial and military capability.*

NEW INSIGHTS

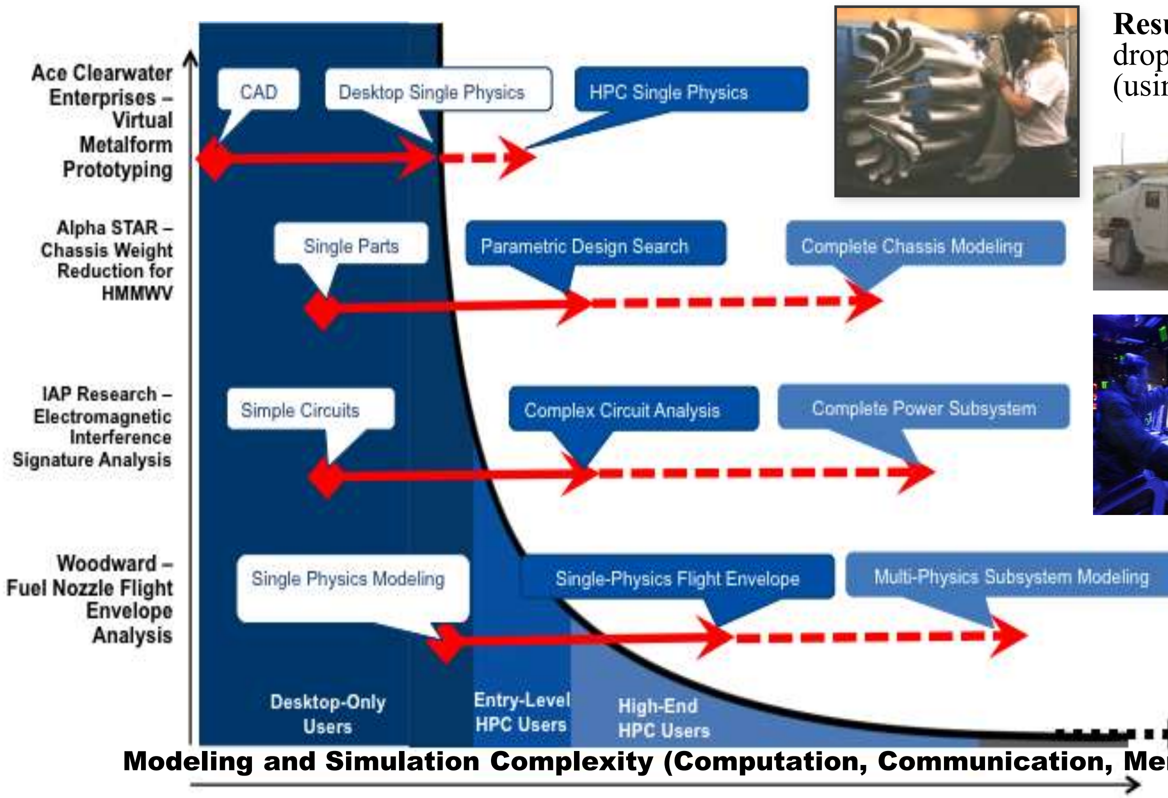


**First-Ever Studies of Desktop Technical Computing Users:**

- *HPC is often perceived as an ultra high-end technology appropriate only for government or academia; **limits supply-chain adoption of virtual prototyping**.*
- *There is a lack of understanding of the business value (**ROI**) of simulation and analysis with HPC; **few public successes among small/medium suppliers.***
- *Access to talent, lack of software, and capital costs are all barriers; **suggests market for on-demand HPC and software for entry-level & periodic users.***

## DoD Supply Chain Pilots

PROJECT GOALS




**Result:** 50% reduction in development time for drop-hammer and hydro forming tooling (using FEA virtual prototyping).

**Result:** HPC parametric search found 70% weight reduction with 230% increase in load for hybrid composite control arm design.

**Result:** HPC analysis with Xyce ~30X reduction in probability of defect at qualification, with direct cost savings estimate $490K and ~12 weeks design time per PNCC power subsystem.

**Result:** Value stream mapping of design cycle show savings of 43% per design iteration and 76% across all iterations. The 120X increase in processing on HPC (4MDOF vs. 480MDOF) provided up to a 5:1 reduction in design failure escapes.

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Each of the pilots had a significant ROI impact unto themselves

But what about scaling to O(100,000) SMMs

# Blue Collar Computing Clients

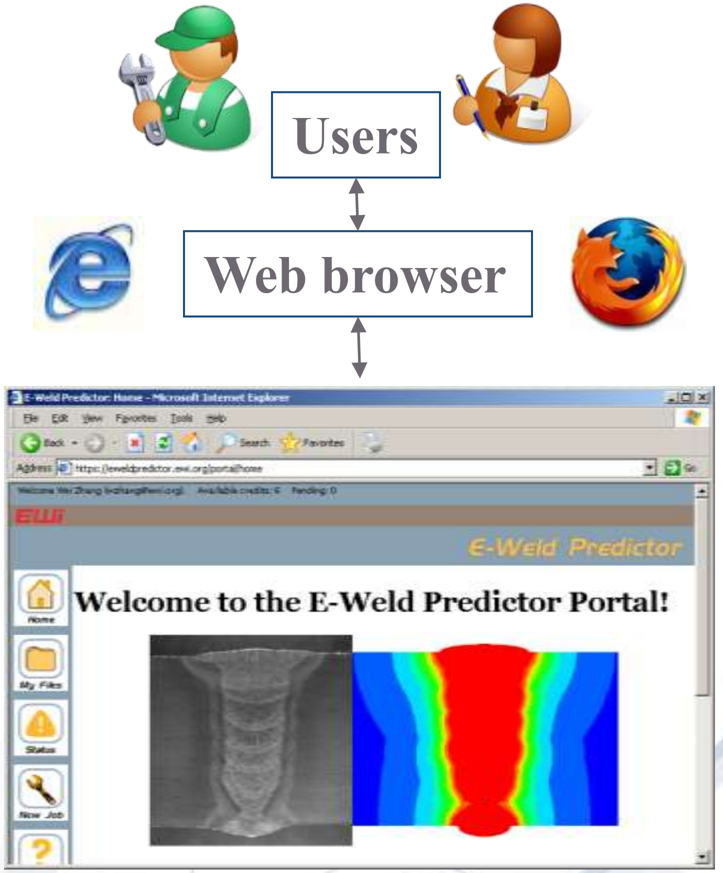
Two classes of industrial clients:

- Experienced HPC users who need access to larger systems for specific tasks ("peaking" facility)
  - E.g., Goodyear, P&G, Ohio auto maker
- Novice - *and some experienced* – HPC users where we develop industry-specific portals in collaboration with industry-focused organizations
  - EWI, PolymerOhio


Empower. Partner. Lead.
Ohio Supercomputer Center

# *Partnership with Edison Welding Institute*
# EWI-OSC WeldPredictor

- Secure website
- Easy access to advanced weld modeling tools
- Arc welding procedures
- Single and multi-pass welding simulation
- Output
  - Temperature
  - Hardness
  - Residual stress
  - Distortion




https://eweldpredictor.ewi.org/

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# WeldPredictor Portal Impact

- WeldPredictor allows industrial companies to access ***advanced weld modeling technology in the cloud***.
- WeldPredictor is free to EWI members
- WeldPredictor changes industrial engineers' thinking from physical prototypes to virtual prototypes and to apply modeling in problem solving.
- About 550 engineers worldwide have used EWI WeldPredictor

| EWI WeldPredictor Portal Impact | | |
|---|---|---|
| | Previously | **WeldPredictor** |
| Expertise Needed | Ph.D. | **B.S.** |
| Analysis Setup | 12 hours | **1 hour** |
| Project duration | 6 months | **1 month** |

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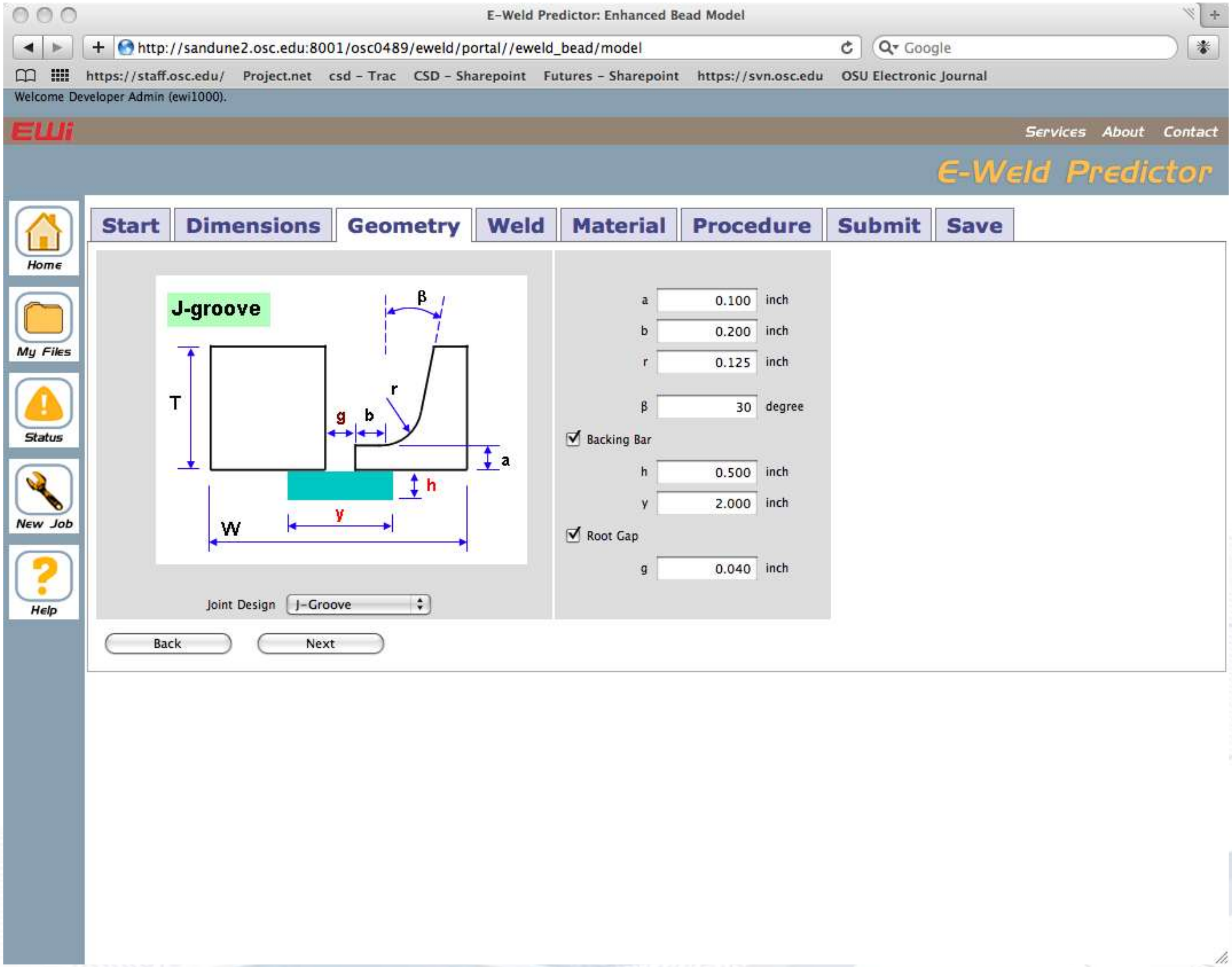
# Weld Geometry Selection

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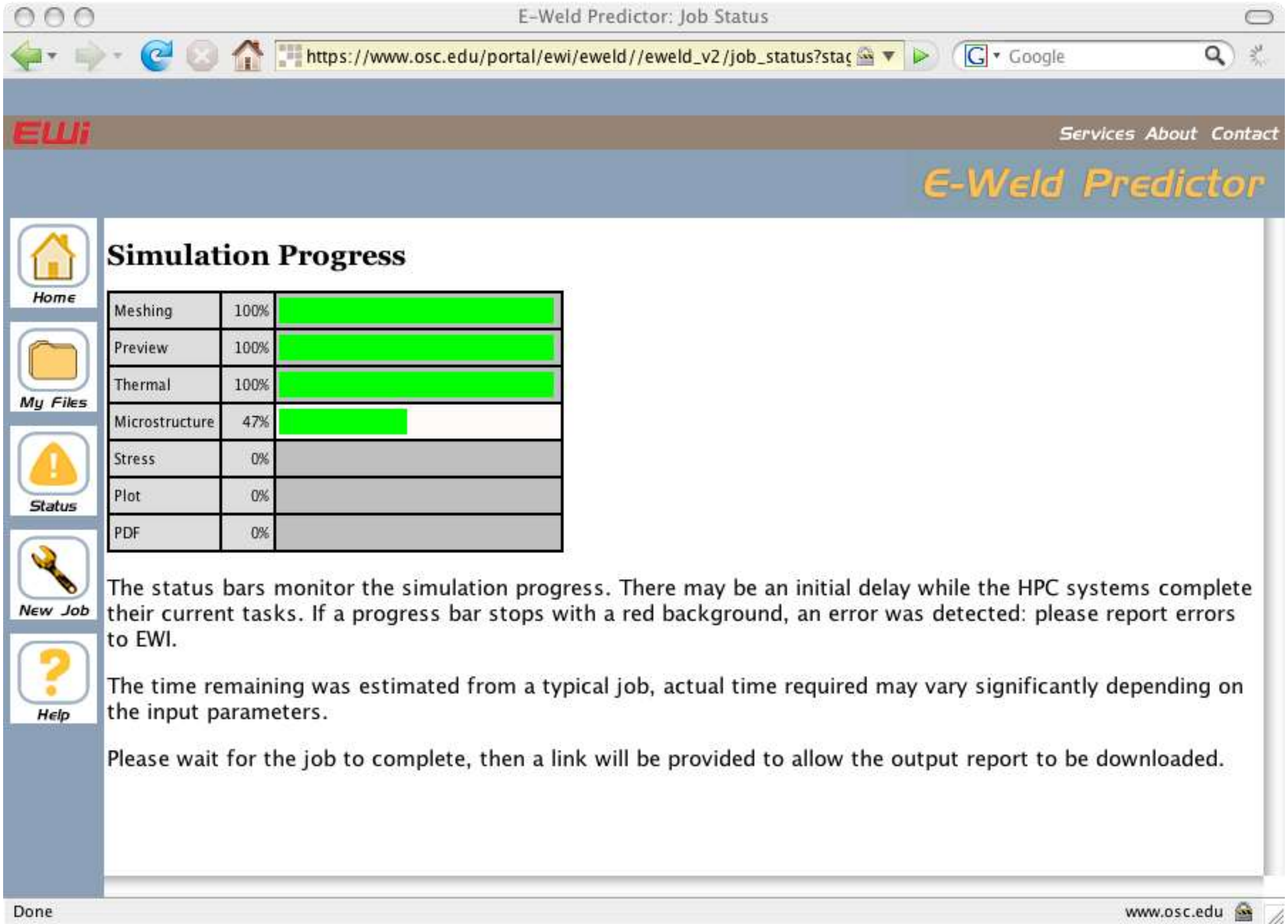
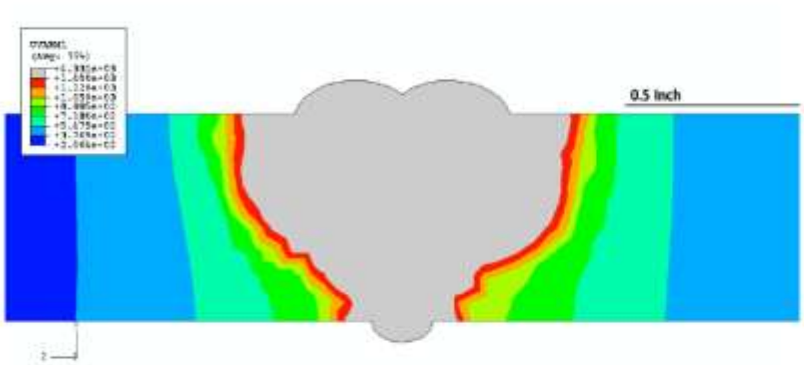
# Status Page


E-Weld Predictor: Job Status
https://www.osc.edu/portal/ewi/eweld//eweld_v2/job_status?stag
Google
EWi
Services About Contact
E-Weld Predictor
Home
My Files
Status
New Job
Help
Simulation Progress
Meshing 100%
Preview 100%
Thermal 100%
Microstructure 47%
Stress 0%
Plot 0%
PDF 0%
The status bars monitor the simulation progress. There may be an initial delay while the HPC systems complete their current tasks. If a progress bar stops with a red background, an error was detected: please report errors to EWI.
The time remaining was estimated from a typical job, actual time required may vary significantly depending on the input parameters.
Please wait for the job to complete, then a link will be provided to allow the output report to be downloaded.
Done
www.osc.edu

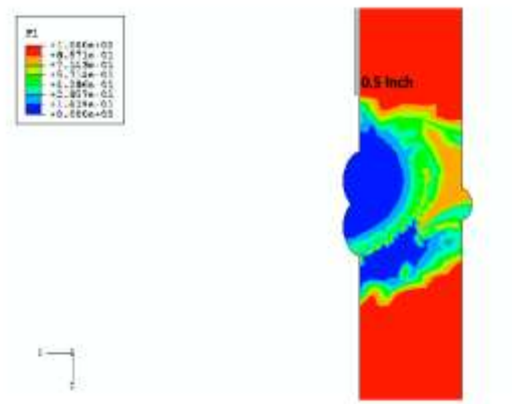
# E-Weld Predictor Example Output

**Distribution of peak temperatures (*C)**

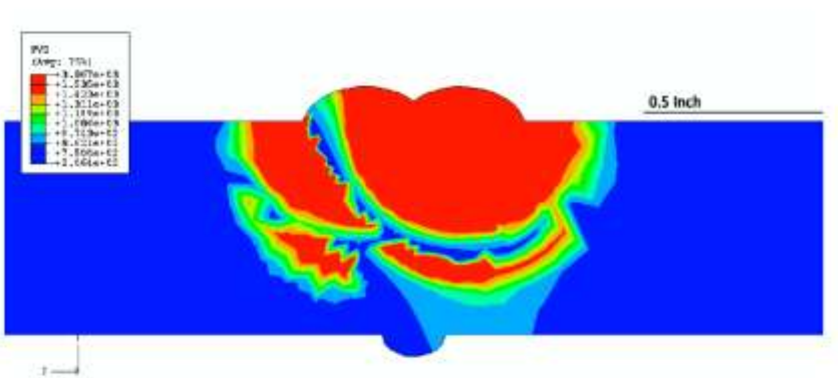



## Section 4 - Microstructure Analysis

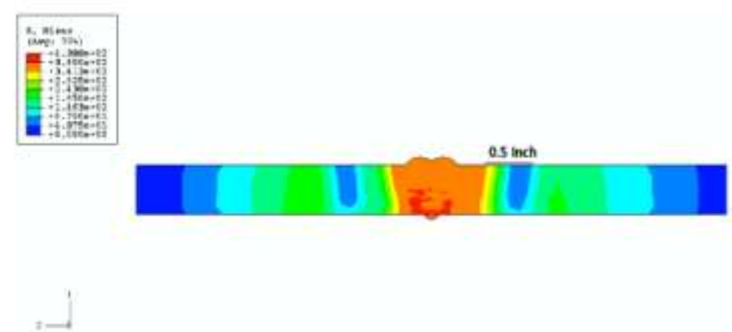
**Distribution of ferrite**




**Distribution of reheating temperatures (*C)**




**Distribution of von mises stresses (MPa).**



# *Partership with PolymerOhio*
# PolymerOhio-OSC PolymerPortal

- Polymer Portal being developed in collaboration with PolymerOhio
- The Polymer Portal will offer:
  - Computational resources and software for modeling/simulation
  - Expertise in polymer science and engineering
  - Training
  - Databases with relevant material properties
  - Advanced instrumentation
  - Business intelligence and strategy
- Offering Moldex3D and Ximex for industry and education training

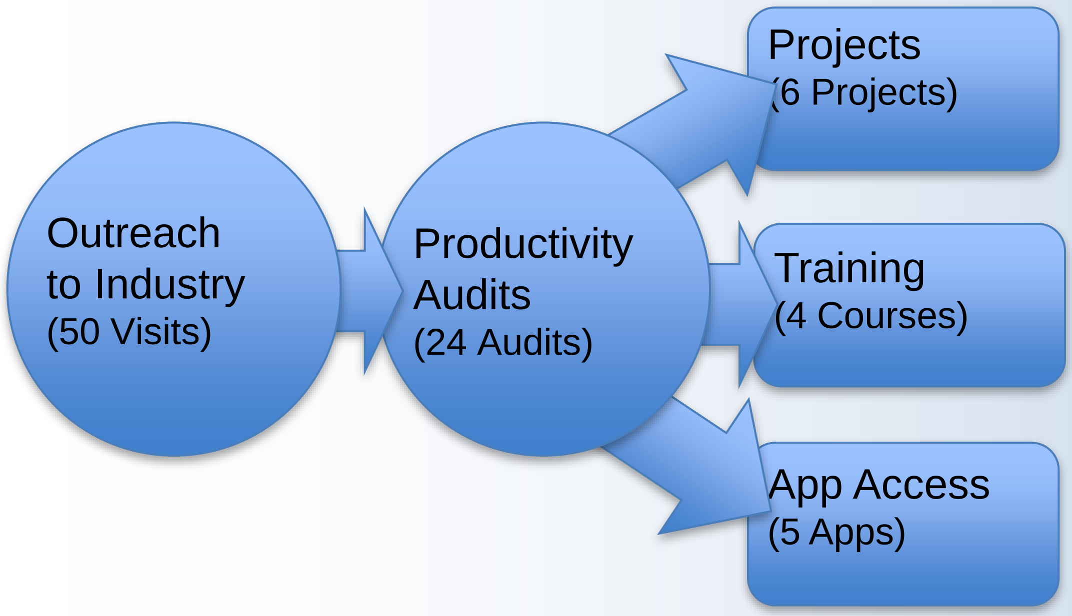
Web front end

- –Pylons
- –JSON
- –Tomcat
- –mySQL
- –JUnit
- –Apache
- –Ant
- –Python and Java

*Software components supporting the OSC Portals*

# MEP Advanced Modeling and Simulation

- Funded by NIST MEP for PolymerOhio and OSC
- Goals:
  - Raise awareness of MS&A in Polymer industry and MEP system
  - Make cost-effective computational methods available to SMEs
- ~$700K for 1$^{st}$ year




**Case studies provide MEP model to:**

- Illustrate MS&A value to production and profitability
- Assist companies in application selection
- Develop training for high value-added MS&A apps
- Engage companies in employee training for MS&A
- Provide broad access to low-cost, productivity-enhancing apps

OH!Polymer PolymerOhio, Inc.

Empower. Partner. Lead. Ohio Supercomputer Center

# Project Chicago – A Proximity Scaling Model to reach 10,000s of companies

## Proximity attributes

- High concentration of manufacturers in small geographic radius
- Local HS, CC, and Univ infrastructure
- Alignment with local EDA/SLED environment

## Execution Model

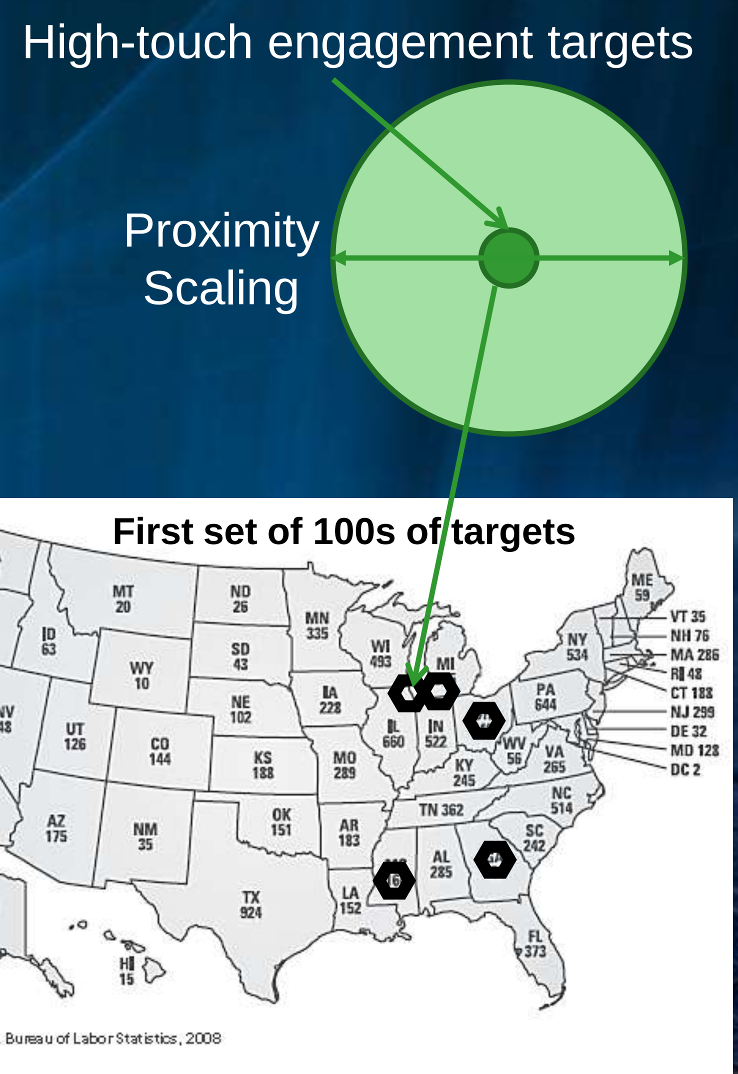
- Highly visible community engagement
- Develop trainers and evangelist network, apply them to
- High-touch interaction with sample companies, using
- Social media enabled following ("reality show") for the community, and
- Delivering broad, low-touch content training and hands-on opportunities for the large proximity target

## Delivery team

- ISVs
- Infrastructure providers (local and MNC)
- Intel
- Local manufacturers (as EBOA)
- Local academic stakeholders

## Metrics

- 300-500 companies in the immediate proximity
- Class-room environment supporting 200 students/week
- Replicable



# Summing up the US MFG MM

- Nearly 280K SMMs in the US
  - NAM
- Nearly half would use MS&A, if they could
  - IDC REVEAL
- Represents nearly the equivalence of the WW HPC Market Segment as we now know it

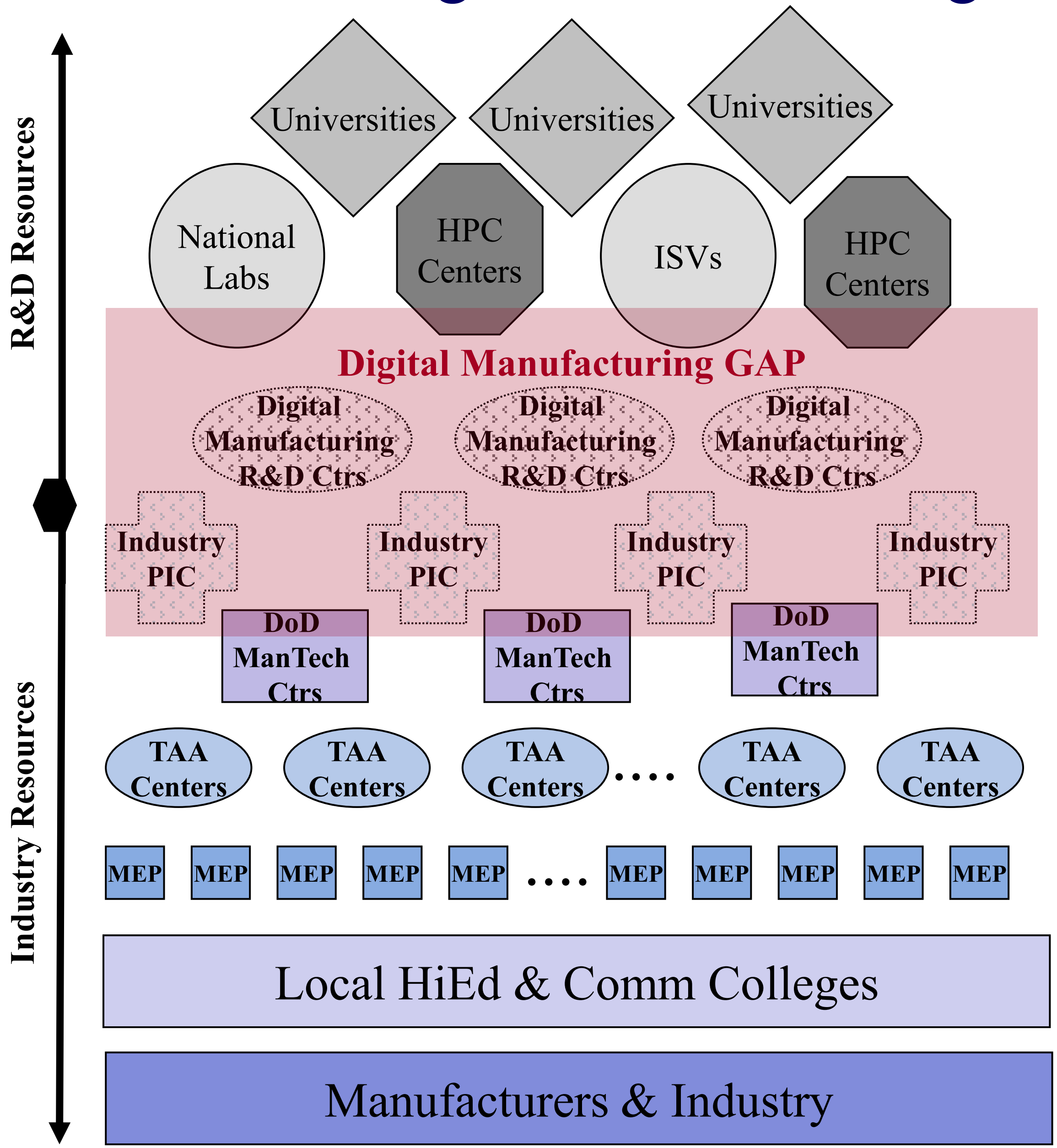

# Definition of Success:

## When the "middle" isn't "missing"

Play Tribute

intel®

# National Digital Manufacturing Strategy Vision




**Existing R&D Expertise**

- Universities
- National Labs
- DoE Labs
- HPC Centers (i.e. OSC, NCSA, etc.)

**Proposed National Manufacturing Innovation Network**

- Digital Manufacturing R&D Centers
- (academic focus)
- Industry Predictive Innovation Collaboration Centers (non-profit e.g. NCMS)

**Trade Adjustment Assistance Centers (TAAC)**

- Approx. 14 National Centers
- Expand mission beyond trade impacted companies

**MEP's (NIST)**

- 60+ National Centers
- New focus on Digital Manufacturing

**Focused Digital Manufacturing Training**

- Community colleges, NAM, Manufacturing web portals