A1.11 Universal Enabling IVHM Technologies in Architecture, System Integration, Databases, and Verification and Validation

Lead Center: LaRC

Participating Center(s): AFRC, ARC, GRC

A vehicle-wide Integrated Vehicle Health Management (IVHM) Project system must be information rich with embedded monitoring and diagnostic/prognostic functions that will penetrate deeper and with smaller granularity into physical components and structures. This will necessitate the development of safety-critical, real-time, distributed, embedded sensing and computing system design, development, integration, and assessment capability for applications with huge numbers of sensing and computing nodes which are networked and dynamically reconfigurable in response to changing physical conditions, modes of operation, failures, damage, and environmental disturbances. Furthermore, the development of advanced anomaly detection, prognostic, and diagnostic architectures will be required. The architecture will be designed to optimize multi-dimensional/objective criteria, enable optimal adaptive redundancy management, support large-scale data, decision, and information fusion, and meet safety, cost, and performance criteria for the IVHM system. However, the development of such a vehicle-wide system must be done by many teams of different disciplines at different locations. Therefore, a standard project database is needed that stores and manages test data, failure statistics, fault modes and effects, diagnostic and prognostic models, simulations, and related documentation for all the systems, subsystems, and components that are part of the complex system for which an IVHM system is being developed.

The IVHM database must also allow for seamless integration with a variety of IVHM algorithms, including data mining, machine learning, and exploratory data analysis tools, in order to enable algorithm development and knowledge discovery using the same database of historical data. The IVHM database will be owned and operated by NASA and will be provided as a service to the aircraft industry, U.S. government, and the R&D community. The database will provide industry standard access controls to protect proprietary data rights as well as to ensure compliance with ITAR and EAR restrictions. Additionally, design tools/decision support systems that enable the design of aircraft while accounting for the sensing, processing, and data mining/analysis needs of IVHM is vital. These tools/systems must enable the designers and the analysts/discipline specialists to work together, rather than as separate entities, and must allow IVHM system design, including study of IVHM system tradeoffs, at the early aircraft design stage.

In order to ensure the safe and reliable application of IVHM technologies to civil aviation, advances in verification and validation (V&V) processes and underlying methods and tools are needed to assure the safety of systems that will become increasingly complex and nondeterministic. Advances are needed in compositional verification that will enable the safe integration of complex adaptive systems with strong guarantees of integrity, fault-tolerance, partitioning, and real-time. New tools, methods, and processes are needed for the V&V of diagnostic algorithms with non-deterministic behavior. The goal of the V&V research is to enable compelling evidence that required
system properties are guaranteed by the composition of constituent parts, and to develop tools, methods and processes that mitigate concerns about design validity, safety, and reliability for complex, nondeterministic software-intensive systems.

Proposals are sought that advance the state-of-the-art in architecture, system integration, databases, and V&V technologies that will facilitate the deployment of IVHM systems that satisfy safety and performance requirements. The potential impact of the proposed technologies should be linked to improvements in large-scale systems design, deployment, safety and reliability, quality and performance. Specific technology areas where contributions are sought include, but are not limited to the following:

- **Design tools/decision support systems** that account for the needs of IVHM, including sensing, processing, data collection, onboard data mining, and fault diagnostics and prognostics algorithms.

- **A project database** that stores and manages test data, failure statistics, fault modes and effects, diagnostic and prognostic models, simulations, and related documentation for all the systems, subsystems, and components. The IVHM database must also allow for seamless integration with a variety of IVHM algorithms, including data mining, machine learning, and exploratory data analysis tools, in order to enable algorithm development and knowledge discovery using the same database of historical data.

- **Advances in compositional verification** supported by High Confidence Real-Time Operating Systems (RTOS), Middleware (MW), and/or Virtual Machines (VM) that may be independently designed and verified. Desired system properties include dynamic re-allocation of computational resources; correct and consistent disambiguation of fault syndromes, particularly with respect to segregating faults within the computational infrastructure from faults in other vehicle systems; and graceful evolution of system capabilities, with minimum adverse effects due to parts and software obsolescence.

- **New tools, methods, and processes** for verification and validation of diagnostic algorithms with nondeterministic behavior. A desired outcome from this research effort would be a demonstration of the relevance of the tools, methods, and processes towards flight software acceptance as applied to a specific non-deterministic algorithm (e.g., neural network, genetic algorithm, fuzzy rule-based inference, etc.).