

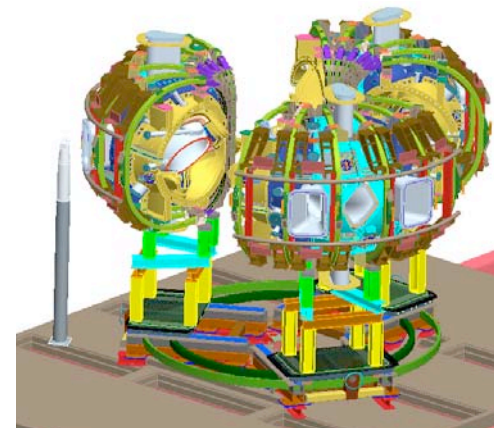
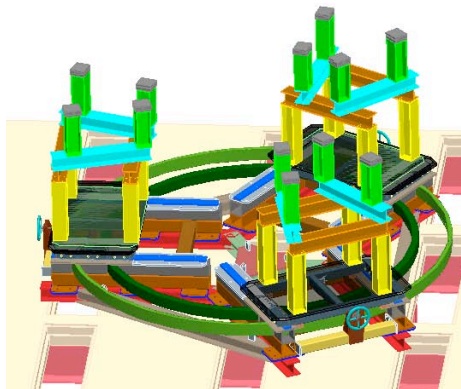
NCSX Machine Assembly

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October 31, 2007

Machine Assembly



- Machine assembly will be performed with detailed procedures
 - Will be based on the detailed assembly plan
 - Will include specific metrology steps
 - Will assure that tolerance goals are met



Machine Assembly

- Component preparations

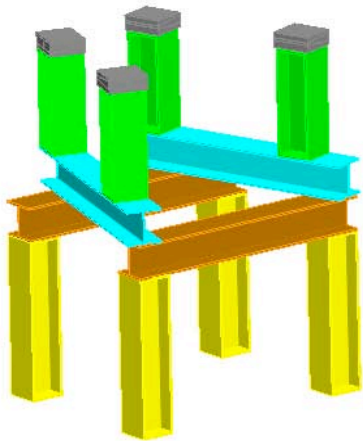


Fig 1a) Period support stand

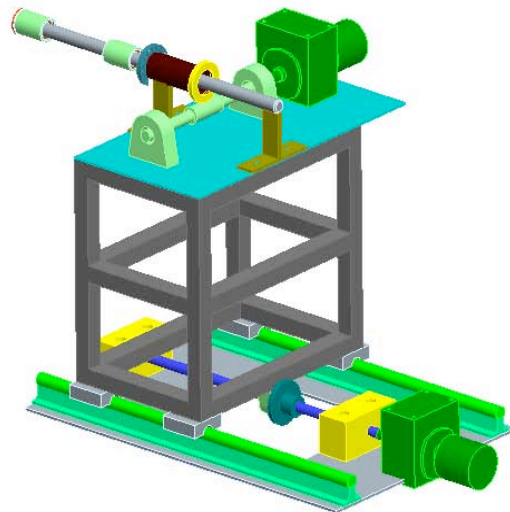


Fig 1b) Spool support stand

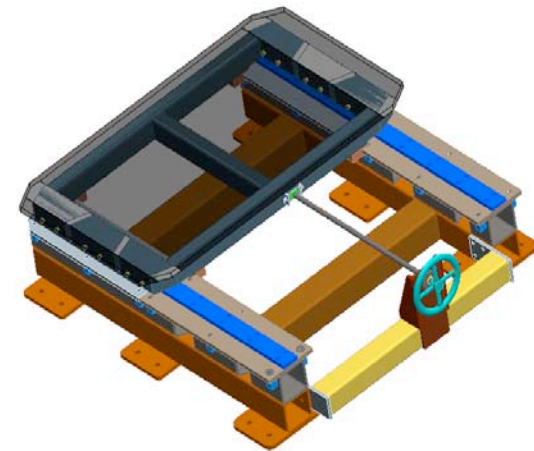


Fig 1c) FPA assembly cart

Machine Assembly

- Test cell metrology set-up and floor deflection test
- Pre-installation set-up and test
 - All tooling will be tested before it is needed

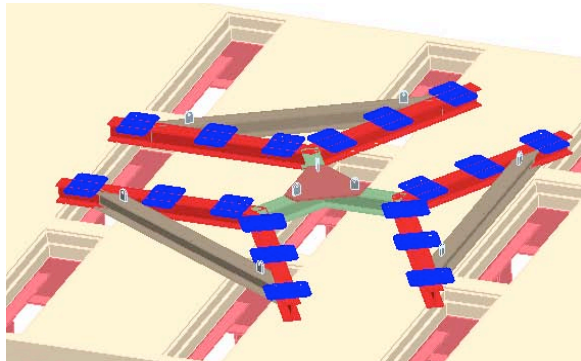


Fig. 2a) Machine base support structure

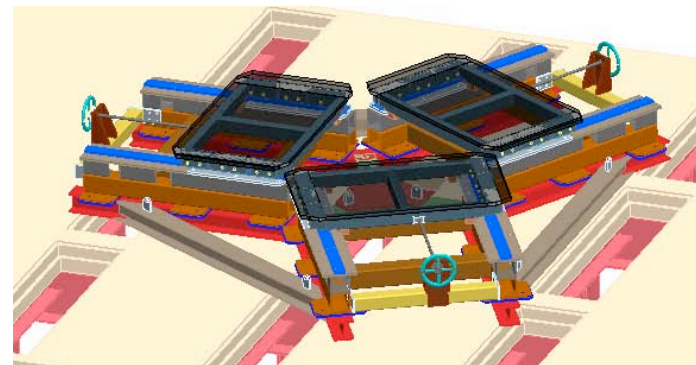
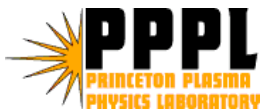


Fig. 2b) FPA assembly carts installed

Risks and Risk Mitigation



- Risk: Test Cell floor deflections exceed tolerances
- Testing: Deflection of floor will be tested by placing concrete blocks on the floor in key locations and measuring the deflection of the floor
- Mitigation: Stiffen bases of equipment to bridge between major beams under floor
- Alternate : Locally reinforce floor structure



Machine Assembly



- Temporary assembly structure used for increased positioning accuracy
 - Involves assembling field periods on one set of structures that have radial motion capability and then transferring to permanent supports
 - Positioning will be within 0.030”
 - Multiple fit-ups/iterations are included in the costs and schedules

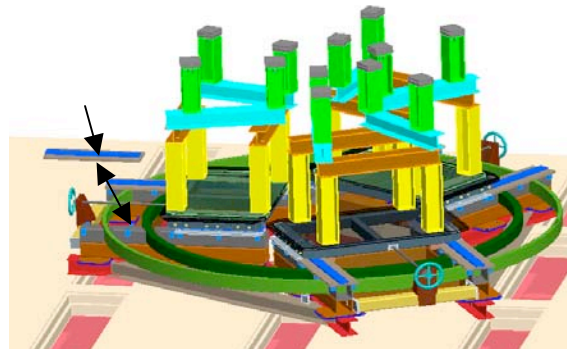


Fig. 2c) Lower coils positioned within the cart rail groves.

Machine Assembly

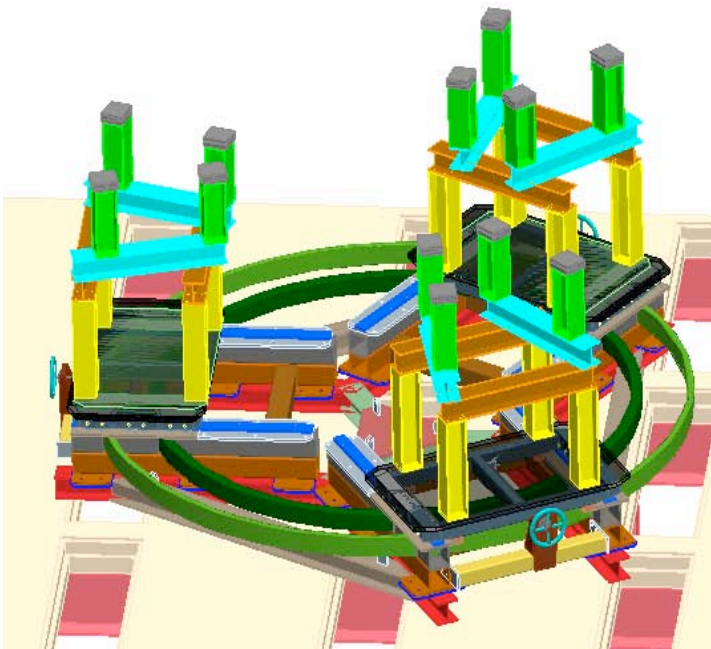


Fig. 2d) FPA cart moved to retracted position.

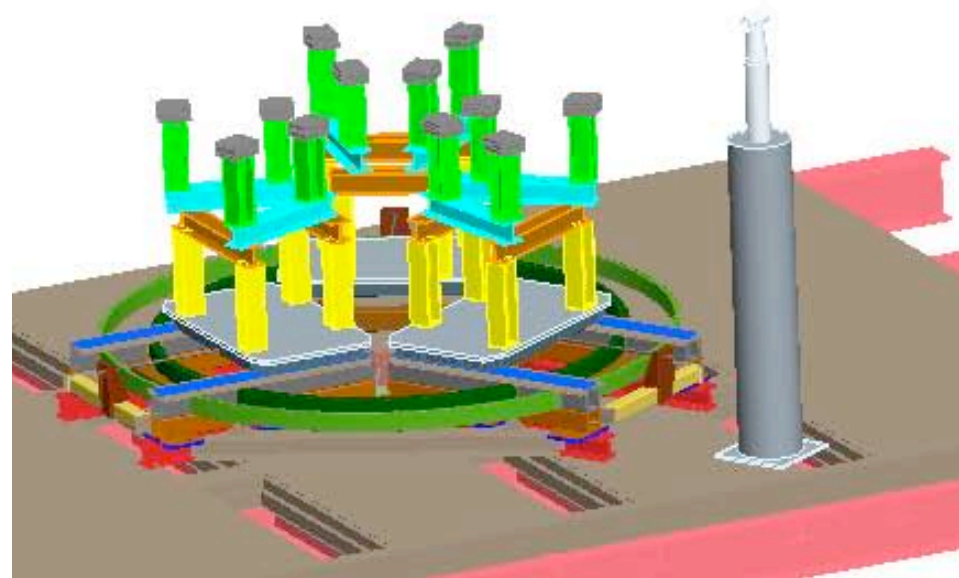


Fig. 3a) Laser support base and pole installed.

Risks and Risk Mitigation

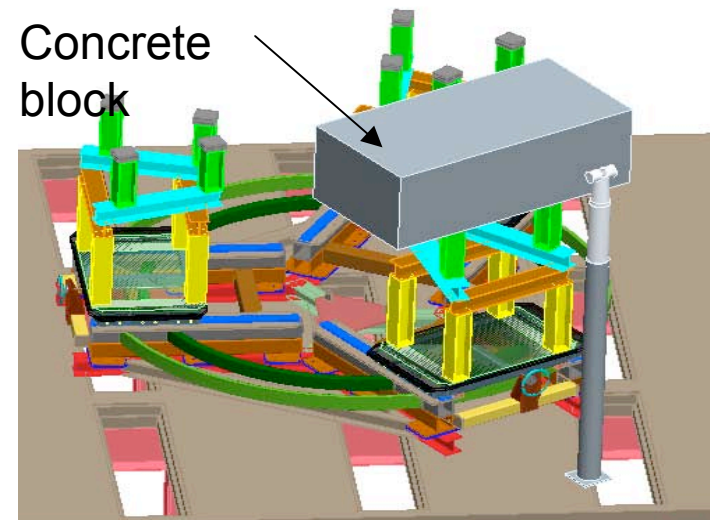


- Risk: Assembly sled not stiff enough or does not have repeatable motion
- Mitigation: Sled will be designed with adequate stiffness and then evaluated with concrete blocks in plenty of time to make design modifications

Machine Assembly



- Metrology/assembly testing of each assembly sled with a dummy load
 - Metrology is 1/3 of the total field work, as has been the experience on coil winding and vacuum vessel assembly
- Then testing each FPA on it's sled prior to final assembly
 - Per experience of Wendelstein 7-X



Risks and Risk Mitigation



- Risk: Metrology equipment not available to support the schedule
- Mitigation: Maintenance contract obtained for metrology equipment. Funds budgeted for a third laser tracker and/or other metrology equipment

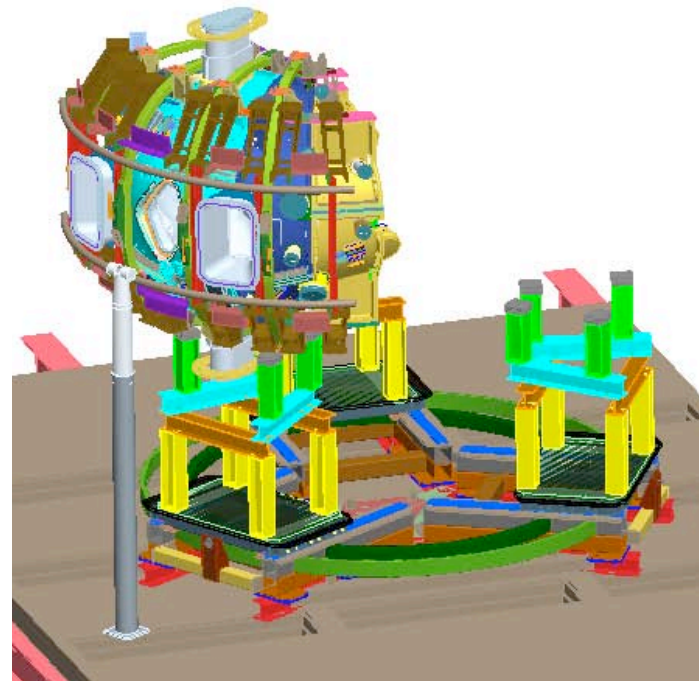
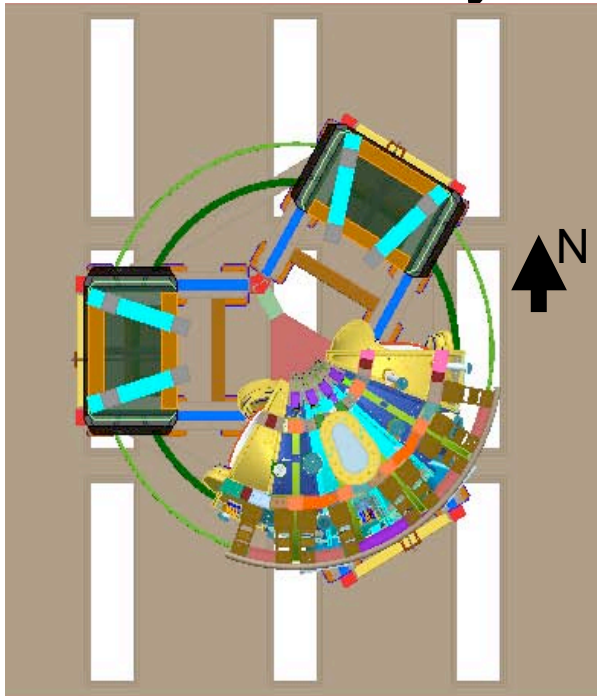
Risks and Risk Mitigation



- Risk: Metrology analysis support delays during peak needs
- Mitigation: Additional support has been budgeted

Machine Assembly

- Field Period Assembly (FPA) installation and assembly test



Risks and Risk Mitigation



- Risk: Field Period Assembly (FPA) alignment not within tolerances
- Testing: Metrology check of position
- Mitigation: Use assembly carts to reposition FPA

Machine Assembly

- Spool piece installation test

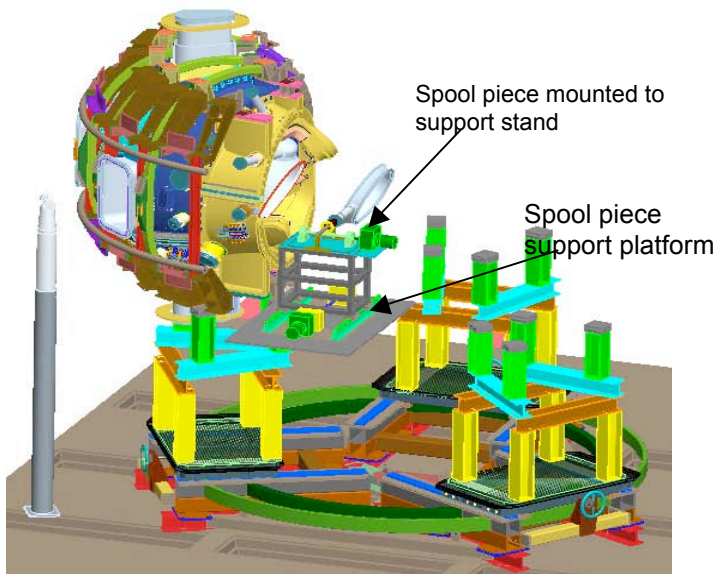


Fig. 5a) Period 1 retracted with spool and support stand installed

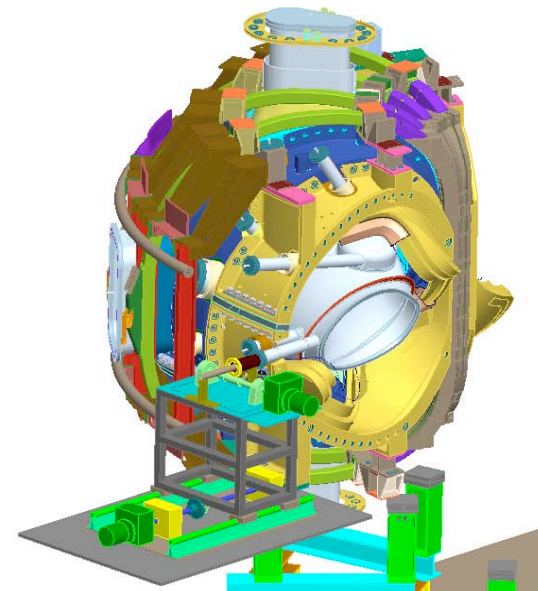


Fig. 5b) Period 1 and spool shown at installed position

Risks and Risk Mitigation



- Risk: Vacuum vessel sectors not in perfect position
- Testing: Measure gap between sectors
- Mitigation: Final machining of vessel spool piece after actual gap is measured

Machine Assembly

- FPA-2 installation

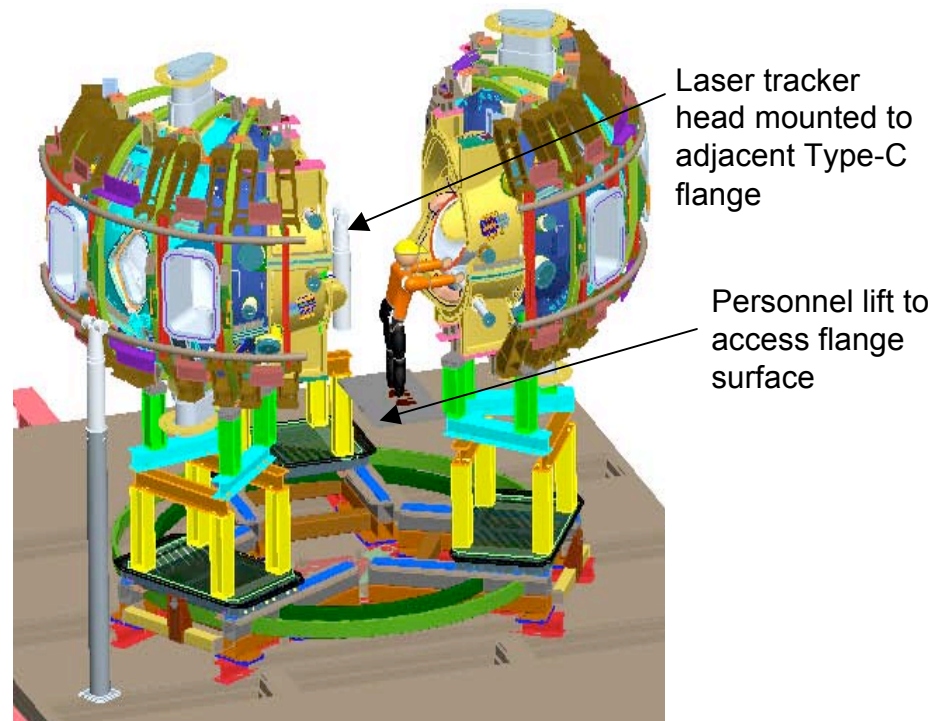


Fig. 6a) Type-C flange measurement

Risks and Risk Mitigation

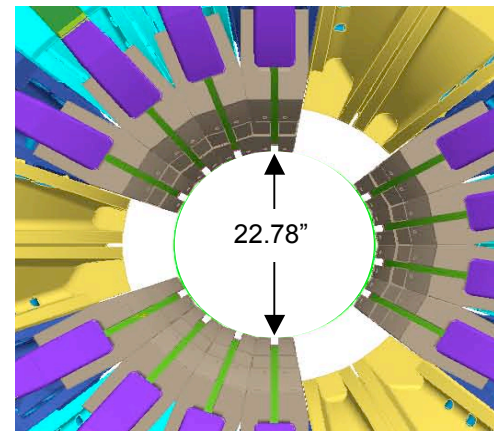
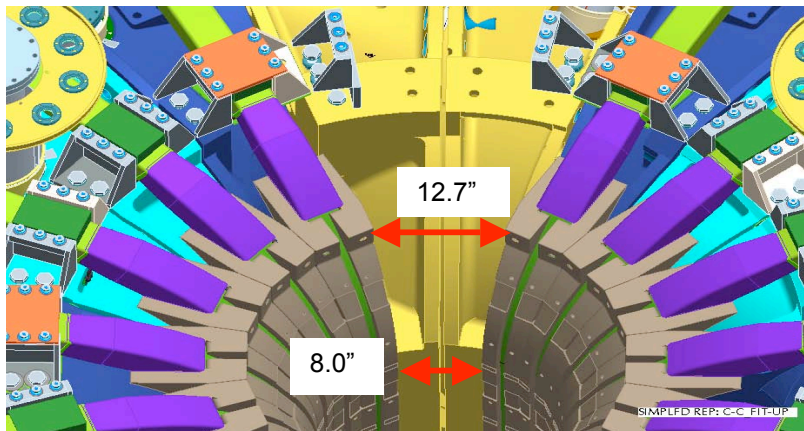


- Risk: Space between modular coils on adjacent FPAs not perfect
- Testing: Metrology to determine actual gap between Type C coils
- Mitigation: Custom shims

Machine Assembly



- FPA-3 installation
- Measure remaining Type-C modular coil flanges
- Type-C inboard shim installation check
 - Very limited space – platform needed for technician



Machine Assembly



- Type-C inboard shim check / installation
 - Temporarily attach a set of outboard shims (top/bottom) and all inboard shims on one Type-C flange of each of the three FPAs
 - Move all FPAs to their installed position
 - Install studs and supernuts at the shimmed locations; torque to 50% of final value
 - Do a hand “wiggle” test for all shims to make sure they are tight
 - If a loose shim is found, back off on sufficient adjacent bolts to allow a replacement shim to be inserted – tighten bolts and repeat

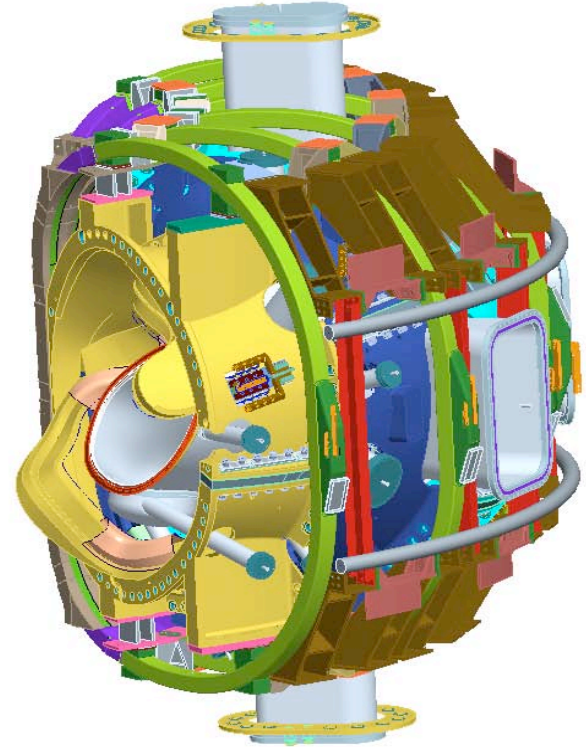
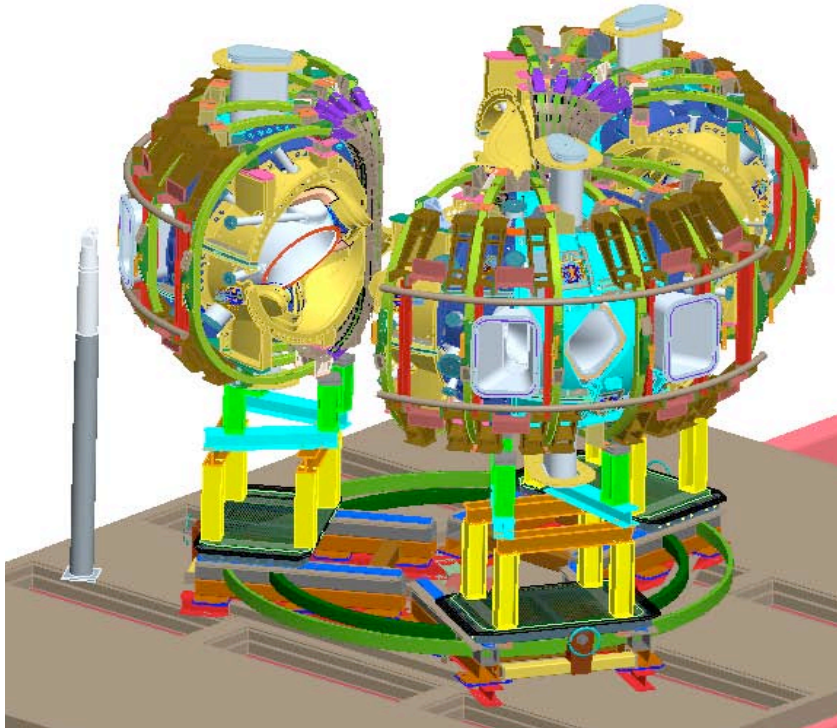
Machine Assembly



- Type-C inboard shim check / installation ^{cont}
 - Measure a minimum of eight tooling balls on each FPA
 - The maximum deviation should be 0.020” or less
 - If deviation exceeds 0.020”, “back office” input is needed on which new shims should be used
 - Loosen hardware, install new shims and repeat
 - With successful metrology measurements, remove all hardware and return each FPA to its retracted position
 - Permanently secure in place all inboard shims. Retain in place all initial alignment outboard shims

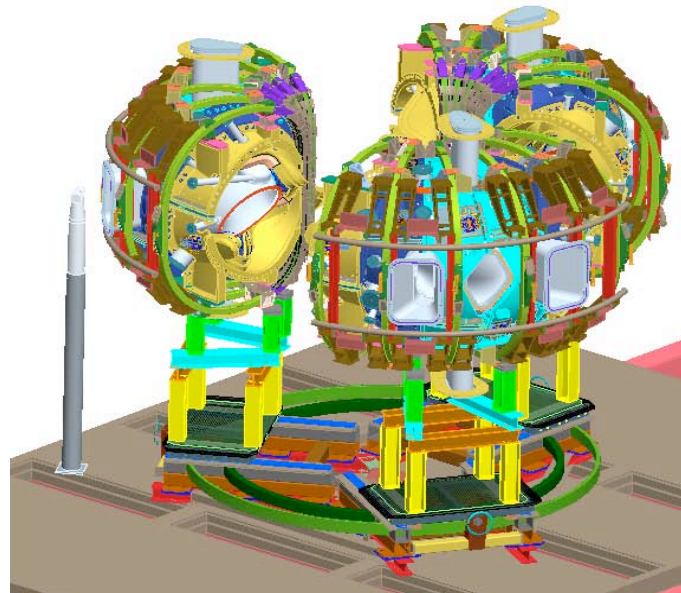
Machine Assembly

- Install remaining TF coils



Machine Assembly

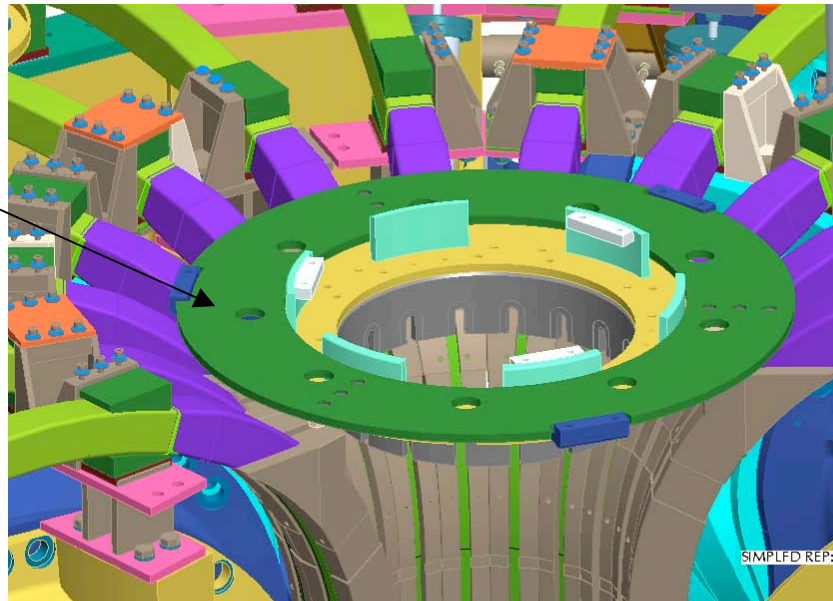
- Install lower coils and solenoid support
- Move all FPAs to installed position
- Move each vacuum vessel section to its final position



Machine Assembly

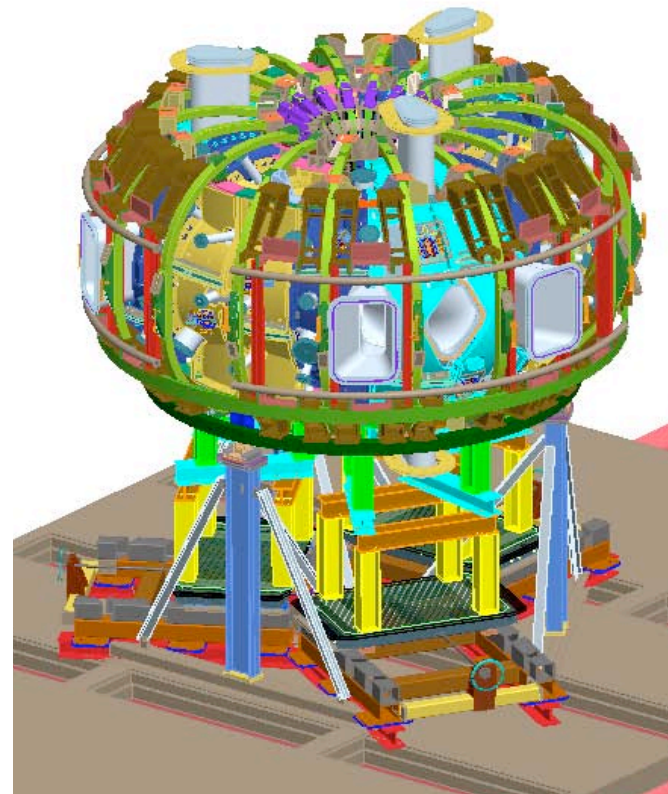
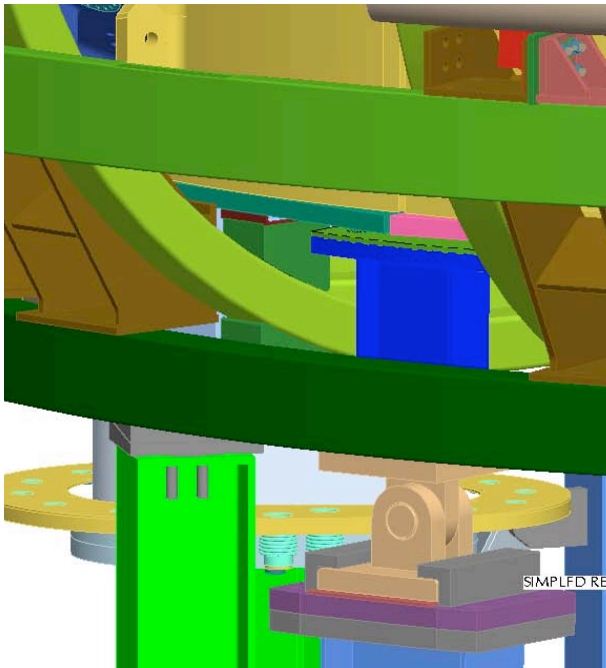
- Move TF coils to final position
- Install lower PF coils

TF centering disk



Machine Assembly

- Transfer weight to final machine support structure



Risks and Risk Mitigation



- Risk: FPA position shifts when load is transferred to permanent supports
- Testing: Metrology determines shift
- Mitigation: Transfer load back to temporary carts, re-set permanent supports to compensate, and repeat

Machine Assembly



- Install vacuum pumping system
- Pumpdown test
- Insulation fill in annulus between modular coils and vacuum vessel
- Install center solenoid
- Install PF coils
- Install auxiliary systems

Tolerance Goals



- Tolerance Goals can be achieved
 - Procedures and tooling, including metrology, are being designed to be consistent with tolerance requirements of within 0.030”
 - Procedures and tooling have been developed for Field Period Assembly which can be carried over to Final Assembly tasks

Tolerance Goals ^{cont}



- Final machine assembly planning is consistent with requirements
 - Assembly access for C-C inboard bolted joint has been studied using CAD modeling and a physical mockup
 - Mitigation measures are being budgeted, planned and implemented for risks that are still outstanding

Summary



- The level of detail for the Machine Assembly has increased significantly in the past year as the Assembly Sequence Plan was generated, task by task estimates were made, assembly risks were identified and ways to mitigate the risks were developed
- Although designs affecting the assembly are at a conceptual level in many cases, conservative estimates which allow for multiple fit-ups, along with experience from the assembly of other devices (PDX, TFTR and NSTX) and the metrology experience gained from the Field Period Assembly, will assure the assembly of NCSX within the ± 0.030 " tolerance requirements