

BREAKING THE CODE

Turbomeca reduces development time by using ANSYS SCADE Suite for helicopter engine control software development.

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The engine control system is a critical part of today's helicopter engines that controls fuel injection and other engine functions. In developing the embedded software that runs the engine control system, Turbomeca switched from manual coding to a model-based design approach that involves the creation of an executable model in a block diagram design environment. Engineers define the functionality of the control system within ANSYS SCADE Suite using blocks that represent algo-

rithms or subsystems. They validate the model and use it to automatically generate embedded code. Turbomeca engineers have developed control systems that are powering the company's two latest engines using the new method. The new process has demonstrated the ability to substantially reduce errors and development time.

Turbomeca, part of the Safran group, is the world's leading producer of helicopter engines and has produced 70,000 engines since its founding in 1938. The company specializes in the design, production, sale and support of low- to medium-power gas

turbines to power helicopters. Turbomeca turbines propel civil, parapublic (such as police and fire department) and defense helicopters for all the leading helicopter manufacturers. Including its joint programs with other manufacturers, 18,200 of its turbines are now in operation, and its engines have provided 90 million operating hours.

DIGITAL ENGINE CONTROL UNIT

Turbomeca's engines are organized into engine families based on the level of power output. Each family of engines

Turbomeca switched from manual coding to a model-based design approach.

Development time was reduced by 30 percent.

includes several different variants that meet the specific requirements of different types of helicopters. The engines have a modular architecture with the key modules being the compressor, combustion chamber and turbine. The digital engine control unit, called the full-authority digital engine control (FADEC), regulates the engine's speed by modulating fuel based on the environment, torque evolution and use case.

The FADEC includes two identical control channels, each of which is capable of independently controlling the engine. The FADEC can transfer control from one channel to the other if a channel is not functioning correctly. Each FADEC platform consists of hardware and an operating system, and it is specified to be compliant with several engine families. Application software is developed for each engine variant to take into account helicopter characteristics and customer needs. There are many commonalities between engine control units of different variants, and a modular architecture has been defined with re-usable components to encourage re-use between different variants.

SOFTWARE DEVELOPMENT PROCESSES

Since 1985, Turbomeca has progressed through four distinct software development processes for developing application software for its FADECs to address improved technological solutions, evolution in airworthiness requirements, and increased software functionality.

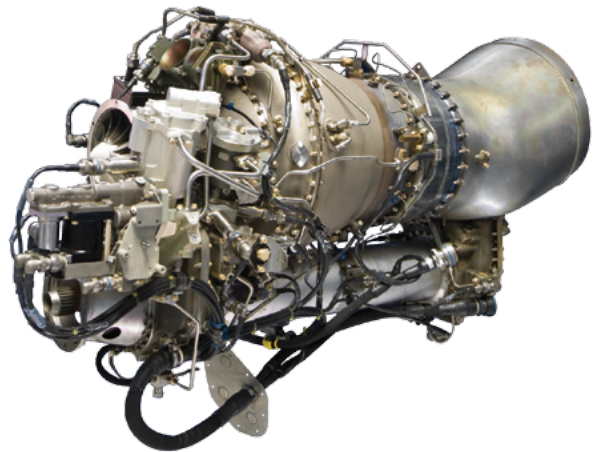
In 2005, Turbomeca developed the G4 software process by implementing a development environment that includes requirements management, model-based design, simulation, automation of tests, and qualified code generation in compliance with DO-178B (the standard used to qualify all avionics software by the FAA, EASA and other certification authorities). SCADE Suite is used in the new software process because model-based development is clearer and more understandable than working with source code for systems teams and promotes co-engineering between systems and software teams.

Model simulation provides an efficient method of detecting functional faults at the earliest possible moment. SCADE Suite delivers an efficient model checker that enables engineers to detect problems early in the design phase rather than later in the integration phase. Test cases can be run in the PC environment rather than in the much more expensive and complicated target hardware environment that is deployed on the aircraft. SCADE Suite incorporates a reusable symbol library that promotes re-use and commonality of design within and across software projects.

SCADE Suite helps reduce development duration and cost by enabling efficient codesign engineering between control law and software teams through the use of formal language and



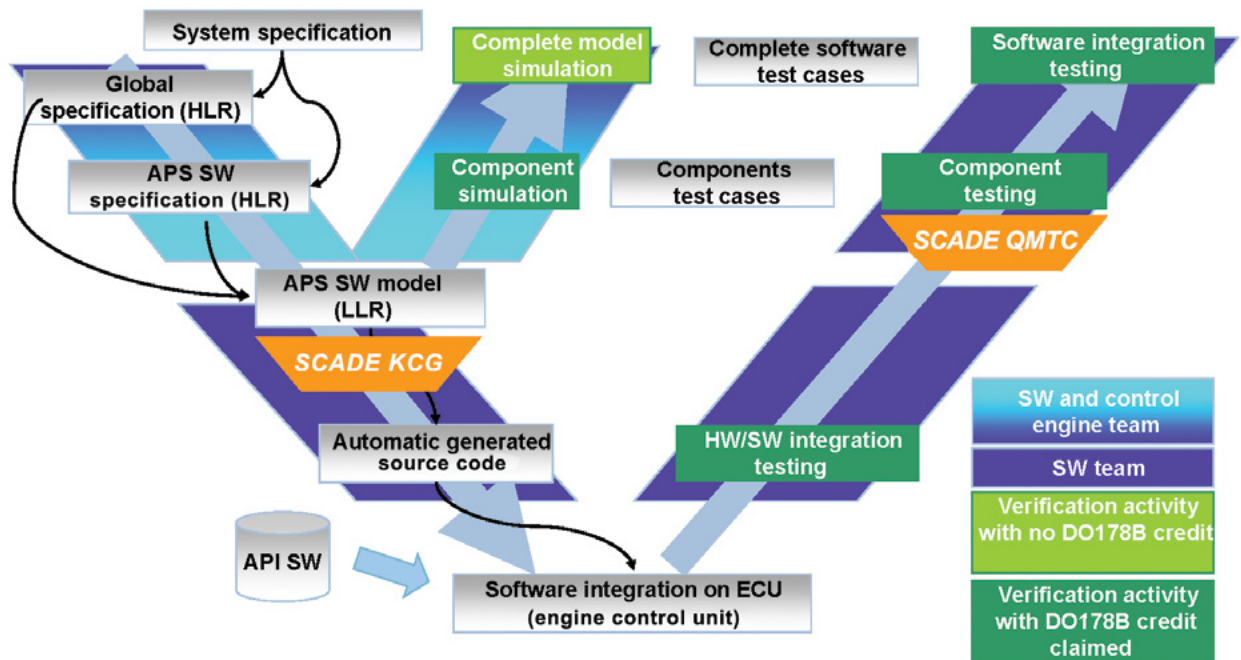
▲ Full-authority digital engine control unit



▲ Arriel 2D engine

methods that are clearer and more understandable than source code and by reducing the code integration phase. Defects are checked at the design level so that they are detected at the earliest possible stage. Using a qualified code generator, SCADE KCG guarantees compliance between the design model and the code, and strongly reduces formal verification at code level. Consistency of modules integration is verified at the model level before generating the C code, eliminating the need for integration verification at the code level. The code generator is qualified as a DO-178B development tool (cf. section 12.2 of DO-178B), so the conformance of the code to the input model is trusted, eliminating the need for verification activities related to the coding phase.

The development team achieved a decrease of 50 percent in the number of open problems on certified versions.



▲ G4 process overview

CODE SHARING AND RE-USE

The G4 process incorporates a generic modular software architecture based on configurable functions that can be easily re-used for multiple software development projects. It has enabled teams to focus on activities for which they have specific skills and easily share data with other teams working on other parts of the project. The application software developed by the G4 process is independent from the target hardware platform, which reduces the time and expense associated with changing hardware platforms.

The G4 process was first used in the development of the FADEC for the Arriel 2D engine, which is designed for light, single-engine helicopters in the 5,000-pound weight class and currently powers Eurocopter AS350 B3e and EC130T2 helicopters. The Arriel family of engines is used on more than 60 percent of all

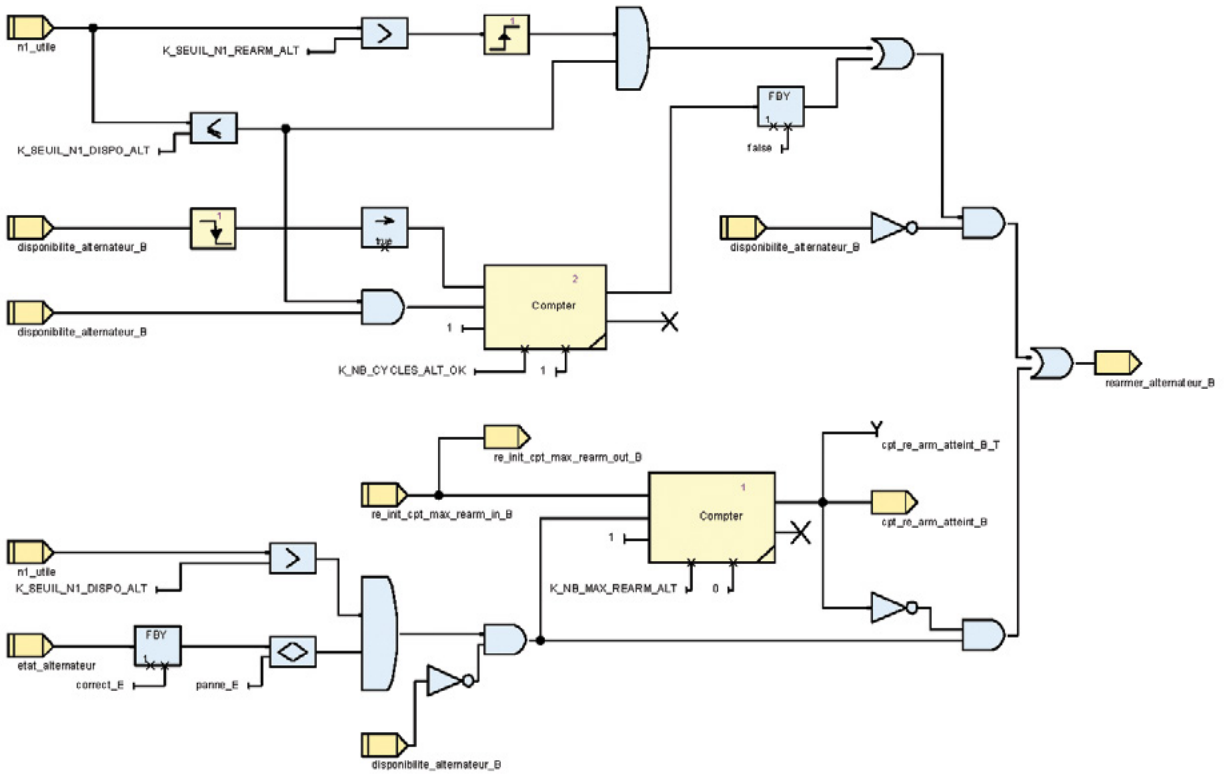
helicopters in the world in the 700-to-900 shaft horsepower (shp) power class. The dual-channel FADEC provides engine state monitoring, including fuel and oil filter clogging. It also regulates gas generator speed and power turbine inlet temperature for better power optimization and increases mean time between unscheduled removal. The time between overhaul at initial entry into service is 4,000 hours, but the target for engines in service is 6,000 hours.

Turbomeca engineers first used the G4 process in developing embedded software for the Arriel 2D engine that was certified in 2011 and the subsequent Arriel 2E that was certified in 2012. The development team achieved a decrease of 50 percent in the number of open problems on certified versions by detecting problems earlier in the development process and correcting them prior to certification. Development

time also was reduced by 30 percent by taking advantage of G4 process improvements, including SCADE Suite. FADEC software for five more engines is currently under development at Turbomeca using the G4 process. The company is also evaluating the latest version of SCADE Suite for future projects because of its potential to bring improvements in compute time and language capability. ▲

ADDITIONAL RESOURCES

 **REDUCING PRODUCT DEVELOPMENT RISK AND COMPLEXITY WITH MODEL-BASED SYSTEMS ENGINEERING AND EMBEDDED SYSTEMS**
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▲ SCADE model for control function that determines whether electricity produced by engine is used to power accessories

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