Summary of Reaction Loads on the SCT Rail Support Positions

This document summarizes the loads experienced at the SCT/TRT rail interface under different Pixel Support Tube (PST) loading conditions. In addition, axial loading of the PST/SCT structure is analyzed, with and without PST forward end flexures fixed, providing the SCT's axial stiffness both as a unit with the PST and alone.

1.0 Constraints and Definitions

1.1 Overall Model Constraints/Assumptions

All of the reaction data summarized here is based on an integrated PST/SCT FEA model run in ANSYS. This model does not take into account the PST insertion rails or their added stiffness to the PST shell. More information on the model assumptions, properties, and results can be found on EDMS under the PST Final Design Review: http://edmsoraweb.cern.ch:8001/cedar/doc.info?document_id=345435&version=1

The PST is joined to the SCT at 4 interlink positions (in the XZ plane) utilizing flexures in 3 positions, with a fixed mount at the 4th. The forward ends of the PST are fixed to the end of the cryostat through flexures as well; in the model, the flexure face that would be attached to the cryostat is fixed with rigid constraints. All of the flexures allow for increased Z flexibility, with the one fixed mount to the SCT acting as the only Z constraint for the PST (Figure 1).

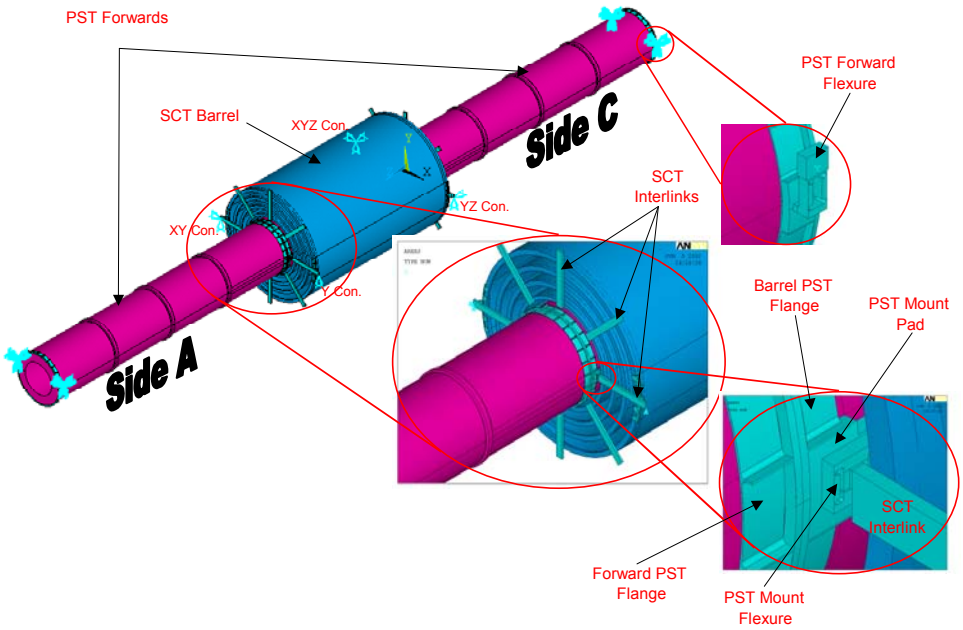

Figure 1. SCT/PST Integrated Model General Support Scheme.

1.2 SCT Rail Supports

The SCT is attached to rails in the TRT through the ends of the four interlinks that lie in the XZ plane (Figure 2). The supports are slightly over-constrained (relative to a pseudo-kinematic support scheme) but allow motion of the SCT across the diameter, as well as in length, from one end relative to the other.

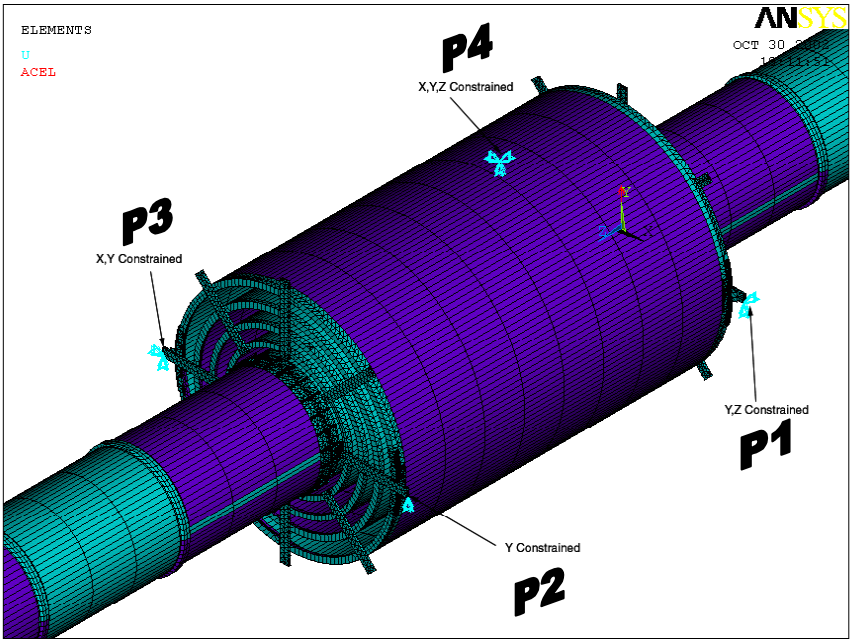

Figure 2. SCT/TRT Rail Interface Supports and Labeling.

No moment constraints are applied; however, the interlinks, modeled as solids, are constrained along the bottom edges of their end surfaces (Figure 3), which results in applying moments in some circumstances. It is unknown whether or not this reflects the actual planned support scheme. The different supports are labeled P1 through P4, and their constraint conditions are listed in Table 1.

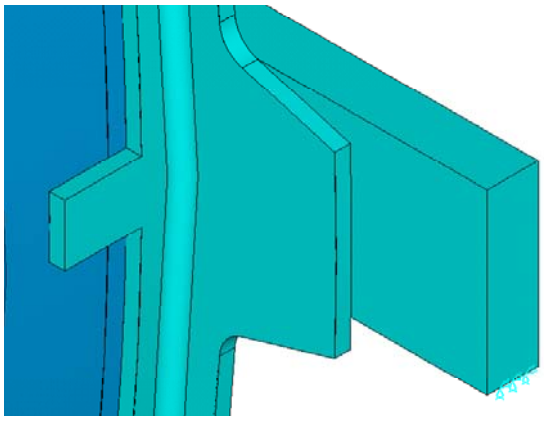

Figure 3. Interlink End Detail, Showing Constrained Line.

Table 1. SCT Interlink Labels and Constraints

Support Label	Constraints		
	dX	dY	dZ
P1	-	x	x
P2	-	x	-
P3	x	x	-
P4	x	x	x

2.0 Gravity and Pixel Detector Weight

The largest reaction loads on the SCT/TRT interlink interfaces come from the simple gravity load of the SCT itself, and the mass of the installed Pixel System. It can also be seen that there are residual moments at the mount locations; these moments could be eliminated depending on the details of the SCT/TRT rail interface, see Table 2.

Table 2. Mount Loads on SCT Interlinks Under Gravity and Pixel Weight.

Component	P1	P2	P3	P4
FX (N)	0	0	-1	-1
FY (N)	-621	-617	-619	-620
FZ (N)	0	0	0	0
MX (Nm)	-3	943	946	-3
MY (Nm)	0	0	-1	0
MZ (Nm)	-346	-344	345	345

3.0 2mm Forward End Offsets

Although much smaller in magnitude than the resultants due to gravity and Pixel loads, the forces and moments encountered during extreme (2 mm) offset of the forward ends of the PST do add substantially to the overall loads between the SCT and TRT. Presented here are the resultants due to the 2mm offsets only; the complete load at any interlink would be a summation of gravity, pixel weight, and any loads due to bending of the PST forwards.

3.1 X Displacements

These resultants are due to bending of the PST forward in the horizontal (XZ) plane, see Table 3. The A side forward tube is displaced.

Table 3. Mount Loads on SCT Interlinks During Forward PST Deflection, dXA=2 mm.

Component	P1	P2	P3	P4
FX (N)	0	0	228	-114
FY (N)	16	-20	22	-18
FZ (N)	-25	0	0	25
MX (Nm)	0	30	-33	0
MY (Nm)	14	0	349	14
MZ (Nm)	9	-11	-8	8

3.2 Y Displacements

These resultants are due to bending of the A side PST forward in the vertical (YZ) plane, see Table 4.

Table 4. Mount Loads on SCT Interlinks During Forward PST Deflection, dYA=2 mm.

Component	P1	P2	P3	P4
FX (N)	0	0	4	-4
FY (N)	-80	135	136	-82
FZ (N)	4	0	0	-2
MX (Nm)	0	-206	-208	0
MY (Nm)	-2	0	6	-1
MZ (Nm)	-45	75	-76	46

4.0 CTE Loading

The following load cases summarize resultants due to thermal expansion of the PST with respect to the SCT. The SCT was assumed constant in temperature, while the PST structures were heated to a uniform temperature of 30 degrees Celsius above the SCT temperature.

4.1 Symmetric

In this case the entire PST structure was heated by 30 degrees Celsius, Table 5.

Table 5. Mount Loads on SCT Interlinks During Symmetric Thermal Expansion of the PST.

Component	P1	P2	P3	P4
FX (N)	0	0	1	0
FY (N)	-1	-1	-1	-1
FZ (N)	-4	0	0	-10
MX (Nm)	0	2	2	0
MY (Nm)	2	0	1	-6
MZ (Nm)	-1	-1	1	1

4.2 Asymmetric

In this case, only the forward C side of the PST was heated, in order to simulate catastrophic heater failure on side A, see Table 6.

Table 6. Mount Loads on SCT Interlinks During Asymmetric Thermal Expansion of the PST.

Component	P1	P2	P3	P4
FX (N)	0	0	-34	33
FY (N)	-4	2	-4	3
FZ (N)	104	0	0	214
MX (Nm)	-1	-3	7	-2
MY (Nm)	-58	0	-52	114
MZ (Nm)	-2	1	2	-1

5.0 Axial Loading

The combined PST/SCT model was loaded along the axial direction (Z axis). Loads were applied to the flange of the forward support tube on the A side of the detector, and the forward flexures were not locked out (thus absorbing a portion of the applied load, and allowing force to be transmitted into the SCT). A force of 200 N (approximately 20% of the Pixel System weight - the anticipated frictional load on the PST during insertion) was applied to the model in 4 different configurations, as described below.

5.1 Original Constraints

The first constraint case is identical to that used in all of the previous analyses. The SCT interlinks were fixed at their ends according to the conditions described in Table 1, and the forward PST flange was loaded with the flexures both attached and removed.

5.1.1 Loads as Installed in the Inner Detector

In the first configuration, the PST/SCT assembly was modeled as it will exist during insertion of the Pixel System, with the exception that the forward flexures are planned to be *locked out* during the actual installation. This situation results in load sharing between the PST forward flexures and SCT/TRT mount points, as can be seen in the resultants in Table 7, which sum to only about 96 N in the Z direction (versus the 200 N applied). Thus the PST forward flexures share load equally with the SCT when they are not locked out.

Table 7. Mount Loads on SCT Interlinks Under 200 N Axial Loading, Original Constraints.

Component	P1	P2	P3	P4
FX (N)	0	0	11	-10
FY (N)	0	0	2	-2
FZ (N)	-31	0	0	-65
MX (Nm)	0	1	-3	1
MY (Nm)	18	0	16	-35
MZ (Nm)	0	0	-1	1

5.1.2 Stiffness of SCT Structure Alone

In order to determine the inherent axial stiffness of the SCT structure, the model was also run with the PST forward flexures removed (on both A and C sides). This resulted in the full 200 N axial load being absorbed by the SCT alone, with a corresponding maximum displacement in the SCT structure of approximately .22 mm. Under the 200 N load, this results in a stiffness of about 900 N/mm. For reference, the resultant loads on the SCT interlinks are shown in Table 8; however, this load case does not represent one that will ever actually exist in practice.

Table 8. Mount Loads on SCT Interlinks Under 200 N Axial Loading, PST Forward Flexures Removed, Original Constraints.

Component	P1	P2	P3	P4
FX (N)	0	0	23	-23
FY (N)	2	-2	3	-3
FZ (N)	-65	0	0	-135
MX (Nm)	1	3	-4	1
MY (Nm)	36	0	35	-72
MZ (Nm)	1	-1	-1	1

5.2 Reduced Constraint Set

Due to the high dependency of the resultants and stiffnesses on the SCT's constraint condition to the TRT, a second constraint case was analyzed in which the Z constraint at Point 1 was removed (see Figure 2 and Table 1 for original conditions). The PST/SCT model was run in this constraint scheme with forward flexures both attached and removed.

5.2.1 Loads as Installed in the Inner Detector

In this case the forward flexures are present but not locked out, see Table 9.

Table 9. Mount Loads on SCT Interlinks Under 200 N Axial Loading, Reduced Constraint Set.

Component	P1	P2	P3	P4
FX (N)	0	0	29	-29
FY (N)	2	-2	4	-4
FZ (N)	0	0	0	-91
MX (Nm)	0	3	-6	1
MY (Nm)	0	0	45	-49
MZ (Nm)	1	-1	-2	1

5.2.2 Stiffness of SCT Structure Alone

In this slightly reduced constraint condition, the axial stiffness of the SCT was reduced by approximately 10%. The maximum displacement increased to about .25 mm under the 200 N load, resulting in a stiffness of approximately 800 N/mm. As expected, the resultants listed in Table 10 show the full 200 N axial load being transferred to Point 4 of the SCT/TRT supports.

Table 10. Mount Loads on SCT Interlinks Under 200 N Axial Loading, PST Forward Flexures Removed, Reduced Constraint Set.

Component	P1	P2	P3	P4
FX (N)	0	0	70	-70
FY (N)	7	-7	8	-8
FZ (N)	0	0	0	-200
MX (Nm)	0	10	-12	2
MY (Nm)	0	0	107	-107
MZ (Nm)	4	-4	-3	3