Model-Centric CAD Design in Aerospace

Is Model-Centric CAD Design for the Birds or the Stars? Neither really. The aircraft and aerospace industries are challenged by government contracts and an aging workforce that prevent it from progressing into the future of delivering electronic 3D CAD models instead of 2D drawings (drawing-centric). Adopting a comprehensive model-centric design system increases productivity with possible cost savings and reduced risk, especially in spacecraft and launch vehicle systems.

What does model-centric design really mean? The perception is that it means more work for the design engineers and more expense for managers.

Small to Medium sized companies benefit the most from model-centric design because it cuts waste and sharpens their competitive edge.

Unfortunately, because a full spectrum model-centric system has not been embraced, implementing model-centric processes tend to require more work for overtaxed engineers and an already strained budget.

The true definition of model-centric, in it's simplest form, means a model is created with all its features, integrated into the next assembly, then that sub-assembly is integrated into its next assembly model, until a full top level system assembly is created. The parts must contain full feature detail and assemblies must be managed for low and high detail fidelity. These models are reviewed, checked, released and maintained in a configuration management system. In addition there are CAD modeling standards enforced on each and every model. Parametric Technologies Corporation (PTC) has outlined a description of CAD modeling standards and practices in an article at: http://www.imakenews.com/ptcexpress/e_article000806331.cfm?x=b11,0,w.

The key step is to ensure that each part and subassembly CAD model is checked against CAD & manufacturing standards, and reviewed at the next assembly to ensure that the model meets critical clearance and assembly standards. Once this is complete, the CAD model can be officially released, locked down, and maintained through configuration management.

In its more complex and system view form, model-centric design requires the cooperation and integration of the following teams: systems design configuration, detailed designers, analysts, system requirements, manufacturing and configuration management. In order to have success creating, maintaining, and transferring 3D models only, all these groups must have the ability to use and approve the 3D models. The collaboration between all these groups offers the principal challenge. **Figure 1** presents the communication paths that need to be established to make model-centric design a success.

There are programs within the aircraft and aerospace industry, Joint Strike Fighter (JSF) and Orion are examples, that have implemented a portion of the model-centric concept, but they are falling short of a comprehensive system with streamlined processes for the design to build release process. Instead, by implementing only a portion of the model-centric design system, they are creating more work and spending more money for all involved. A complete system must be adopted in order to realize any true cost and productivity savings.

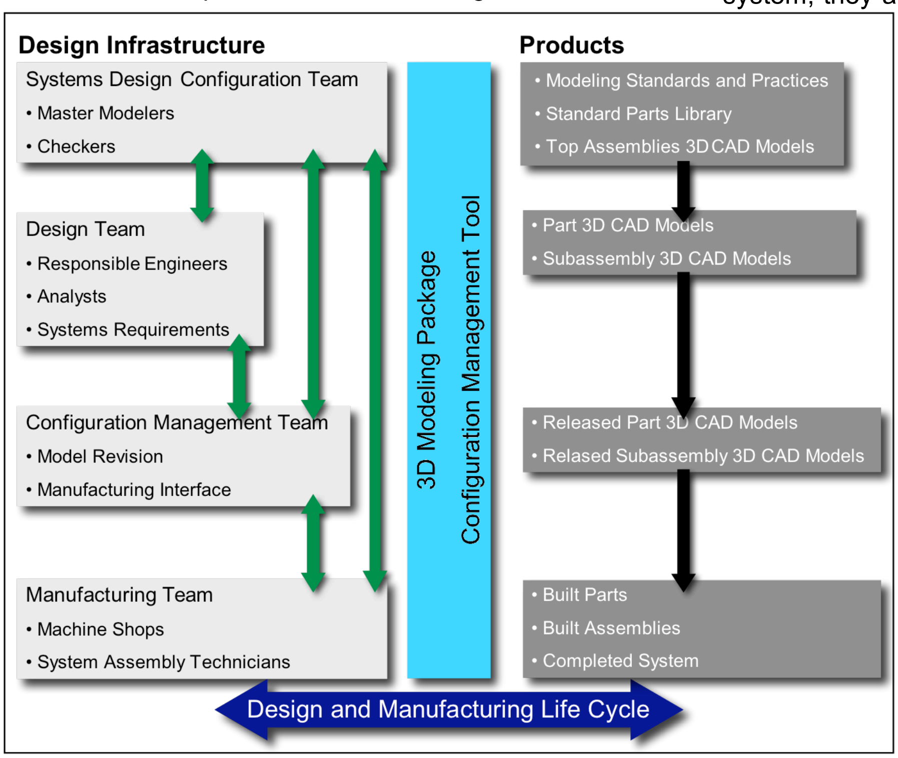

Figure 1: A Model-Centric Design System Can Modernize Your Design to Build Process

Why hasn't the aerospace industry taken full advantage of powerful CAD software such as CATIA and Pro Engineer? The software and hardware technology tools are in place, but it is difficult for large companies, especially, to make a fundamental shift in how business is done and mission success is realized.

The common perception is that making a shift in engineers' thinking, processing and developing of hardware is a task of gargantuan proportions and cannot be tackled given the current levels of funding for aerospace. But this is simply not true. It will save money in the long run. Engineers are accustomed to researching and following processes; the problem lies in the lack of industry and corporate commitment to make the leap into the next generation of hardware manufacturing.

Corporate commitment is essential to ensure that all those teams that need to be involved, reference **Figure 1**, have the authority to work together and the potential efficiencies of the system can be realized.

In addition to corporate commitment, there are a number of stumbling blocks. The most obvious is to demand that government customers eliminate drawings as the deliverable products. Changing the contracts to deliver only 3D models along with a coherent model-centric process and strategy to create, deliver and maintain these models, will motivate the contractor to improve their process.

Shouldn't the CAD modeling be the responsibility of the engineer? And why aren't the designers making full-featured models? Because the designer is required to only deliver a 2D drawing and not a 3D model, models are not their priority. Quite likely if a 3D model was the deliverable, the designers would be making pristine models.

In the old Mylar days, the designer made a bunch of pretty pictures, and then threw the design over the wall for the drafter to complete the design (tolerances, clearance fits, GD&T, surface finishes, etc.). However, now that we have beautiful and elaborate 3D models, the perception is that the design is complete once the models are complete. This becomes a problem because each designer has his own idea of what a "good" model is. This illustrates the next issue, which is there are no CAD modeling standards. CAD standards should be developed similar to a drafting standard.

Fixing the perception of the drawing release process is the next challenge. Generally executive management teams believe that once a CAD model is built and they see a picture, which is generally a screen shot, it is ready to go to the machine shop. This is an enormous problem because once a concept is visualized; it has a long way to go before it can be confidently delivered to a manufacturing process. Most believe that modern CAD tools have eliminated the detailed design and checking process and when programs are bid, not enough time and money is committed to this step.

In addition, the perceived elimination of this step has destroyed the traditional hierarchy of a designer, analyst and drafter. Just because one software program can be used to do all three, doesn't mean the time spent is any less. Specifically, the designer and drafter are now one person, but with no relief in the processes to release the engineering. So the designer spends an unimaginable amount of time walking through the halls of the building to get their drawing released. Where as, if the process was streamlined, well documented and electronic, it would be faster and much less frustrating to the designer. This would leave time to evaluate the hardware function and not the release process.

Let's review an example, to understand why a CAD standard is essential. Designer of bracket A doesn't worry about keeping the model perfect, he is more concerned with getting his drawings out. But, designer of subassembly B integrates bracket A with box C. Because all parts are now created via 3D model, the designer integrating parts A, B & C believing they are fully modeled. Because there are no standards, or a process in place to evaluate and release them, he has to trust the designers of A, B and C that they have modeled each part in full detail.

This is where the trouble begins. Let's assume that bracket A's CAD model was a low priority for the designer and the hole pattern wasn't modeled to exact nominal dimensions. Box C was missing a fillet and exact connector lengths. Designer of subassembly B happily makes his installation drawing without knowing there is a potential interference. The technician installs the box and notices an interference. Now the bracket and box designs are on critical path and may delay the launch date. A model-centric design system would have caught these errors long before any hardware was manufactured or assembled, saving critical path schedule and hardware rework.

Overtaxed engineers need their corporations to embrace a full spectrum model-centric system to reduced their workload and free their time to generate creative solutions to complex problems.

Here is an example of using a model-centric system to avoid potential problems. Imagine a vehicle that includes 10,000 parts. A top-level assembly master-modeler evaluates clearances between cables and structure for installation of an electronics box that is to be assembled late in the assembly and test schedule. He discovers a connector that is very close to a piece of structure and is likely to incur damage upon installation. Before the box is installed the cable is rerouted and during assembly the master modeler provides a caution for that area.

Because the technicians were alerted to the problem prior to installation, they were able to prevent damage during final assembly. Subsequently, the model-centric system prevented a possible mission failure or schedule delay for repairs.

Without a model-centric system, what could have happened is upon installation the cable came in contact with nearby structure, causing the cable to crack. Because the cable is buried inside it is missed by visual inspection. The spacecraft passes a pre-launch ambient test because it still has continuity. The damage is never discovered and the assembly proceeds. However, once the spacecraft is launched, it fails because induced vibrations from launch break the conductor in the connector, yielding the uplink/downlink communication to fail. This causes mission failure; all from not adopting a model-centric design system.

This is a relatively dramatic example, but even if the connector damage was caught, the replacement cost and schedule impacts are unacceptable at that stage in a spacecraft assembly. Though this is an unlikely scenario, because of the thousands of talented dedicated cognizant engineers and technicians that build spacecraft, it is necessary because the aerospace industry is in the business of reducing risk and it is essential that systems work as intended and everyone is 100% confident.

Once all this good process and procedure is in place, maintenance of the 3D CAD models becomes the crucial step. The model must look exactly like it is built and vice versa. If not, somewhere in the assembly process, interference may be discovered before or after it caused damage, again putting that part of the system on the critical path.

Lastly, the aerospace industry has recognized that there is an aging workforce and that they are having difficulty transferring the technical information to the next generation employees. Along with this, comes the resistance to change. The general culture of aerospace designers is that all of that is a lot of work and what we have now works. That is the aerospace motto, right, "If it ain't broke don't fix it"? Well it is broke. With an increasingly competitive aerospace market and the constant struggle to meet schedule and budget, can you afford a critical path assembly interference, mechanisms failure, or worse yet, hardware damage to irreplaceable parts? The answer is no and because schedule delays due to repairs will result in profit loss.

In addition, the new graduates have no experience building hardware and even less at creating 2D drawings. Drafting skills are no longer taught at universities and even less emphasis is placed on Geometric Dimensioning and Tolerancing (GD&T). New graduates have very little direction and mentorship and therefore cannot understand the criticality of GD&T on part manufacture and function. The aerospace workforce has very few people with experience of having created 2D drawings and 3D models for manufacture.

Is implementing a model-centric process going to cost millions of dollars? If the aerospace industry and contractors could get focused and make the leap to a model-centric design and manufacture integrated with accurate and concise configuration management, it would be less costly and design engineers would be more confident in their hardware's outcome.

Model-centric CAD design and documentation is not rocket science, it is just sound process.

Here are a few questions and answers that help guide the aerospace industry into the next generation of design and manufacturing.

1. What is preventing the transition?

a. Lack of industry and corporate commitment
b. Lack of communication between all disciplines
c. Contract deliverables require 2D drawings
d. Perception of the detailed drawing process
e. No CAD standards and processes
f. Workforce in transition

2. How Do You Do It?

Here are some steps to setup a successful process plan for model-centric design system:

a. Overcome the fear of change. Most machine shops are accustomed to receiving 2D drawings, but most will welcome the reduced effort of direct 3D model transfer. However, working closely with the machine shops during the transition from 2D to 3D is important to ensure success.

b. Layout CAD part and assembly modeling best practices.

c. Implement CAD Standard Part Libraries that include fasteners, washers, nuts, bearings, pins, etc. This library must also include a process for accepting new parts and maintaining existing parts.

d. Setup a review, checking and release process for each model and lock models if they are released. Decide what level of drawing, if at all, will accompany the model.

e. Setup Roles & Responsibilities for part and assembly designers. There must be a master modeler responsible for the top assembly and each subsequent subassembly must also have a responsible designer. These designers are responsible for the design and the CAD models. Adjust this hierarchy as needed as the design matures, but never let an assembly or part left unattended. Master modelers can ensure that top assemblies can be efficiently loaded and visualized.

f. Provide hardware and software tools to implement these tasks that are appropriate with the assembly size and the companies resources.

g. Design every feature into a single part, include tolerances and exact sizing.

h. Assemble every part to the assembly, include all additional pieces that are not traditionally modeled, such as tape, insulation, and cabling.

i. For every change, maintain the model and all associated documentation and be consistent.

3. How do you use existing software and hardware?

This is an easy one, just do it! Existing computers and CAD software are adequate tools to implement a streamlined process. Pro-Engineer, CATIA, and SolidWorks all have facilities for embedding 3D annotations into their models. All that is needed, is to setup a practice, based on your existing drafting guide and transfer the data required on a 2D drawing onto a 3D model. It's just a matter of where the information is stored. Not everything will be perfectly automated, but there is enough technology available to get the process rolling. Once the large companies start demanding additional functionality, the CAD software will follow suit.

However, don't let this be the hang-up. The functionality is in the process, not in the technology.

4. How do you get the manufacturers on board?

Machinists do not want to build a bad part, but schedules, cost and poor documentation sometimes get in the way of generating the "right" part, or the part intended by the designer. Again, this is where there is adequate technology already in place to complete this job. When a machinist receives a 2D drawing (generally generated from a 3D model), they have to program their Computer Numerical Code (CNC) machine tool with the 3D model information. Most CNC machines today, even in the smallest shops, can directly import 3D model information of some form. The remaining challenge is to work with machine shops to setup the 3D model as the design authority. Most shops will welcome this simpler exchange of data and welcome it. Of course, all the tolerance information must be in place, but this can be done via a 2D reduced dimension drawing, if necessary. In fact, some manufacturers may already be implementing similar processes for other industries.

5. Do you have to be a fortune 500 company to implement it?

No. Any company, no matter how small can implement a process appropriate for their hardware products and company size. In fact, the smaller the company, the less resistance and the simpler the process will be to setup.

Small Companies (< 50 employees): Easiest to implement because process and procedure changes have less stumbling blocks. These companies have the least amount of time to be messing around with drawings and mistakes because there is not a large infrastructure in place to do checks and balances. If there is a good, failsafe, process in place, a few people can be much more effective. The drawback here is that all the members of the team may be one person. Even though small companies have limited resources, the resources required can be as simple as a list of guidelines, inexpensive CAD software like SolidWorks and an Excel spreadsheet for configuration management.

Medium Companies (50 – 200 employees): There will still be limited resources, but there will be more access to higher end computer and CAD software. In addition there will be more people to manage and more communication loops to close, but the paths of resistance will still be minimal. Here the process can still be simple, quick and clean, but because more people are involved it becomes a higher priority than it is for the small company. Medium sized companies can benefit the most from a model-centric design process system. It will cut the waste, keeping the competitive edge, but also maintain quality products with few mistakes, making them more attractive to prospective customers.

Large Companies (> 200 employees): Large companies have the largest infrastructure to overcome and the most heritage and process to change. Change is the hardest part of implementing this new process. On the flip side, there are many resources that can be allocated to generating, implementing and maintaining the process. Large companies will also benefit by improving the quality of their hardware and maintaining their schedules, in exchange for higher award fees and profits.

The big question is, is it worth it? Will the engineers do it? The answer is yes and the engineers will be delighted that their job is well defined and their hand wringing is reduced. CAD modeling is easy, compared to the science, reliability and materials of a successful space vehicle. By streamlining and focusing on making the easy stuff easy, there will be more resources available to spend on finding creative solutions to the most challenging problems.

Considering all this, aerospace professionals will hopefully agree that model-centric design is not rocket science; it is just sound process.

Written by Jennifer Herron:

Jennifer Herron is a Mechanical Design Engineer with 12+ years of experience in the aerospace business. She is currently consulting for companies looking to convert their processes to model-centric.

jennifer.herron@mac.com, www.action-engineering.com

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