Data and Analytics for Materials Research

Sustainability, Public/Private Partnerships, and Industry Needs and Interests

David Furrer and Rajiv Naik

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OUTLINE

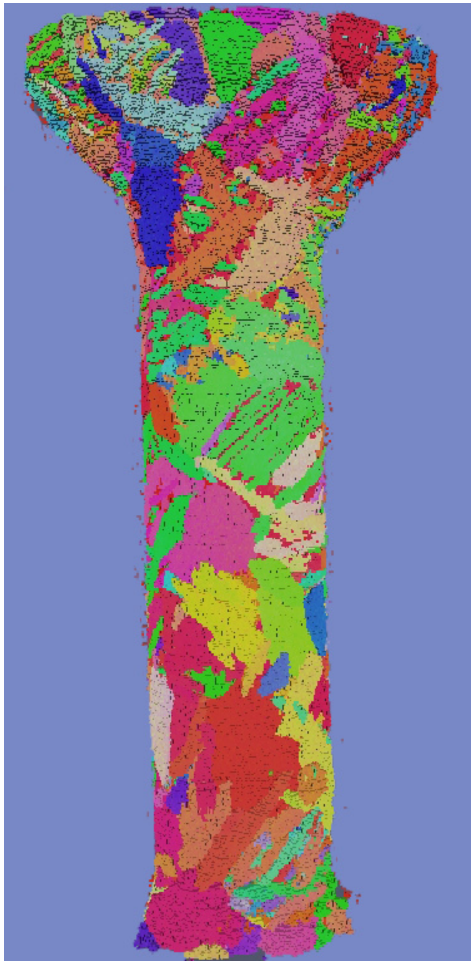
- Industry Needs and Interests
- Public/Private Partnerships
- Sustainability
- Summary

Industry Requirements for Data & Analytics

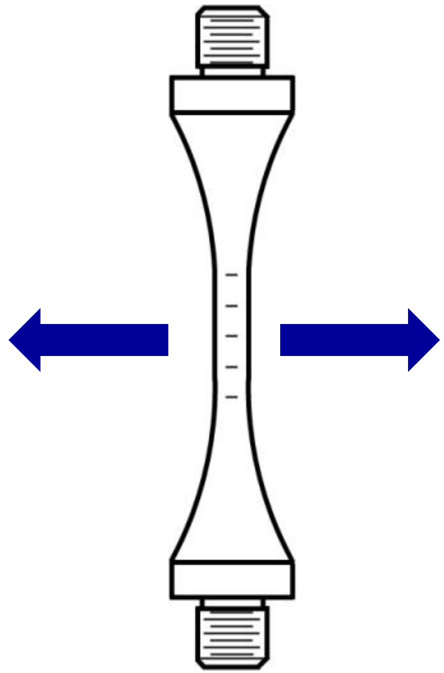
- Material Definitions
- Model Development
- Material Pedigrees based on Processing

MATERIALS DEFINITIONS

What a tensile test looks like.....



Source: Rollie Dutton - AFRL



MIL-HBK-5H

Table 5.4.1.0(b). Design Mechanical and Physical Properties of Ti-6Al-4V Sheet, Strip, and Plate

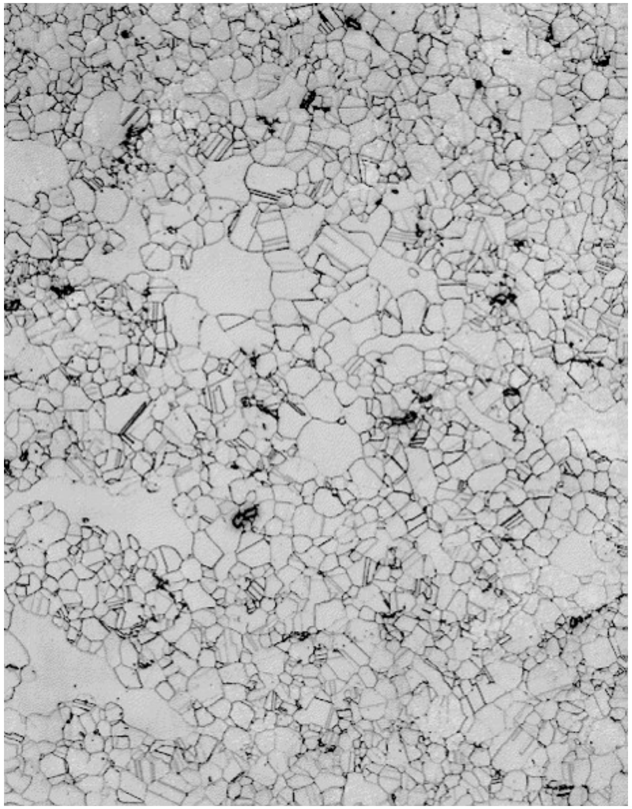
Specification	AMS 4911 and MIL-T-9046, Comp. AB-1					MIL-T-9046, Comp. AB-1			
Form	Sheet		Plate			Sheet, strip, and plate			
Condition	Annealed					Solution treated and aged			
Thickness, in.	≤ 0.1875		0.1875-2.000		2.001-4.000	≤ 0.1875	0.1875-0.750	0.751-1.000	1.001-2.000
Basis	A	B	A	B	S	S	S	S	S
Mechanical Properties:									
F_{tu}, ksi:									
L	134	139	130[a]	135	130	160	160	150	145
LT	134	139	130[a]	138	130	160	160	150	145
F_{ty}, ksi:									
L	126	131	120	125	120	145	145	140	135
LT	126	131	120[a]	131	120	145	145	140	135
F_{cy}, ksi:									
L	133	138	124	129	124	154	150	145	...
LT	135	141	130	142	130	162	...	...	...
F_{su}, ksi	87	90	79	84	79	100	93	87	...
F_{bru}, ksi:									
(e/D = 1.5)	213[b]	221[b]	206[b]	214[b]	206[b]	236	248	233	...
(e/D = 2.0)	272[b]	283[b]	260[b]	276[b]	260[b]	286	308	289	...
F_{bry}, ksi:									
(e/D = 1.5)	171[b]	178[b]	164[b]	179[b]	164[b]	210	210	203	...
(e/D = 2.0)	208[b]	217[b]	194[b]	212[b]	194[b]	232	243	235	...
e, percent (S-basis):									
L	8[c]	...	10	...	10	5[d]	8	6	6
LT	8[c]	...	10	...	10	5[d]	8	6	6
E, 10^3 ksi	16.0								
E_c, 10^3 ksi	16.4								
G, 10^3 ksi	6.2								
μ	0.31								
Physical Properties:									
ω, lb/in.^{3}	0.160								
C, K, and α	See Figure 4.5.1.0								

a The rounded T_{99} values are higher than specification values as follows: F_{tu}(L) = 131 ksi, F_{tu}(LT) = 132 ksi, and F_{ty}(LT) = 123 ksi.
b Bearing values are "dry pin" values per Section 1.4.7.1.
c 8%—0.025 to 0.062 in. and 10%—0.063 in. and above.
d 5%—0.050 in. and above; 4%—0.033 to 0.049 in. and 3%—0.032 in. and below.

To a Materials Engineer | **To a Mechanical Engineer**

MATERIALS DEFINITIONS

Advanced characterization enabling modern definitions



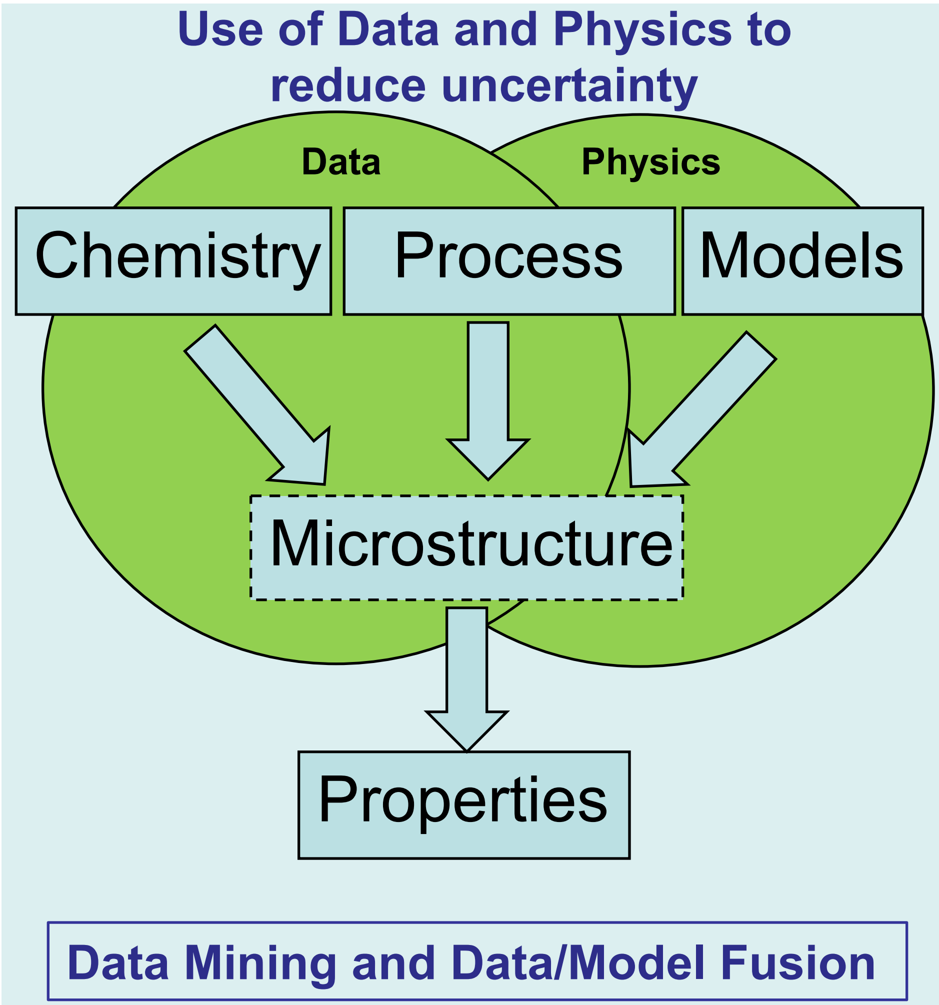
Source: Prat & Whitney

Source: Pratt & Whitney

Optical and OIM Images of Partially Recrystallized Waspaloy

MATERIALS INFORMATICS

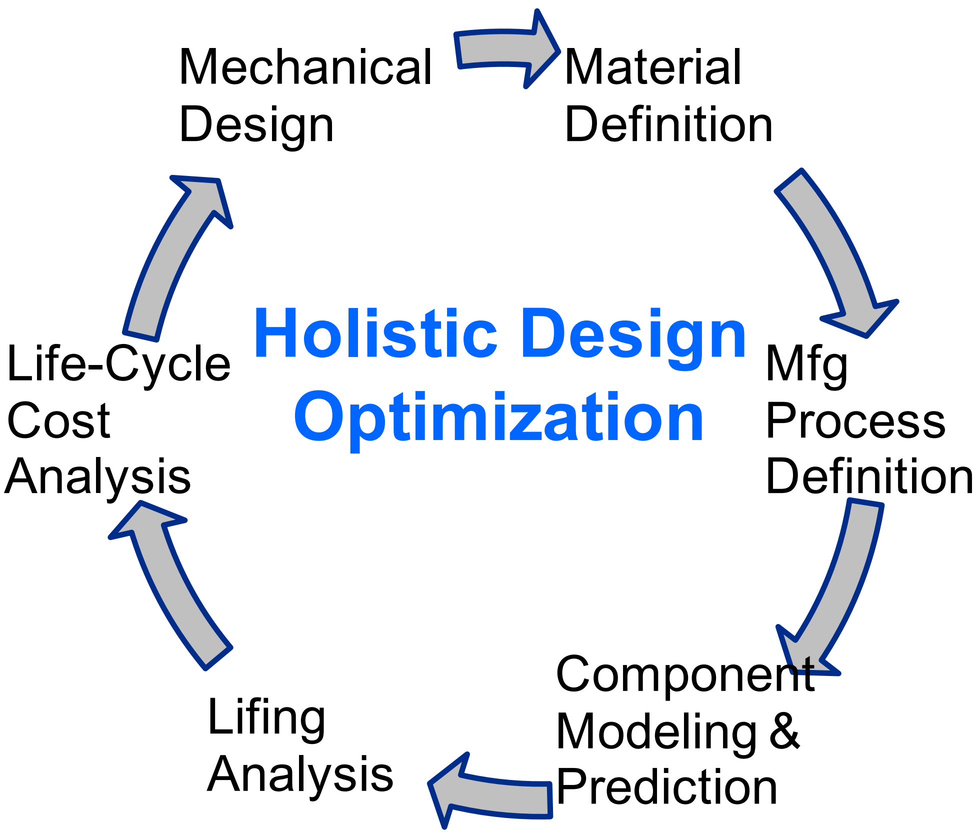
Use of data and modeling



- Capture and Re-Use Materials Data and Meta-Data ("Digital Thread")
- Establish Enhanced Models to Support Future Materials Definitions and Design Functions
- Quantify Uncertainty of Models and Enhance Understanding to Minimize Future Testing

COMPUTATIONAL MATERIALS MODELING

Fit for purpose focus



Materials Modeling:

Enhanced material definition

Mechanism-based understanding

Path-dependent predictions

Mfg Process Modeling:

Material processing path definition

Component Modeling:

Location-specific optimization

Integrated Computational Materials Engineering (ICME)

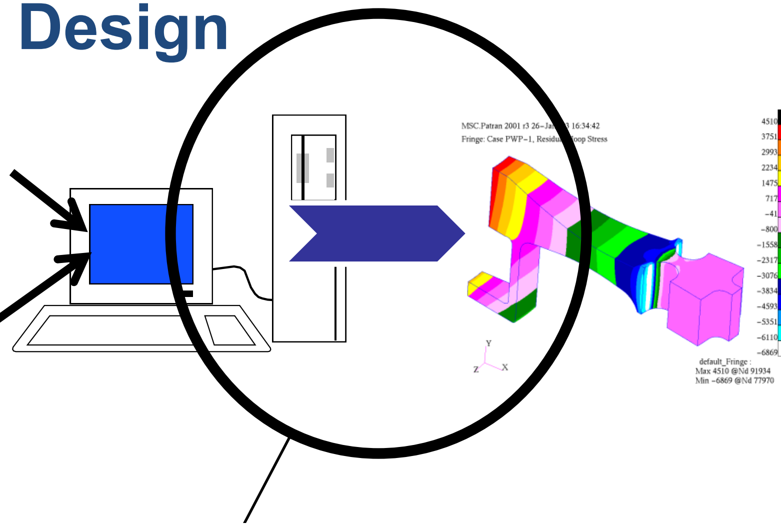
MODEL-BASED DEFINITIONS

Use models to link design, producibility & properties

Component Design

Model-based Mt'l definition

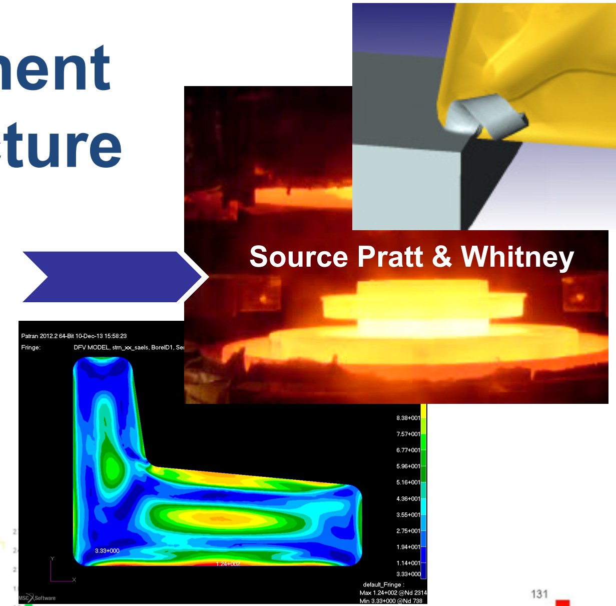
Model-based Mfg process definition

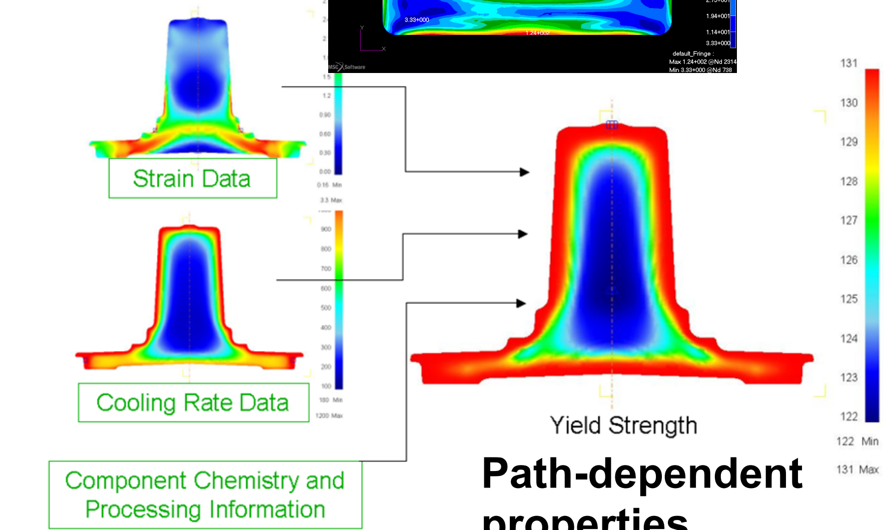


Parametric model includes local structure and properties

Component Manufacture

Model-based component definition



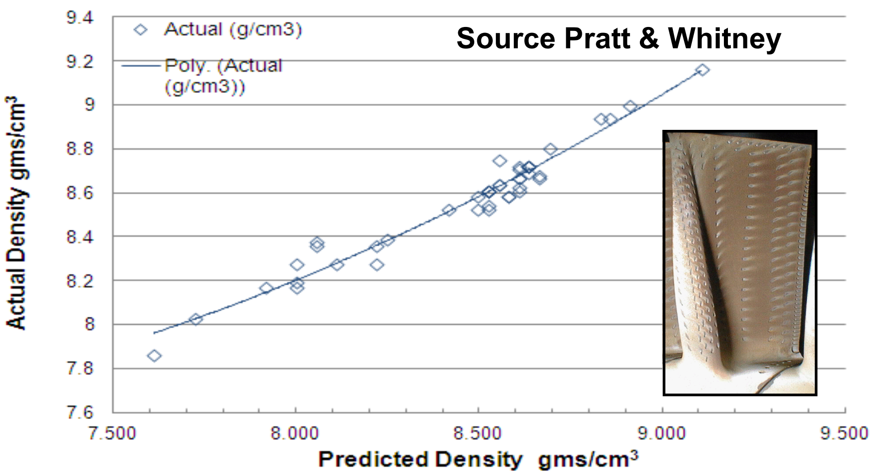


Path-dependent properties

Utilization of Modeling to Predict Component Capabilities and Proactively Mitigate Producibility Risks

COMPUTATIONAL MATERIALS MODELING

Single Crystal Alloy Design Optimization

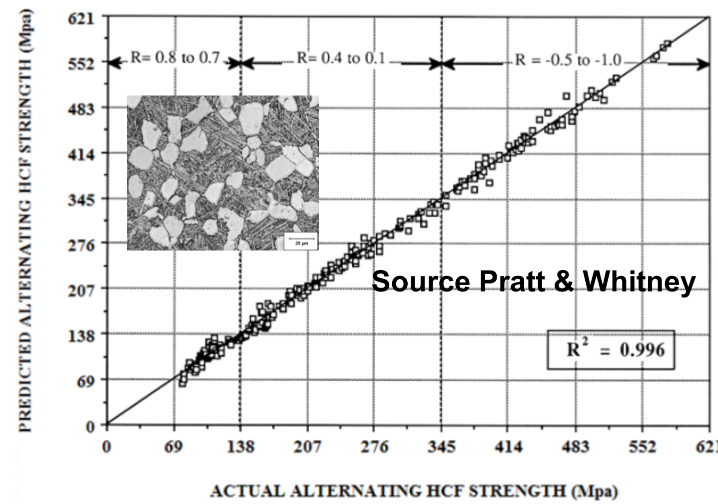


Computational model-based alloy design

Reduce rare earth elements

Rhenium-free alloy developed in < 2yrs

Microstructure sensitive materials behavior modeling



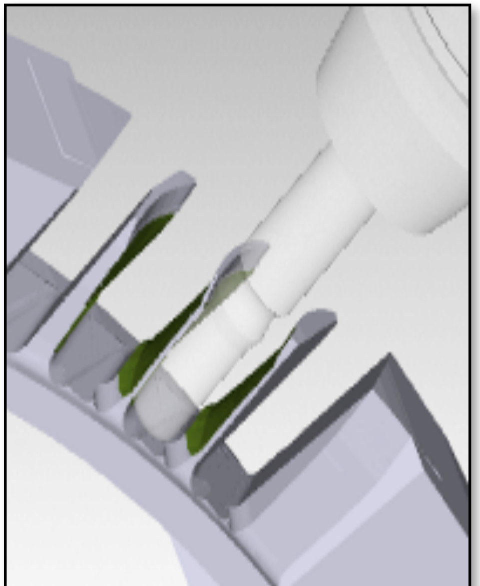
Advanced rotor alloys to enable higher temperature cycles

Chemistry and microstructure-based fatigue models

Location-specific component mechanical property predictions

COMPUTATIONAL PROCESS MODELING

Physics-based models can drive optimization



Source Pratt & Whitney

Production cutter path files

Constraints
- Force limit
- Chip load limit
- Feed rate allowed

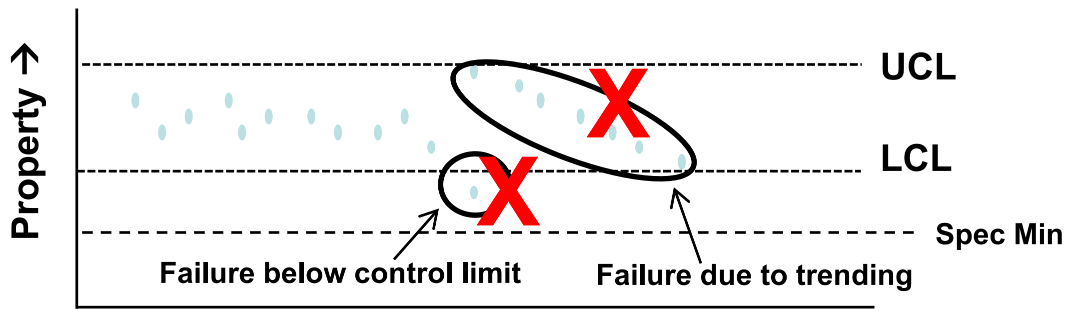
Model & Optimization

Optimized cutter path files

Machining process optimization reduces cycle time and increases cutter survival rate

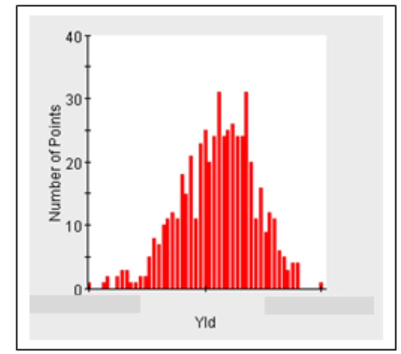
CRITICAL INFRASTRUCTURE ELEMENTS

Goal is prediction and control of capabilities

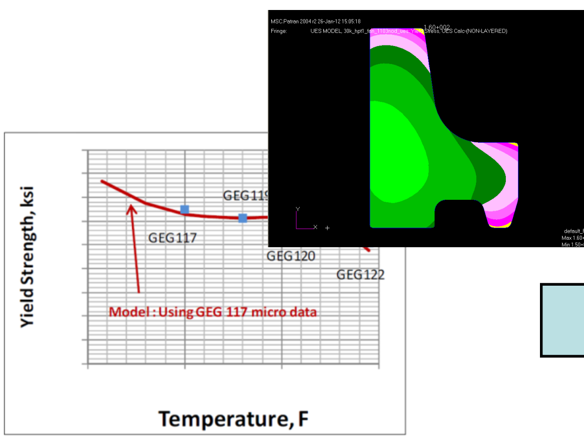


Data Capture

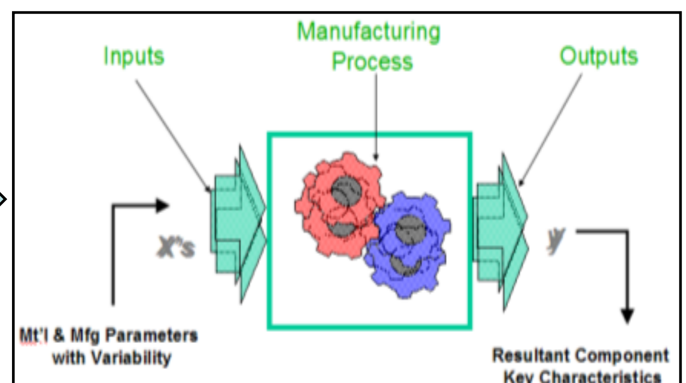
Design for Variability



Predicted Material and Component Properties



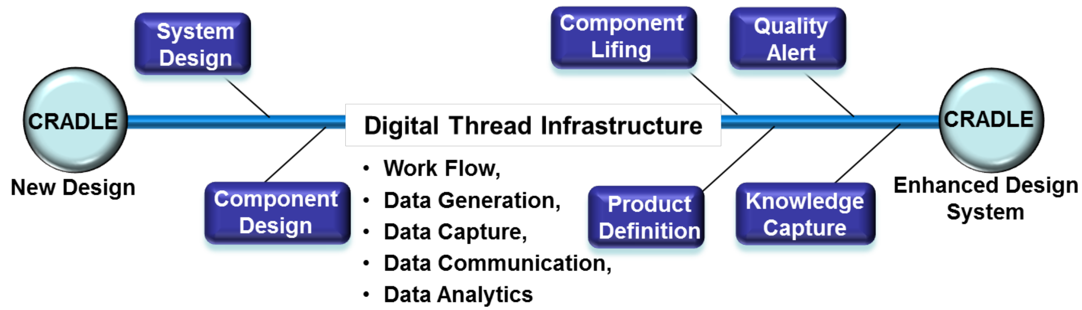
Materials Modeling

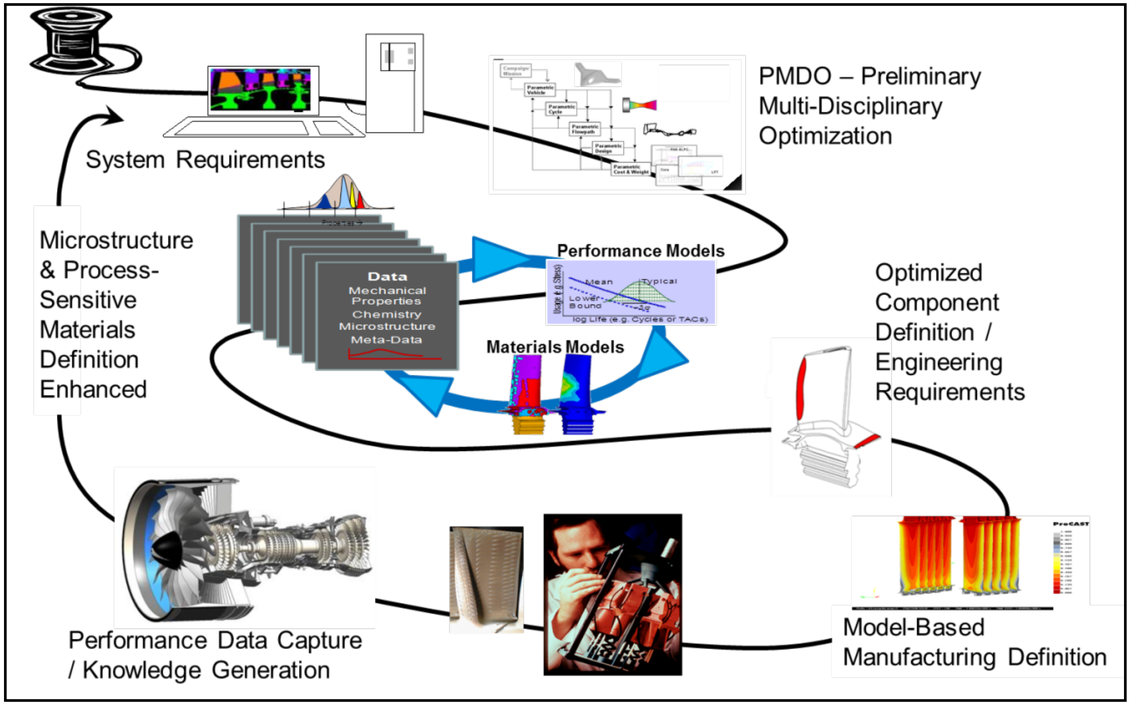


DIGITAL THREAD INFRASTRUCTURE

Benefits

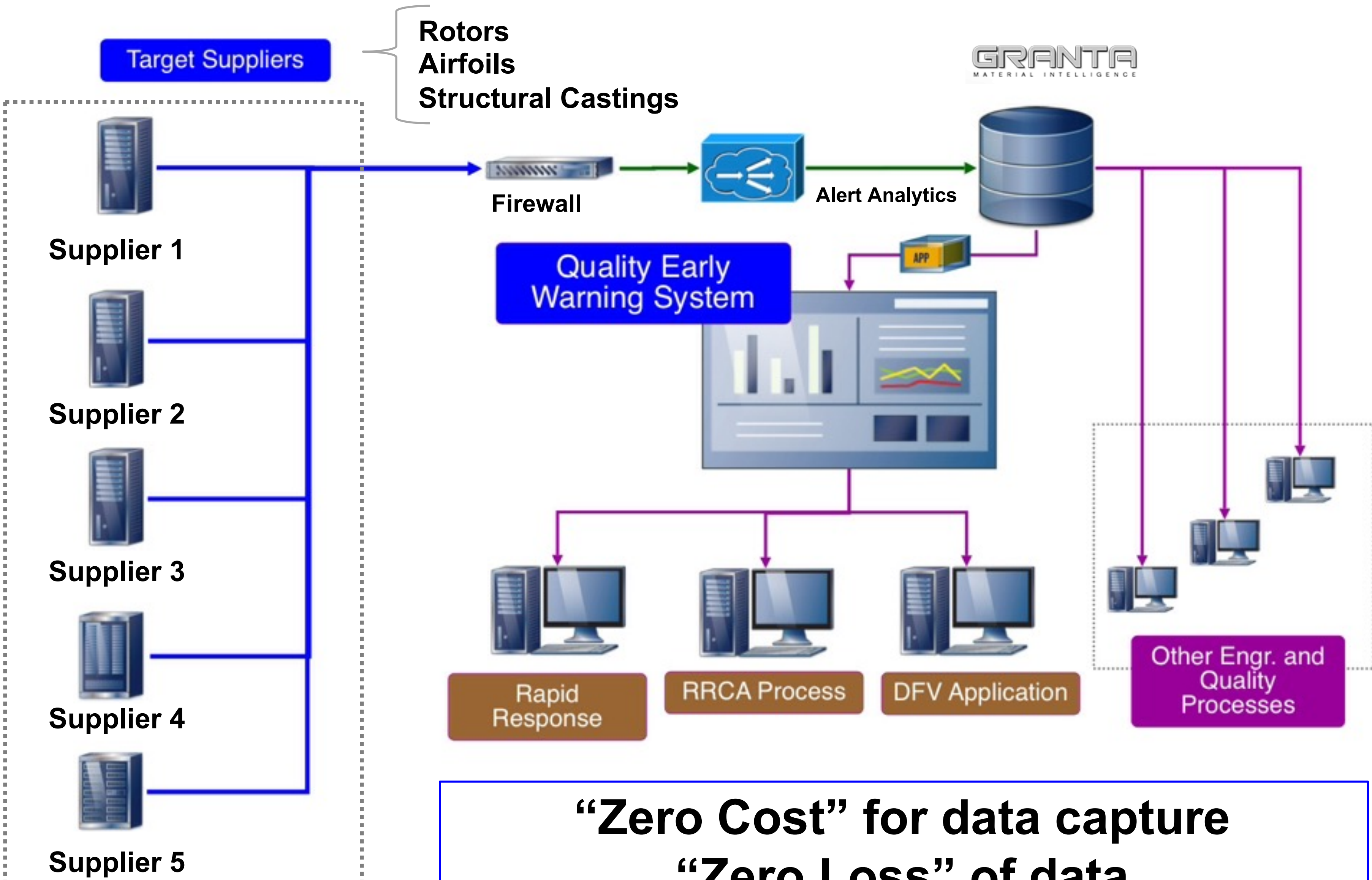
- Performance-based design capabilities
- Real-time analytics for improved decision-making
- Enhanced sustainment and usage-based component lifing
- Proactive and adaptive correction of production issues





Source Pratt & Whitney

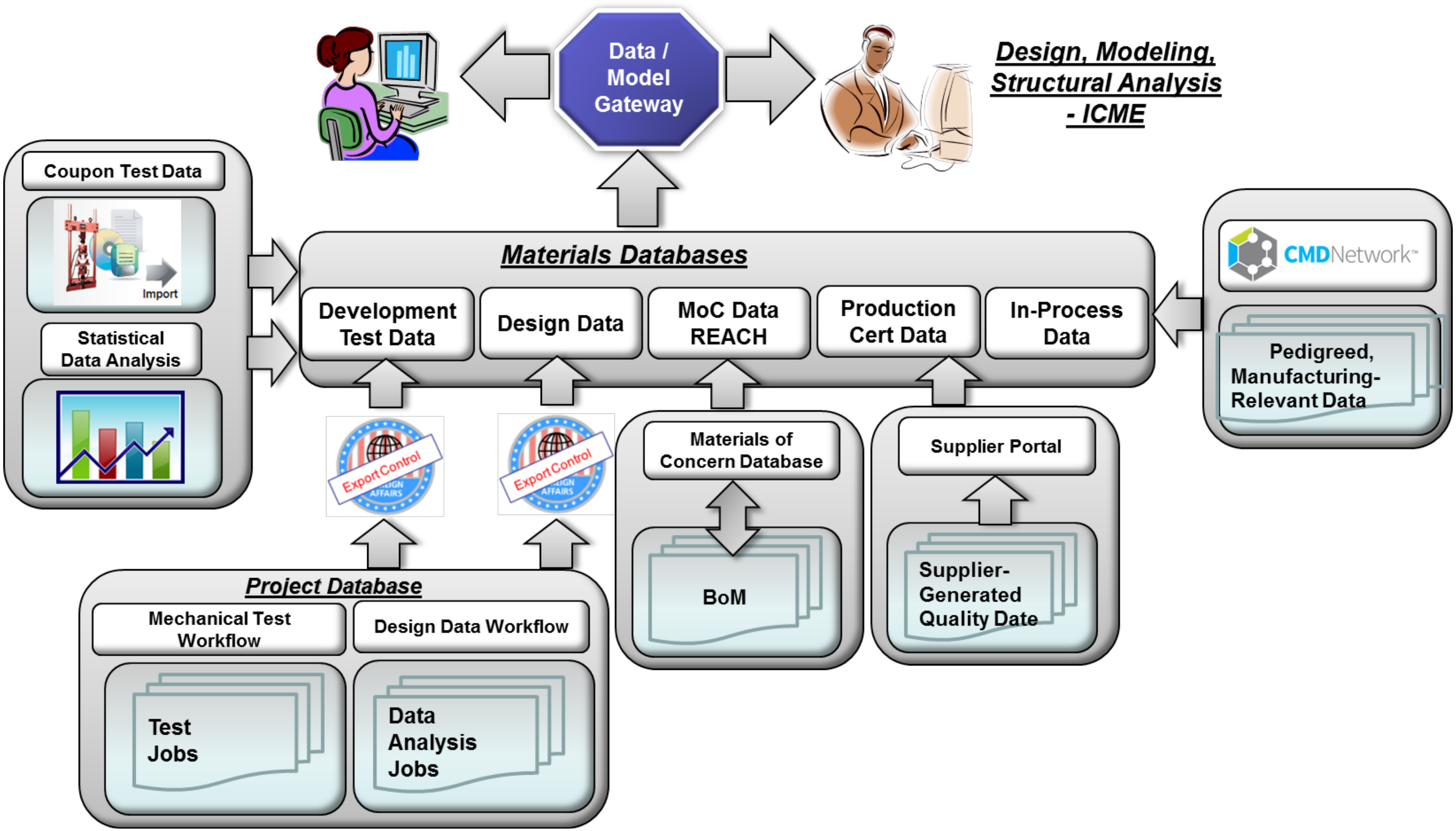
MATERIALS DATA CAPTURE



"Zero Cost" for data capture
"Zero Loss" of data

MATERIALS DATA INFRASTRUCTURE

Data comes from many sources



FUNDAMENTAL DATA GAPS

- Education
- Linkages between engineering disciplines
- Identification of pre-competitive technology
- Incentives for organizations to collaboratively fill gaps in needed technology capabilities
- Standards for data, communication, computational linkages

EFFECTIVE COLLABORATION APPROACHES

- Focused research
- Clear and accessible benefits
- Win-Win approach for research and results
- Favorable funding framework

PROFESSIONAL SOCIETIES

Professional societies are actively supporting collaboration and integration of inter-disciplinary research and technology

- ASM-International: Programming; Materials Data Management
- TMS: Programming; Education; Computational Tools Repository
- AIAA: Programming; Education
- Others……

PROFESSIONAL SOCIETIES

ASM-International

CMDNetwork

http://www.asminternational.org/web/cmdnetwork

PROFESSIONAL SOCIETIES

TMS

The Orlando Materials Innovation Principles

TMS is leading collaboration efforts to establish common framework for sharing and publishing

http://www.tms.org/orlandoprinciples/

SUPPLY-CHAIN CONSORTIA

The Material Data Management Consortium (MDMC)

Managing critical data in aerospace, defense, and energy

http://www.mdmc.net/

Materials Data Management Consortium (MDMC)

Granta-Ltd Led Industrial Sponsored Consortium

UNIVERSITY / INDUSTRY CONSORTIA

MPI METAL PROCESSING INSTITUTE

Centers for Focused Pre-Competitive Research

- **ACRC** Advanced Casting Research Center
- **CHTE** Center for Heat Treating Excellence
- **CR³** Center for Resource Recovery and Recycling
- **CMPD** Center for Materials Processing Data

http://wp.wpi.edu/mpi/

CMPD CENTER FOR MATERIALS PROCESSING DATA

UCONN UNIVERSITY OF CONNECTICUT

ASM INTERNATIONAL

UB

WPI

Clean, pedigreed data for manufacturing process simulation

UNIVERSITY / INDUSTRY CONSORTIA

CMPD CENTER FOR MATERIALS PROCESSING DATA

WPI UB ASM INTERNATIONAL UCONN UNIVERSITY OF CONNECTICUT

HOME ABOUT RESEARCH MEMBERSHIP TEAM CONTACT CENTERS

Gain access to all needed transient materials property relevant to manufacturing in one location….

Collaborate on and develop trusted, highly pedigreed data…..

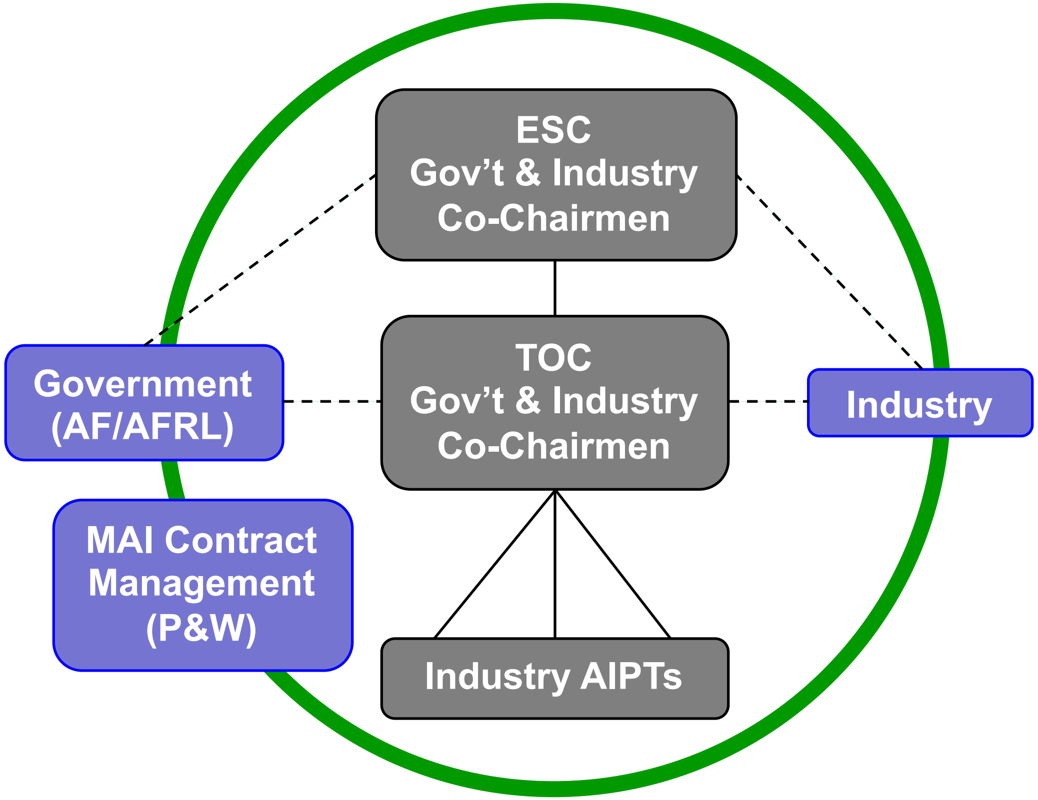
http://wp.wpi.edu/cmpd/

GOVERNMENT / INDUSTRY COLLABORATIONS

Consortia and Centers that have been long-running are a result of being successful at delivery of Win-Win solutions

Metals Affordability Initiative (MAI) is an example of a successful Government and Industry Consortium

Many successful projects have resulted from this collaborative program



SUSTAINMENT

Clear, Tangible Benefits

WIN - WIN

SUMMARY

- Data and data analytics are critical for materials research and application
- Model-based material and process definitions are emerging
- Data is required for optimal application of models
- Collaboration on pre-competitive data and technology critical for speed of new development
- Sustainment will result from clear benefits and WIN-WIN strategies