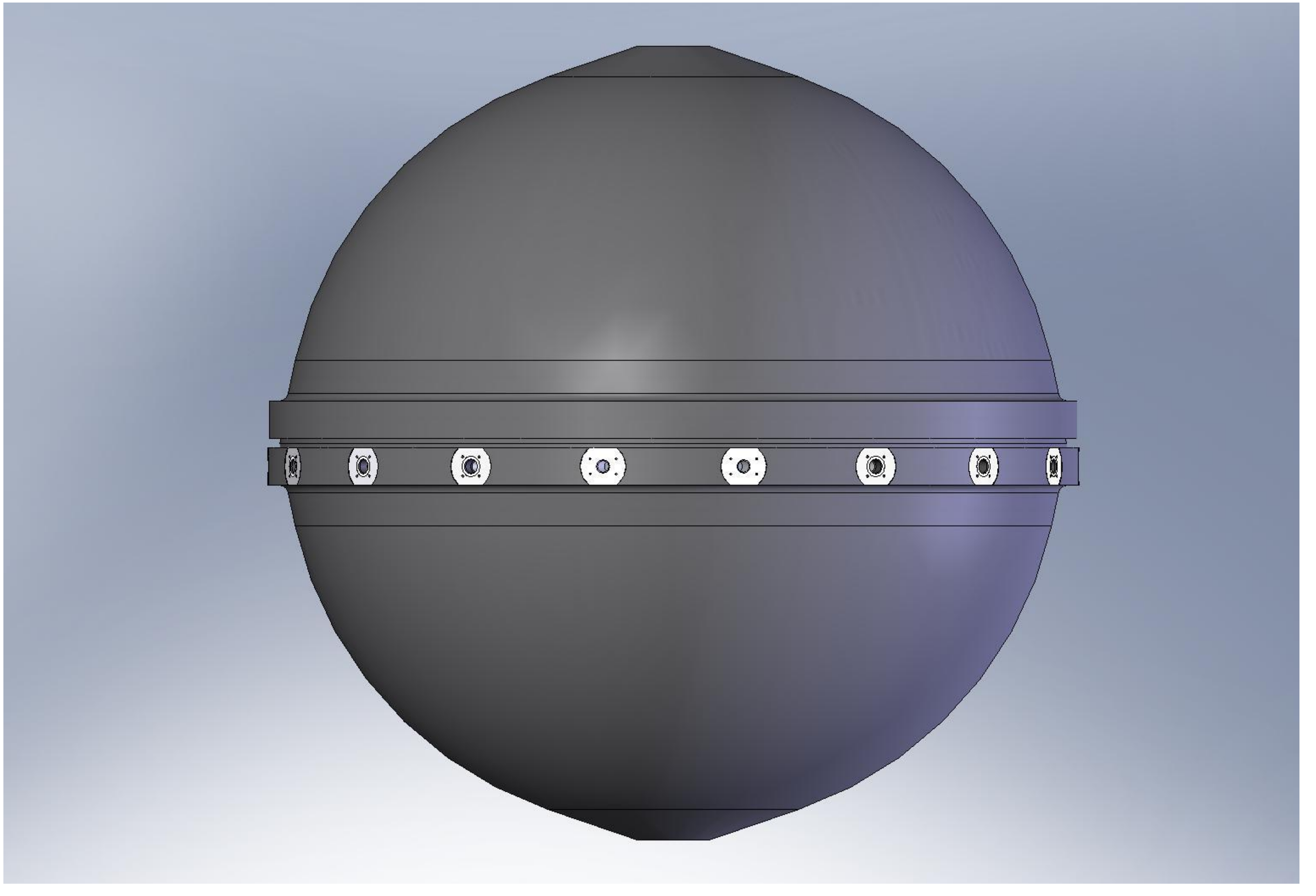
4000m ESP Sphere
CDR

Agenda

- Functional Requirements Review
- Design Factors
- Stresses
- Buckling * (We have a buckling problem.)
- External review comments
- Weight balance
- Interfaces
- Fabrication Plan
- Test Plan
- Schedule
- Risk Elements

Environmental Sample Processor 4000m Sphere

CDR



Main Housing Requirements

- Fit current and planned deployable hardware that would also deploy in surface housing.
- Allow expansion for 1 year deep ESP operations.
- Design depth: 4000m, FS of 2.0 to buckling, or 1.5 to yield.
- Penetrations
  - All penetrations for internal connections to be in bottom half.
  - 14 MinK's
    - 4 batteries
    - 1 DWSM power
    - 1 Mooring/Cable power
    - 3 context sensors
    - 1 external sampler
    - 1 modem
    - 1 ethernet
    - 1 console
    - 1 spare
  - Sample/Exhaust: Two face sealed ports to allow ¼" NPT feed thru (similar to surface and 1k deep architecture.
  - Venting: Two SAE #4 ports, with tube on the interior running to top and bottom.
  - Pressure relief: No pressure relief port req'd if face seal design leaks under bolt stretch.
- Fasteners sized to compress o-rings plus 5 psid internal pressure (purge venting)

Design Factors

- Material: Cast 6Al-4V Titanium (Grade 5), Annealed
  - Syt: 120ksi (Wah-Chang, ASTM B367)
  - Syc: 135 ksi (de-rated from nominal141 ksi, Matweb, AMS 4911)
- Pressure Shell:
  - 1.5 to Syc (Compressive yield strength)
  - Max Allowable: 90 ksi in pressure shell
- Penetrations (Dimensional stability):
  - 1.375 to Syc
  - Max Allowable: 98 ksi in penetrations
- Higher stresses, up to 122 ksi, allowed in non-issue areas.

- Buckling: 2.0 to critical buckling presure
  - We are not meeting this right now.
  - FEA not matching the Roark’s numbers.

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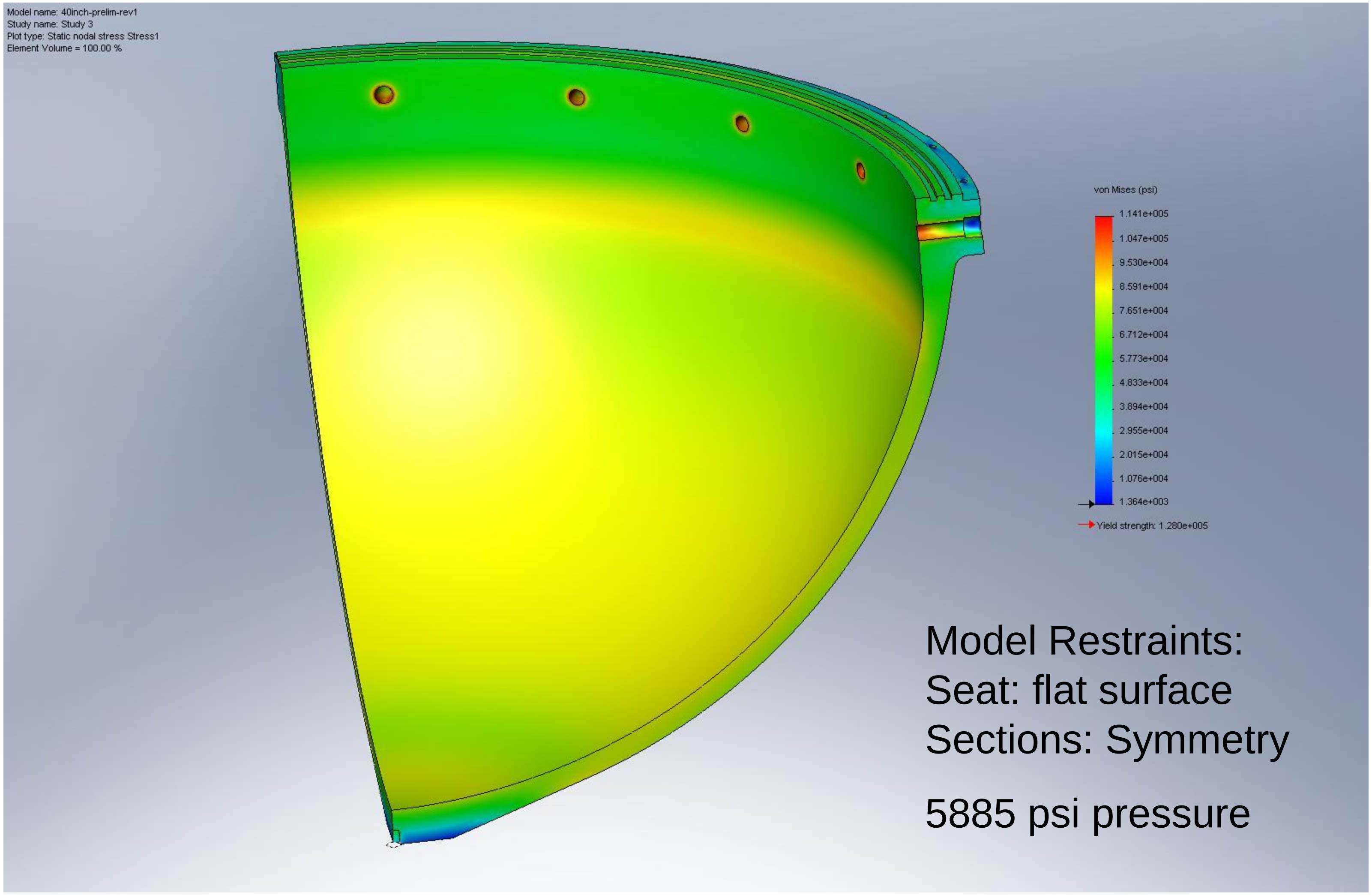
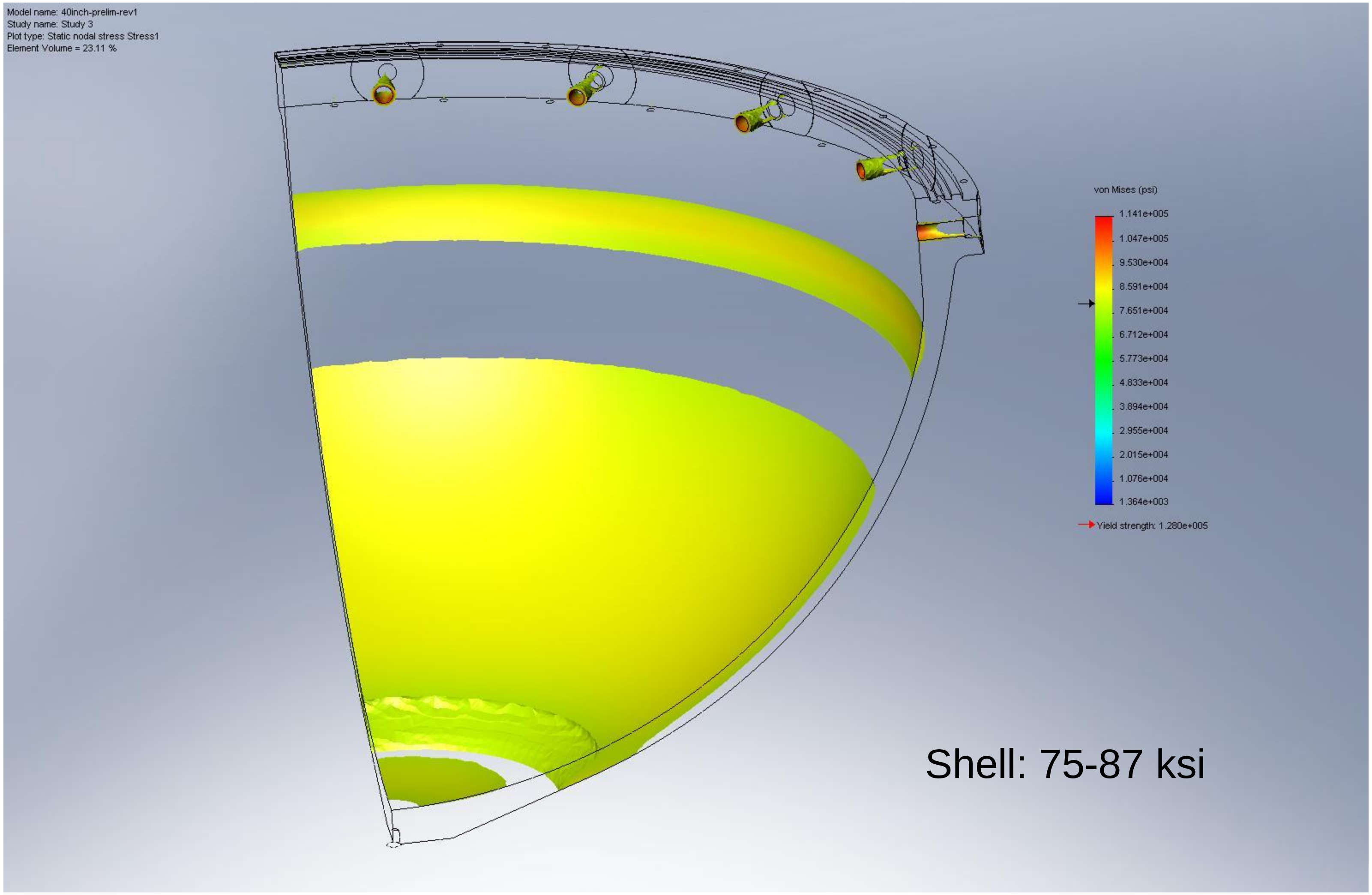
Shell Stress



Shell Stresses > 80 ksi



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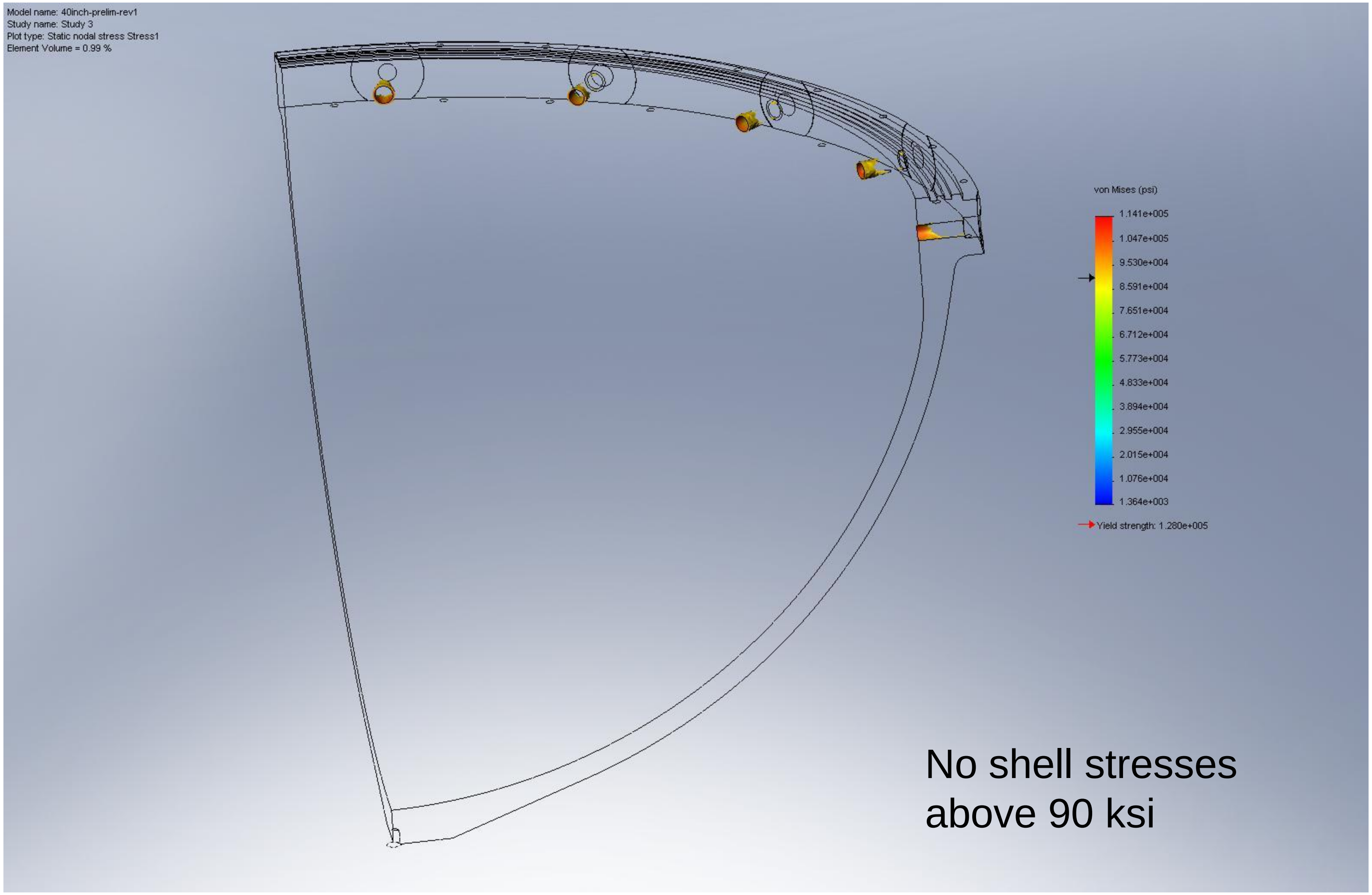
Shell Stresses > 90 ksi



Environmental Sample Processor 4000m Sphere

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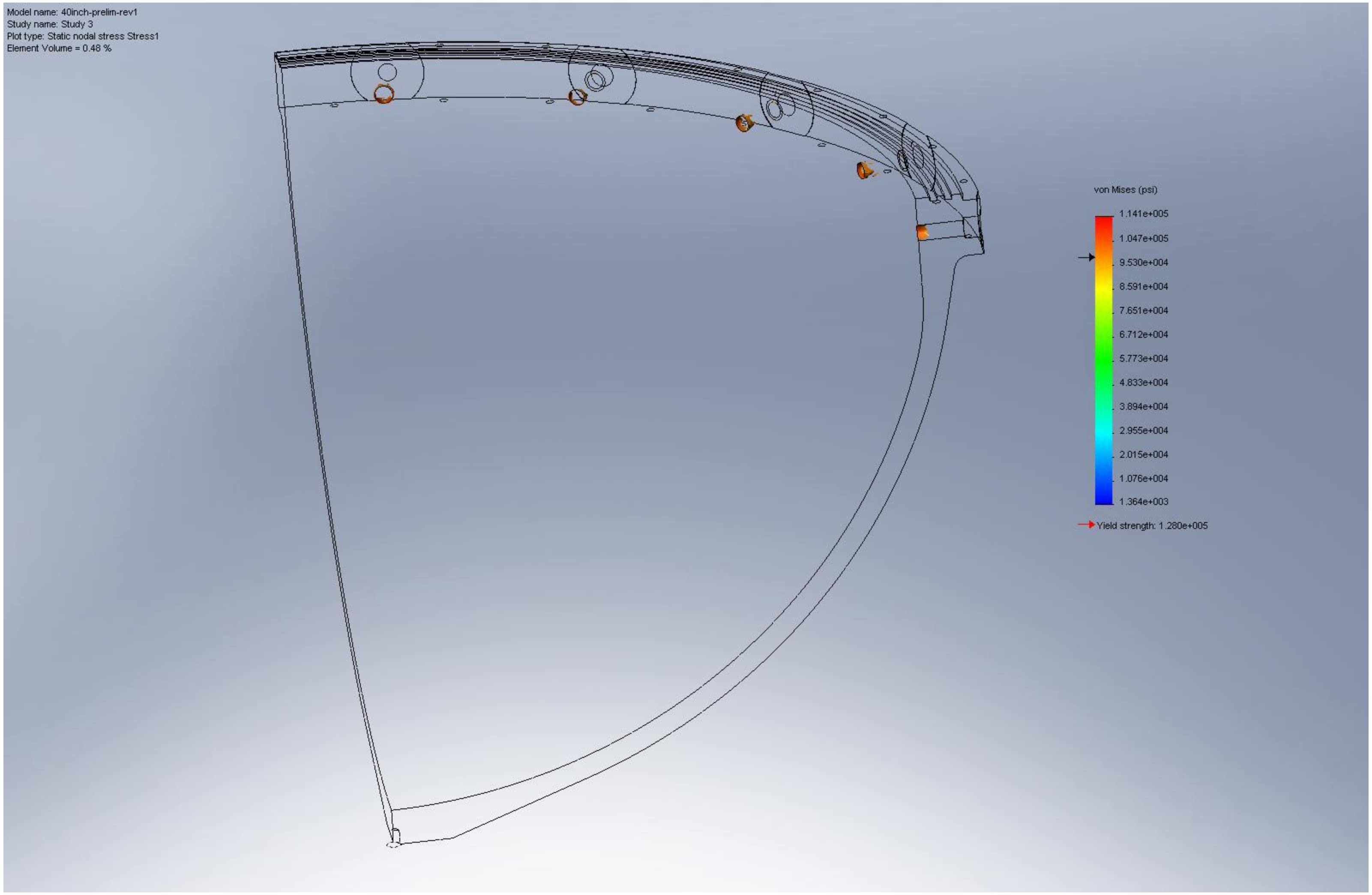
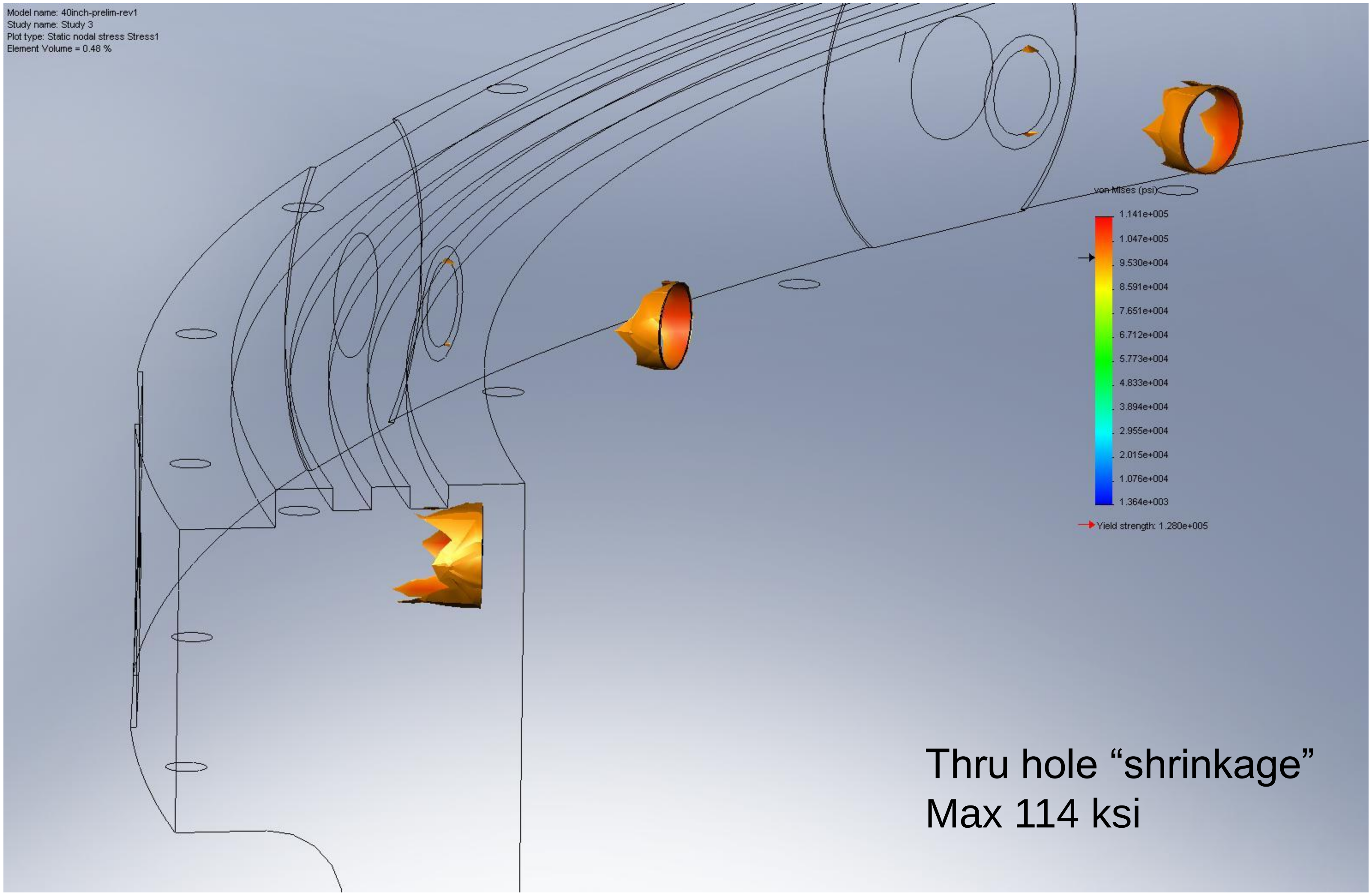
Shell Stresses > 98 ksi



Shell Stresses > 98 ksi Zoomed



Thru hole “shrinkage”
Max 114 ksi

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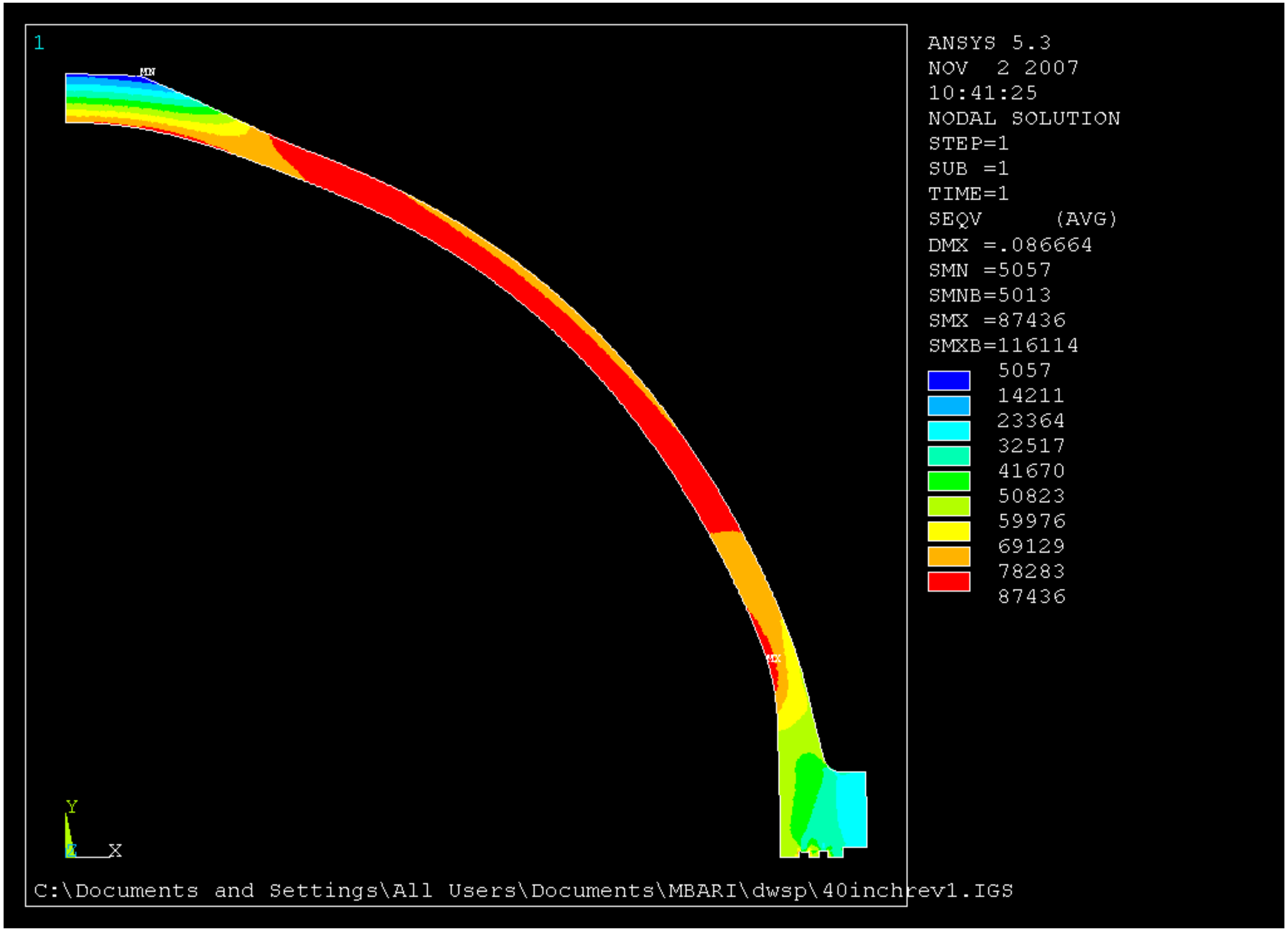
Mark Greise Review
Shell Stress

ANSYS
max

87.4 ksi



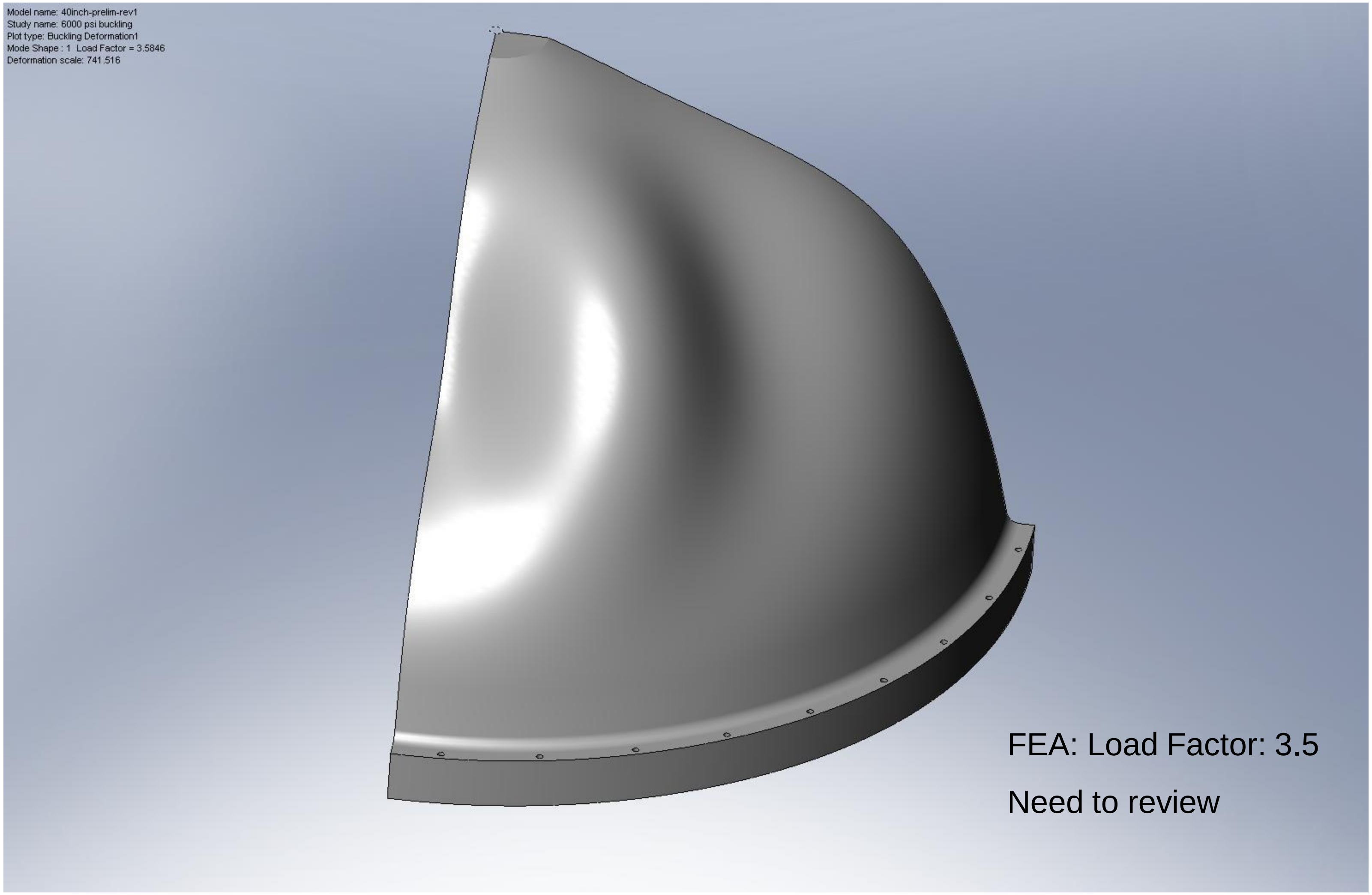
Buckling is a problem!

- Buckling formula (Roark’s) give a critical buckling pressure of around 8000 psi.
  - Deep Sea P&L Under Pressure program: 7,913 psi thin wall buckling
  - Our MathCAD PV60-Hemisphere sheet gives 8,160 psi
- FEA (Cosmos) gives a buckling (of pure hemisphere) around 16,500 psi (2.8 load factor)

- Need to resolve the difference. Problem is (probably) in the FEA analysis.

- Mark Greise can also look at the buckling condition.
- Most likely solution is to thicken up the wall.

FEA ¼ Shell Buckling



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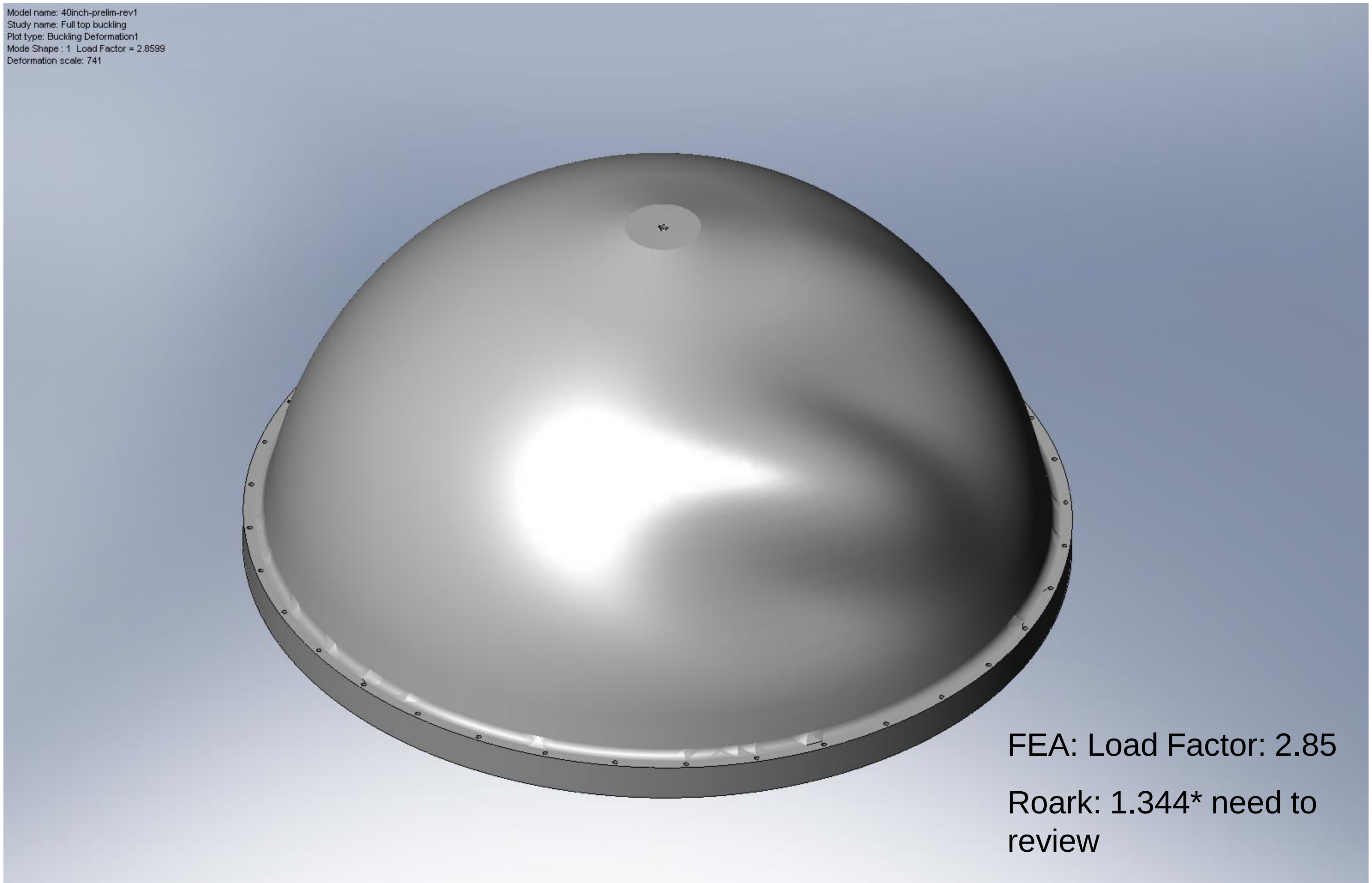
FEA Full Shell Buckling



FEA: Load Factor: 2.85

Roark: 1.344* need to review

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Revised Weight Estimate

Elevator Weight Balar	No.	unit	WEIGHT IN AIR (lb.)			Displaced Water (lb.)		WEIGHT IN SEA WATER (lb.)	
Elevator frame (Al)			160.0	est	wet	60.52		99.5	
Syntactic Foam (40lb	4	cf	160.0		wet	256.17		-96.2	
Drop Weight			140.0		wet	18.29		121.7	
Release mech			10.0		wet	3.78		6.2	
Support Brackets (UHMW P.E.)			40.0	sw	wet	44.14		-4.1	
Transponder			8.0					8.0	
40" ID Ti sphere (empty)			800.0	wt	wet	1424.84		-624.8	
ESP core			86.0	wt	dry			86.0	
MFB's			40.0		dry			40.0	
ESP fluid load, waste full			80.0	est	dry			80.0	
DWSM val 8.5x24 cyl			75.0	wt	wet	50.00		25.0	
Pumps			25.0		dry			25.0	
Valve actuators	8		15.0		dry			15.0	
Interconnect tubing/fittings			20.0	est				20.0	
Batteries	4	ea	432.0		wet	264.0		168.0	
Cables			10.0	est	wet	10.0		0.0	
Sample cyl			75.0	wt	wet	50.00		25.0	
Oil	15	L	30.2	wt	dry			30.2	
Waste cyl			75.0	wt	wet	50.00		25.0	
Oil	15	L	30.2	wt	dry			30.2	
Oil container (plastic)			5.0	est	wet	5.0		0.0	
Oil	5	L	10.1	wt	wet	11.37		-1.3	
TOTAL			**2326.5**					**78**	

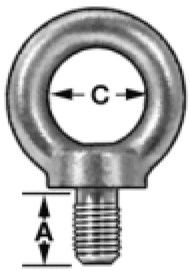
4k Deep ESP Sphere Interfaces

- 14 MINK FCR fittings
  - Eliminates accidental back out of threaded in fittings.
  - Sea pressure engages face seal.
  - Double o-ring redundancy (1 face, 1 radial)
- 4 Fluid/Vent ports (mushroom caps)
  - Eliminates regular assembly/disassembly of threads on the housing.
  - Double face seal o-ring redundancy
- ESP mounting
  - Polyurethane adhered mount ring in bottom
  - Support truss from sphere flange. (Either bottom or top mount to ESP) Requires internal radial drill/tap at flange
- Additional internal equip
  - Support bracket from sphere flange. Requires internal radial drill/tap at flange
  - Polyurethane adhered mounts.

4k Deep ESP Sphere Interfaces Continued

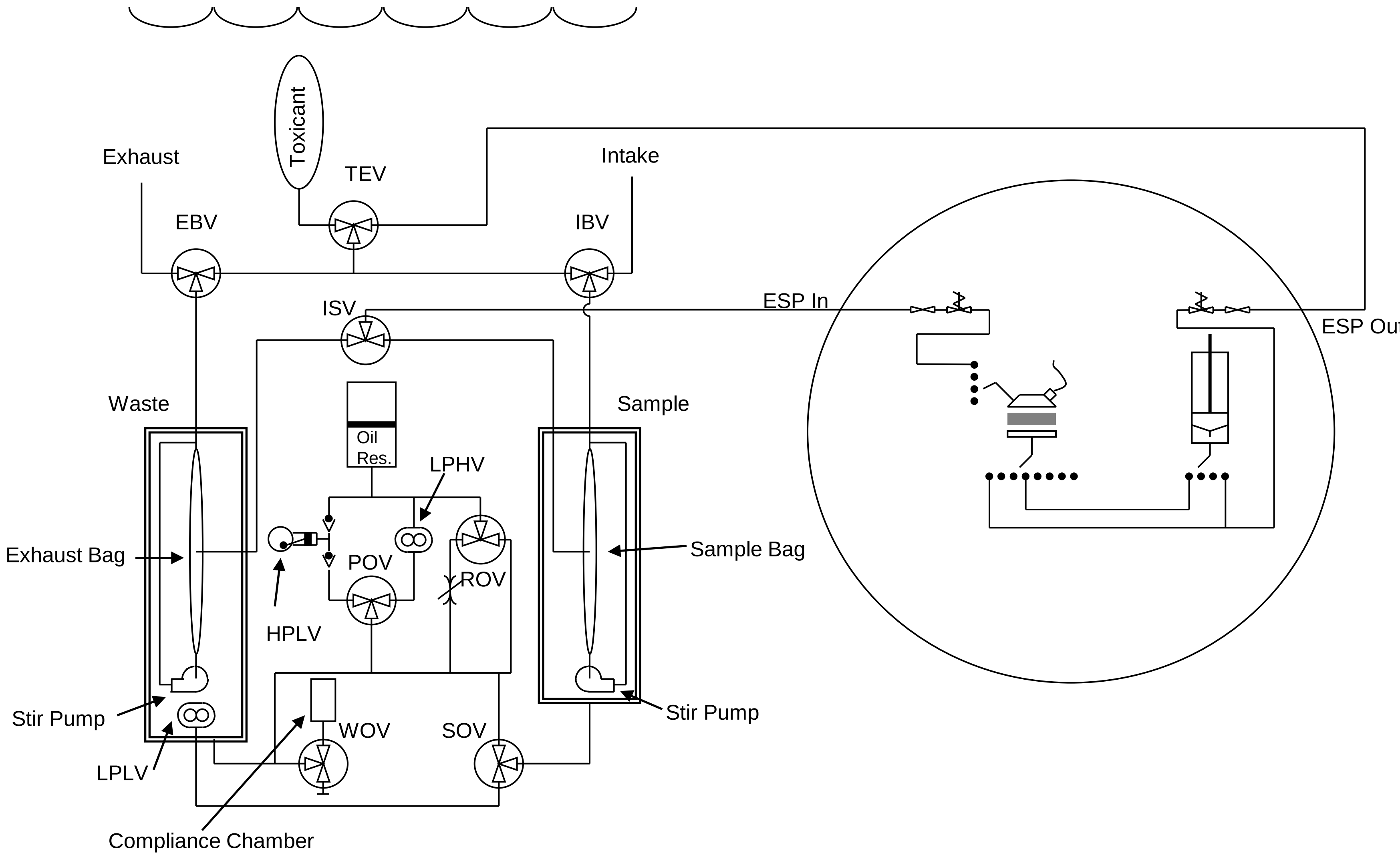
- Sphere fasteners
  - 36 ¼" Grade 2 titanium threaded rod or bolts, torque to 30 in-lbs
  - Provides 20000 lbf o-ring compression and internal vent pressure resistance.

- Single top lift eye
  - ½-13 Titanium eye (semi-permanently installed) McMaster: 3103T32
  - 2750 lbf lift capacity Dry sphere: 800 lbs, flooded sphere: 2240 lbs
  - Shorten shank (A) to ½" (does not reduce capacity)



- Sphere to frame mounting
  - Sphere flange bolting (likely using ends of sphere fasteners)
  - Bottom lift eye hole.

ESP with Deep Water Sampler
Selected Configuration
AquaLung



Fabrication Plan

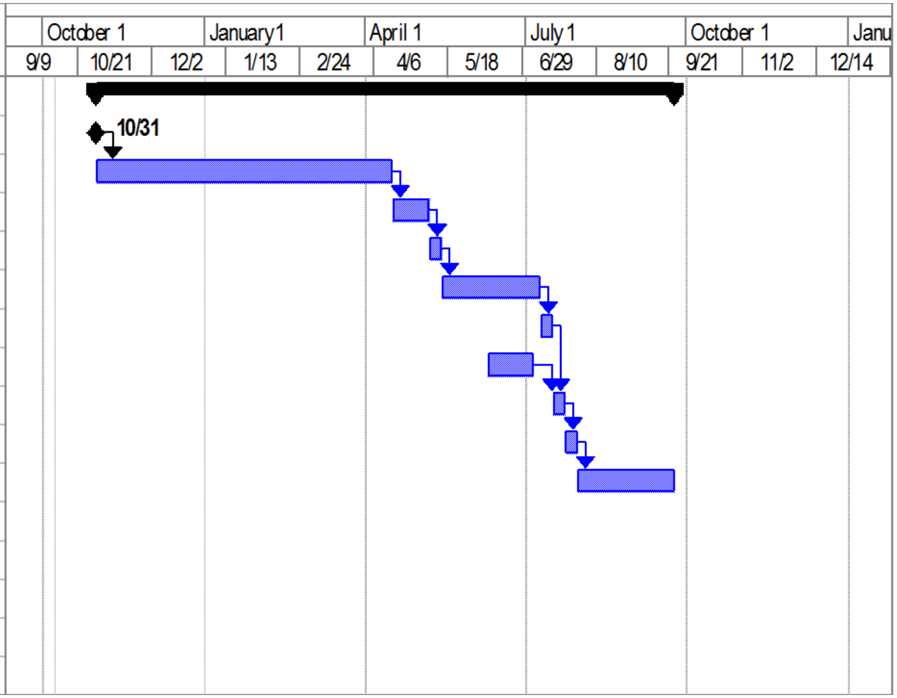
- Develop casting pattern (Wah Chang)
- Cast Hemispheres and 2 sets of coupons
- HIP castings and coupons (annealing)
- X-ray and dye-pen castings.
- Repair any defects (if req'd)
- Re-Anneal if req'd
- Get baseline Syc (2nd set coupon material tests)
- Finalize machining dimensions
- Machine hemispheres (with inspections as needed.)
- Make wood filler
- Install fittings (MinK's and Thru ports.)
- Assemble sphere
- Hydrotest

Test Plan

- X-ray and dye-pen castings.
- Material coupon testing
  - Tensile done normally by Wah Chang
  - We do compression testing as well.
- Hydrotest 100% of depth rating or 110% of planned working depth.
  - Monitoring of displaced volume (distortion)
  - Strain gauges?

Main Housing Schedule

ID		Task Name	Duration	Start
1		**4kHousing**	**235 days**	**Wed 10/31/07**
2		Order	0 days	Wed 10/31/07
3		Casting	120 days	Wed 10/31/07
4		X-ray	15 days	Wed 4/16/08
5		Shipping	5 days	Wed 5/7/08
6		Machining	40 days	Wed 5/14/08
7		Shipping	5 days	Wed 7/9/08
8		Make wood filler	20 days	Mon 6/9/08
9		Assemble	5 days	Wed 7/16/08
10		Hydrotest	5 days	Wed 7/23/08
11		Cruise prep time	40 days	Wed 7/30/08



Risk

- Schedule: casting time, machining time, etc.
- Cost; overruns due to casting, machining, material costs.
- Sphere failure (during test) mitigated by monitoring volume distortion during hydro-test.