

Platform Engineering Approach to the Electrical Systems Architecture Development Process

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ABSTRACT

Until recently, the electrical systems architecture that connects hardware devices and their accompanying control components were not separately a part of formal certification mandates. This changed with the advent of the FAR Part25 Subpart H EWISⁱ (Electrical Wire Interconnection Systems) mandate. Interestingly this mandate, like certain others, does not impose specific solution. Instead it provides a structure that outlines what must be accomplished from a variety of perspectives - safety, signal separation, part selection, etc. The designer has some flexibility on which decisions to make, but those decisions can have significant cross-domain impact, which in turn, have influence on the intended product performance.

What is needed is a method to design, verify and build virtually the entire electrical architecture with confidence that the best architecture is defined within the program constraints. In order to accomplish optimum results, design tradeoffs must be made in the context of the entire platform. The requirements for electrical platform engineering (EPE) COTS solutions are extensive and would seem to favor custom-built in-house software for electrical platform design and development. But increasingly, leading aerospace firms are turning to ground-breaking new solutions from COTS tool vendors, and discovering that these software products adapt readily to proprietary needs.

This paper explains how some of the challenges of the past are giving way to new solutions that capitalize on data-centricity and apply automated methods using design rules, constraints, and diagram generation. The paper advocates for a systematic "platform engineering" approach as a forward-looking solution for electrical systems architecture development.

INTRODUCTION

The challenges of specifying, designing, and building the electrical distribution architecture for aircraft platforms have always been extremely complex. Today, complexity is increasing even further due to several factors:

- Aircraft electrical content continues to increase. Driven by weight and reliability concerns, many of the traditional hydraulic and pneumatic systems are being replaced by electrical systems.ⁱⁱ This causes more electrical content that must be managed in the same (or less) space within the aircraft.
- This design environment has always been plagued with a complex change-management environment. This is because the geometric configuration of a platform is already quite mature by the time electrical systems definition and integration takes place. It is very costly to correct wiring-related errors late in the design process. Until now the available tools were inadequate to help define the wiring systems architecture early in the process.
- Engineers historically have provided safe-flying aircraft, though often at great expense. Wiring systems have been overdesigned, with the commensurate weight implications. Excess weight means less range and higher cost to operate the aircraft. With today's fuel costs already high, and expectations of even higher costs going forward, any area that impacts weight is under close scrutiny. The need to design for safety while achieving platform weight objectives is crucial.
- The emergence of the EWIS regulatory mandate has added some complex new considerations for designers.ⁱⁱⁱ Until just over a decade ago, internal electrical wiring was not considered a likely source of safety risks among aircraft in the world's passenger fleets. But a series of fatal airplane crashes in the span of just a few years quickly raised the

visibility of wiring-related failures and alerted regulators and the flying public alike to the critical nature of aircraft wiring^{iv}. This much-publicized spate of accidents and subsequent studies became the impetus for major changes in the way that aircraft wiring practices were viewed by regulators.

Many of the findings that led to today's EWIS mandates indicated problems with wiring installation and maintenance rather than design^v. Still, commercial aircraft companies have realized that if EWIS mandates are considered very early in the design process, then potential concerns can be studied and modeled. This enables sound, informed engineering decisions to be made when the cost of revisions, refinements, and additions is still relatively low. And importantly, capturing EWIS mandates in an electronic form that leverages algorithmic solutions is compelling proof that a manufacturer seeking certification has implemented a repeatable and consistent design process. However, doing this means a broadening of the electrical systems design perspective from systems to the entire platform.

A LOOK AT THE PROCESS

The design of wiring architecture has traditionally been a downstream-centric, late-stage activity. However, potential problems can actually start very early in the design process. This is due to the fact that the mechanical design of the platform - a domain that is a key stakeholder in electrical design - is quickly maturing while the electrical systems development is still relatively early in its definition phase. Exacerbating the problem is that the area of electrical design typically has one of the highest rates of change as compared with other design domains.^{vi} As changes ripple through in the electrical design phase, their impact on the mechanical environment can be significant. Even the communication of the change is often challenging due to internal organizational dynamics. Many companies are organized into vertical "silos" of engineering teams, and decisions made by one team get handed "over the wall" to another team to evaluate, understand and plan for.

The key to reducing the number of design changes is to provide a means to share the data and design constraints that will eventually impact the engineering team consuming the data. A simple example demonstrates this communication challenge:

A systems engineer is defining a connection between an antenna and a receiver. The engineer determines that the distance between the antenna and the receiver must not exceed 10 feet due to the need to minimize the coaxial cable RF loss. How does the systems designer capture and communicate that length constraint to the engineering team that is defining the path for that cable? In a drawing note? Or

possibly by annotating the connection on the diagram? Often there is no standard in a company or its systems suppliers that defines how to communicate this type of information.

Now we fast forward to the next phase: the wiring integration team gets the system design and must ensure that the physical implementation and coordination with the 3D design occur. But what if the wiring designer misses the drawing note? What if there is no note? If we play out this scenario, the coaxial cable might get routed such that it exceeds its 10-foot design constraint. When the cable is tested in the lab, it exhibits a greater RF loss than expected. This spawns a change order and forces the organization to go back and fix the routing issue and update the manufacturing documentation, among other associated tasks. There must be a better method!

In the past, it has often been difficult to produce an accurate, early-stage specification for the harness architecture since there hasn't been a good way to embed design constraints with all the data that can be shared across multiple domains. The resultant process is therefore one of initial specification followed by repeated changes. The problem is that every change costs money and the architecture that results may not be ideal from the cost and weight perspectives.

In truth, a great deal of information exists at an early stage, and it can be used to define and evaluate harness architecture alternatives. Electrical systems and their connectivity will have been defined, usually via functional and logical schematics from the OEM platform team or individual system houses. Performance requirements such as zoning for temperature rating or EMC class will have been described. Information relating equipment placement and geometric constraints defining the routing of the wire harness will also be available. Additionally, performance details of every component are known early and can be stored in a library for reuse. What needs to happen is to make this information available early, in a form that is useful for various platform-level engineering tasks.

Figure 1 shows^{vii} four significant steps along the wiring systems architecture development and support process. Even though there are many other steps in the process, one can use just four groups of activities to encapsulate the major events that occur: Define, Design, Build and Service.

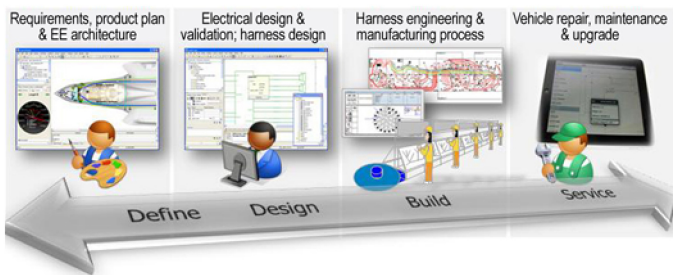


Figure 1. Platform Wiring Systems Development Process

As previously mentioned, early in the design flow during systems and subsystems design, many design decisions are being made in the MCAD area at the same time. MCAD designers ideally would like to know how much space should be allocated and reserved for electrical wiring bundles. The conundrum is how to get high confidence in the wiring architecture configuration before the physical wiring is fully defined.

Irrespective of the tool solution, some key technology foundations must exist in order to attain an improved business process. First, the data must be represented and stored in a form that guarantees a true representation at any point in its lifecycle, and this data must be able to be reused easily. Second, meeting platform-level regulatory mandates requires that the designer be able to capture design and intellectual property (IP) in order to support consistent design decisions. Lastly, there must be a way to algorithmically implement systems requirements into the physical implementation. This is key to defining the optimum wiring architecture very early in the development process in a form that allows for easy trade studies.

DEFINE

Let's take a look at the opening step in the process. The goal is to converge on a harnessing architecture as early in the design process as possible using initial systems and subsystems designs as input. To enable reuse of the systems data, the electrical systems and subsystems must be defined in a way that captures not only the connectivity data, but also any design constraints. As demonstrated earlier, the systems designer will have various types of design constraints that must be followed by anyone defining the physical implementation. Examples include minimum wire gauge, EMC separation, shielding requirements, and so forth. These are all extremely important to the implementation of the systems in the platform.

Many companies value the easy comprehension that comes with a graphical representation of a system design, and most COTS tools provide a means to draw a picture. However, the

similarity among COTS solutions ends there. Some full-featured COTS tools provide the mechanism to actually represent the data “underneath” the picture in a form that allows a complete description of the system and its constraints. For example, added to the high-level connectivity description would be parameters such as power and signal characteristics, EMC classifications and various other attributes.

Figure 2 depicts a systems design that defines not only the connectivity between devices but also a conductor's properties that describe its EMC classification and other system characteristics. These properties will be used in the platform-level perspective that follows. Since this graphical depiction contains underlying live data, it can be electrically validated using diverse methods including qualitative analysis, sneak circuit detection, FMEA, and others.

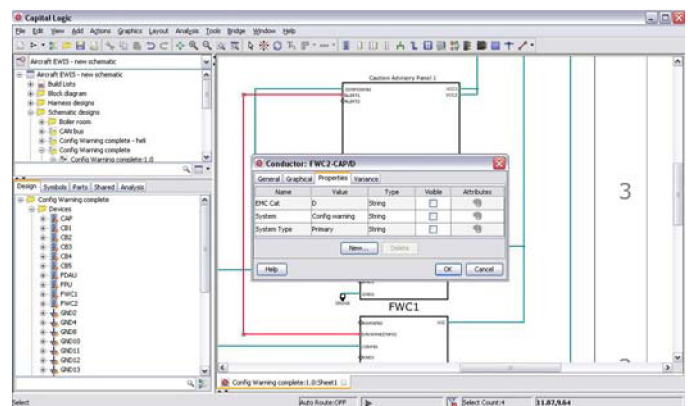


Figure 2. Systems Design with Conductor Properties¹

Concurrently with the previous diagram, an engineer would create a topology roadmap (Figure 3) of the anticipated harness roadmap, typically before the 3D model is mature. This roadmap identifies areas in which devices from the systems schematics would be placed. The roadmap also contains information on possible signal routes based on the conductors' constraints working in tandem with the topology constraints. A platform-based engineering approach fully embraces the concept that a designer can work with a specific set of design data while interacting with other emerging system design elements to get a platform perspective on the challenge.

¹This and all subsequent screen images are taken from the Mentor Graphic Capital™ electrical platform engineering suite.