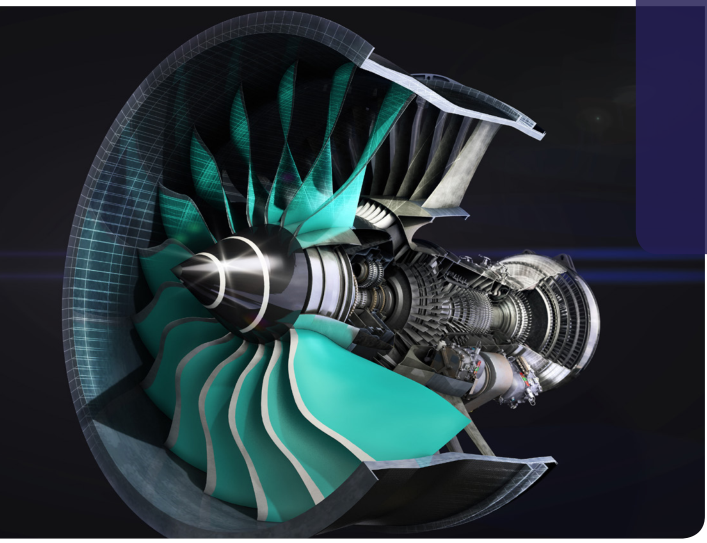
Rolls-Royce

AVIATION

Arcada and Capella for a large complex mechanical system



"Rolls-Royce used Arcadia / Capella to define the architecture of a large civil aerospace turbofan engine, to manage system complexity and minimise the associated risk.

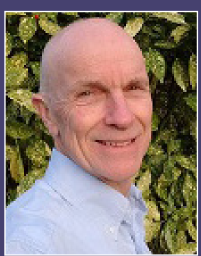
Context

Rolls-Royce is one of the world's leading engineering technology companies focusing on world-class power and propulsion systems. Rolls-Royce pioneers' cutting-edge technologies delivering clean, safe and competitive solutions to meet cross sector power needs.

Rolls-Royce's UltraFan® is a new generation of engine to power short-haul and long-haul aircraft. The UltraFan® features a new geared architecture (a power gearbox introduced between the fan and the turbine) to ensure that the fan, compressors and turbines all run at their optimum speed improving overall performance.

A large complex product such as the UltraFan® has multiple interactions across diverse systems and sub-systems. Often these interactions are unwanted and are related to material flows, at extreme temperatures, pressures, and energy flows through the engine. Such interactions lead to emergent system behaviour and this can extend beyond the engine to impact the powerplant (engine plus nacelle) and the aircraft. Furthermore, architectural design decisions taken at one level in the overall system hierarchy, can influence the architecture at a higher level.

Management of this iterative system development is a challenge given the need to capture all interactions and system behaviour at any given level yet keep the design space as open as possible at lower levels. All too often the default tendancy is to capture a system solution as the system requirement, simple because the solution is 'known'. This is especially true when a product is developed in a 'brown field site' drawing from experience of developing similar previous products.



Jim Daly

Jim Daly has nearly forty years' experience in aerospace engine development: fuel systems; control systems; software development; process improvement and thirteen years in current role as a System Architect at Rolls-Royce, responsible for whole engine architecture and since 2016 deployment of MBSE at the whole engine level.

Solution

Initially, the task was to model an oil system for the Ultarfan® power gearbox. It was felt that, like all systems engineering techniques, MBSE was more likely to uncover some unknown behaviour or interaction when applied to a novel system.

At the outset there were three main objectives:

- To integrate requirements and definition into the model
- To define a system architecture for the power gearbox oil system
- To integrate the safety process with the modeling (ARP4754A compliant)

It quickly became apparent that to capture all the oil system interactions, desired functionality, emergent behaviour, systems and components, a model of the whole engine was required. A single whole engine model would mean an extemely large complex model that would be difficult to comprehend and maintain.

Rolls-Royce's solution was to create a federated model (i.e. a model of models) that covers the complete product system hierarchy incorporating models of: the oil system; the engine; engine systems and sub-systems; the powerplant and the aircraft. Each individual model within this federated model defines a system architecture based on function and constraints dictated by spatial restrictions, failure propagation and emergent behaviour.

A federated model must allow for concurrent development of this system hierarchy and facilitate iterative system development whereby design decisions taken at a lower level in the hierarchy can be iterated back up and captured at a higher level as appropriate. This allows for functionality to be identified and captured at its true point of origin whilst keeping the system design space as open as possible.

Why Capella ?

The creation of a federated model of the complete product system hierarchy was facilitated using the 'sub-system transition' feature available as a 'plug-in to Capella. This feature transitions functions, system elements and interactions from within an existing model to either a brand-new model or to an existing model. Transition to new or existing models allows specialists teams to work on individual models to fully develop sub-systems with the federated model providing the context for the sub-system. Design decisions can be iterated back up the model hierarchy and new functionality and system interactions can be introduced to existing sub-system models by repeating the transition.

Each distinct system (in the product system hierarchy) was captured and developed in a single Capella model within the federated model. Following the in-built Arcadia framework this started with a 'black box' definition at the System Analysis (SA) level through the Logical Architecture (LA) level and then definition of the system architecture in the Physical Architecture (PA) level.

For a large complex mechanical product with numerous interactions and emergent behaviour, it is imperative that new functionality, new systems and interactions can be added at the point that they naturally emerge as a system is developed through the Arcadia levels. Capella fully supports this need with unconstrained functional and system modelling (e.g. not constrained by the UML/SysML principles of composite association). Moreover, multiple views of SA, LA or PA diagrams within the Arcadia framework can be used to depict the iterative development of a system and capture design decisions and rationale.