Summary of Design Plans from 8/26/03 UW visit

1. We should design for installation of full azimuths at one time. This is driven by schedule concerns (144 L0 modules need to get installed in ~20 weeks).
2. Appropriate gluing load is 30 g/cm^2 (UW assumes 35 in their FEA)
    - 353 g per L0 sensor, 2.121 kg for one azimuth (L0A)
    - 1161 g per L1 module, 3.484 kg for one azimuth (L1A)
3. Structure deflections under these loads are unacceptably high when structures are supported at the ends so it is thought that the sensor gluing loads need to be reacted along the full sensor gluing length using interior mandrels. "Unacceptable" deflections reported were 37(50) microns for L0(L1) (relative to shape without gravity). Some portion of this will go away once the gluing load is removed, even if the epoxy is fully cured. UW will try to evaluate what portion is locked in during glue cure.
4. Mandrel deflections for realistic support points and various loading conditions required for module installation and de-mounting of populated structures need to be calculated to determine if this is a workable solution and if so what materials are required. The default solution discussed was to use the steel mandrels the CF inner shells are being fabricated on (or duplicates).
5. During module installation we require the support rod to extend 5" through the RT05 bore and that the silicon edge be located 3" from the face of the RT05 (a.k.a. indexing head). In addition we require another 500mm of rod beyond the L0 structure hybrid area for staging of the L0B hybrid birdcage and to manage the DJC for L0. This makes the total L0 support rod length 1500mm with 1375mm outside the RT05. The RT05 bore is 50mm (tolerances will be checked and communicated to all parties).
6. Azimuthal constraint of the CF structures to inner mandrels seems complicated unless the clearance to the mandrels in ½ mil or less. Otherwise stress levels in the pins will be high when the load is applied to the silicon and the structure settles to the mandrel surface. Azimuthal constraint needs to be revisited once UW evaluates the fit of the mandrel to the bore of the structure. An alternative solution to using the pins was not put forth in the discussions.
7. Allowable stress levels in the silicon during any operation were discussed in the context of crack propagation from edge defects.

Ultimate stress is thought to be about 15 ksi. Allowing for a factor of 5 stress concentration from edge defects gives an upper bound of 3 ksi. A factor of 2 or 3 safety margin should be applied to this, bring allowable stresses down to the 1.0-1.5 ksi.

8. The cooling manifolds and extension cylinders are expected to be fully installed and connected when L0/L1 are installed into that assembly. This implies that the L2-5 structure extends to Z=830mm at that time. {Bill has some sketches in AutoCAD indicating nominal manifold locations and the layout of the Z=830 bulkhead which determines cable and cooling tube locations at that point. They have been passed to UW subsequent to the meeting.}

Note that not all parties were present during the following discussions and that some discussion points are related to thoughts since the meeting.

Discussion points on module installation.

- It was suggested that unloading the silicon after the glue spreading is complete (1-2 hours) would reduce the deflections of the structures to acceptable levels. The load would be reduced 50-75%, but not completely removed. The outstanding issue is whether the epoxy would redistribute itself during the subsequent time of the cure cycle.
- Similar arguments were made for installation of only 2 or 3 L0 sensors or single L1 modules at a time, though in this case there is no reduction of load during the cure cycle so no redistribution of epoxy is required to take place. Again, schedule is the main objection.
- Concerns were raised about the use of a mandrel inside L1 since the end disks extend inwards at many azimuths to lock into the L1 structure and to provide mounting points to L0. This requires significant areas of the mandrel be removed to allow these protrusions to past. One suggestion put forth was that we use a partial mandrel that fits through the bore and then is raised up to contact the inside surface where modules are being glued. Then the structure is rotated while the “shoehorn” mandrel remains fixed. This implies extensive survey and setup of coordinate systems for each azimuth, which in principle may not be required when rotating a structure tied to the RT05 rigidly.

Discussion about load transfers and mating

- In all concepts the Z=0 end of the structure is near the RT05 during module installation. The RT05 provides a fixed support condition at

that end of the support rod. At the opposite end a simple support is envisioned, beyond the end of the CF structures, i.e. near Z=850mm for L0 and near Z=650mm for L1. Note that cooling tubes and cables extend to Z=1300mm so any support must allow for these to pass through it, e.g. a spider disk on cam followers. The remaining overhang of support rod beyond the support point will help to straighten the rod through the CF structures, while also providing a place to stage the L0B hybrid birdcage and manage the cables as they are installed. We must take care that other loads NOT be applied to any free overhanging beam (e.g. electrical testing people leaning on it while attaching cable ends to purple cards).

- After populating the structure the support rod would be put in a cantilever support condition holding it at Z=850 and Z=1500mm and extracted from the RT05. A long lead in on the end of the shaft will allow us to adjust the supports as the rod is extracted to avoid any abrupt motion as the end of the shaft leaves the RT05.
- We must avoid over-constraining the structures during mating. This means we cannot engage pins while we are still on a tight fitting mandrel. The principle suggestion here was that a light weight (hollow CF hex tube) extension off the Z=0 end of the support rod. This extension would be about the length of the L0 structure. The end of the extension would be aligned to the bore of L1 and then the L0 structure would be slid off the mandrel onto the looser fitting extension rod. At this point 2 options are available. Option 1 is that the L0 structure continues to be pushed with L1 and the L0 support rod fixed. In this case the Z=0 disk of L0 would slide on the bore of L1 (or on a Kapton sheet inserted in the bore). Option 2 would be to keep the L0 structure and support rod fixed and move them in unison into L1 (or L1 over them). The latter requires a long travel slide that is not required for the former. At the end a mechanical “finger” would be slid inside L0 at Z=0 to position it close enough to engage the pins without constraining the structure (we need to get within about 5 mils for the pins to start into the bearings).
- Another proposal was to put a broomstick through L1 to couple to the Z=0 end of the L0 structure. The only significant difference between this and the previous paragraph is that the end of the rod would be supported beyond the Z=0 end of the L1 structure, reducing the cantilever of this beam. Bill pointed out that this may not be optimal as a cantilever beam has relatively little curvature near the unsupported end while a simply supported beam has maximal

curvature at its center; both these points are essentially where the L0 structure must slide on the mandrel, hence we desire minimal curvature of the beam.

- It was generally felt that whatever solution is derived for getting L0 into L1 it seems reasonable that the same solution, or something very similar, will get this package into L2-5 and hence that discussion should follow fleshing out the mating of L0 to L1.
- The desire for interchangeable structures was discussed and the main sticking point is accurate bearing and pin placement. FNAL has developed a good method for placing bearings on bulkheads using the CMM's as well as accurate pin placement in staves using hard tooling that clamps pairs of pins in V-grooves. The outcome of the discussion was that UW would investigate the tooling they require for placing pins and bearings on their structures. It was suggested that the same tooling be used to place pins or bearings on all structures so that interchangeability is preserved. The difficulties remain of alignment of the pins to the castellated surface ideal centerline and clocking of mount points from one end to the other.