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CUST 303 - Using AFX and Simulate to Design and Analyze Large Radio Telescope Structures

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The CCAT Submillimeter Radio Telescope

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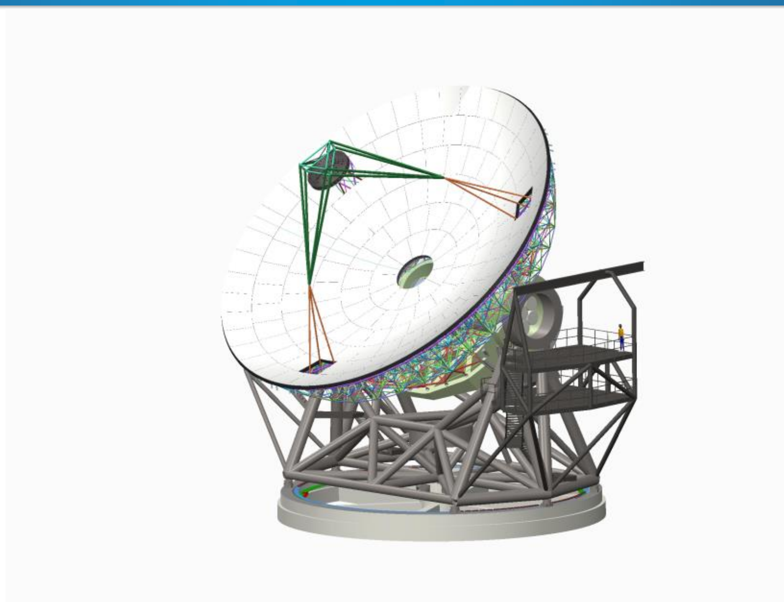
Dish Side



The CCAT Submillimeter Radio Telescope

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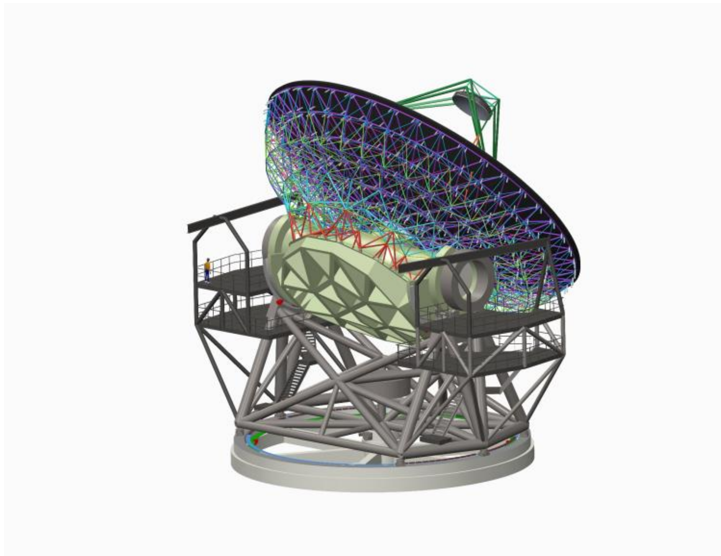

The CFRP Backing Structure

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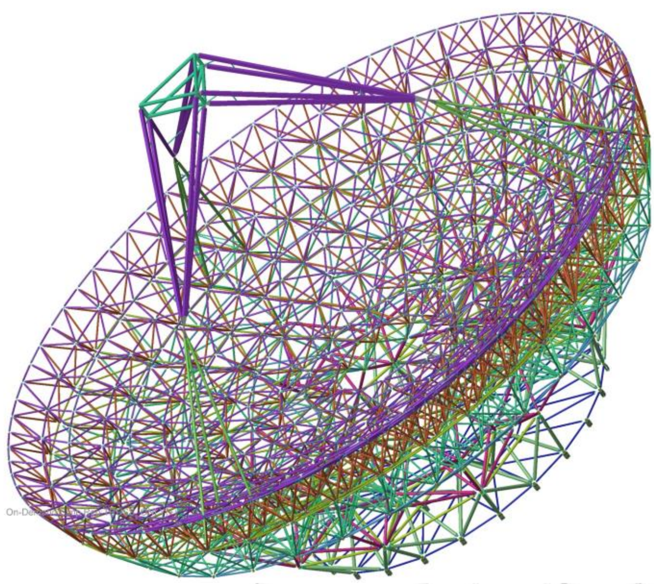
Only the truss structure



Side View

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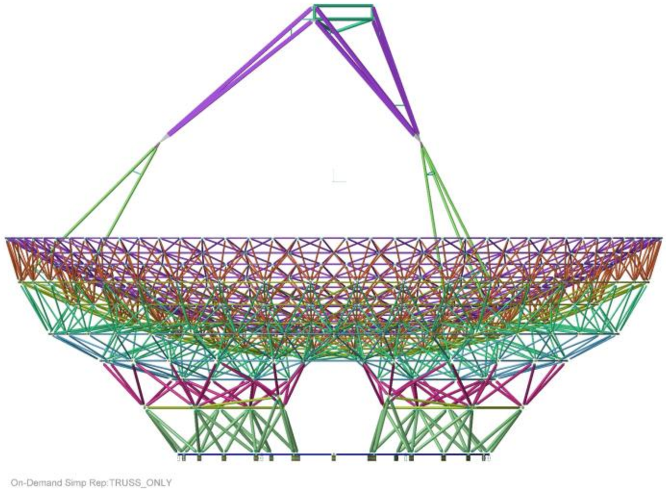
View down the Elevation Tube



Top View

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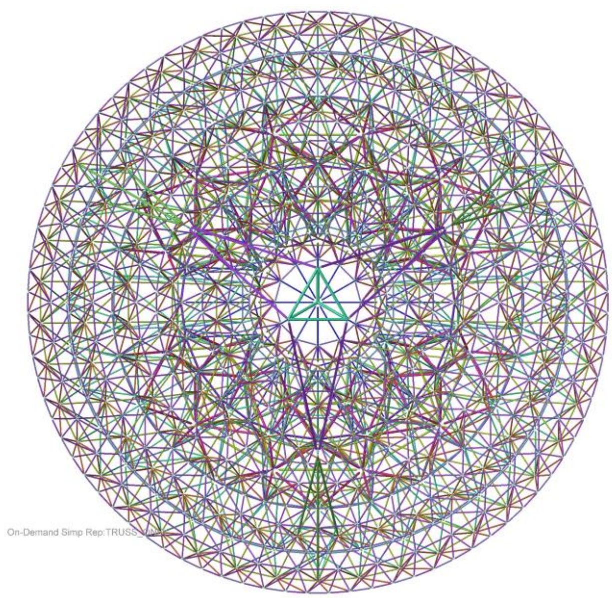

The Challenge

Some Requirements

- 25 meter diameter reflector
- No more than 5 µm RMS surface figure error over the entire primary reflector.
- No more than 1 µm RMS surface figure error over the entire secondary reflector.
- f/0.8 Gregorian optical design
- 0º C to -30º C Operational temperature range.
- 0.2 ppm/ºC CTE over the entire primary structure.
- Construction at 5600 meters.
- No more than 2 mm of primary to secondary axial misalignment over the 60º range of elevation tipping.

Some Simple Specs

These resulted from the requirements

- To meet the CTE requirements we designed the truss with:
  - 16,000 kg of CFRP.
  - 10,000 kg of PH-4 stainless steel.
  - 6,000 kg of Invar-32
  - 32 double blade flexures for the interface to the 1450 tonne steel mount
- To meet the stiffness requirements we designed the truss with:
  - 180 GPa CFRP for the backing structure tubes
  - 3000+ tubular beams with multi-part end fittings
  - 9 different CFRP tubing sizes, large diameter and thick walled at the bottom to small diameters for the upper layers
  - 200 GPa Rectangular tubes for the secondary structure
- To analyze the structure There are:
  - 12,000+ beam elements
  - 7000+ masses
  - 486 rigid links
  - 72 meshed surfaces
- There are many more, but these are the ones important to this presentation.

It's all about advance planning

But, you won't get it right the first time.

- A large model like this will require a couple of reboots to get a configuration that will make everyone happier.
- Advance planning will make this process much easier.
- This is the type of model that benefits from top down planning.
- Consider using Component Interface features. Take the time to configure them early and use coordinate systems when possible.
- When possible, subassemblies should be assembled to stable high level coordinate systems. Avoid using other parts for assembly references.
- Research the tools that you are going to use.
- Become a power user of the Find tool.
- Use Notebooks to define global parameters.

The Point Cloud and AFX

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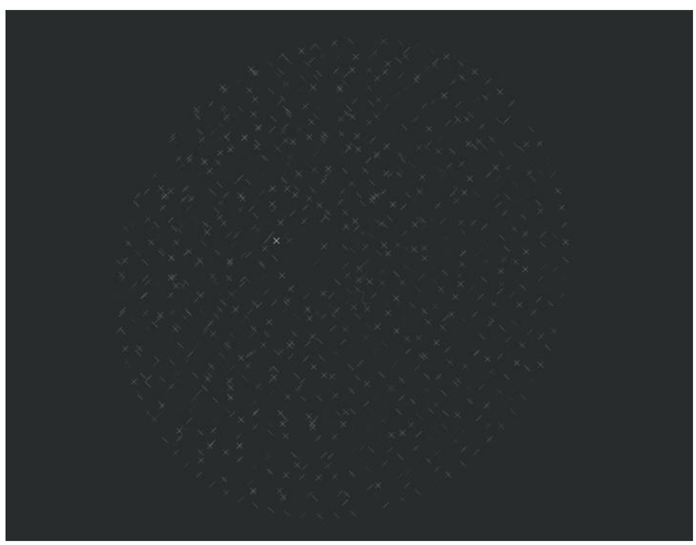
A point cloud is the foundation of the CCAT backing structure

- AFX needs a start point and an end point to place a part.
- This can be a pair of datum points, a curve, or a pair of vertexes.
- For a large assembly such as the CCAT backing structure, points are the easiest to produce and maintain.
- It may be easiest to create the points in a spreadsheet and import them to PTC Creo.
- The points should be very near the top of the assembly tree.
- The points need to be stable with few parents.
- The CCAT point cloud was created with a cylindrical coordinate system in Excel.



Global Parameters and Notebooks

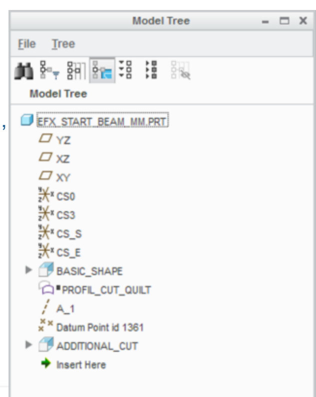
Remember that global parameters are a one-way street.

- Once an AFX part is created it has no connection to the base part. But the AFX part will take whatever you put in the prototype part's environment and duplicate it to the created part. In AFX the prototype part is referred to as a section.
- As with all parts, a parameter created in a part is local to that part. This creates a problem if you want to change a property common to a large number – possibly hundreds – of parts.
- Global parameters can handle this easily. Created in notebooks, global parameters are linked to parts and assemblies with the 'Declare' command. When a part declares a notebook it has access to the notebook's datums and parameters.
- This access is read only, so it is not directly useful for optimization studies.
- Global parameters will allow you to change one value, say a beam's wall thickness, and after a regeneration hundreds to thousands of parts will change.

What do you want your beams to do for you?

Be creative!

- There are some interesting AFX parts buried in the PTC installation directory, see:
  - C:\Program Files\PTC\Creo 3.0\M030\Common Files\afx\parts\profiles\custom_start_beams
- The model tree of one of the start parts is shown to the left; It is quite simple. The 'BASIC_SHAPE' feature is the profile of the extrusion. The 'Additional_Cut' is also extruded, but not required.
- You can change the sketches to whatever works for you. You can add relations, change colors, add datums, sketches, add features, pro-program, etc. But, DO NOT change the original datum features.
- When you declare a notebook to this file the parameters in the notebook become visible to the part.
- When you are finished modifying the part, save a copy in a new directory under the profiles subdirectory.
- To make this part visible on the AFX selection menu you must modify the 'sel_list.txt' file in the profiles directory. You then must also add a 'sel_list.txt' file to the new directory. These files have the same name but they have a different format.



AFX and Simulate

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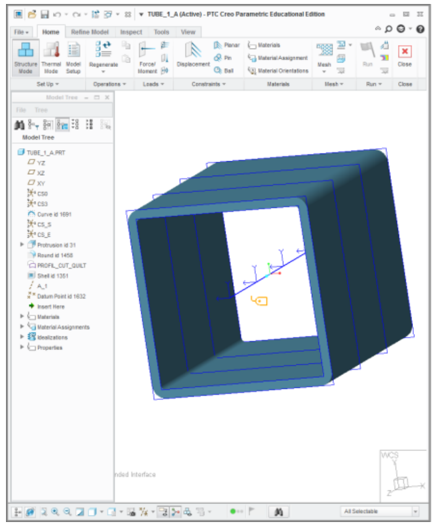
Imbedding Simulation Features into the Beams

- Simulation features can be added to the part, in this case a beam was added.
- Relations are used to size the beam section. The beam section can use dimensions that are internal to the part or global parameters.
- Other simulation features can be added: masses, shells, regions, AutoGEM controls, etc.
- Any features that are added must satisfy the standard Simulate rules when the part is added to an assembly environment.
- The FEM mode is also a valid choice.



Prepping the Part for entry into Simulation

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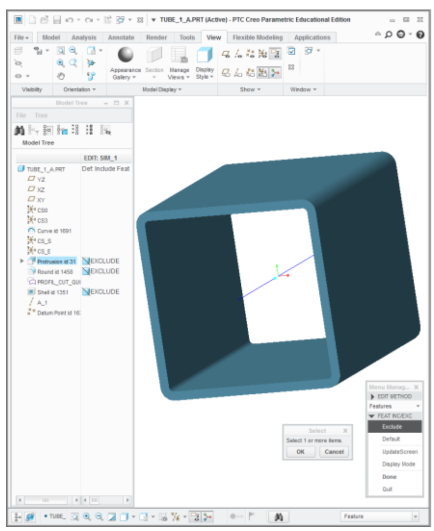
Simplified Representations can also be used at the part level.

- Use simplified representations to prepare the part for entry into the simulation environment.
- To use the beams or shells in Simulate the solid features must be excluded.
- The simulation features will still be present when entering Simulate.
- If the solid features are not excluded then Simulate will attempt to incorporate them into an analysis.
- Here we are creating a user defined simplified rep named ‘sim_1’.



The CCAT Truss Elements

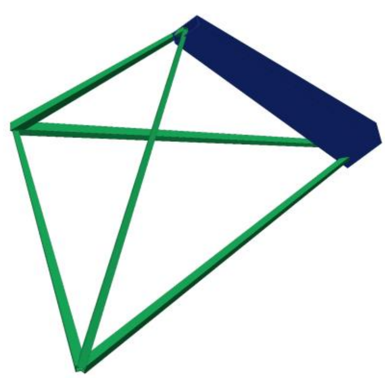
An example:

- The prototype CCAT truss elements were configured to be both a design model and a simulation element. This way only one, not two, models had to be maintained.
- Each prototype beam had interfaces to automate the assembly of end fittings after the beam was placed in the model.
- When a part was placed into an assembly relations were used to:
  - Calculate length requirements for the CFRP, Invar, and steel to achieve a CTE of .2 ppm/C°
  - The tube ends were cut back to create the proper length of CFRP tube.
  - The interfaces were positioned to properly place the steel and invar end fitting.
  - Seven simulation beams were connected together to model the lengths of the CFRP tube and the exposed lengths of the metal end fittings.
  - Two simulation masses were positioned to account for non-structural mass.
- After all of the AFX parts were placed in a subassembly the end fitting models were placed using the interfaces imbedded in the AFX parts.

Being Creative

Putting it together with tapered tubes.

- The tetrahedron to the right was created with an AFX prototype part that has a sweep feature rather than a constant cross section.
- To control the dimensions each tube has six global parameters in a central notebook. They are:
  - Beginning_height_x
  - Endding_height_x
  - Height_wall_thick_x
  - Beginning_width_x
  - Endding_width_x
  - Width_wall_thick_x
  - Where x is replaced with a number for the specific tube type that being created.
- These tubes also have a midplane shell as part of the extrusion with an AutoGEM control to control mesh size.



Use Subassemblies and Symmetry

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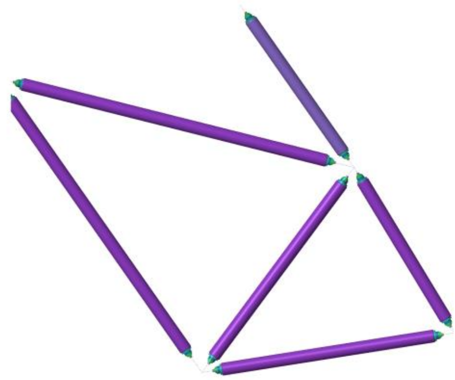
Subassemblies can make AFX workflow a lot easier.

- Find repeating patterns and create a subassembly for each pattern. This is critical for creating an AFX model that is easier to build and maintain.
- When you identify a truss pattern:
  - Create a subassembly
  - Align it to the top level master coordinate system
  - Copy the top level points and features associated with the pattern into the subassembly
  - Add the AFX parts to the subassembly
  - Return to the top level assembly and apply the pattern
- The section of truss to the right was repeated 42 times around the top edge of the truss!
- The end fittings were added later using interfaces that were added to the AFX prototype part.



Preparing the Top Level Assembly for Simulate

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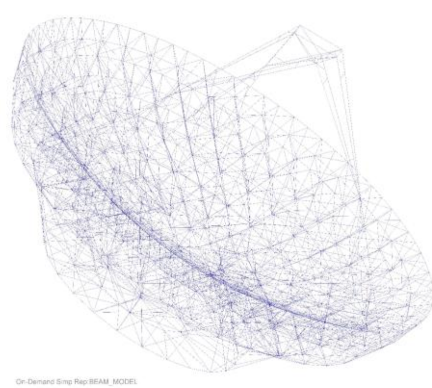
Only take what you need into the simulation environment.

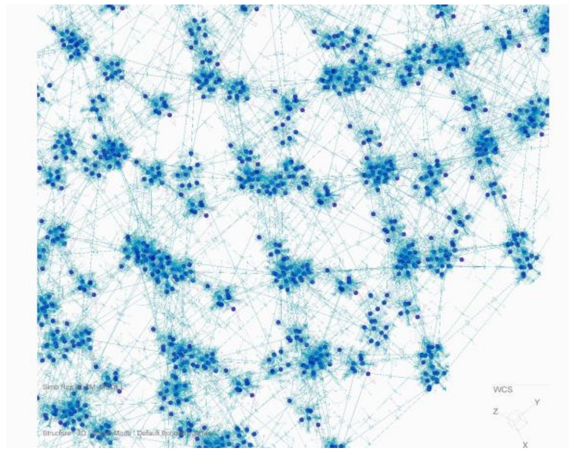
- A special simplified rep must be created in the assembly to allow the assembly to enter the simulation environment.
- Parts that do not need to enter the simulation environment are excluded.
- Parts that are to enter the simulation environment must be included with the user defined simulation simplified rep. In this case this would be the ‘sim_1’ representation created on the last slide.
- The figure to the right is what is left after the new simplified simulation rep is created. The blue curves are part of the AFX part. They must be visible if the beams are to be visible in the simulation environment.



Entering The Simulation Environment

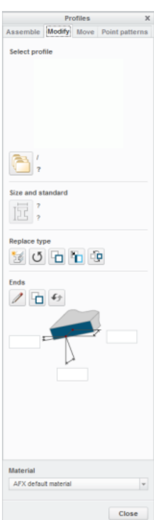
Decision Point: Native or FEM?

- The procedures that have been outlined work for both Native and FEM mode in the simulation environment.
- PTC Creo 3.0 can now produce a NASTRAN 2013 compatible deck. PTC Creo will only produce a subset of the all possible NASTRAN commands, but it will satisfy most of PTC users' needs.
- At this point one adds constraints, loads, and any idealizations that were not embedded within the AFX elements.
- The image to the right is a section of the truss showing beams, masses, and rigid links. Only the rigid links were placed by hand at the subassembly level; everything else came in with the AFX sections.
- Each AFX part brought with it 7 beams and 2 masses, plus the coordinate system to define the material direction for the CFRP.



Late Life Change; The Workflow for Changing Times

A little painful, but it could be a lot worse.



- How to change the form or function of a truss element.
  1. Open any declared notebook(s) and add any new parameter or relations that will be needed.
  2. Regenerate the notebook. Any new global parameters will not be visible without a regen.
  3. Open the prototype AFX part that needs to be changed and make the needed changes.
  4. Save a copy of the modified prototype. Do not save the modified part.
  5. Open the sel_list.txt file in the directory that contains the new part, and add the name of the new AFX part. Save and close sel_list.txt.
  6. Close PTC Creo, restart PTC Creo, and reload the top level assembly. The new AFX parts are registered only at startup.
  7. Open the subassembly with the parts that need to be changed out.
  8. Go to the Framework ribbon and open → Profiles → Modify and select the replacement part.
  9. Select the New Section icon, the one with the gold star.
  10. Click on the parts that need to be replaced. Click the part in the model tree or the model window. The new part name will replace the old name.
  11. Save and close the subassembly when done.

Tips

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- Most patterning should be done at the subassembly level.
  - Patterning AFX parts within a subassembly will result in added work when changing an old part far a new part.
  - When a patterned AFX part is replaced only the first part of the pattern will be replaced.
  - The pattern will need to be deleted and replaced to all parts of the new type.
- Declare notebooks only where access to the global parameters is needed.
- If the AFX part does not need to be aligned to a section orientation plane then right click when prompted for one. The part will be placed without alignment.
- For a large assembly consider using the Find tool for creating or editing the simulation simplified rep.
  - The simplified rep creation/edit window can be incredibly slow for large assemblies.
  - Place a parameter in the AFX prototype part that will identify the part as a member of the simplified rep.
  - If using the creation/edit window disable the preview window to speed up the response time.

Tips Continued

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- When placing an AFX part the first point picked will always be the starting point the extrusion.
- If various features in an AFX part are hidden, then any simulation features may be hidden in the simulation environment. The simulation feature is still part of the analysis, but it may not be visible.
- If you need to know the length of an AFX part after it has been placed in the assembly:
  - Create a reference dimension between the datum points that are part of the prototype part.
  - This is good for relations that depend on the length of the part, but the length is not known ahead of time.
  - The relations can be used to drive BOM parameters.

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