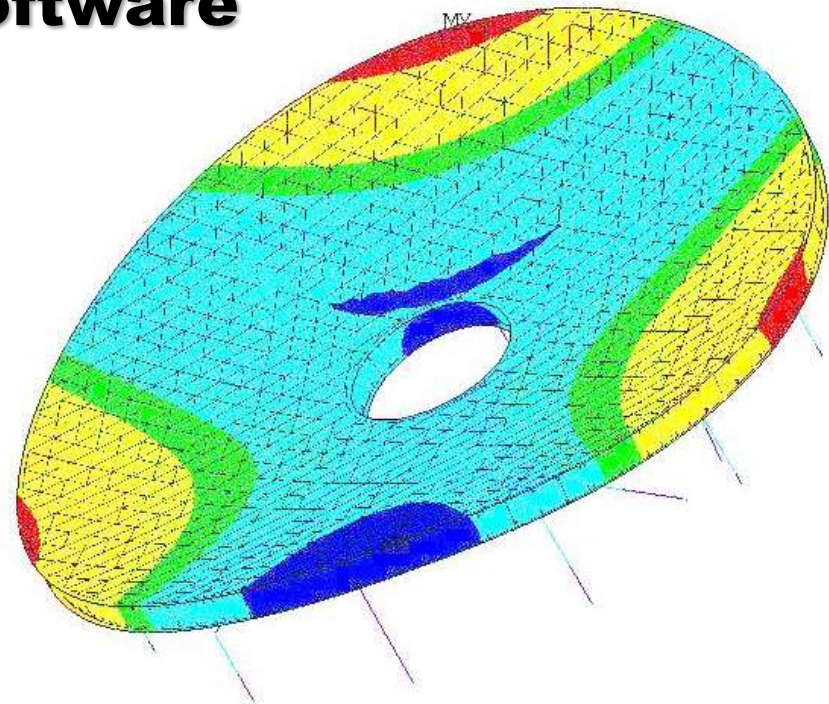
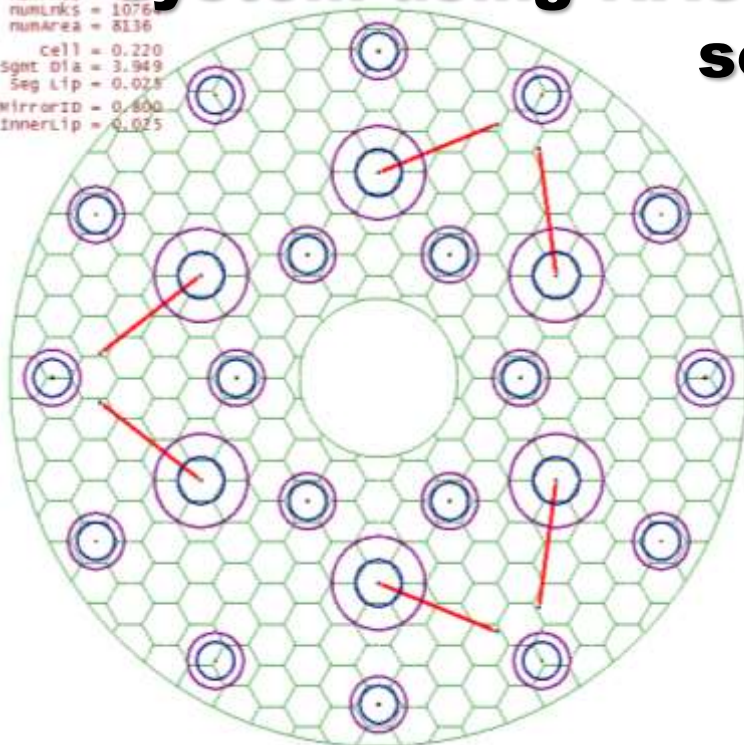




Integration of mirror design with suspension system using NASA's new mirror modeling software

```
numLinks = 1076  
numArea = 8136  
cell = 0.220  
sgmt dia = 3.949  
Seg Lip = 0.028  
MirrorID = 0.800  
InnerLip = 0.025
```



William R. Arnold Sr., Sr. Principal Engineer, DAI, Huntsville, AL.

Ryan M. Bevan, NASA Intern, NASA MSFC, Huntsville, Al.

Dr. Phil Stahl, AMTD PI, NASA MSFC, Huntsville, Al.

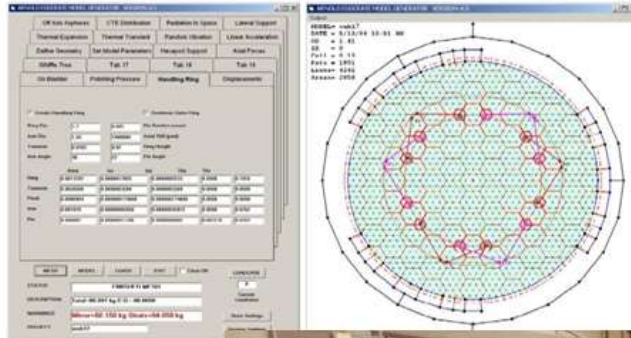
INTRODUCTION

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 (PREDECESSOR PROGRAM USED ON KEPLER)

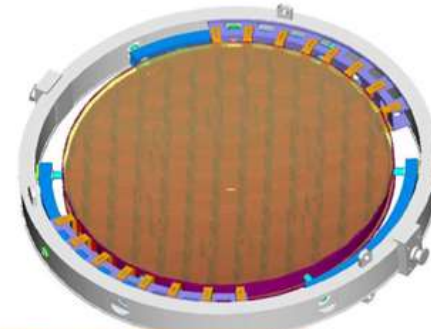
Integrated Design of Handling Equipment



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

Kepler

Primary Mirror in Flipping Ring



enforced slots in the mirror the unit can act as a surfaces or fragile edges

2004





STEPS IN A BASIC MIRROR DESIGN TRADE STUDY



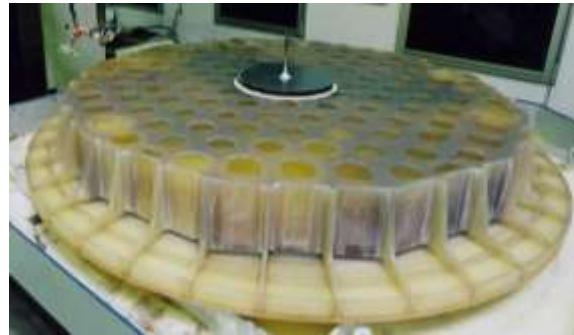
- **EVALUATE MATERIALS AND CONSTRUCTION**
 - MASS, COST, RISK, SCHEDULE ... LOOK AT SEVERAL CHOICES
- **MIRROR ONLY PERFORMANCE (MODES, WEIGHT)**
 - GET FEEL FOR GEOMETRIC & THICKNESS INFLUENCES
- **MIRROR & OPERATIONAL SUPPORT**
 - MODE SHAPES, FREQUENCIES (ON ORBIT BEHAVIOR)
- **MIRROR, OPERATIONAL & AUXILIARY SUPPORT**
 - LAUNCH CONDITIONS, MIN FREQ, LOCAL STRESSES, ETC
- **OPTIMIZE GEOMETRY, THICKNESS, ETC**
 - CELL SIZE, EDGE ZONES, LOCAL REINFORCEMENT, CONSTRUCTION

MATERIAL CHOICE DICTATES CONSTRUCTION METHOD

FRIT BONDED ULE



POCKET MILLED ZERODUR



CAST BOROSILICATE



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

QUICK INTRO TO MODELER

Arnold Mirror Modeler(c) 2.3.5.0

Cell Width: 0.4

Output Format: ANSYS, ABAQUS, NASTRAN

Supports: By Segment, Whole Mirror

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

Num Rings: 0
Sgmt Gap: 0.075
Sgmt Dia: 4
Sgmt Lip: 0.032

Inner Dia: 0.3
Inner Lip: 0.032
Outer Dia: 2
Mirror Lip: 0.05

Model Statistics

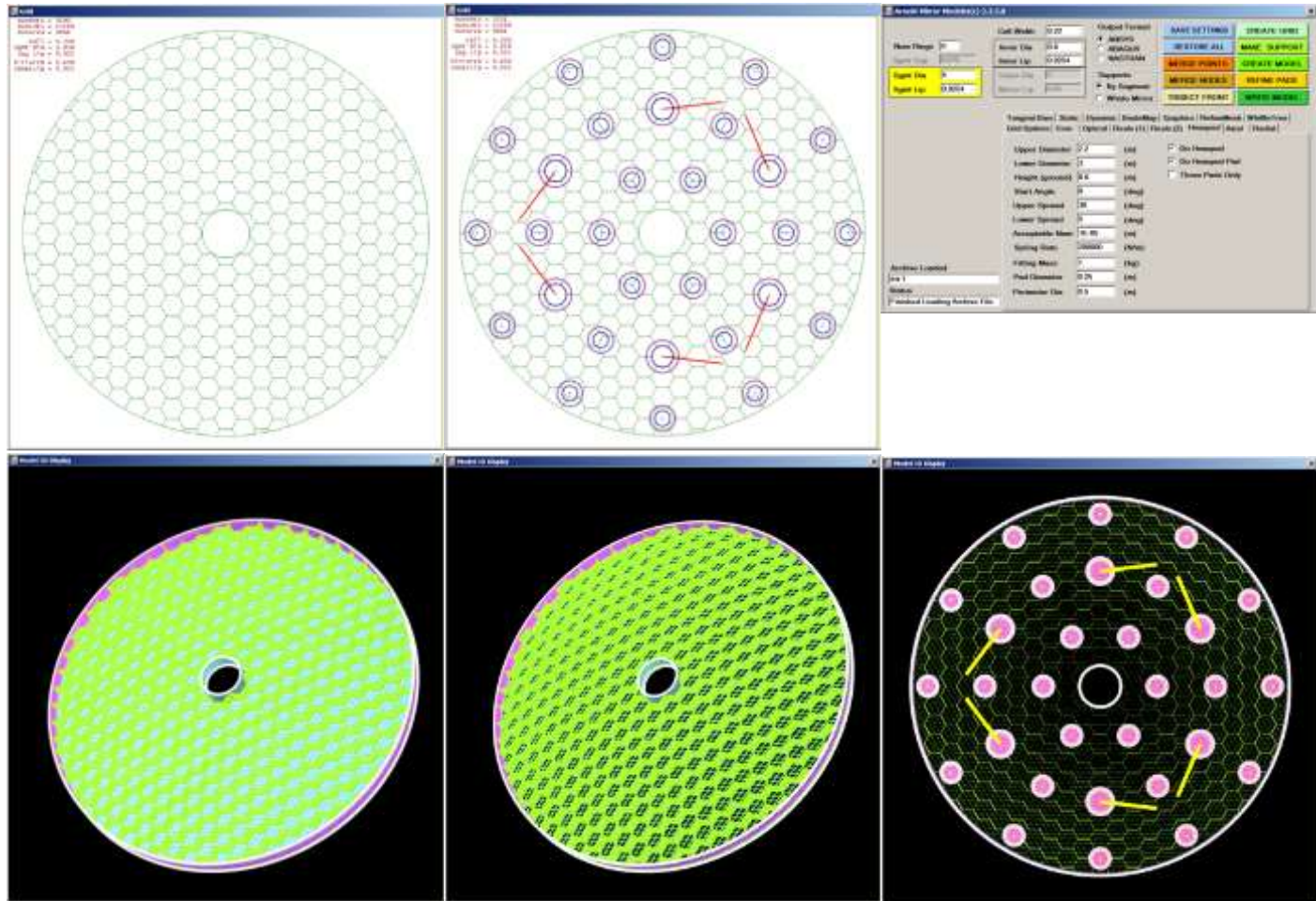
10668	num Nodes
25693	num Elems
1923.165	Weight (kg)
12.69881	Area (m ²)
151.4445	AD (kg/m ²)
1278.041	Faces (kg)
645.313	Core (kg)
75.07938	Edges (m)
0.45941	Milled (m ³)

Archive Loaded: None
Status: 12 bad aspect ratio elems

Grid Options	Core	Optical	Reals (1)	Reals (2)	Hexapod	Axial	Radial
r, 1	0.0125	Front Facesheet	<input checked="" type="checkbox"/>	Show			
r, 2	0.0125	Back Facesheet	<input checked="" type="checkbox"/>	Show			
r, 3	0.010	Front IsoGrid Web	<input type="checkbox"/>	Show			
r, 4	0.0125	Segment Outer Seal	<input checked="" type="checkbox"/>	Show			
r, 5	0.0125	Inner Seal Ring	<input checked="" type="checkbox"/>	Show			
r, 6	0.010	Core Web	<input checked="" type="checkbox"/>	Show			
r, 7	0.010	Back IsoGrid Web	<input type="checkbox"/>	Show			
r, 8	0.0125	Front Outer Seg Lip	<input checked="" type="checkbox"/>	Show			
r, 9	0.0125	Back Outer Seg Lip	<input checked="" type="checkbox"/>	Show			
r, 10	0.010	Isogrid Fillet Front	<input type="checkbox"/>	Show			
r, 11	0.010	Isogrid Fillet Back	<input type="checkbox"/>	Show			
r, 12	0.00	Mirror Outer Seal	<input type="checkbox"/>	Show			

Mirror Material: ULE, Zerodur, E6, Fused Silica, BK7, Silicon Carbide

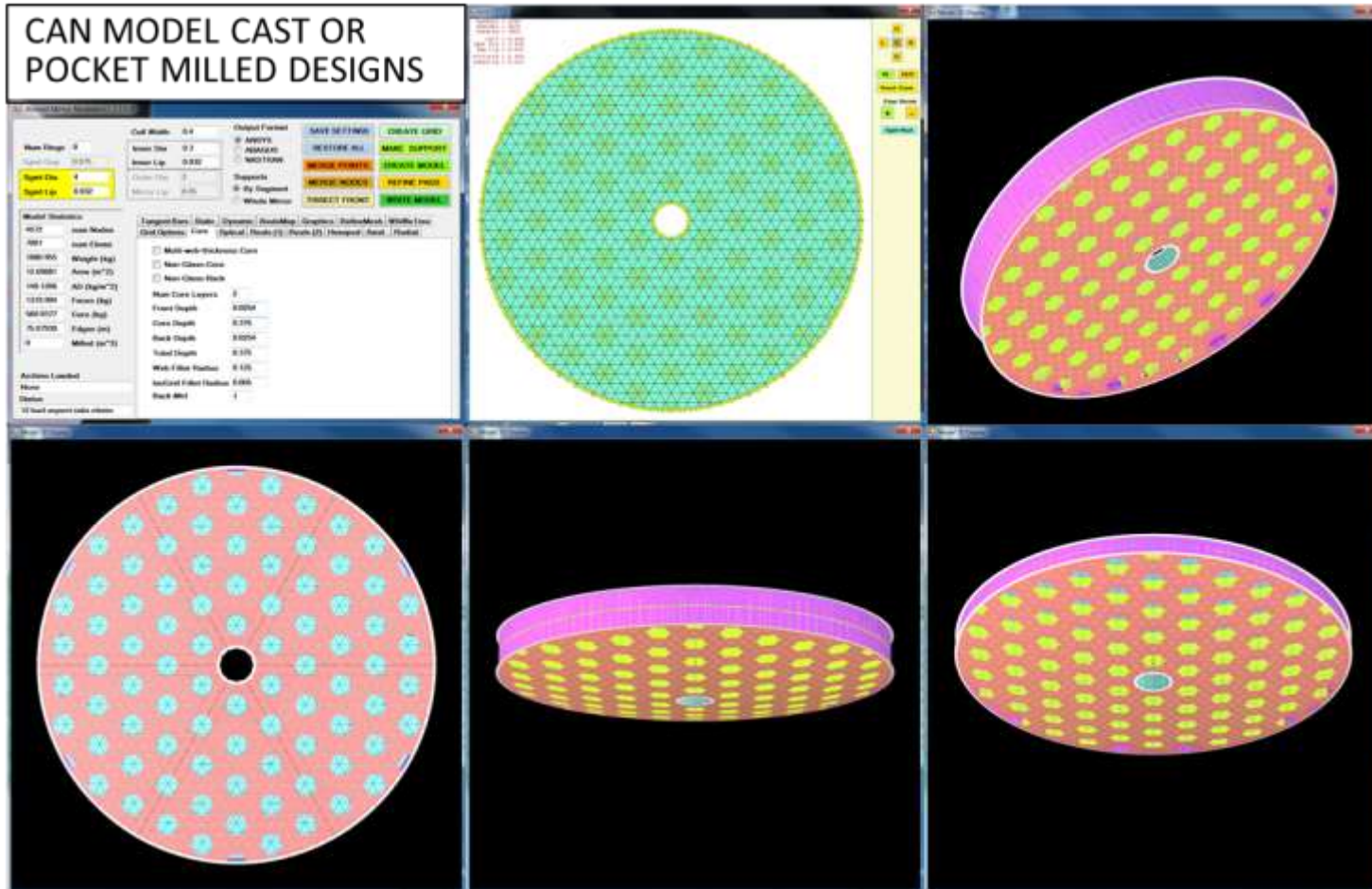
ONE GRID PATTERN CAN CREATE MANY VARIATIONS



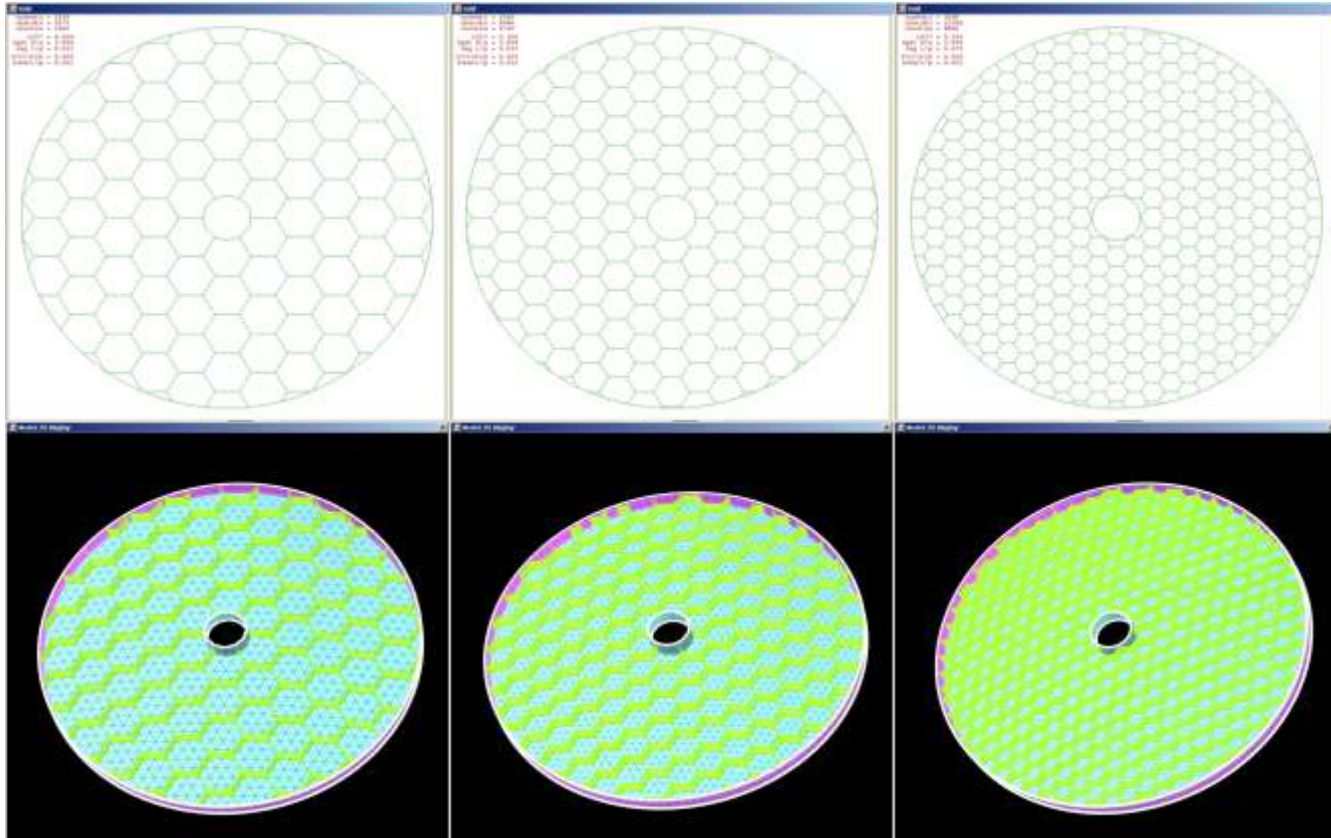


QUICK EXAMPLE OF TRADE STUDY USING THE MODELER

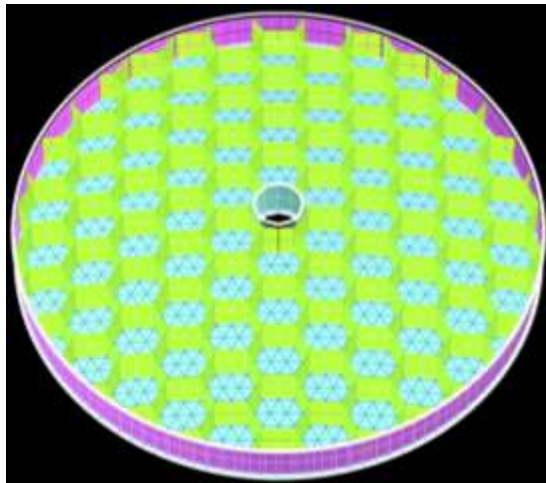
STEP 1 - EVALUATE MATERIAL CHOICES & CONSTRUCTION



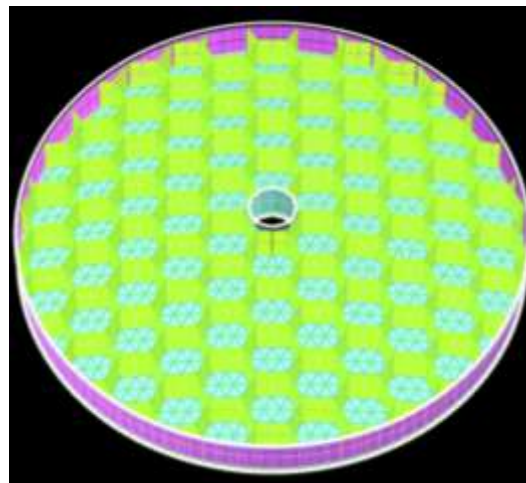
TYPICAL INITIAL STEP TRY DIFFERENT CELL SIZES



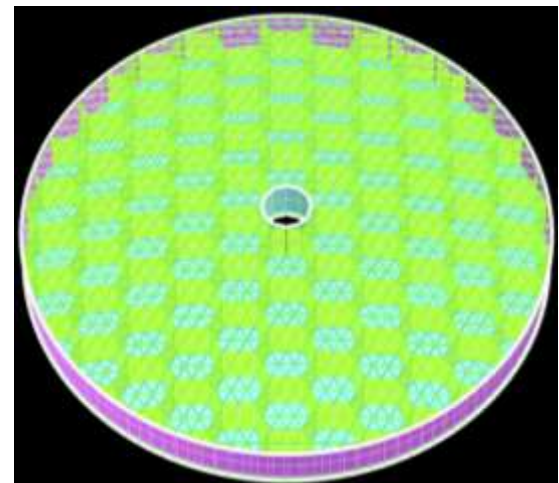
SAME GRID CAN GENERATE MULTIPLE CONSTRUCTION STYLES



NO ISOGRID

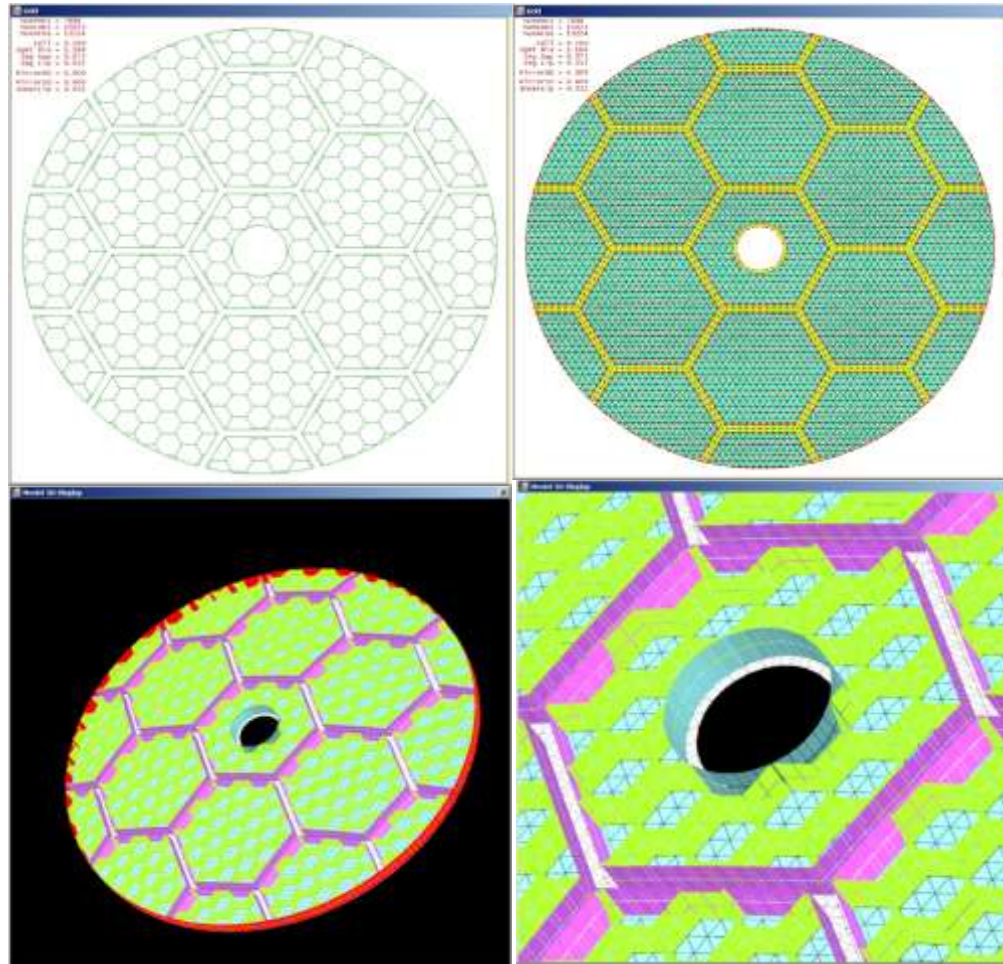


FRONT ONLY ISOGRID

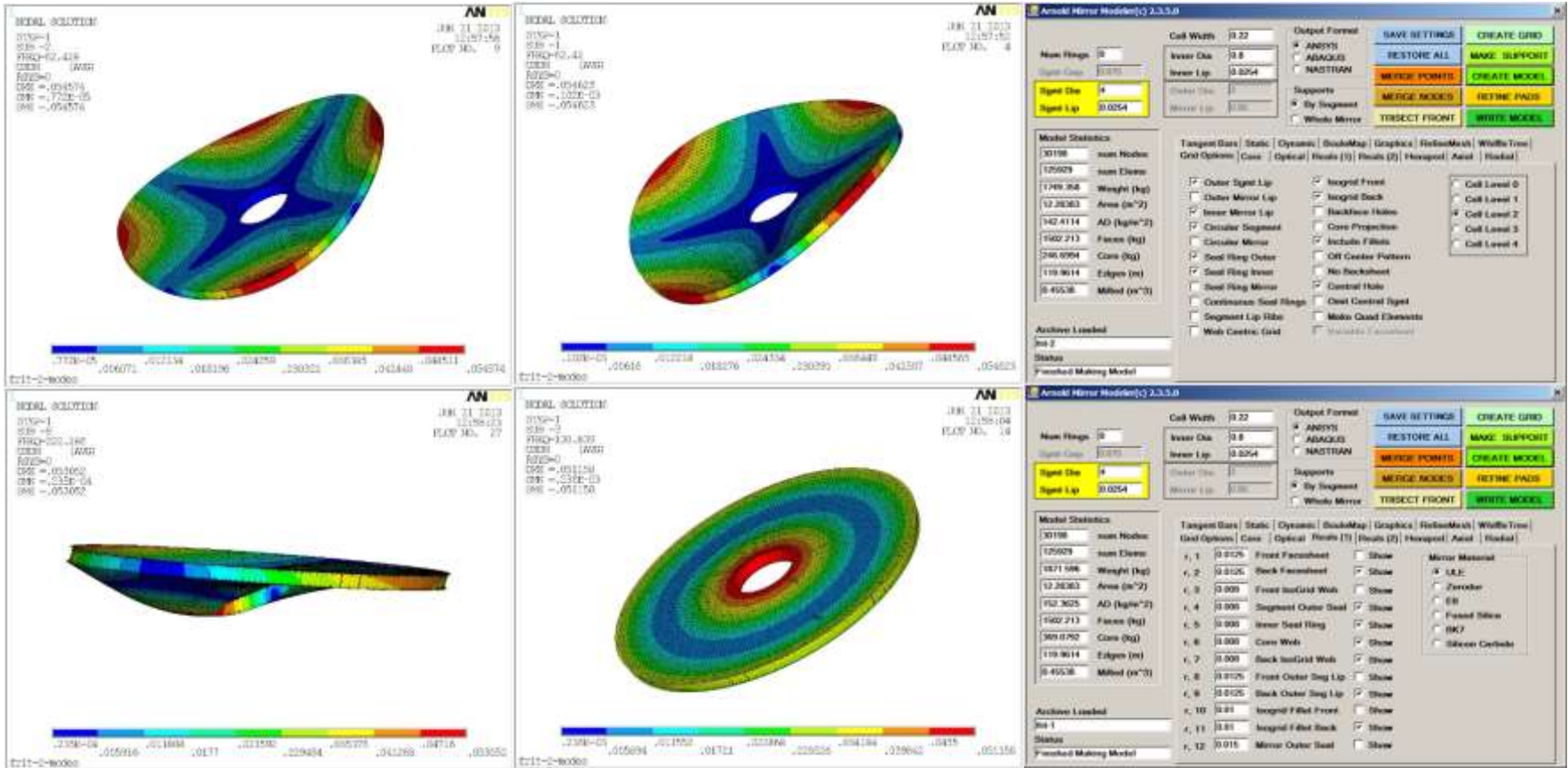


FRONT & REAR ISOGRID

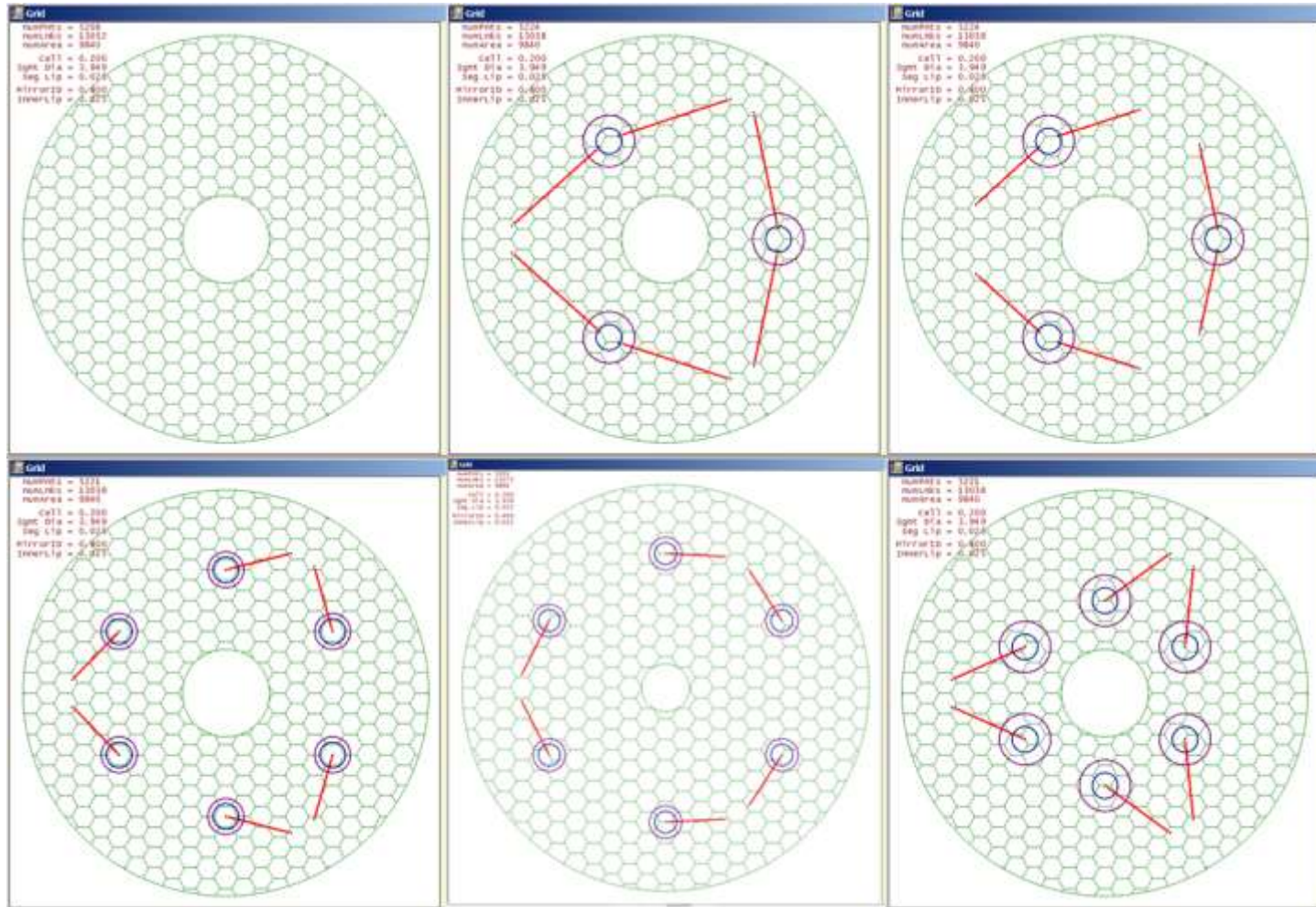
MULTI-SEGMENT LTF CONSTRUCTION CAN BE MODELED



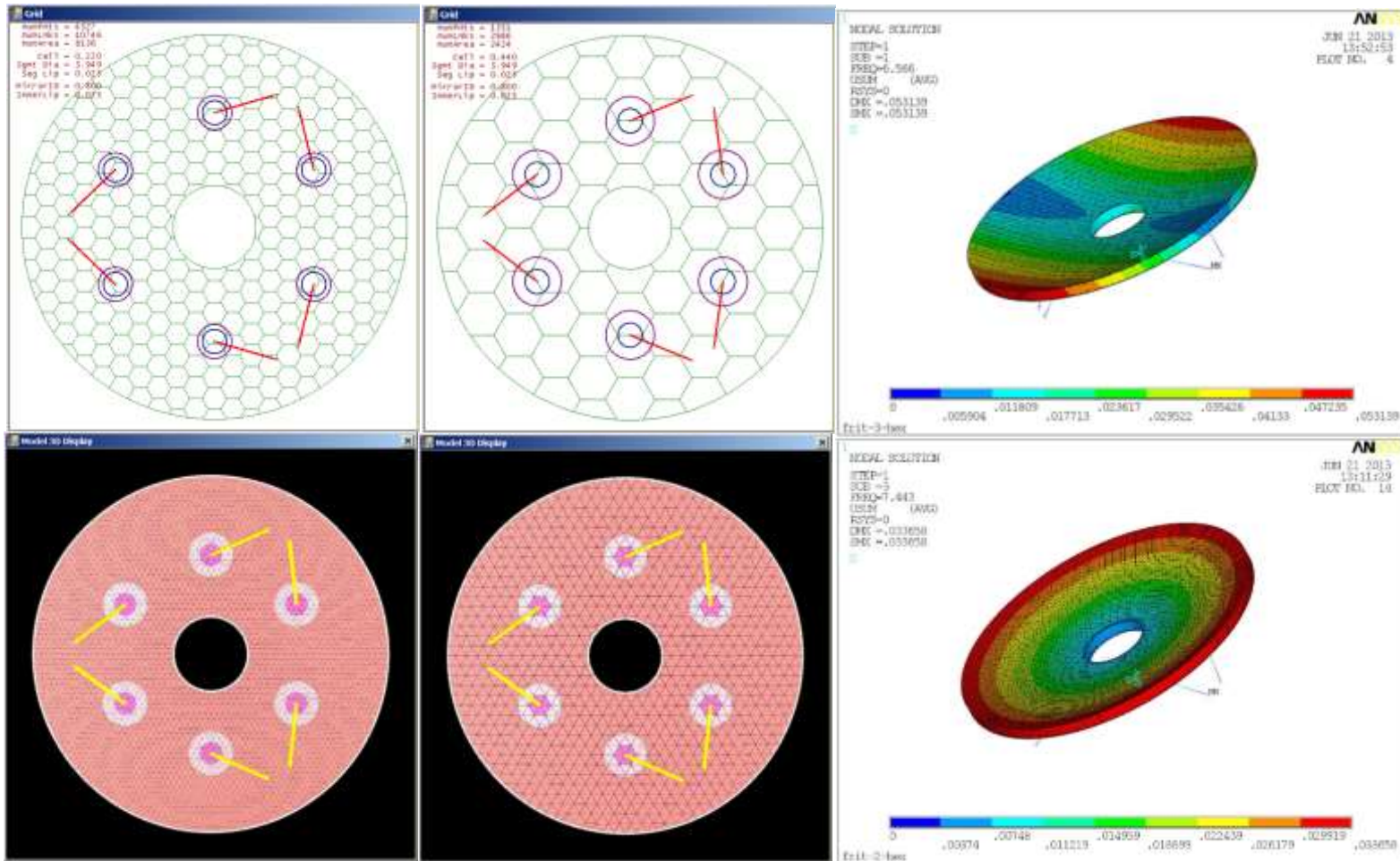
STEP 2 – EVALUATE MIRROR ONLY PARAMETERS



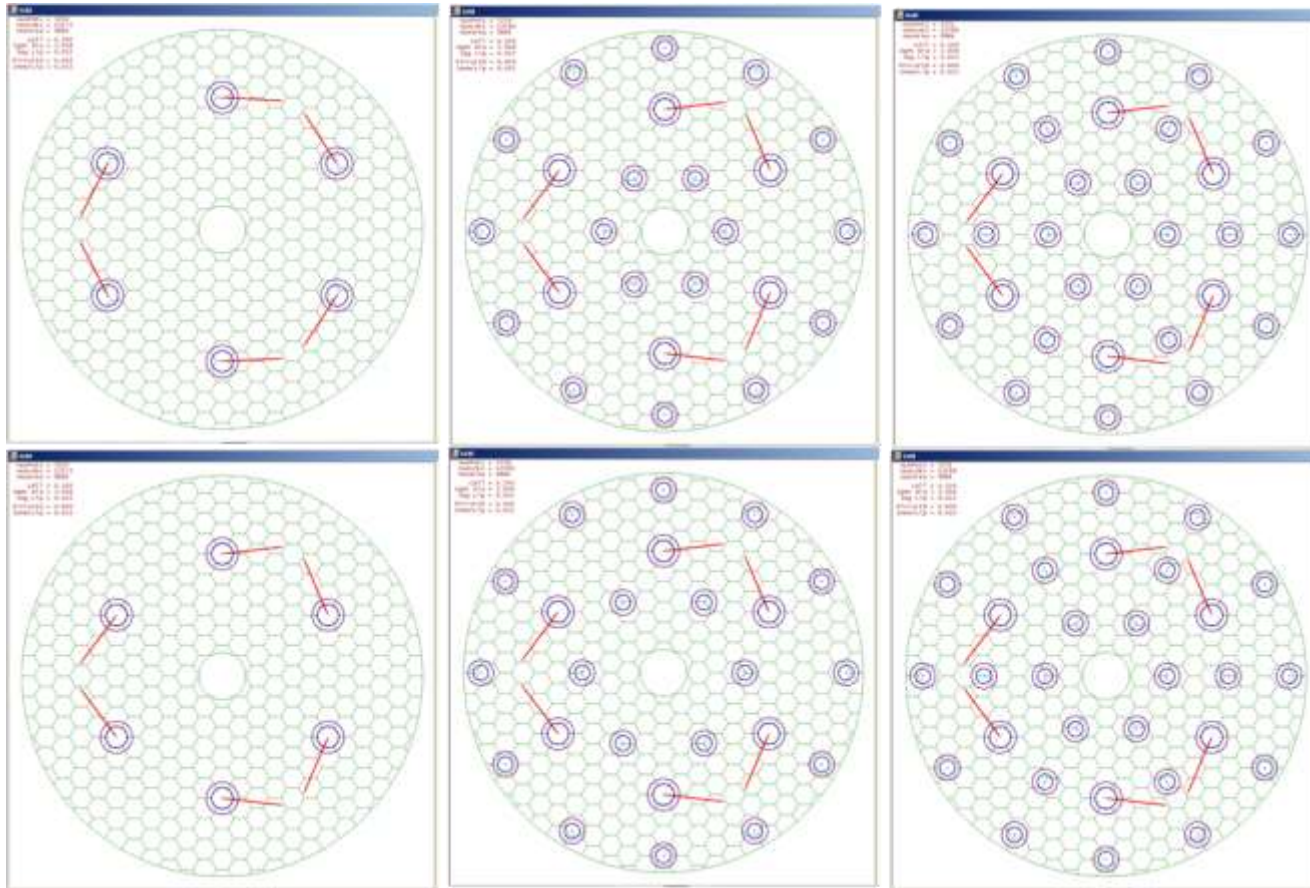
STEP 3 - EVALUATE MIRROR & OPERATIONAL SUSPENSION



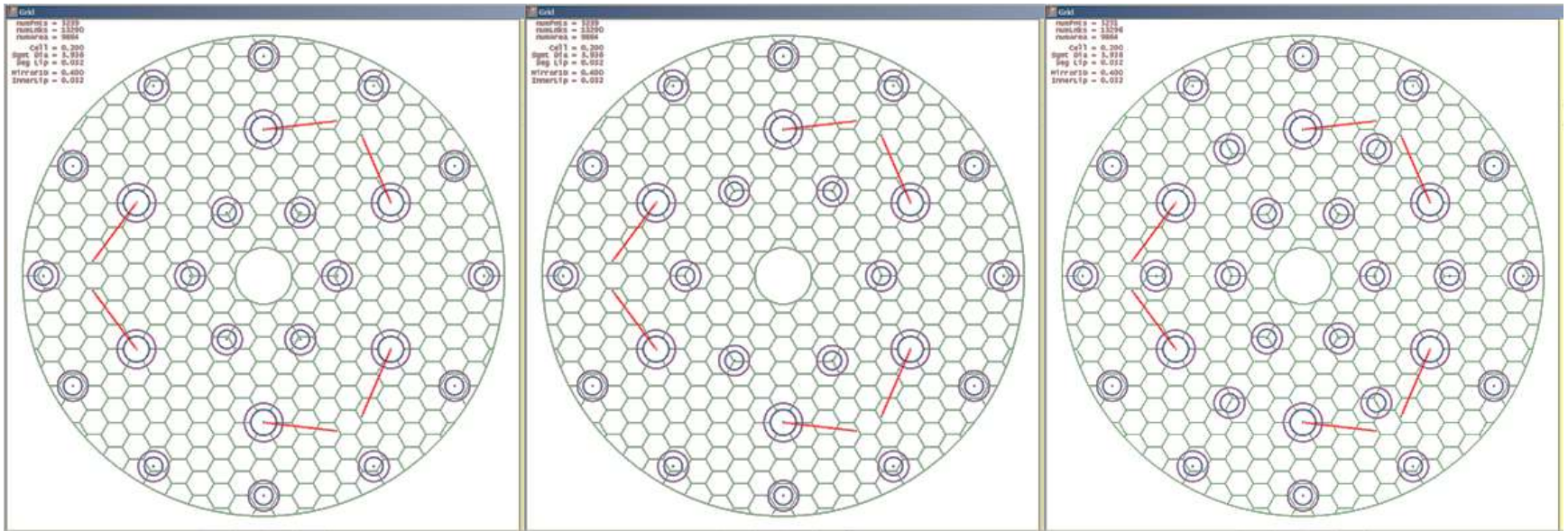
EVALUATE CELL SIZE & SUSPENSION GEOMETRY



STEP 4 – ADD AUXILLARY SUPPORT SYSTEM

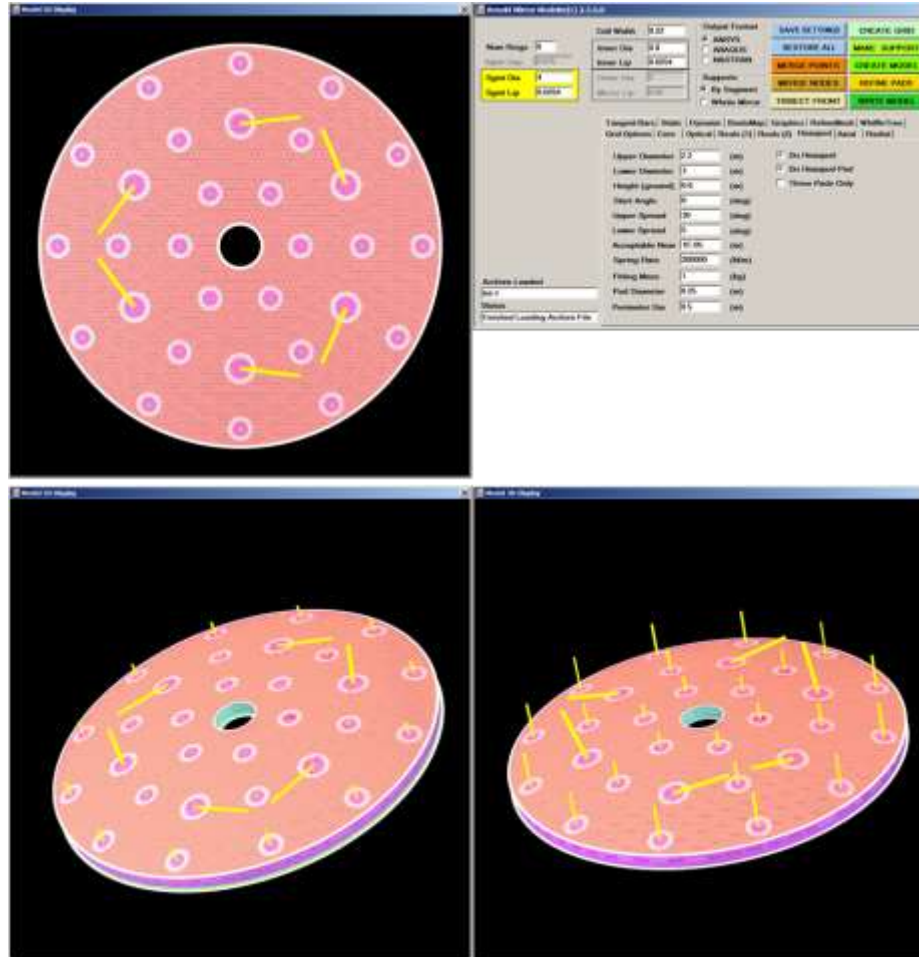


TRY MULTIPLE VERSIONS OF AUXILLARY SUPPORT SYSTEM

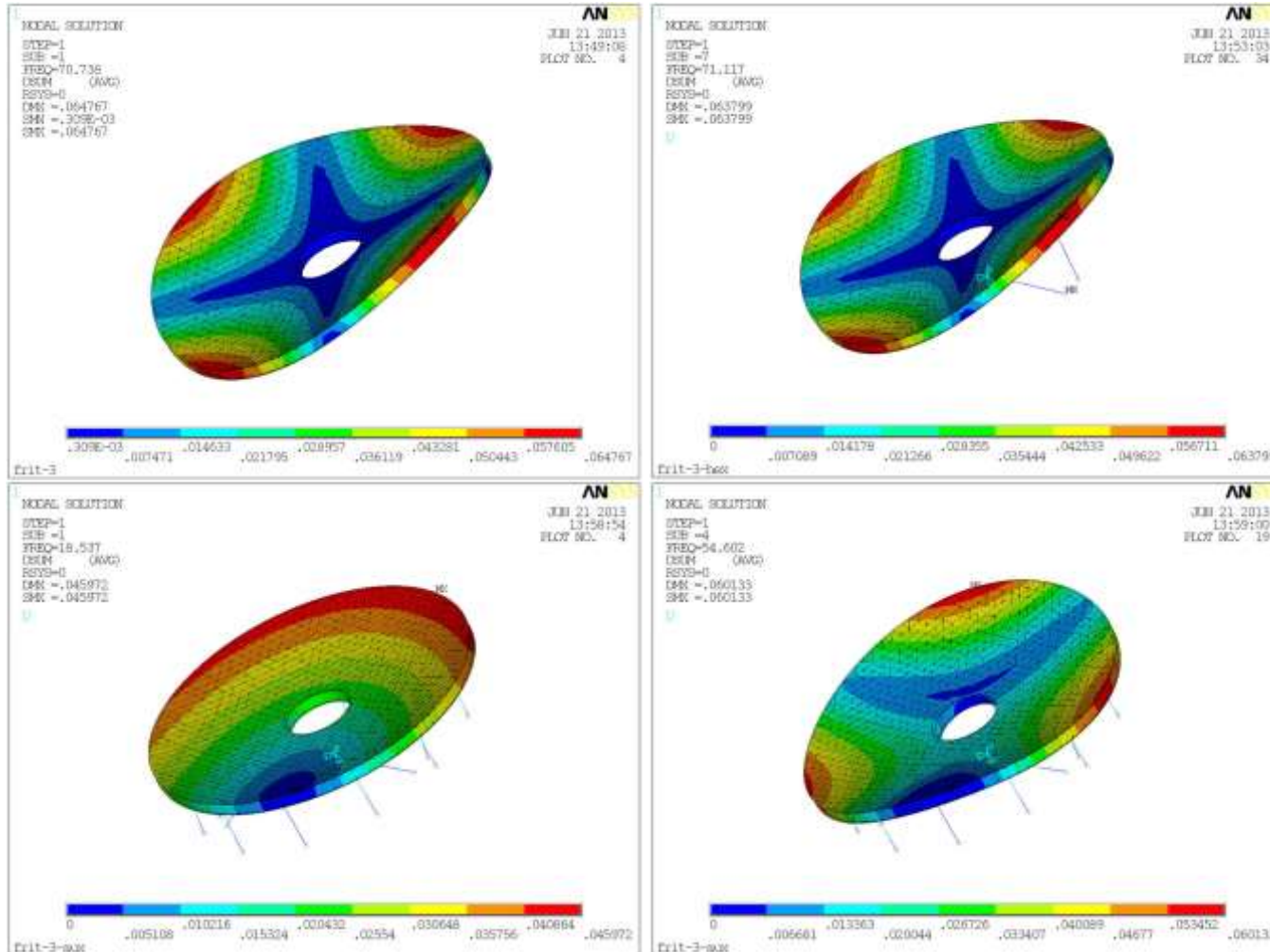


**ADJUSTING GROUP DIAMETERS, NUMBER OF
 DIAMETERS AND STARTING ANGLES**

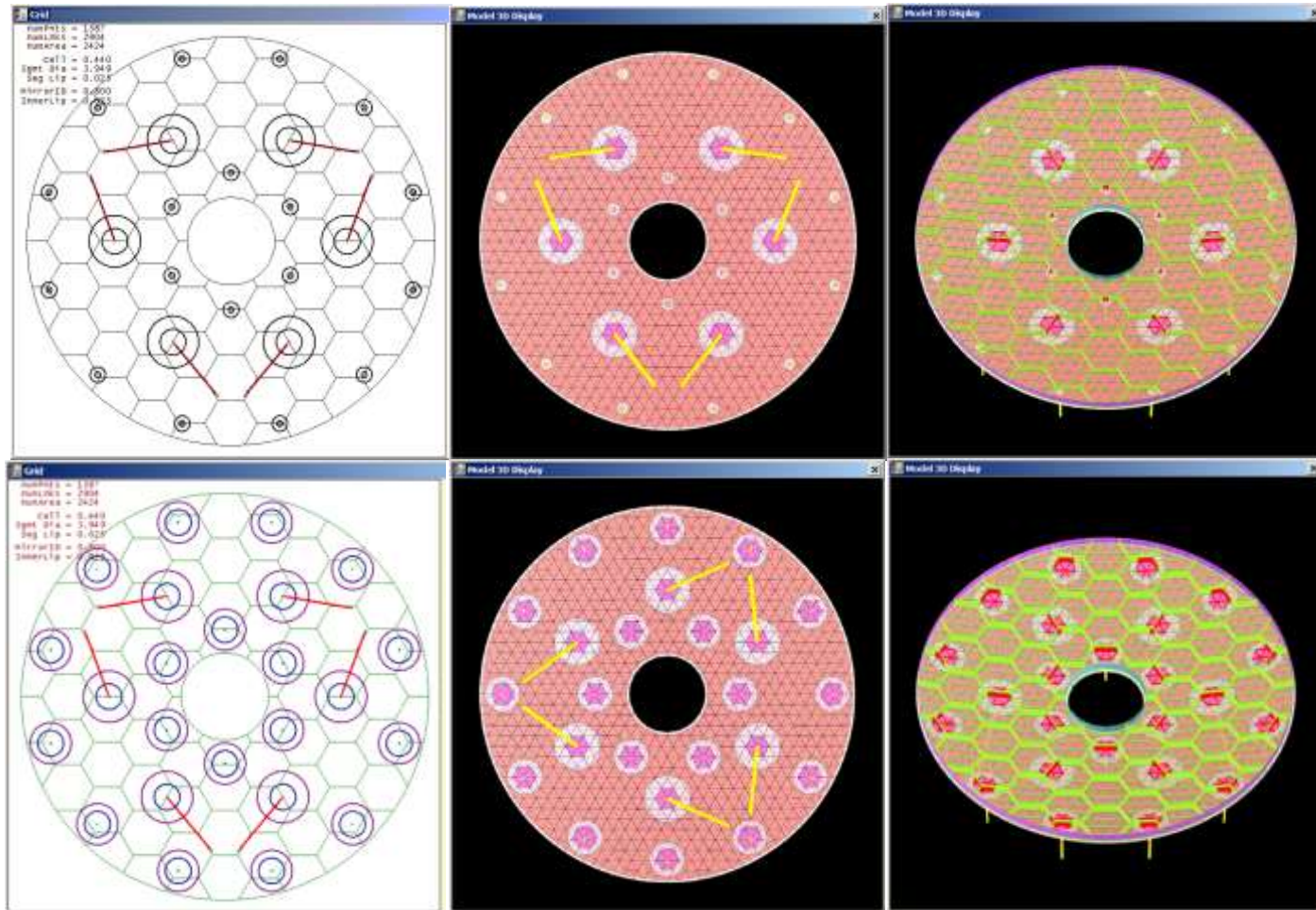
STEP 5 – OPTIMIZE GEOMETRY, THICKNESS & REINFORCEMENTS



ADJUSTING SUSPENSION PARAMETERS



ADJUSTING PARAMETERS TO IMPROVE STIFFNESS





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**