

Finite Element SOFC Analysis with *SOFC-MP* and *MSC.Marc/Mentat-FC*

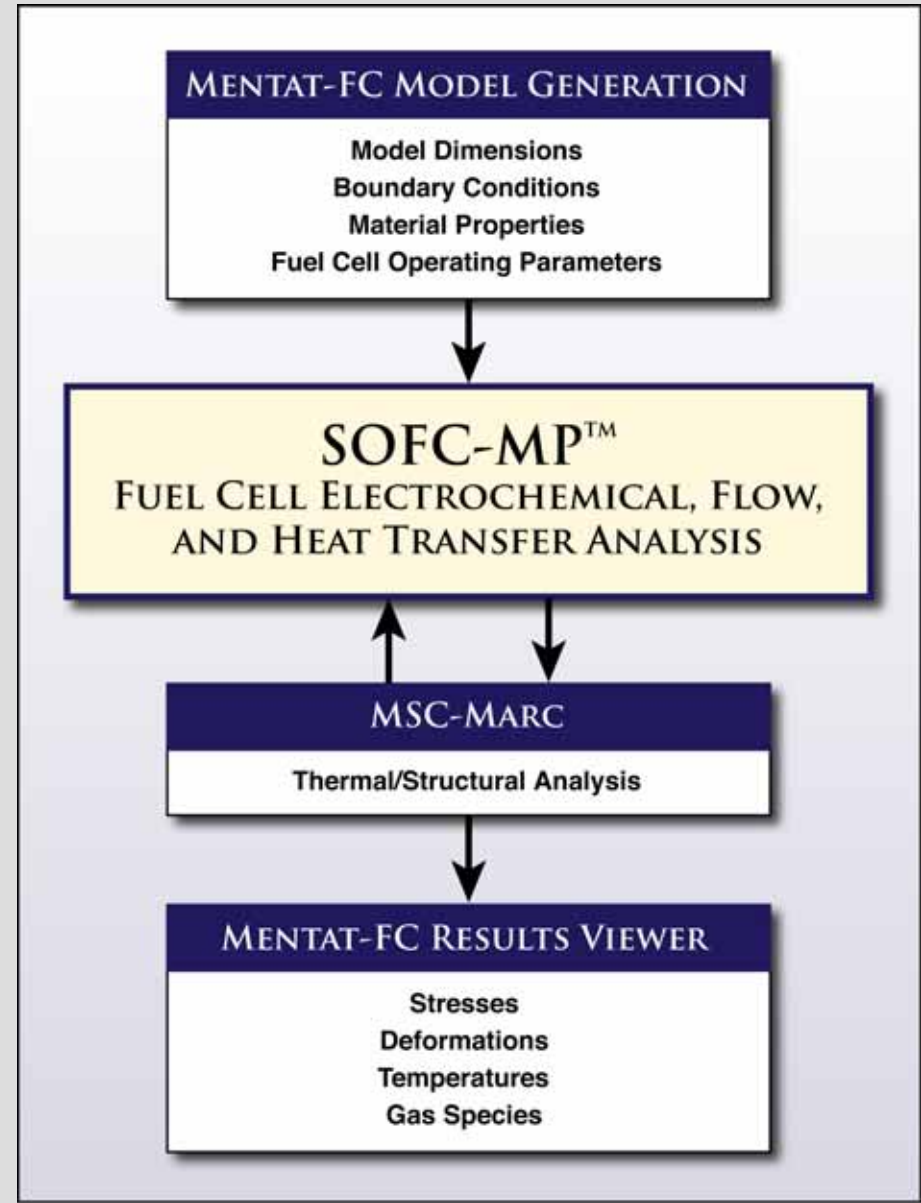
Ken Johnson,
Speaker

Pacific Northwest National Laboratory

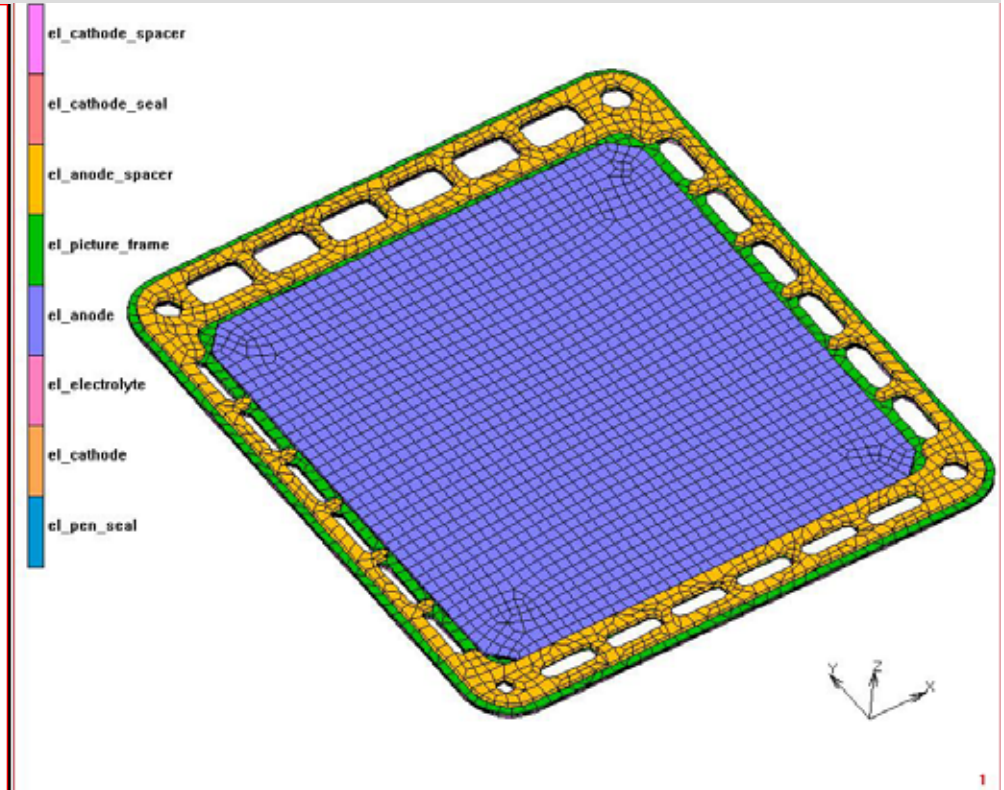
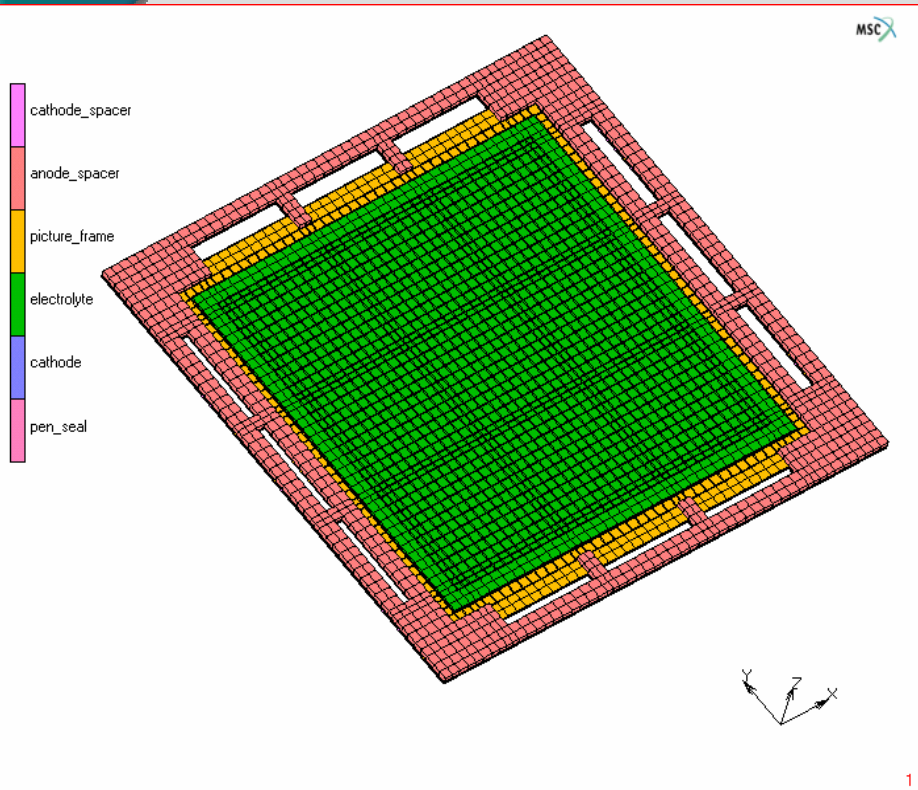
SECA 6th Annual Workshop,
April 18-21, 2005

Solution Flow

- ▶ *Mentat-FC*:
Graphical User Interface for flexible finite element model generation.
- ▶ *SOFC-MP*:
Finite element based electrochemistry, flow and heat transfer solution.
- ▶ *MSC.Marc*:
Finite element stress analysis with temperatures from *SOFC-MP*.



Mentat-FC: Parametric and CAD based Models



Parametric

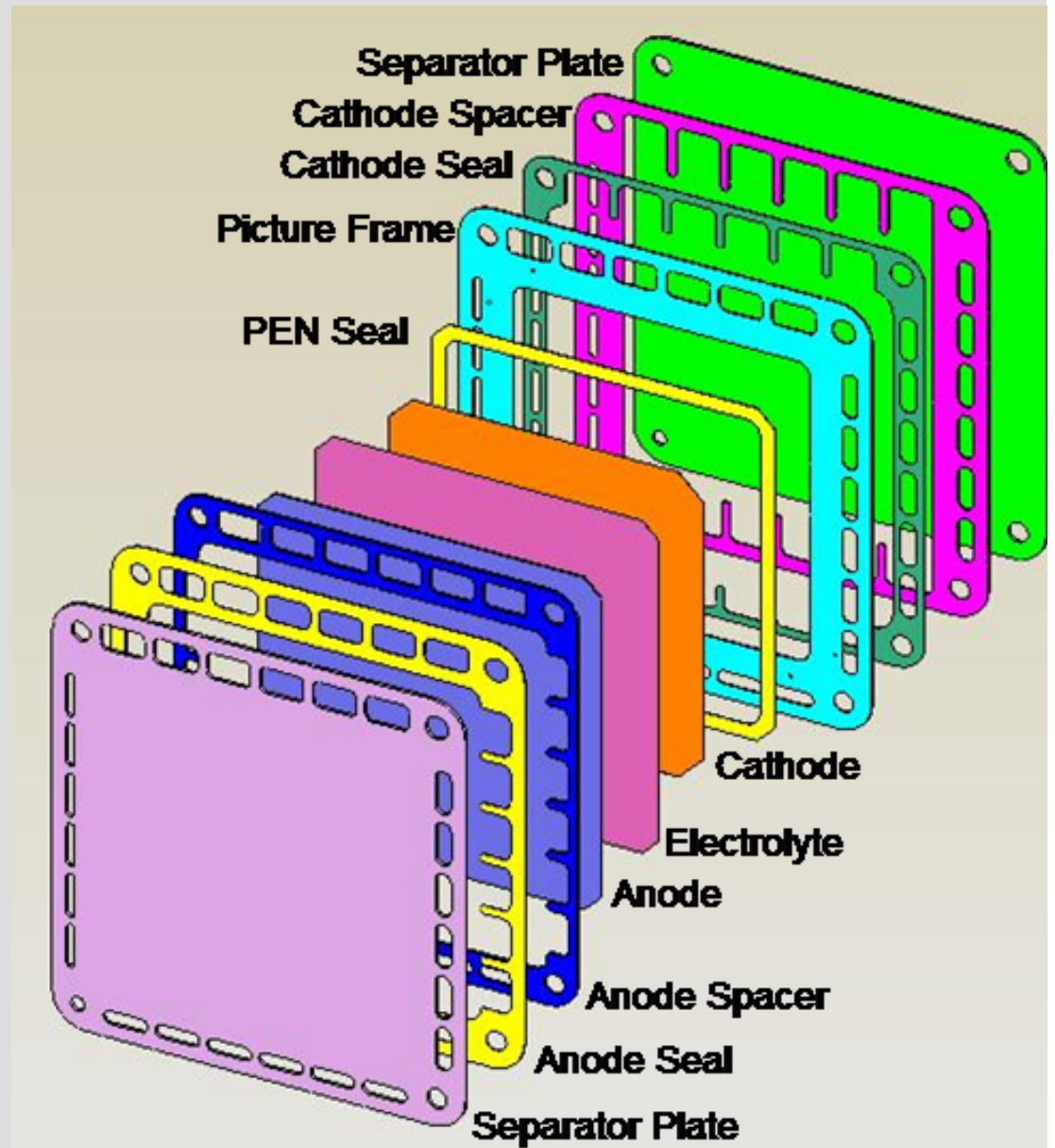
- Fixed SOFC designs
- Meshed from dimensional parameters
- Used for parametric design studies

CAD Based

- Meshed from user CAD files
- Accepts existing FE meshes
- Quick generation of very complex models

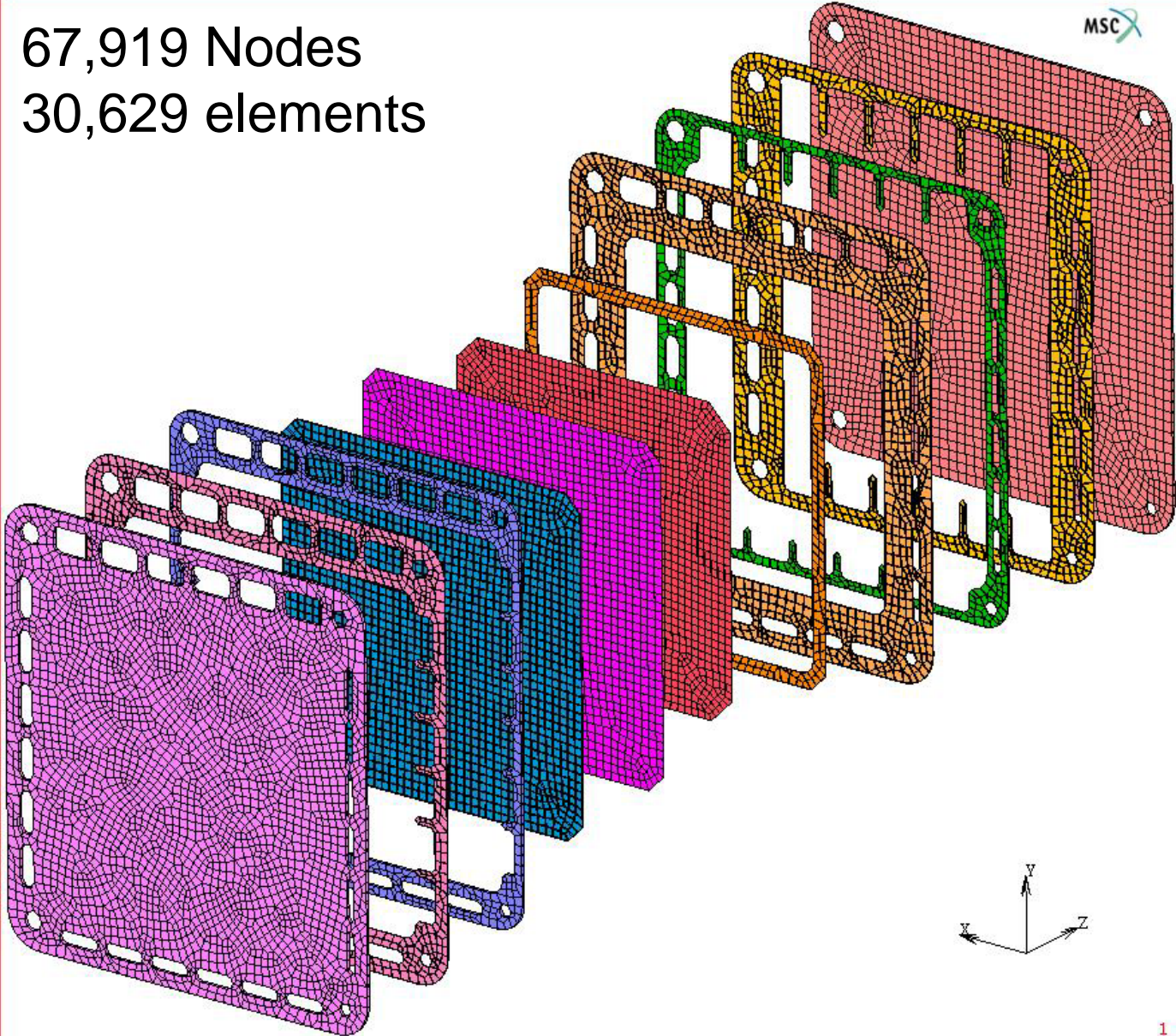
Mentat-FC: Model Generation from CAD Geometries

- ▶ Finite element grid meshed from CAD volumes.
- ▶ Generic ACIS file format used.
- ▶ Layers identified by name.
- ▶ Material properties assigned to components from the database.
- ▶ Contact and boundary conditions are defined.



Mesh Generated from CAD

67,919 Nodes
30,629 elements



Generic Model Regions are Defined for Meshing

- ▶ **Required Regions** - define bounds of the electrochemical and flow calculations:
 - PEN layers = Anode, Electrolyte, Cathode.
 - Fuel = Inlet, Outlet, Anode flow channel.
 - Air = Inlet, Outlet, Cathode flow channel.
 - Separator plates.
- ▶ **Additional Regions** – define the PEN Support Structure = components making up the manifolds, seals, and structure around the PEN.
 - Anode and Cathode spacers.
 - PEN support frame.
 - Seals.

Material Data and Electrochemical Parameters

- ▶ Material data base for thermal, electrical, and structural properties is included for:
 - Metallic interlayers and support plates
 - Seals,
 - Anode, electrolyte, and cathode layers
- ▶ Electrochemistry parameters
 - I-V relationships
 - Fuel and Air composition and flow rates.
 - Startup conditions

Features of *SOFC-MP*

- ▶ Generic fuel and oxidants can be simulated. NASA's CEA code used for chemical equilibrium and species calculations.
- ▶ Finite element based flow, temperature and electrochemistry calculations. Thermal and structural solutions use the same mesh.
- ▶ Reduced dimensional analysis for fast flow solution.
- ▶ Contact algorithms treat incompatible meshes for contacting solids with different surface profiles.

Reduced Dimensional Approach for Fast Approximate Solutions

Reduced Analysis

- ▶ Electrochemistry – 1D through thickness of the PEN
- ▶ Flow
 - Manifolds – Use an analytical pipe flow approximation
 - Channels across Cell – 2D with hydraulic approximation for varying channel height.
- ▶ Temperature – 3D for solids, 2D in flow domains.

Full 3D Analysis

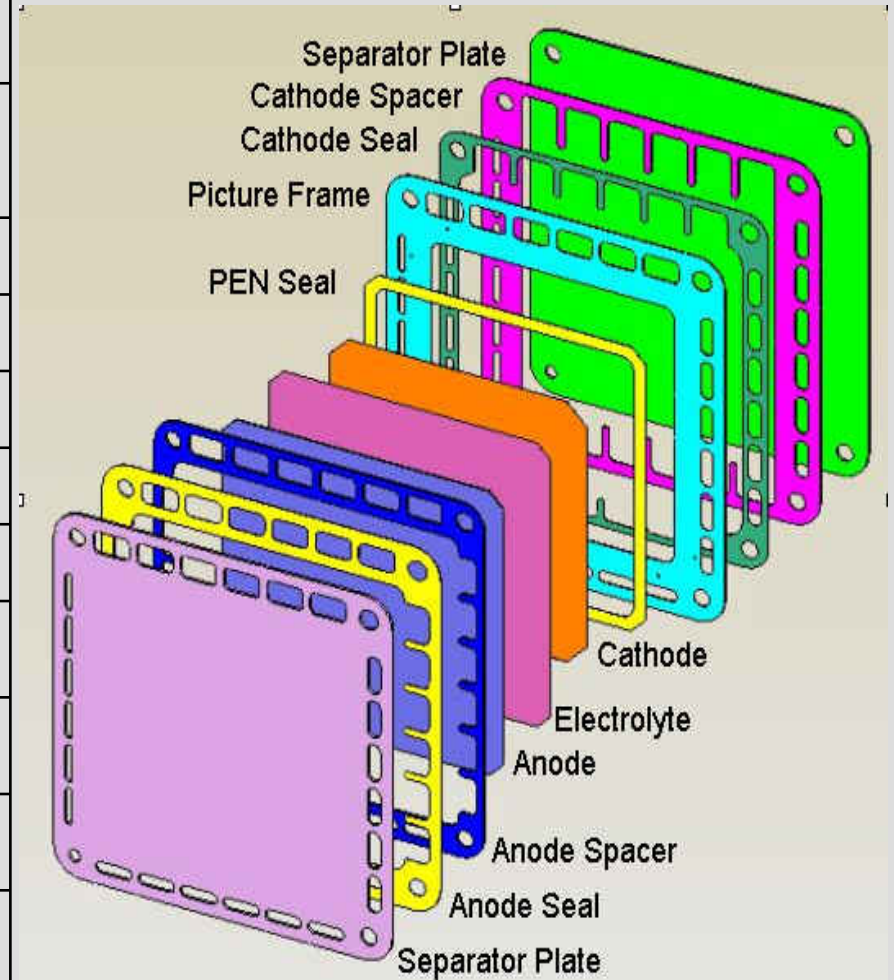
- ▶ Stress and Distortion – 3D in solids.

Solution Performance

- ▶ Algorithms are efficient for rapid analysis and extension to transient thermal-mechanical analysis.
- ▶ Single cell examples on a single processor (Memory~1.5 Gb)
 - *Mentat-FC* Mesh generation ~ 15 min.
 - *SOFC-MP* solution ~20 min.
 - *MSC.Marc* stress solution ~ 3 min.
- ▶ Coarse stack models with up to 3 cells have been run on the PC.
- ▶ Significant multi-cell analysis requires parallel processing for:
 - Increased memory
 - Reduced compute time.

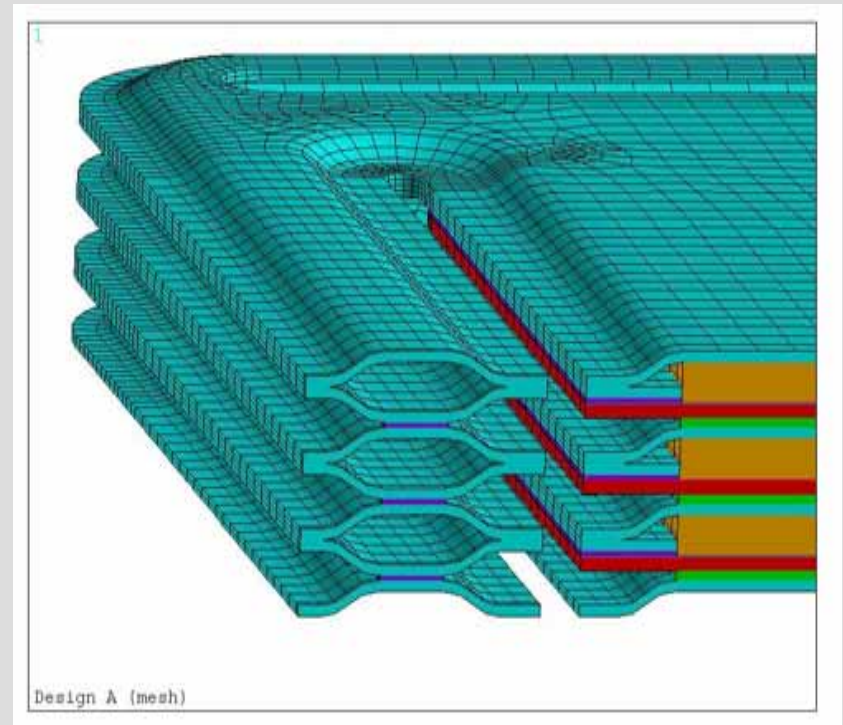
Generating a Model from CAD files

Required Components	Additional Components
Separator Plate – Blank	Anode Seal
Fuel Flow	Anode Spacer
Anode	Picture Frame
Electrolyte	Pen Seal
Cathode	Cathode Seal
Air Flow	Cathode Spacer
Separator Plate	
Fuel In	
Fuel Out	
Air In	
Air Out	



Importing Existing FE Meshes

- ▶ User provides meshes identified for individual components.
- ▶ Can mix and match with CAD generated components.
- ▶ Fuel and Air cavities must also be meshed.
- ▶ Incompatible meshes are allowed through contact.
- ▶ Hex v.s. tetrahedral elements
 - Hex and wedge elements give smaller mesh and more accurate stresses in solid layers.
 - Tetrahedral mesh is sufficient for mapping temperatures in fuel and air.



Example ANSYS mesh read into Marc

Starting Mentat-FC

Mentat-FC

Mentat-FC Solid Oxide Fuel Cell Analysis Program

A cooperative effort between:

MSC SOFTWARE
SIMULATING REALITY

SECA

Pacific Northwest National Laboratory
Operated by Battelle for the U.S. Department of Energy

NETL
NATIONAL ENERGY TECHNOLOGY LABORATORY

Parametric SOFC Allows for input of parametric dimensions for SOFC

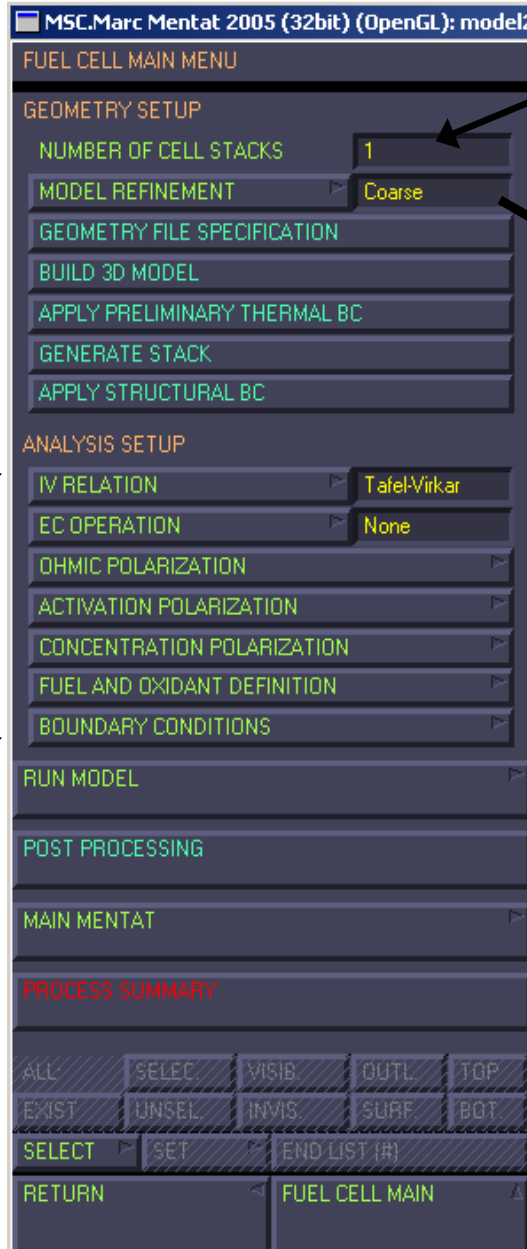
CAD Input SOFC Allows for input of generic CAD/FEA files

Cancel

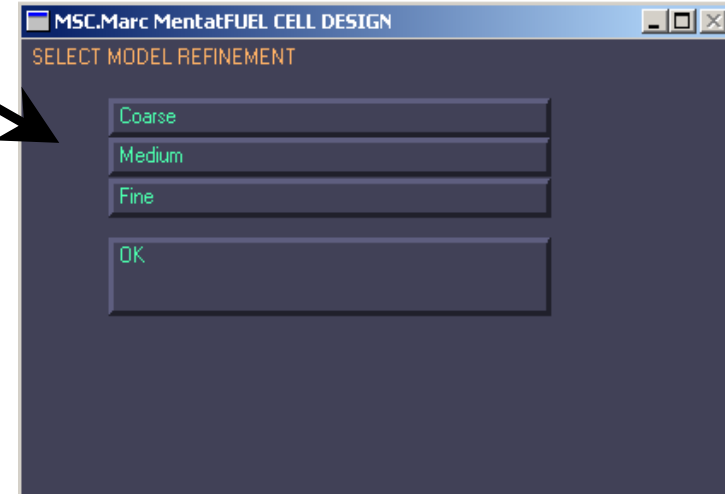
The CAD Opening Menu

Model Generation

EC Cell Performance



No. of cells in stack



CAD file specification

GEOMETRY SETUP

NUMBER OF CELL STACKS: 1

MODEL REFINEMENT: Coarse

GEOMETRY FILE SPECIFICATION →

BUILD 3D MODEL

APPLY PRELIMINARY THERMAL BC

GENERATE STACK

APPLY STRUCTURAL BC

ANALYSIS SETUP

IV RELATION: Tafel-Virkar

EC OPERATION: None

OHMIC POLARIZATION

ACTIVATION POLARIZATION

CONCENTRATION POLARIZATION

FUEL AND OXIDANT DEFINITION

BOUNDARY CONDITIONS

RUN MODEL

POST PROCESSING

MAIN MENTAT

PROCESS SUMMARY

ALL SELEC VISIB OUTL TOP

EXIST UNSEL INVIS SURF BOT

SELECT SET END LIST (#)

RETURN FUEL CELL MAIN

Major Component Geometry Files Input

PNL FUEL CELL INPUT - MAJOR COMPONENTS

Required

Component:	File:	file select	Extrudable?	Material
anode	D:/pnrl/phase2/phase2_working_directory/test_install/ANODE1.SAT	file select	<input checked="" type="checkbox"/>	anode
cathode	D:/pnrl/phase2/phase2_working_directory/test_install/CATHODE1.SAT	file select	<input checked="" type="checkbox"/>	cathode
electrolyte	D:/pnrl/phase2/phase2_working_directory/test_install/ELECTROLYTE1.SAT	file select	<input checked="" type="checkbox"/>	electrolyte
separator	D:/pnrl/phase2/phase2_working_directory/test_install/SEPARATOR PLATE1.SAT	file select	<input checked="" type="checkbox"/>	ss-430
separator_blank	D:/pnrl/phase2/phase2_working_directory/test_install/SEPARATOR PLATE BLANK1.SAT	file select	<input checked="" type="checkbox"/>	ss-430
fuel_in	D:/pnrl/phase2/phase2_working_directory/test_install/fuel in1.SAT	file select	<input checked="" type="checkbox"/>	fuel
fuel_out	D:/pnrl/phase2/phase2_working_directory/test_install/fuel out1.SAT	file select	<input checked="" type="checkbox"/>	fuel
fuel_flow	D:/pnrl/phase2/phase2_working_directory/test_install/KJmod-fuel flow1.SAT	file select	<input type="checkbox"/>	fuel
air_in	D:/pnrl/phase2/phase2_working_directory/test_install/air in1.SAT	file select	<input checked="" type="checkbox"/>	air
air_out	D:/pnrl/phase2/phase2_working_directory/test_install/air out1.SAT	file select	<input checked="" type="checkbox"/>	air
air_flow	D:/pnrl/phase2/phase2_working_directory/test_install/air flow1.SAT	file select	<input type="checkbox"/>	air

Specify number of additional components : 6

Specify scale factor to convert input geometry to m units (default = 1.0): 1.0

Scale Factor

OK

Additional Component Geometry Files Input

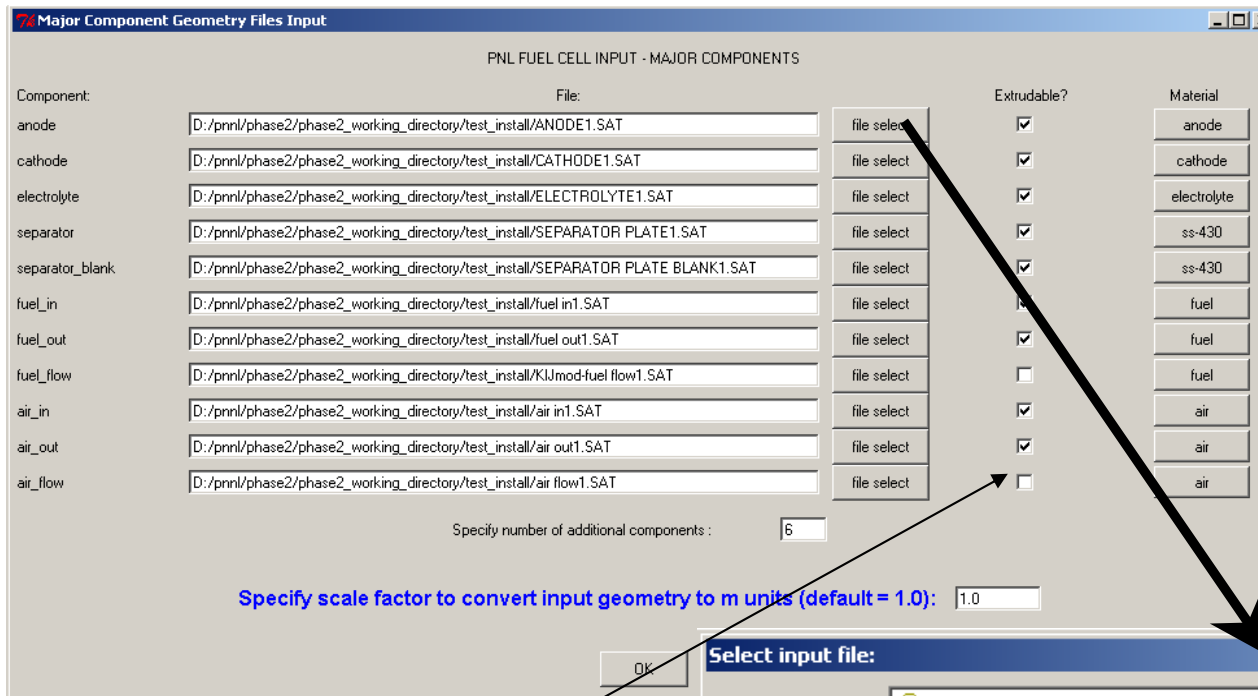
PNL FUEL CELL INPUT - ADDITIONAL COMPONENTS (6)

Additional

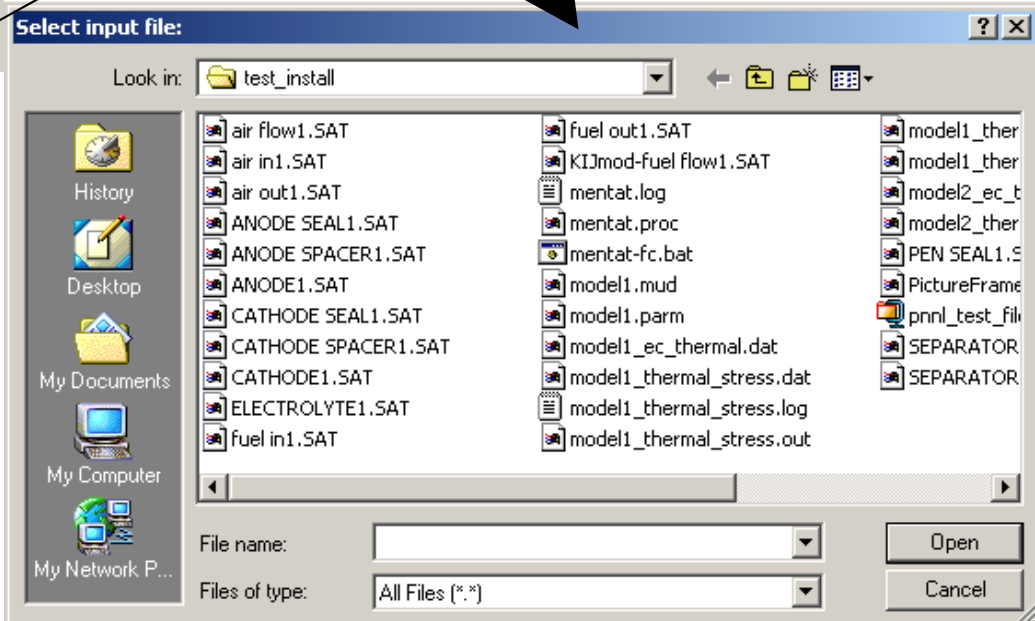
Component:	File:	file select	Extrudable?	Material
Additional Component 1	D:/pnrl/phase2/phase2_working_directory/test_install/ANODE SPACER1.SAT	file select	<input checked="" type="checkbox"/>	ss-430
Additional Component 2	D:/pnrl/phase2/phase2_working_directory/test_install/ANODE SEAL1.SAT	file select	<input checked="" type="checkbox"/>	ss-430
Additional Component 3	D:/pnrl/phase2/phase2_working_directory/test_install/CATHODE SPACER1.SAT	file select	<input checked="" type="checkbox"/>	ss-430
Additional Component 4	D:/pnrl/phase2/phase2_working_directory/test_install/CATHODE SEAL1.SAT	file select	<input checked="" type="checkbox"/>	ss-430
Additional Component 5	D:/pnrl/phase2/phase2_working_directory/test_install/PEN SEAL1.SAT	file select	<input checked="" type="checkbox"/>	ss-430
Additional Component 6	D:/pnrl/phase2/phase2_working_directory/test_install/PictureFrame1.SAT	file select	<input checked="" type="checkbox"/>	ss-430

OK

CAD file specification (continued)



Specify scale factor to convert input geometry to m units (default = 1.0): 1.0



Extruded = surface mesh
extruded through thickness

Non-extruded = Tetrahedral
meshing of air and fuel solids

Material Specification

Major Component Geometry Files Input

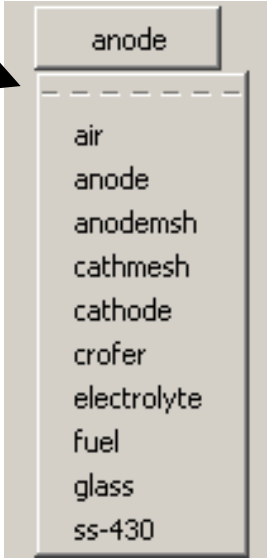
PNL FUEL CELL INPUT - MAJOR COMPONENTS

Component:	File:	file select	Extrudable?	Material
anode	D:/pnnl/phase2/phase2_working_directory/test_install/ANODE1.SAT	file select	<input checked="" type="checkbox"/>	anode
cathode	D:/pnnl/phase2/phase2_working_directory/test_install/CATHODE1.SAT	file select	<input checked="" type="checkbox"/>	cathode
electrolyte	D:/pnnl/phase2/phase2_working_directory/test_install/ELECTROLYTE1.SAT	file select	<input checked="" type="checkbox"/>	electrolyte
separator	D:/pnnl/phase2/phase2_working_directory/test_install/SEPARATOR PLATE1.SAT	file select	<input checked="" type="checkbox"/>	ss-430
separator_blank	D:/pnnl/phase2/phase2_working_directory/test_install/SEPARATOR PLATE BLANK1.SAT	file select	<input checked="" type="checkbox"/>	ss-430
fuel_in	D:/pnnl/phase2/phase2_working_directory/test_install/fuel in1.SAT	file select	<input checked="" type="checkbox"/>	fuel
fuel_out	D:/pnnl/phase2/phase2_working_directory/test_install/fuel out1.SAT	file select	<input checked="" type="checkbox"/>	fuel
fuel_flow	D:/pnnl/phase2/phase2_working_directory/test_install/KJmod-fuel flow1.SAT	file select	<input type="checkbox"/>	fuel
air_in	D:/pnnl/phase2/phase2_working_directory/test_install/air in1.SAT	file select	<input checked="" type="checkbox"/>	air
air_out	D:/pnnl/phase2/phase2_working_directory/test_install/air out1.SAT	file select	<input checked="" type="checkbox"/>	air
air_flow	D:/pnnl/phase2/phase2_working_directory/test_install/air flow1.SAT	file select	<input type="checkbox"/>	air

Specify number of additional components :

Specify scale factor to convert input geometry to m units (default = 1.0):

OK

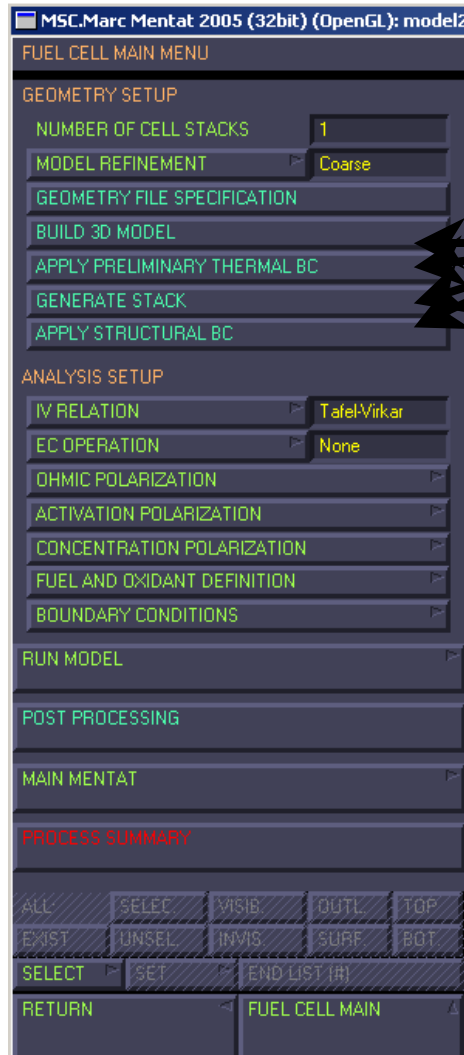


- anode
- cathode
- electrolyte
- ss-430
- ss-430
- fuel
- fuel
- fuel
- air
- air
- air
- air
- fuel
- glass
- ss-430

Material properties are from the SECA database:

- PNNL and ORNL data on cell materials.
- PNNL data on seal materials.

Finite Element Model Generation



Four 'action' buttons to provide for complete fuel cell model generation

1. Mesh solids
2. Define exterior surfaces
3. for radiation and convection.
4. Duplicate cells for stack mesh
5. Apply structural boundary conditions

Parametric Based Model Input

MSC.Marc Mentat 2005 (32bit) (OpenGL): model2

FUEL CELL MAIN MENU

GEOMETRY SETUP

- NUMBER OF CELL STACKS
- CURRENT DESIGN CONFIGURATION
- MODEL REFINEMENT
- GEOMETRY SET UP
- BUILD 2D FOOTPRINT
- BUILD 3D STACK GEOMETRY

ANALYSIS SETUP

- IV RELATION
- EC OPERATION
- OHMIC POLARIZATION
- ACTIVATION POLARIZATION
- CONCENTRATION POLARIZATION
- FUEL AND OXIDANT DEFINITION
- BOUNDARY CONDITIONS
- PROCESS SUMMARY
- UPDATE ANALYSIS MODEL

RUN MODEL

POST PROCESSING

MAIN MENTAT

ALL SELEC VISIB OUTL TOP
EXIST UNSEL INVIS SURF BOT
SELECT SET END LIST (#)
RETURN FUEL CELL MAIN

MSC.Marc Mentat FUEL CELL DESIGN

DEFINE FUEL CELL DESIGN

- Cross-Flow
- Co-Flow
- Counter-Flow
- OK

MSC.Marc Mentat FUEL CELL DESIGN

Select Stack Structure for Cross-Flow Fuel Design Definition

- Planar Stack Structure
- Vertical Stack Structure
- Vertical PEN Stack Structure
- OK

MSC.Marc Mentat FUEL CELL DESIGN

INPUT CROSS-FLOW DESIGN PLANAR STACK/PEN DIMENSIONS (Meters)

FUEL MANIFOLD		OUTLET EDGE	
Inlet Edge	.005	Outlet Edge	.005
Inlet Length	.0150	Outlet Length	.0150
Inlet Width	.0033	Outlet Width	.0062
Inlet Seal Width	.005	Outlet Seal Width	.005
No. of Inlet Channels	6	No. of Outlet Channels	6
Total Inlet Area (sq meters)		Total Outlet Area (sq meters)	

Fuel Manifold Dimensions Guide

MSC.Marc Mentat FUEL CELL DESIGN

INPUT VERTICAL STACK COMPONENT DIMENSIONS (Meters)

SEPARATOR PLATE BLANK	
Thickness	0.0012 Material SS-430

COMPOSITE SEAL 1	
Seal Thickness	0.0002 Seal Material SS-430
Spacer Thickness	0.00116 Spacer Material Glass Seal

PICTURE FRAME	
Thickness	0.0005 Material SS-430

COMPOSITE SEAL 2	
Seal Thickness	0.0000 Seal Material SS-430
Spacer Thickness	0.00075 Spacer Material Glass Seal

MSC.Marc Mentat FUEL CELL DESIGN

INPUT VERTICAL PEN COMPONENT DIMENSIONS (Meters)

PEN	
Anode Thickness	0.0006 Material Anode
Electrolyte Thickness	0.00001 Material Electrolyte
Cathode Thickness	0.00005 Material Cathode

PEN ATTACHMENT TO PICTURE FRAME

PEN Layer	Cathode
Picture Frame Layer	Top
Attachment Method	Bonded

COMPOSITE SEAL 3	
Seal Thickness	0.0002 Material Glass Seal
Spacer Thickness	0.0 Material SS-430

PEN Stack Dimensions Guide

OK

Defining Cell Performance

ANALYSIS SETUP

- IV RELATION: Tafel-Virkar
- EC OPERATION: None
- OHMIC POLARIZATION
- ACTIVATION POLARIZATION
- CONCENTRATION POLARIZATION
- FUEL AND OXIDANT DEFINITION
- BOUNDARY CONDITIONS
- PROCESS SUMMARY
- UPDATE ANALYSIS MODEL

MSC.Marc MentatFUEL CELL DESIGN

DEFINE IV RELATION

Tafel-Virkar

Butler-Volmer

OK

MSC.Marc MentatFUEL CEL...

SELECT OPERATION OPTION

Total Voltage

Total Current

Fuel Utilization

OK

MSC.Marc MentatFUEL CEL...

TOTAL VOLTAGE OPERATION

Total Voltage = voltage * no. of cells in stack:

Voltage (V): 0.7

No of Cells: 1

Total Voltage (V): 0.7

COMPUTE VOLTAGE

OK

MSC.Marc MentatFUEL CEL...

TOTAL CURRENT OPERATION

Total Current = current * active PEN area:

Current (A/cm²): 1.0

Active PEN area:

Total Current (A): 0

COMPUTE CURRENT

OK

MSC.Marc MentatFUEL CEL...

FUEL UTILIZATION OPERATION

Fuel Utilization (%): 0.50

OK

Ohmic Polarization

MSC.Marc Mentat FUEL CELL DESIGN

OHMIC POLARIZATION OPTIONS

For TAFEL-VIRKAR Relation

Electrolyte Conductivity ($k = T \cdot \text{prefactor} \cdot \exp(\text{eff act en})$)

Effective Activation Energy

Prefactor

	Anode Parameters:	Cathode Parameters:	Interconnect Paramet
Temperature (K)	<input type="text" value="1273"/>	<input type="text" value="1273"/>	<input type="text" value="1273"/>
Ohmic Resistance	<input type="text" value="3.33e-5"/>	<input type="text" value="7.69e-5"/>	<input type="text" value="4.0e-5"/>

For BUTLER-VOLMER Relation

Electrolyte Conductivity ($k = AT^3 + BT^2 + CT + D$):

A

B

C

D

	Anode Conductivity:	Cathode Conductivity:	Interconnect Conduct
Activation Energy	<input type="text"/>	<input type="text"/>	<input type="text"/>
Pre-factor	<input type="text"/>	<input type="text"/>	<input type="text"/>
Porosity	<input type="text"/>	<input type="text"/>	
Conductivity	<input type="text"/>		

Activation Polarization

MSC.Marc Mentat FUEL CELL DESIGN

ACTIVATION POLARIZATION OPTIONS

For TAFEL-VIRKAR Relation

Temperature (K):	Exchange Current (A/	Tafel Prefacto
923	0.051e-4	0.031
973	0.107e-4	0.028
1023	0.113e-4	0.0248
1073	0.132e-4	0.0247

For BUTLER-VOLMER Relation

Exchange Current ($j = \text{prefactor} \cdot \exp(-\text{act. energy}/RT)$):

Activation Energy

Prefactor

Symmetry Factor

OK

Concentration Polarization

MSC.Marc Mentat FUEL CELL DESIGN

CONCENTRATION POLARIZATION OPTIONS

For TAFEL-VIRKAR Relation

Testing Fuel Pressure (atm):

H2	0.96
H2O	0.04
CO	0.0
CO2	0.0

Temperature (K):

923
973
1023
1073

Anode Current Density (A/cm²):

3.184e-4
4.74e-4
4.953e-4
5.65e-4

For BUTLER-VOLMER Relation

Concentration Polarization Parameters:

	Anode	Cathode
Porosity		
Tortuosity		

OK

Fuel and Oxidant Definition

MSC.Marc Mentat ...

FUEL AND OXIDANT

INLET FUEL

Pressure (atm)	1.0
Temperature (K)	967
Flow Rate (gmol/sec)	4.236e-4
Composition (Molar Fraction %)	
H2	0.95
H2O	0.05
CO	0
CO2	0
CH4	0

INLET OXIDANT

Pressure (atm)	1.0
Temperature (K)	967
Flow Rate (gmol/sec)	1.69e-2
Composition (Molar Fraction %)	
O2	0.21
N2	0.79

OK

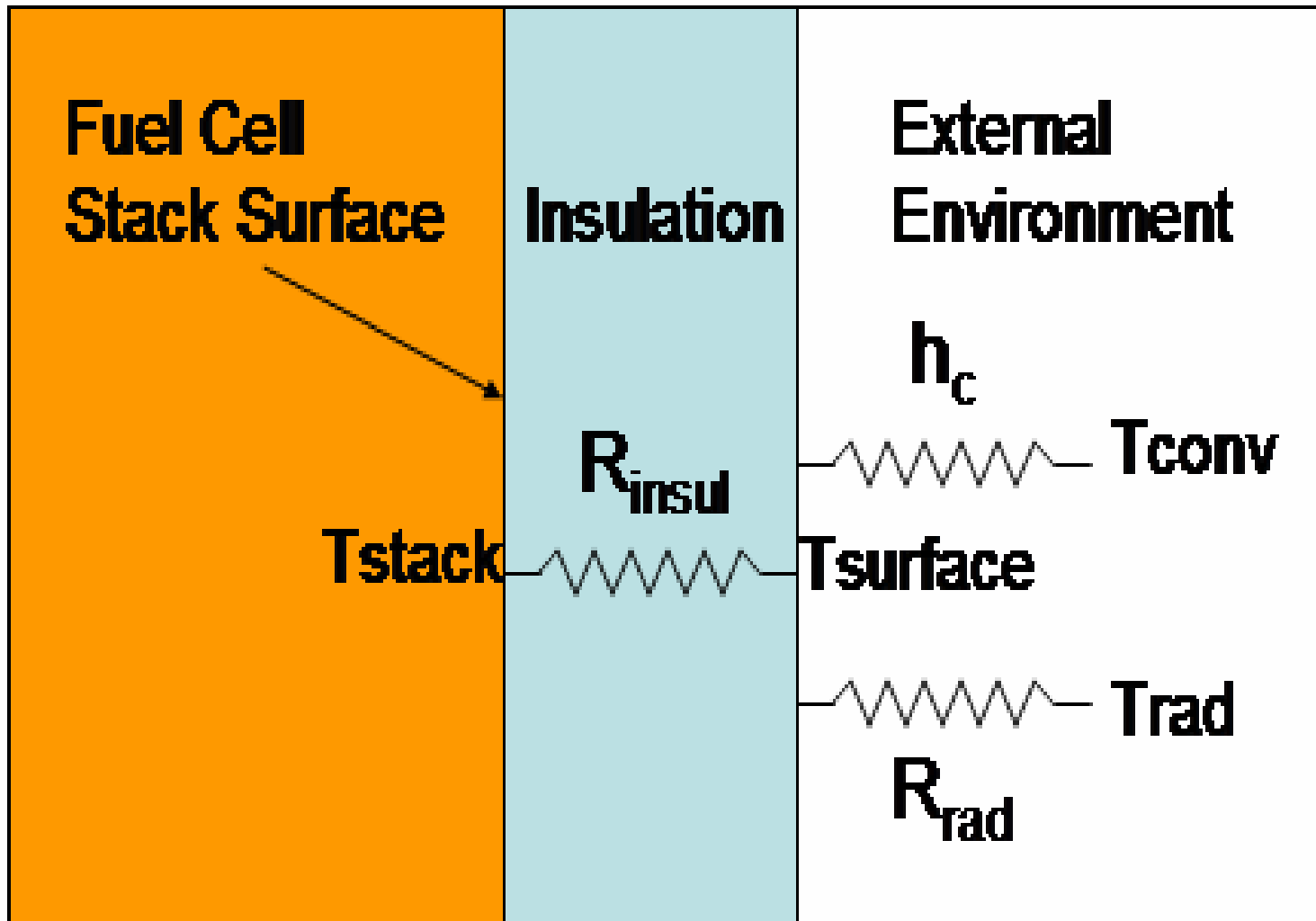
Stack Flow Rate

Fuel Composition

Stack Flow Rate

Oxidant Composition

Stack Boundary Conditions



Boundary conditions defined on top, sides, and bottom of stack

Stack Boundary Conditions

MSC.Marc Mentat FUEL CELL DESIGN

THERMAL BOUNDARY CONDITIONS

Initial Stack Temperature (K)

Surface Heat Transfer:

STACK INSULATION

	Top	Bottom	Vertical Sides
Thickness (m)	<input type="text" value=".01"/>	<input type="text" value=".01"/>	<input type="text" value=".01"/>
Conductivity (W/m-K)	<input type="text" value=".07"/>	<input type="text" value=".07"/>	<input type="text" value=".07"/>

RADIATION

	Top	Bottom	Vertical Sides
Emissivities (unitless)	<input type="text" value=".7"/>	<input type="text" value=".7"/>	<input type="text" value=".7"/>
Sink Temperature (K)	<input type="text" value="293"/>	<input type="text" value="293"/>	<input type="text" value="293"/>

CONVECTION

	Top	Bottom	Vertical Sides
Film Coef (W/m ² -K)	<input type="text" value="3.0"/>	<input type="text" value="5.0"/>	<input type="text" value="13.0"/>
Air Temperature (K)	<input type="text" value="293"/>	<input type="text" value="293"/>	<input type="text" value="293"/>

MECHANICAL BOUNDARY CONDITIONS

Stress Free Stack Temperature (K)

Include Creep Effects - Event Duration (seconds)

Model Solution

MSC.Marc Mentat 2005 (32bit) (OpenGL): model2

FUEL CELL MAIN MENU

GEOMETRY SETUP

NUMBER OF CELL STACKS 1

MODEL REFINEMENT Coarse

GEOMETRY FILE SPECIFICATION

BUILD 3D MODEL

APPLY PRELIMINARY THERMAL BC

GENERATE STACK

APPLY STRUCTURAL BC

ANALYSIS SETUP

IV RELATION Tafel-Virkar

EC OPERATION None

OHMIC POLARIZATION

ACTIVATION POLARIZATION

CONCENTRATION POLARIZATION

FUEL AND OXIDANT DEFINITION

BOUNDARY CONDITIONS

RUN MODEL

POST PROCESSING

MAIN MENTAT

PROCESS SUMMARY

ALL	SELEC	VISIB	OUTL	TOP
EXIST	UNSEL	INVIS	SURF	BOT
SELECT	SET	END LIST (R)		
RETURN	FUEL CELL MAIN			

RUN JOB

USER SUBROUTINE FILE

No Domains for DDM

WRITE EC PARAMETER FILE EDIT EC PARAMETER FILE

TITLE SAVE MODEL

SUBMIT (1) ADVANCED JOB SUBMISSION

UPDATE MONITOR KILL

STATUS	Not Submitted			
CURRENT INCREMENT (CYCLE)	0			
SINGULARITY RATIO	0			
CONVERGENCE RATIO	0			
ANALYSIS TIME	0			
WALL TIME	0			
TOTAL	CYCLES	0	CUT BACKS	0
	SEPARATIONS	0	REMESHES	0
EXIT NUMBER	0		EXIT MESSAGE	

EDIT OUTPUT FILE LOG FILE STATUS FILE ANY FILE

OPEN POST FILE (RESULTS MENU)

RESET OK

Write EC parameter file

Submit Analyses

The Post Processing Menus

MSC.Marc Mentat 2005 (32bit) (OpenGL): model2

FUEL CELL MAIN MENU

GEOMETRY SETUP

- NUMBER OF CELL STACKS: 1
- MODEL REFINEMENT: Coarse
- GEOMETRY FILE SPECIFICATION
- BUILD 3D MODEL
- APPLY PRELIMINARY THERMAL BC
- GENERATE STACK
- APPLY STRUCTURAL BC

ANALYSIS SETUP

- IV RELATION: Tafel-Virkar
- EC OPERATION: None
- OHMIC POLARIZATION
- ACTIVATION POLARIZATION
- CONCENTRATION POLARIZATION
- FUEL AND OXIDANT DEFINITION
- BOUNDARY CONDITIONS

RUN MODEL

POST PROCESSING

MAIN MENTAT

PROCESS SUMMARY

ALL	SELEC	VISIB	OUTL	TOP
EXIST	UNSEL	INVIS	SURF	BOT
SELECT	SET	END LIST (#)		
RETURN	FUEL CELL MAIN			

Mentat-FC Post Processing

Select Results Option:

Post Variable:

Cell Component:

Stack Number:

Mentat-FC Post Processing

Select Results Option:

Post Variable:

Cell Component:

- Temperature
- Heat Generation Rate
- Partial Pressure of H2
- Partial Pressure of O2
- Partial Pressure of H2O
- Partial Pressure of CO
- Partial Pressure of CO2
- Partial Pressure of CH4

Mentat-FC Post Processing

Select Results Option:

Post Variable:

Cell Component:

Stack Number:

Mentat-FC Post Processing

Select Results Option:

Post Variable:

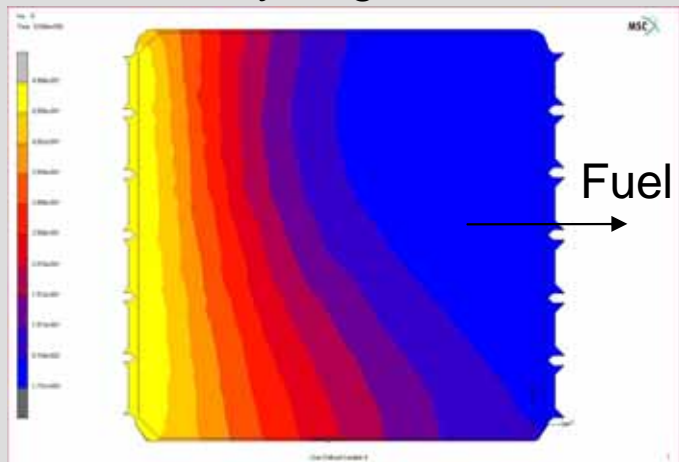
Cell Component:

Stack Number:

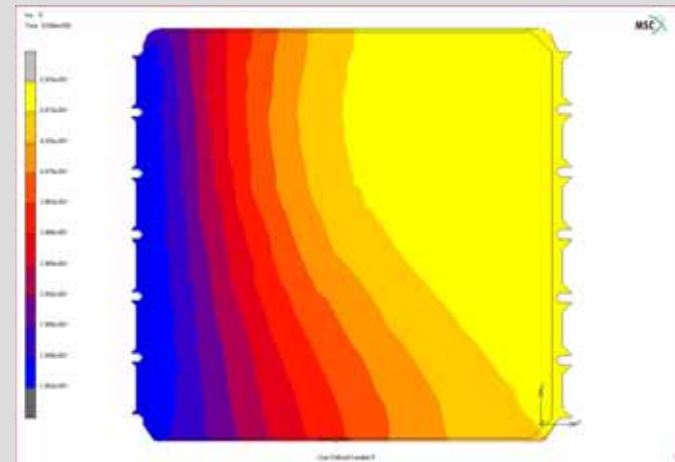
Fuel Species

(Inlet Fuel: 0.6 H₂, 0.1 H₂O, 0.3 CO, 0.1 CO₂)

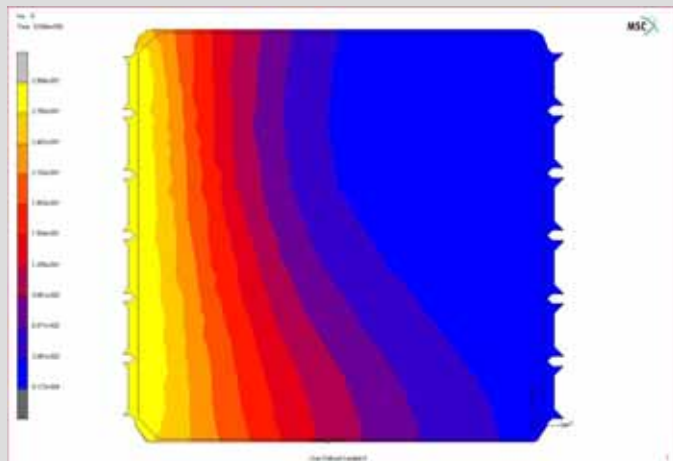
Hydrogen



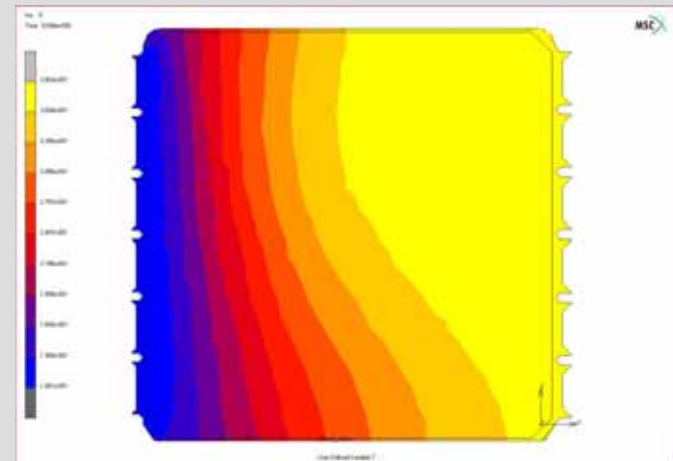
Water



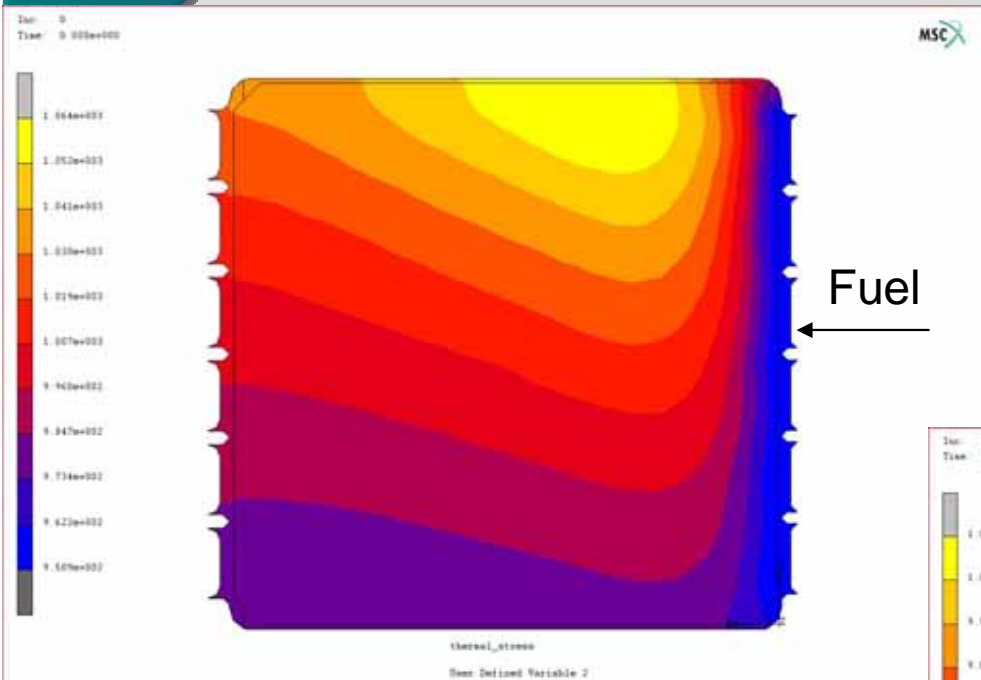
CO



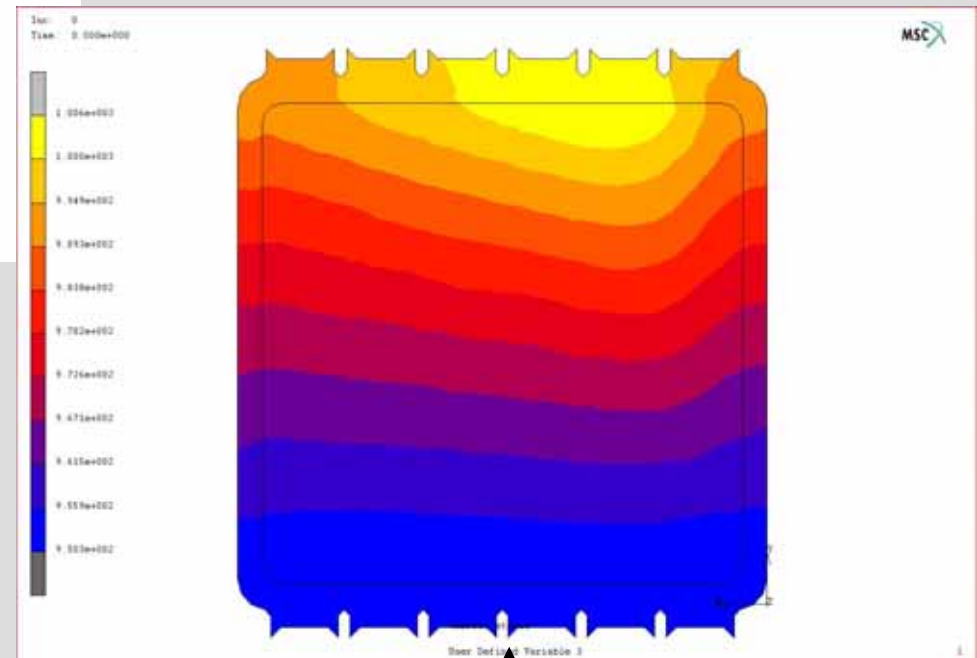
CO₂



Fuel and Oxidant Temperature

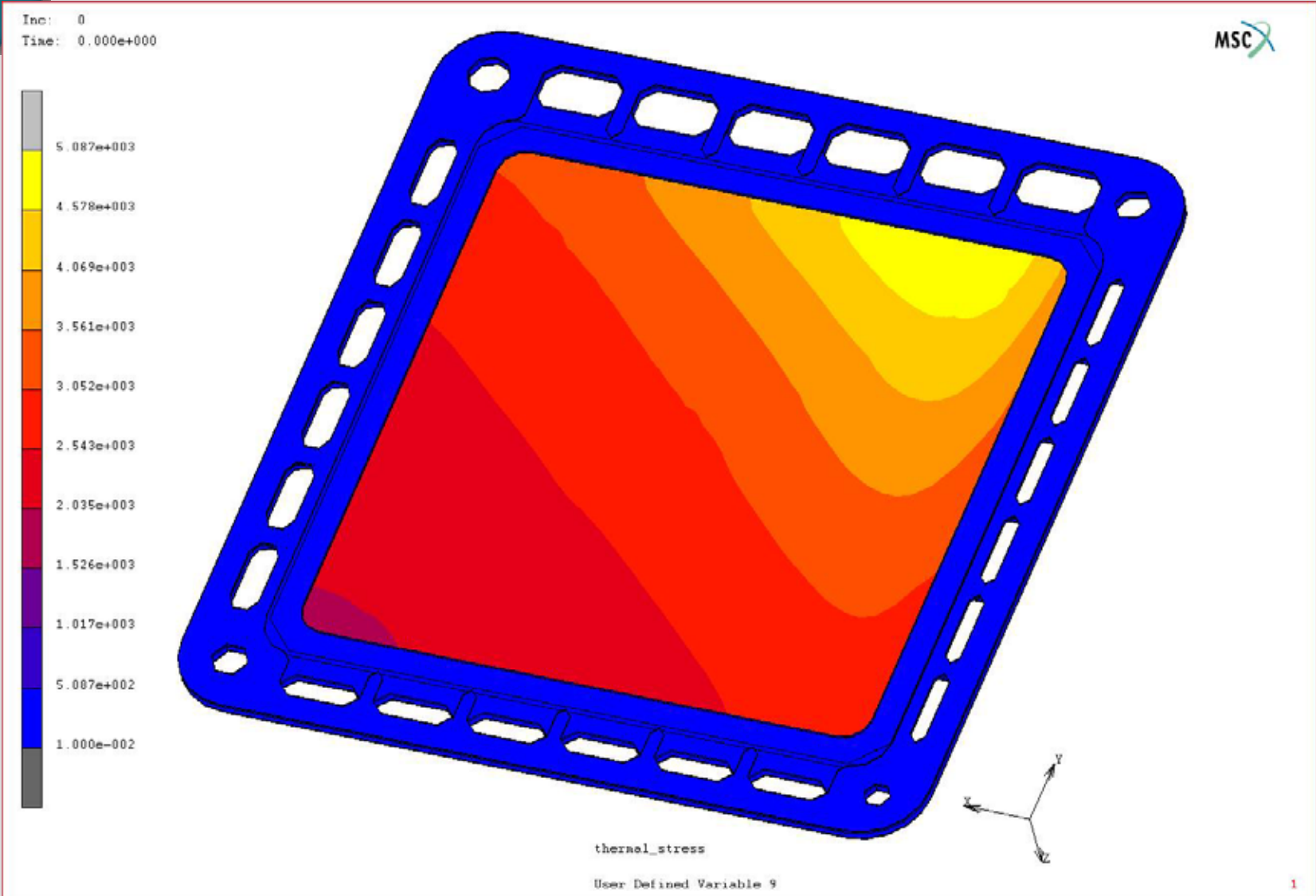


Fuel Temperature



Air Temperature

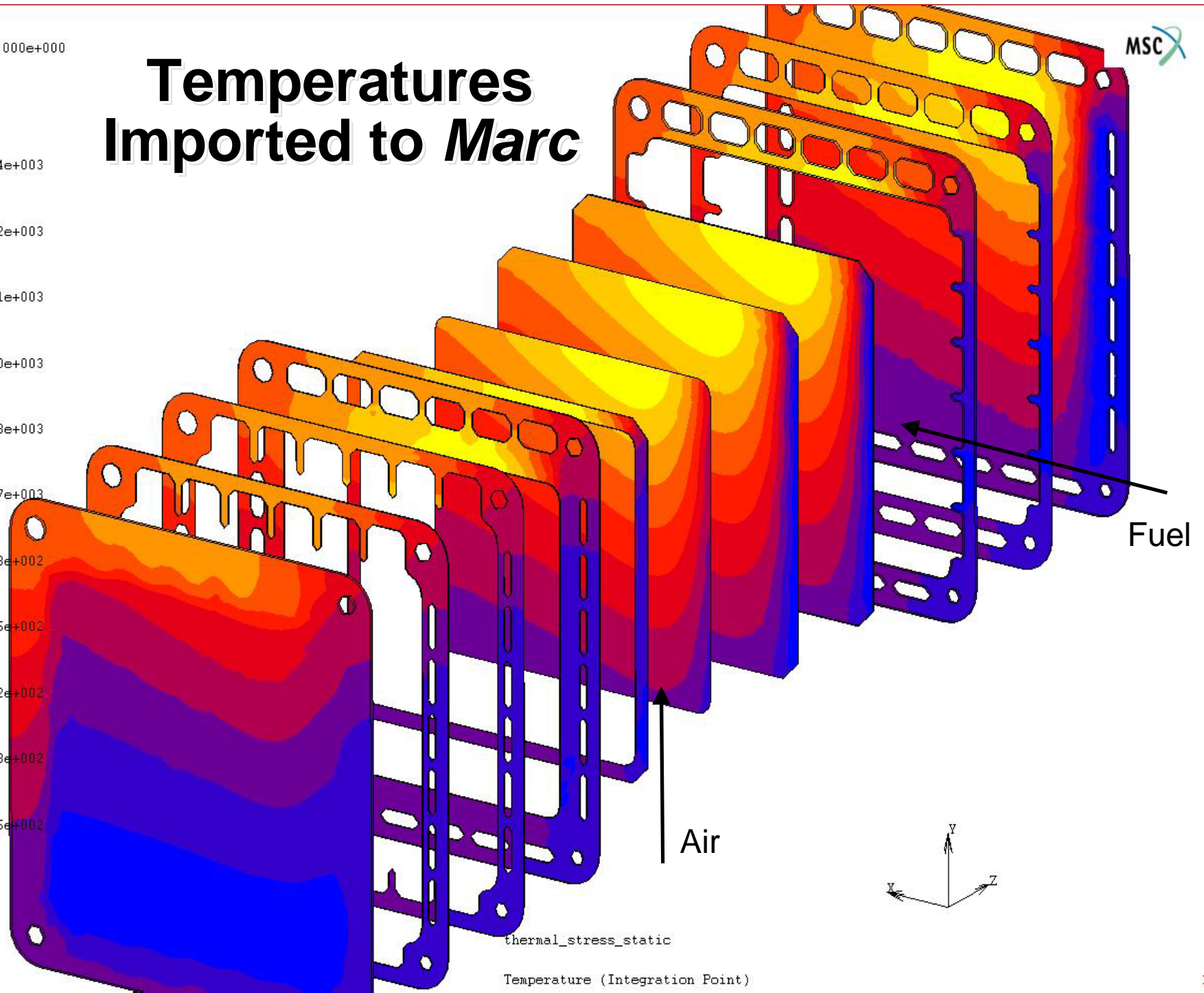
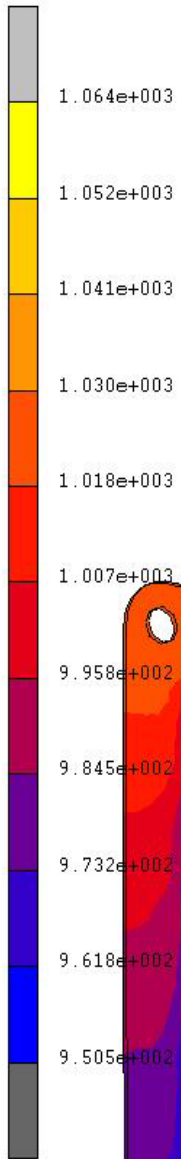
Current



Inc: 1
Time: 1.000e+000



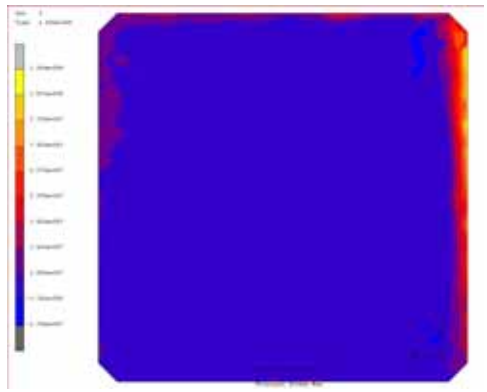
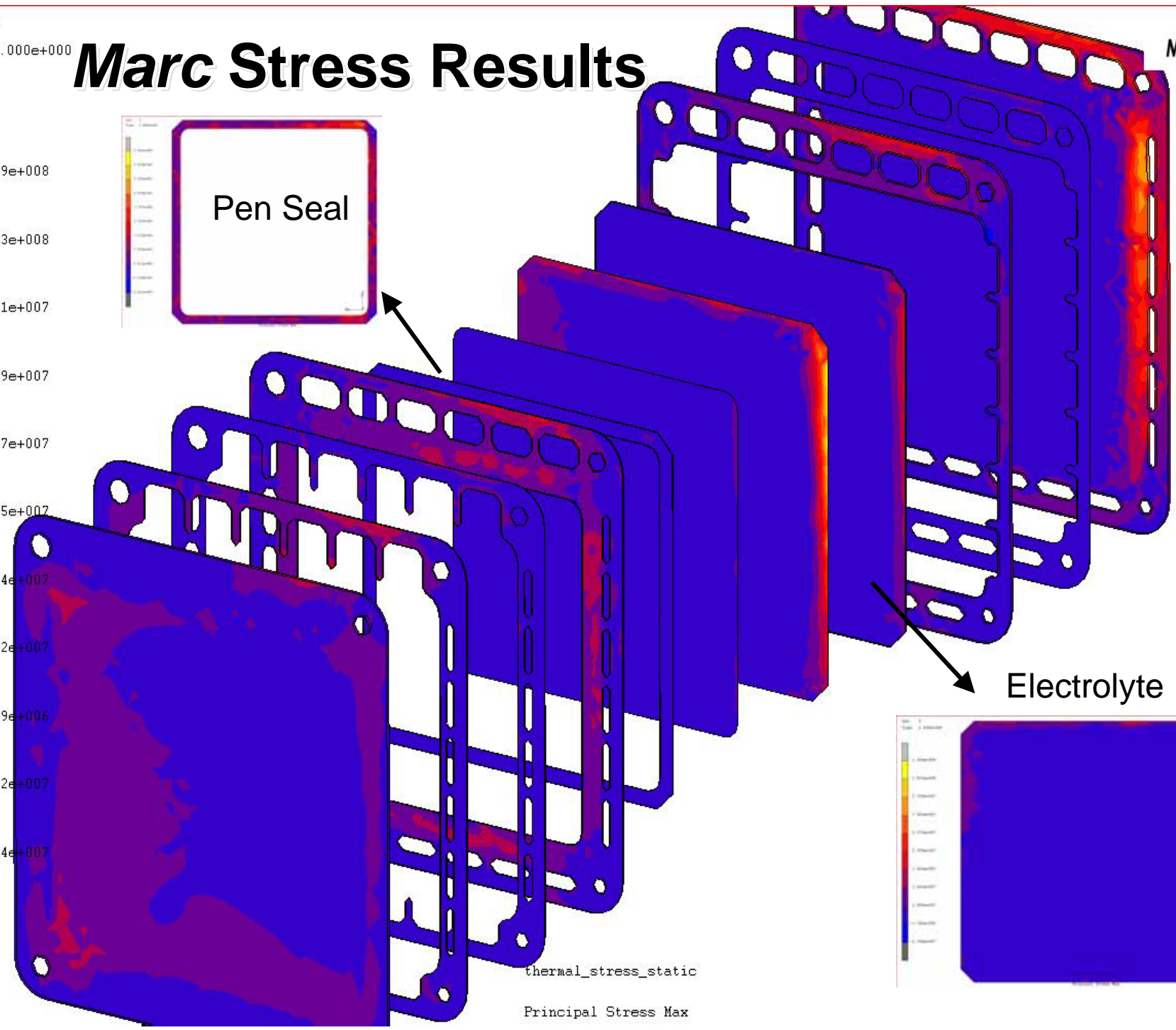
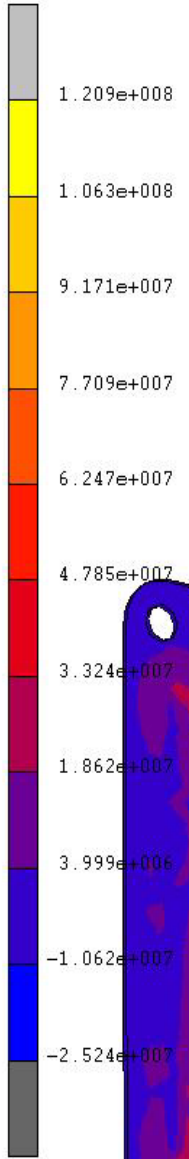
Temperatures Imported to *Marc*



thermal_stress_static
Temperature (Integration Point)

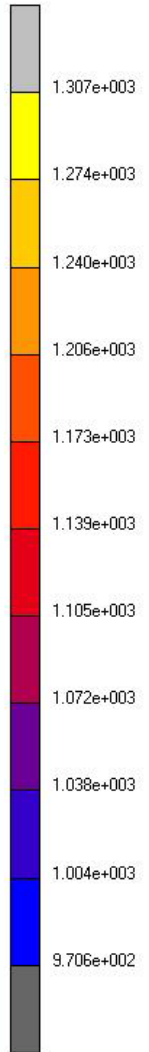
Inc: 1
Time: 1.000e+000

Marc Stress Results



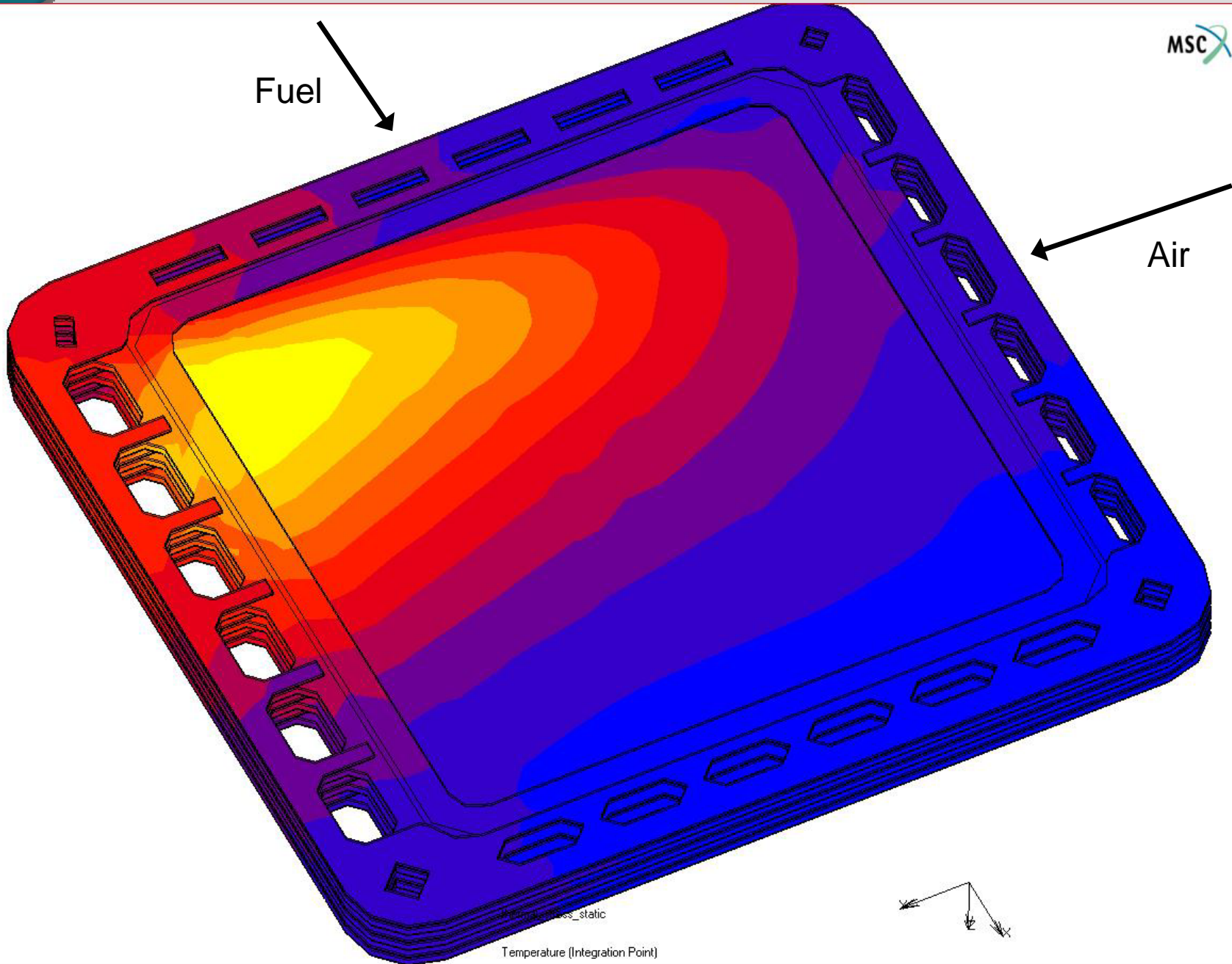
3-Cell Model directly from CAD

Inc: 1
Time: 1.000e+000

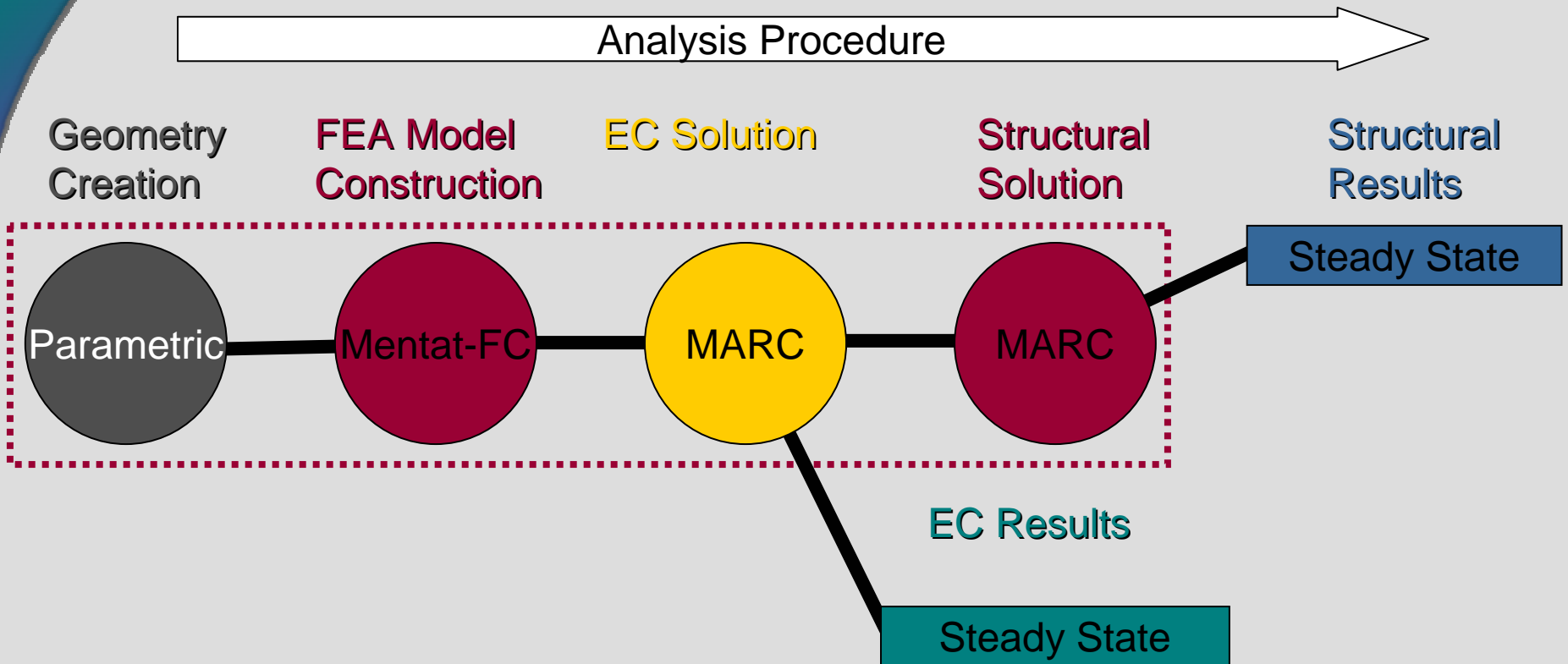


Fuel

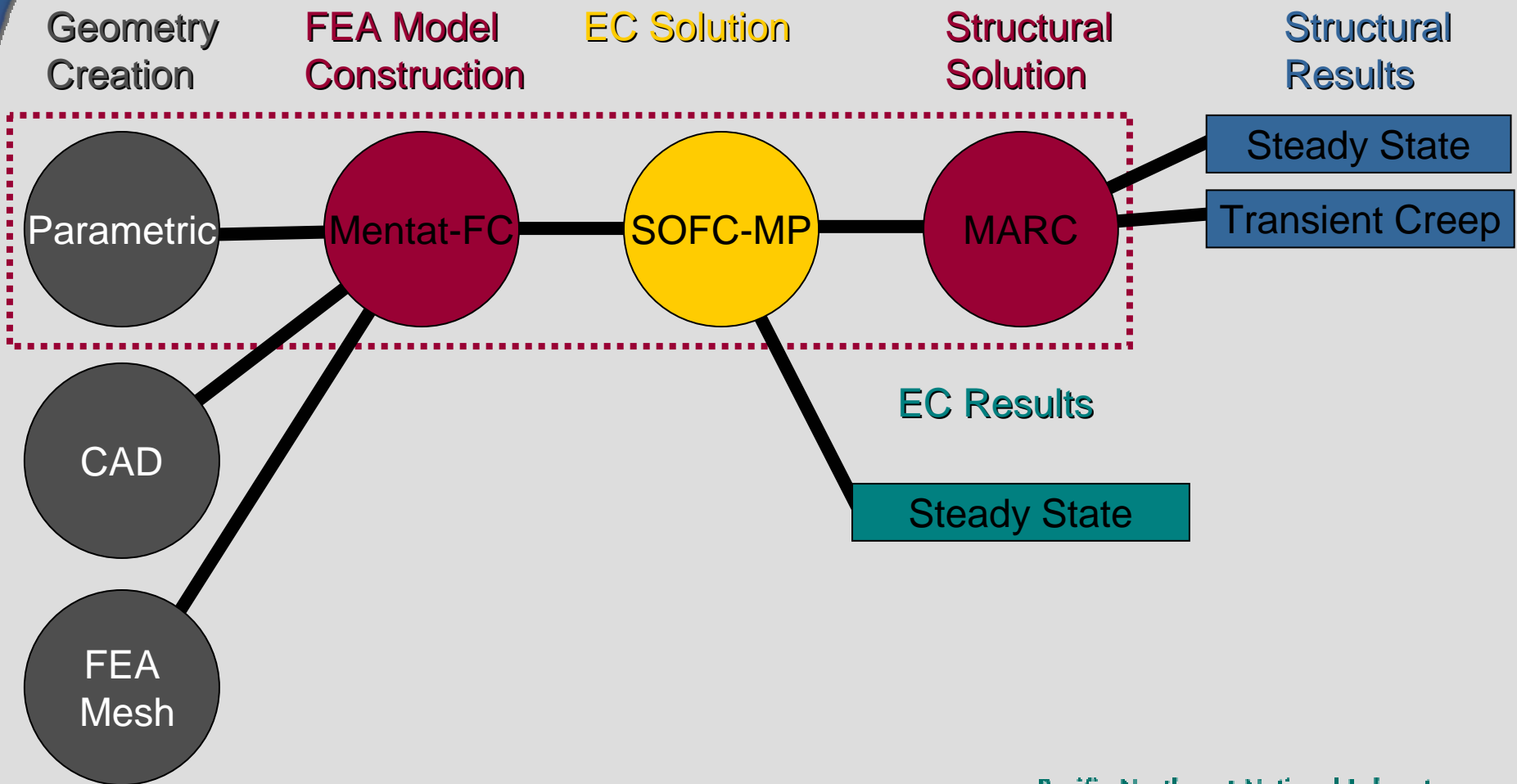
Air



Mentat-FC: Original Parametric GUI

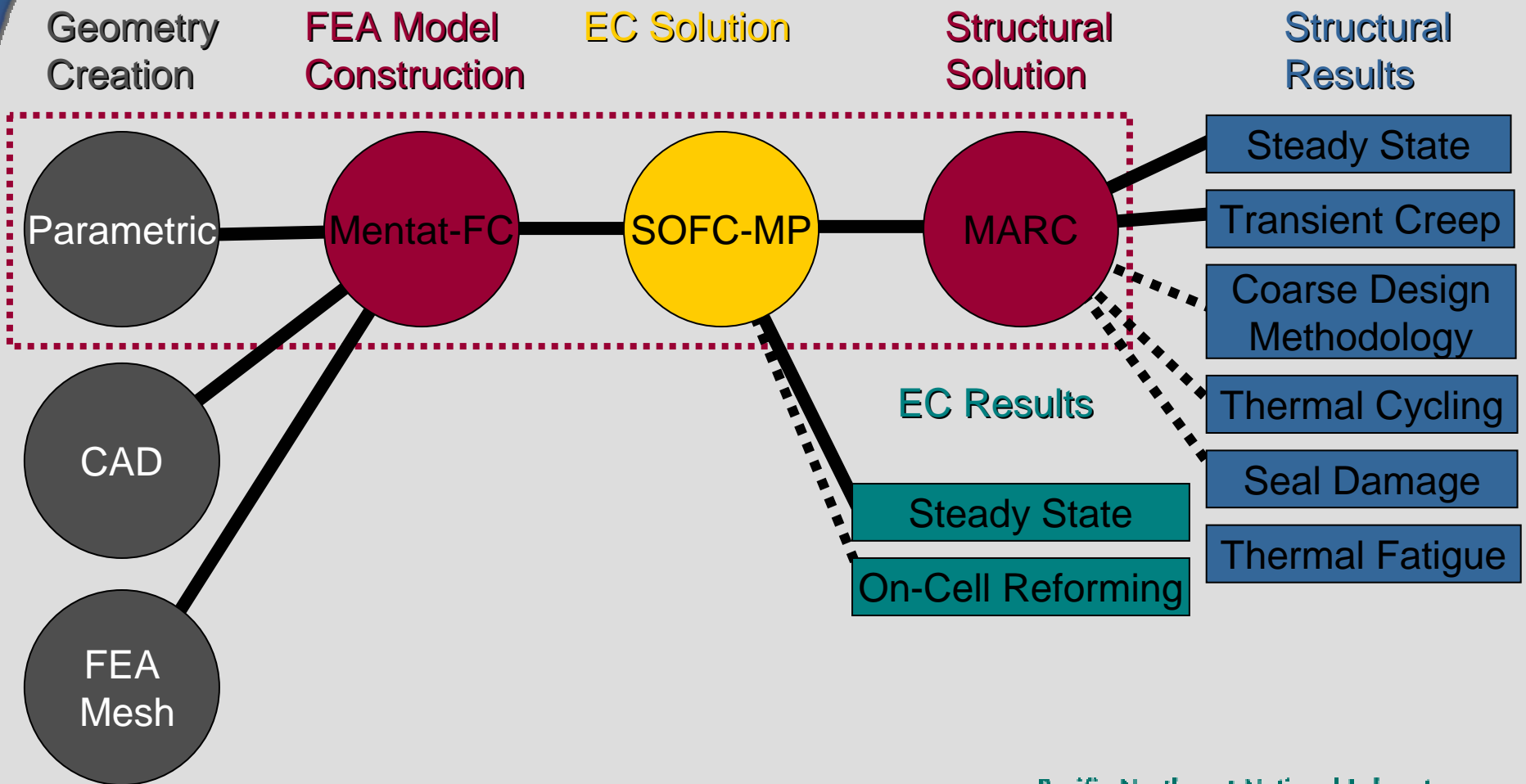


Mentat-FC: Present Modeling Tool

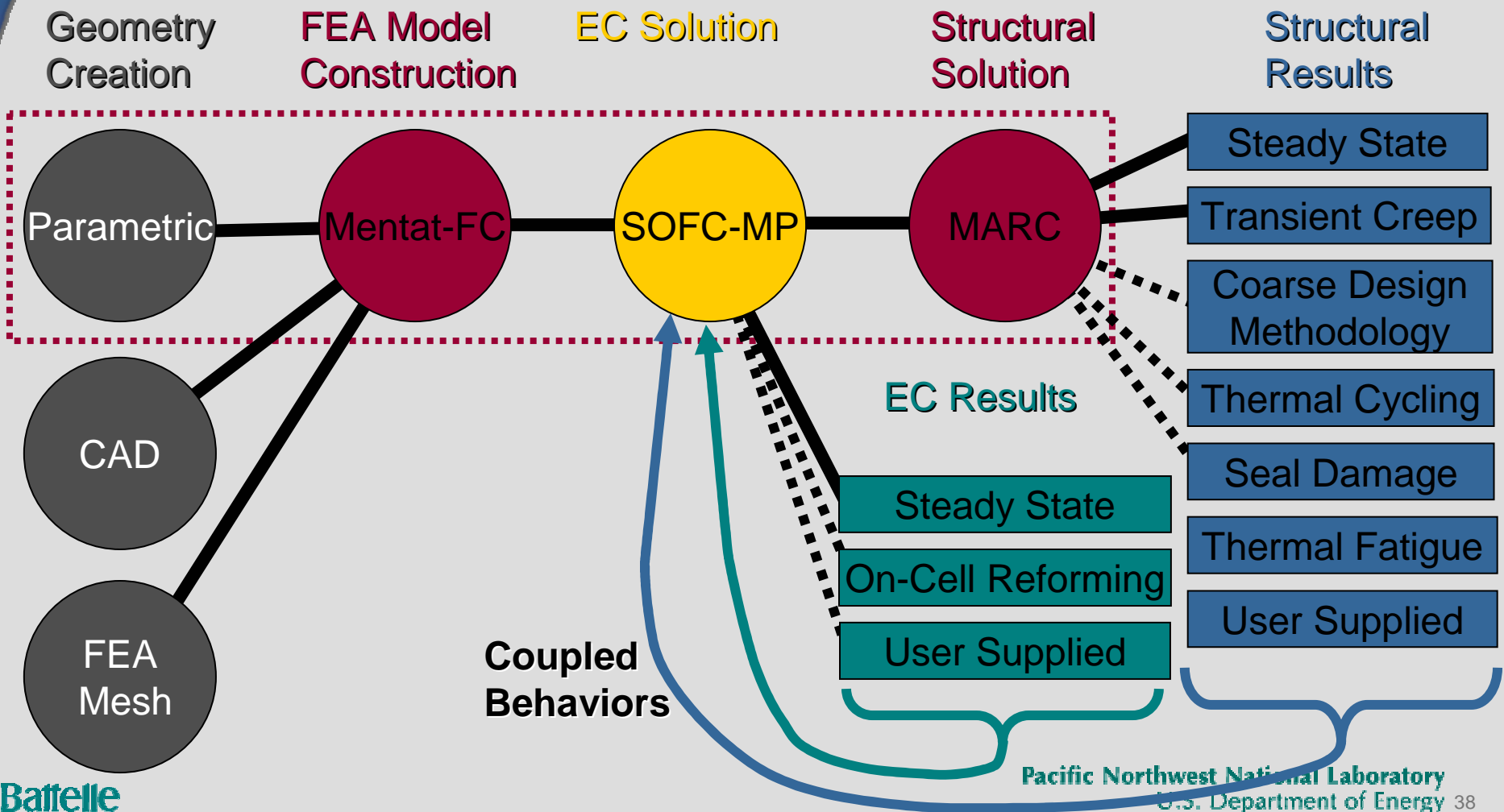


Mentat-FC: In-Progress Modeling Suite

Analysis Procedure



Completed Modeling Suite



How to get this software and more training

- ▶ MSC Evaluation Licenses
- ▶ PNNL Summer Workshop

Questions?

5-minute break before starting

the live demo of

SOFC-MP and MSC.Marc/Mentat-FC

Test Problems

- ▶ 1-Cell course model from CAD
- ▶ 3-Cell model from existing ANSYS mesh files.
- ▶ 1-Cell cross-flow parametric model
- ▶ 1-Cell co-flow parametric model
- ▶ 1-Cell counter-flow parametric model

Fuel Species

