IV. Results and Discussion:

Introduction:

Figure 1. below shows the basic 120 degree single period FEA Nastran model of the vessel with cyclic-symmetric boundary conditions. To the left are the model details and loading conditions investigated. (This model was also used as input for the Spark disruption modeling).

Model Details:
38,906 DOF's
7782 GRID POINTS
7,228 CQUAD4
1,018 CTRIA3
40 MPC's
4 SPC's

Boundary Conditions:
Cylic-Symmetry @ welded edge via MPC's, vertically fixed @ top clevis, circumferentially top & bot. of NB port

Normal Operating Loads:
Uniform external 14.7 psi
Gravity – 1g
Temperature 200 deg.C (max.)
Bakeout: 400 deg.C (max)

Off-Normal (EM Disruption) Loads:
320kA Plasma @ 1.7T
210kA Plasma @ 2.0T (High Beta)
320kA Plasma @ 1.7T @dZ=10cm
(Inductively coupled solutions)

NCSX VACUUM VESSEL NASTRAN 120 DEG. FEA MODEL

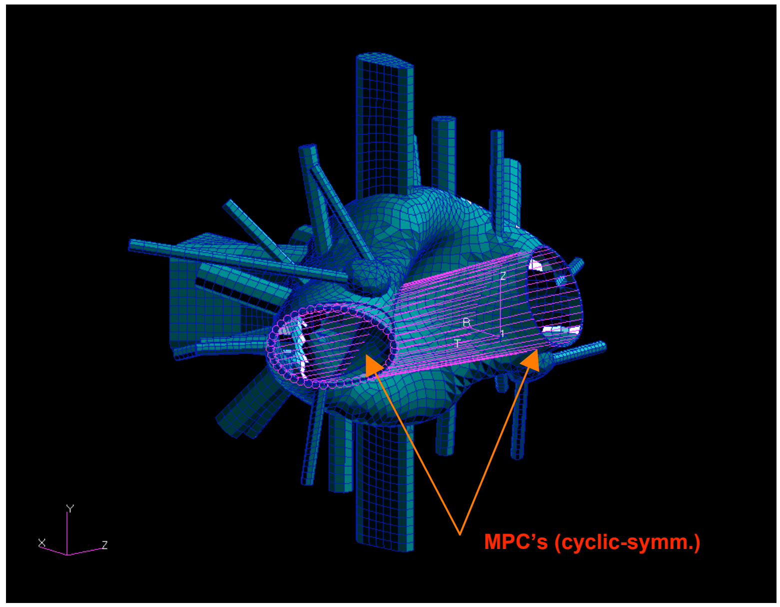

Figure 1. NCSX Vacuum Vessel Nastran FEA Model

The model contains all diagnostic and Neutral Beam ports as of 2 April '04 including the two new RF turret ports. The closure weld flanges and spool section are also modeled (see section III for a detailed list of the ports). The cyclic-symmetric boundary conditions are modeled using multipoint constraints (MPC's – the magenta lines shown in Fig. 1) which constrain identical displacements to occur at the corresponding grid points on both weld flange boundaries (simulating the stiffness of the full 360 degree structure).

Atmospheric loads:

Figure 2. is a contour plot of displacements due to atmospheric pressure showing a peak displacement of 0.25" at the upper and lower ends of port-2 (at the 1st port flange). The deflection of ports 2 (and 9) are the result of a local inward displacement of the vessel shell in the flat area of the shell in the vicinity of these two ports as shown in Figure 3 (note the upper range of the contour levels in this plot has been limited to 0.125" to accentuate the local displacement contours).
Figure 4. shows the Tresca stress contours on the outer shell surface for atmospheric loading with the peak stress of 15.2 ksi occurring in the areas of high curvature near the top (and bottom) of the shell.

To reduce the shell and port deflections in the vicinity of ports 2 and 9, some internal reinforcing ribs may be employed. Figure 5. illustrates the effect of adding some 0.375 thick, 1" high tee section reinforcing ribs on the shell interior. The peak shell displacement between ports 2 and 9 is reduced by about a third with the addition of these ribs. The displacement at the end of port 2 has also been reduced from 0.25" to 0.15". The peak Tresca stress in the high curvature region of the shell however, remains about the same (15 ksi)

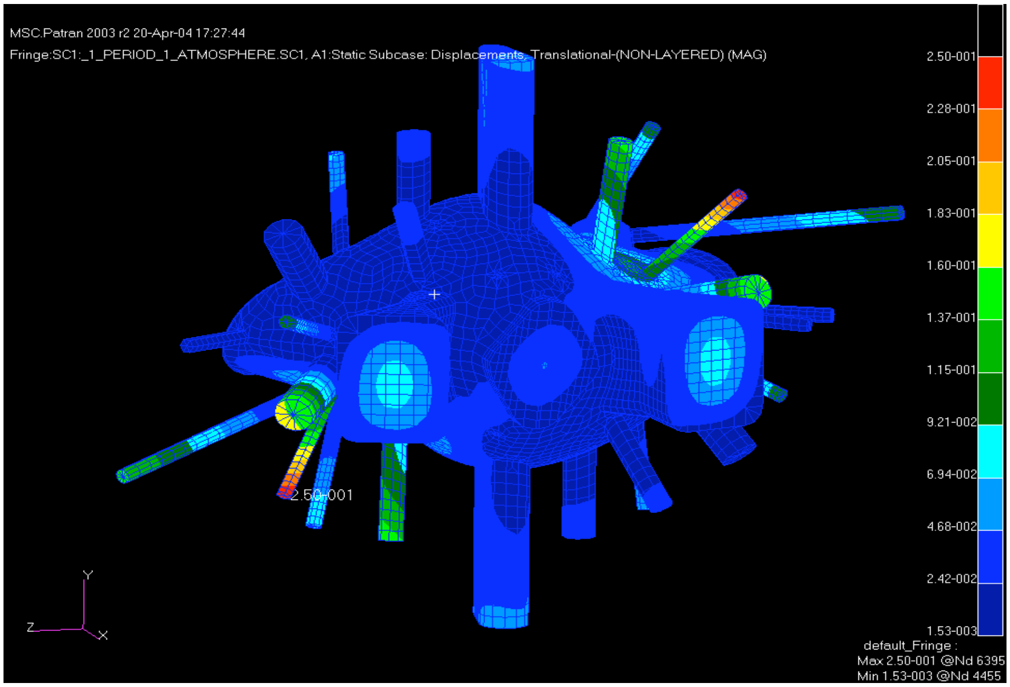

Figure 2. Run 120bbe3: 1 Atmosphere External Pressure Only

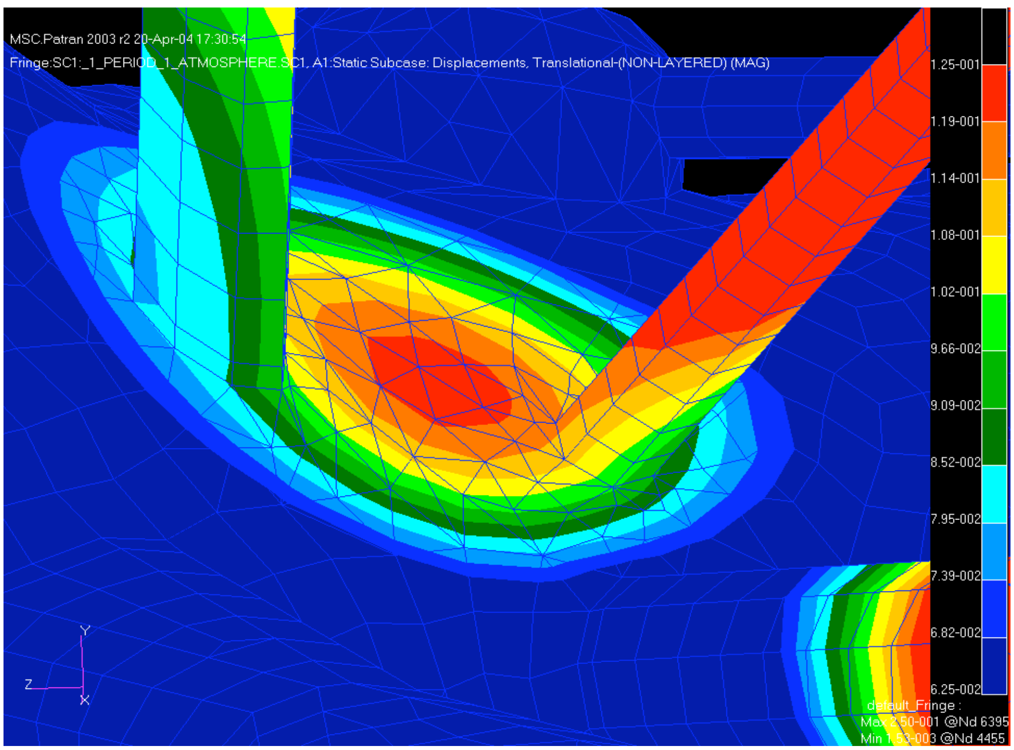

Figure 3. Run 120bbe3: 1 Atmosphere External Pressure Only – showing a peak shell displacement of 0.125" between ports 2 & 9

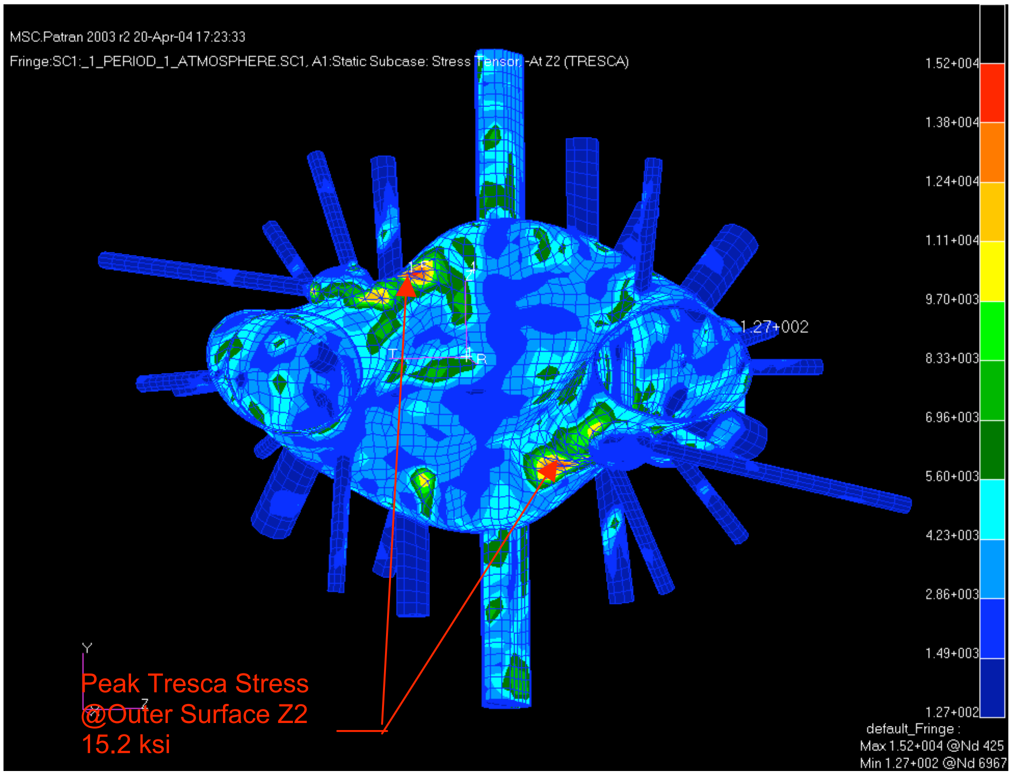

Figure 4. Run 120bbe3: 1 Atmosphere External Pressure Only –Tresca Stress - Z2

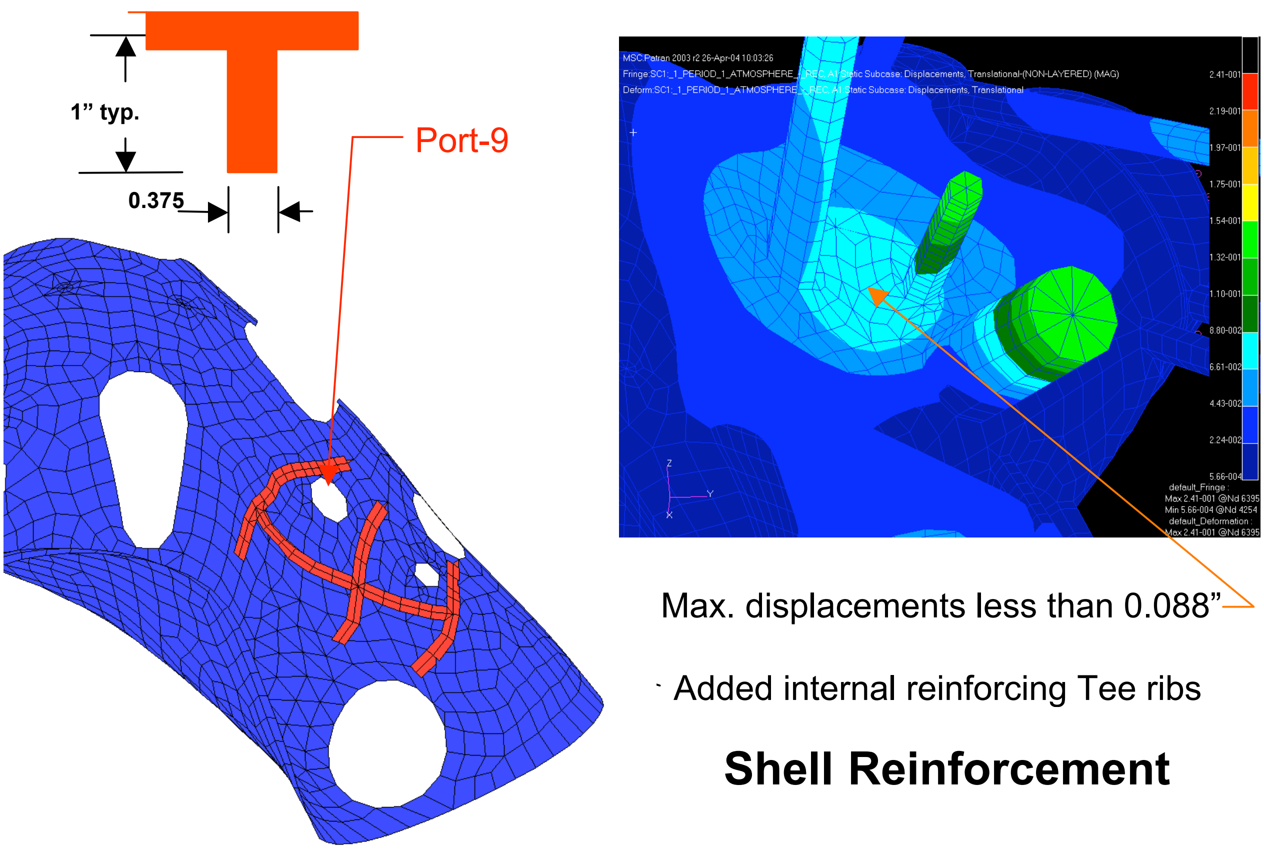

Figure 5. Run 120bbe2a-tribsf with internal shell reinforcement (disp. Reduced by 30%)

Atmospheric + Gravity loads:

Figure 6. is a plot of displacement contours for the atmospheric + gravity loading condition indicating a peak displacement of 0.255” at port 2. In general, the results for this loading condition are similar to the pressure only condition, the main difference being the Tresca stress contours shown in figure 7. which indicate a peak of 20.9 ksi at the base of the RF port turret intersecting the shell. The stress distribution in the other portions of the shell are similar to the pressure only loading condition.

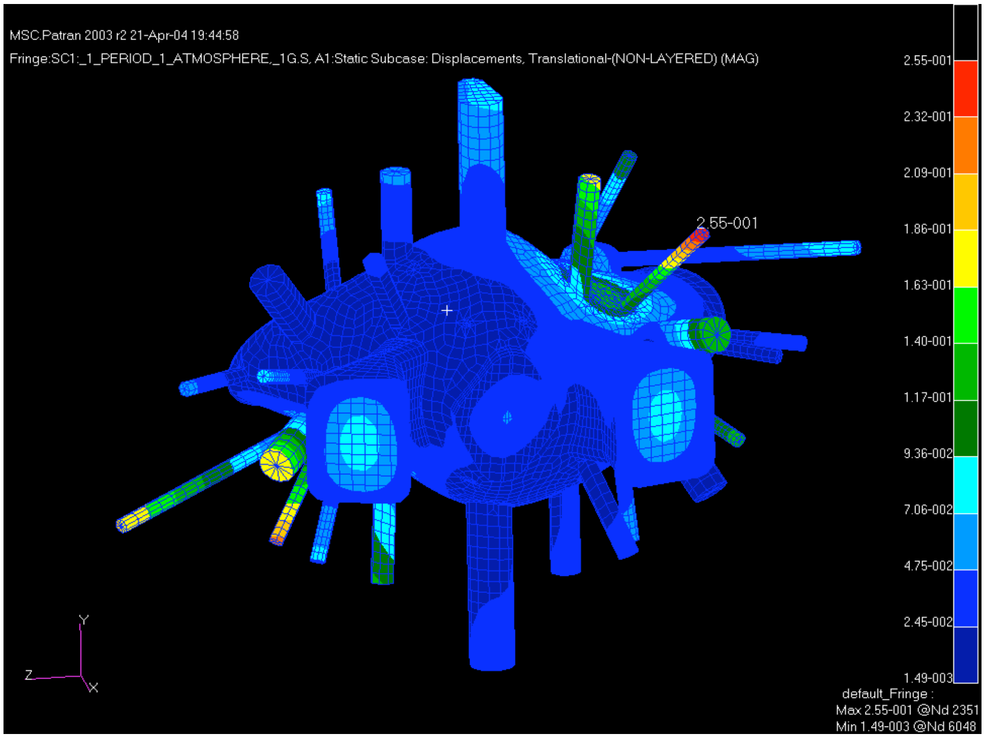

Figure 6. Run 120bbe3g – 1 Atmosphere External Pressure + 1g Gravity Loading

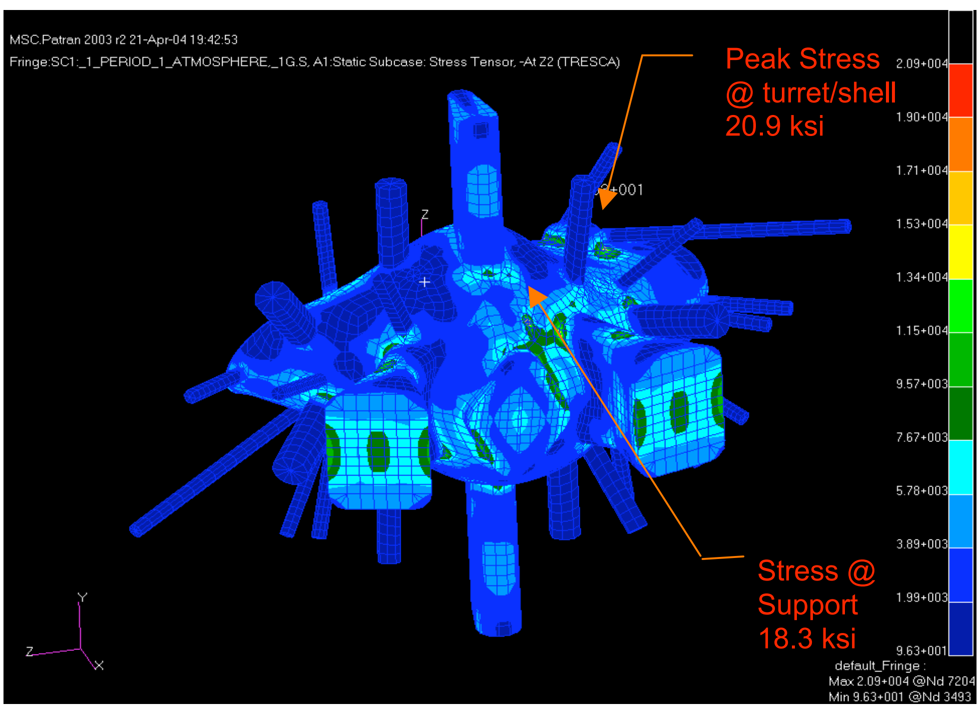

Figure 7. Run 120bbe3g – 1 Atmosphere External Pressure + 1g Gravity Loading