ICME with ModelCenter

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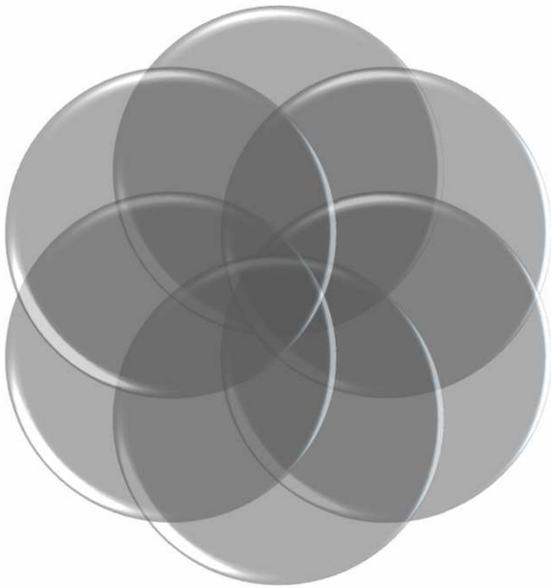
Phoenix Integration
V1.0 R1

PHOENIX INTEGRATION

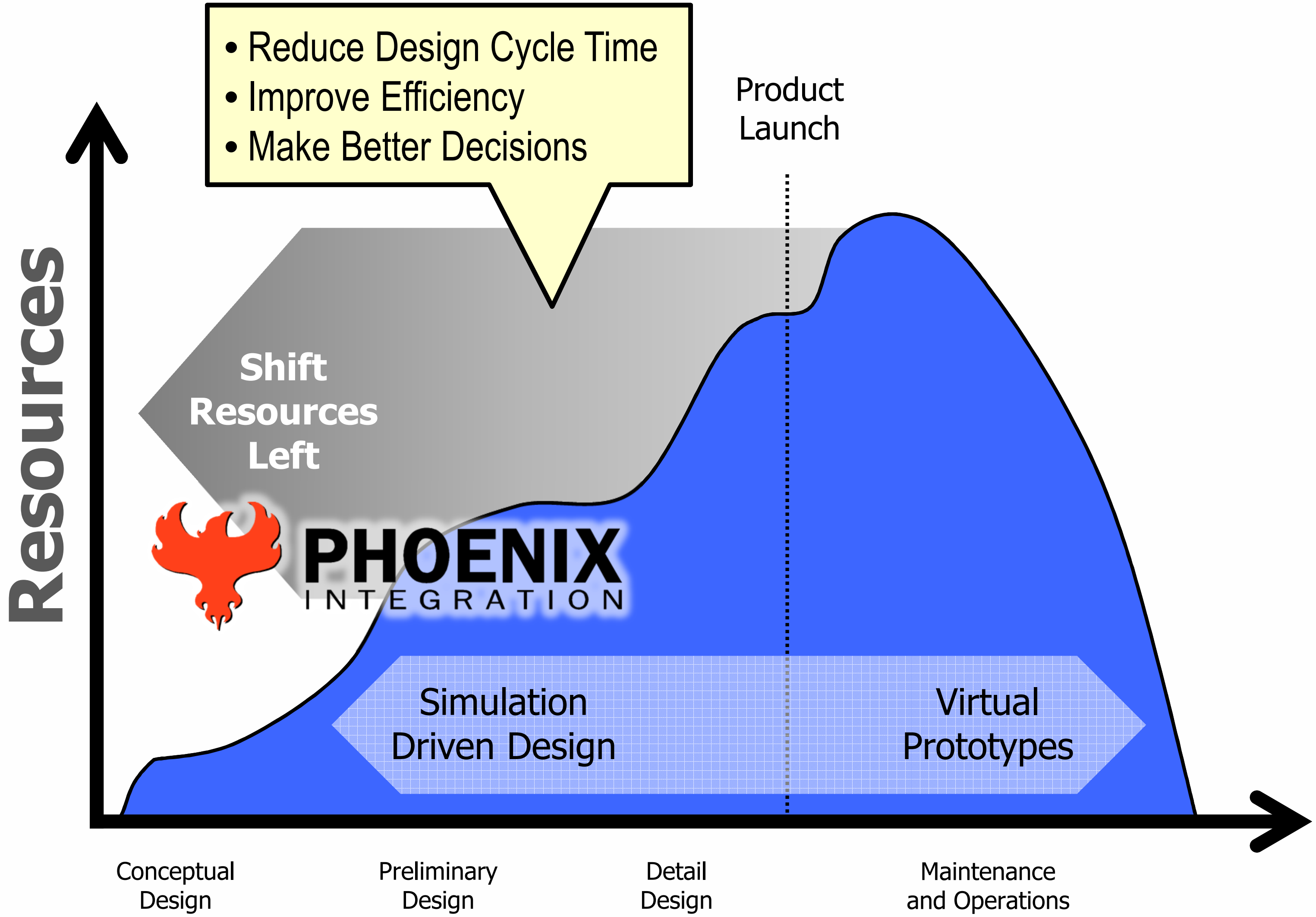
DESIGN**PROCESS**OPTIMIZATION


PRIVATE SELECTION
WILLIAMS-SONOMA
PODS
Grill Mates
STEAK
RUB


Market
Specification
Concept design
Detail design
Manufacture
Sell

ModelCenter

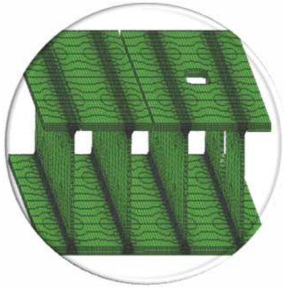
Industry Trends



- Empower Design for Manufacturing (DFM)
  - Enables engineers to understand how a product is designed to function, how it is manufactured, and how it fails at the limits of performance
- ICME – Integrated Computational Materials Engineering
  - “the integration of materials information, captured in computational tools, with engineering and product performance analysis and manufacturing process simulation” (National Research Council 2008b)

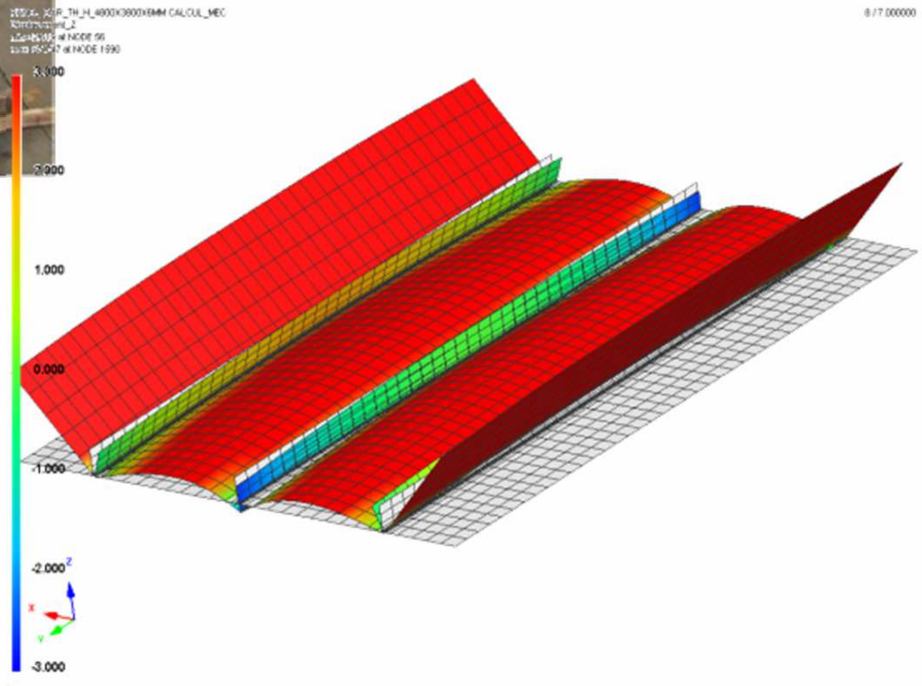
Business Challenges

Designs are validated "as designed" as opposed to "as manufactured"



CAE typically takes a reactive role in Product design

Each discipline exists in its own silo


3.000
2.000
1.000
0.000
-1.000
-2.000
-3.000

Design as Manufactured - Welding

What Is Weld Distortion?

- "Due to local heating and cooling during welding, complex thermal stresses occur during welding; and residual stress and distortion result after welding."
- These local residual stresses build until enough force is created to permanently deform the structure.

What are the Benefits of Predicting Weld Distortion?

- Better Planning
  - Software Tools can provide accurate distortion predictions.
  - Lead to Less Weld Distortion → Less Repair → Less Costs

Less Costs = Opportunity to Build More Parts = Higher Profits

- Why Are Software Tools Not Used Everywhere Today?
  - Current Tools Are ***NOT*** Intuitive (easy to use), nor provide a clear path to minimize distortion.

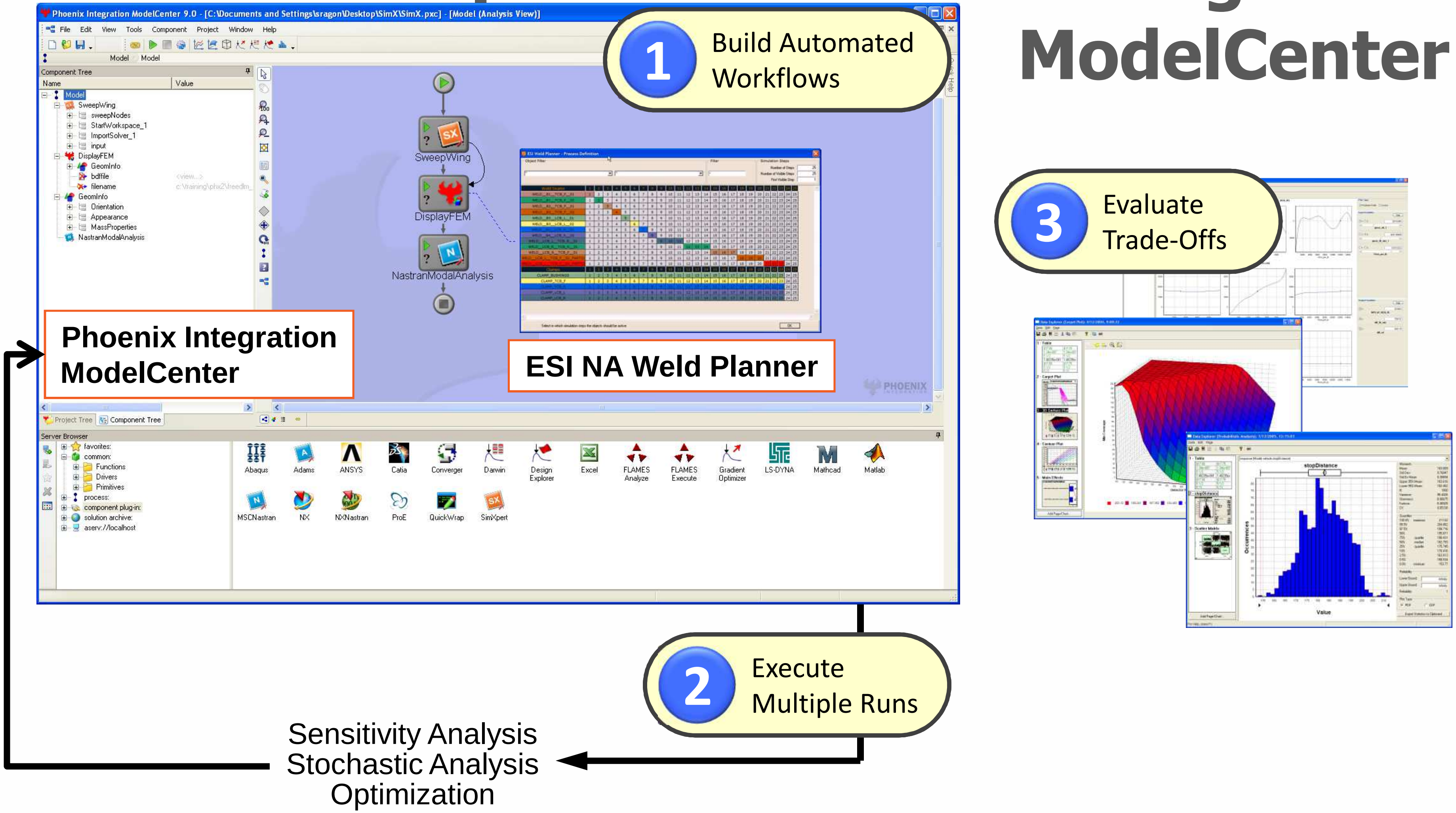
Basically… Today's tools require a dedicated analyst to utilize.

- Unrealistic Expectation & Lack of Trust
  - If the analyst says the part should distort 1", it better distort 1"

What are the Benefits of Predicting Weld Distortion?

- What is the Answer?
  1. Simplify the Models (Use the 80% Rule To Solve Majority of Problems – Not all welding and distortion problems).
  2. Provide a Wizard to Drive the Process
  3. Utilize ModelCenter to Drive Best Weld Sequence to Minimize Distortion.
  4. Incorporate new weld sequences into manufacturing process.
  5. Ensure feedback between engineering and manufacturing so process continually improves.

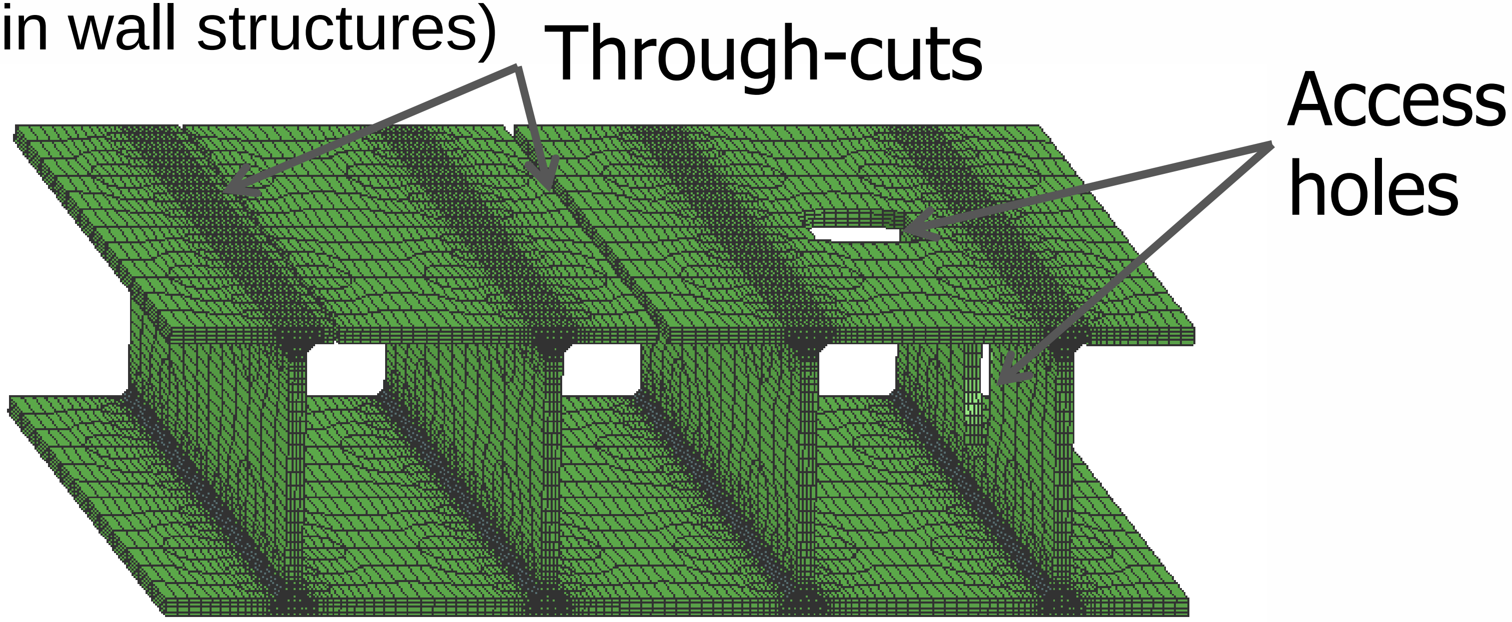
Example with Phoenix Integration ModelCenter



Minimize Weld Distortion Through Sequence Optimization

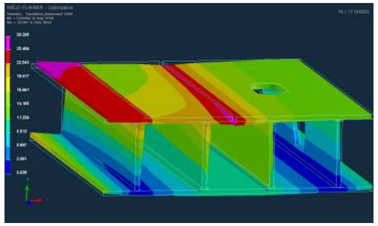
Simple Demonstrator

- ESI WeldPlanner simulation
  - Steel Structure with Stiffening plates
  - Weld Sequence Optimization
  - 3D Elements (Can also be done with 2D Elements for thin wall structures)

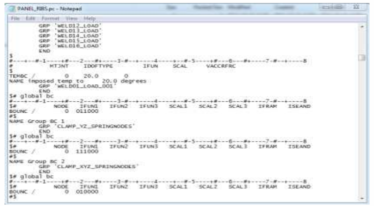


Simple Demonstrator

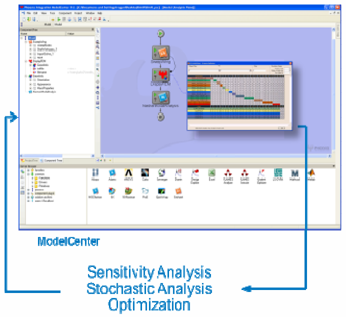
- ESI Weld Planner Model File Is Passed to Phoenix Integration ModelCenter
- Sensitivity Analysis Is Completed to Determine Worst Weld Paths
- Stochastic-Optimization Sequence is Created and Run to Minimize Distortion
- Results Provide Plot Of Outliers and Best Discovered Sequence



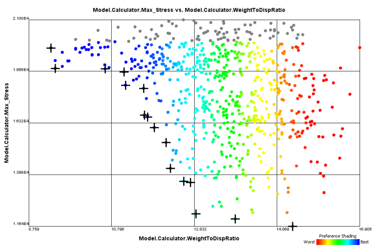
Weld Planner Results



Weld Planner Model File



ModelCenter Sensitivity, Stochastic-Optimization



Optimal Sequence Established

Results

- 72 Permutations were created and run.
- Each Permutation are Variations in Sequence
- Max Distortion is Calculated throughout each permutation.
- Results are gathered and Sorted Based On Max Distortion.
- Final Sequence is Provided
- New Sequence Resulted in **<u>17% Reduction in Distortion</u>**

indeper	depend	depend	depend	depend	depend	depend	depend	depend	depend
11	2	6	5	1	9	10	13	16	33.71946
10	2	6	1	5	9	10	13	16	33.36781
9	2	5	6	1	9	10	13	16	31.6919
23	6	5	2	1	9	10	13	16	31.37589
59	1	2	5	6	9	10	13	16	29.82107
49	1	2	5	6	9	10	13	16	29.70996
13	5	1	6	2	9	10	13	16	29.1893
2	1	5	2	6	9	10	13	16	29.10808
3	1	5	6	2	9	10	13	16	28.17705
4	1	6	2	5	9	10	13	16	28.15972
5	1	6	5	2	9	10	13	16	28.02104

Worst Sequence
Highest Distortion

Each Row Represe
A Permutation a.k.
A New Sequence

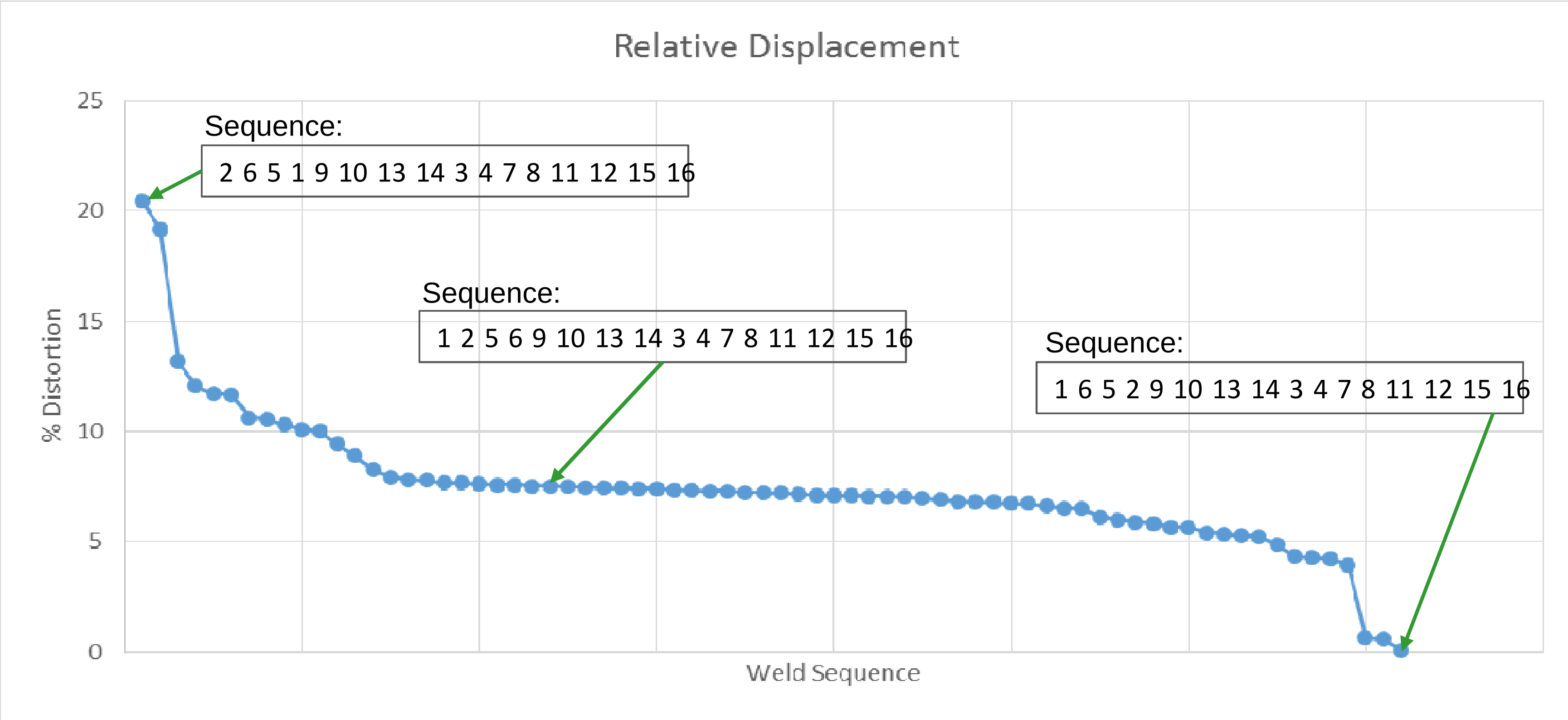
Best Sequence
Lowest Distortion

Weld Sequences

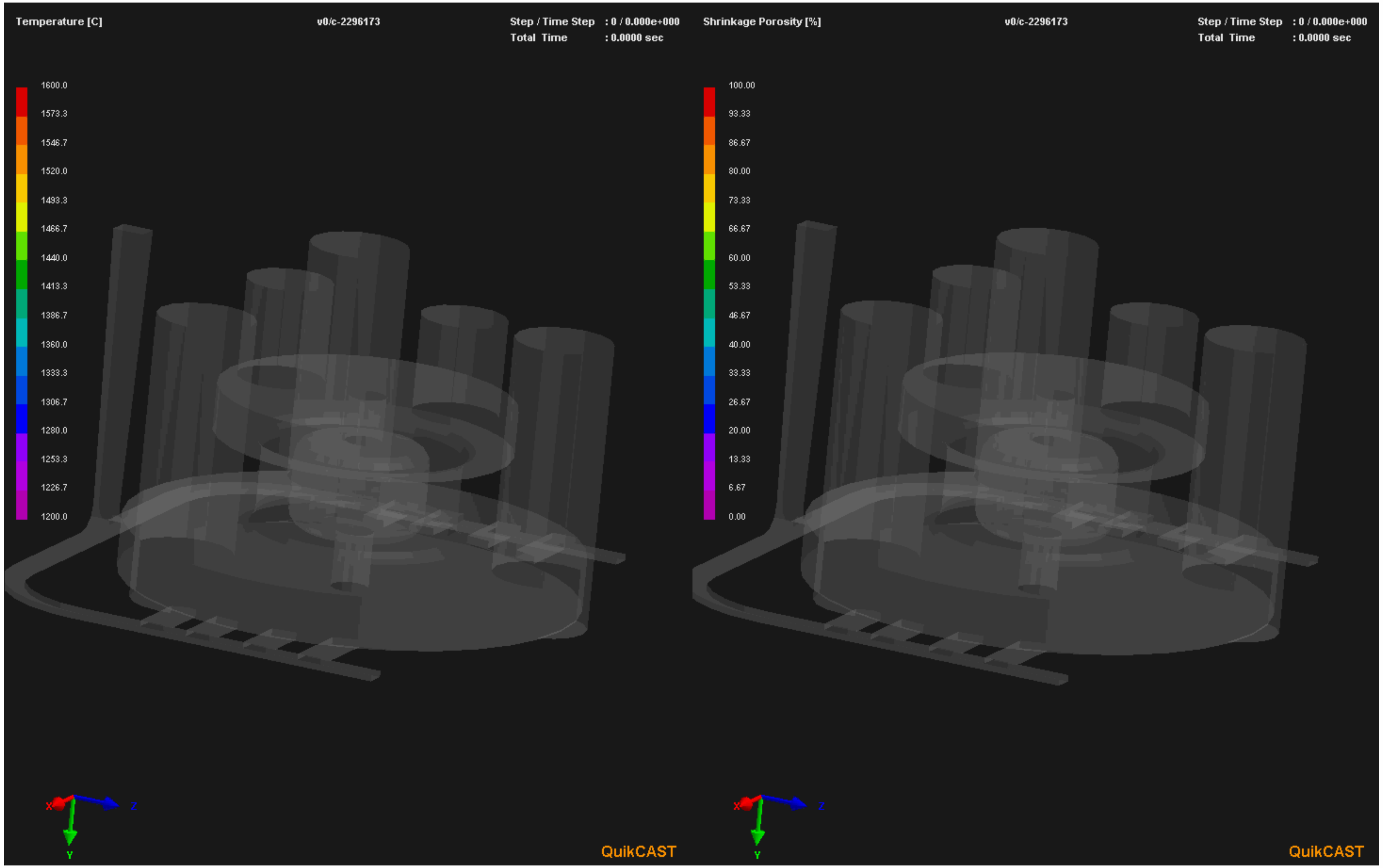
Blocking

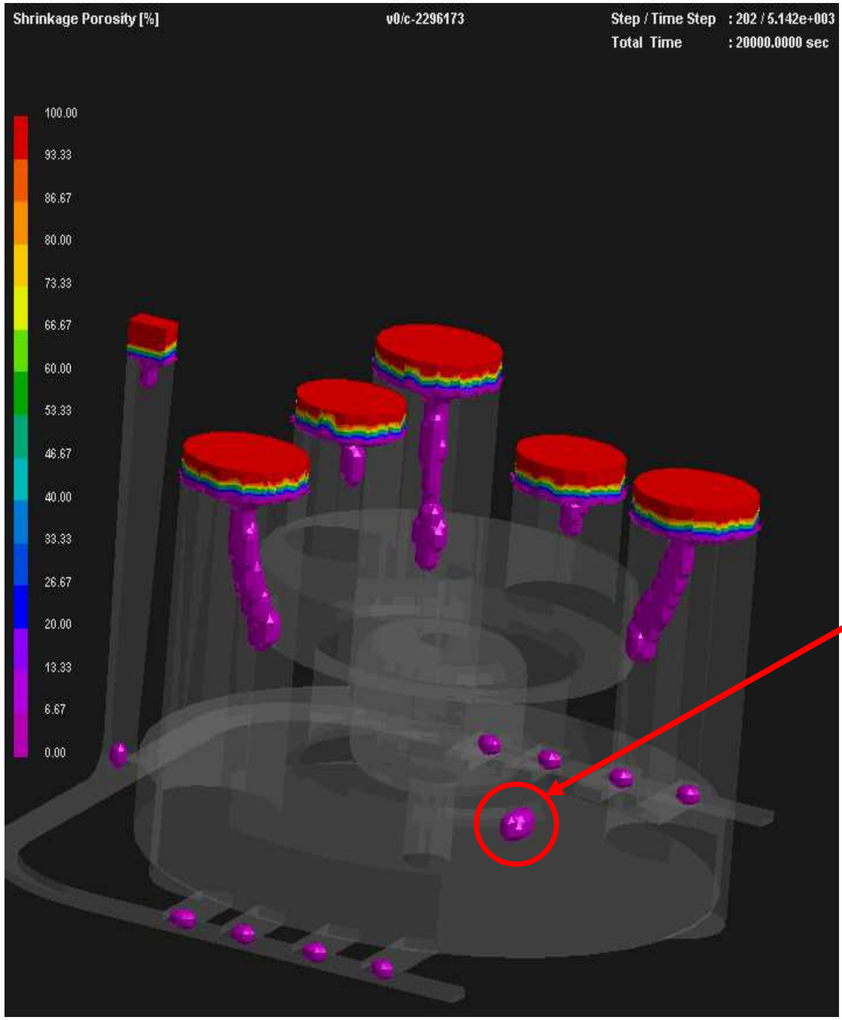
Not All 72 Sequences Are Shown

Weld Sequence Optimization



All 72 Permutations (Sequences) are Shown


Temperature [C]
v0/c-2296173
Step / Time Step : 0 / 0.000e+000
Total Time : 0.0000 sec
1600.0
1573.3
1546.7
1520.0
1493.3
1466.7
1440.0
1413.3
1386.7
1360.0
1333.3
1306.7
1280.0
1253.3
1226.7
1200.0
QuikCAST
Shrinkage Porosity [%]
v0/c-2296173
Step / Time Step : 0 / 0.000e+000
Total Time : 0.0000 sec
100.00
93.33
86.67
80.00
73.33
66.67
60.00
53.33
46.67
40.00
33.33
26.67
20.00
13.33
6.67
0.00
QuikCAST

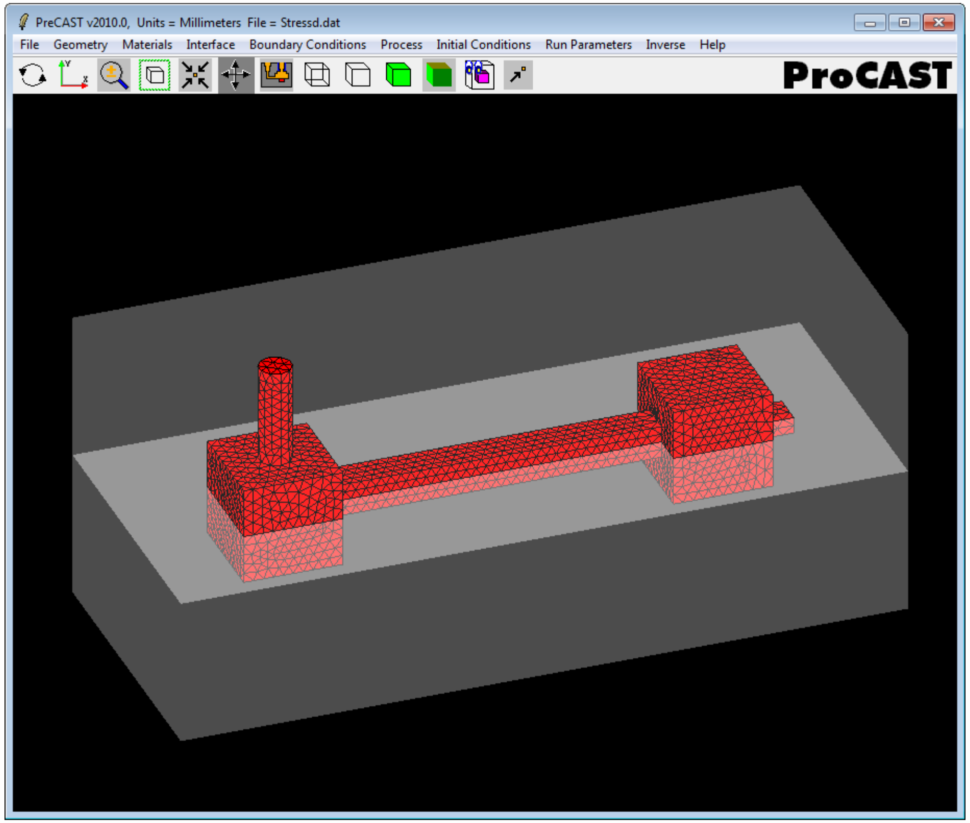


Courtesy: ACI Alloy Casting

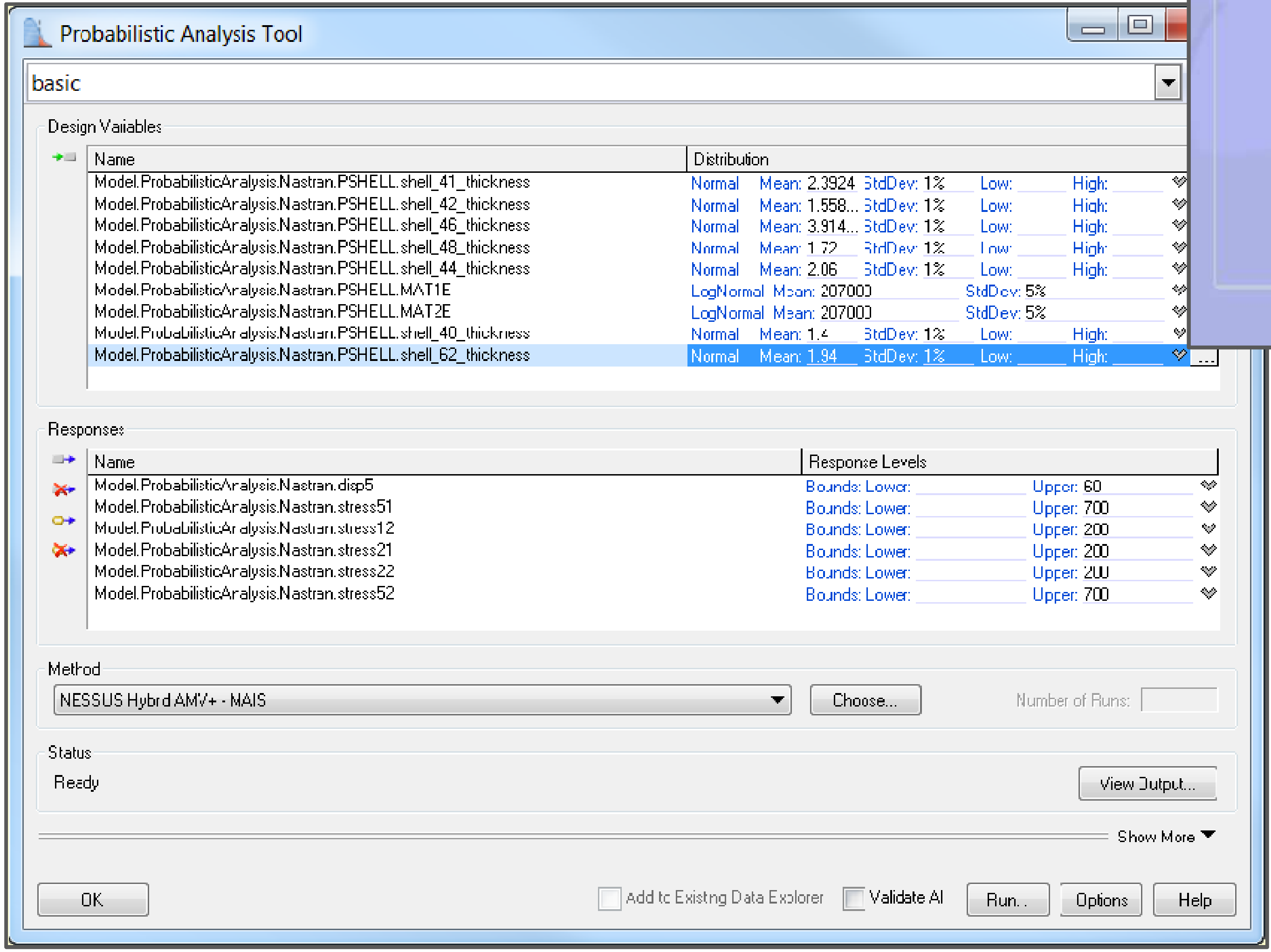
Design as Manufactured - Casting

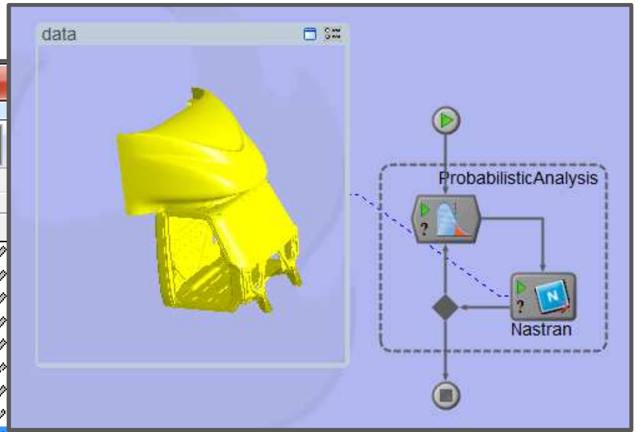
ProCAST

- Simulates the casting process
  - Given geometry, materials and a casting process, ProCAST can predict the material behavior during the steps of the casting process
- What happens if you don't like the result?
  - Utilize human expertise to manually try alternate solutions

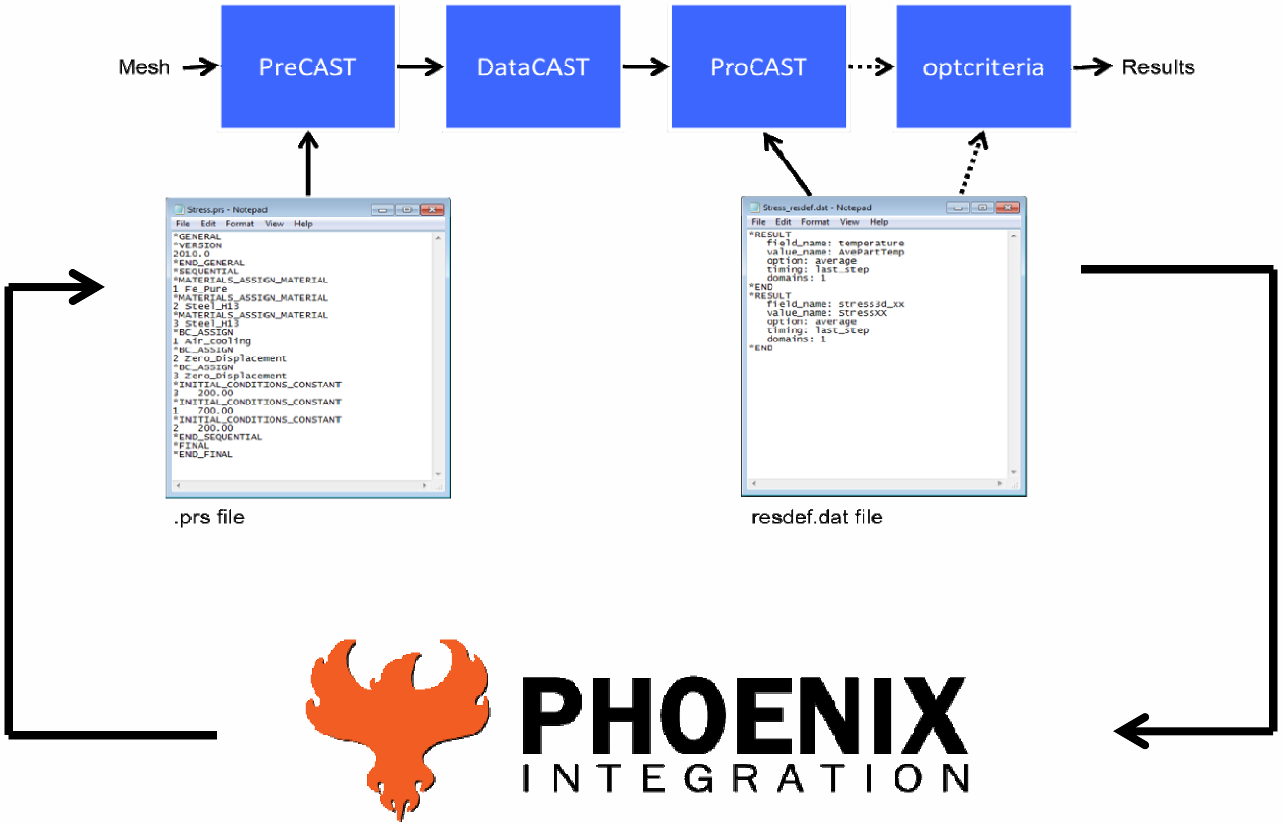


Model Setup


Probabilistic Analysis Tool
basic
Design Variables
Name
Distribution
Model.ProbabilisticAnalysis.Nastran.PSHELL.shell_41_thickness
Normal Mean: 2.3924 StdDev: 1% Low: High:
Model.ProbabilisticAnalysis.Nastran.PSHELL.shell_42_thickness
Normal Mean: 1.558... StdDev: 1% Low: High:
Model.ProbabilisticAnalysis.Nastran.PSHELL.shell_46_thickness
Normal Mean: 3.914... StdDev: 1% Low: High:
Model.ProbabilisticAnalysis.Nastran.PSHELL.shell_48_thickness
Normal Mean: 1.72 StdDev: 1% Low: High:
Model.ProbabilisticAnalysis.Nastran.PSHELL.shell_44_thickness
Normal Mean: 2.06 StdDev: 1% Low: High:
Model.ProbabilisticAnalysis.Nastran.PSHELL.MAT1E
LogNormal Mean: 207000 StdDev: 5%
Model.ProbabilisticAnalysis.Nastran.PSHELL.MAT2E
LogNormal Mean: 207000 StdDev: 5%
Model.ProbabilisticAnalysis.Nastran.PSHELL.shell_40_thickness
Normal Mean: 1.4 StdDev: 1% Low: High:
Model.ProbabilisticAnalysis.Nastran.PSHELL.shell_62_thickness
Normal Mean: 1.94 StdDev: 1% Low: High:
Responses
Name
Response Levels
Model.ProbabilisticAnalysis.Nastran.disp5
Bounds: Lower: Upper: 60
Model.ProbabilisticAnalysis.Nastran.stress51
Bounds: Lower: Upper: 700
Model.ProbabilisticAnalysis.Nastran.stress12
Bounds: Lower: Upper: 200
Model.ProbabilisticAnalysis.Nastran.stress21
Bounds: Lower: Upper: 200
Model.ProbabilisticAnalysis.Nastran.stress22
Bounds: Lower: Upper: 200
Model.ProbabilisticAnalysis.Nastran.stress52
Bounds: Lower: Upper: 700
Method
NESSUS Hybrid AMV+ - MAIS
Choose...
Number of Runs:
Status
Ready
View Output...
Show More
OK
Add to Existing Data Explorer
Validate All
Run...
Options
Help

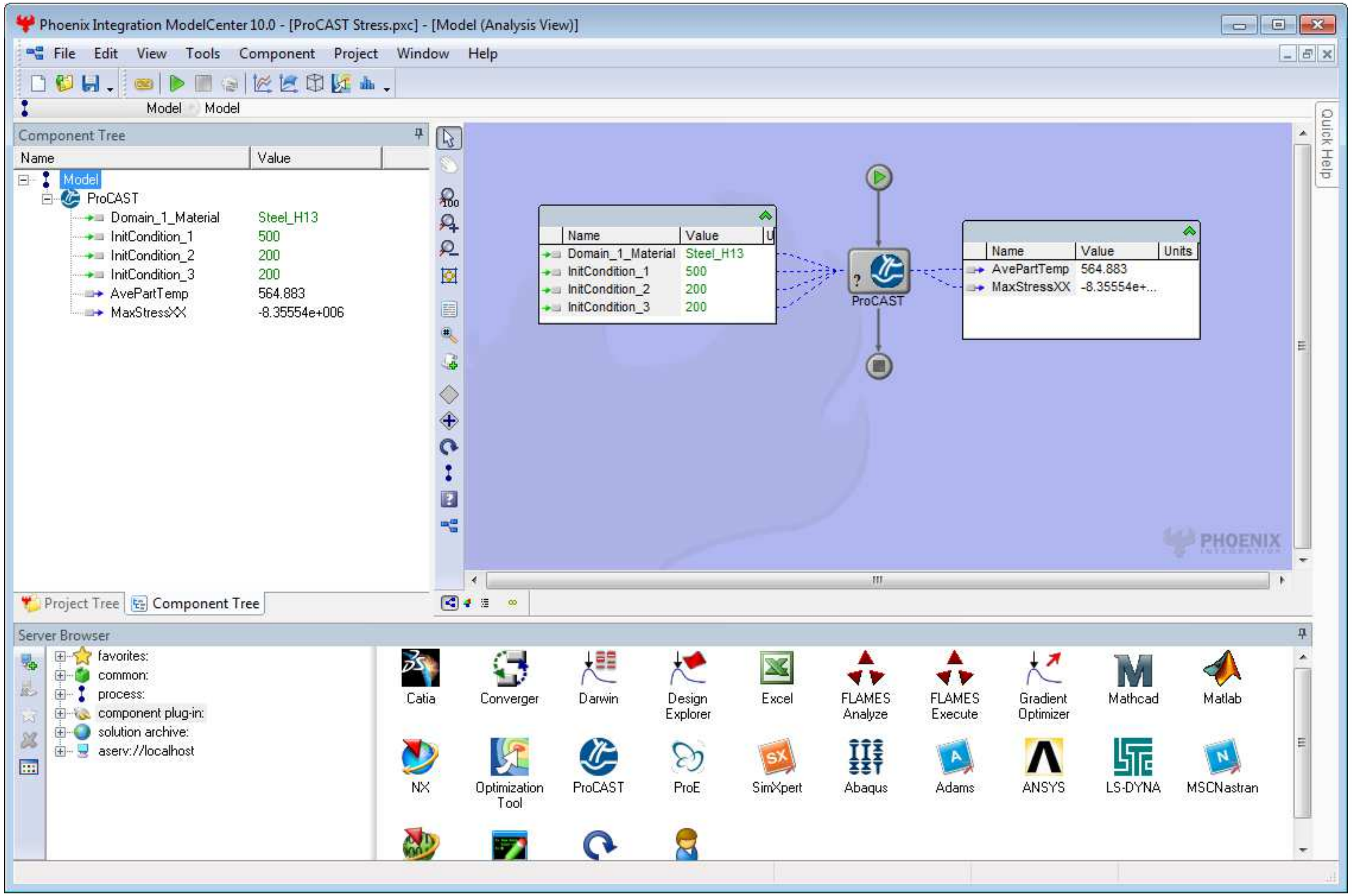

data
ProbabilisticAnalysis
Nastran

Automating ProCAST



Sensitivity Analysis
Design of Experiments
Optimization
Robust Design

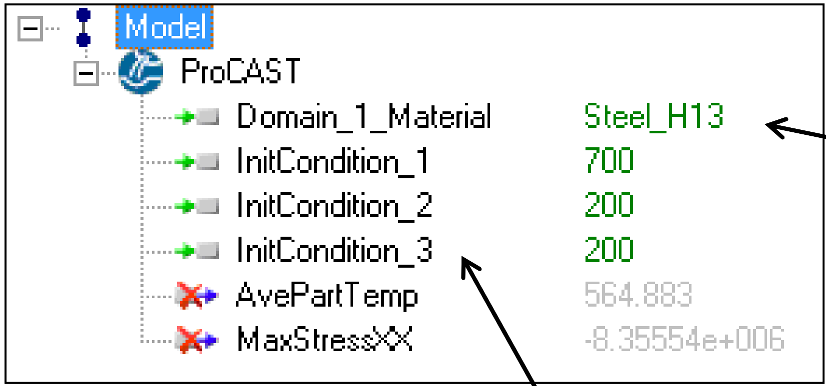
ModelCenter

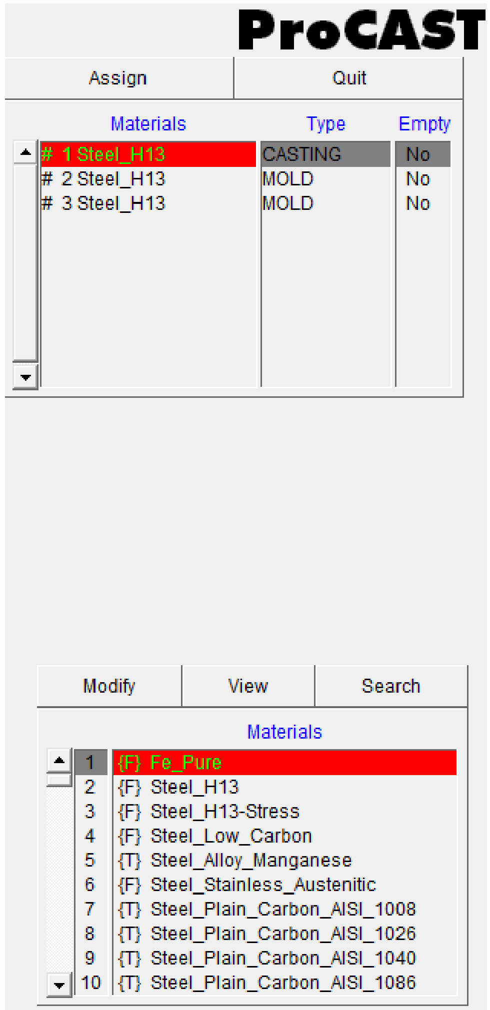


Design Optimization

- Run virtual experiments
  - Run ProCAST 10's, 100's, or even 1000's of times in an automated fashion
- Trade Study Types:
  - Sensitivity
  - Design of Experiments
  - Optimization
  - Probabilistics

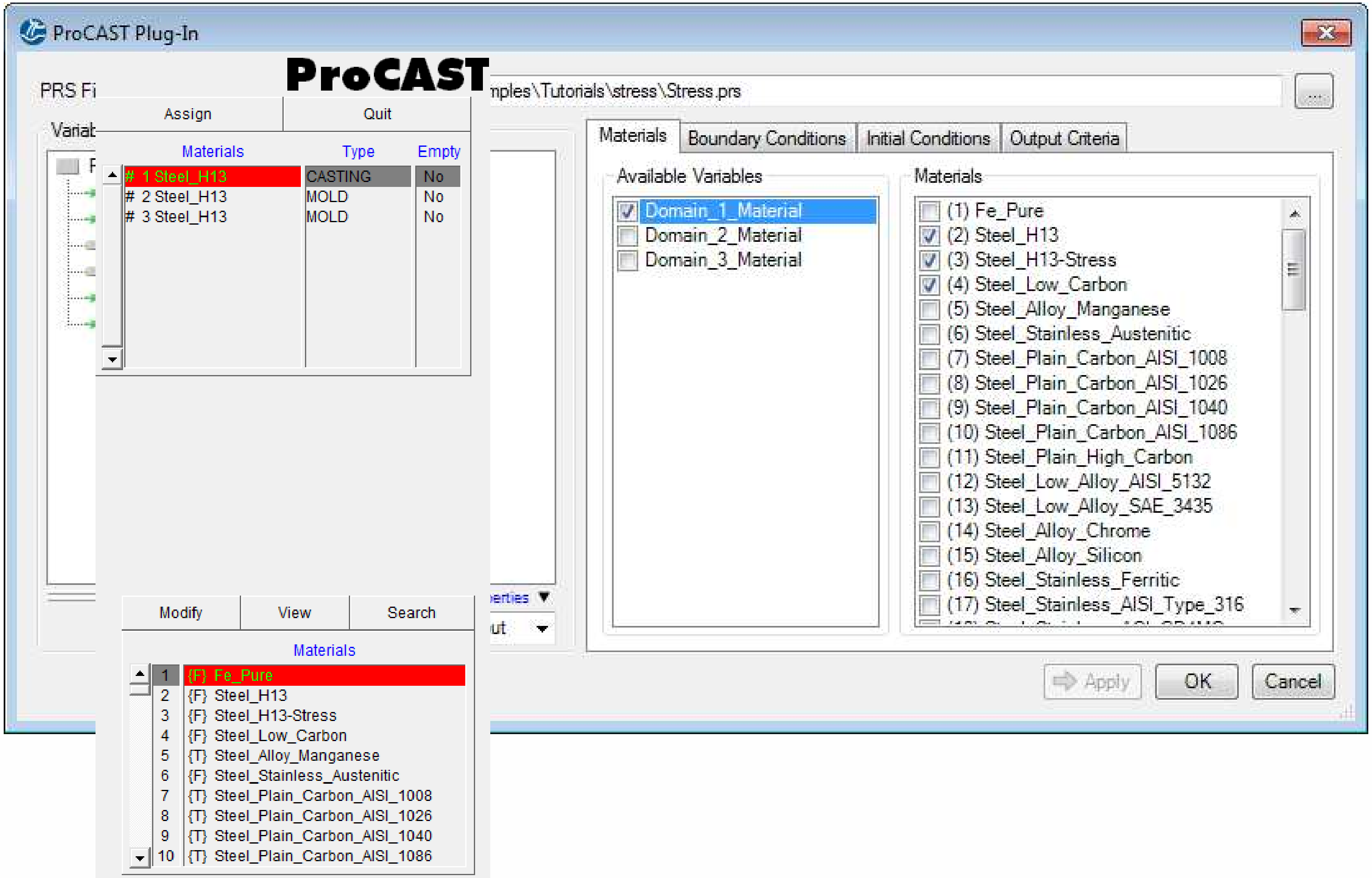
Variables


Model
ProCAST
Domain_1_Material Steel_H13
InitCondition_1 700
InitCondition_2 200
InitCondition_3 200
AvePartTemp 564.883
MaxStressXX -8.35554e+006

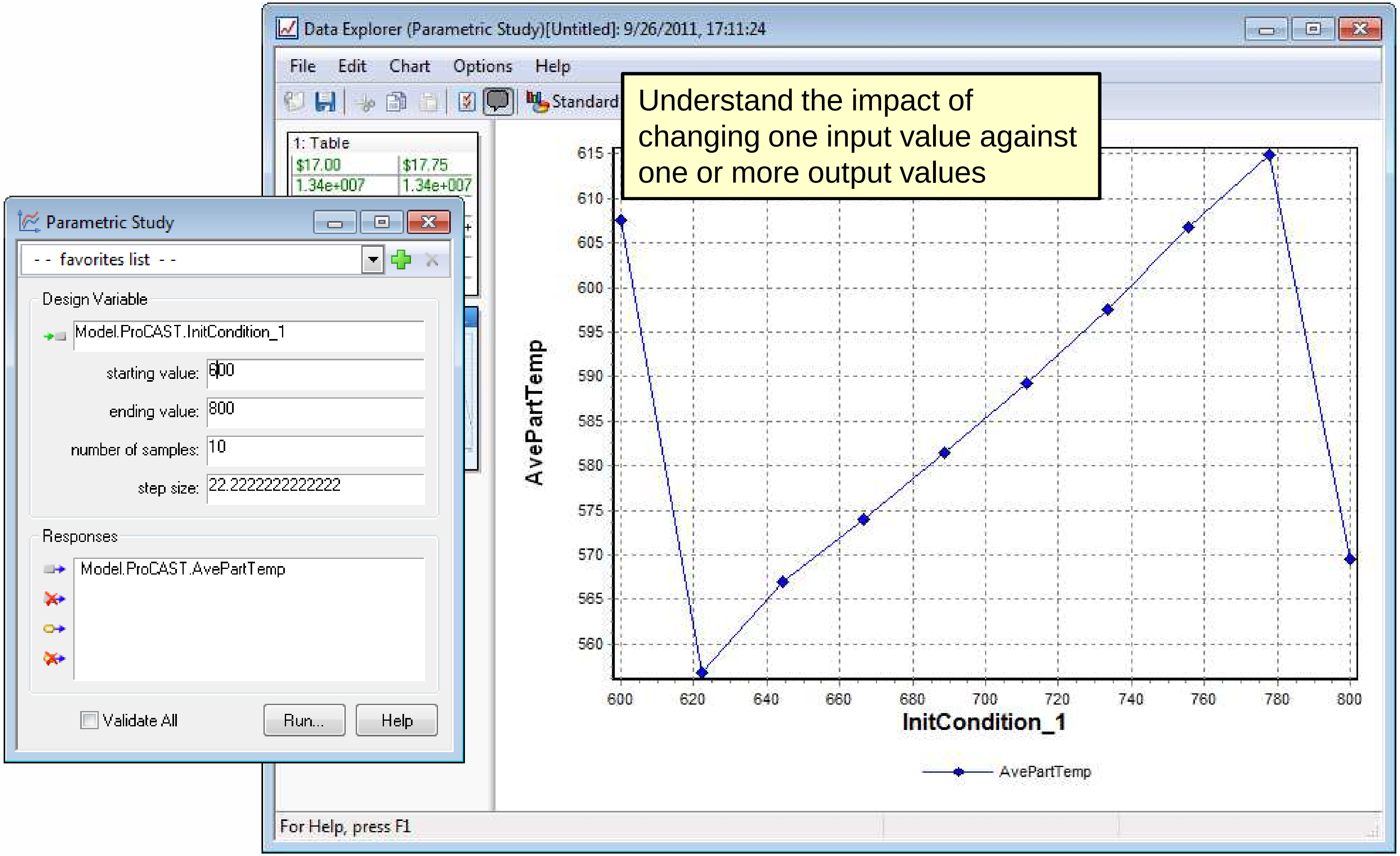

ProCAST
Assign
Quit
Materials
Type
Empty
1 Steel_H13 CASTING No
2 Steel_H13 MOLD No
3 Steel_H13 MOLD No
Modify
View
Search
Materials
1 {F} Fe_Pure
2 {F} Steel_H13
3 {F} Steel_H13-Stress
4 {F} Steel_Low_Carbon
5 {T} Steel_Alloy_Manganese
6 {F} Steel_Stainless_Austenitic
7 {T} Steel_Plain_Carbon_AISI_1008
8 {T} Steel_Plain_Carbon_AISI_1026
9 {T} Steel_Plain_Carbon_AISI_1040
10 {T} Steel_Plain_Carbon_AISI_1086


ProCAST
Store
Quit
Materials
Temperature
C
1 Steel_H13 800.00
2 Steel_H13 200.00
3 Steel_H13 200.00

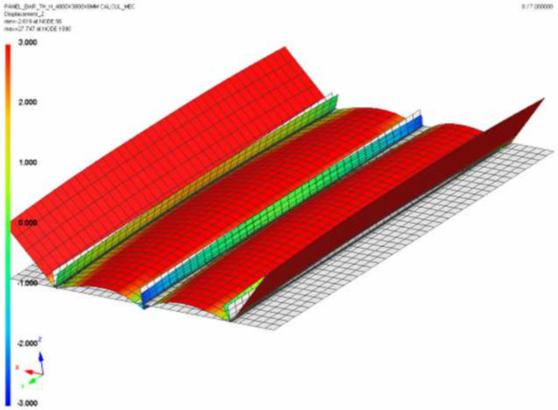
ProCAST Plug-In for ModelCenter



Parametric Studies



Design for Manufacturing



Welding Optimization

Casting Optimization

Industry Consortiums

- LIFT (ALMII)
- America Makes (NAMI)
- IACMI
- MAI – HOW5
- Power America

ALCOA · BOEING · CHRYSLER · COMAU · DNV·GL · EATON · GE · Huntington Ingalls Industries · Johnson Controls · LOCKHEED MARTIN · United Technologies Research Center · ABS · CARPENTER · GREDE · ITW · MATERION · Metalsa · nemak · TENNECO · TRUMPF · Altair · esi · MSC Software · PHOENIX INTEGRATION · Thermo-Calc Software

LIFT Industry Partners

Special Thanks

- ESI: Tony Davenport/Brian Shula – Welding Simulation
- ESI: Sam Scott – Casting Simulation