

Technical and Historical Overview of MetaH

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POCs

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Technical Overview

MetaH provides the means to express, analyze and implement the architecture for real-time, embedded software. In this paper, *architecture* refers to the way the components of a system are connected and controlled. Describing the details of components (e.g., their algorithms) is beyond the scope of MetaH. MetaH works with architectural characteristics to predict overall system behavior and permit rapid change in the components.

MetaH is a Computer Aided Software Engineering (CASE) toolset built around a specification language, the same general category as a number of commercial toolsets (e.g. Rational Rose, Aonix Software-Through-Pictures, Cayenne TeamWork). However, MetaH has been specialized to support the architectural specification, analysis, integration and verification of real-time embedded systems. There are some existing commercial toolsets that claim to have the same purpose, e.g., ObjecTime (ObjecTime Ltd., Ontario, Canada), ObjectGEODE (CS Verilog International, Toulouse, France), ControlShell (Real-Time Innovations Inc., Sunnyvale, CA), Tau (Telelogic AB, Malmö, Sweden), and Real-Time Studio (ARTiSAN Software Tools Ltd., Cheltenham, UK). These products are targeted primarily toward the telecommunications industry.

What makes MetaH a little different from its competitors is that it was developed for real-time embedded systems from the outset. Therefore the language has complete and precise semantics for real-time task and communication scheduling, partitioning, faults and errors. With suitable inputs, MetaH can predict the reliability of a system, and can determine whether the tasks can be correctly scheduled and are isolated properly. The Honeywell MetaH toolset greatly simplifies the development of the systems in its market. In addition to the modeling and analysis tools, the MetaH toolset also partially automates the software integration process using a configurable system executive. The system executive design has been tailored to provide very low time overheads, very small code size, and ease of verification.

The specification language used by MetaH for describing architectures is currently undergoing standardization by a task group under the SAE AS-5 Embedded Computing Systems Committee.

MetaH is an emerging technology that is not currently in use on any production program. A modified version of the language and toolset was included on a ground-based testing system supplied by NASA to International Space Station developers worldwide. Otherwise, to date MetaH has only been used for advanced development and demonstration projects. Therefore a discussion of the intended and possible uses for MetaH is somewhat speculative. Here are some potential markets for MetaH, based on experience and studies to date.

- Most of the studies, demonstrations and technology exchanges that have involved MetaH have been for avionics applications, both civil and military, including: International Space Station ground-based test system, Boeing 777 flight management systems, business jet real-time operating systems, Lockheed-Martin Joint Strike Fighter vehicle control and C-130 mission management system.
- Medical devices have requirements for high reliability and safety, and control systems for some medical devices may be well suited for MetaH. We have had some technical discussions with personnel from Siemens Research Center and Guidant Corporation. However, it is uncertain how much of this market is discrete-event control (where MetaH is currently weak) versus continuous control (where MetaH is currently very strong). Applicability in this market may depend on maturing and implementing discrete-event capabilities that are still in the research phase.
- Automotive control systems, particularly power train and braking systems, seem well suited for MetaH. They have high performance requirements (control rates of several kilohertz, higher than most avionics systems), and stringent efficiency and size requirements due to high recurring hardware cost. Future drive-by-wire and brake-by-wire systems will have extremely high reliability and safety requirements. We have had some technical discussions with personnel from Ford and Visteon, and these exchanges are consistent with the potential use of MetaH in this market.
- Robot control systems built using Honeywell MetaH tools have been demonstrated on simulators, though not yet in actual robots. Robot control systems combine a need for real-time execution and, in some markets, high reliability and assurance of safety. To date work in this area consists of one demonstration program focused on unmanned ground vehicles.
- Engine control systems, jet and turbine as well as automotive, seem well suited for MetaH. Like automotive applications, they have high performance and efficiency and reliability and assurance requirements. Applied Dynamics International is developing an interface between the BEACON/MatLab CACSE toolset and MetaH, and we have demonstrated use of the tools together. This is suggestive because BEACON was originally developed and used by GE to produce jet engine control software. We have also had some technical discussions with personnel from General Electric Research Center, these exchanges are consistent with the potential use of MetaH in this market.

Historical Evolution of MetaH

MetaH stems from internal research performed at Honeywell Technology Center (then called Honeywell Systems and Research Center) in the late 1980's. This research focused on the coordinated development of real-time scheduling models together with the scheduling software, so that mathematical models could be used to predict and verify the timing behavior. The suggestion that "a target environment would be developed hand-in-hand with its formal scheduling models so that the validity of the models is assured" appears in the paper "On the Accuracy of Predicting Rate Monotonic Scheduling Performance," Tri-Ada 1990, which summarizes some of the early results and concepts that guided the creation of MetaH.

This was followed by studies of actual applications and their requirements. Two applications in particular were studied. First, Honeywell Commercial Avionics Systems (then called Air Transport Systems) was developing the Aircraft Information Management System for the Boeing 777 commercial aircraft. MetaH development was influenced by many requirements for this system, notably time and space partitioning and assurance of safety. Second, Honeywell Defense Avionics Systems, as a subcontractor to Lockheed-Martin, had delivered and supported demonstration of a research C-130 mission management system for the Air Force. MetaH development was influenced by this system's requirements for multi-processor communication and synchronization. This phase culminated in the design and development of a prototype (called at that time the Honeywell Aerospace Compiled Kernel), where a description of application requirements would be used to both configure the executive and to generate the system schedule. These results are summarized in various internal reports from 1990 and 1991, and in the external publication "The Honeywell Aerospace Compiled Kernel," special session at the 1991 Real-Time Systems Symposium.

In August 1991 Honeywell Technology Center started work on the DARPA Domain-Specific Software Architectures program, which provided the funding needed to realize these concepts in a robust prototype of the MetaH language and toolset (about \$4M government plus \$1M Honeywell). This program, which ran from late 1991 to late 1996, was primarily responsible for creating the MetaH language and toolset (together with other tasks and deliverables). Notable new ideas developed and demonstrated on this program were the extension of the input specification to a full-fledged "architecture description language," the concept of "automatic co-generation" of analytic models and implementation from the same specification, the coordinated use of multiple domain-specific tools (e.g. controls, displays) with MetaH as a software and systems integrator, the addition of formal reliability and partition impact modeling and analysis capabilities, slack scheduling, and high-speed bus scheduling and communication. Several external papers were published on this work, one of the earliest being "Domain-Specific Software Architectures for Adaptive Guidance, Navigation and Control" at the March 1992 Computer Aided Control System Design conference.

From 1997 through 1999 the MetaH toolset was extended in a number of ways on the Evolutionary Design of Complex Software program, jointly funded by DARPA, Army AMCOM and Honeywell. This program resulted in a MetaH that was more compatible with relevant standards and open systems goals. The configurable executive was

rewritten with two standard interface layers (POSIX and Ada95), and before the end of the program an SAE working group was created to develop a standard Avionics Architecture Description Language using the MetaH language as the starting point. This program also resulted in technical enhancements in the areas of slack scheduling and dynamic reconfiguration. Several external papers have been published or submitted for publication describing aspects of this work. The toolset as it exists today is the version developed on this program.

Starting about mid-way through the DSSA program, MetaH began to be used on other programs. On most of these programs Honeywell personnel used MetaH to develop demonstration systems for external customers such as DARPA, Air Force, Boeing, Lockheed-Martin, and Georgia Institute of Technology. We also engaged in technology exchanges with programs that did not use the MetaH language or toolset itself, e.g. the transition of slack scheduling technology into the Primus Epic DEOS civil aviation operating system.

Evaluation copies of MetaH have been provided under license to a large number of US firms, primarily in the aerospace industry. Army AMCOM Software Engineering Directorate (then MICOM SED) was the first non-Honeywell organization to use MetaH internally in a significant way, on an internal research and demonstration program that started about 1993. In 1996 a customized version of the MetaH toolset was included in the International Space Station MATE, a ground-based testing system that was provided by NASA to ISS team members worldwide. Otherwise, MetaH has never been used on a production program, only for advanced development and demonstration projects.