

MassToGrids

A New Process for Applying Mass to FEMs

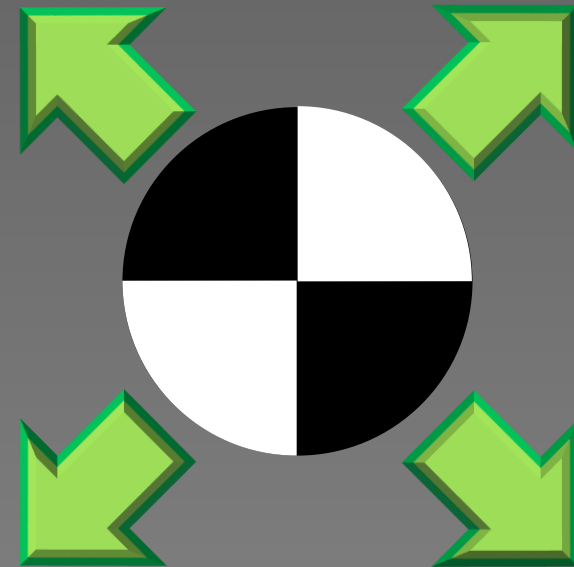
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Mass Properties Group

Gulfstream Aerospace Corporation

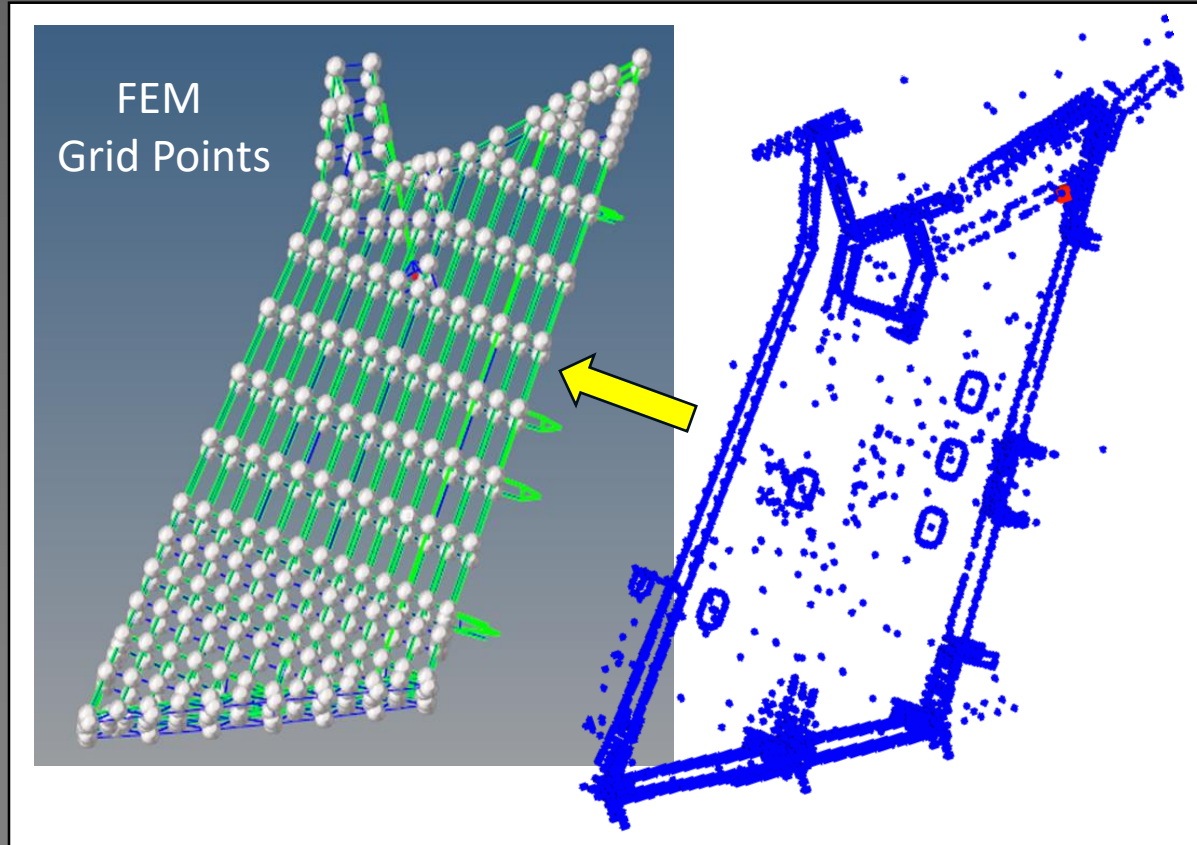
March 18, 2021



BACKGROUND

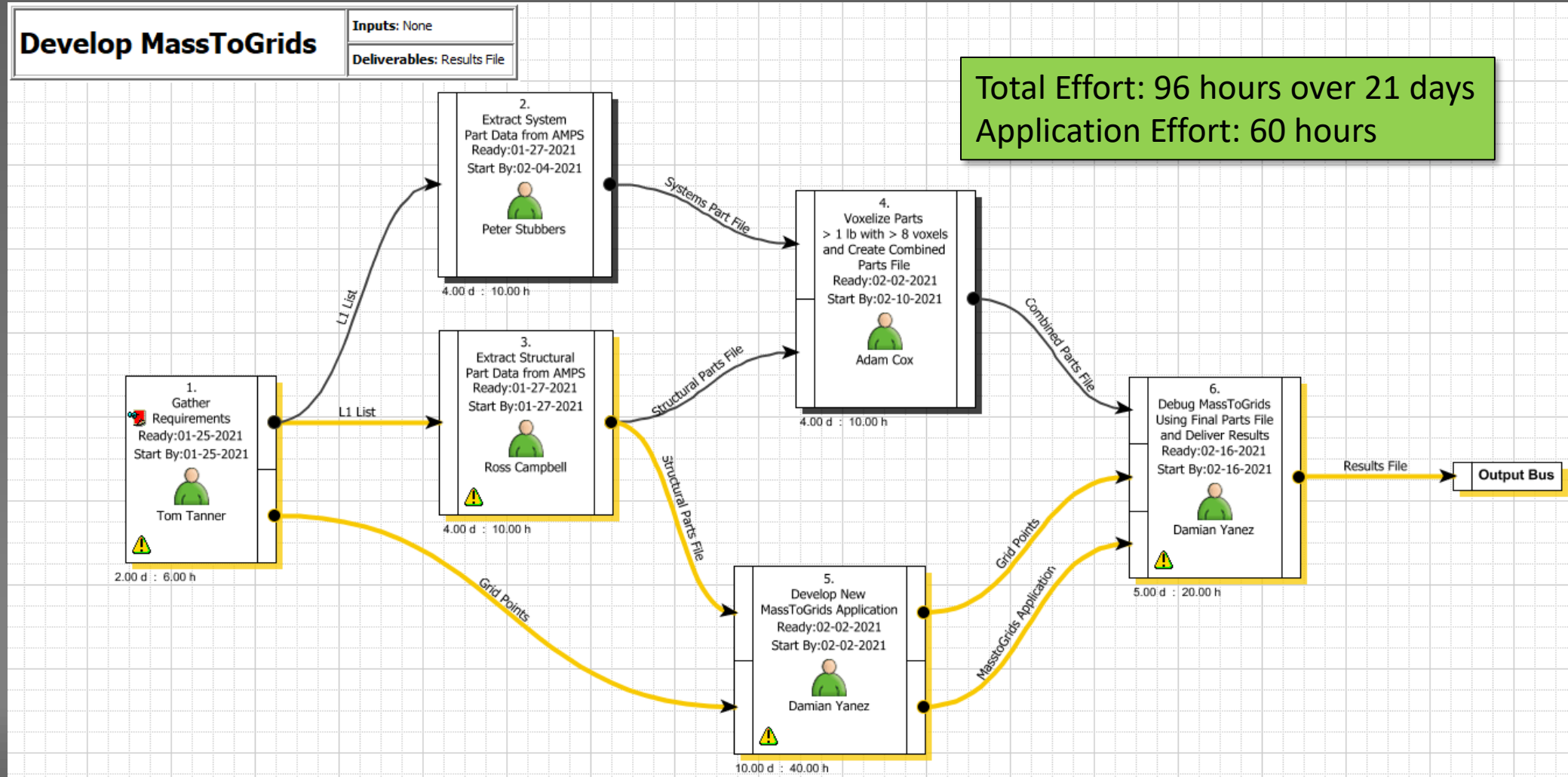
- The Mass Properties Department at Gulfstream developed and maintains an Aircraft Mass Properties System (AMPS) containing the weight and center of gravity (CG) of *millions* of parts for Gulfstream aircraft.
 - AMPS is tied directly to the Engineering product structure in the SmarTeam PLM system for 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

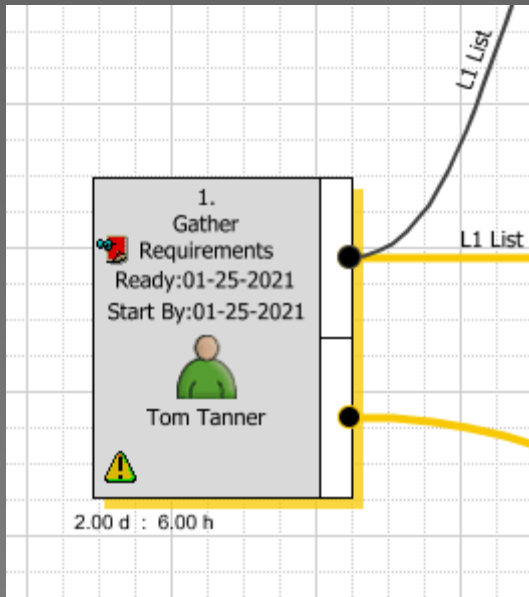


Rapidly distribute thousands of part masses to the FEM grid points while maintaining the overall mass properties

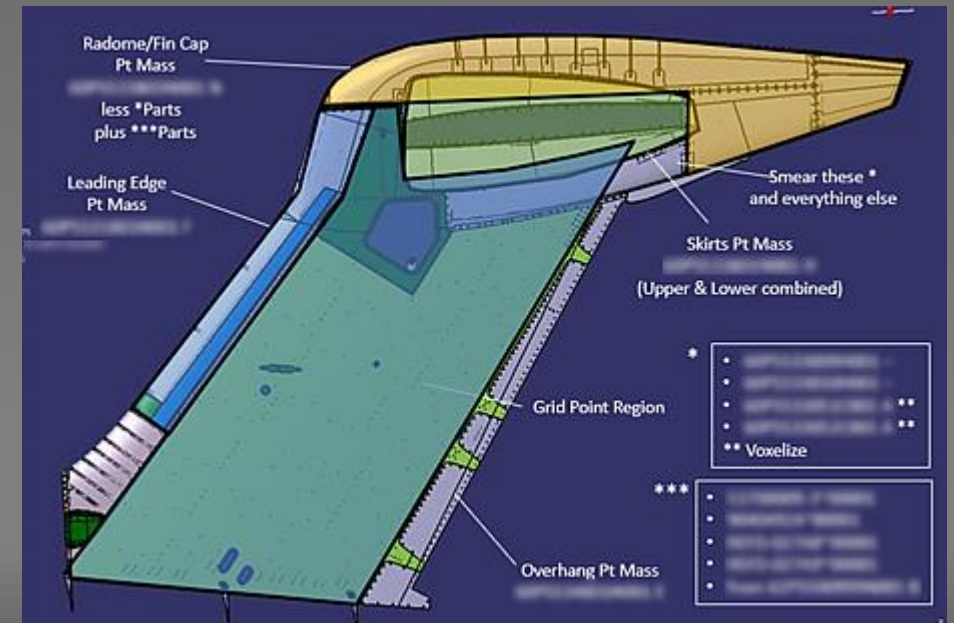
OUR APPROACH – Develop New Process & Tool



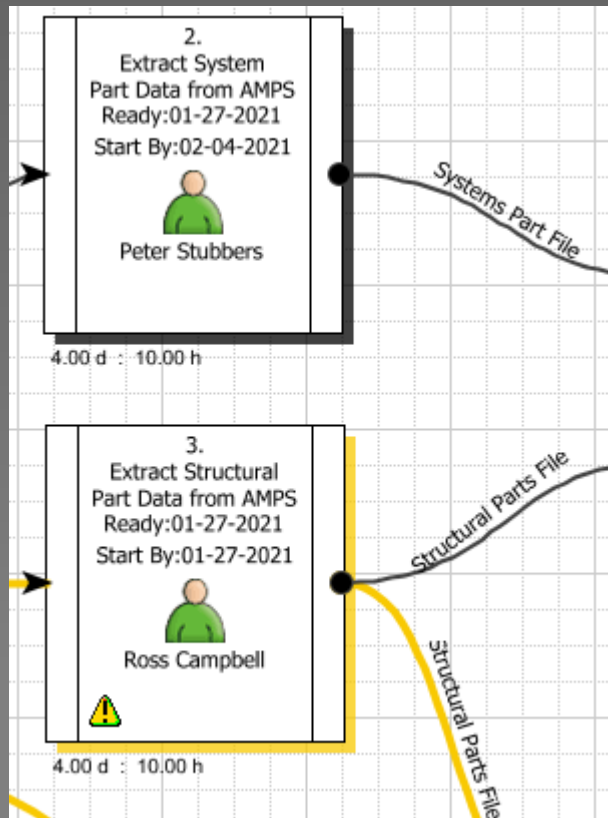
THE SOLUTION – Step 1: Gather Requirements



- 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.



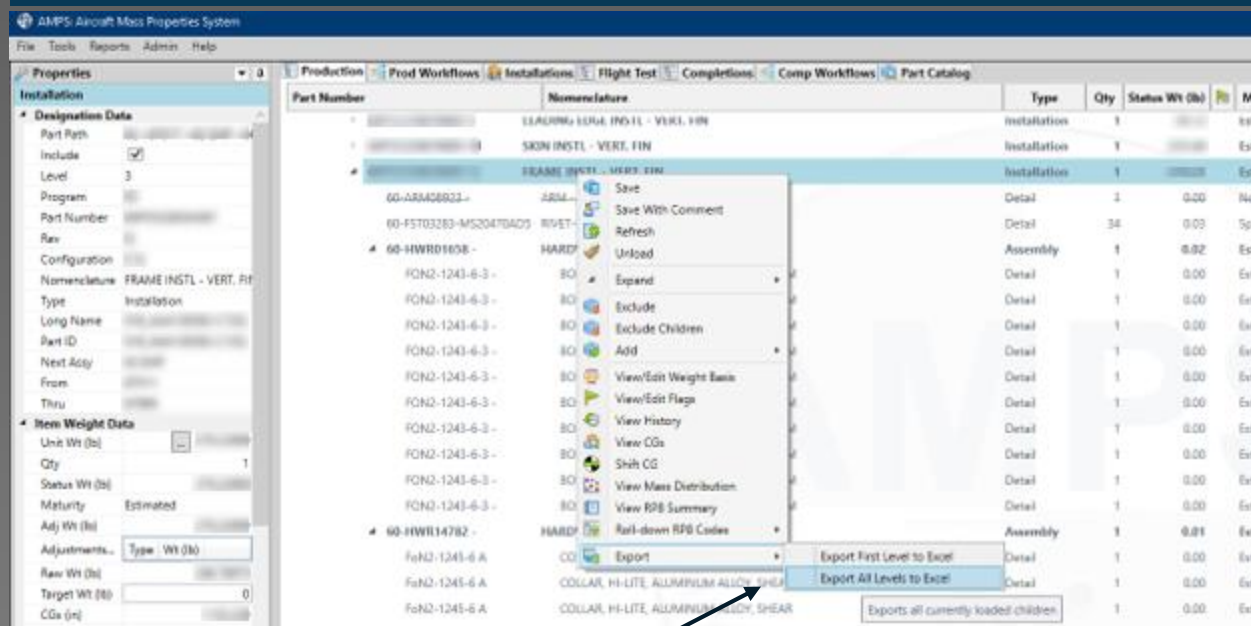
THE SOLUTION – Steps 2 & 3: Extract System & Structural Parts



- 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.

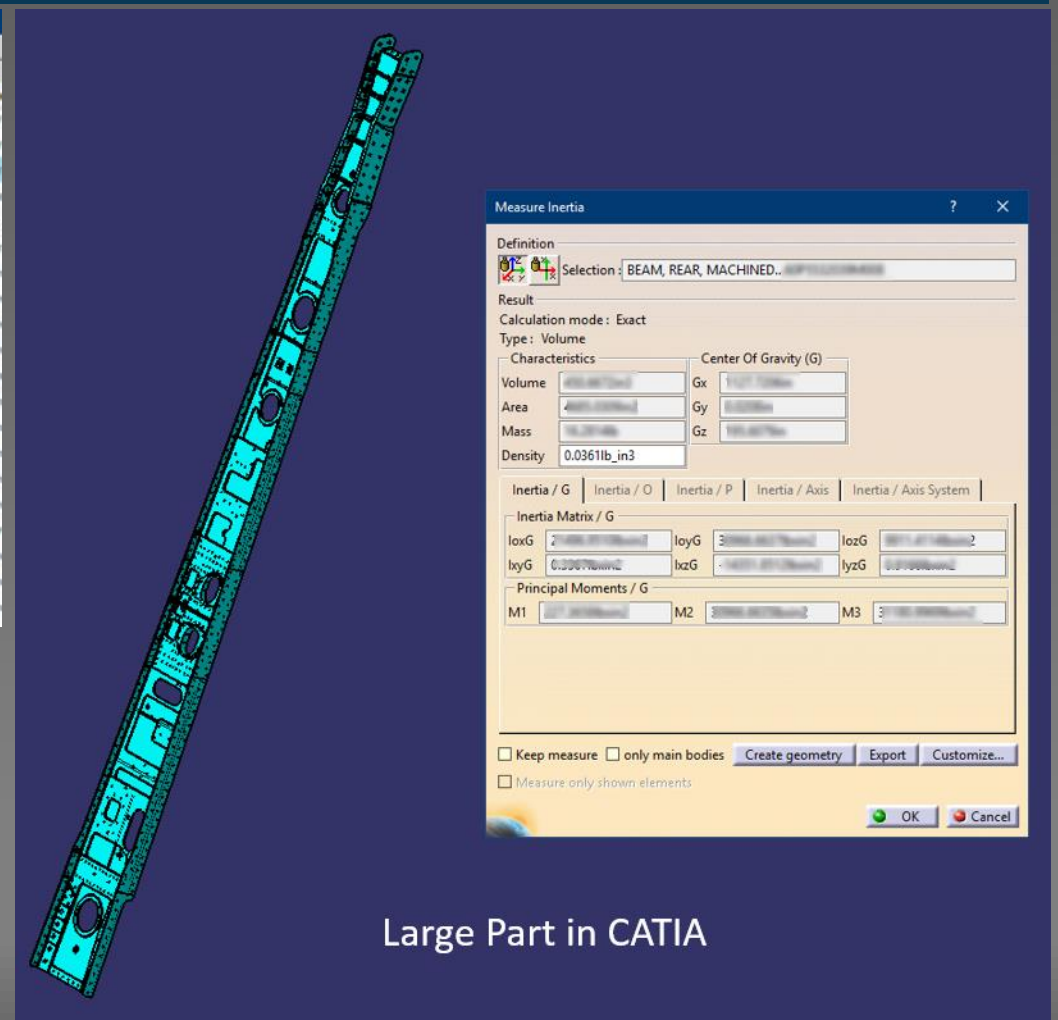


THE SOLUTION – Steps 2 & 3 Details



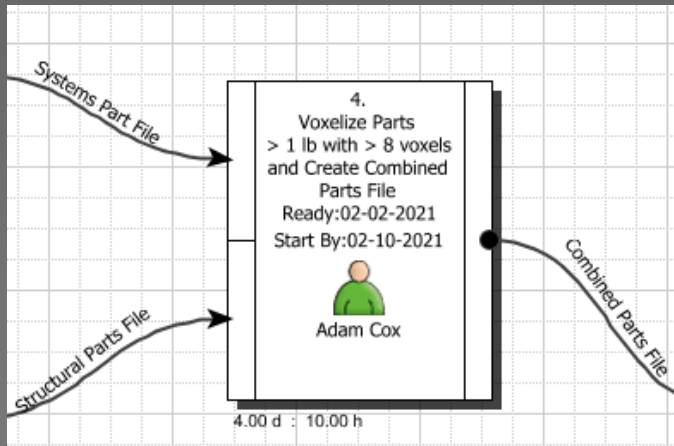
AMPS L1 Export

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

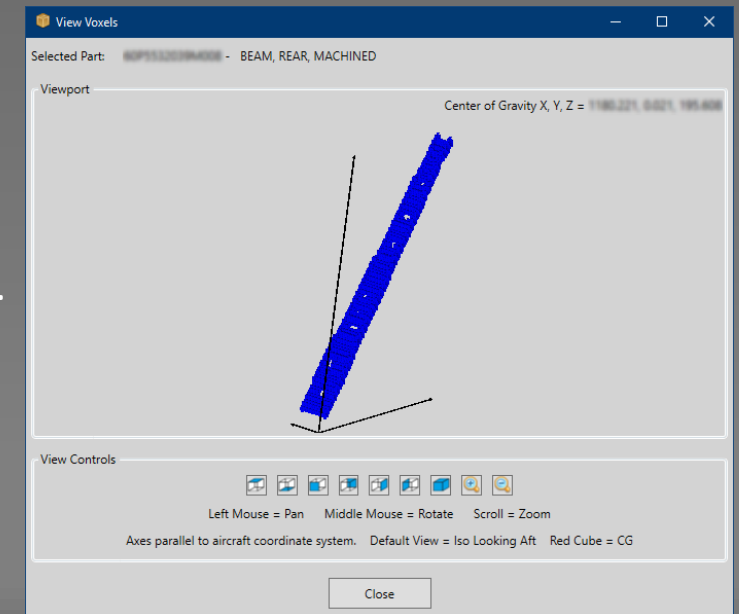


Large Part in CATIA

THE SOLUTION – Step 4: Voxelize Large Parts & Combine

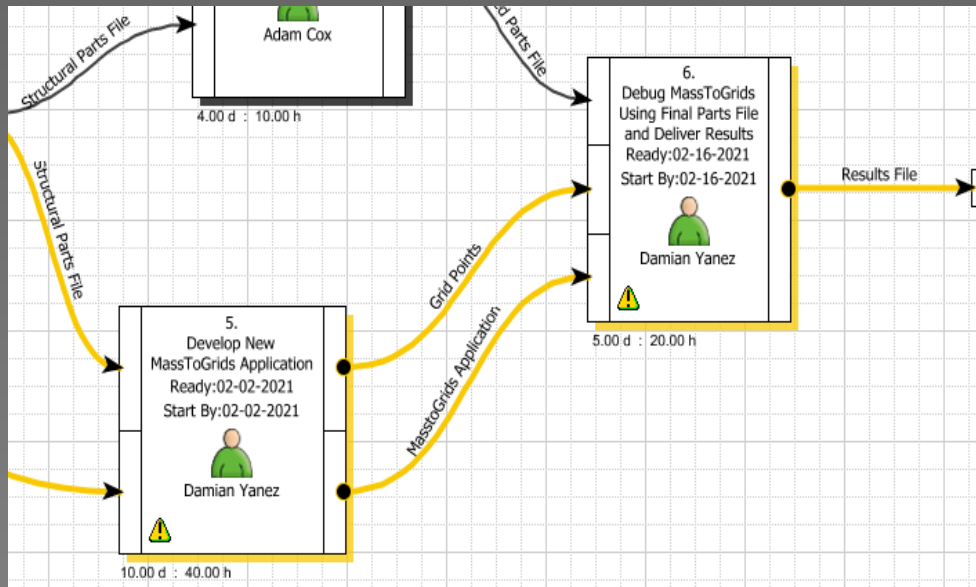


- Combined the system and structural part files into a single spreadsheet.
- Queried PLM tables for detail parts contained in the L1s from the L1 list having > 8 voxels (1" cube per voxel)
 - Resulted in 193,680 records.
 - Each record consists of an instance identifier, part number and the centroid 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.



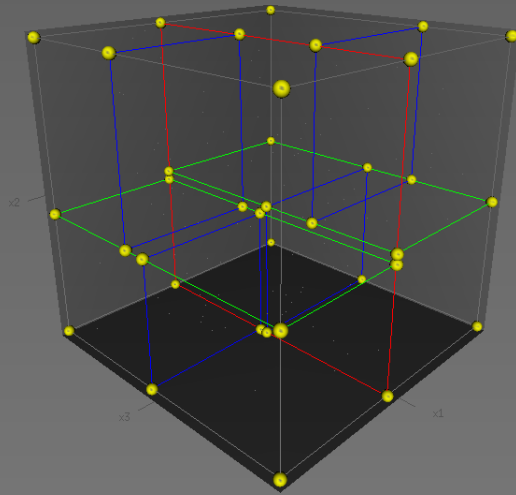
AMPS Voxel Viewer

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)

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

Local MOIs
 (about parallel axis
 at item CG)

Transfer Terms
 (to global reference)

Transfer Term
 (to total CG)

Where:

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

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

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

Similar for I_{Oyy_T} , I_{Ozz_T}

THE RESULTS

MassToGrids

Select the file containing part masses to be distributed: 11 Feb Dataset.xlsx

Select the file containing the grid points to be used: 11 Feb Dataset.xlsx

Force Inertia Match?: ☒ Run Export

* NOTES: - Part file must include columns labeled 'Include, PartNumber, Revision, Nomenclature, Status Weight, CGx, CGy, CGz, Ixx, Iyy, Izz, Pxy, Pxz, Pyz'
 - Grid file must include columns labeled 'Node ID, X, Y, Z'
 - Exported files may be found in your 'MassToGrids Exports' directory on your Desktop.

Data Display

Input Masses Grid Points Results

Grid ID	Grid Wt	X	Y	Z	Ixx	Iyy	Izz	Pxy	Pxz	Pyz
500001	2.3957	1056.250	6.090	140.835	345	1010	641	0	358	17
500002	3.13504	1056.250	4.050	140.835	452	1322	839	-1	468	23
500004	3.22065	1056.250	-4.050	140.835	464	1358	862	-1	481	23
500005	2.65264	1056.250	-6.090	140.835	382	1119	710	0	396	19
500011	0.45881	1063.430	7.022	139.874	66	193	123	0	68	3
500013	3.21931	1056.250	2.296	140.835	464	1358	862	-1	481	23
500015	0.58083	1063.430	-7.022	139.874	84	245	155	0	87	4
500021	0.52202	1070.640	7.767	138.908	75	220	140	0	78	4
500022	0.59282	1070.660	6.127	138.934	85	250	159	0	89	4
500023	3.51555	1056.250	-2.296	140.835	507	1483	941	-1	525	25
500024	0.44584	1070.660	-6.127	138.934	64	188	119	0	67	3
500025	0.43142	1070.640	-7.767	138.908	62	182	115	0	64	3
500031	0.54034	1077.880	8.324	137.938	78	228	145	0	81	4
500032	0.61323	1077.900	6.784	137.964	88	259	164	0	92	4
500034	0.46827	1077.900	-6.784	137.964	67	197	125	0	70	3
500035	0.39346	1077.880	-8.324	137.938	57	166	105	0	59	3
500041	0.31512	1085.160	8.698	136.963	45	133	84	0	47	2
500042	0.43665	1085.180	7.158	136.989	63	184	117	0	65	3

Title	Description	Weight	Xcg	Ycg	Zcg	Ixx	Iyy	Izz	Pxy	Pxz	Pyz
Total at Grid Points	389 Items	875.11038	1147.175	-0.020	186.132	1804620	3485430	1748510	-2413	1170095	4042
Total of Parts	111450 Items	875.11038	1148.262	-0.046	186.795	1804620	3485430	1748510	-2413	1170095	4042
	Delta	0	-1.086	0.026	0.663	0	0	0	0	0	0

Done.

- 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

AutoSave

G700 Vertical Tail Mass Distribution to Grids Rev A...

Yanez, Damian

File

Home

Insert

Page Layout

Formulas

Data

Review

View

Developer

Help

SMARTeAR

MS

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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?
