UT-BATTELLE

MERIT Hg System Final Design Review

Hg Target System Design

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MERIT Collaboration Meeting

MIT Plasma Science & Fusion Center

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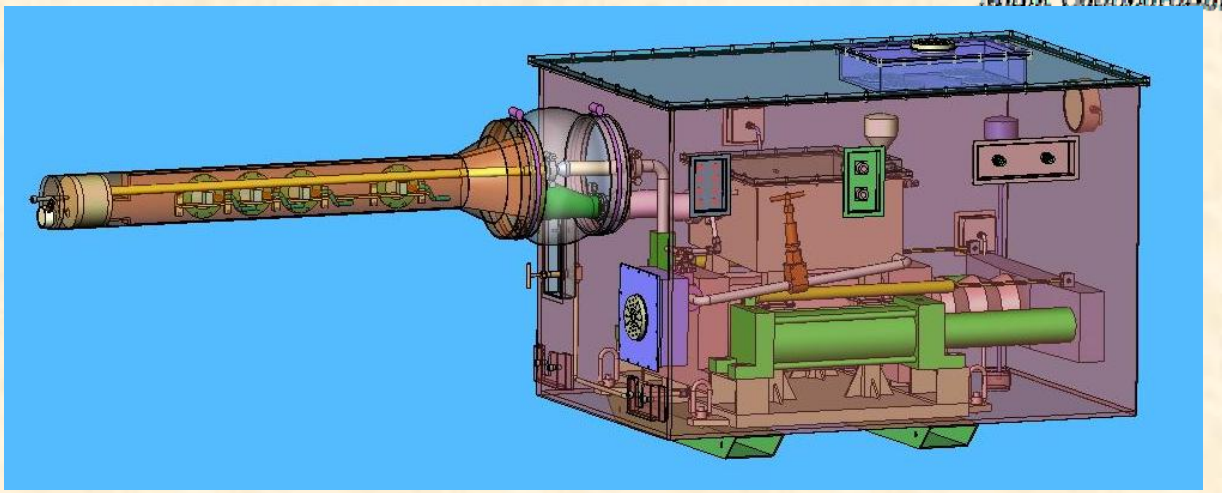
OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY

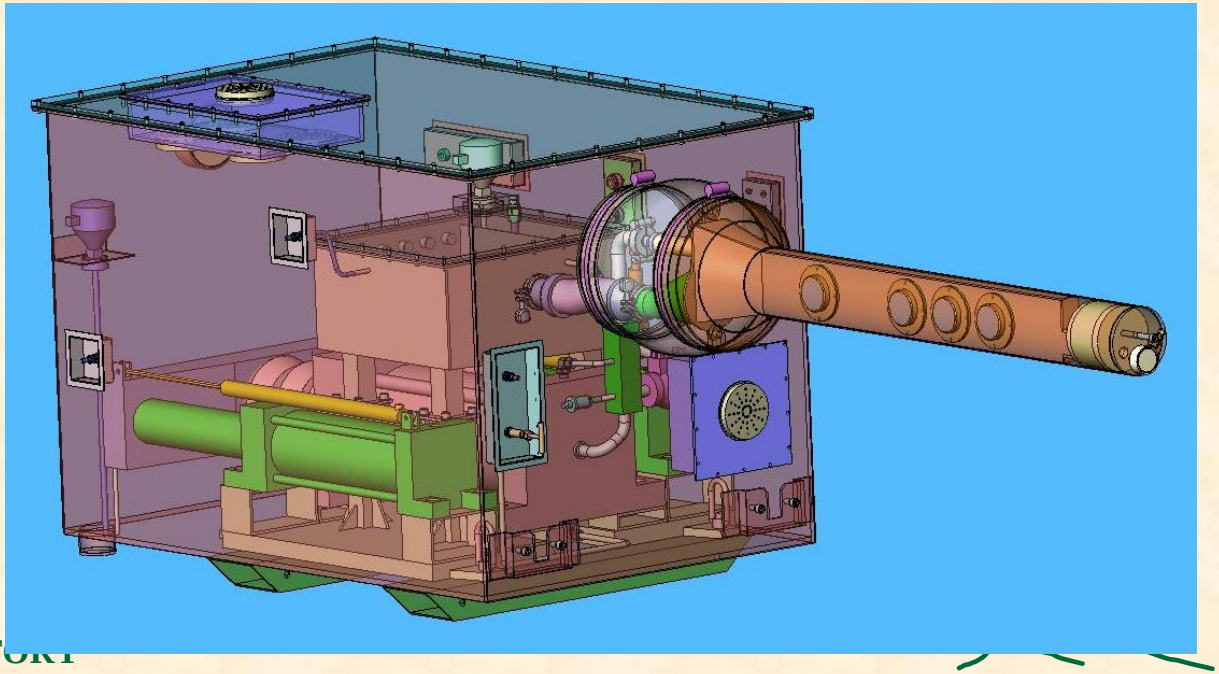
Outline - Component Details

- **Syringe**
- **Primary containment**
- **Secondary containment**
- **Baseplates**

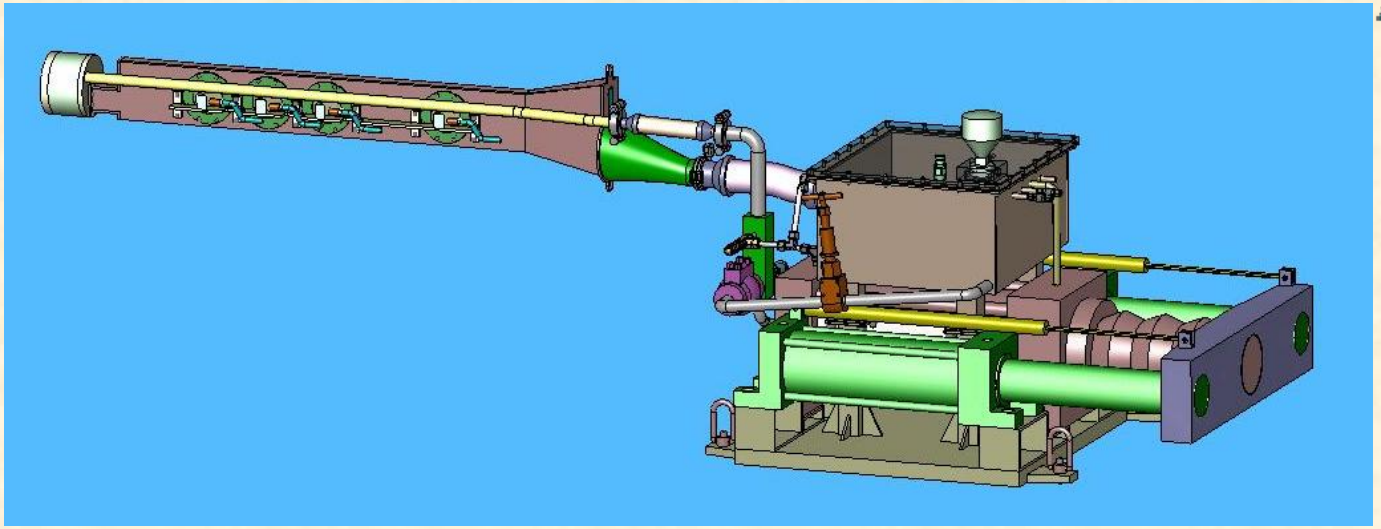
Hg Delivery System

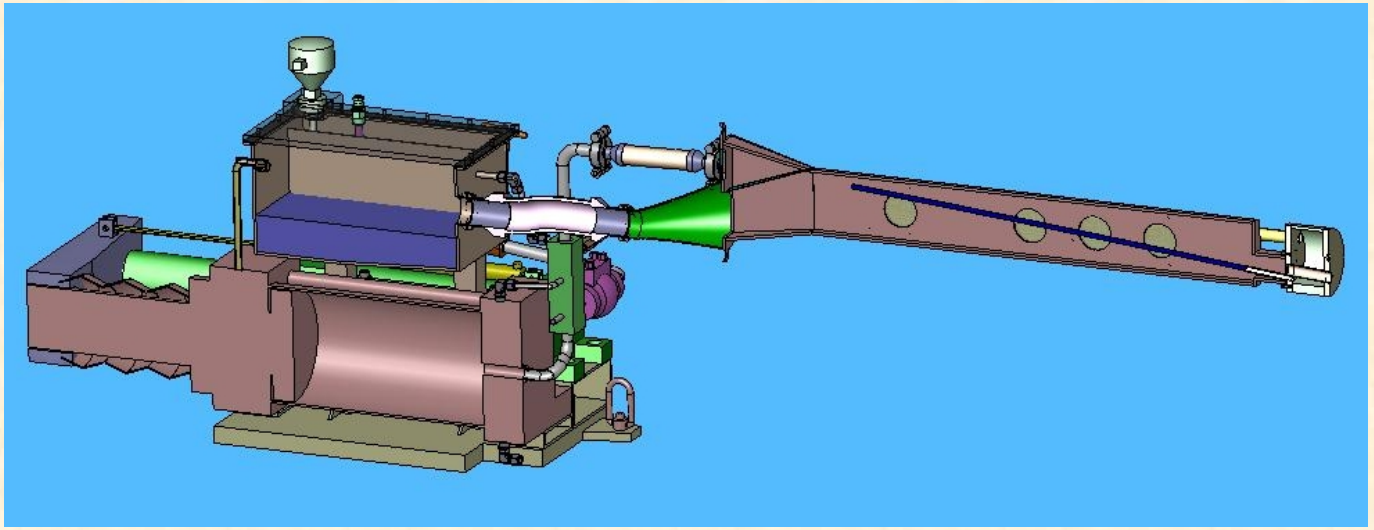
- **Capacity 23liters Hg (~760 lbs)**
- **Provides 1cm dia, 20m/s jet for up to 12 sec**
- **Secondary containment size 960mm x 1475mm x 960mm**
- **Estimated weight 2T with Hg**





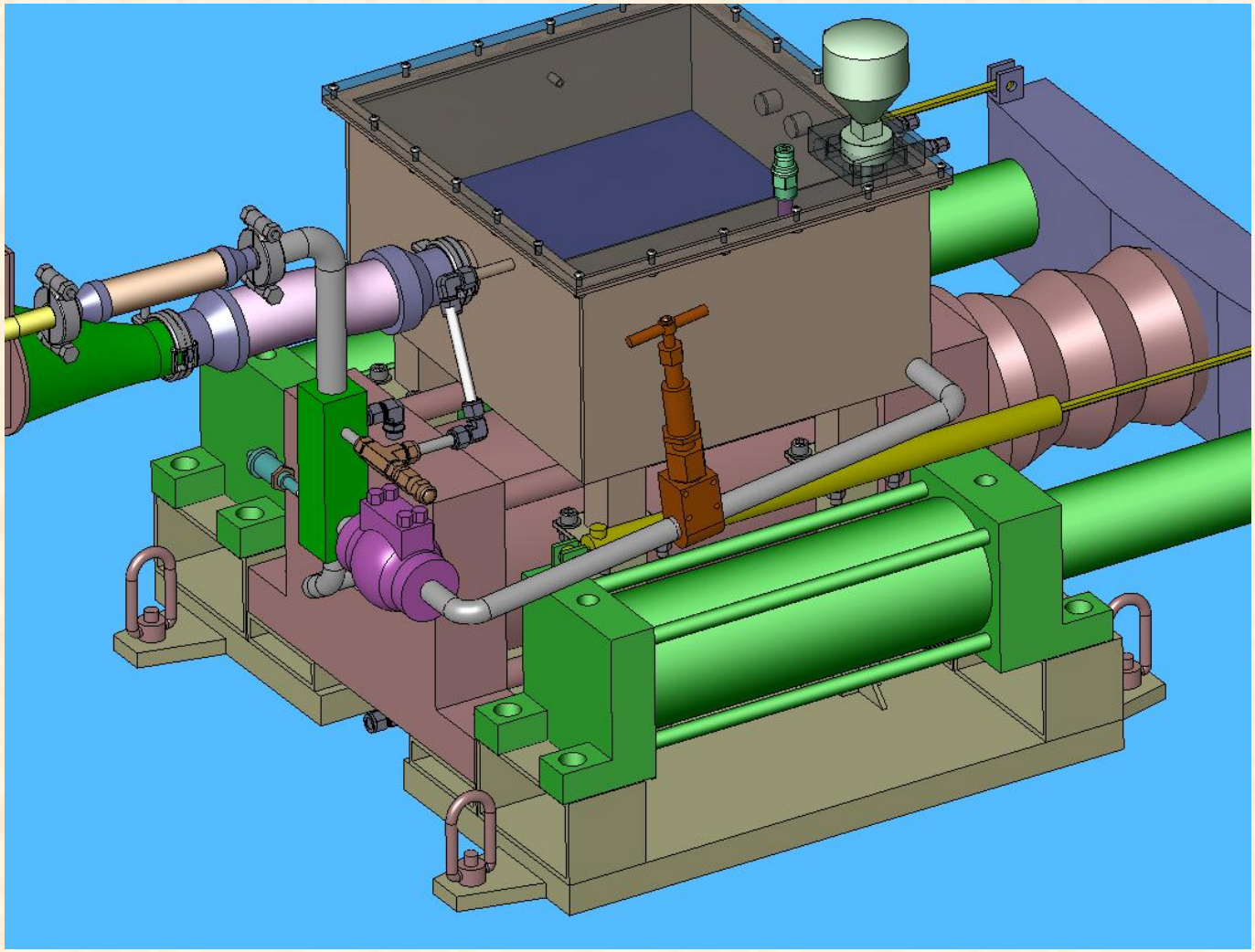
Hg Syringe System





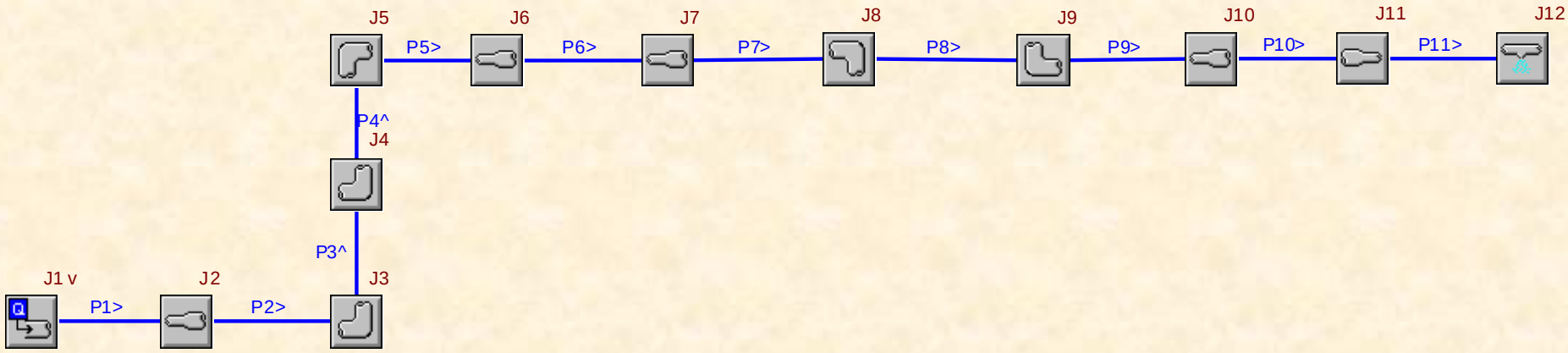
Hg Syringe System

- **Hg flow rate 1.6liter/s (24.9gpm)**
- **Piston velocity 3.0cm/s (1.2in/sec)**
- **Hg cylinder force 525kN (118kip)**



Fathom Flow Simulation

- **System diagram for Hg flow**
- **Results indicate maximum pressure requirement of ~780 psi (50 bar) for baseline plenum/nozzle configuration**
- **Design system for max pressure of 1000 psig (70 bar)**



Fathom Details

Pipe Output Table

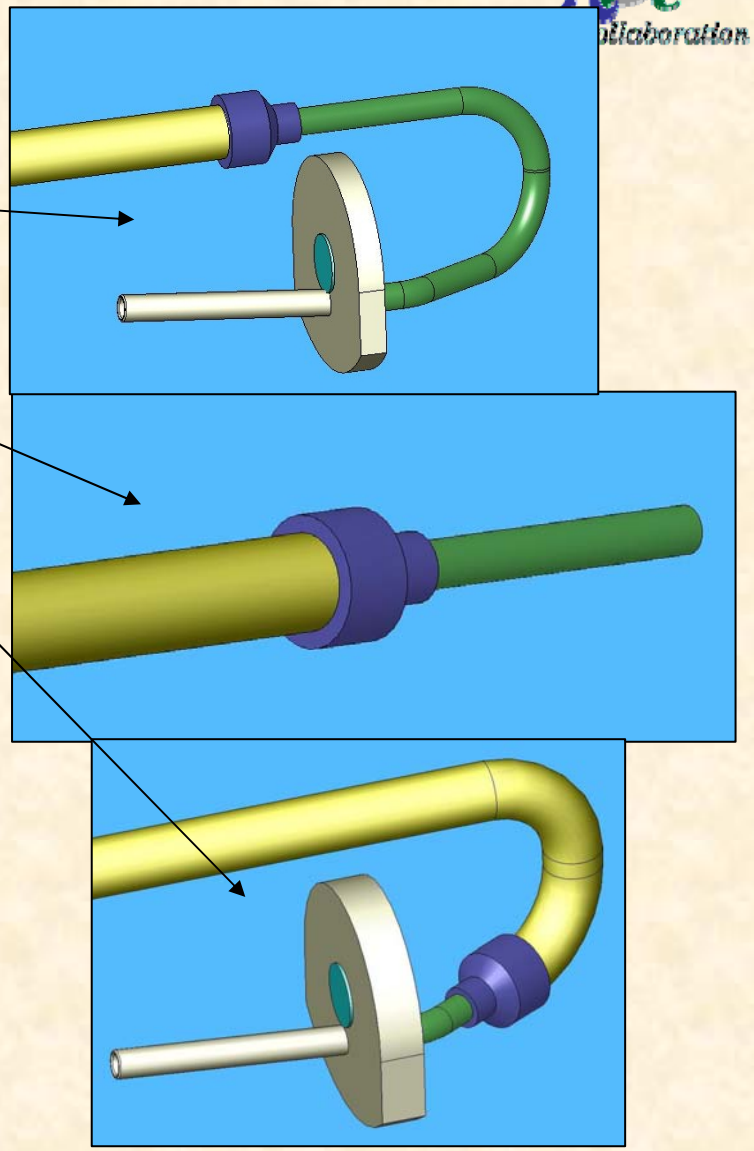
Pipe	Name	Pipe Nominal Size	Vol. Flow (gal/min)	Length (inches)	Flow Area (inches2)	Velocity (feet/sec)	Reynolds No.	fL/ D + K	P Stag. In (psig)	P Stag. Out (psig)	dP Stag. Total (psid)	P Static In (psig)	P Static Out (psig)	dP Static Total (psid)
1	Hg Cylinde	10 inch	24.9	15	78.854	0.101	6.86E+04	0.0296	784	784	2.77E-05	783.9	784	2.77E-05
2	Cylinder D	1 inch	24.9	1.5	0.864	9.24	6.56E+05	0.0256	780	780	0.199779	772.2	772	0.199779
3	Cylinder D	1 inch	24.9	0.8	0.864	9.24	6.56E+05	0.0136	777	776	0.302768	769	769	0.302768
4	Hg Manifol	1 inch	24.9	16.1	0.864	9.24	6.56E+05	0.2745	774	764	9.772281	765.9	756	9.772281
5	Hose Inlet	1 inch	24.9	2.1	0.864	9.24	6.56E+05	0.0358	761	760	0.279691	752.8	752	0.279691
6	Flex Metal	1 inch	24.9	10.5	0.945	8.449	6.27E+05	0.17	760	759	1.110492	753.7	753	1.110492
7	Hg Supply	1 inch	24.9	1.86	0.594	13.433	7.91E+05	0.0284	755	755	0.469346	738.7	738	0.469346
8	Hg Supply	1 inch	24.9	6.7	0.594	13.433	7.91E+05	0.1024	752	750	1.690654	735.3	734	1.690654
9	Hg Supply	1 inch	24.9	44	0.594	13.433	7.91E+05	0.6726	747	736	11.1028	730.8	720	11.1028
10	Plenum	5 inch	24.9	3	20.006	0.399	1.36E+05	0.0105	721	721	0.000153	720.6	721	0.000153
11	Nozzle	1/2 inch	24.9	4	0.108	74.271	1.86E+06	0.1491	469	394	75.21312	-35.3	-110	75.21312

All Junction Table

Jct	Name	Junction Type	Elevation Inlet (inches)	Loss Factor (K)	dH (inches)	P Stag. In (psig)	P Stag. Out (psig)	dP Stag. Total (psid)	P Static In (psig)	P Static Out (psig)	dP Static Total (psid)	T Inlet (deg. F)
1	Syringe Pi	Assigned F	0	0	0	784	784	0	784	783.9	0	68
2	Area Chan	Area Chan	0	4,128.12	7.895	784	780	3.8729	784	772.2	11.682	68.2
3	Bend 1	Bend	0	0.33841	5.388	780	777	3.011	772	769	3.011	68.2
4	Bend 2	Bend	1.15	0.27347	4.354	776	774	2.7736	769	765.9	2.774	68.2
5	Bend 3	Bend	18	0.33841	5.388	764	761	3.3789	756	752.8	3.379	68.3
6	Pipe to Fle	Area Chan	19.5	0.00733	0.117	760	760	0.0572	752	753.7	-1.223	68.3
7	Flex to Tub	Area Chan	19.5	0.60087	7.999	759	755	3.924	753	738.7	13.901	68.3
8	Tubing Ber	Bend	19.5	0.17406	5.857	755	752	2.8734	738	735.3	2.873	68.3
9	Tubing Ber	Bend	19.5	0.17406	5.857	750	747	2.8734	734	730.8	2.873	68.3
10	Plenum Inl	Area Chan	19.5	0.94145	31.682	736	721	15.5414	720	720.6	-0.952	68.3
11	Nozzle Inle	Area Chan	19.5	17,240.17	512.271	721	469	251.2909	721	-35.3	755.894	68.3
12	Spray	Spray Disc	19.5	0.78106	802.957	394	0	393.8837	-111	-504.6	393.884	75

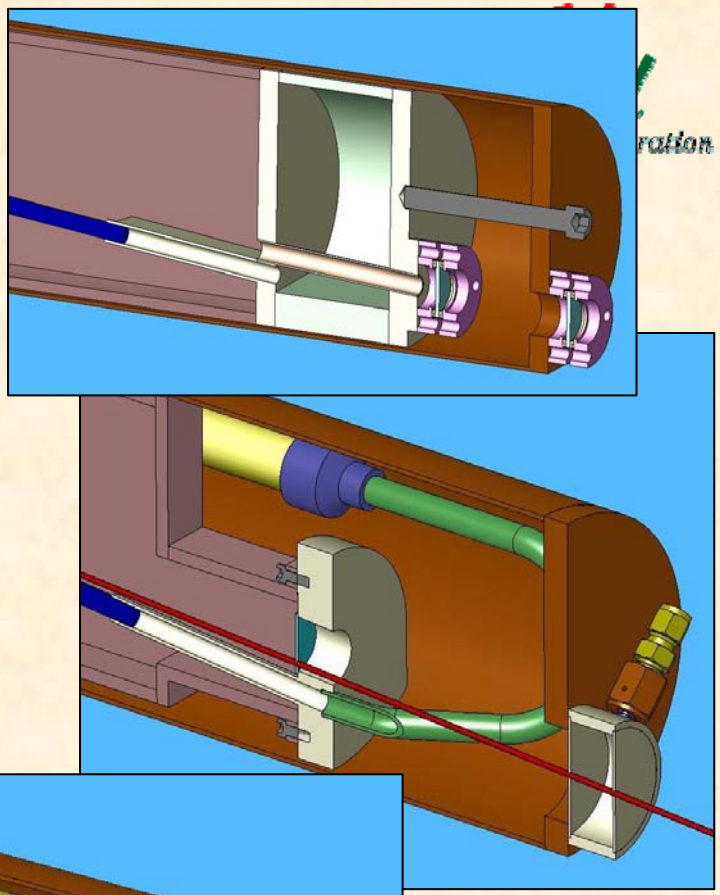
Other Fathom Simulations

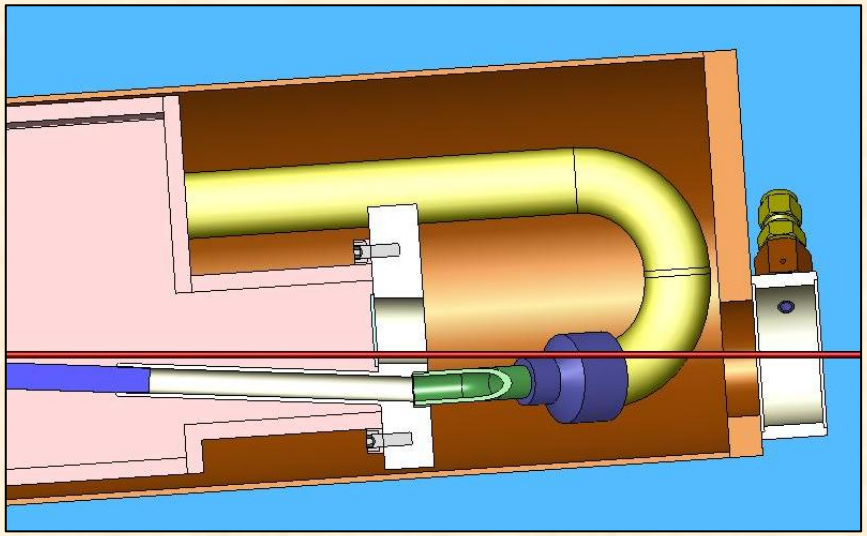
- 1/2" tubing bend
  - Cylinder pressure 1200 psi (83 bar)
- No-bend short 1/2" tube
  - Cylinder pressure 710 psi (48 bar)
- 1" tubing bend
  - Cylinder pressure 780 psi (54 bar)
- All 1/2" tubing from end of flex metal hose, no plenum
  - Cylinder pressure 1910 psi (130 bar)
- Any non-plenum design should minimize number of bends & length of nozzle tubing
- Don't let syringe pump limit nozzle configuration - recommend changing system design pressure to 1500 psi (103 bar) to match Hg cylinder rating

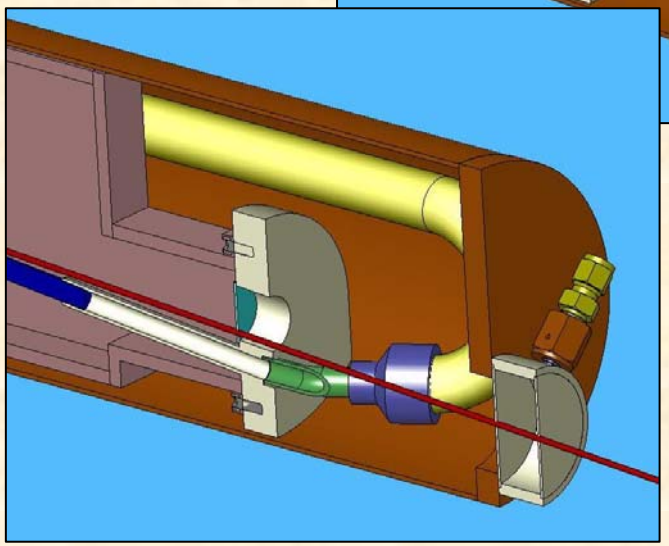


Non-Plenum Nozzles

- **Room is available to eliminate plenum, keep tubing under beam**
- **Flow streamlines become more of an issue**
  - **Desire to move bend further from nozzle**

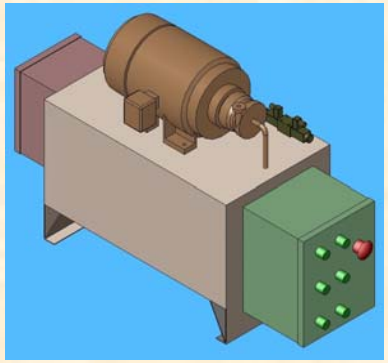


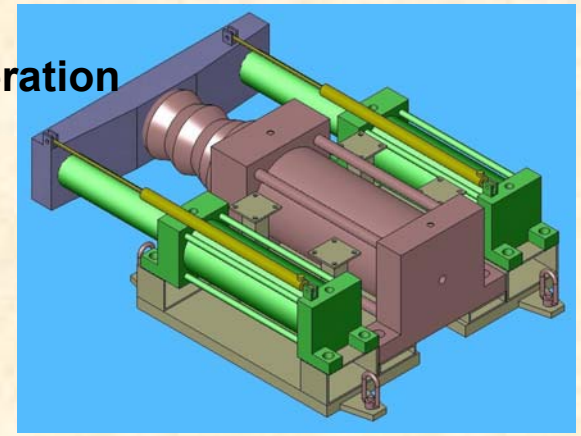




Syringe Procurement

- **Complete system design based on specified requirements**
- **Piston pump (inside secondary containment)**
  - **One 10-inch Hg Pump Cylinder**
  - **Two 6-inch Drive Cylinders (one with integrated position sensor)**
  - **Tie beam**
  - **Baseplate**
  - **Hydraulic hoses inside secondary for operating Drive Cylinders**
- **Hydraulic pump (outside secondary containment)**
  - **Pump, motor, reservoir**
  - **Proportional, directional control valve**
  - **Hydraulic hoses between pump & secondary containment**
  - **Motor controller**
  - **Variable voltage transformer for U.S. and European operation**
- **Hydraulic fluid (drum)**
- **Integration of system components**
- **System testing with water**

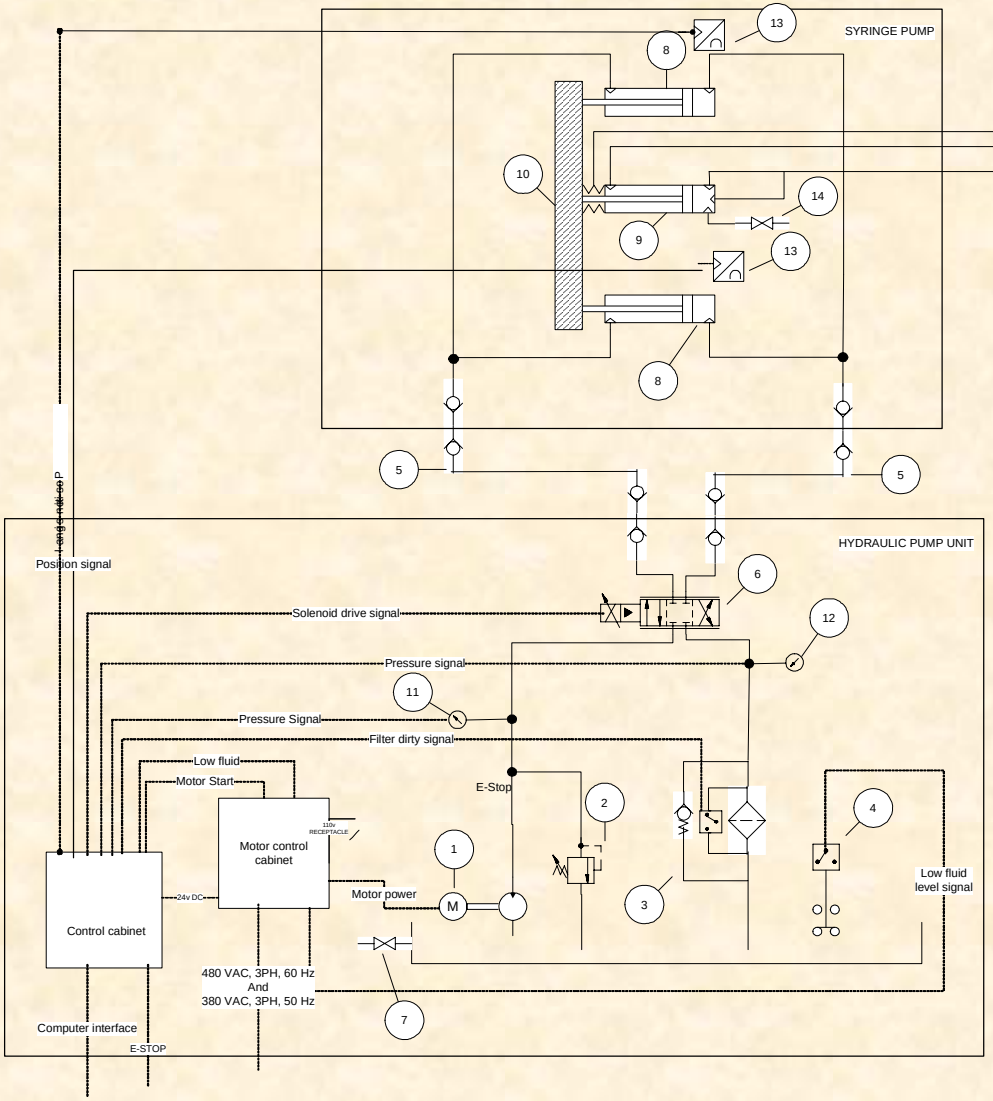


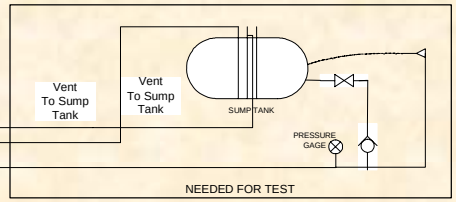


Syringe Procurement Status

- **RFQ sent to 5 vendors, 4 submitted quotes**
  - **Requested prices for std cylinders & SS cylinders**
  - **Low bid: $60K (std), $68K (SS)**
  - **Subcontract awarded to Airline Hydraulics (Edison, NJ)**
  - **Chose SS cylinder option**
  - **Kickoff meeting being scheduled for next week**
- **Vendor required to host a syringe design review 30 days after contract award, prior to ordering materials**

Syringe Hydraulic Schematic





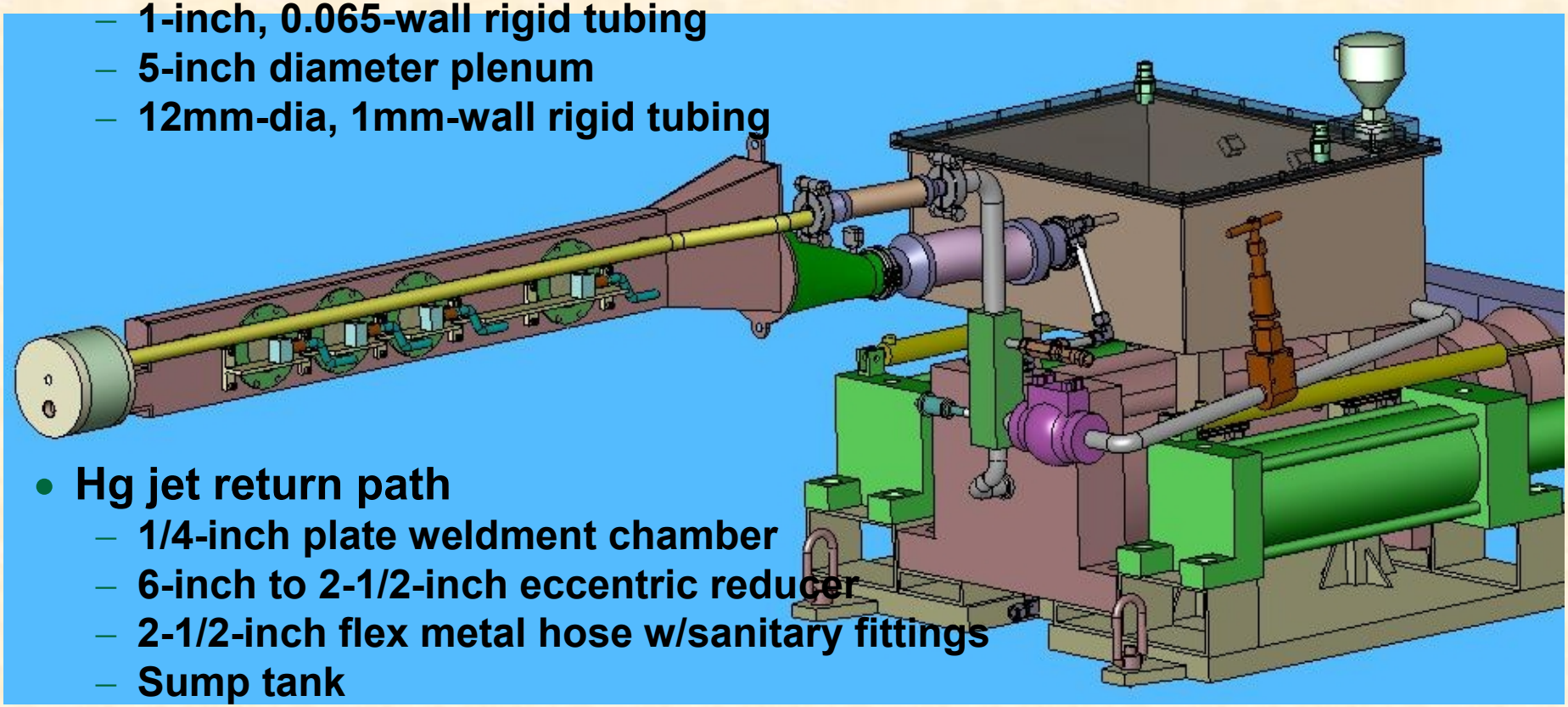
Bill of Materials

Find No.	Name	Description	Qty.
1	pump and motor	TEFC motor, pump, mounted vibration absorbing pads	1
2	relief valve	set for 3300 PSI	1
3	filter	filter with electrical filter dirty switch and bypass valve	1
4	level switch	reservoir low level cutoff switch	1
5	hose	hose length 65 ft., quick connections both ends	2
6	proportional valve	Bosh 4 WREE or equivalent	1
7	ball valve	reservoir drain valve with TBD end fitting	1
8	hydraulic cylinder	hydraulic cylinder, 15" stroke	2
9	hydraulic cylinder	mercury syringe cylinder, bore 10", stroke 15", 4 ports as noted	1
10	tie-beam	beam providing mechanical connection between cylinders	1
11	pressure sensor	electronic pressure sensor with attachable indicator display, 0-4000 psi, signal 4-20ma	1
12	pressure sensor	electronic pressure sensor with attachable indicator display, 0-500 psi, signal 4-20ma	1
13	position sensor	linear potentiometer, Celesco CLWG or equivalent	2
14	ball valve	cylinder drain valve with TBD end fitting	1

August 24, 2005

Primary Containment

- **Hg supply flow path**
  - **1-inch Sch 40 pipe**
  - **1-inch flex metal hose w/sanitary fittings**
  - **1-inch, 0.065-wall rigid tubing**
  - **5-inch diameter plenum**
  - **12mm-dia, 1mm-wall rigid tubing**



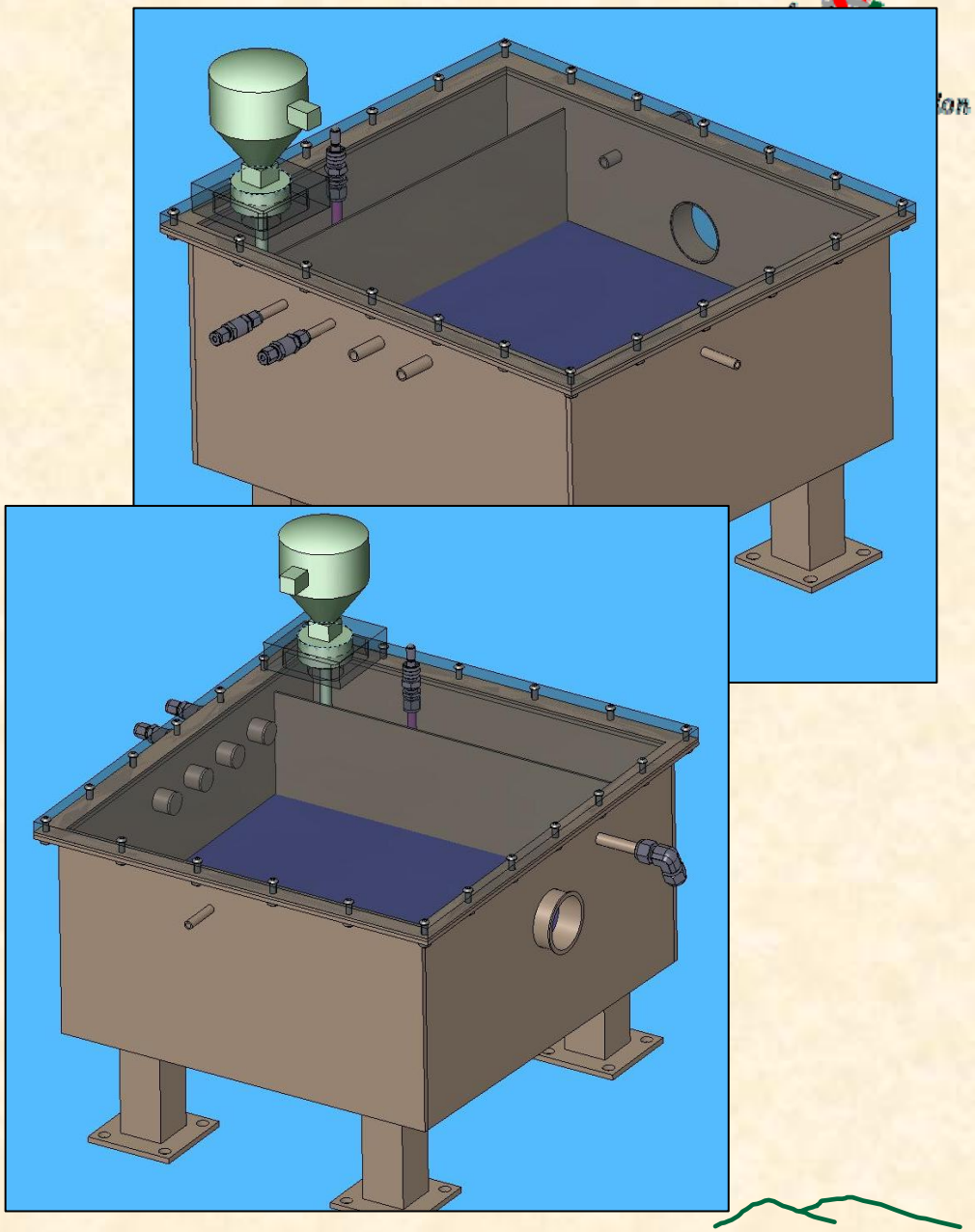
- **Hg jet return path**
  - **1/4-inch plate weldment chamber**
  - **6-inch to 2-1/2-inch eccentric reducer**
  - **2-1/2-inch flex metal hose w/sanitary fittings**
  - **Sump tank**

Normal Syringe Operations

- **Slowly extend cylinder to fill Hg cylinder from sump**
- **Slowly retract cylinder to starting position & prefill Hg supply piping**
- **Some time after trigger is received, ramp cylinder to full speed**
  - **Need engineering solution to prevent possibility of sudden cylinder start – will discuss with syringe vendor**
- **Steady-state jet for 1sec**
- **Ramp cylinder to zero velocity**
  - **Sudden stop can cause flow separation & Hg hammer**

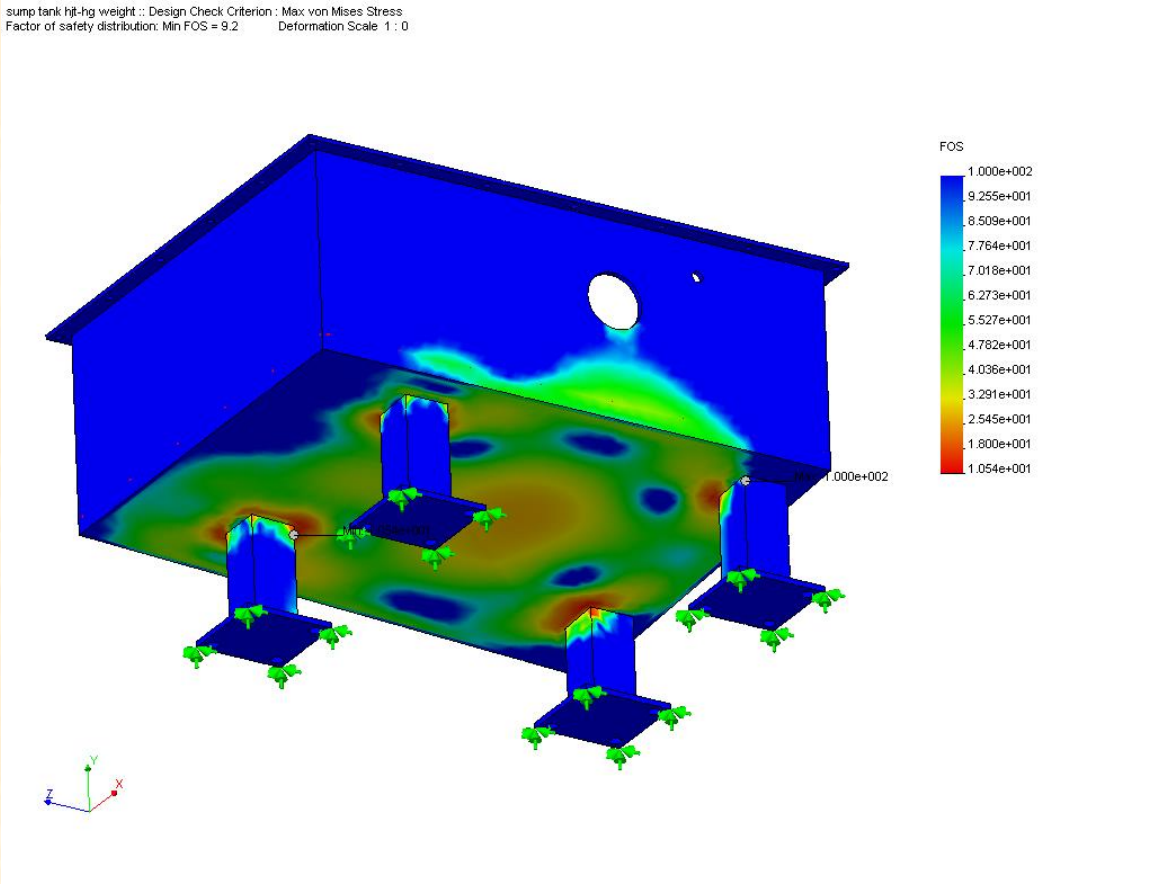
Sump Tank

- **Fabrication: 1/4" plate SS304L/316L**
- **Ports for Hg fill & extraction, Hg level sensor, syringe vents, breather checkvalves, supply line relief**



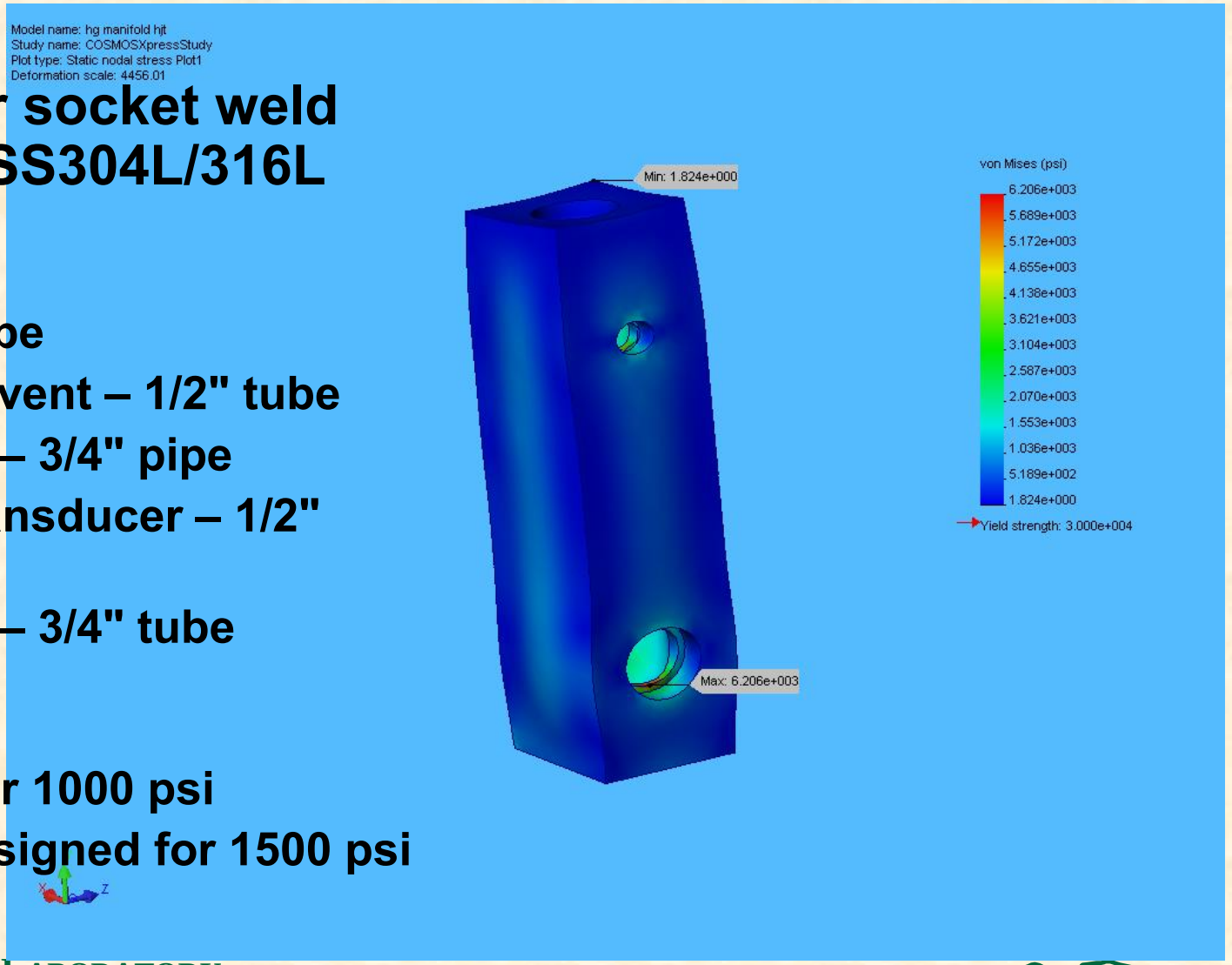
Sump Tank Analysis

- **800-lb Hg load on tank bottom**
- **Min FOS > 9**



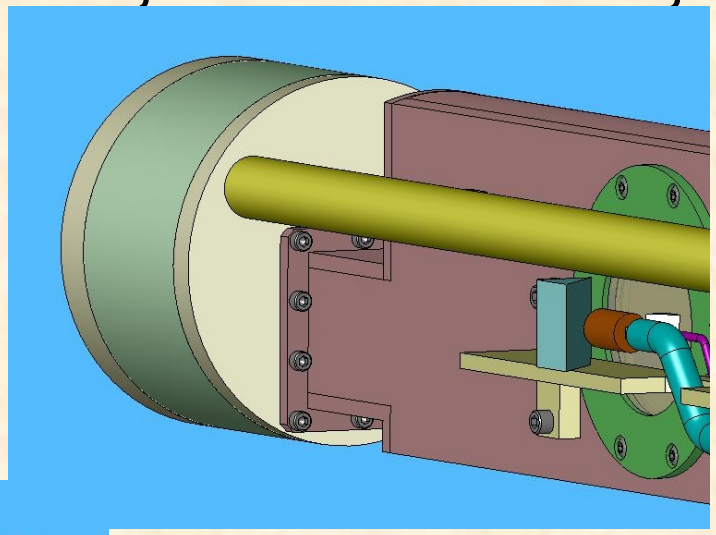
Manifold

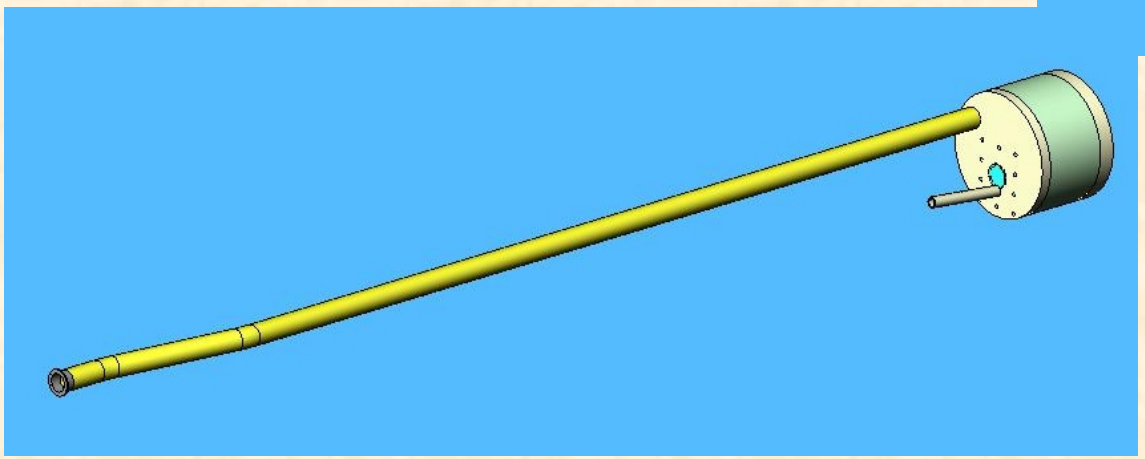
- **Designed for socket weld fabrication, SS304L/316L**
- **Channels**
  - **Flow – 1" pipe**
  - **Hg cylinder vent – 1/2" tube**
  - **Sump drain – 3/4" pipe**
  - **Pressure transducer – 1/2" tube**
  - **Relief valve – 3/4" tube**
- **FEA results**
  - **FOS = 4.8 for 1000 psi**
  - **Will be redesigned for 1500 psi**



Hg Plenum

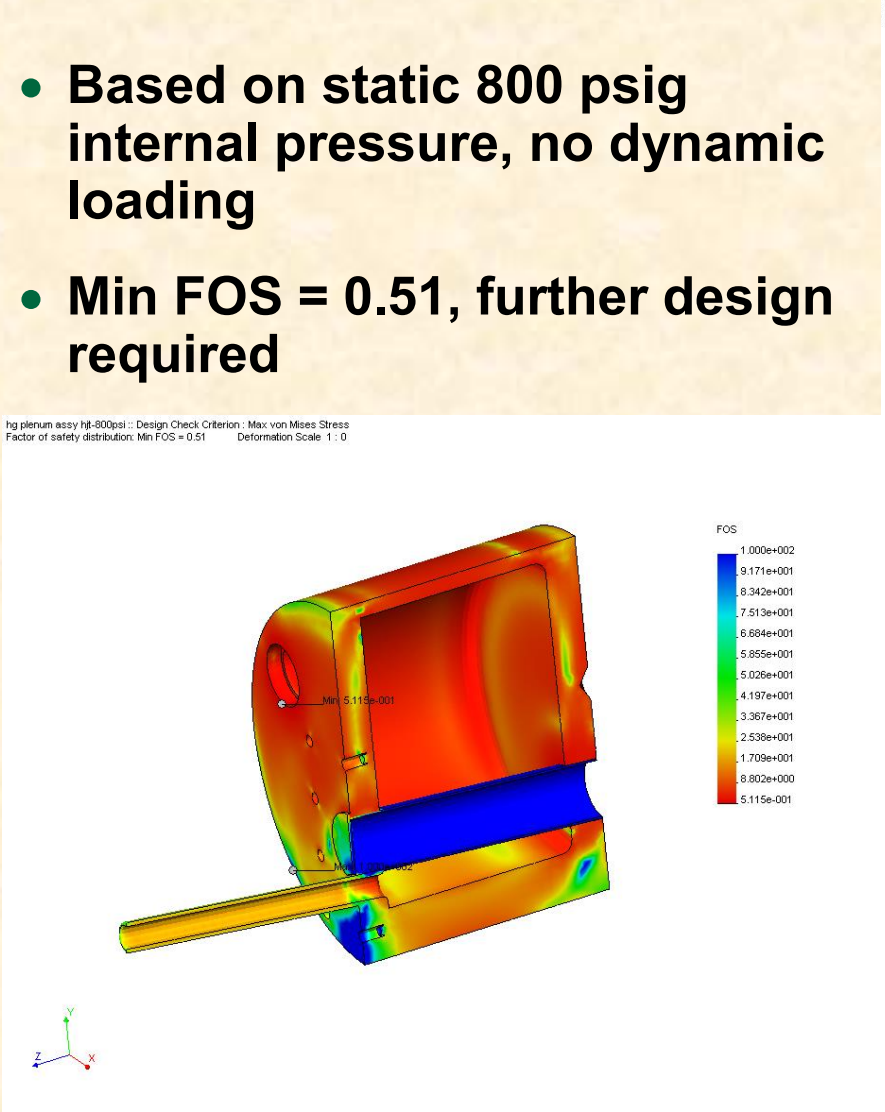
- **Fabrication incorporates nozzle, beam window, and Hg supply tubing**
- **Replaceable module**

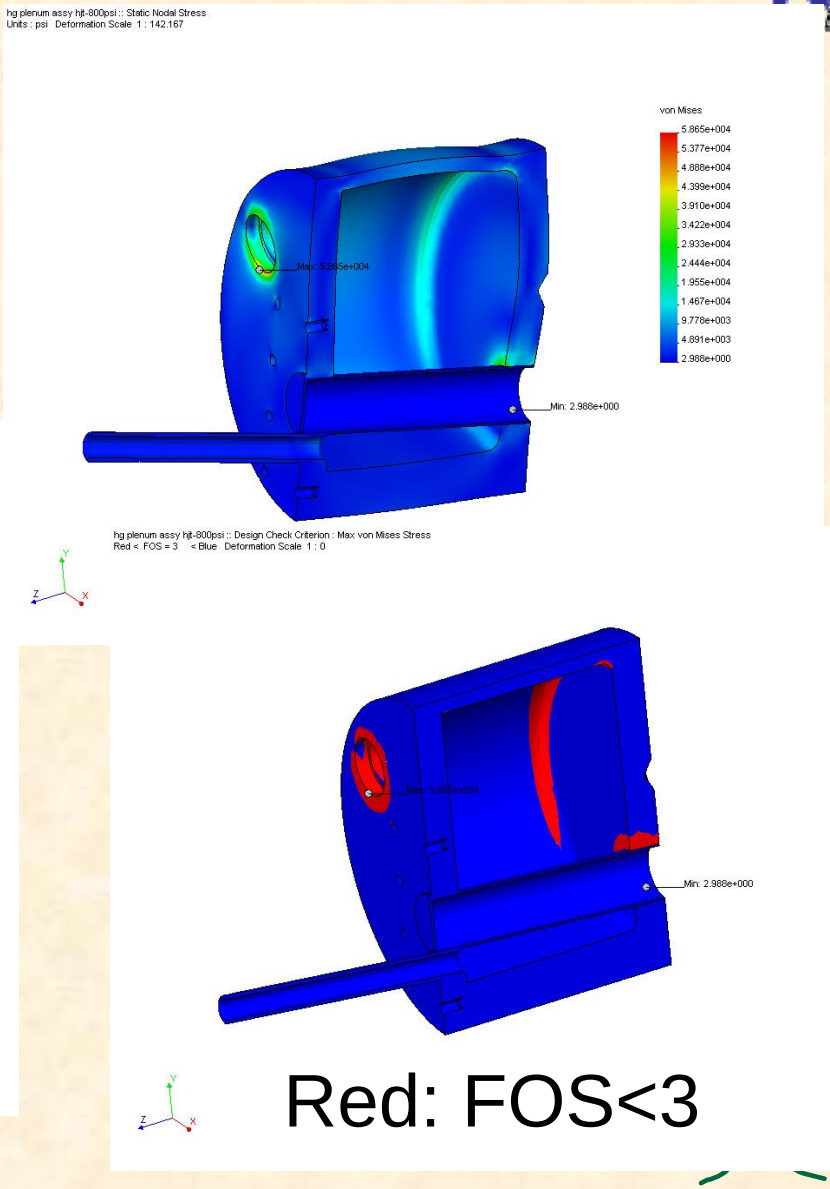




Hg Plenum Analysis

- **Based on static 800 psig internal pressure, no dynamic loading**
- **Min FOS = 0.51, further design required**





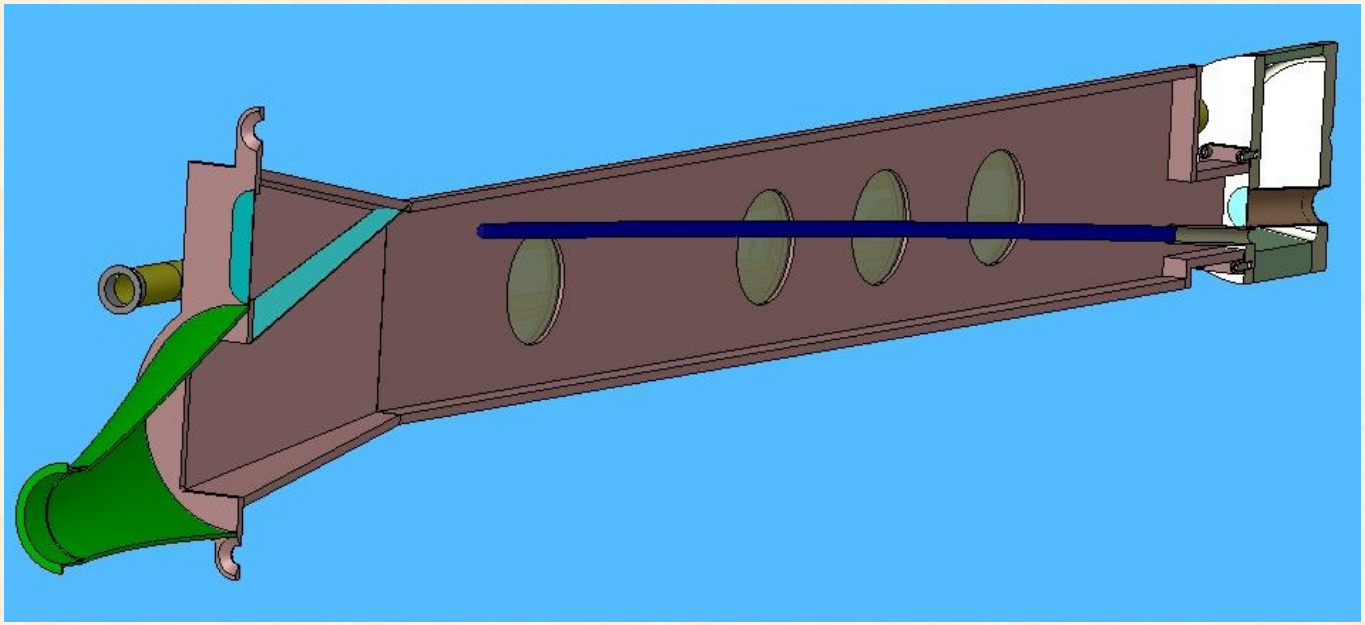
Red: FOS<3

Primary Containment Pressure Ratings

- **Pressure Ratings Table**

Primary Containment Beam Windows

- **Single layer Ti6Al4V, 1mm thick**
- **Hg deflector acts as beam window, made from same material**
- **Horizontal beam kick**
  - **6mm @ primary window**
  - **18mm @ secondary window**
- **Downstream window sized to accommodate horizontal beam kick and small changes in magnet tilt**

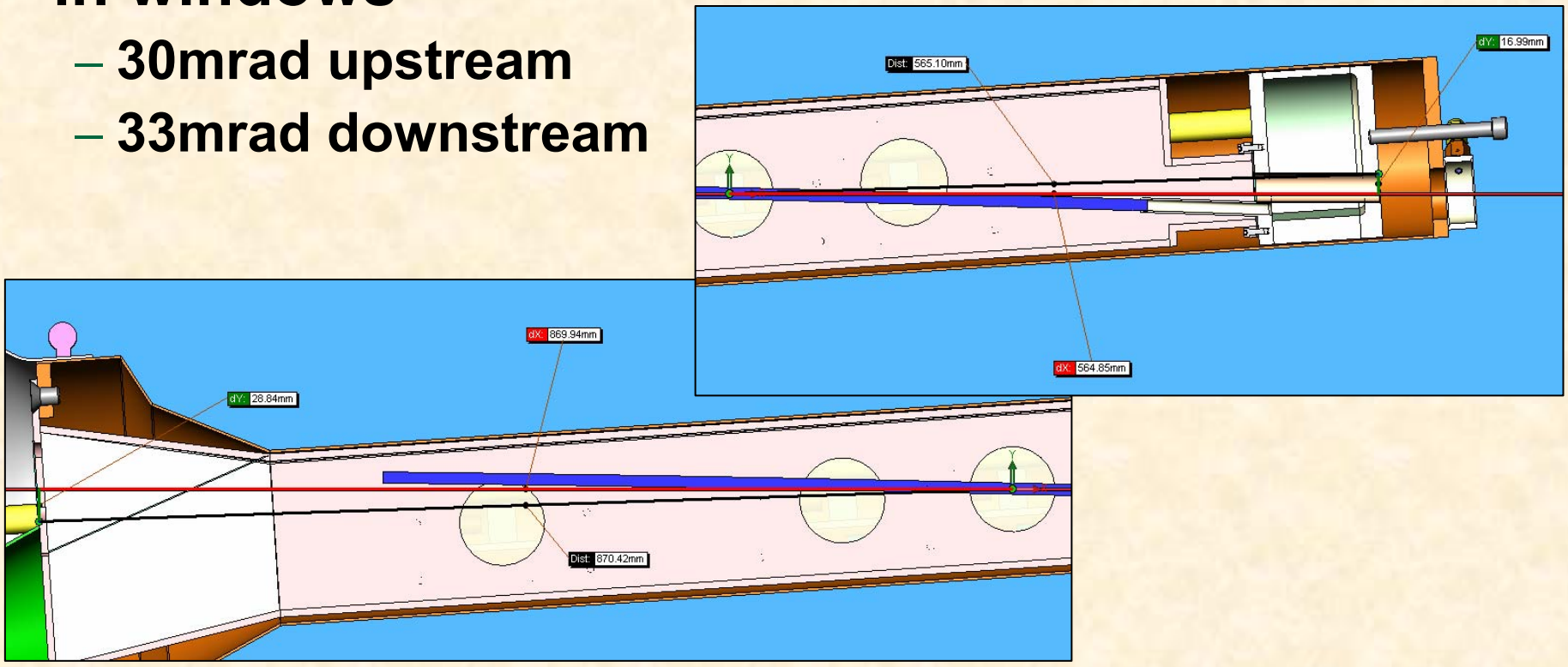


Hg Deflector

- **Simplifying analysis indicates imparted force on plate of 425N (95lb)**
- **Using Ti6Al4V thickness of 1mm gives a safety factor < 1**
- **Recommend deflector thickness of 2mm**
  - **FS = 3.5**

Accommodating Tilt Changes

- **Hg delivery system can accommodate some amount of decreasing tilt angle and keep beam in windows**
  - **30mrad upstream**
  - **33mrad downstream**

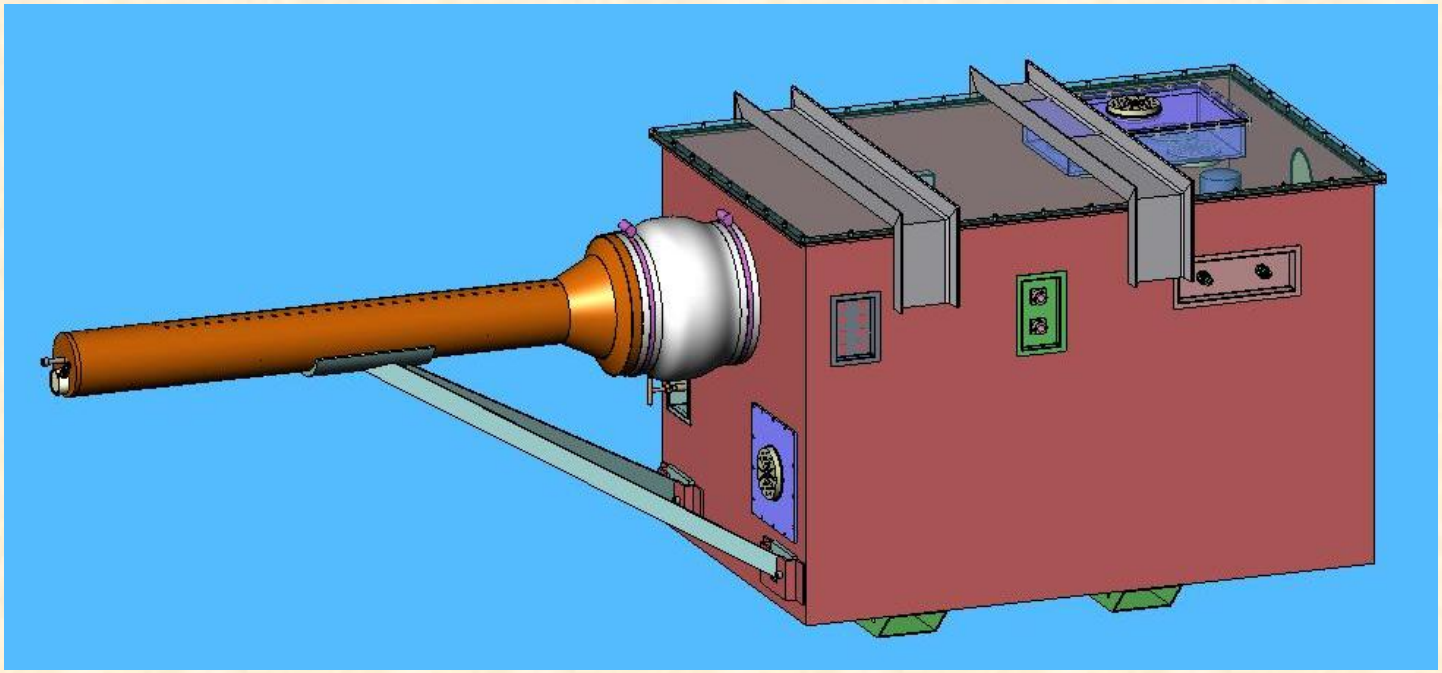


Beam Window Fabrication Issues

- **Do not have definitive answer to question of weldability between Ti6Al4V and SS304L/316L**
- **If reliable process is found, it likely will require some development by fabricator to establish welding parameters**
  - **Material samples and added cost**
- **Can windows be SS316L/304L?**

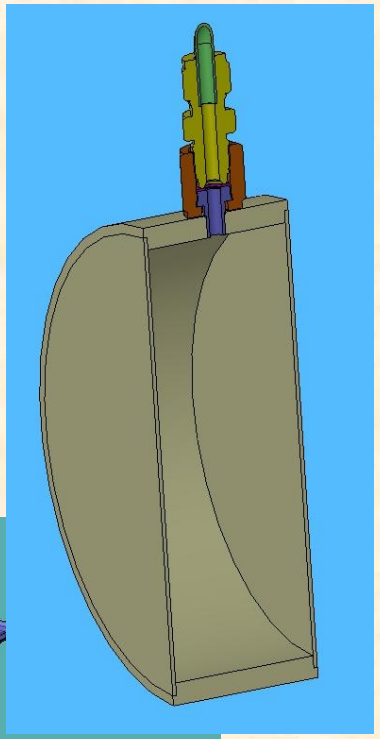
Secondary Containment

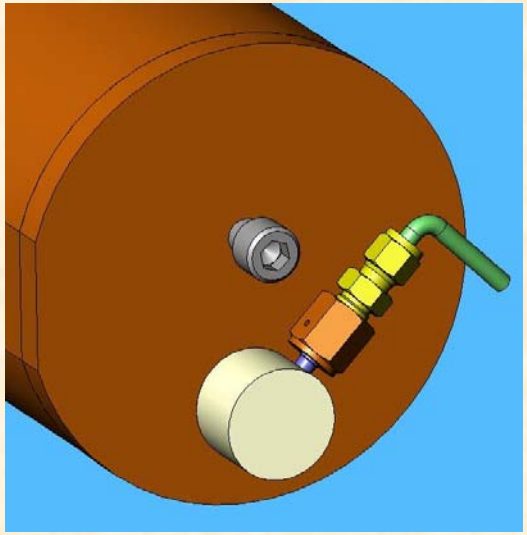
- **SS304L/316L 1/2" bottom plate, 1/4" front, sheet metal sides & back (7ga, 0.179")**
  - **May add stiffeners to sides & back**
- **Flexible sleeve (non-metallic, combustibility issue)**
- **SS304L/316L cylindrical sleeve (13ga, 0.089")**
- **Passive filtration**
  - **Filtered inlet and outlet, both will be have shutoff gates**

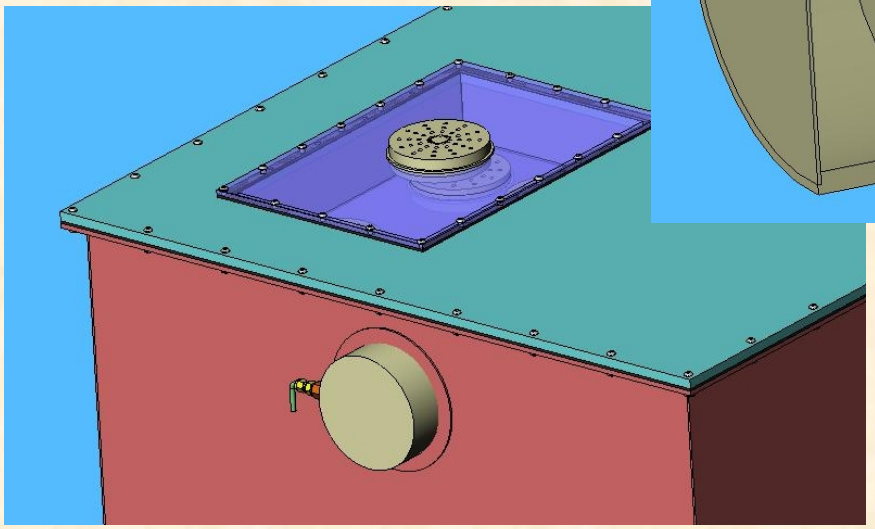


Secondary Containment Double Beam Windows

- **Similar in construction to Hg plenum**
- **SS pipe with Ti6Al4V caps**
  - **All Ti if necessary, but attachment to secondary containment still an issue**
- **Flexible tubing back to hydraulic system**
- **Pressurize and monitor to detect failure**
  - **Can also vacuum monitor, but pump and larger tubing required**
  - **Will test at ORNL, determine final method**

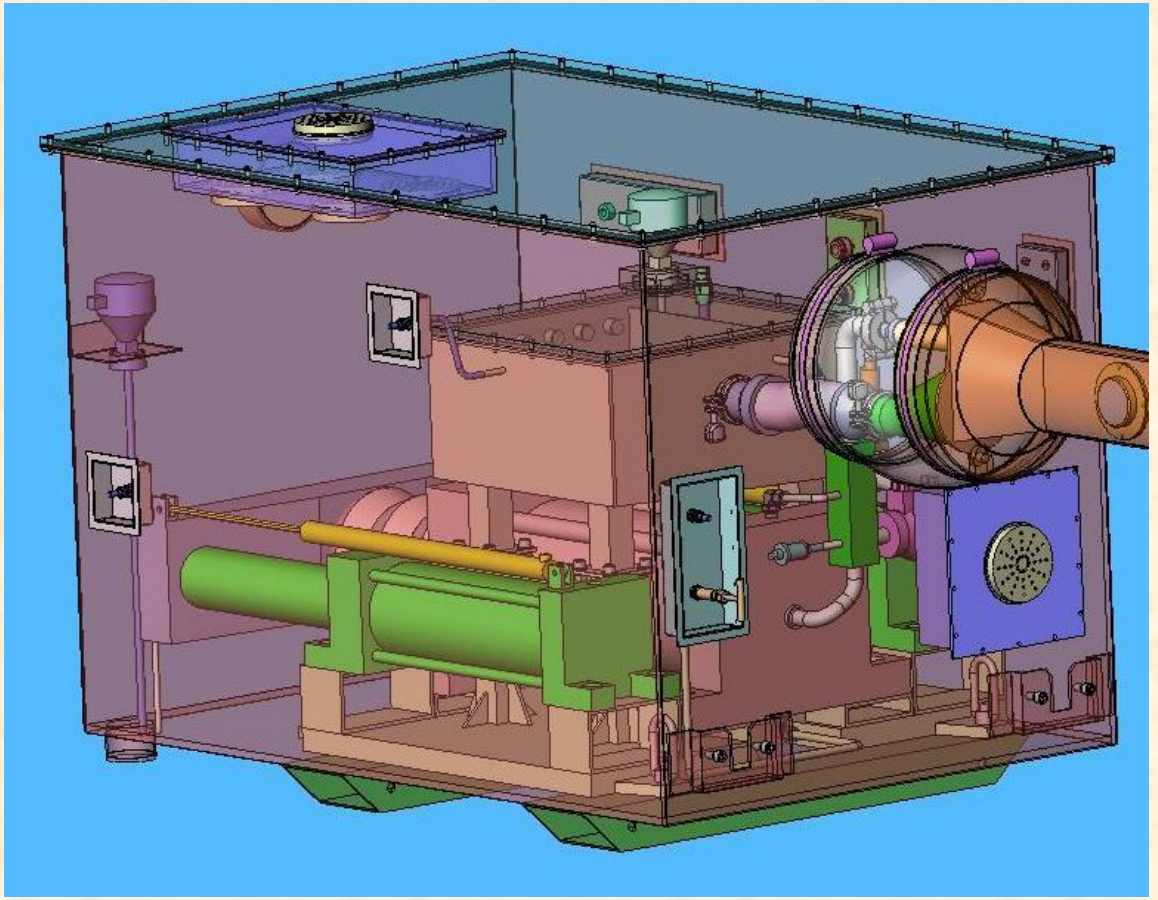






Secondary Containment Access Ports

- **Optical diagnostics**
- **Instrumentation**
- **Hydraulics**
- **Hg drain & fill (without opening secondary)**
- **Hg extraction (in event of major leak in primary containment)**



Secondary Containment Monitoring and Filtering

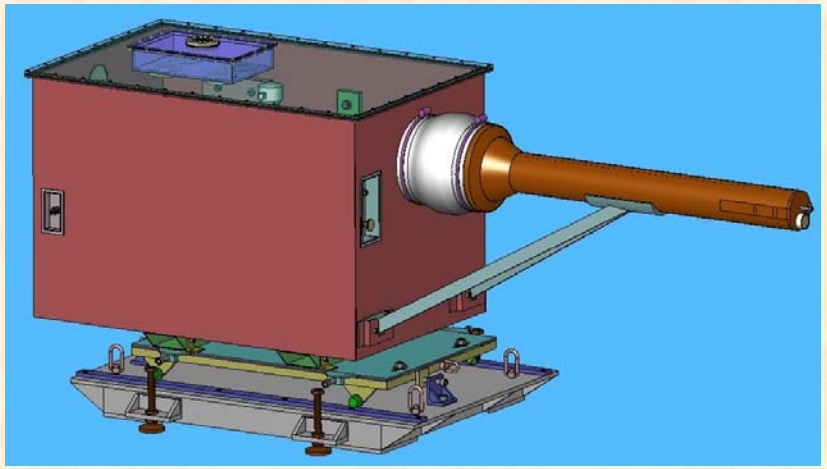
- **Two Hg vapor monitors for secondary volume**
- **Passive filtration with shutoff, can connect to active filtration system**
  - **Will have single cartridge rather than respirators**
- **Third vapor monitor for passive filter exhaust and/or tunnel monitoring**
- **Investigating whether monitors can be moved away from experiment**

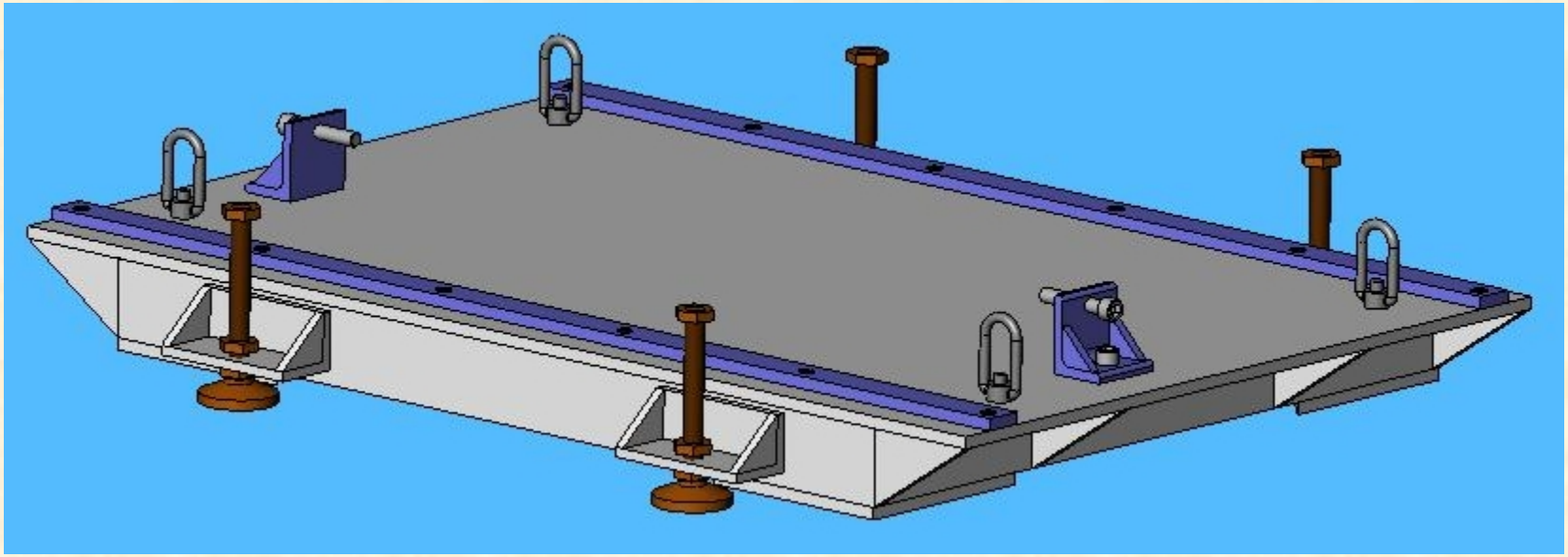
Baseplates

- **Purpose – provide mobility, alignment, and structural support for experiment components**
  - **Experiment requires magnet tilt of 66mrad (3.8°)**
- **Two baseplates**
  - **Target transporter**
  - **Common baseplate**

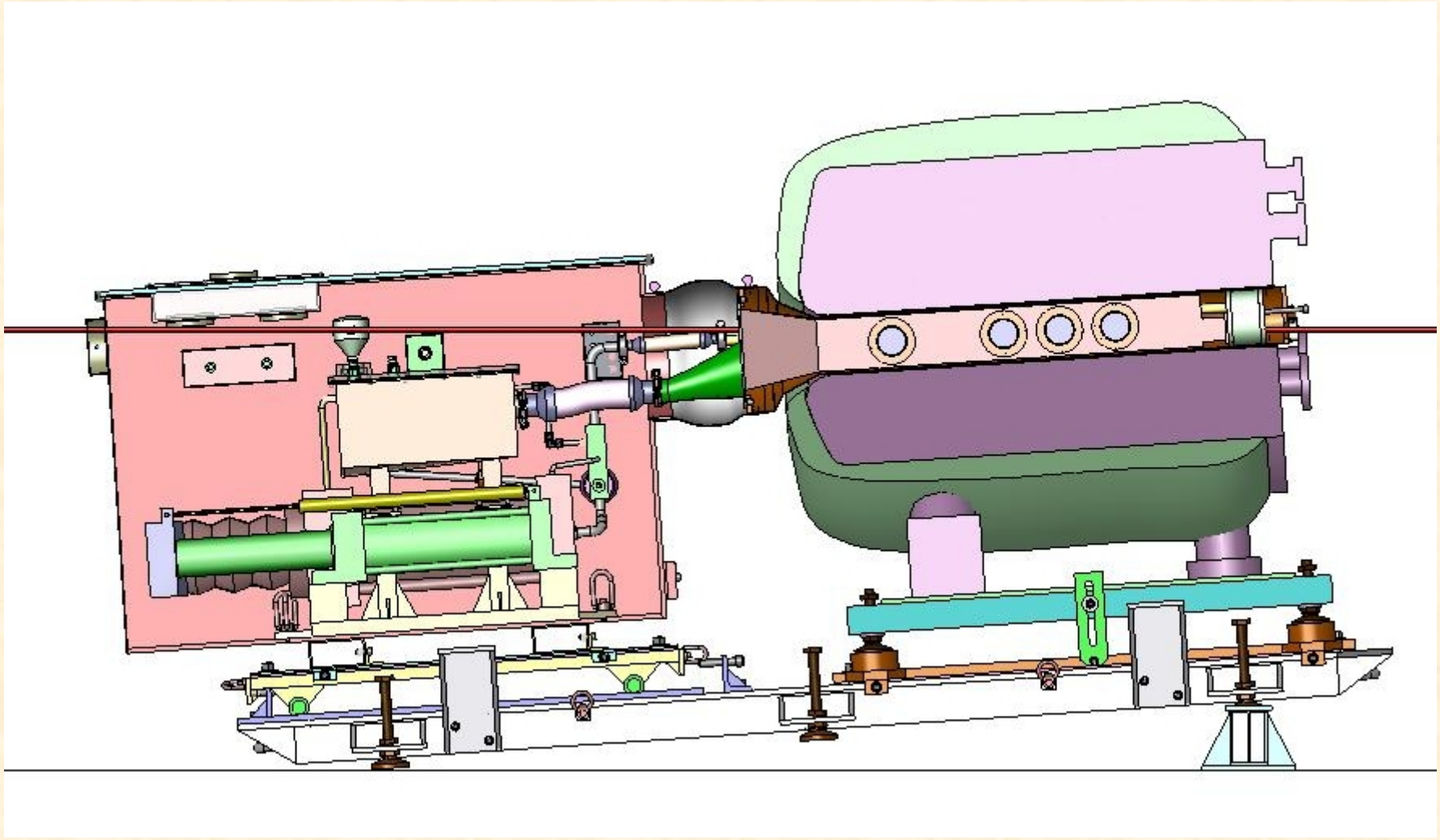
Target Transporter

- **Transports Hg system inside tunnel using Hilman rollers**
  - **O/A length 62" (1.6m)**
- **Rails for Hg system cart wheels**
- **Jack bolts prevent rolling**
- **Swivel hoist rings for lifting & cart tie-down**
- **Material: AL6061-T6**



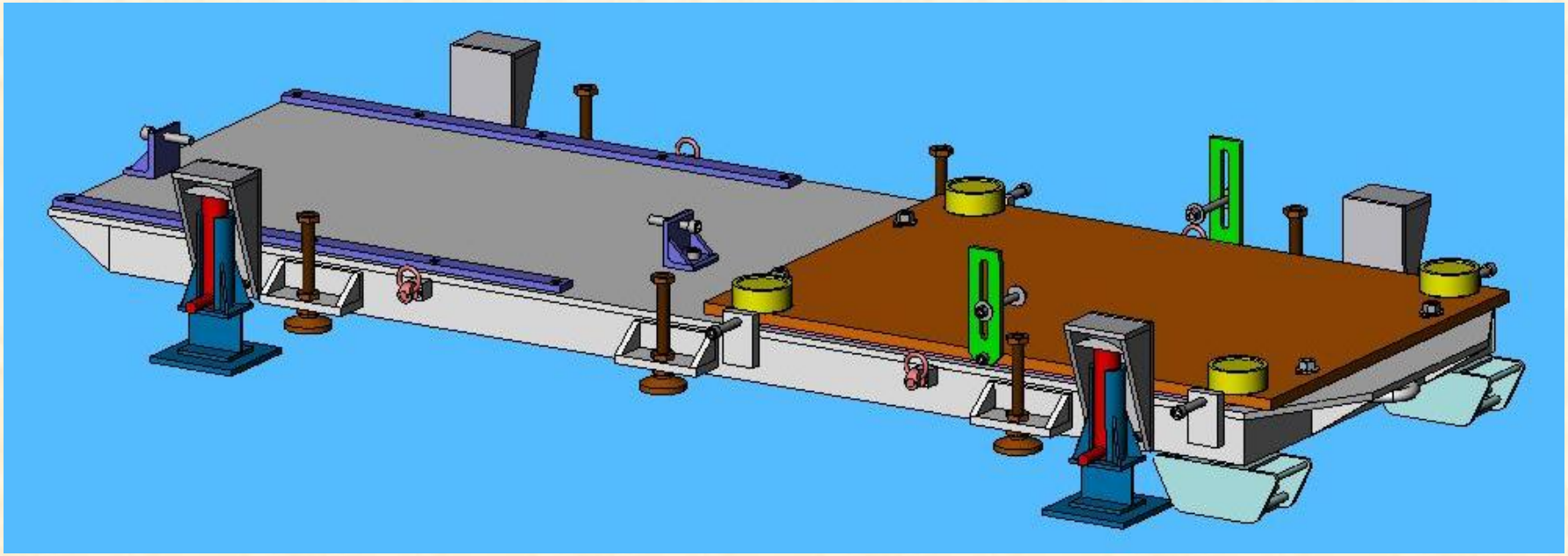


MERIT Side View



Common Baseplate

- **Shares design with transporter baseplate**
  - **O/A length 124" (3.15m)**
- **Rollers used to grossly align solenoid to beam**
- **Provides lateral movement of solenoid for alignment to beam once rollers removed**

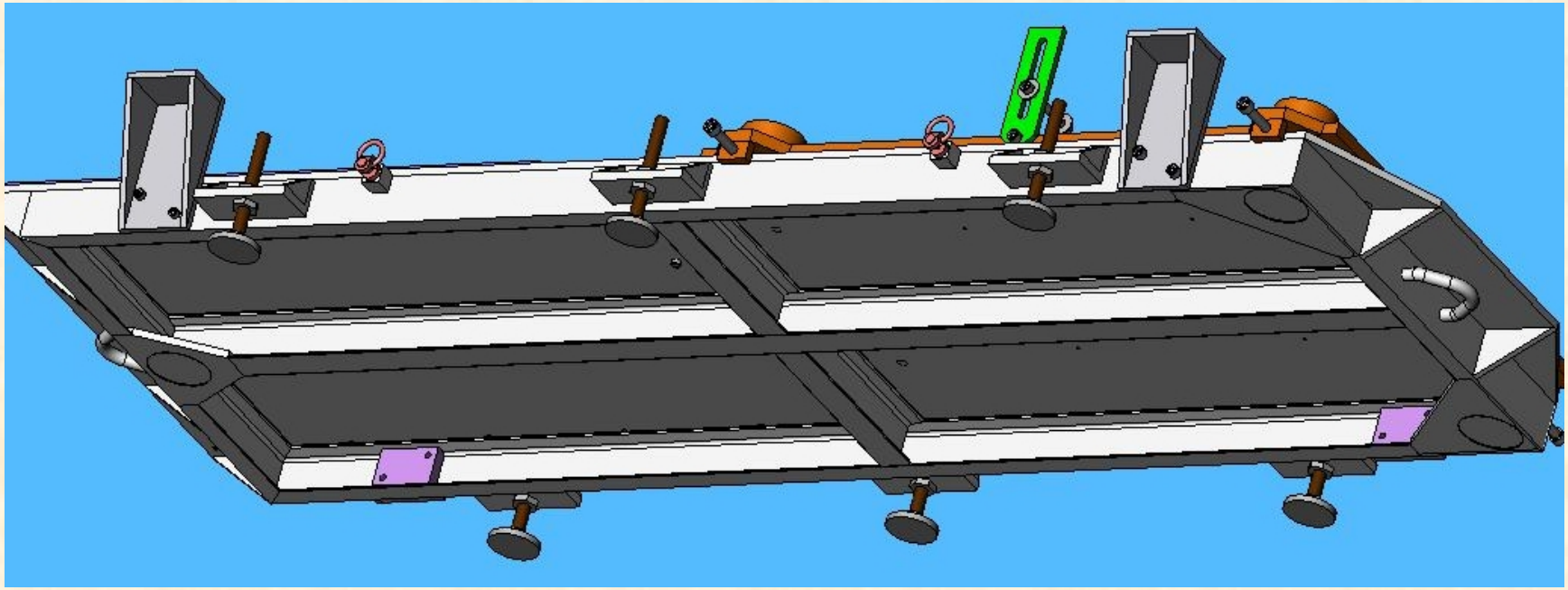


Design Constraints & Requirements

- **Total supported weight**
  - **Magnet: 9000 lbs**
  - **Hg System with 23liter Hg: 4000 lbs**
  - **Baseplate: 1000 lbs**
  - **Movement requires lateral force of 700 lbs (μ_s = 0.05 per Hilman)**
- **Maximum width of 1.3m (51") to meet CERN facility constraints**
- **Fabrication material to be non-magnetic (chose AL 6061-T6)**
- **Must have lifting & leveling provisions**
- **Currently not anchored to floor – is there a need?**

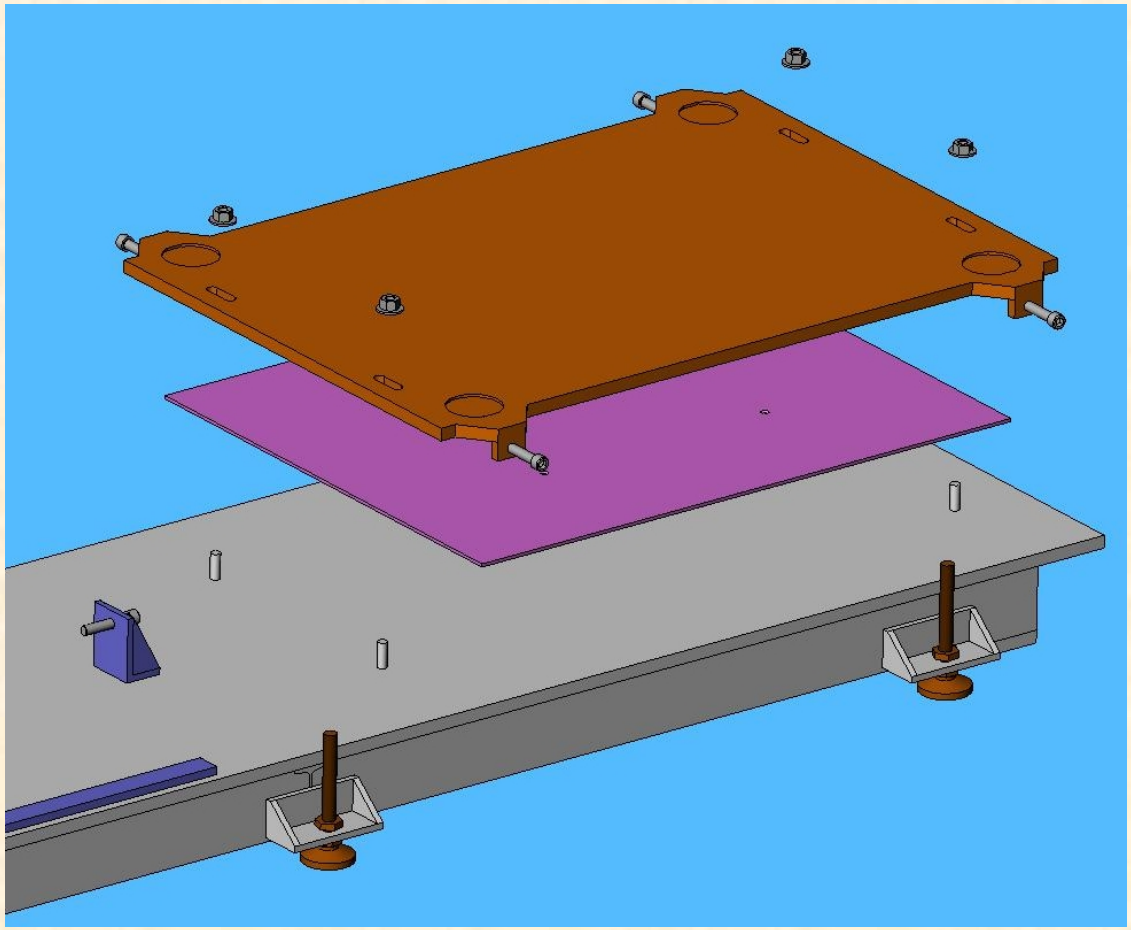
Common Baseplate Structure

- **4-inch AL channel frame, I-beam internal supports**
- **Hilman roller support plates**
- **Welded leveling jack gusset plates**
- **Side-load swivel hoist rings for lifting**
- **Removable jack stand gussets**



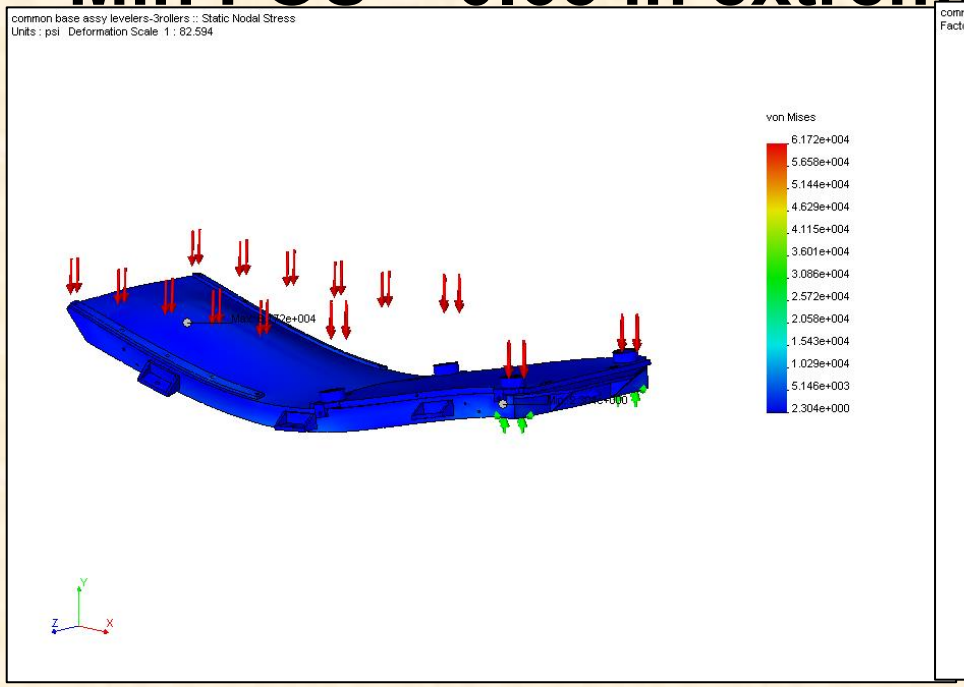
Magnet Lateral Alignment

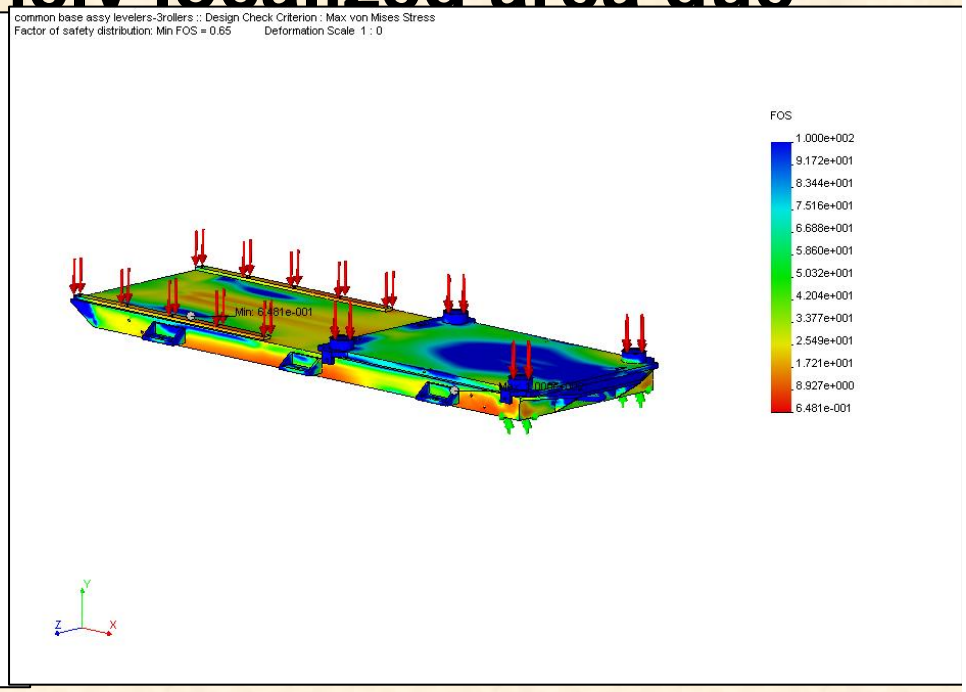
- **Gross adjustment provided by Hilman rollers**
- **Low-friction surface plate sits between magnet support plate and baseplate**
- **Weld studs with nuts hold final position**
- **Jackbolts provide lateral moving force**
- **Lateral adjustment range ±25mm**



Common Baseplate Structural Analysis – 3 Rollers

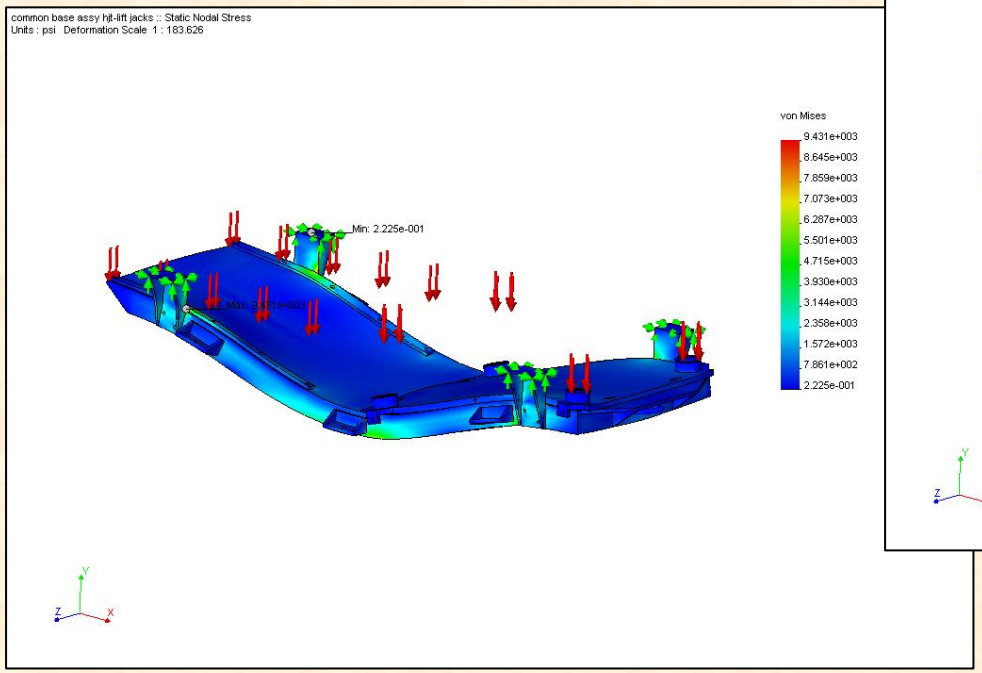
- **Condition: loaded baseplate carried by 3 Hilman rollers**
- **Min FOS = 0.65 in extremely localized area due**

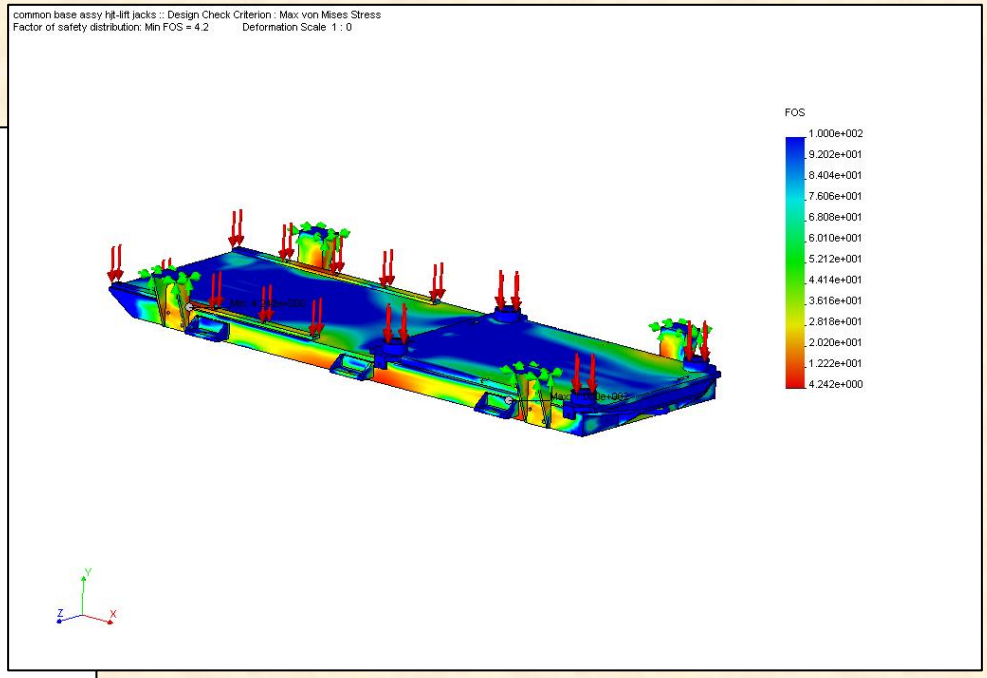




Common Baseplate Structural Analysis – 4 Lift Jacks

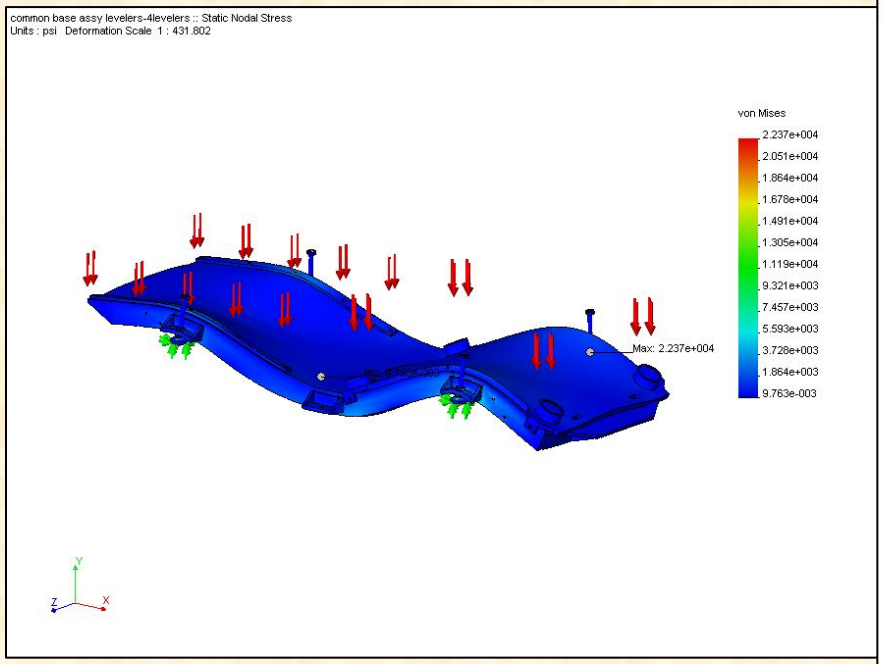
- **Condition: loaded baseplate supported by 4 hydraulic jacks**
- **Min FOS>4**

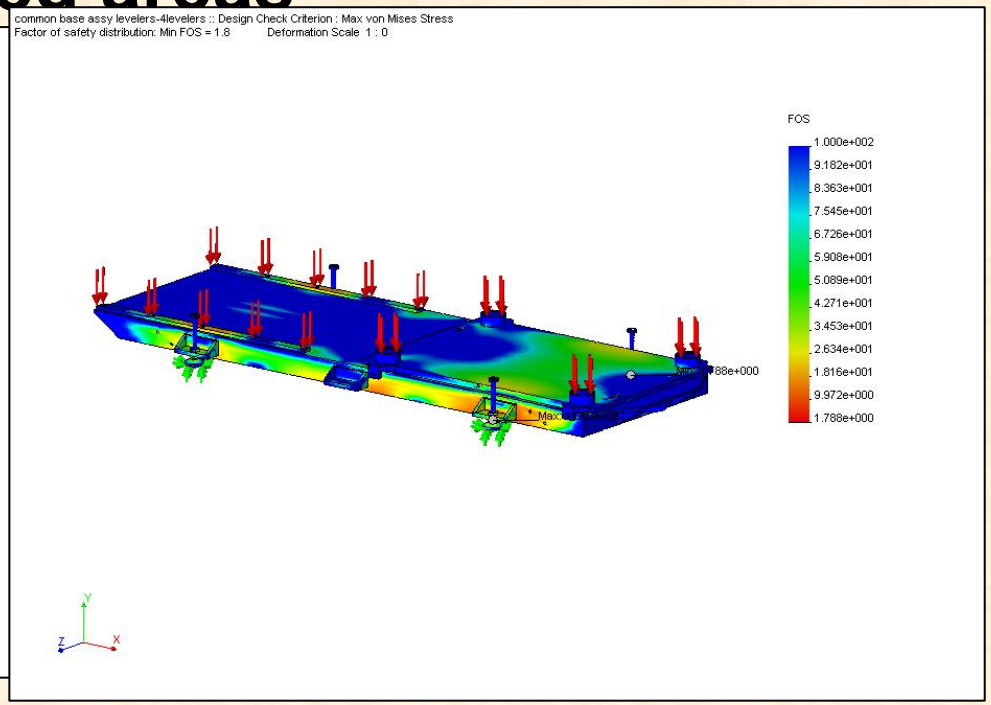




Common Baseplate Structural Analysis – 4 Leveling Jacks

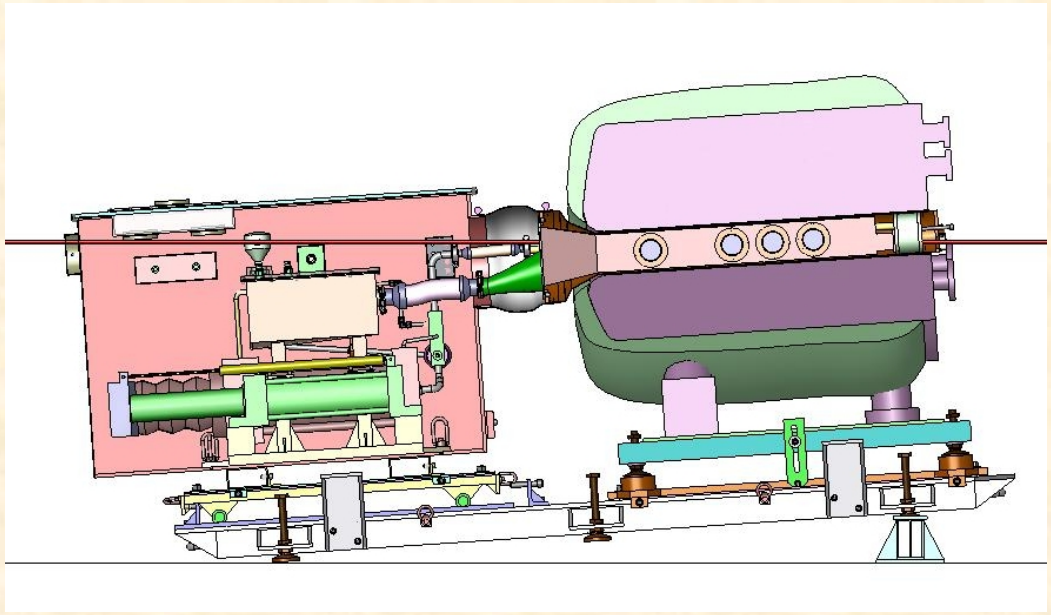
- **Condition: loaded baseplate supported by 4 leveling jacks**
- **Min FOS=1.8 in localized areas**





Some Final Design Details

- **Some dimensions of Hg delivery system can't be finalized until syringe design is complete**
- **Will need magnet as-built height on its base**



Remaining Design Work

- **Finalize procured component details for drawings**
- **Drawing check**
- **Sensor / instrumentation wiring diagram**
- **Generate fabrication vendor list**
- **Write procurement specification**

Design Issues

- **Nozzle configuration – plenum vs non-plenum**
- **Nozzle details – length, exit features**
- **Final dimensions for syringe system, magnet height**