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Present and future diagnostics and prognostics of ground combat vehicles

Elena Bankowski and Christopher Miles
US ARMY TACOM, Warren, Michigan 48397-5000

1. PRESENT AND PAST DEVELOPMENTS IN DIAGNOSTICS

Diagnostics capability of ground combat vehicles has to be compatible with the Army Diagnostic Improvement Program. Present systems are capable of performing health monitoring and health checks using internal embedded resources. They employ standard sensors and data busses that monitor data signals, measurements and built-in test (BIT). These devices provide a comprehensive source of data to accomplish complete and accurate system level diagnostics and fault isolation at line replaceable unit (LRU) level. They provide system health monitoring and prognostics capability for subsystems consisting of engine, transmission, power pack interface, gauge cluster unit and others. Prognostics routines provide diagnostics capability to identify the cause of failure, when failure is predicted, and corrective action to prevent unscheduled maintenance action. Ground combat vehicle's health status and prognostic information are displayed to operator, crew, and maintenance personnel. Present systems use common data/information interchange network in accordance with standards defined in the Joint Technical Architecture (JTA) to provide access to vehicle's health data. The technologies utilized in present systems include embedded diagnostics, combat maintainer, revised maintenance concept, schematic viewer, etc. Implementation of these technologies significantly reduced maintenance hours of ground combat vehicles. Today's Main Battle Tanks (MBT) contains a multitude of processors. Yet systems such as Abrams provide redundancy only between the hull electronics unit and the turret electronics unit. The Abrams employs duplicate processors hosting redundant software in different vehicle compartments. Over a half a million lines of software code span multiple processors. The software in the Abrams tank was created in a highly sophisticated development and testing environment.

The U.S. Army Next Generation Software Engineering Technology Area (Next Generation) proposed Statistical Usage Testing (SUT) in the Post Production Software Support (PPSS) project for the U.S. Army's MBT. Usage models were supported by Markov chain process, test management, test case generation and statistical testing. We implemented a prototype tool for composing top-level models and lower-level sub-models. This Model Compose utility allowed for the development of sub-models similar to subroutine development in programming. The major lessons learned from the SUT project were:

- SUT can positively impact MBT testing, since the focus is on operational usage;
- usage modeling is feasible in the MBT environment;
- usage modeling uncovers a number of issues that relate to behavior and testing;
- A logical and complementary relationship exists between the current testing approach used by Next Generation and SUT.

The SUT modeling techniques was applied to the Driver's Integrated Display (DID), a component of the soldier-machine interface of the tank. Since then, additional LRUs with increasing complexity have been modeled using SUT. In applying modeling techniques, a high degree of complexity was observed,

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consisting of the numbers of screens to be modeled and the amount of information that could impact a tester's next action. These challenges were overcome using some innovative approaches. Next Generation investigated the feasibility of using SUT in the PDSS test environment. The primary motivation was the realization that there were not enough test assets, people or time to test the main battle tank software for each release. The purpose of the SUT approach was to determine better ways to test increasingly complex systems and system of systems in the future. The paper [1] reported on work performed applying the SUT. Significant progress has been made since that time. Efforts are now underway to combine SUT with other approaches to automated testing, and scale it up even further.

2. DIAGNOSTICS AND PROGNOSTICS OF FUTURE SYSTEMS: HEALTH AND SITUATION CONTROL METHOD

The proposed new technology for health monitoring, diagnostics and prognostics of future systems will utilize federated software and probes approach. Gauges will determine if the system operates within acceptable performance bands by monitoring data provided by the probes. Health monitoring system will use models of missions to make intelligent choices considering tasks criticality. Prognostics of system's LRUs will be based on probes data and statistical usage models. Future weapon platforms will host a significant increase in software. The processing burden of the front line vehicles will require a further increase in processing capability. Next generation weapon systems processing requirements will grow with the incorporation of intelligent decision aids, sensor fusion, and advanced communications. A future system will have 2×10^6 configuration combinations. Cost, reliability, space, and mission requirements will preclude achieving redundancy with dedicated, embedded processors that duplicate functionality. The next generation systems vision is that a collection of general-purpose processors connected to a common bus will be scattered throughout the vehicle and assigned dynamically to the various vehicle control and mission-specific tasks as required. This approach, shown in Figure 1, reduces cost and provides greater effective redundancy, since any healthy processor can be assigned to any task. Next generation systems process requires extensive monitoring and analysis capabilities to track whether the weapon system is operating properly. A robust reconfiguration capability is required to reorganize the assignment of tasks to processors to respond to hardware and software failures and to changed mission requirements.

The proposed technology is health and situation control (HSC) for diagnostics and prognostics of ground combat vehicles. The HSC continually tests the processing elements with Probe/Agent technology. Algorithms within the HSC assess the health of the processors based on a criticality scoring system that considers mission requirements. Probes are launched by the HSC query processing elements. The probed data is sent to a gauge that has a variable sensitivity or gain. Statistical usage models and criticality scoring control the sensitivity of the gauge. In response to the gauge, the replicating process launches agents that can insert anomalous events for diagnostic purposes. In this context, a probe is a subset of an agent having only the ability to query without affecting framework, I/O protocol or Quality of Service. Each weapon system fitted with the HSC will control self-repair and reconfiguration of on-board processors utilizing a statistical based intelligent scoring system. It considers criticality of the function in the current battlefield situation. HSC is a software system that will enhance the performance of a weapon system by providing on-the-fly reconfiguration to accommodate the loss or malfunction of processing elements or to optimize onboard performance capability. Selected software components of soldier machine interface in a crew station will be modeled using HSC architecture modeling techniques. The hardware environment will be modeled so that HSC analysis tools can select compatible hosts from candidate processors. Missions will also be modeled so that HSC tools can make intelligent choices considering the task criticality. HSC will detect faults and select the optimal crew station configuration to maintain essential functionality in response to current battlefield conditions. HSC will construct correct configurations of software to load onto a vehicle for combinations of weapons systems, sensors, and missions. It will collect usage and runtime error data that can be used to improve the software development and testing processes. HSC-collected usage information and runtime error patterns will be fed back into Next Generation SUT models to improve the modeling fidelity and software testing process. Success of this aspect of HSC will be measured by the reduction in time for the SUT models to identify, isolate and repair errors. HSC architecture descriptions will be used to improve SUT usage modeling techniques and processes. The HSC Probe Controller will serve as an agent for the HSC Controller, reporting the health of the weapon system elements. Off-vehicle probes will be also launched to assess the health of companion vehicles within the Operations Unit. Figure 2 illustrates the HSC controller system health check process. Figure 3 shows the prognostics screen concept for different LRUs of the tank, based on the HSC and SUT methods.

3. CONCLUSION

The Health and Situation Control will test the processing elements continually with Probe/Agent technology. The HSC architecture descriptions will be used to improve usage modeling techniques and processes. The HSC-collected usage information and runtime error patterns will be fed back into Next Generation SUT models to improve the modeling fidelity and software testing process. Success of this aspect of HSC will be measured by reduction of time of the SUT models development. HSC will enhance the performance of a weapon system by providing on-the-fly reconfiguration to accommodate the loss or malfunction of processing elements or to optimize onboard performance capability.

4. REFERENCES

1. M. S. Saboe, P. Gilbert, A. Kouchakdjian, "Applying Statistical Usage Testing (SUT) on a High-Complexity Application", *Proceedings of the Workshop on Statistical Methods in Software Engineering for Defense Systems,* National Academy of Sciences, Washington DC, July 2001.

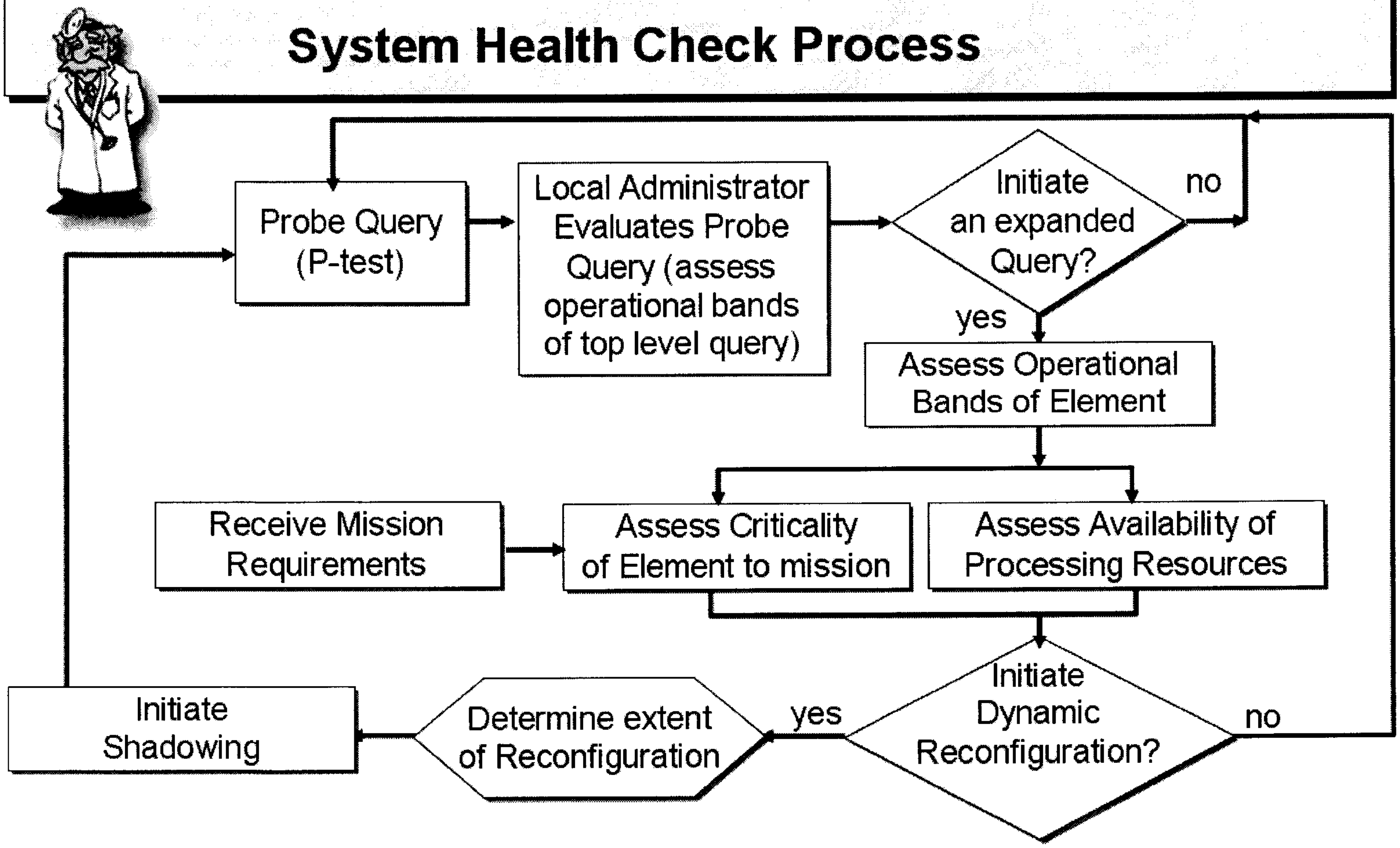
5. ILUUSTRATIONS

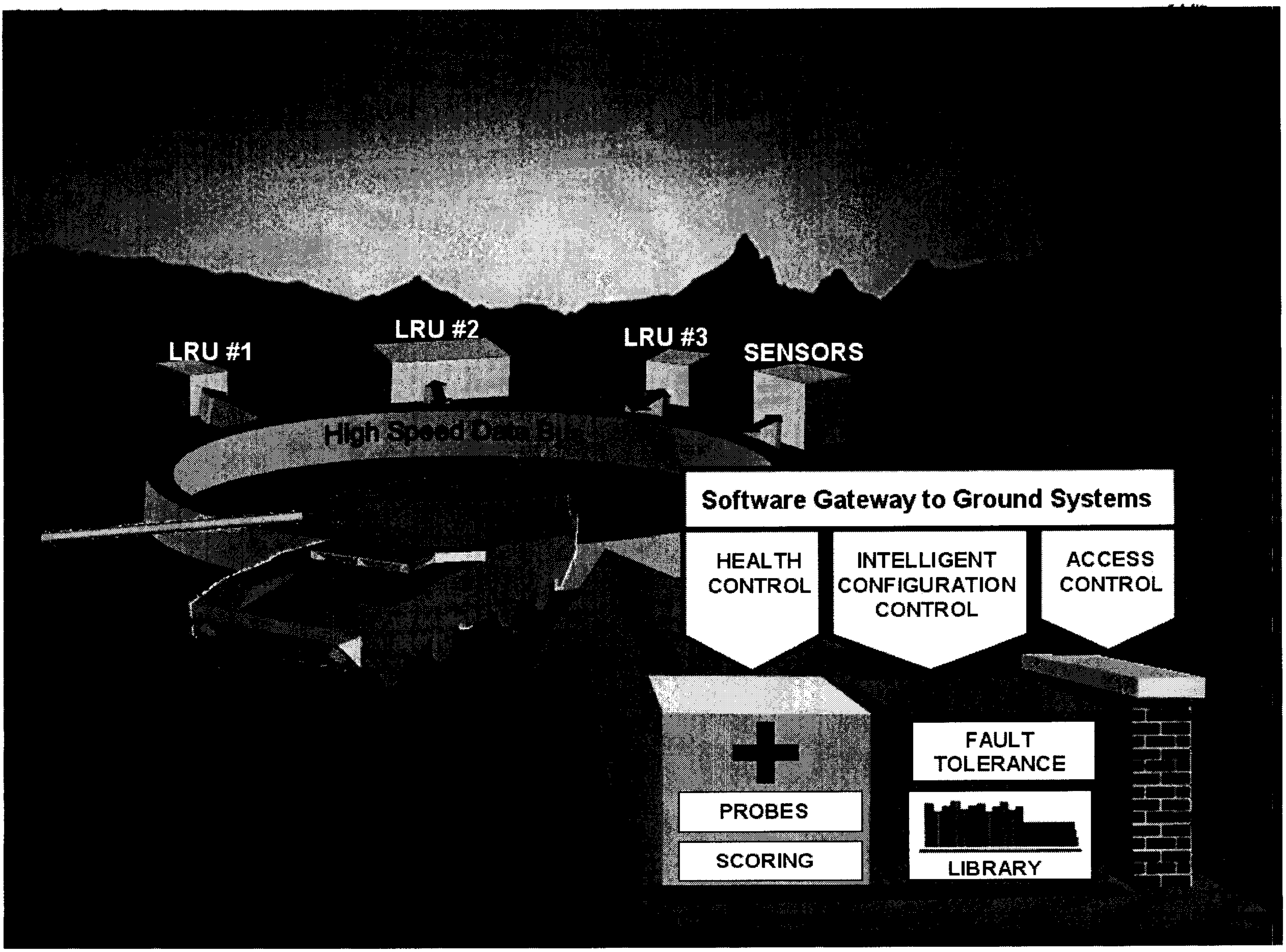
Figure 1. The Next Generation health and situation control process.

Figure 2: System health check process diagram.

Figure 3: Commander's display showing the prognostics screen concept.

System Health Check Process




LRU #1
LRU #2
LRU #3
SENSORS
High Speed Data Bus
Software Gateway to Ground Systems
HEALTH CONTROL
INTELLIGENT CONFIGURATION CONTROL
ACCESS CONTROL
PROBES
SCORING
FAULT TOLERANCE
LIBRARY

Proposed Prognostic Screen