HAWC CDR

Cryostat

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HAWC Cryostat Features

- **Vapor cooled He^4 cryostat**
  - One reservoir for LHe (no LN_2 reservoir required)
  - Two vapor cooled shields (Outer Vapor Cooled Shield (OVCS) and Inner Vapor Cooled Shield (IVCS))
- **Reservoir design to accommodate Adiabatic Demagnetization Refrigerator (ADR) assembly**
- **Coaxial Fill/Vent tube assembly**
- **Indium seal for ADR insert and fill tube at reservoir**
- **Spring tensioned, adjustable Kevlar straps for He-cooled assembly**
- **G-10 fiberglass laminate tabs/links for vapor cooled shields**
- **Polyethylene window**
- **All materials Aluminum 6061- T6 except coaxial necktube which will be 304 stainless steel and the suspension components, which are made of G10, Kevlar, and stainless steel**
- **Cryostat will be designed and built in accordance with "*SOFIA FAA Certification Procedures Manual*" (Section 300) and other applicable guidance**

Cryostat Components

Adiabatic demagnetization refrigerator (ADR)

Opto-mechanical system (OMS)

Fill and vent tube **GSFC**

Instrument mounting flange **UC**

Cryostat vacuum shell (CVS)

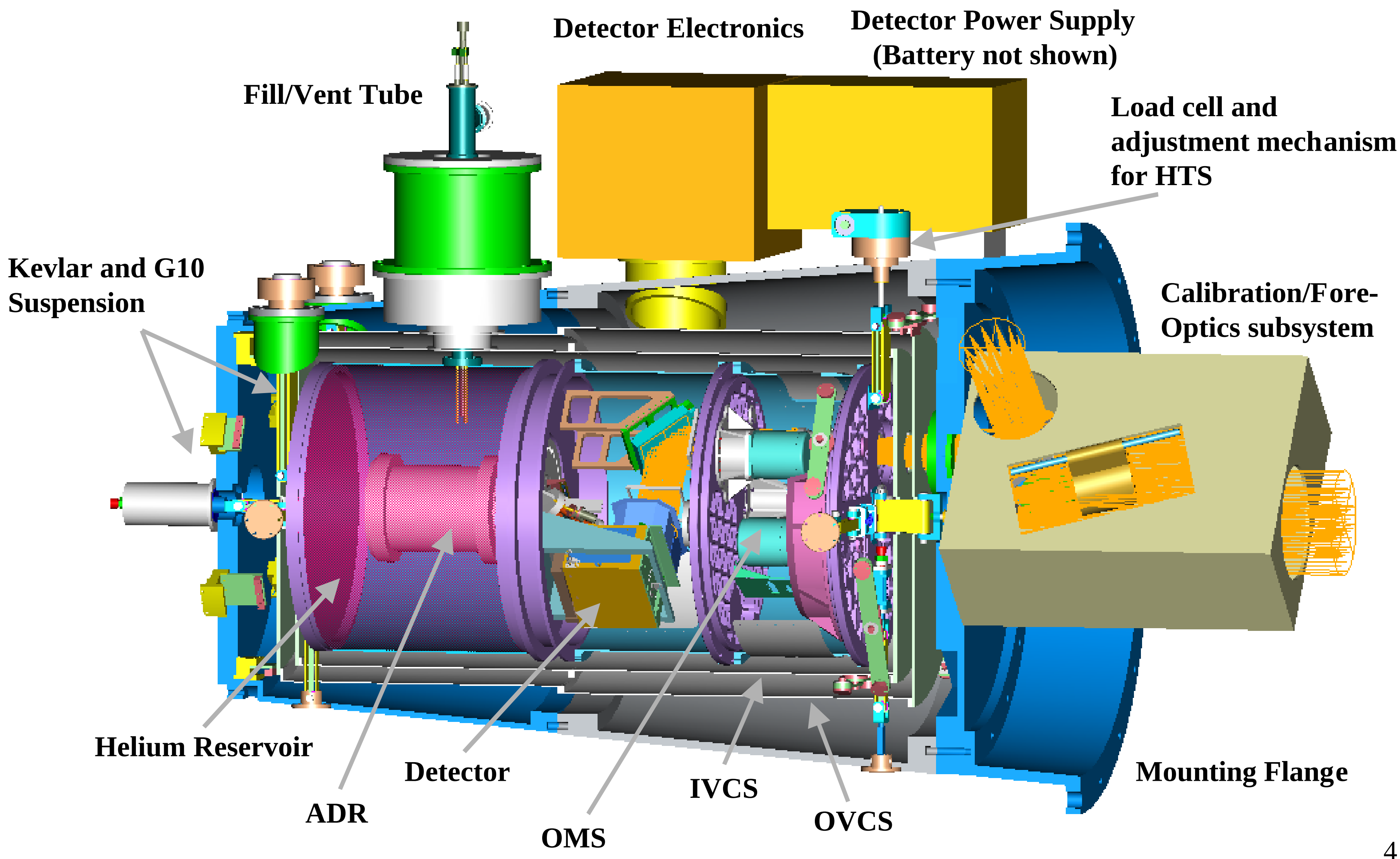
Polyethylene cryostat window

Vapor cooled shields and G-10 suspension

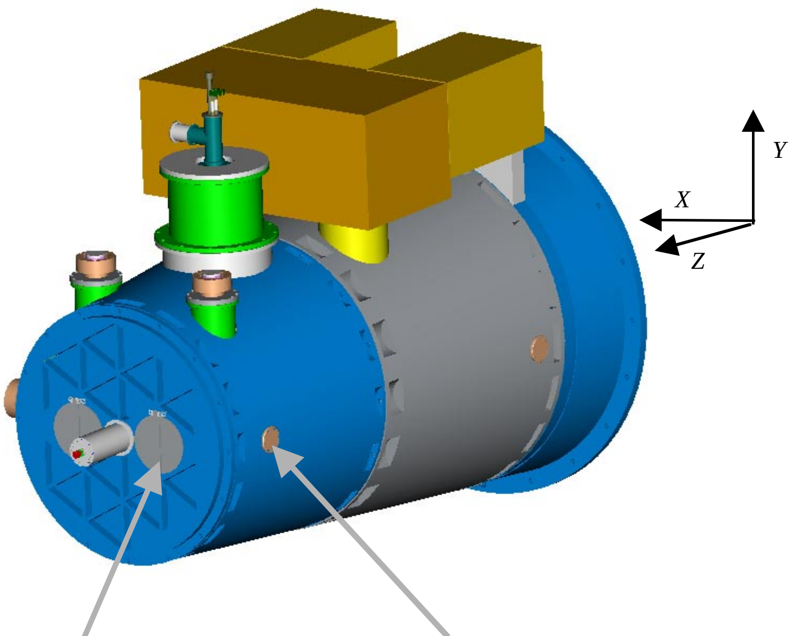
Helium thermal strap (HTS) Kevlar suspension system

Helium reservoir

HAWC Cryostat (cutaway)



HAWC Cryostat (full)



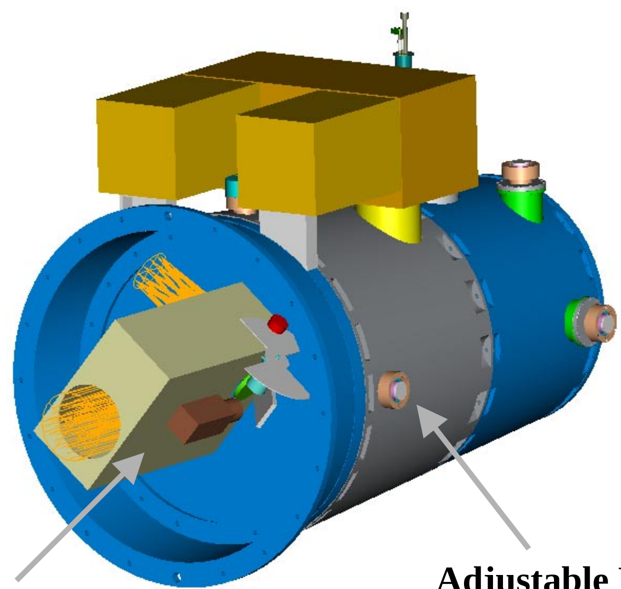
Cryostat pressure reliefs

Flush HTS mounts

Instrument mass properties:

1322 lbm

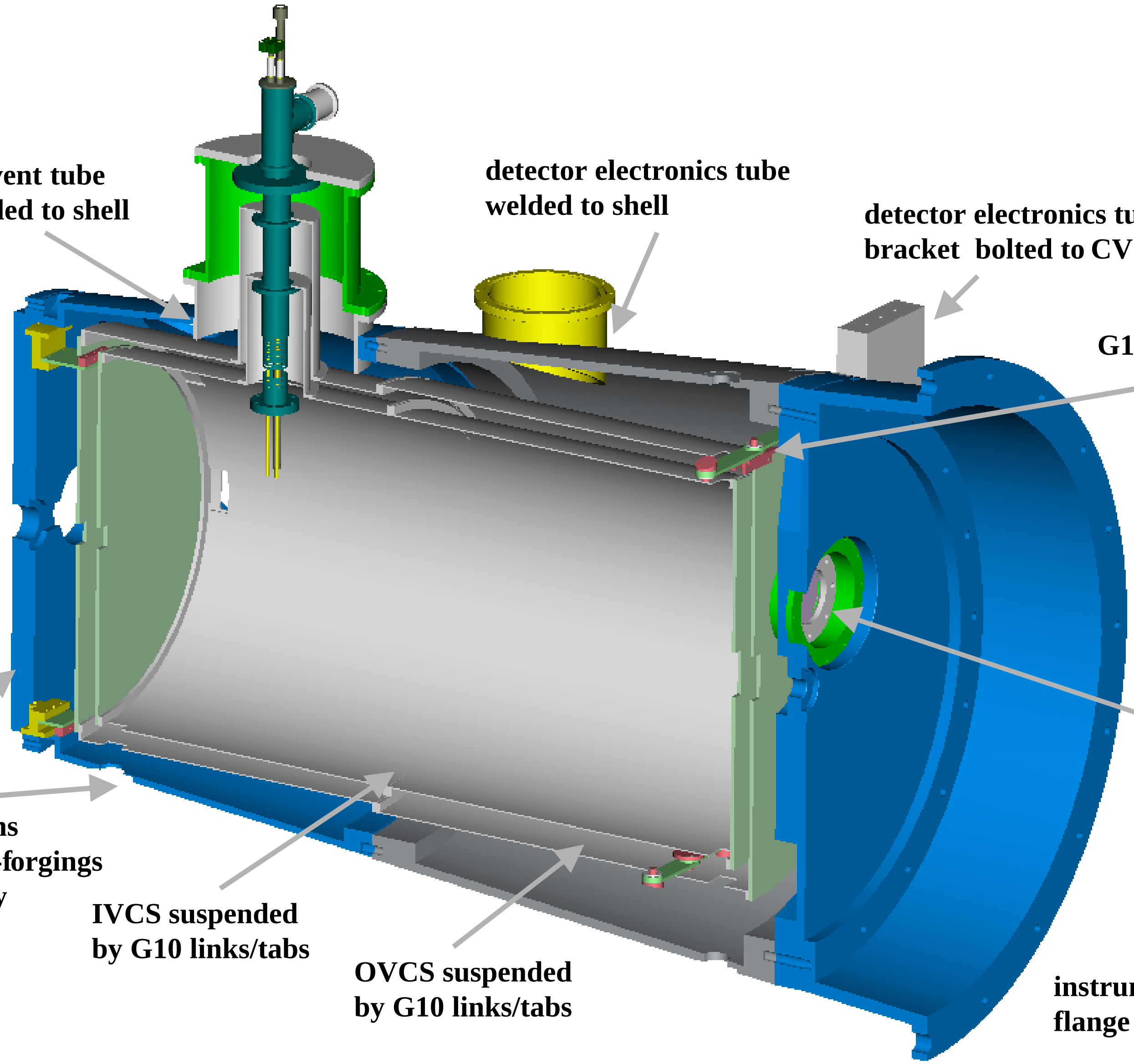
Center of Gravity = (0.2, 4.5, 27.1) inches



Fore optics / external calibration

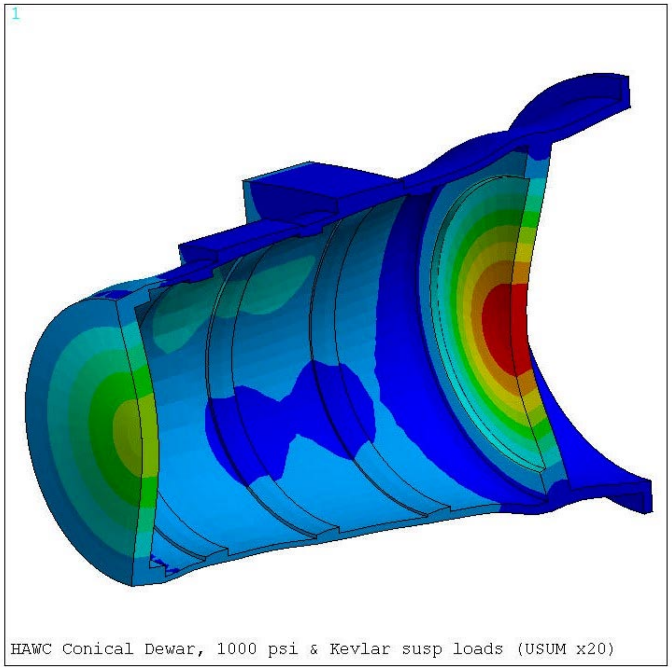
Adjustable HTS mechanism

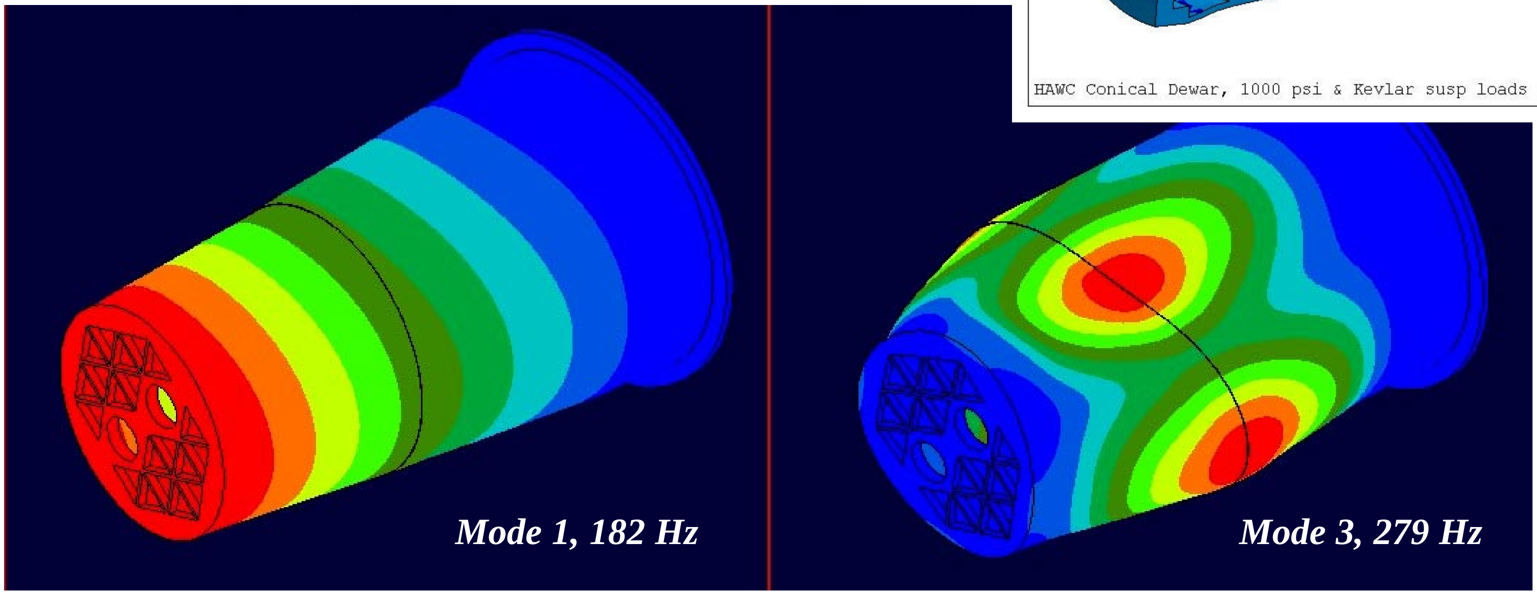
HAWC Cryostat (cutaway)



Cryostat Performance

- **Cryostat is a stiffness-driven design**
- **Inherently strong**
- **Shape optimized to achieve high natural frequency and fit within dynamic envelope**

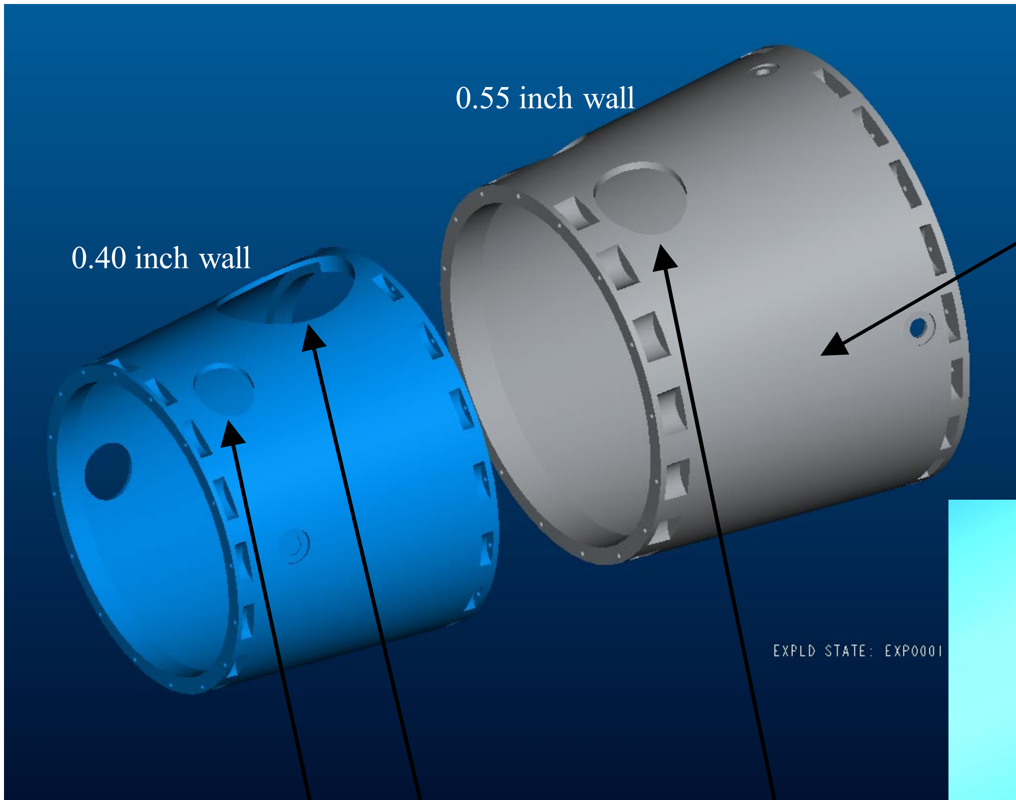




HAWC Weight

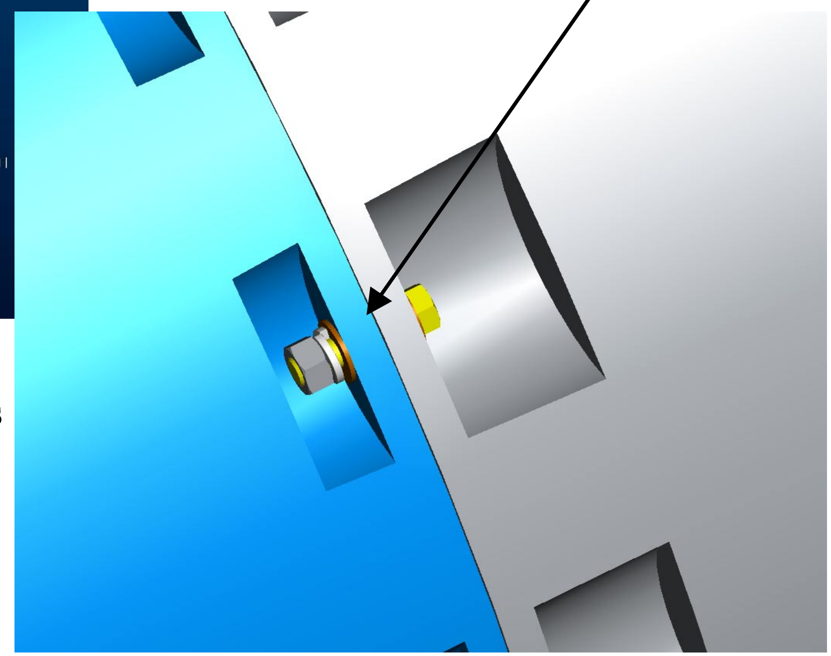
sub-assembly	"as designed" mass (lbm)	
HIMF	109	Mass reduction (40-50 lbm) possible with a corresponding reduction in natural freq. (HIMF–CVSFC)
CVSAC	116	
CVS1	200	
CVS2	103	
CVSFC	53	
OVCS	46	
IVCS	38	
He reservoir	52	
OMS	115	
HTS system	75	
G10 system	10	
Detector	15	
Internal optics	15	Design detail may lead to increase
ADR	70	Design estimate at about 50 lbm
Fill tube sys	24	
Detector electronics	213	Design estimate around 150 lbm
External calib. sys	48	Design detail may lead to increase (External calib. sys, Misc. hardware)
Misc. hardware	20	
HAWC total	**1322**	Goal for total weight after final Refinement of design is 1200 lbm
% budget	100%	

Cryostat section joints



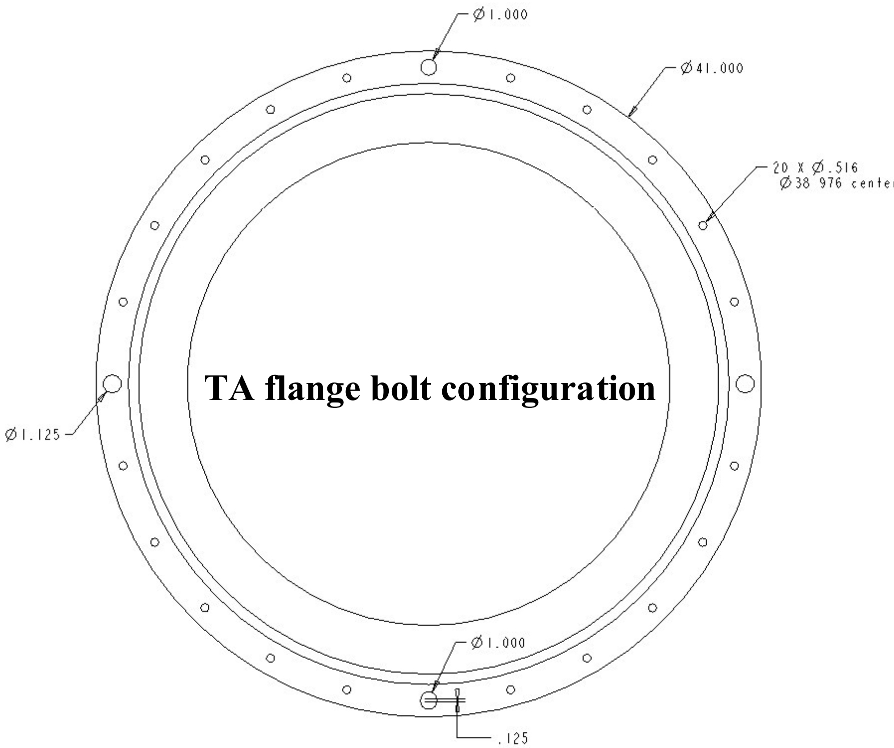
Ring-forged cylinders with machined detail

External hex cap screws with washers, lock washer, and hex nut



Holes for welding support tubes **HTS, Fill/vent, & Detector Electronics**

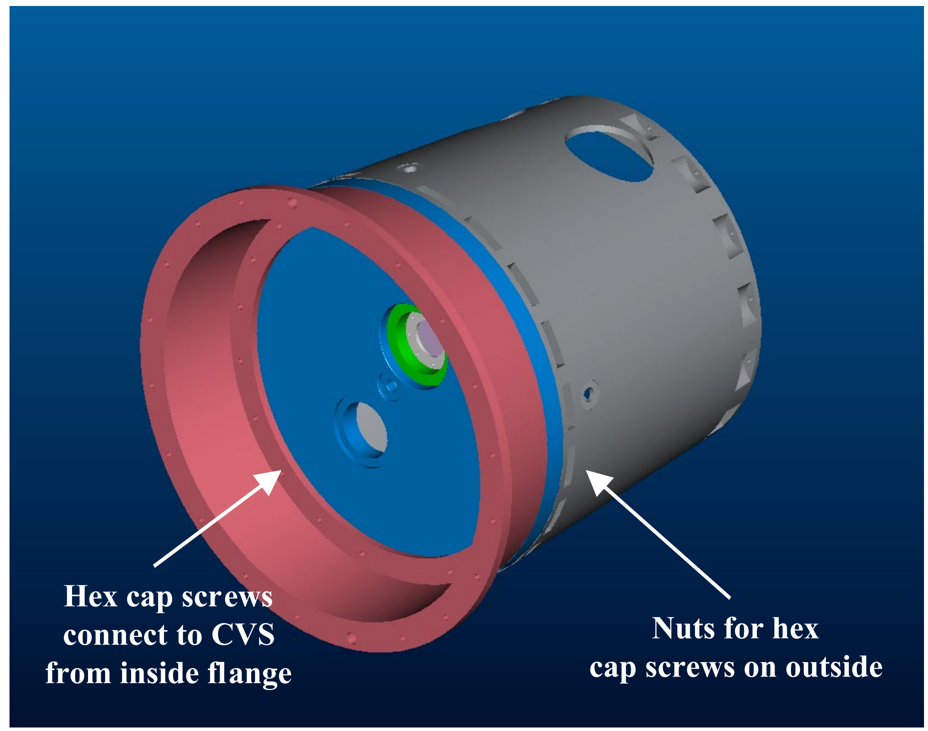
Mounting flange



Only 12:00 pin and 6:00 slot will be used, along with 20 bolts, to align and restrain instrument

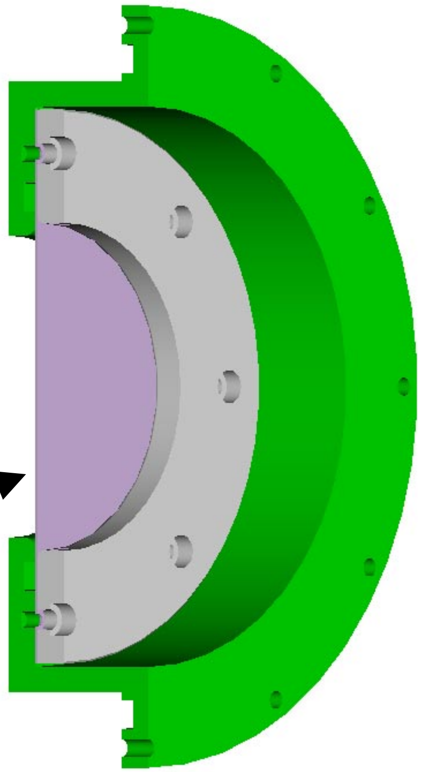
Connection with CVS:

- Hex cap screws through CVSAC to CVS1
- Each screw sealed separately to contain cabin pressure
- Vacuum o-ring seal within screw diameter



Cryostat Window

All bolted joints in compression

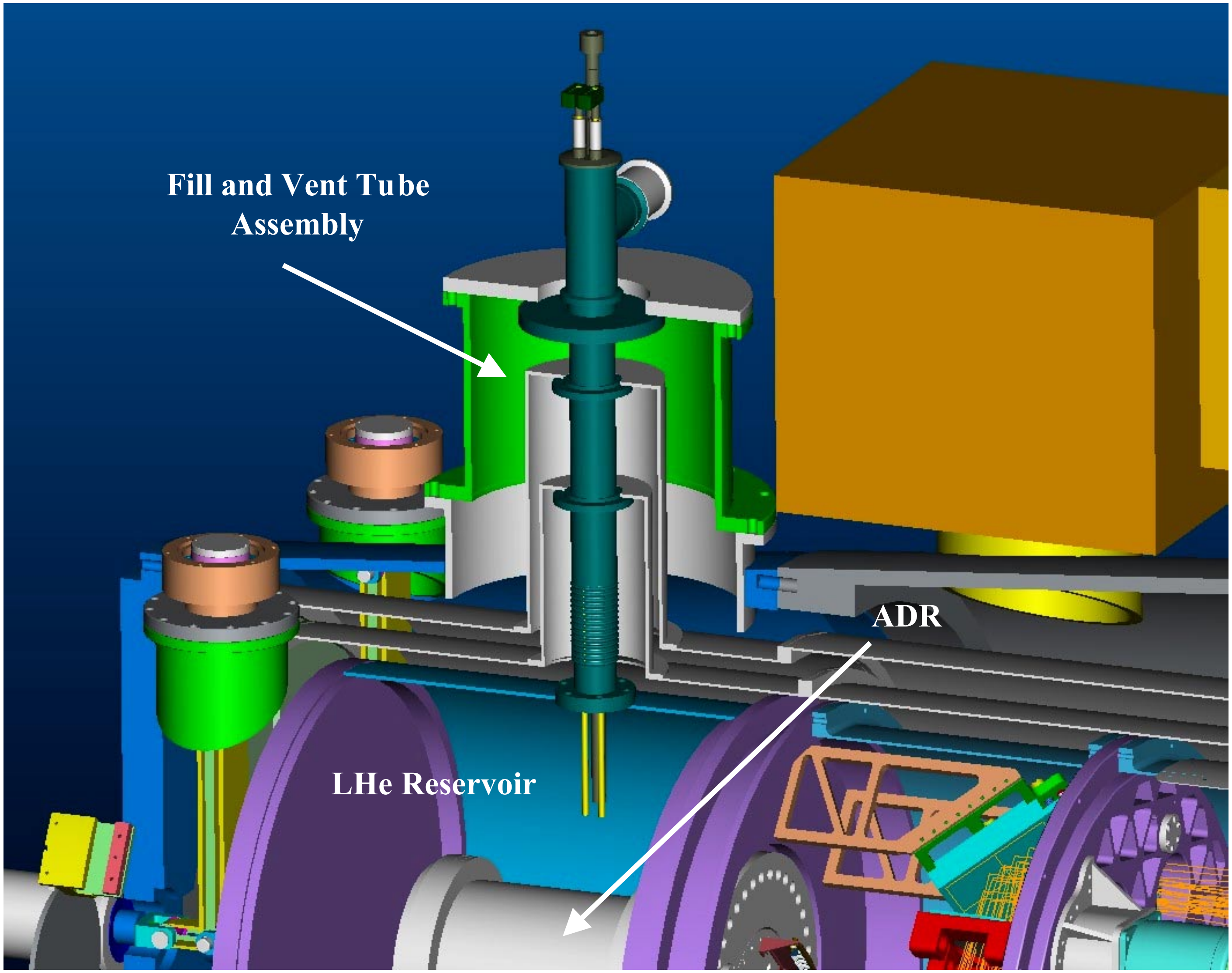


HDPE
0.033 inch thick
3.0 inch dia.

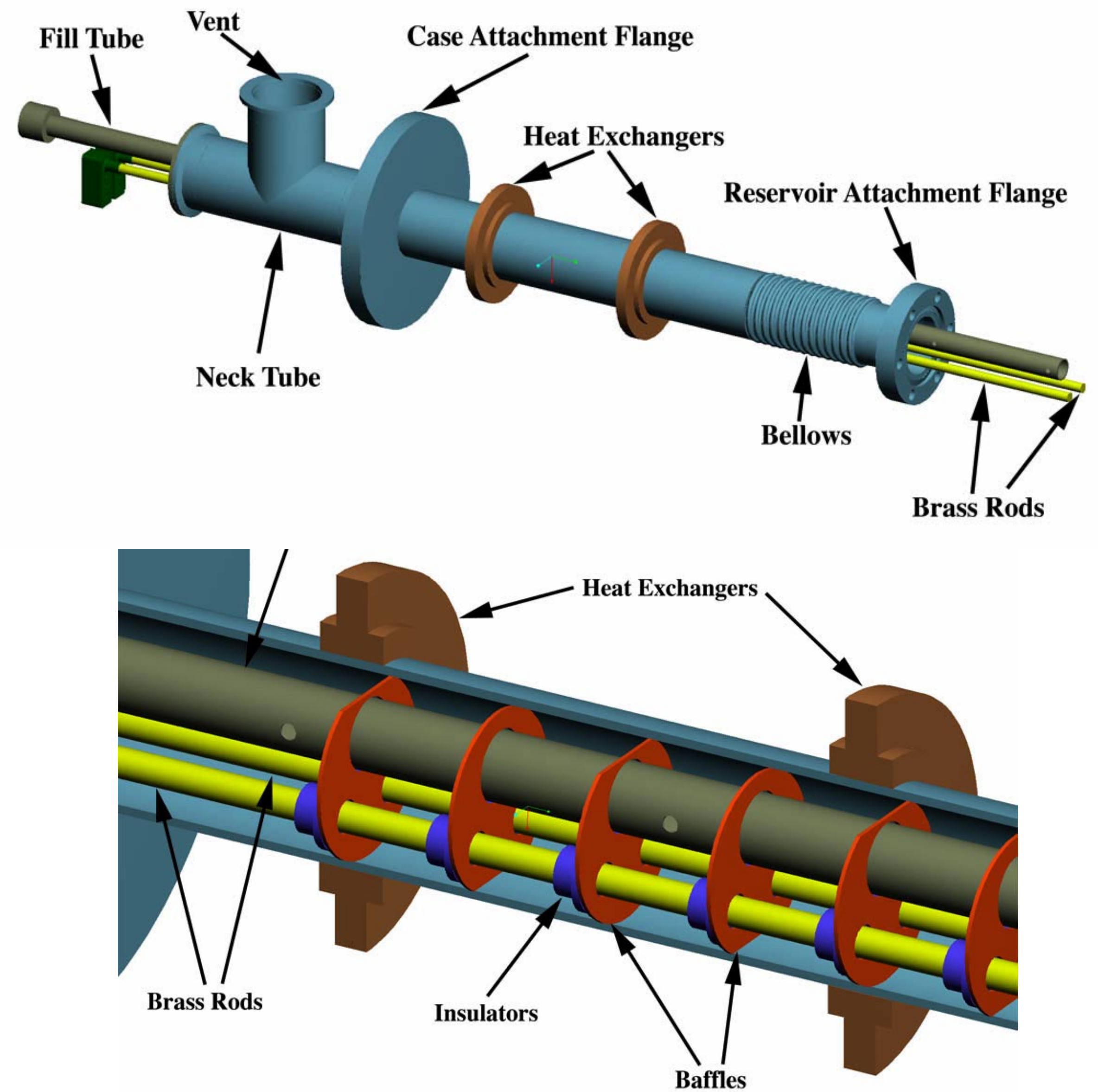
Difficult to capture analytically....testing pursued.

	thickness (in)	intial center deflection (in)	long-term center deflection (in)	short-term strength (psi)
UHMWPE	0.020	0.308	0.428	> 44
HDPE	0.033	0.227	0.239	100
PP	0.020	0.220	0.285	NA

Fill and vent tube



Fill and vent tube



HTS System

• Each orthogonal direction restrained by a fixed **"hard"** strap and **"spring"** strap in series with a spring assembly.

• Spring assembly maintains the straps in **tension** as system changes temperature and if Kevlar® creeps.

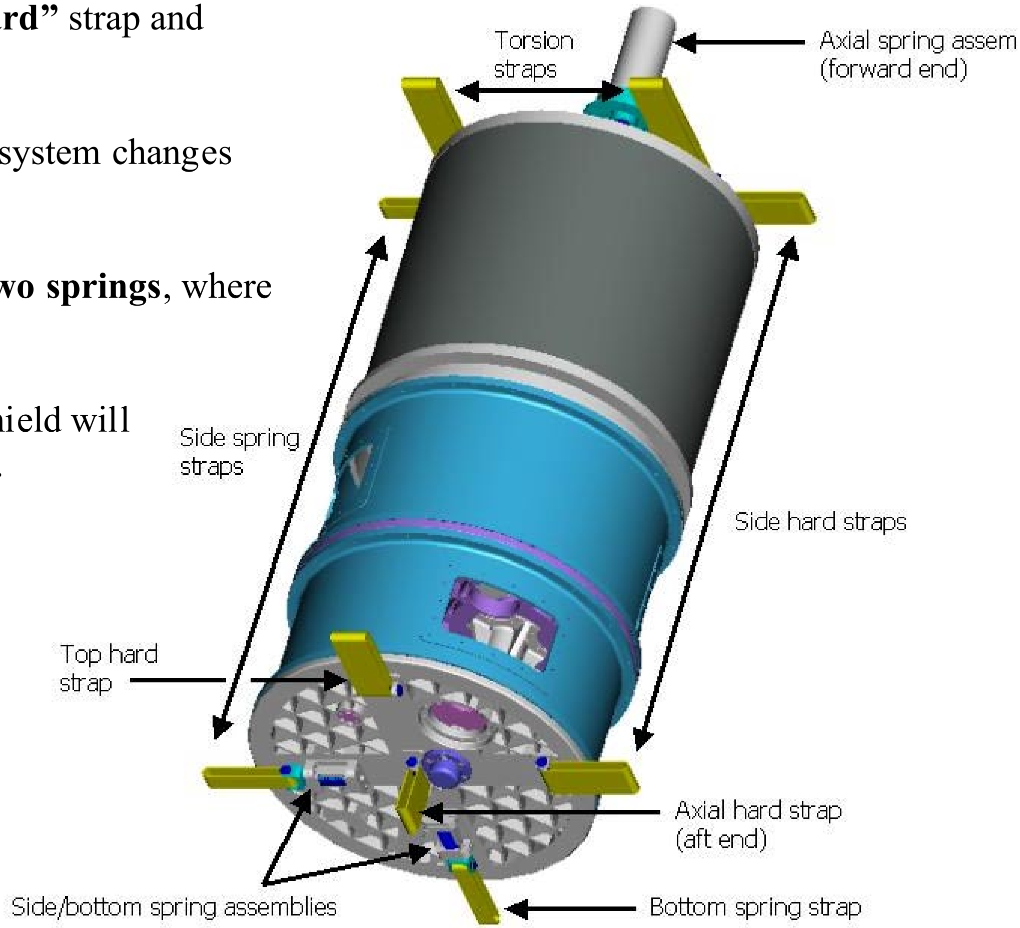
• System design based upon **simple mass between two springs**, where stiffer spring controls the harmonic response.

• Designed for emergency loads so that the helium shield will remain intact and properly restrained within cryostat.

• More specifically,

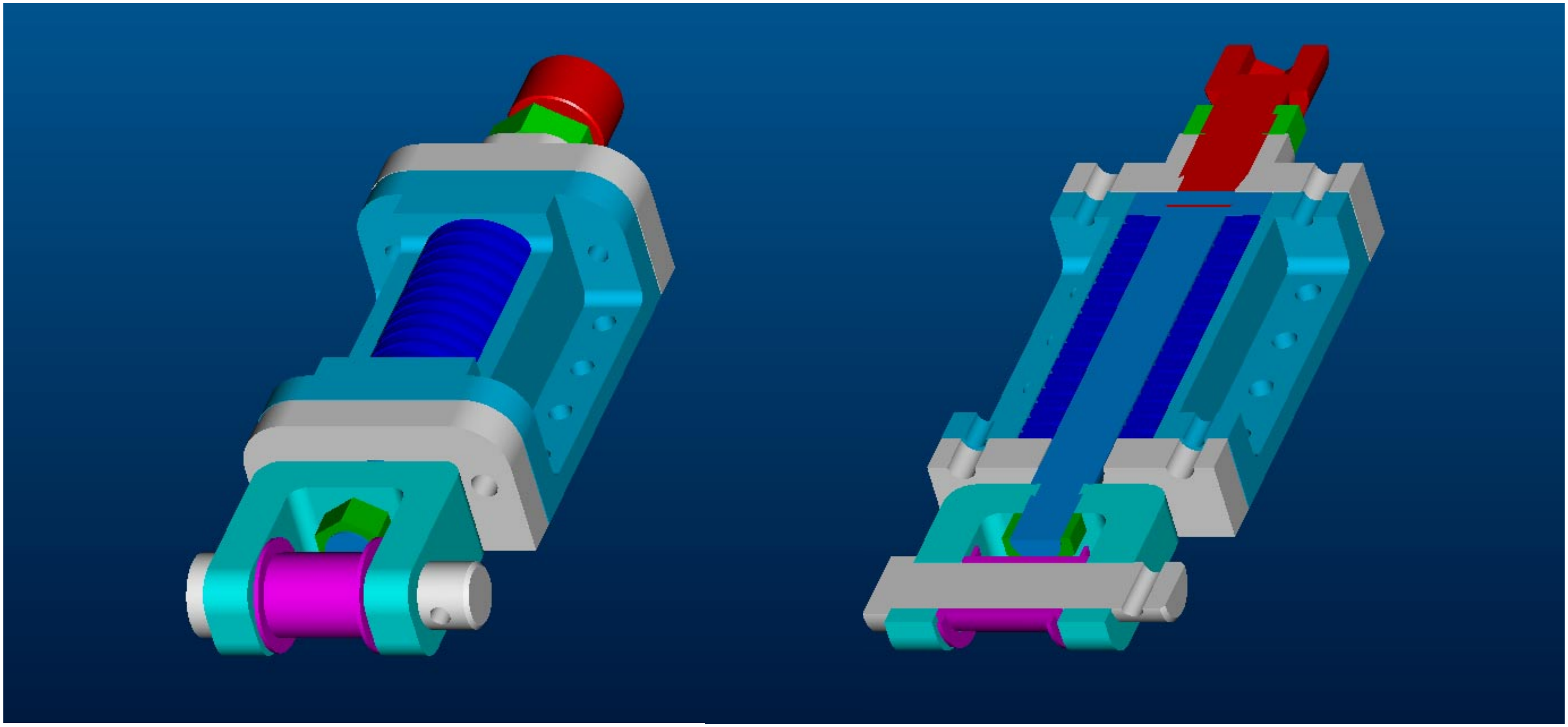
✓fixed **hard** straps are precisely arranged to address the 6.0 g downward and the 9.0 g forward **emergency** loads;

✓the **spring** straps and spring assemblies are designed to remain in tension and prevent any **snap-back** due to the 3.0 g upward and 1.5 g aft emergency loads.



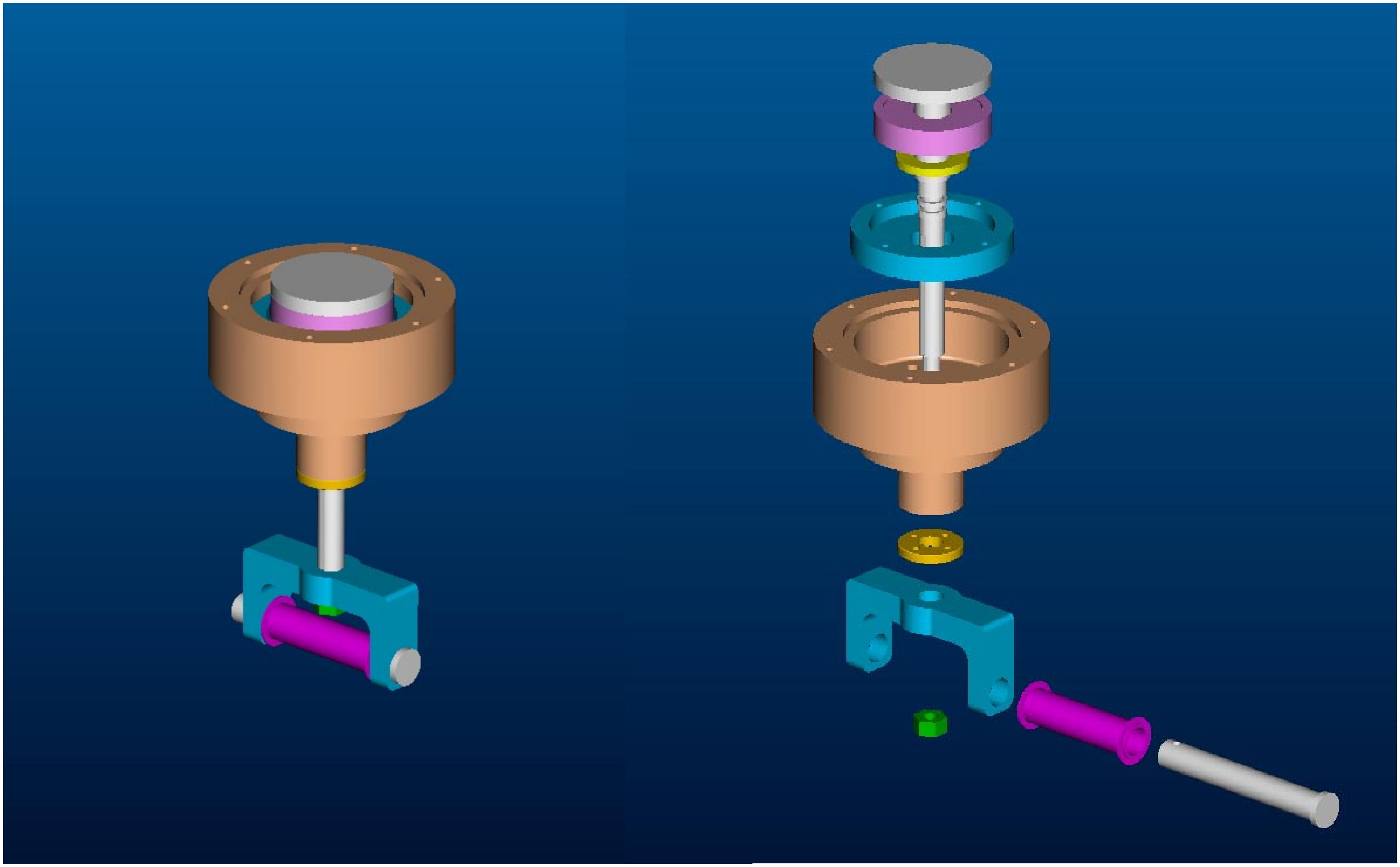
HTS Mechanisms

Kevlar strap spring assembly



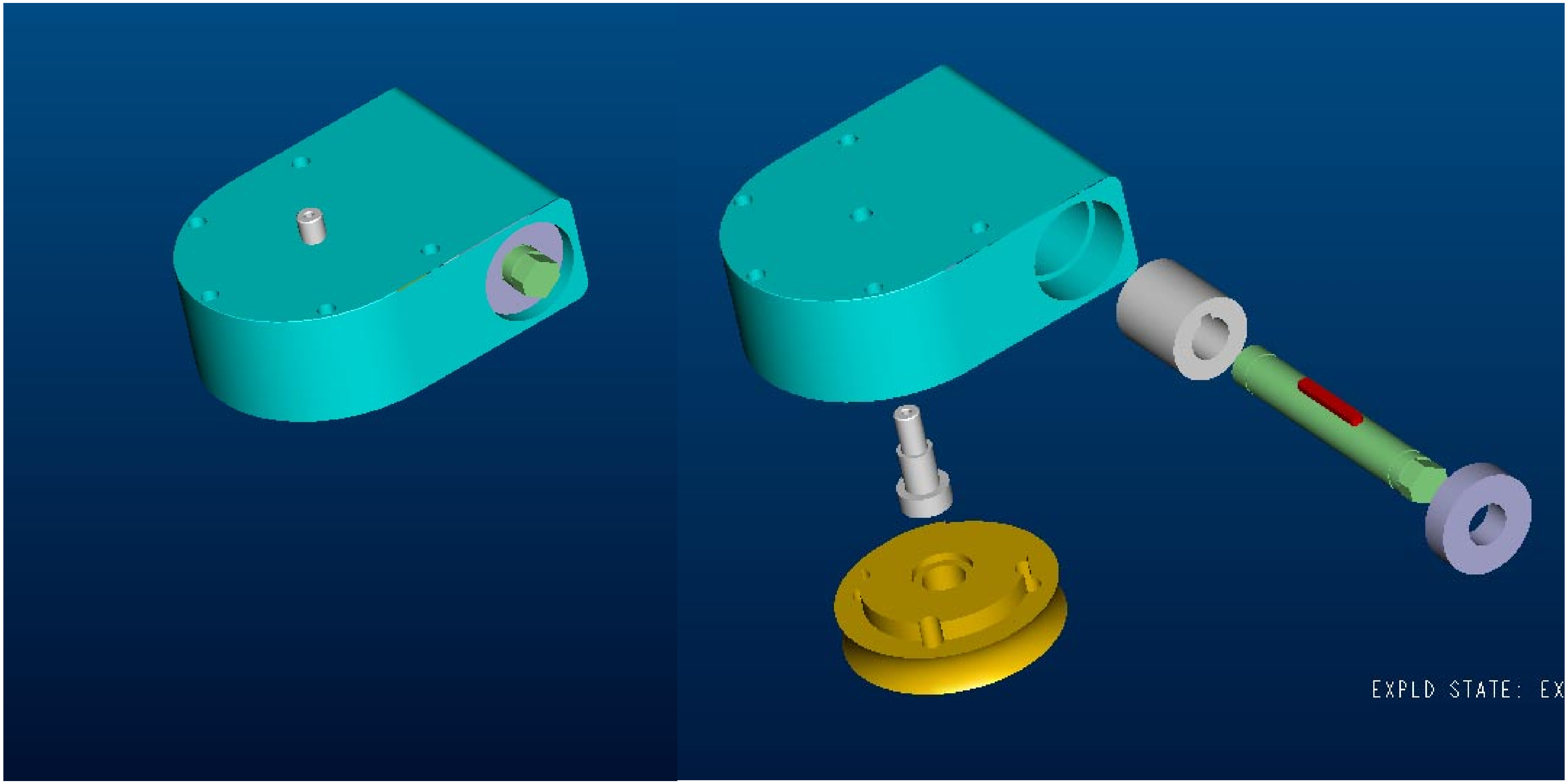
HTS Mechanisms

Kevlar strap adjustment mechanism



HTS Mechanisms

Kevlar strap worm drive



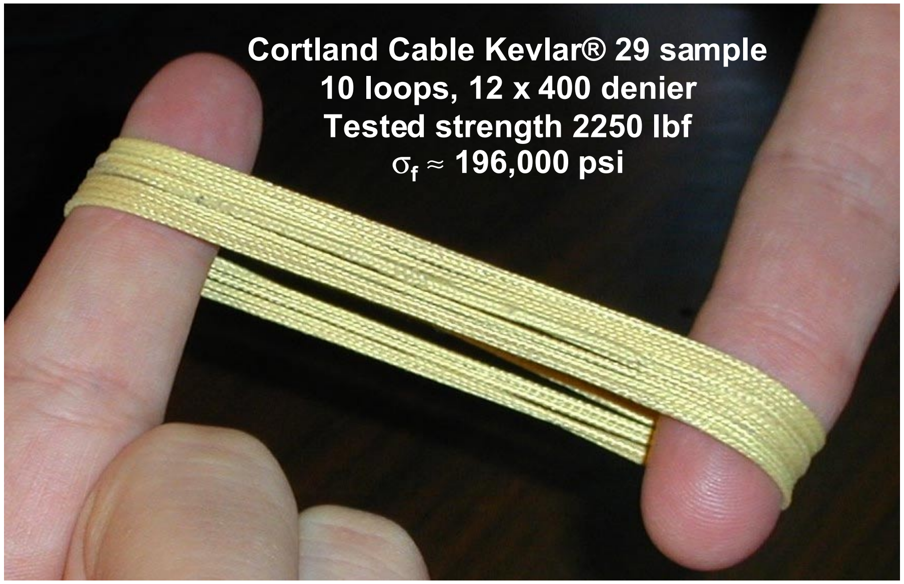
HTS Strength

Tenacity (gram weight / denier, g/d) approach:

Du Pont Kevlar® 49 yarn test data:

- 1140 denier yarn
- Breaking strength = 59.3 lbf
- Breaking tenacity = 23.6 g/d

In the case of the axial hard strap,
(23.6 g/d) x (2 x 20 loops) x (12 x 2840 d) = 3.217×10^7 g
= *70926 lbf*

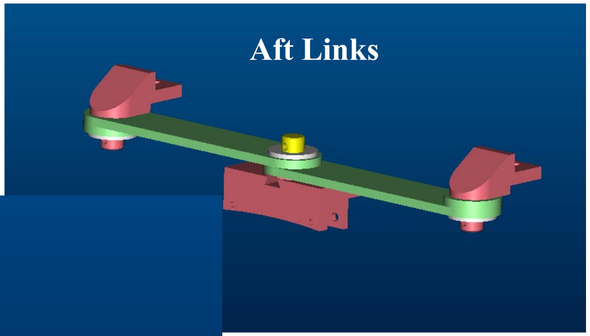


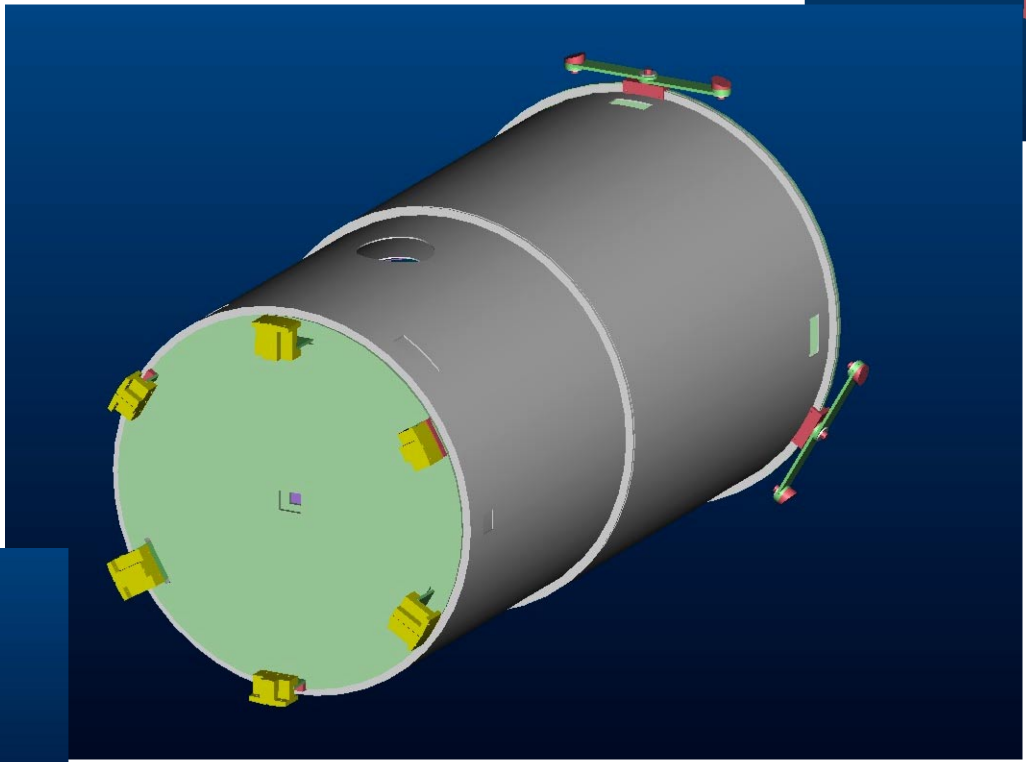
Failure stress approach:

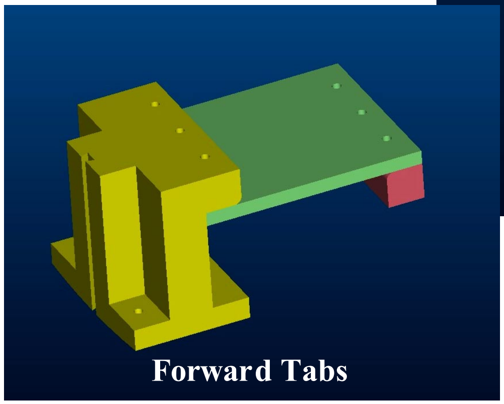
$\sigma = F_f / A$
A = (2 x no. loops) x (no. of yarns in braid) x (yarn denier) x (1/density)
= (2 x 20) x (12) x (2840g/900000cm) x (1/1.45g/cc)
= 1.04 cm^2
= 0.162 in^2
F_f = 196,000 psi x 0.162 in^2
= *31750 lbf*

VCS G10 system

- Links designed to only carry lateral loads as a system, keeping shield concentric







- Tabs at front endplate restrain shield axially

Thermal Model

EXCEL Thermal Network Spreadsheet (oct9, '98)

NOTES:
- Labels (variable names) are used throughout the spreadsheet to help make equations A little more self-explanatory.
- Up to 40 conductors and 20 nodes may be included in the model, and are numbered sequentially from left to right.
- Set up nodal connectivities in Rows 40 and 41, and set the correct numbers in "# of nodes" and "# of conductors".
- Run the Assembly Macro "Assemble" in order to set up the temperature and energy balance equations.
- Boundary temperatures should be typed in directly, in place of the assembled temperature calculation equation, or should be set equal to the Initial T
- Cut and paste the conductivity equations (see below) into row 50 to calculate temperature dependent properties.
- Under the OPTIONS menu, set Calculation to (manual, iteration, 100 iterations, max change 5).
- The variable "relax" (see cell B25) is used to control how quickly the model will converge. Acceptable values are 0<"relax"<=1 (higher gives faster c
- Use 0.8 for most systems, and no higher than 0.3 for a refrigerator system (usually not very stable). Set to a lower value if solution is not stable.
- Set "Initial Values" to TRUE to set up an initial condition; set to FALSE to allow iterative solution.

GSFC
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Initial values	**FALSE**
# of nodes	**6**
# of conductors	**26**
Cryogen	Superfluid He
Temperature	1.3K
Hv	21 J/g
rho	145g/liter
cp	5.2J/g-K
relax	**0.8**
sigma	5.67E-12W/cm K^4
Tank load	0.7594 W
mdot	0.0362 g/s
Tank vol	**68 liters**
Lifetime	3.156 days

Dimensions	**Qty**	**ID (cm)**	**OD (cm)**	**L (cm)**
Vent Line	1	4.7625	5.0927	
Fill Line	1	1.1684	1.27	
Magnet leads	2		0.508	
OVCS	1		61.3	116.3243
IVCS	1		56.1	111.2443
He shield	1		50.2	105.5293
Kevlar, OVCS	0		0.22	0
Kevlar, IVCS	0		0.22	0
Kevlar, He shield	380		0.22	15.9752631
Wiring				
detector leads	900		0.0127	
opto-mechanism le	12		0.01524	
	Qty		**A (cm^2)**	**L (cm)**
G10, OVCS	15		1.8145125	11.4935
G10, IVCS	15		1.8145125	5.1435
G10, He shield	0		0	0