CAD at the Edge of Design Complexity

Today, the challenges of design complexity are everywhere. No example is more formidable than multi-system parts that sit at the intersection of functional design, system engineering and collaborative development.

Introduction

There is little doubt: products are only getting more complex. They are an increasingly complex mix of mechanics, electronics and software. These products incorporate ever more complicated technologies. They must comply with regulations that are only getting more stringent, not more relaxed.

Design isn't just becoming more complex at the *product level*. Some of the most challenging cases of design complexity take place within the *individual parts* that sit at the intersection of functionally driven design and system engineering. These parts must satisfy the requirements of many systems, each of which changes as engineers explore new design alternatives. The result can be a chaotic nightmare.

Computer Aided Design (CAD), of course, is supposed to help solve the problem. However, feature-based modeling approaches for such complex parts are susceptible to failures. Direct modeling approaches lack the intelligence to drive smart change. New CAD capabilities are needed to help engineers tame this design complexity.

This eBook begins by looking closely at the dynamics involved in designing functionally driven parts that require system engineering practices and team collaboration. It then goes in depth into the hurdles associated with traditional CAD in supporting that effort. Lastly, it reviews new CAD capabilities that fill the gap between the two.

Design complexity is making life harder for engineers and designers today. The good news is that emerging CAD capabilities are beginning to keep pace.

Every part is designed with form, fit and function in mind. Some parts, however, serve more of an engineering purpose than others. That is particularly the case with multi-system parts.

Multi-System Parts

The term *multi-system part* is simple in its definition: "one part that belongs to many systems, satisfying requirements in each." Examples are also easy to identify. Aircraft frames provide structural integrity, but are also a critical part of the fuel, communications and weapons systems. Automotive engine blocks are part of the powertrain but also belong to the braking and climate control systems. Designing such a part, however, is far from simple.

Dedicated teams of engineers define and allocate requirements for each part in the system. Once each requirement is satisfied, the entire system functions. Each engineer on a system's team is responsible for ensuring that each part fulfills its requirements.

When a single part belongs to multiple systems, engineers from each system's team must design collaboratively. They must design some aspect of the part so that it satisfies their system's requirements. However, they must also avoid designing a result that invalidates the work of other engineers who are trying to satisfy their own system's requirements.

Power Windows System | Engineer #2
requirements over safety and closure controls

Climate Control | Engineer #4
requirements for air flow,
speeds and controls
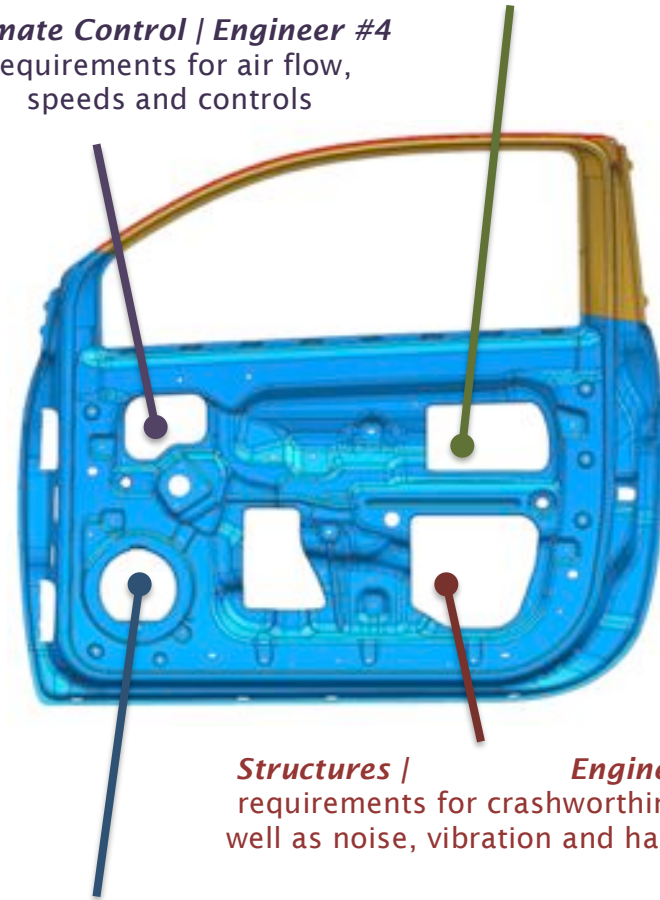
Structures | *Engineer #3*
requirements for crashworthiness as well as noise, vibration and harshness

Infotainment System |
Engineer #1 requirements for speaker

Automotive Doorframe
Image provided by Siemens PLM

CAD has always provided powerful capabilities to enable a team of engineers to collaboratively design assemblies. As engineers design separate parts, the assembly gets updated to reflect those changes. Enabling many engineers to collaboratively design a single part, however, is a practice fraught with danger.

The Construction Geometry

Finished geometry is rarely created directly. Instead, construction geometry serves as an intermediate step used to generate final geometry. This is a common practice, especially for parts with complex forms.

For multi-system parts, many engineers need to design their own sets of geometry in the part to satisfy the requirements of their system. As a result, each engineer creates his or her own construction and finalized geometry.

Failures from Unintended Dependencies

Construction geometry, by itself, is not a problem. The real issue emerges when it is unintentionally referenced to create other geometry. This results in a network of dependencies between different kinds of geometry. If a failure occurs early in the model, then it triggers a cascade of failures in the model.

For engineers designing multi-system parts, this is a terrifying prospect. Each engineer knows that other engineers are creating construction and final geometry in the part. Unfortunately for all of them, it's not always clear what geometry is safe to reference. As a result, it becomes extremely difficult to insulate work from cascading failures in a model.

The Threat of Wholesale Changes

The biggest concerns aren't always about model failures. Sometimes a wholesale change is required where an entire set of geometry is completely replaced by a different set of geometry. Problems arise, of course, when the set of geometry being replaced is referenced by subsequent geometry. This can occur frequently when it is not clear which geometry is safe to reference.

In multi-system parts, the need to swap out such geometry sets is very real. Systems undergoing radical change often result in dramatic differences in requirements that are passed down to these parts. Figuring out how to untangle dependencies between these different sets of geometry can be excruciatingly painful.

Implications for the Business

Dealing with such issues might be painful. But what does it all mean?

Ultimately, the consequences of wholesale design changes require time to resolve, often including new builds of models. Many of today's engineering projects are already on tight schedules that cannot accommodate the large delays of these activities.
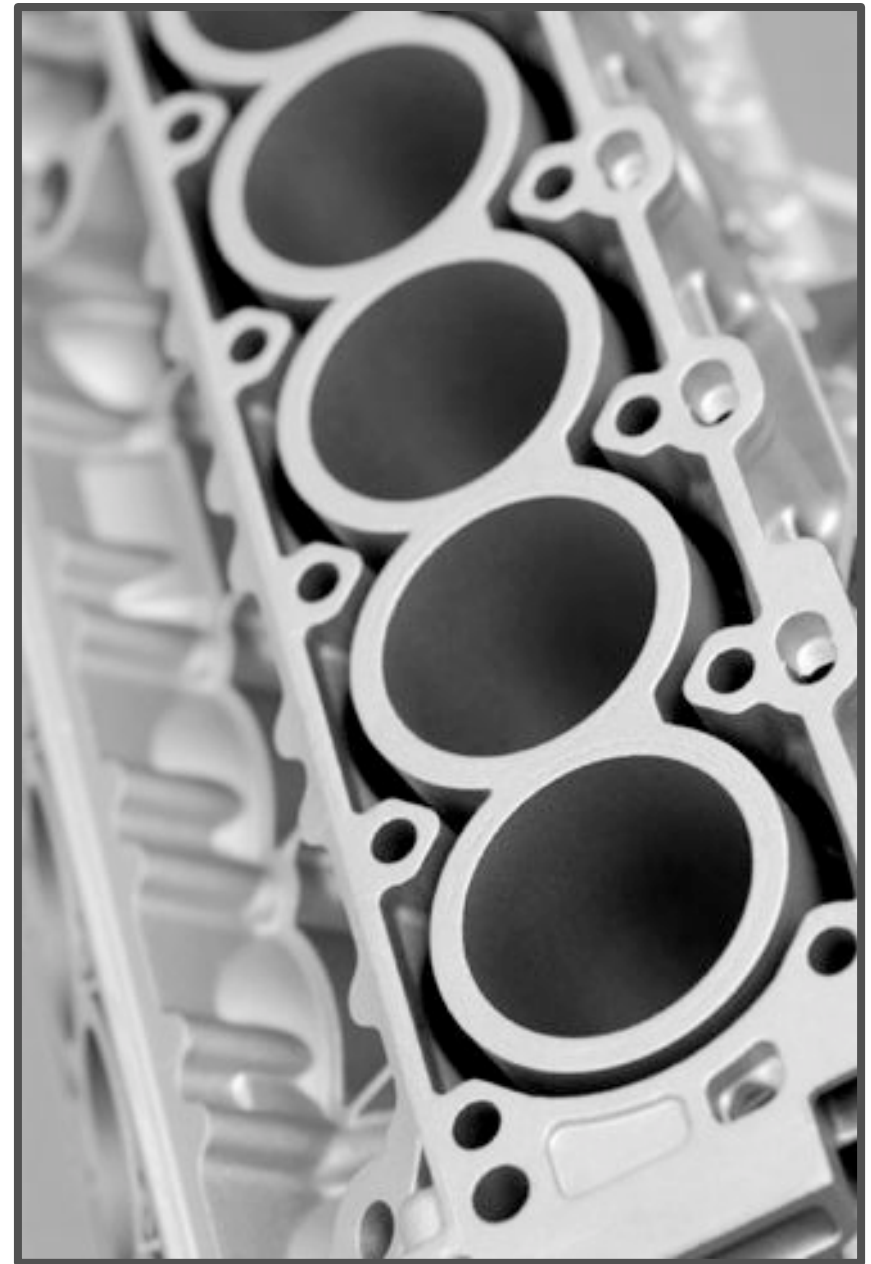
The past few years have seen changes in CAD technology. New modeling approaches have emerged. Deeper integration with PLM systems has been developed. More simulation functionality is available. Some of these changes include advances relevant to the design of multi-system parts that enable engineers to insulate their design work from other engineers' changes.

Explicitly Defining Inputs

The first capability lets the engineer explicitly identify parameters and geometry from the multi-system part that can be used as the basis for their design work. By doing so, the engineer places these inputs into an isolated workspace where they become the only items that can be referenced. This minimizes the risk of creating unintended dependencies that lead to model failures.

Working in Isolation

The second capability enables the engineer to perform design work in an isolated workspace. Other engineers working in the same multi-system part cannot view construction geometry within the isolated workspace. Therefore, they are unable to use the construction geometry as reference and create unintended dependencies.

Nor can the engineer working in the isolated workspace see any geometry other than explicitly defined inputs mentioned previously. Again, the purpose is to avoid creating unintended dependencies. In the isolated workspace, the engineer can experiment, iterate and explore without jeopardizing the stability of the model.

	Input Geometry	Construction Geometry	Output Geometry
Engineer working on their own geometry in a multi-system part	Engineers select publically accessible geometry and publish it into the isolated workspace.	In the isolated workspace, engineers can create construction geometry referencing the inputs. This can be used to create output geometry.	Engineers select geometry in the isolated workspace and publish it back into the publicly accessible workspace.
Other engineers working in the same multi-system part	Other engineers can see and reference this geometry.	Other engineers cannot see or reference this geometry.	Other engineers can see and reference this geometry.

Explicitly Defined Outputs

The third capability lets the engineer explicitly identify parameters and geometry that should appear back in the multi-system part. This represents the final geometry that satisfies the requirements of the system. All of the output geometries from the different engineers collectively comprise the finished multi-system part.

The Advantages

In combination, these three capabilities combine to offer two distinct advantages.

1. The explicit definition of inputs and hiding construction geometry both reduces the risk of creating unintended dependencies that lead to model failures.

2. Providing an isolated design workspace and hiding external geometry provides the engineer with a clean and uncluttered design environment.

Summary and Conclusions

This eBook has covered a lot of ground. Here's a recap.

Multi-system Parts Complexity

Today, design complexity isn't just about mechatronics, more complicated technologies or regulatory compliance. Some of the most challenging cases of design complexity occur in multi-system parts that must satisfy the requirements of many systems. Because different teams of engineers often design different systems, multi-system parts often force design collaboration between many engineers.

Construction Geometry and Unintended Dependencies

CAD has always provided powerful capabilities to aid in design. However, the capabilities of traditional CAD offer little assistance when it comes to multi-system parts. In these situations, different engineers create their own sets of construction geometry. It's not always clear which geometry is or is not safe to reference. As a result, a model failure early in the model can trigger a cascade of failures across systems. This reality acts as a difficult constraint especially when engineers consider wholesale changes.

New Capabilities Offer Promise

Recent advances in the CAD industry, however, offer real promise to address these problems. Three different kinds of CAD capabilities allow engineers to insulate their design work from that of others:

- First, engineers can designate parameters and geometry as inputs.
- Second, those inputs become part of an isolated workspace where engineers can develop their geometry.
- Third, engineers can then identify what geometry is the output. The outputs from all of the different engineers then collectively define the multi-system part.

Advantages of the New Capabilities

The main advantage behind these new capabilities is insulating an engineer's work from changes or even model failures initiated by other engineers. That allows engineers to avoid the effort required to fix or even rebuild models, which ultimately enables organizations to avoid the related delays to the design schedule.

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