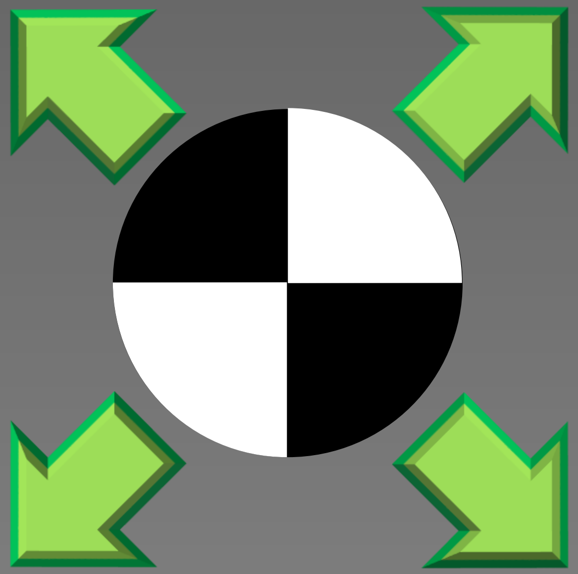
MassToGrids

A New Process for Applying Mass to FEMs



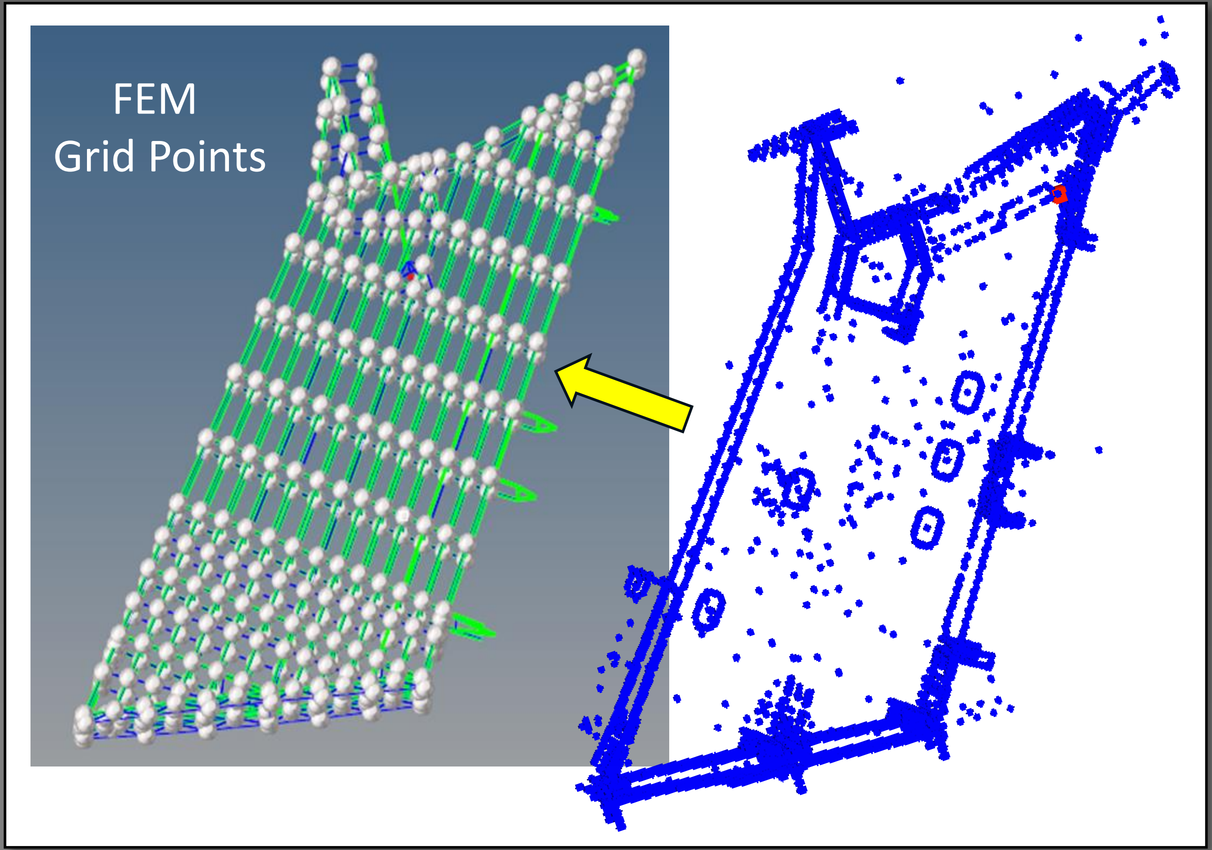
Presented by:
Damian Yañez, Ross Campbell and Adam Cox
Mass Properties Group
Gulfstream Aerospace Corporation

March 18, 2021

BACKGROUND

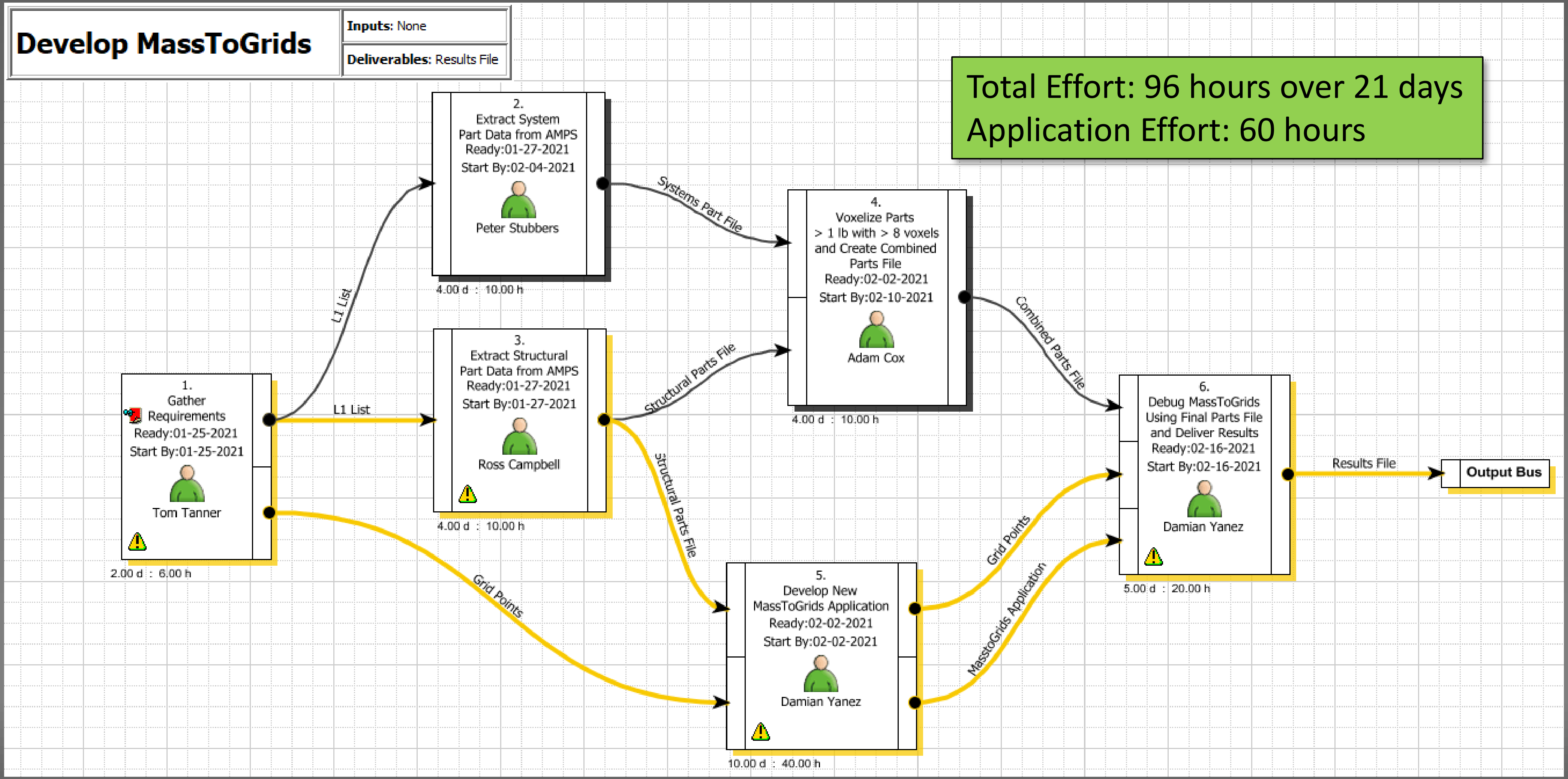
- The Mass Properties Department at Gulfstream developed and maintains an Aircraft Mass Properties System (AMPS) containing the weight and center of gravity (CG) of ***millions*** of parts for Gulfstream aircraft.
    - AMPS is tied directly to the Engineering product structure in the SmarTeam PLM system for near real-time updates and configuration control.
- Stress and Loads / Dynamics rapidly needed appropriate masses applied to their Finite Element Model (FEM) for an important study.
    - Dynamic and modal analyses of aircraft empennage.
- **Problem:**
    - Number of grid points (~500) much smaller than number of parts (~10,000).
    - Larger parts represented by single CG point with no local inertias.
    - Grid points at different positions than parts in 3D space.
    - Past method was highly simplified with limited accuracy and extremely labor intensive.
    - Time crunch.

THE CHALLENGE

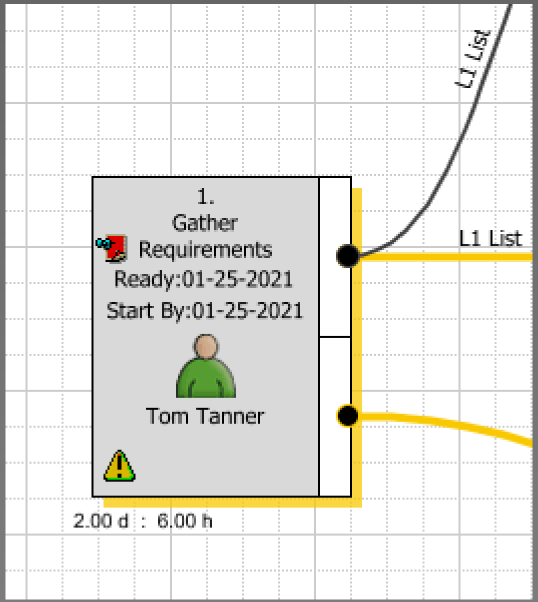


Rapidly distribute thousands of part masses to the FEM grid points while maintaining the overall mass properties

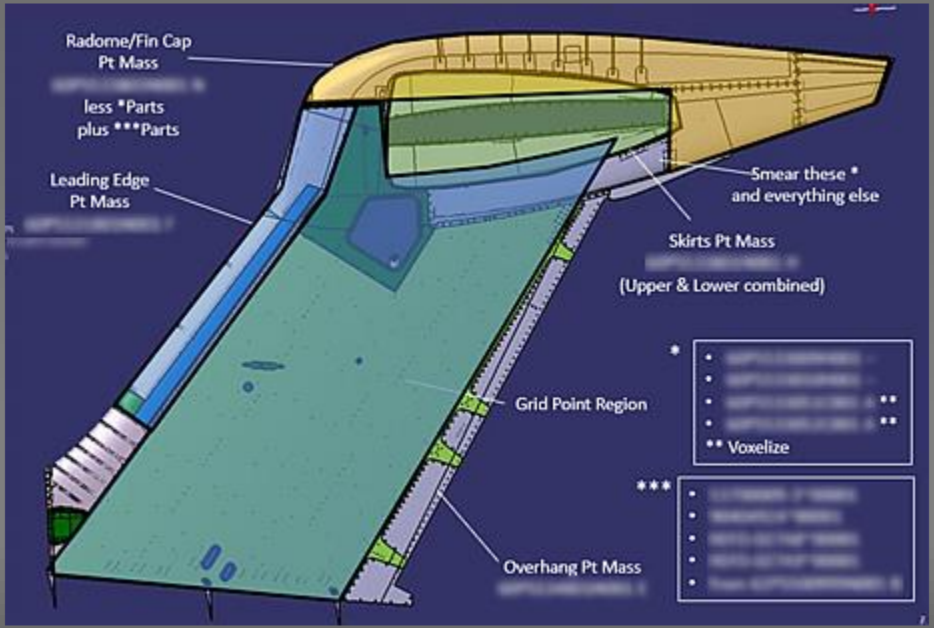
OUR APPROACH – Develop New Process & Tool



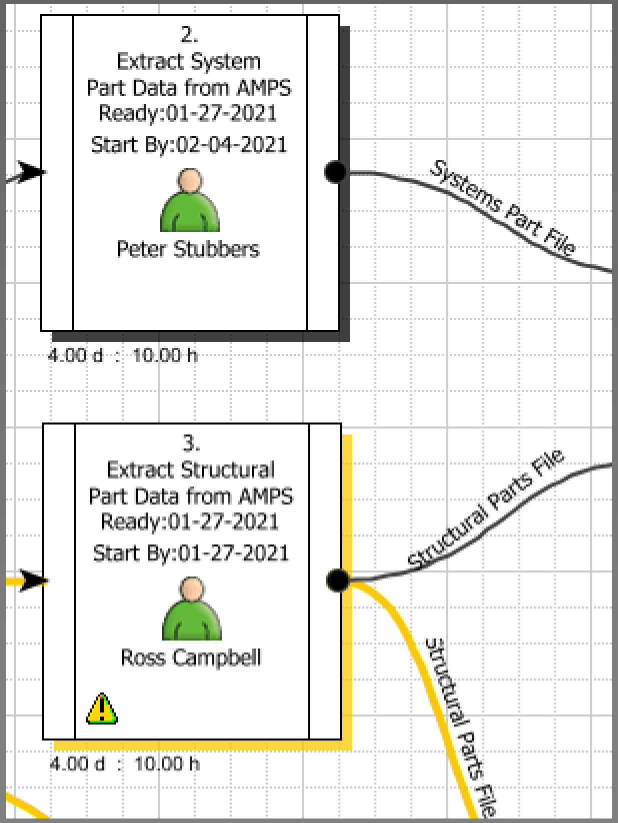
THE SOLUTION – Step 1: Gather Requirements



- Determined the Level 1 (L1) installation drawings to include.
- Obtained the target grid points from our Stress customer.
- Identified large parts and assemblies to be handled as single point masses
- Created this process for producing the desired results.
- Identified requirements for application development.

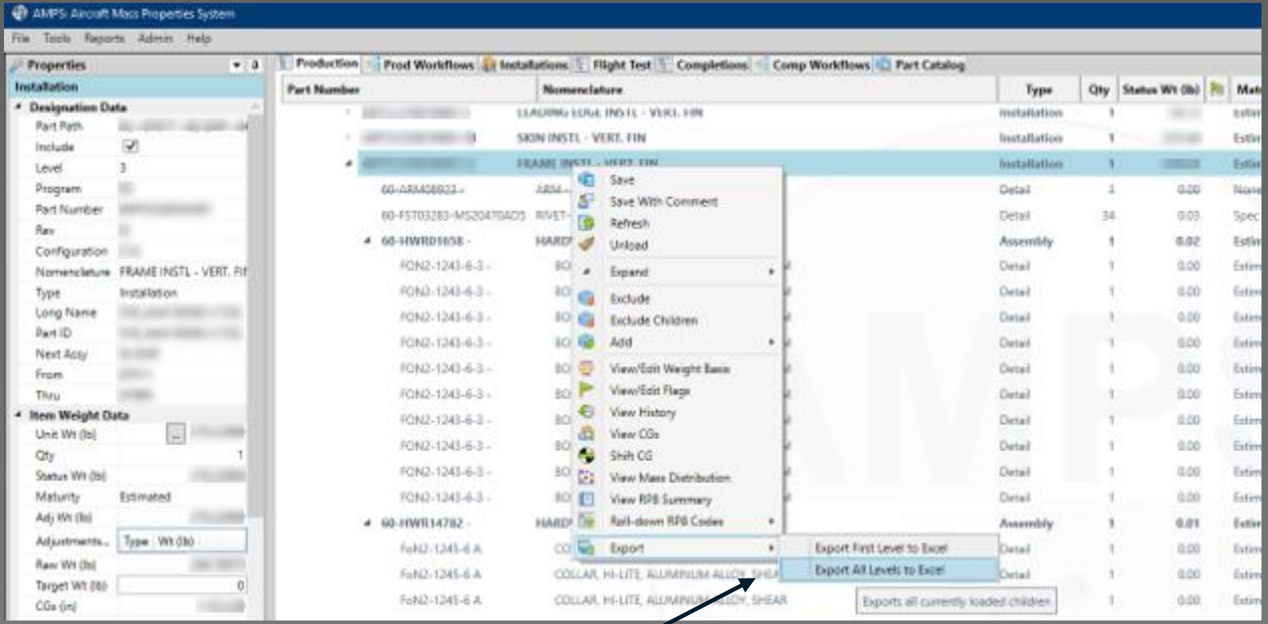


THE SOLUTION – Steps 2 & 3: Extract System & Structural Parts

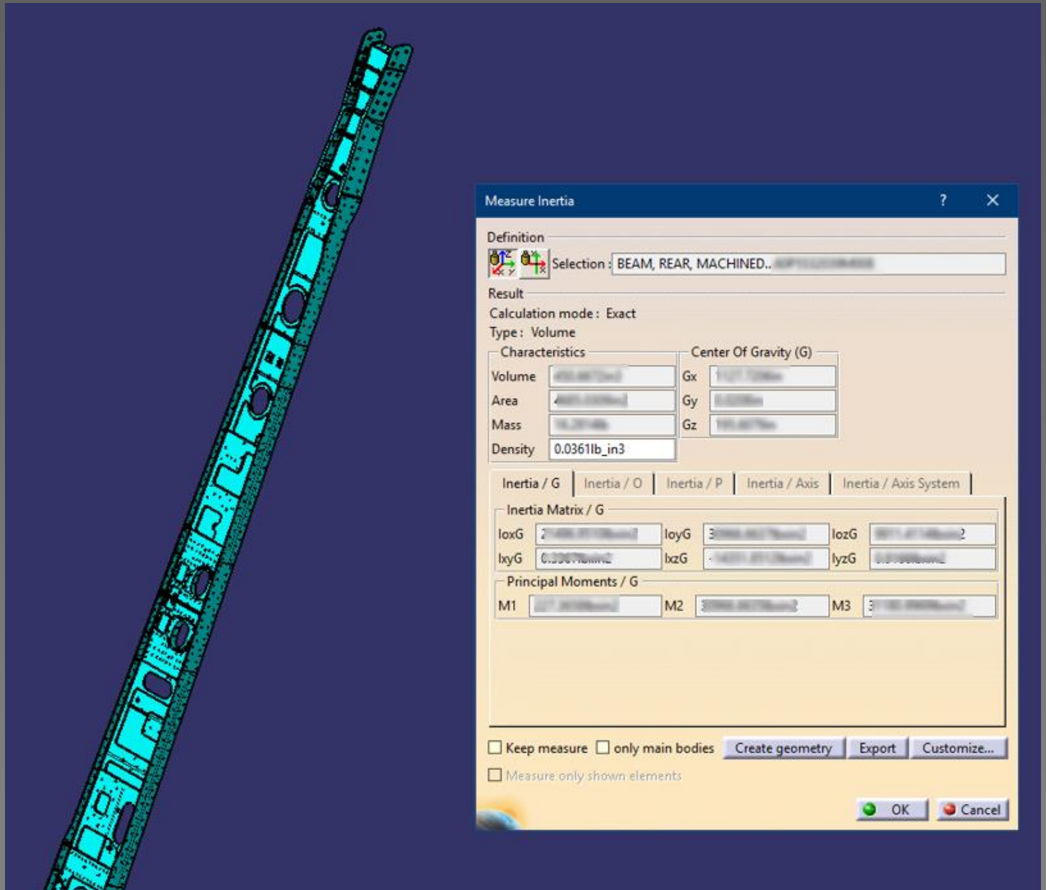


- Using L1 list, exported required parts from **AMPS** into Excel spreadsheets.
- Removed assemblies from the export, leaving only detail parts.
- Separated point mass parts from parts to be distributed.
- Identified larger parts and calculated local inertias using CATIA.
- Totaled up the mass properties of the details to use as targets.

THE SOLUTION – Steps 2 & 3 Details



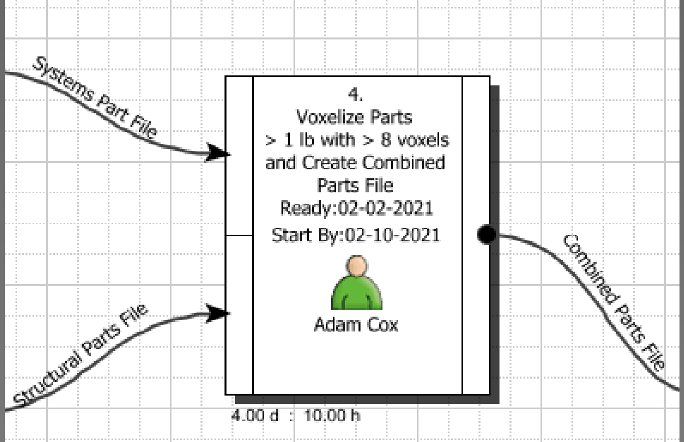
AMPS L1 Export



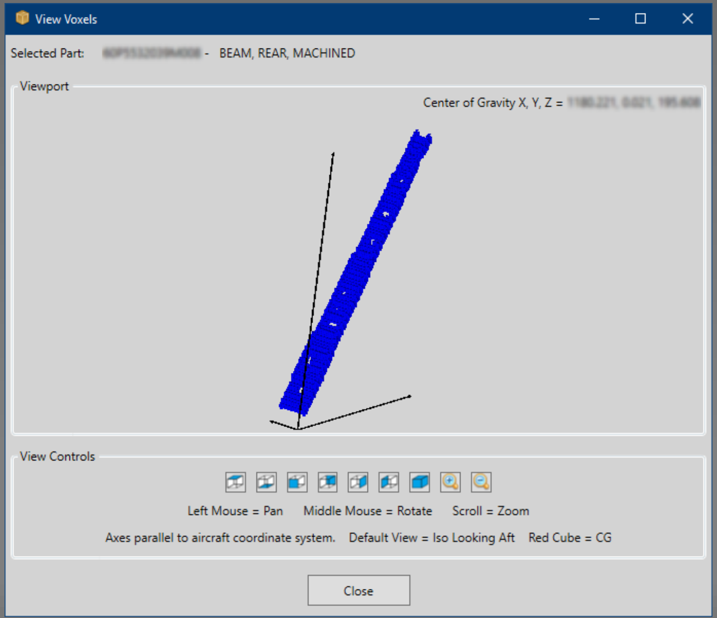
Large Part in CATIA

- Expand each L1 in AMPS and export with right click.
- Add inertias for parts > 1 lb using CATIA (adjust density)

THE SOLUTION – Step 4: Voxelize Large Parts & Combine

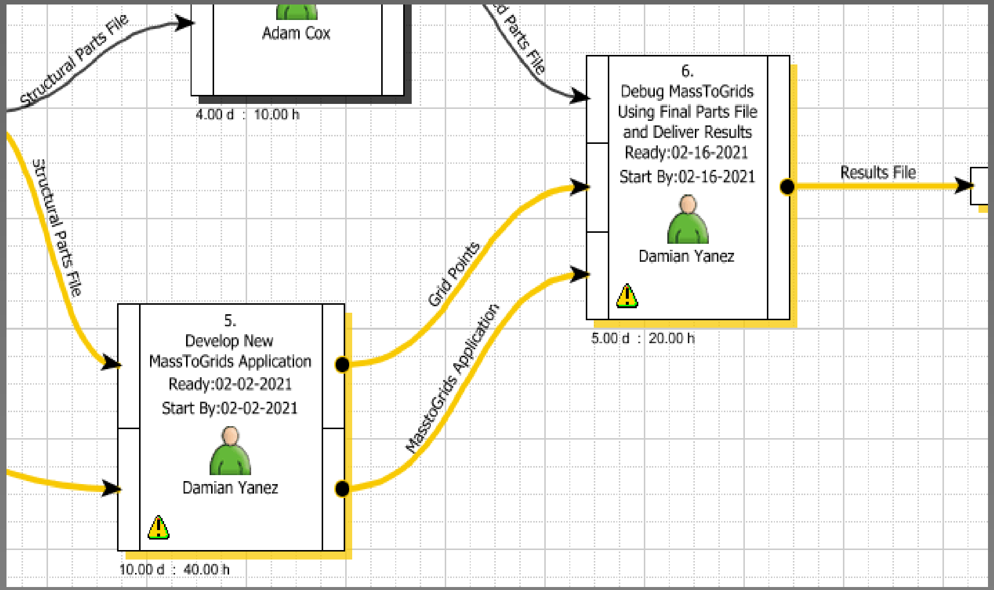


- Combined the system and structural part files into a single spreadsheet.
- Queried PLM tables for detail parts contained in the L1s from the L1 list having > 8 voxels (1” cube per voxel)
    - Resulted in 193,680 records.
    - Each record consists of an instance identifier, part number and the centroid of the voxel.
- “Voxelized” these parts by evenly dividing the weight into separate subparts at the voxel centroids.
    - Improves accounting for local inertias and geometry distribution.
- Replaced the single line parts in the combined spreadsheet with the voxelized parts.
- Delivered the combined parts file for import into the new MassToGrids tool.



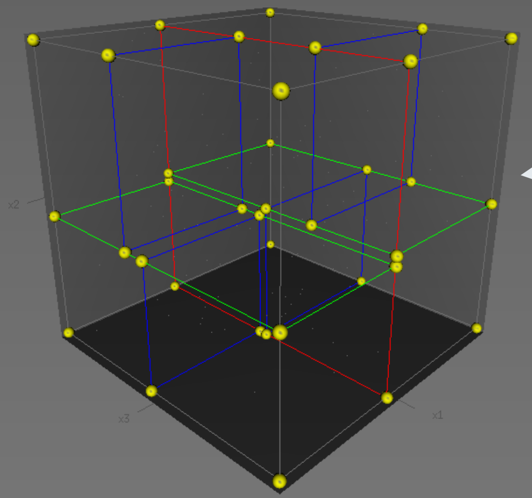
AMPS Voxel Viewer

THE SOLUTION – Steps 5 & 6: Develop MassToGrids Application



- Created new ClickOnce C#/WPF/.Net project using Visual Studio.
    - Base objects for Parts, GridPoints, …
    - List objects for Parts, GridPoints, Results, …
- Set up application GUI using XAML with data binding.
    - Input mechanisms for Parts and Grid Points files.
    - Run options, threading, error handling, …
    - Output tables
    - Export
- Developed distribution algorithm

THE SOLUTION – MassToGrids Distribution Algorithm



- Grid points sorted into 3D K-d tree for quick nearest neighbor search. (Binary space partitioning – Bentley)
- For each part:
  - K-nn search for nearest 4 grid points to part CG.
  - Divide the part weight and distribute to 4 points based on distance to each point (nearest point gets the most weight, furthest gets least).
  - Add part weights to any existing weight at the 4 grid points.
- Compute total mass properties of all the parts as target.
- Compute total mass properties of all the grid points.
- Compare and adjust the inertias if desired.

Total MOI (about axis parallel to X axis at total CG) | Local MOIs (about parallel axis at item CG) | Transfer Terms (to global reference) | Transfer Term (to total CG)

$$I_{oxx_T} = \sum_{i=1}^{n} I_{oxx_i} + \sum_{i=1}^{n} m_i({y_i}^2 + {z_i}^2) - m_T({y_T}^2 + {z_T}^2)$$

Where:

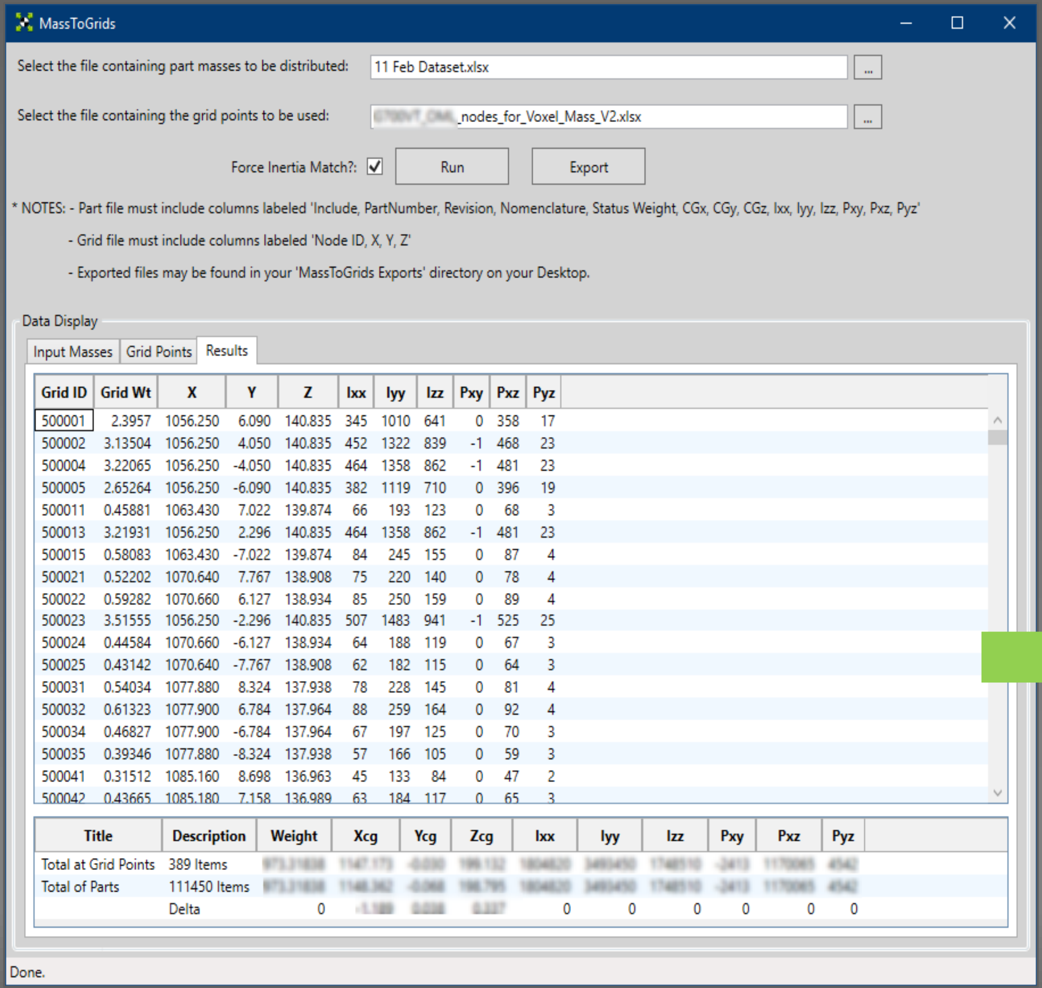
$$m_T = \sum_{i=1}^{n} m_i$$ — Total Mass

$$y_T = \frac{\sum_{i=1}^{n} m_i y_i}{m_T}$$ — Total CG in y direction

$$z_T = \frac{\sum_{i=1}^{n} m_i z_i}{m_T}$$ — Total CG in z direction

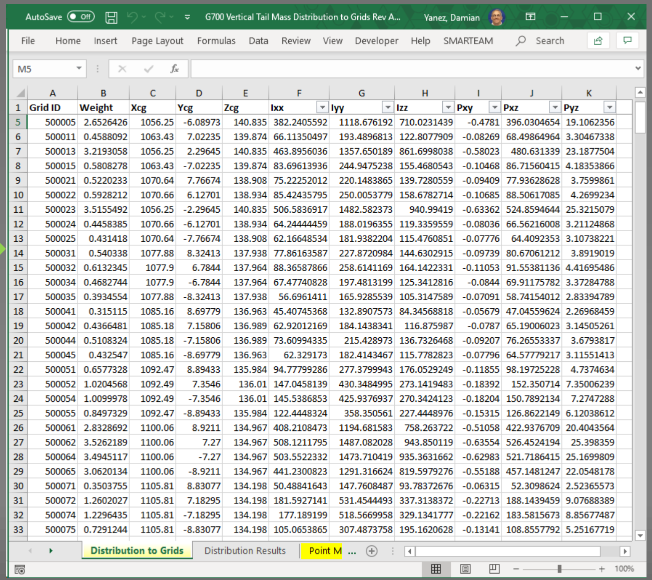
Similar for I_{oyy_T}, I_{ozz_T}

THE RESULTS



- 111,450 part items distributed to 450 grid points in 8 seconds.
- Overall weight and inertias matched exactly.
- Xcg within 0.78 in., Ycg within 0.24 in. , Zcg within 0.27 in.

Export



FUTURE OPPORTUNITIES FOR IMPROVEMENT

- Integrate MassToGrids into AMPS.
- Automate most steps.
- Refine CG matching algorithm.
- Allow user to select number of grid points for nearest neighbor search.
- Find a better way to apportion voxel weights.

QUESTIONS?