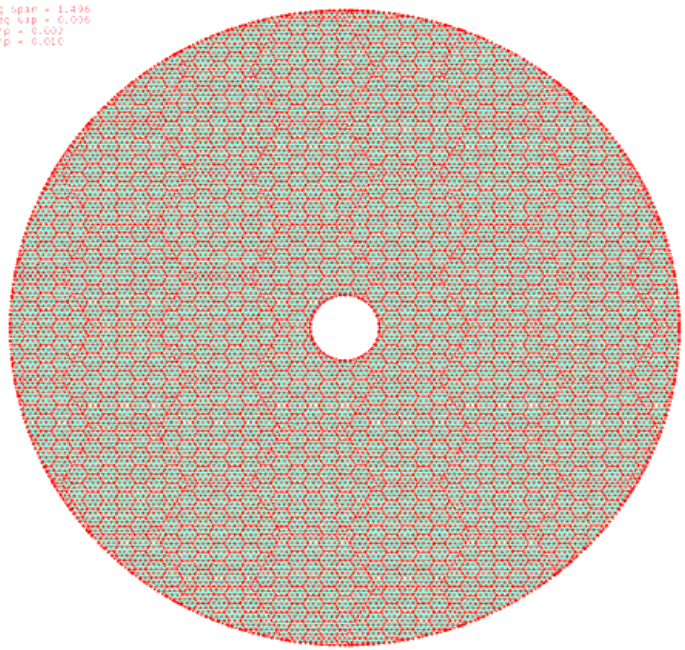
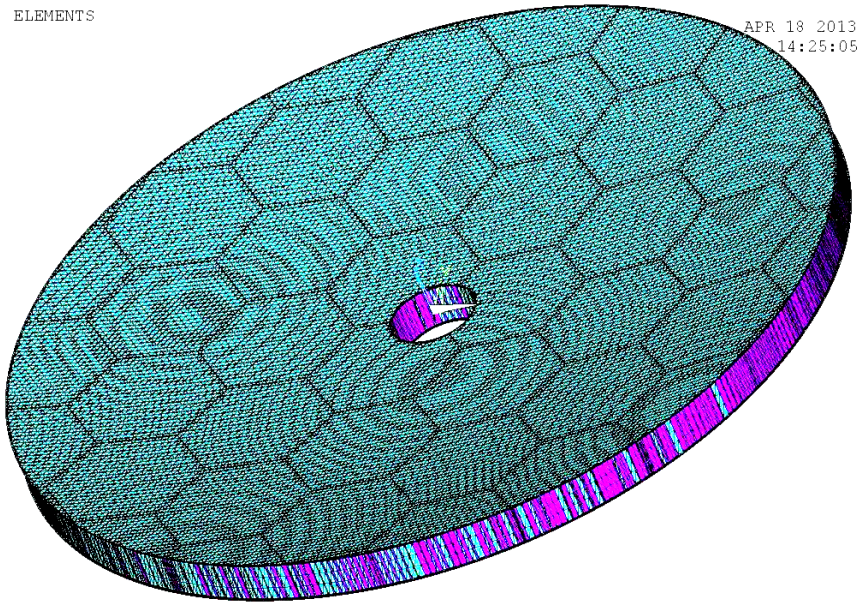
Next-generation lightweight mirror modeling software





William R. Arnold Sr., Sr. Principal Engineer, DAI, Huntsville, AL.
Mathew Fitzgerald, NASA Intern, NASA MSFC, Huntsville, Al.
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Dr. Phil Stahl, AMTD PI, NASA MSFC, Huntsville, Al.

INTRODUCTION

- **The modeler was developed to handle all current and projected mirror construction techniques and materials.**
- **It can be used to model both individual mirrors, arrays of mirrors and “fused segmented” mirrors**
- **It uses a new generation of algorithms and code written for Windows 7 © and beyond**
- **Designed for rapid trade studies of both gross geometry as well as detailed parameter (thickness) optimization and integrated suspension design.**

INTRODUCTION

TOOLS FOR INTEGRATED DESIGN OF MIRRORS & SUSPENSION SYSTEMS

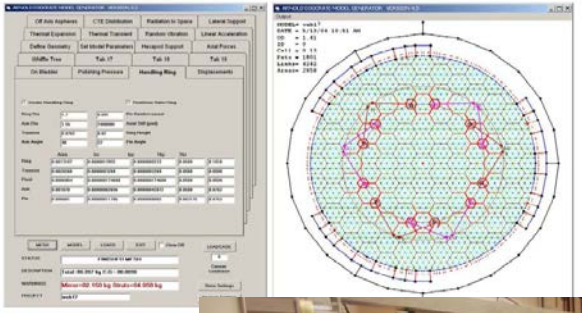
- WHY WE ARE INTERESTED IN THESE TOOLS
  - LARGER SPACE-BASED UV TELESCOPES BEING PLANNED.
  - LAUNCH CAPABILITIES REMAIN UNCERTAIN
  - COST & SCHEDULE TO BUILD COMPLEX FEM MODELS
  - THIS APPROACH WAS VERY SUCCESSFUL ON KEPLER
- SUBSTRATE MATERIALS & FABRICATION ADVANCES
  - ULE (FRIT OR LOW TEMPERATURE FUSION)
  - ZERODUR (POCKET MILLED & ACID)
  - BOROSILICATE (CAST)
- SUSPENSION SYSTEMS & LIGHTWEIGHT OPTICS
  - OPERATIONAL (KINEMATIC)
  - AUXILLARY LAUNCH (DISENGAGES ON ORBIT)
  - HOW MIRROR DESIGN INTERACTS WITH SUSPENSION(S)

INTEGRATED APPROACH TO DESIGN WORKS
(PREDECESSOR PROGRAM USED ON KEPLER)

L3 communications Brashear | CORNING | JDS Uniphase OCLI Products | Ball Aerospace & Technologies Corp.

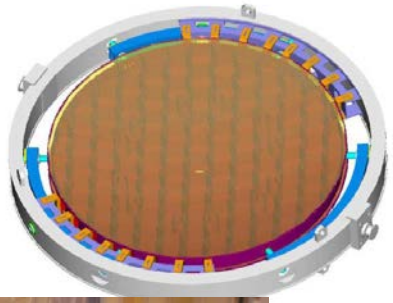
L3 communications Brashear | CORNING | JDS Uniphase OCLI Products | Ball Aerospace & Technologies Corp.

Integrated Design of Handling Equipment



Design tool allows evaluation a
of the mirror blank. As mirrors
manufacturing requires careful
were added to the blank specifi

Primary Mirror in Flipping Ring

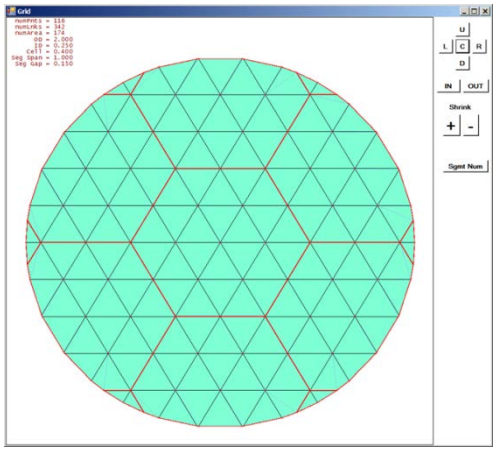


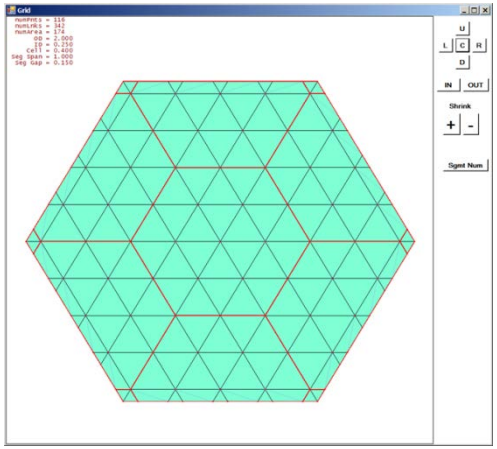
nforced slots in the mirror
he unit can act as a
l surfaces or fragile edges.

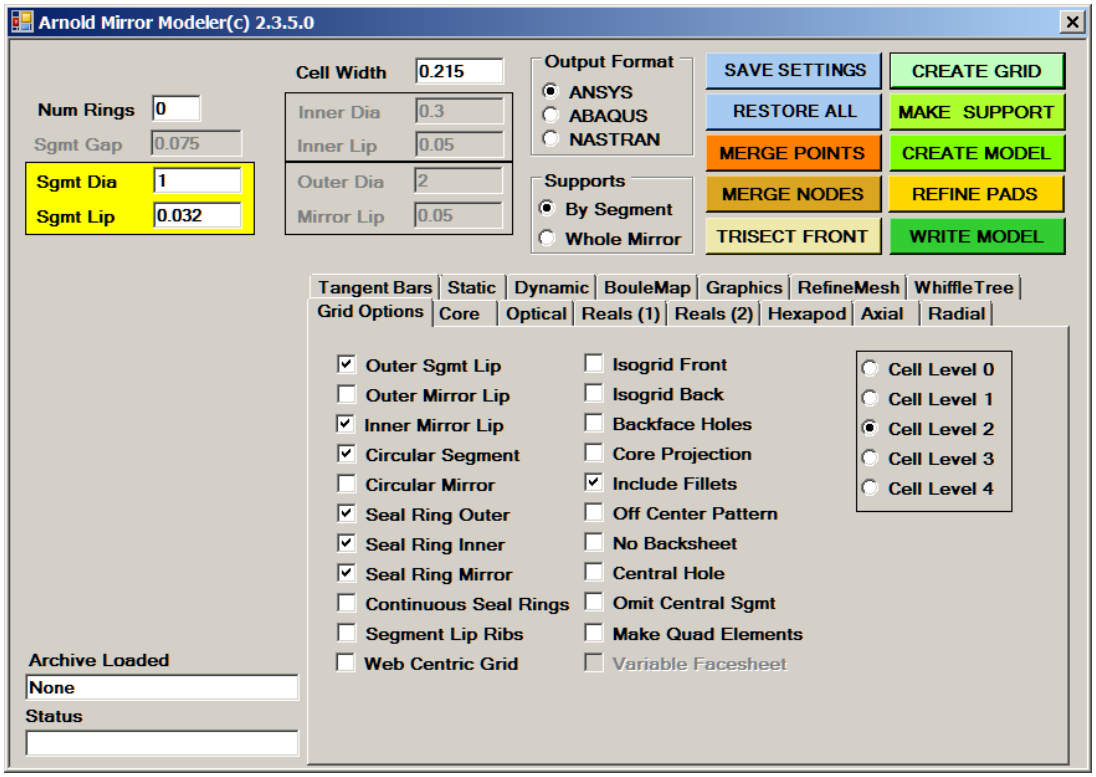
Kepler

2004 18

WIDE VARIETY OF OPTIONS TO MODEL ALMOST ANY MIRROR STYLE

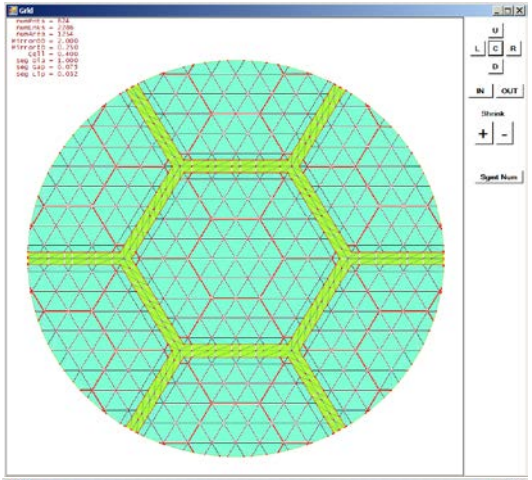


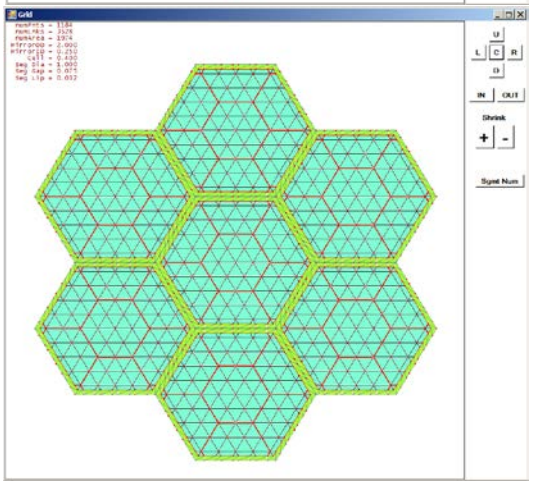


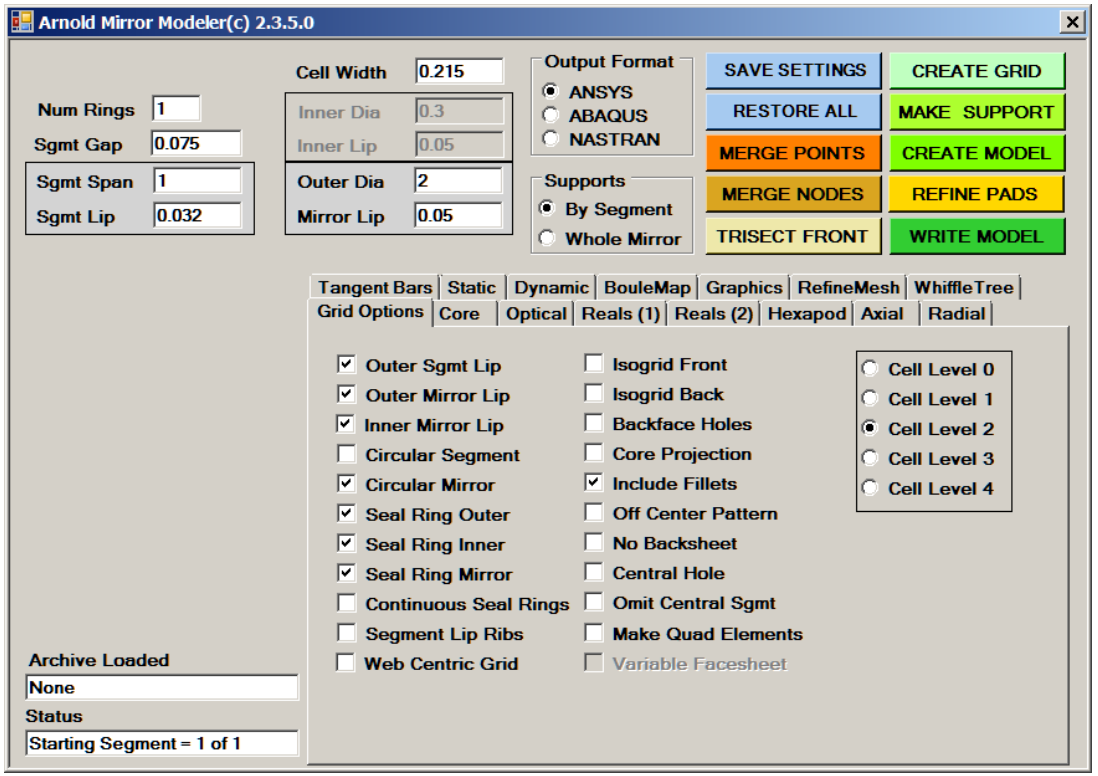


SIMPLE SINGLE BLANK MIRRORS

WIDE VARIETY OF OPTIONS TO MODEL ALMOST ANY MIRROR STYLE

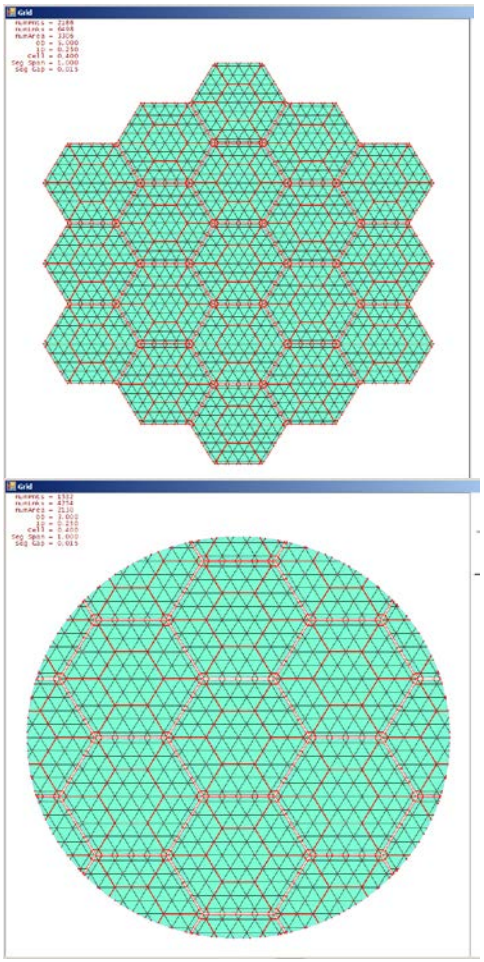




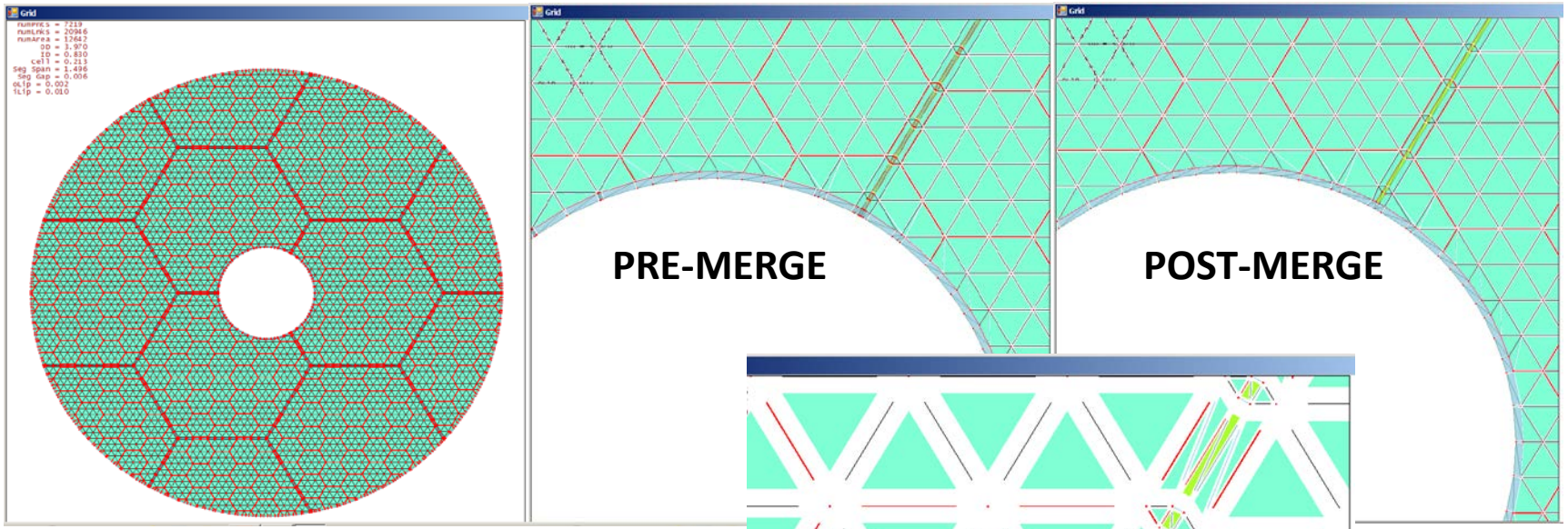


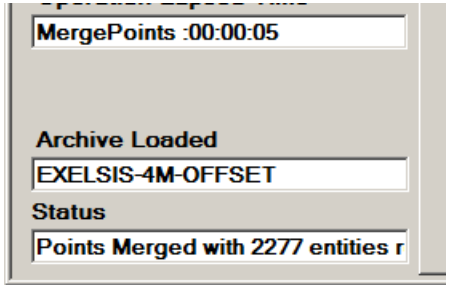
MULTIPLE SEGMENT MIRRORS

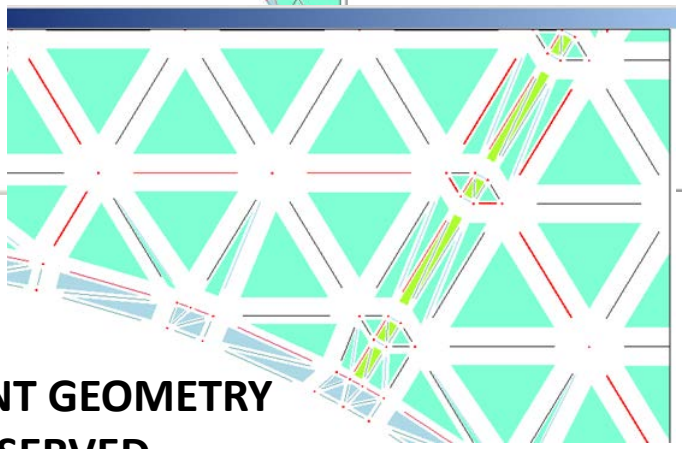
MANY CONFIGURATION OPTIONS ARE AVAILABLE



COMPLEX SEGMENTED ASSEMBLIES CAN BE MERGED INTO A SINGLE STRUCTURE



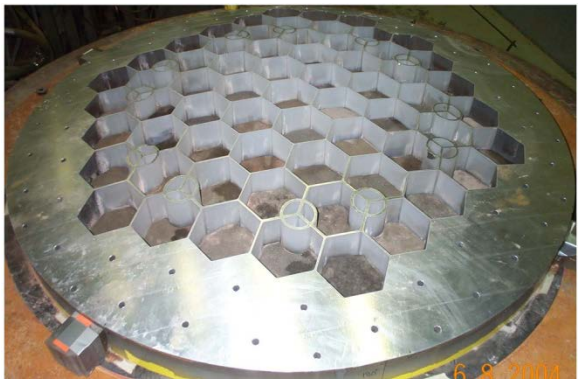


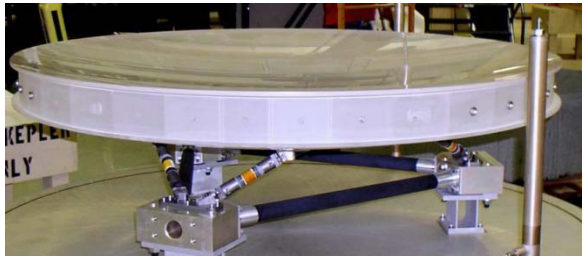


JOINT GEOMETRY PRESERVED

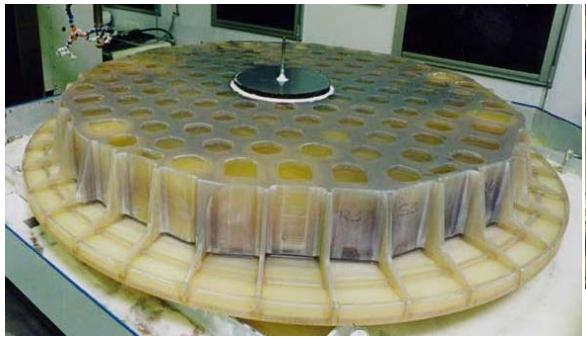
MATERIAL CHOICE DICTATES CONSTRUCTION METHOD

FRIT BONDED ULE

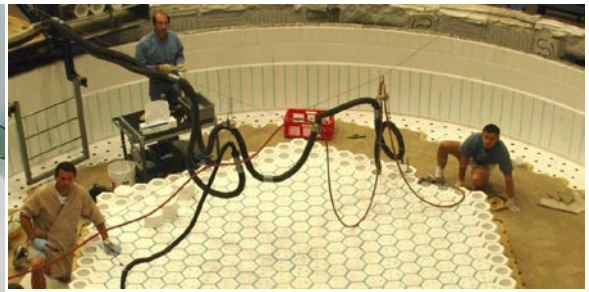


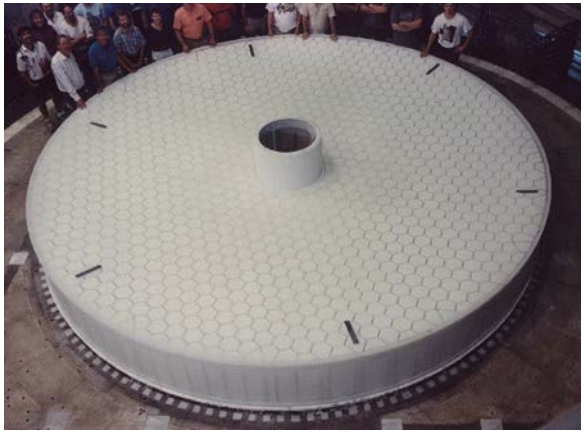


POCKET MILLED ZERODUR



CAST BOROSILICATE

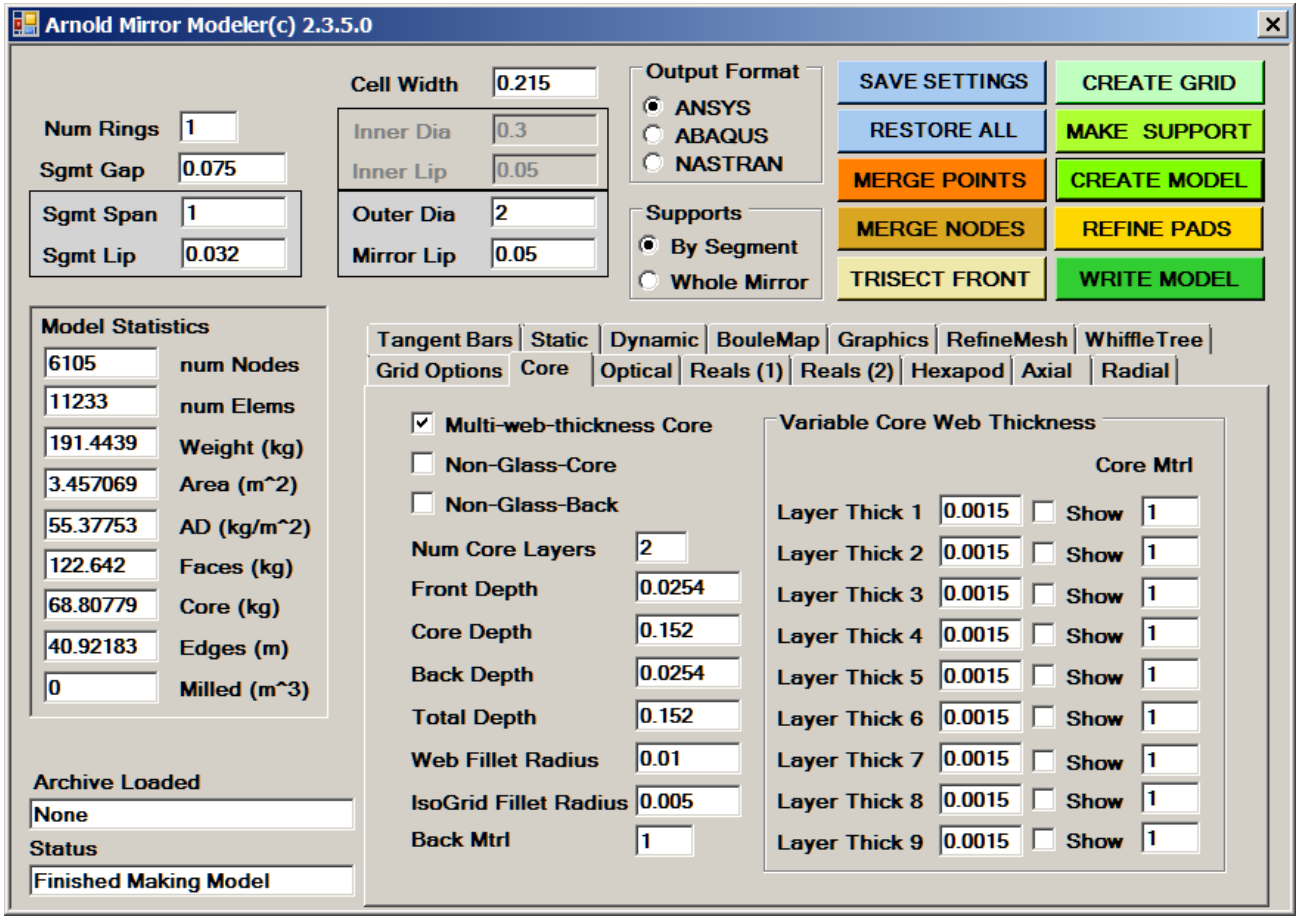




***LOW TEMPERATURE FUSION IS AN ALTERNATIVE ASSEMBLY, REQUIRES SLUMPING**

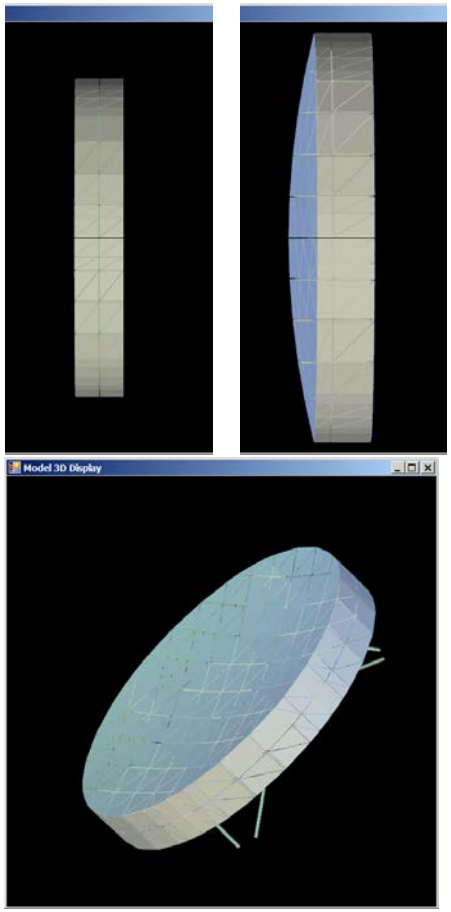
ANY CONSTRUCTION METHOD AND MATERIAL CAN BE MODELED

CORE WEB THICKNESSES CAN BE VARIED THRU DEPTH



MODEL STATISTICS AVAILABLE ONCE CREATE MODEL FINISHES

MIRROR OPTICAL PRESCRIPTION FLATS, PRIMARY & SECONDARIES



Arnold Mirror Modeler(c) 2.3.5.0

Num Rings 1
Sgmt Gap 0.075
Sgmt Span 1
Sgmt Lip 0.032

Cell Width 0.215
Inner Dia 0.3
Inner Lip 0.05
Outer Dia 2
Mirror Lip 0.05

Output Format: ANSYS, ABAQUS, NASTRAN
Supports: By Segment, Whole Mirror

SAVE SETTINGS | CREATE GRID
RESTORE ALL | MAKE SUPPORT
MERGE POINTS | CREATE MODEL
MERGE NODES | REFINE PADS
TRISECT FRONT | WRITE MODEL

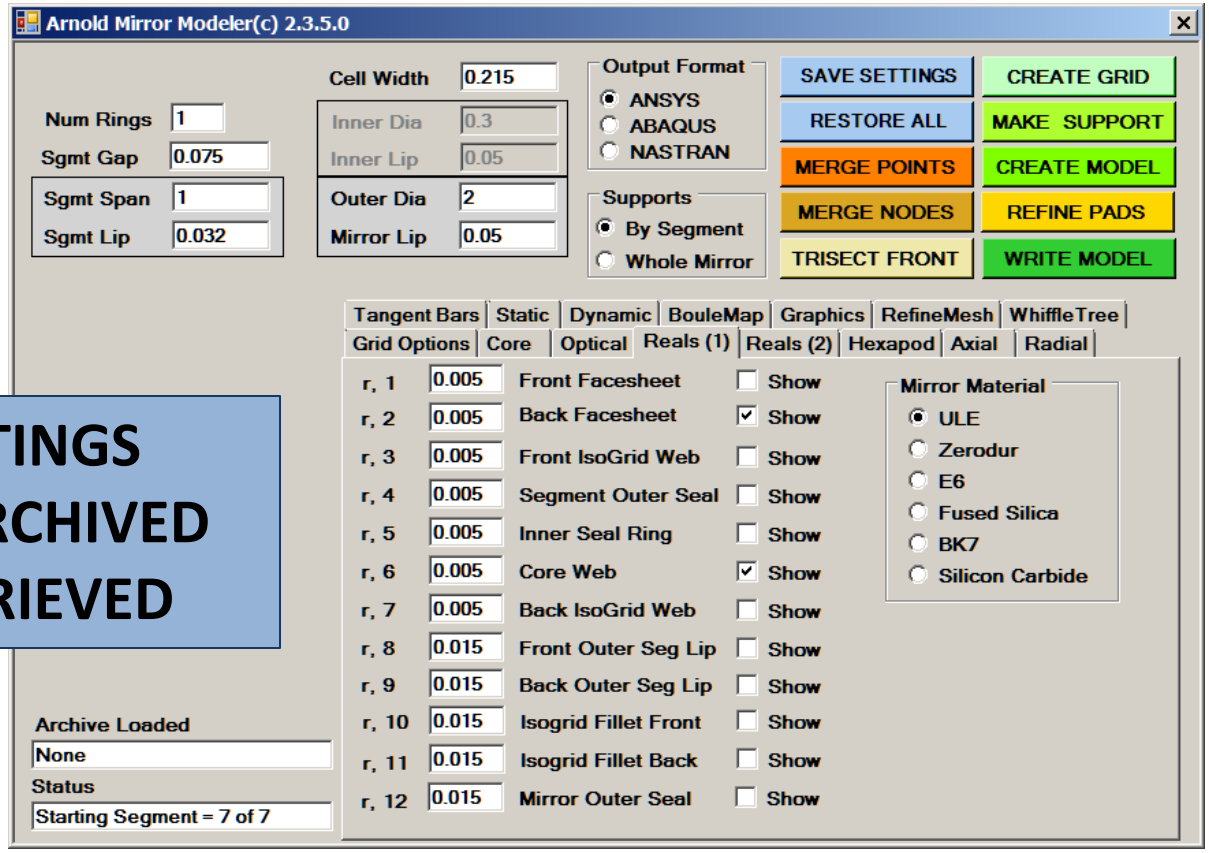
Tangent Bars | Static | Dynamic | BouleMap | Graphics | RefineMesh | WhiffleTree
Grid Options | Core | Optical | Reals (1) | Reals (2) | Hexapod | Axial | Radial

Radius 2
Conic -1
Aspheric Order 0
Coefficient(1) 0
Coefficient(2) 0
Coefficient(3) 0
Coefficient(4) 0
Coefficient(5) 0

Flat Mirror
Flat Backed Mirror
Convex Mirror

Archive Loaded
None
Status
Starting Segment = 7 of 7

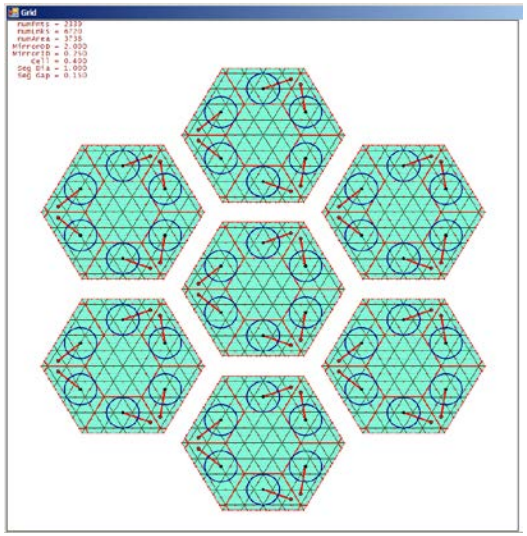
INITIAL ELEMENT THICKNESS & MIRROR MATERIAL OPTIONS

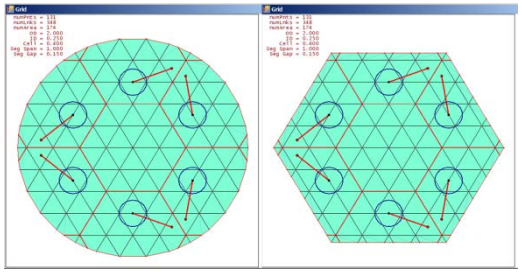


ALL SETTINGS CAN BE ARCHIVED AND RETRIEVED

INPUT DECKS CAN BE GENERATED FOR ANSYS, ABAQUS or NASTRAN

HEXAPOD STYLE SUSPENSION PER SEGMENT OR WHOLE MIRROR





Arnold Mirror Modeler(c) 2.3.5.0

Num Rings 1
Sgmt Gap 0.075
Sgmt Span 1
Sgmt Lip 0.032

Cell Width 0.215
Inner Dia 0.3
Inner Lip 0.05
Outer Dia 2
Mirror Lip 0.05

Output Format: ANSYS / ABAQUS / NASTRAN
Supports: By Segment / Whole Mirror

SAVE SETTINGS | CREATE GRID
RESTORE ALL | MAKE SUPPORT
MERGE POINTS | CREATE MODEL
MERGE NODES | REFINE PADS
TRISECT FRONT | WRITE MODEL

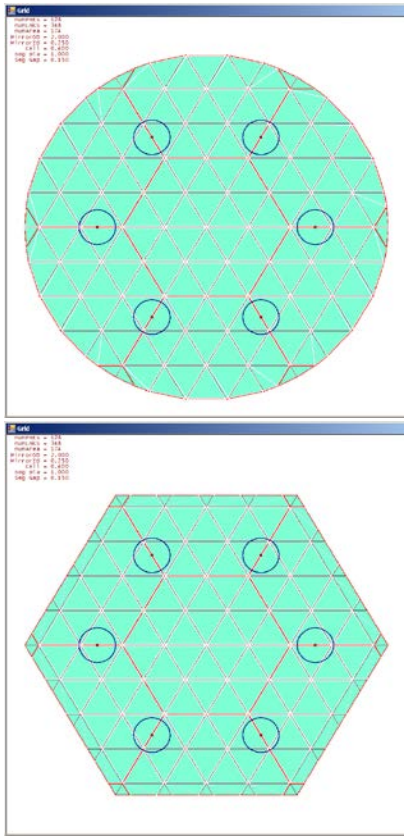
Tangent Bars | Static | Dynamic | BouleMap | Graphics | RefineMesh | WhiffleTree
Grid Options | Core | Optical | Reals (1) | Reals (2) | Hexapod | Axial | Radial

Upper Diameter	0.6	(m)
Lower Diameter	0.8	(m)
Height (ground)	0.25	(m)
Start Angle	0	(deg)
Upper Spread	30	(deg)
Lower Spread	5	(deg)
Acceptable Near	1E-05	(m)
Spring Rate	200000	(N/m)
Fitting Mass	1	(kg)
Pad Diameter	0.21	(m)
Perimeter Dia	0.315	(m)

☐ Do Hexapod
☐ Do Hexapod Pad
☐ Three Pads Only

Archive Loaded: None
Status: Starting Segment = 7 of 7

AXIAL STYLE SUSPENSION PER SEGMENT OR WHOLE MIRROR



Arnold Mirror Modeler(c) 2.3.5.0

Num Rings 1
Sgmt Gap 0.075
Sgmt Span 1
Sgmt Lip 0.032

Cell Width 0.215
Inner Dia 0.3
Inner Lip 0.05
Outer Dia 2
Mirror Lip 0.05

Output Format: ANSYS / ABAQUS / NASTRAN
Supports: By Segment / Whole Mirror

SAVE SETTINGS | CREATE GRID
RESTORE ALL | MAKE SUPPORT
MERGE POINTS | CREATE MODEL
MERGE NODES | REFINE PADS
TRISECT FRONT | WRITE MODEL

Tangent Bars | Static | Dynamic | BouleMap | Graphics | RefineMesh | WhiffleTree
Grid Options | Core | Optical | Reals (1) | Reals (2) | Hexapod | Axial | Radial

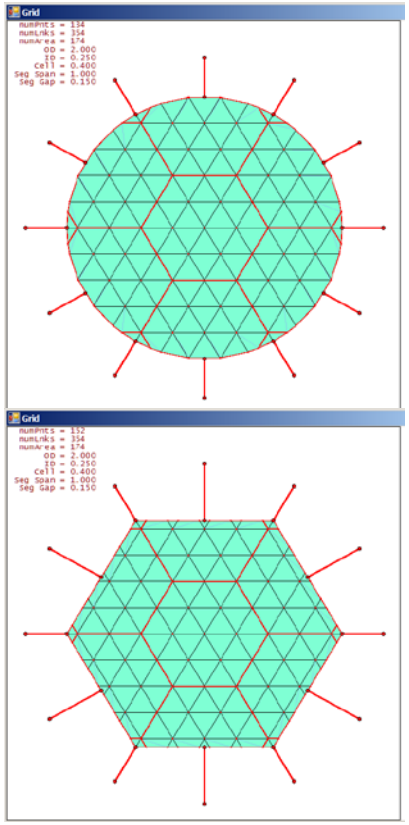
Do Axial Support
Do Axial Pads

Pnts	Diameter (m)	Start Ang (deg)	Spring Rate (N/m)
2	0.6	30	20000
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

Fitting Mass 1 (kg)
Support Ground 0.25 (m)
Acceptable Near 1E-05 (m)
Pad Diameter 0.25 (m)
Axial Perimeter Dia 0.375 (m)

Archive Loaded: None
Status: Starting Segment = 7 of 7

RADIAL STYLE SUSPENSION PER SEGMENT OR WHOLE MIRROR



Arnold Mirror Modeler(c) 2.3.5.0

Num Rings 1
Sgmt Gap 0.075
Sgmt Span 1
Sgmt Lip 0.032

Cell Width 0.215
Inner Dia 0.3
Inner Lip 0.05
Outer Dia 2
Mirror Lip 0.05

Output Format: ANSYS / ABAQUS / NASTRAN

Supports: By Segment / Whole Mirror

SAVE SETTINGS | CREATE GRID
RESTORE ALL | MAKE SUPPORT
MERGE POINTS | CREATE MODEL
MERGE NODES | REFINE PADS
TRISECT FRONT | WRITE MODEL

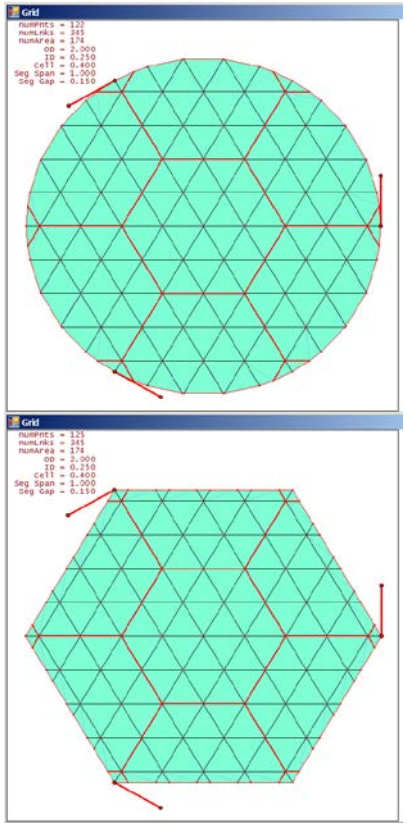
Tangent Bars | Static | Dynamic | BouleMap | Graphics | RefineMesh | WhiffleTree
Grid Options | Core | Optical | Reals (1) | Reals (2) | Hexapod | Axial | Radial

Do Radial Support

Num Points 12
Support Length 0.15 (m)
Spring Rate 20000 (N/m)
Start Angle 0 (deg)
Fitting Mass 1 (kg)
Acceptable Near 1E-05 (m)

Archive Loaded: None
Status: Starting Segment = 7 of 7

TANGENT BAR SUSPENSION PER SEGMENT OR WHOLE MIRROR



Arnold Mirror Modeler(c) 2.3.5.0

Num Rings 1
Sgmt Gap 0.075
Sgmt Span 1
Sgmt Lip 0.032

Cell Width 0.215
Inner Dia 0.3
Inner Lip 0.05
Outer Dia 2
Mirror Lip 0.05

Output Format: ANSYS, ABAQUS, NASTRAN

Supports: By Segment, Whole Mirror

SAVE SETTINGS | CREATE GRID
RESTORE ALL | MAKE SUPPORT
MERGE POINTS | CREATE MODEL
MERGE NODES | REFINE PADS
TRISECT FRONT | WRITE MODEL

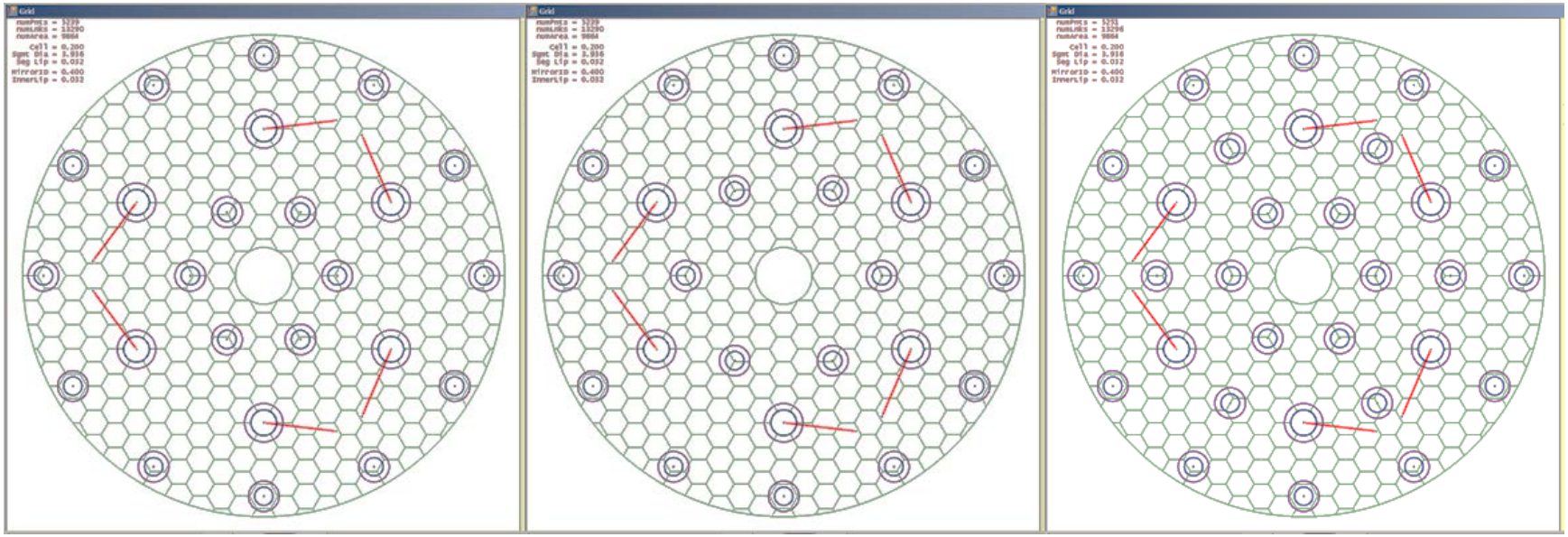
Grid Options | Core | Optical | Reals (1) | Reals (2) | Hexapod | Axial | Radial
Tangent Bars | Static | Dynamic | BouleMap | Graphics | RefineMesh | WhiffleTree

Do Tangent Bars

Number of Tangent Bars 3
Tangent Bar Start Angle 0
Tangent Bar Length 0.15
Tangent Bar Spring Rate 20000
Tangent Fitting Mass 1 (kg)

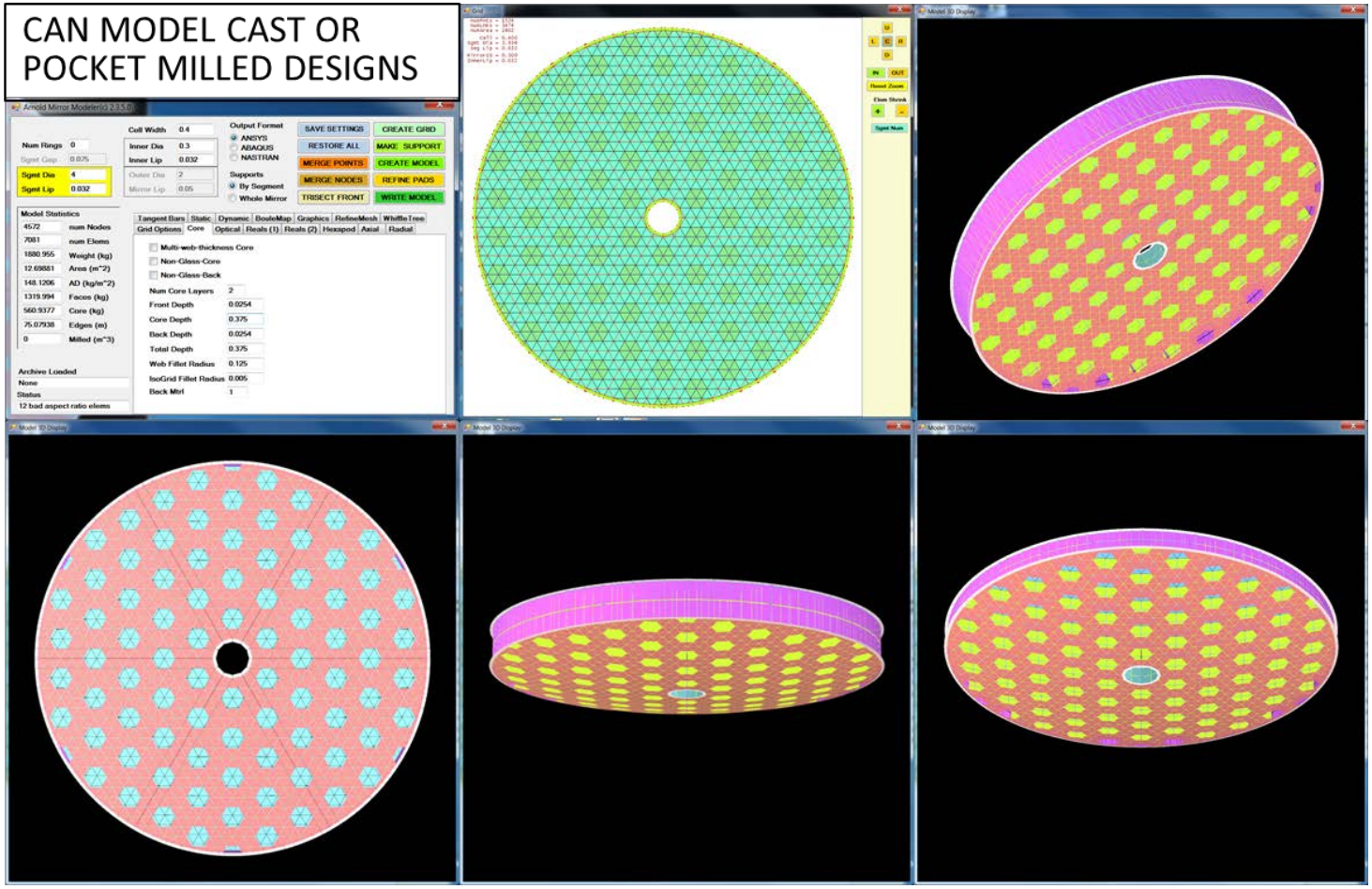
Archive Loaded
None
Status
Starting Segment = 7 of 7

MULTIPLE SUPPORT TYPES CAN BE COMBINED

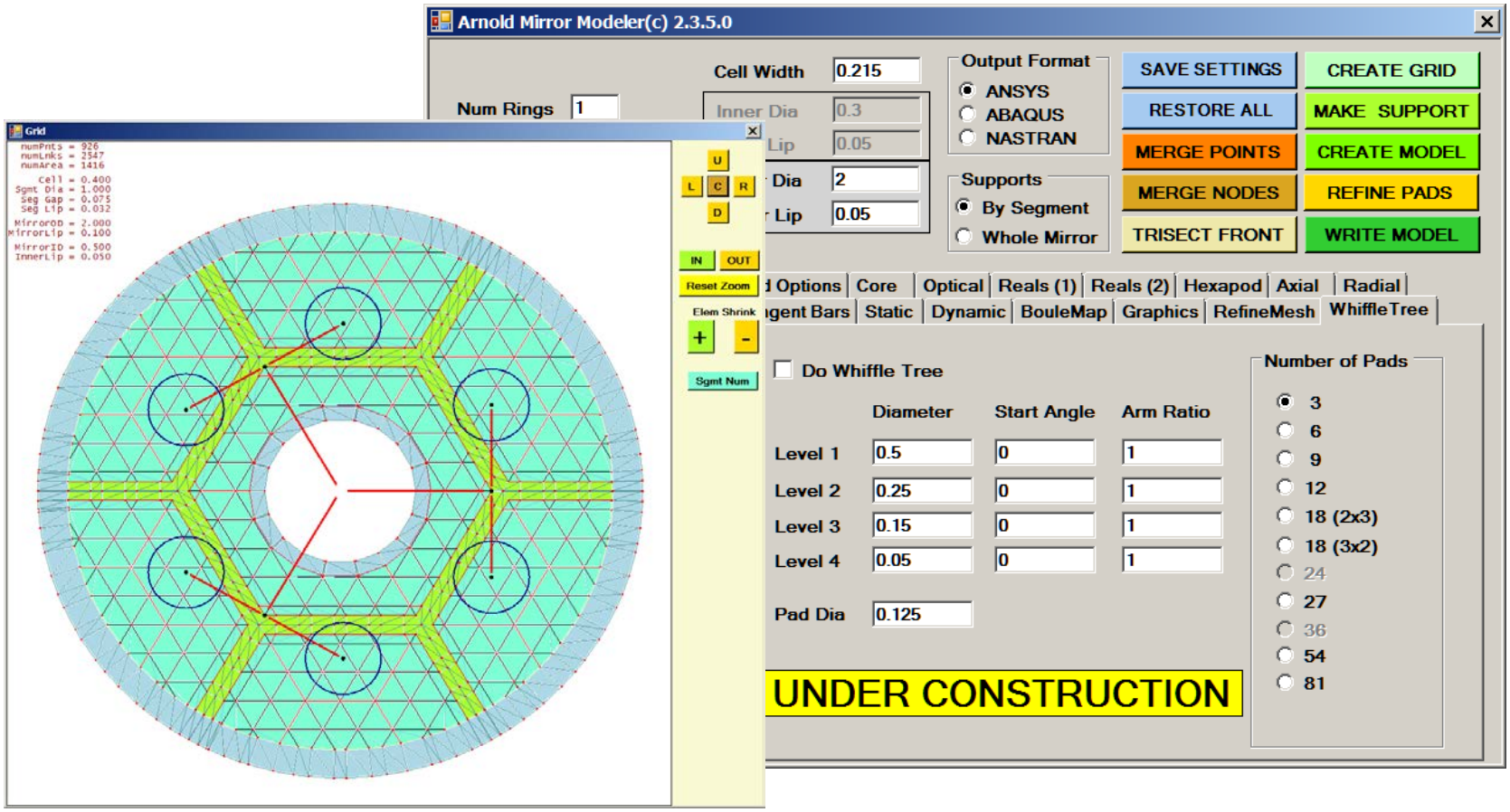


ADJUSTING GROUP DIAMETERS, NUMBER OF DIAMETERS AND STARTING ANGLES

EVALUATE MATERIAL CHOICES & CONSTRUCTION

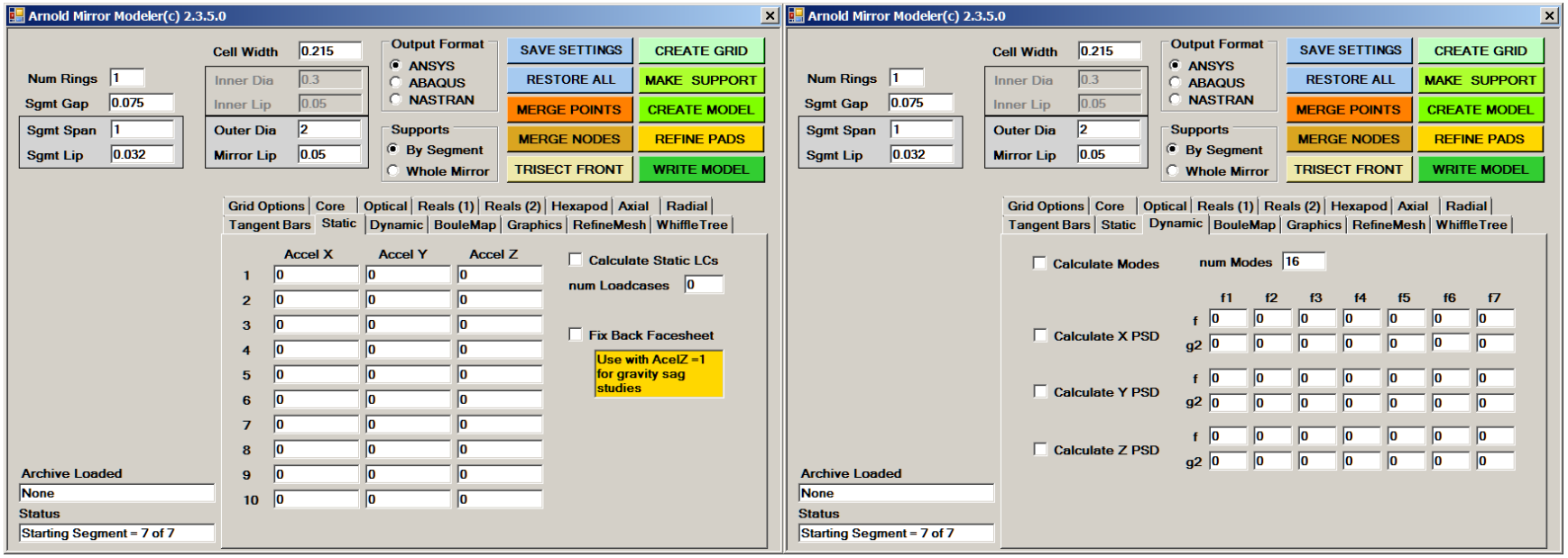


WHIFFLE TREE SUPPORTS
CURRENTLY UNDER DEVELOPMENT



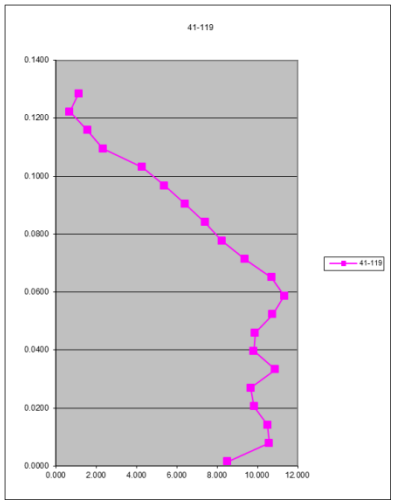
YOU CAN DEFINE LOAD CASES

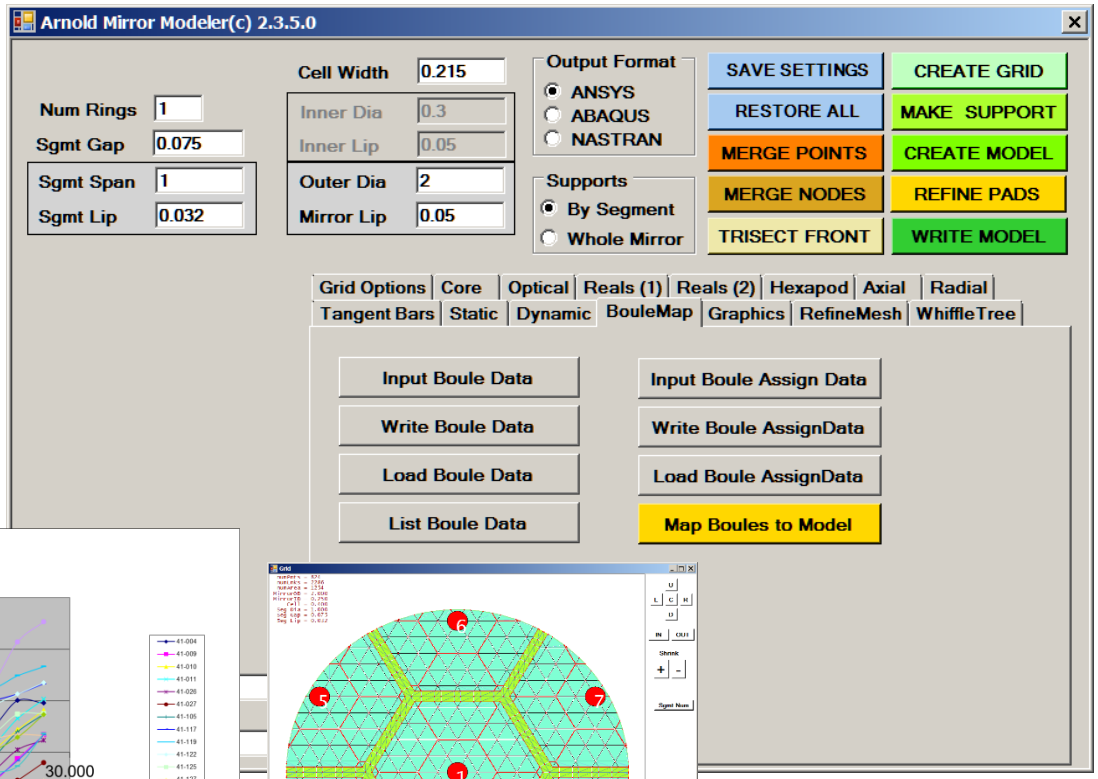
STATIC, MODAL & PSD

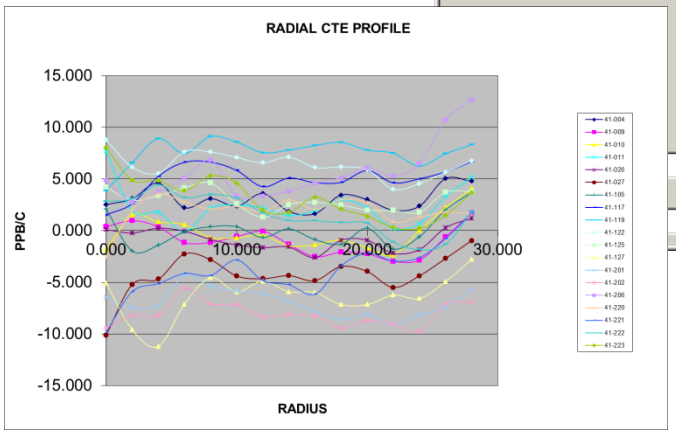


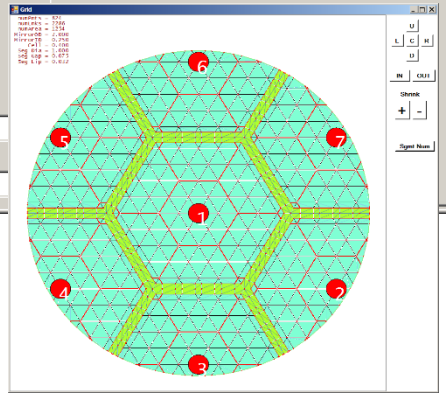
- ANSYS: GENERATES ANALYSIS STREAM COMPLETE WITH PLOTS AND RESULT FILES
- ABAQUS: GENERATES ANALYSIS STREAM, USES ABAQUS/CAE PYTHON SCRIPT FOR PLOTS & RESULTS
- NASTRAN: GENERATES ANALYSIS STREAM, USES FEMAP OR PATRAN FOR PLOTS & RESULTS

IF ULE© BOULE CTE DATA AVAILABLE IT CAN BE MAPPED ONTO THE MODEL



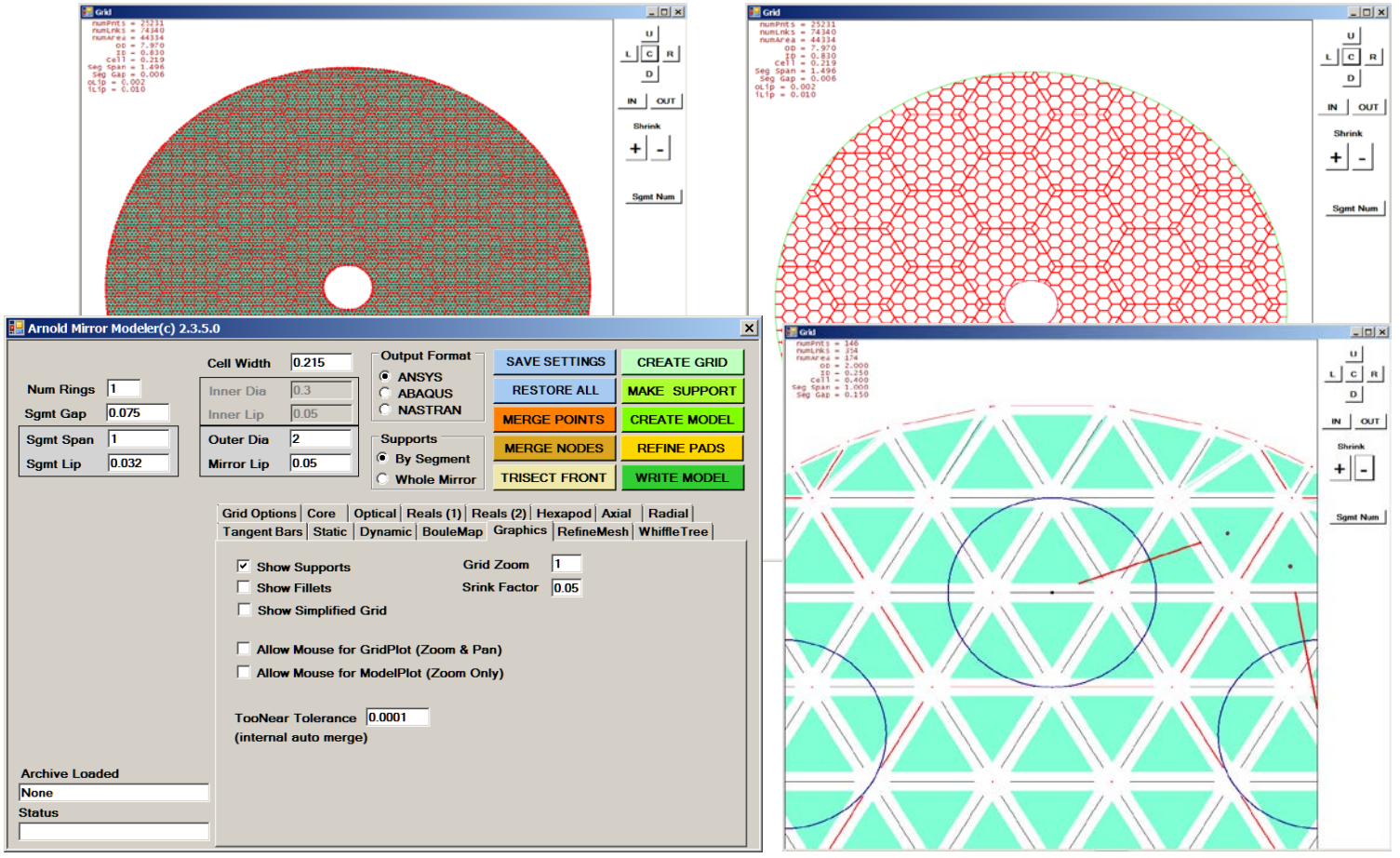






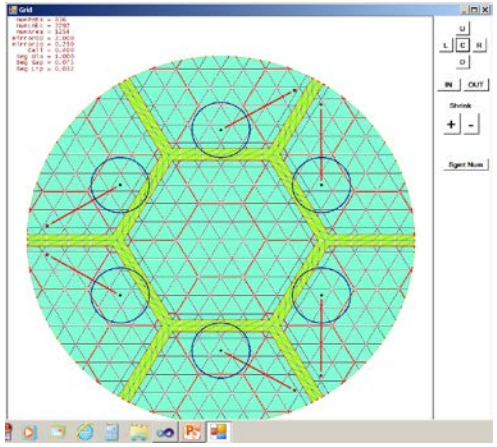
SEGMENT ID CAN BE SHOWN ON GRID

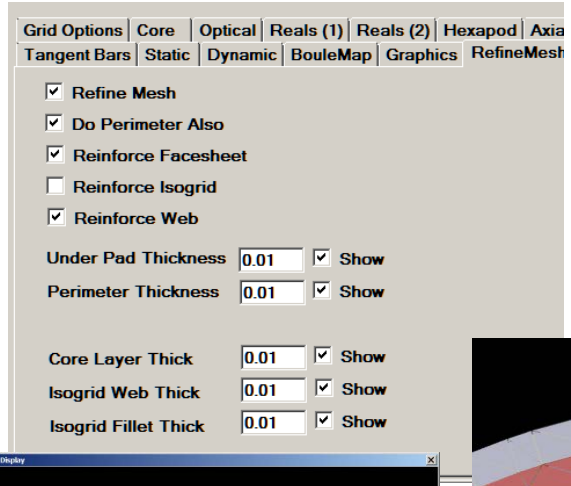
GRID PLOTTING OPTIONS

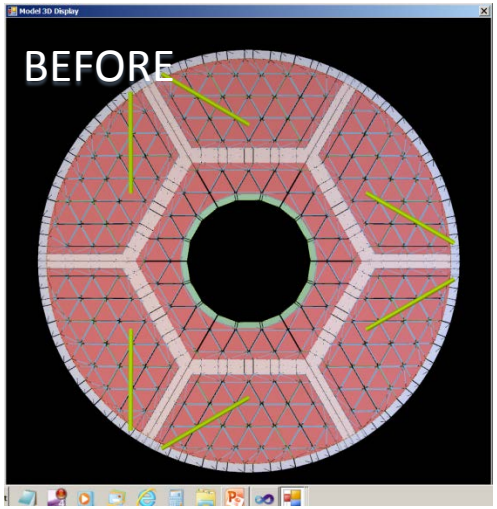


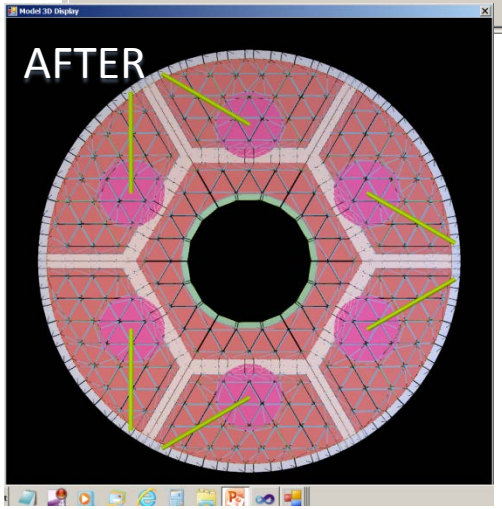
SIMPLIFIED MESH, PAN & ZOOM, ELEMENT SHRINK

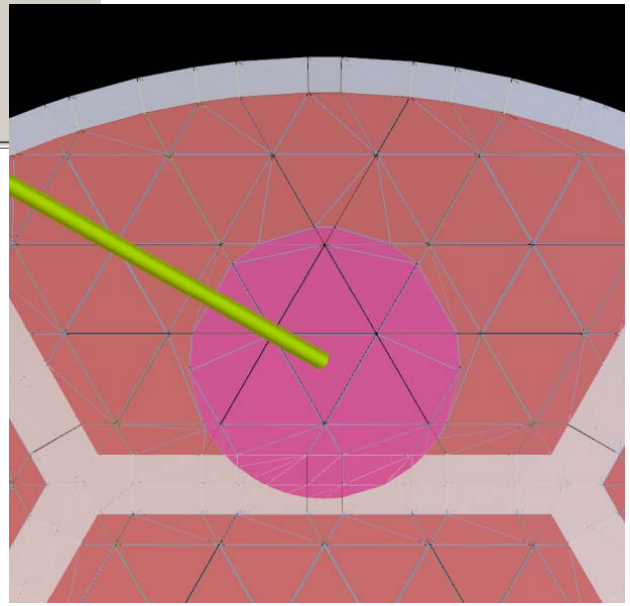
LOCALIZED MESH REFINEMENT UNDER SUPPORT PADS



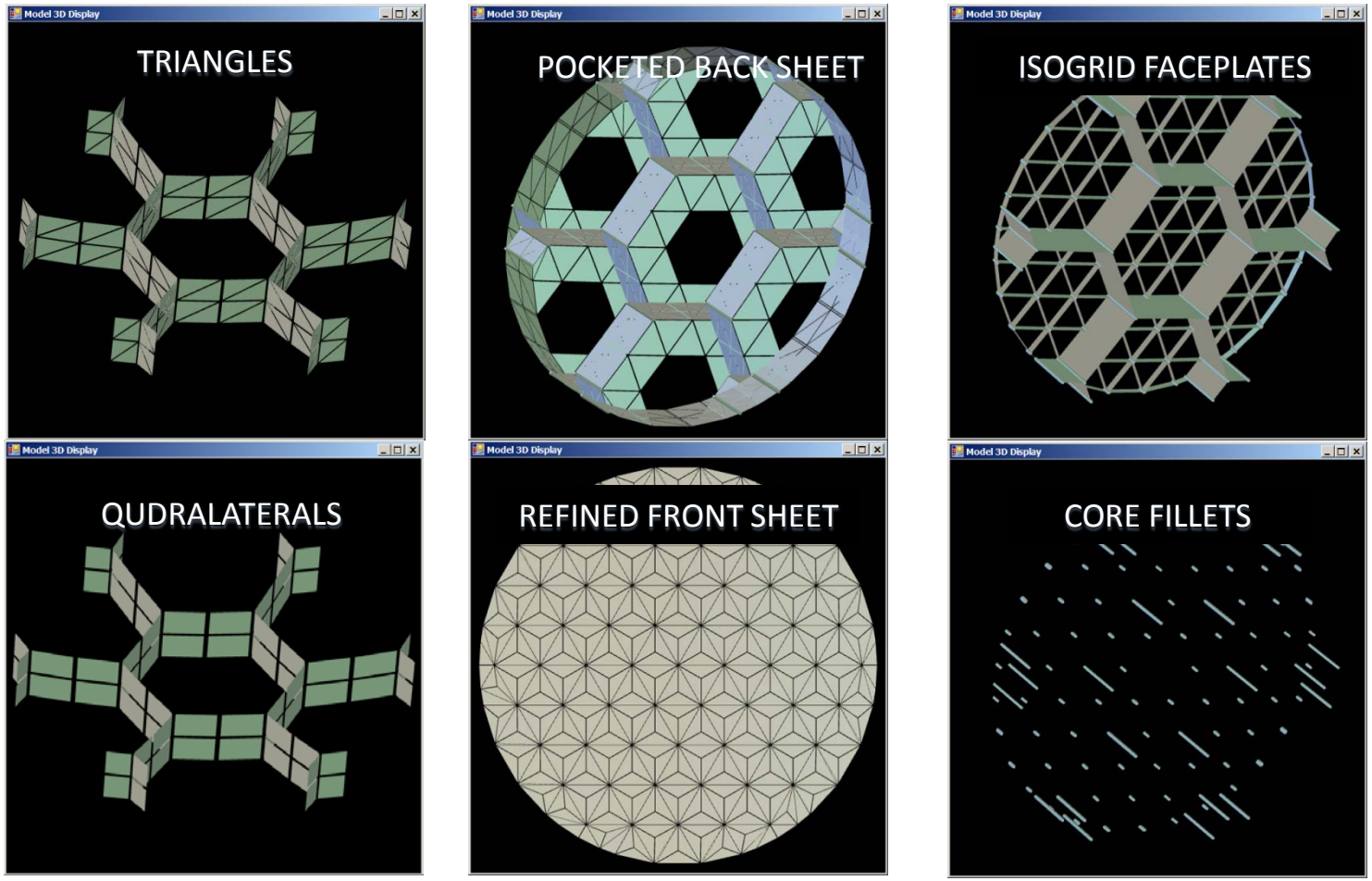




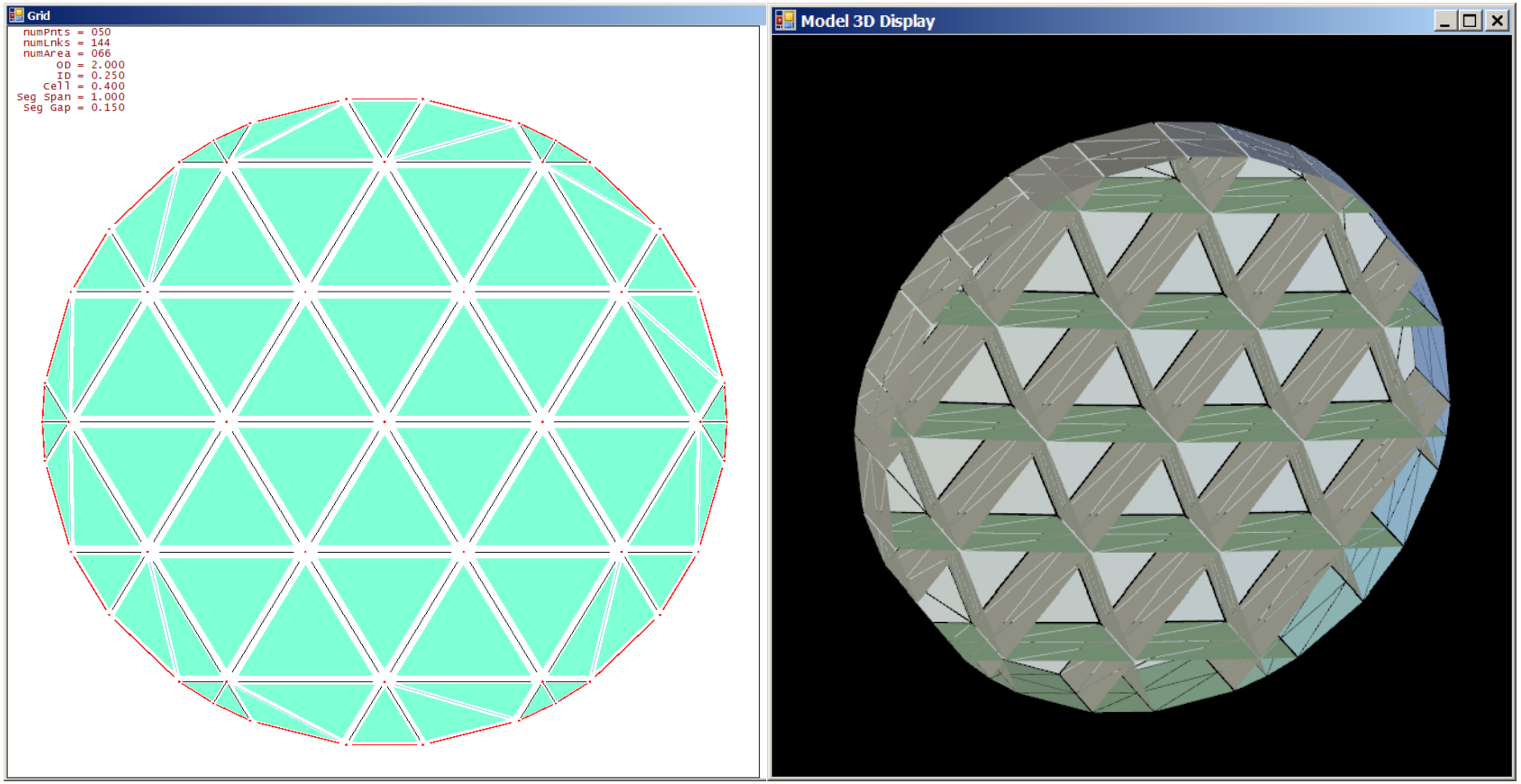




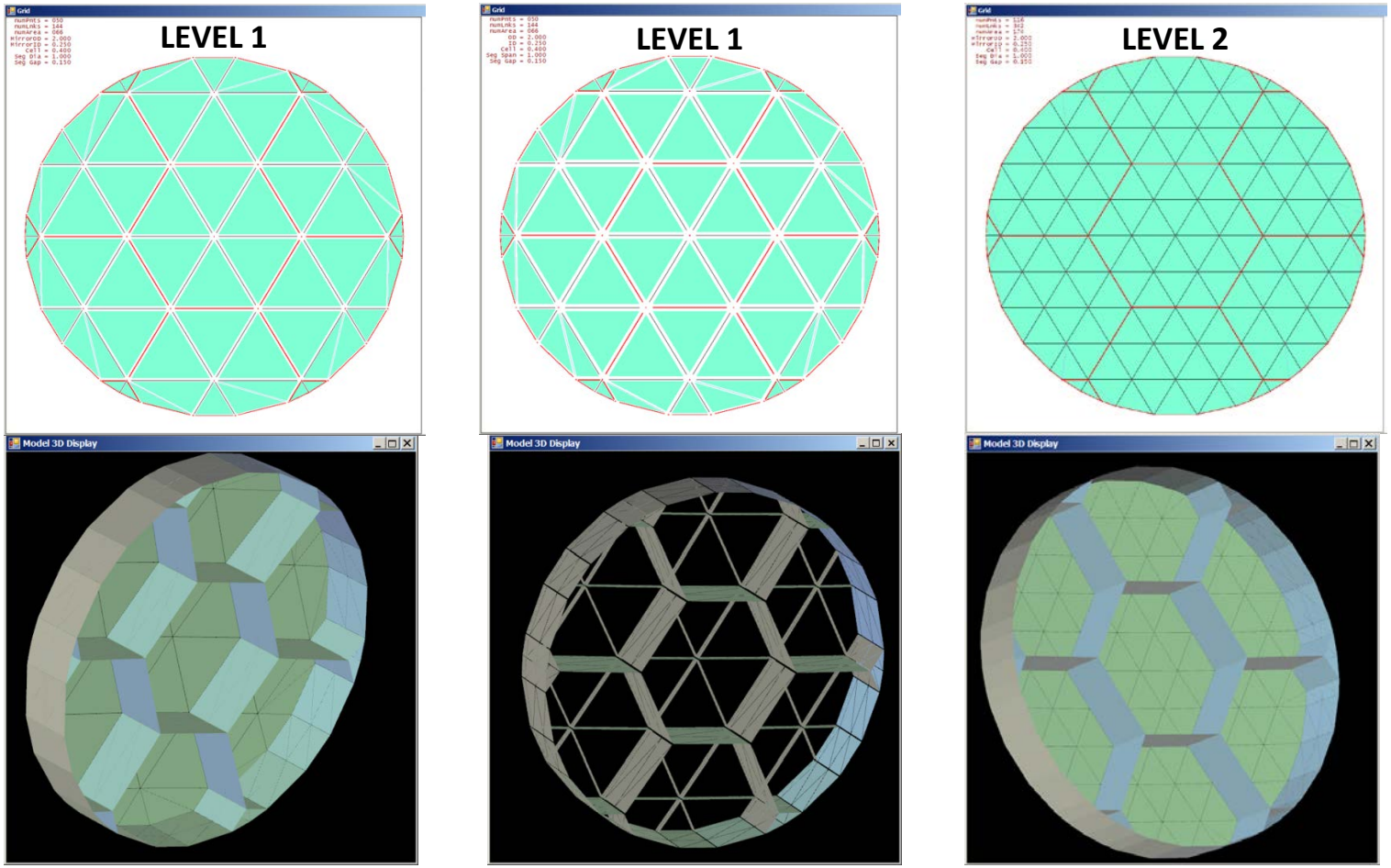
A LOT OF MESHING OPTIONS AVAILABLE



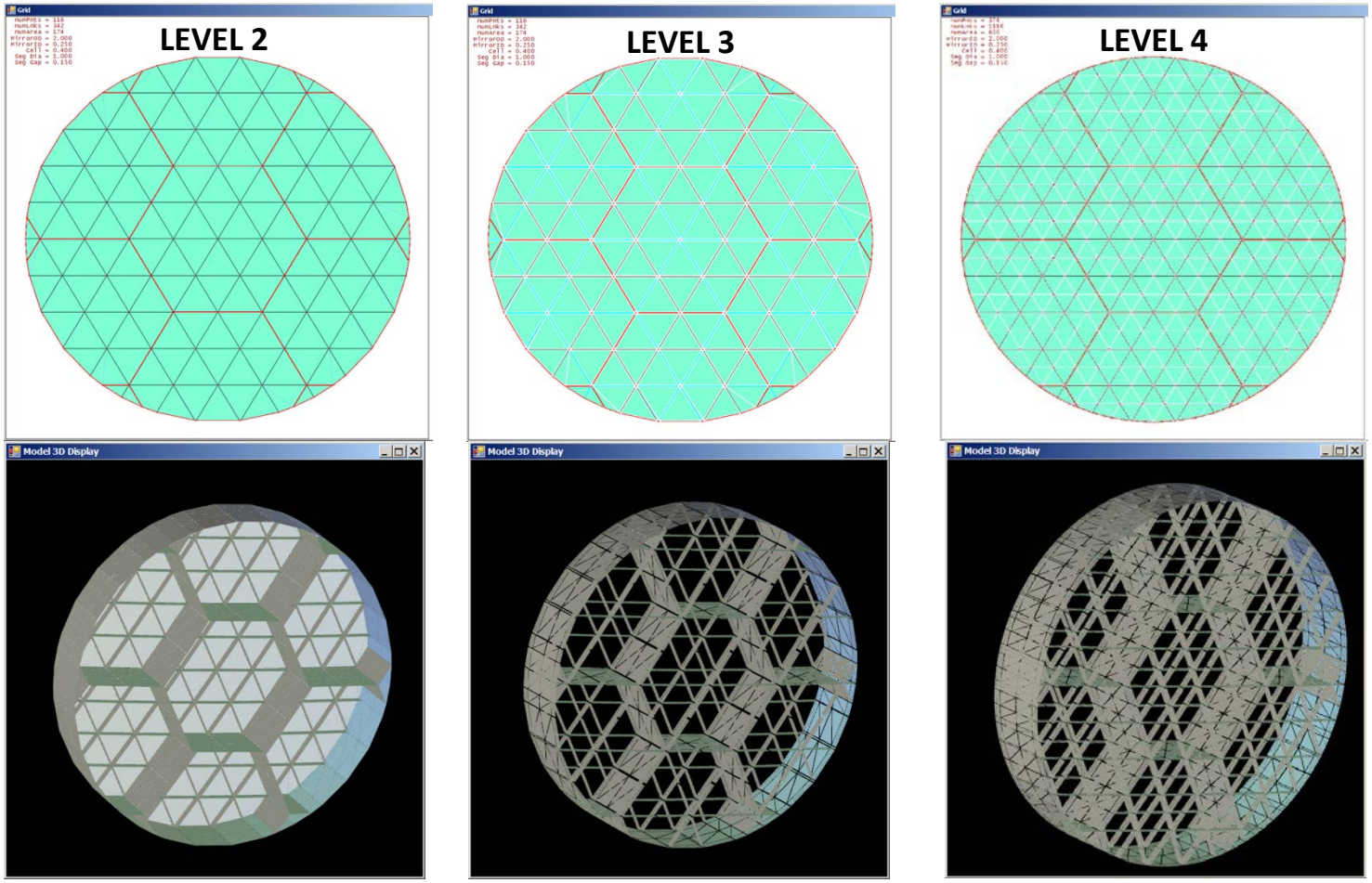
CAN MODEL A PURE ISOGRID CORE [LEVEL0]



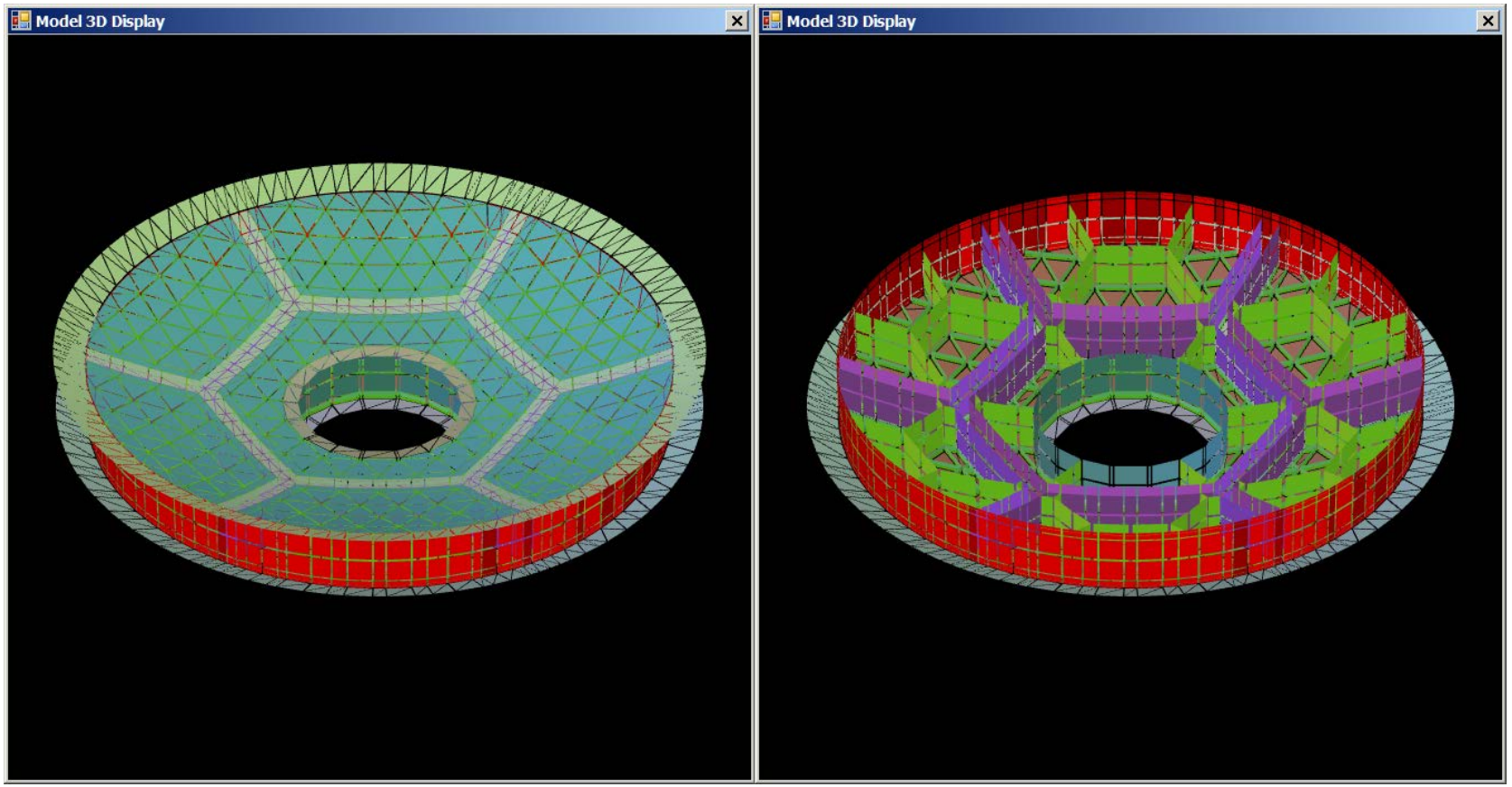
GRID COMPLEXITY LEVELS (CONT)



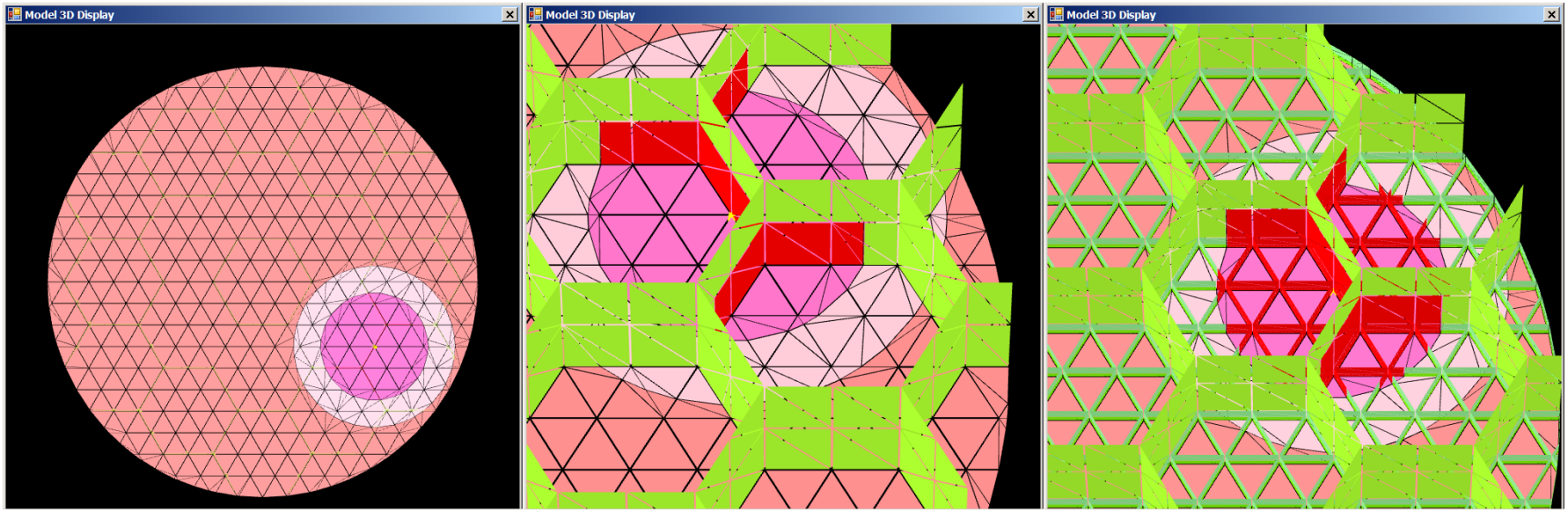
GRID COMPLEXITY LEVELS (CONT)



MODEL DISPLAY NOW SUPPORTS COLOR-BASED REAL CONSTANTS

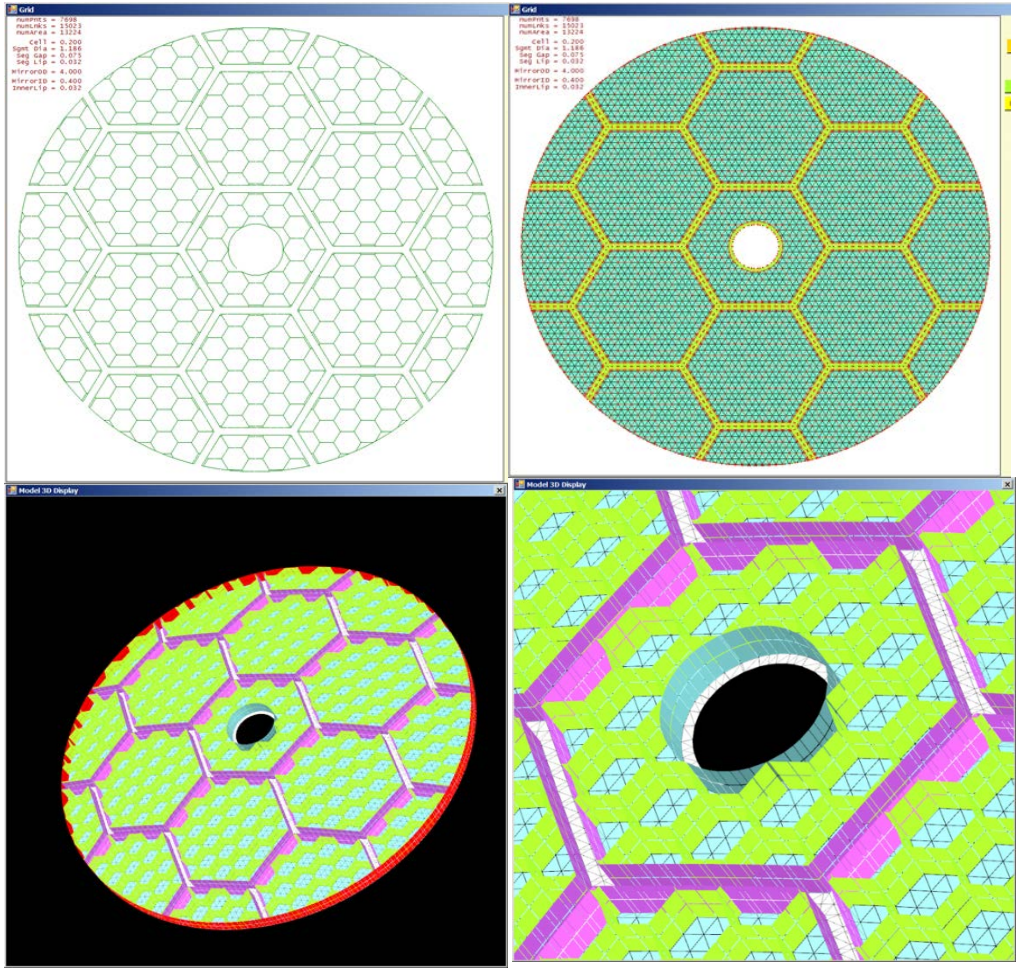


LOCALIZED REINFORCEMENT & MESH REFINEMENT UNDER PADS

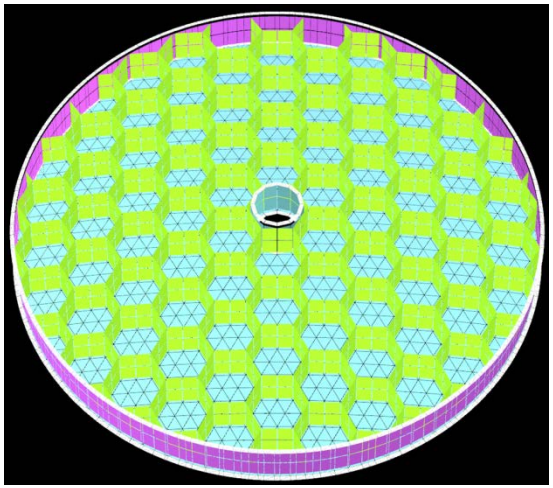


A perimeter around pad can be reinforced or just mesh refined . The core structure can be stiffened as well as any back facesheet isogrid pattern in region of bond pads.

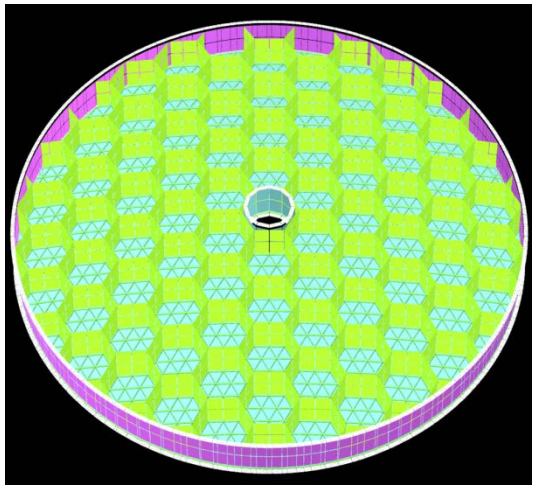
MULTI-SEGMENT LTF CONSTRUCTION CAN BE MODELED



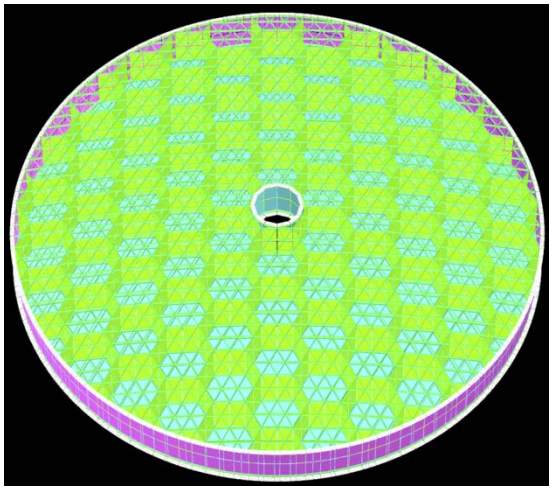
SAME GRID CAN GENERATE MULTIPLE CONSTRUCTION STYLES



NO ISOGRID

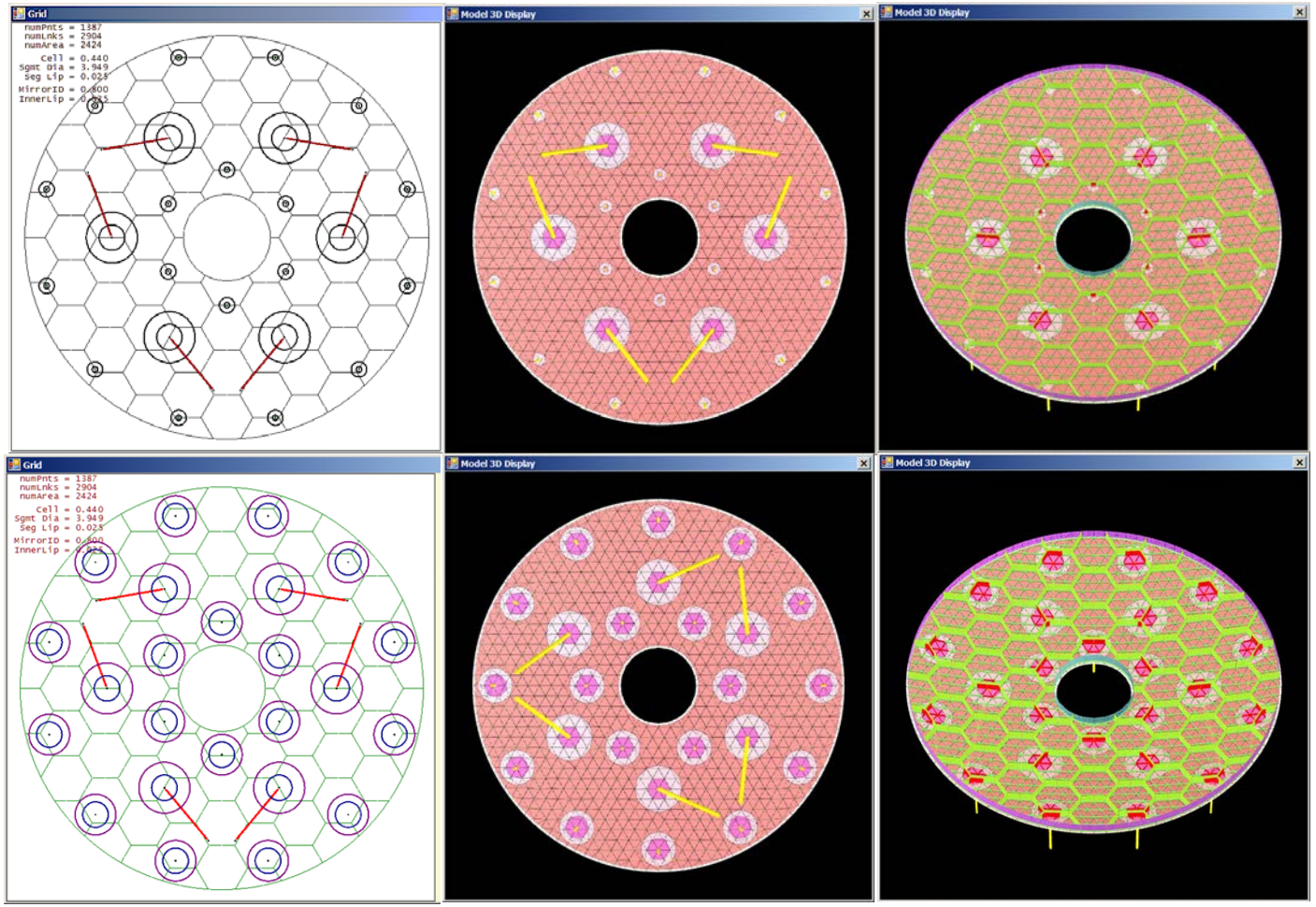


FRONT ONLY ISOGRID

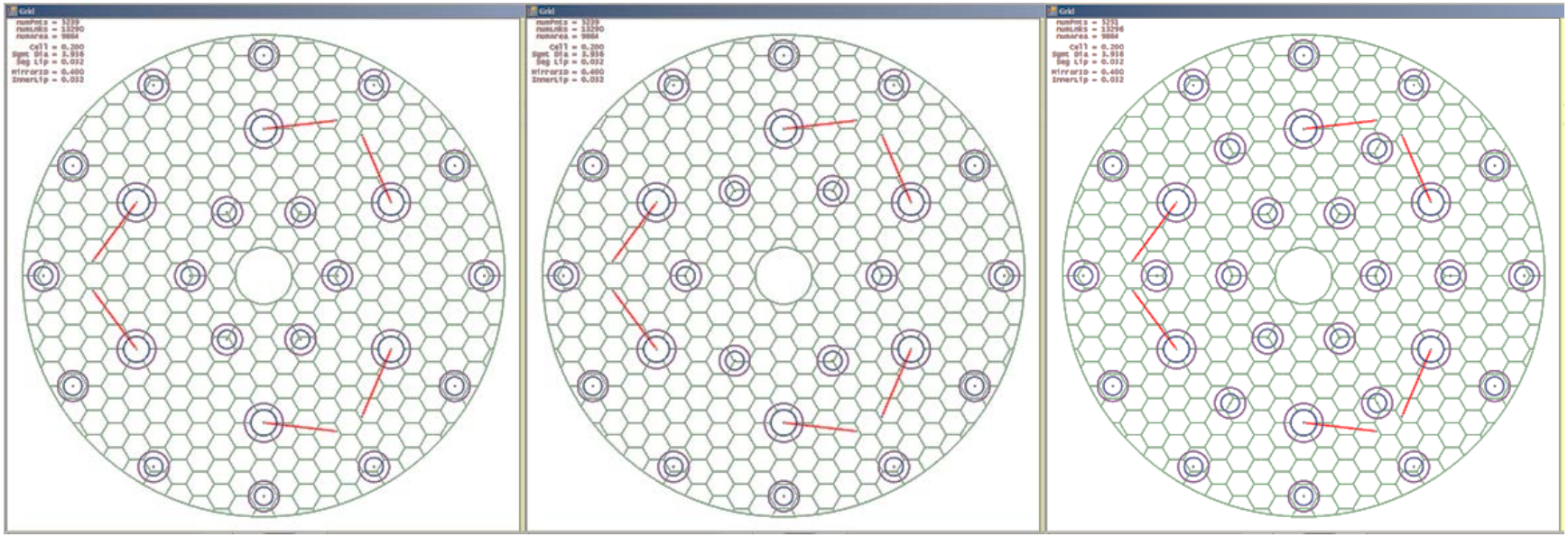


FRONT & REAR ISOGRID

ADJUSTING PARAMETERS TO IMPROVE STIFFNESS



TRY MULTIPLE VERSIONS OF AUXILLARY SUPPORT SYSTEM



ADJUSTING GROUP DIAMETERS, NUMBER OF DIAMETERS AND STARTING ANGLES

SUMMARY

- FEATURES AND CAPABILITIES OF MODELER TO MAKE THE PROCESS ECONOMICAL
  - REDUCED MODEL GENERATION TIME
  - ANY MATERIAL AND CONSTRUCTION METHOD SUPPORTED
  - CAN PRESET LOADS AND RESULT PROCESSING
  - ARCHIVE AND RESTORE ALL SETTINGS IN MODELER
- VALUE OF INTEGRATED DESIGN METHOD
  - CAN EVALUATE FEASIBILITY OF CONSTRUCTION METHOD
  - OPTIMIZE OPERATIONAL PERFORMANCE
  - LAUNCH SURVIVAL
- TIME PERMITTING, QUESTIONS & DEMONSTRATION

STATUS

- **Currently undergoing ITAR review to determine any distribution restrictions.**
- **NASA is working on licensing, revision control and error reporting mechanisms.**
- **User Manual and tutorials under development.**
- **Short coarse or seminar under discussion.**
- **List of possible enhancements and requested features growing daily.**

- **Time permitting are there any questions?**