BAE SYSTEMS

Why Design for Testability Sooner?

21 October 2008

Bruce Bardell, Technical Fellow

Bradley Chief Architect

BAE Systems

BAE SYSTEMS

Agenda

- Ground Combat Vehicle Capabilities
- Levels of Maintenance
- Diagnostic Technology Evolution – past and future
- Prognostics Definition
- Diagnostics Concept Design and Decomposition
- Possibilities for Enhancement
  - Unit Level Diagnostics (8)
  - Direct Support Diagnostics (5)
  - Unit Level Diagnostics & Prognostics (1)
  - Prognostics (3)

Ground Combat Vehicle Overview - Vehicle Capabilities

BAE SYSTEMS

- **Level of Technology in capabilities typical of Ground Combat Vehicles**
  - **Mobility**
  - **Lethality**
  - **Communication**
  - **Survival**
  - **Transport**

Vehicle Capabilities - Mobility

- **Major components**
  - **Turbocharged or supercharged reciprocating diesel engine**
  - **Hydraulically controlled automatic transmission**
  - **Other loads – hydraulic pumps, pneumatic pumps, refrigeration compressors, direct drive engine compartment cooling fans, electrical generators, and the supercharger**

Vehicle Capabilities – Lethality

- **Capabilities Provided**
  - **target sighting**
  - **weapon pointing**
  - **ammunition management**
  - **round discharge**
- **Technology Evolution – target sighting**
  - **hard-mounted passive telescope with elevation axis adjustment**
  - **Remote superelevation adjustment**
  - **Electronic measurement of target range**
  - **Coupling target range measurement to superelevation adjustment**
  - **Imaging of other than visible wavelengths**
  - **Rasterized video imagery to permit display on conventional CRTs and emerging flat panel displays**
  - **Remote viewing at selected crew workstations**

Vehicle Capabilities – Lethality continued

BAE SYSTEMS

- **Technology evolution – weapon aiming**
  - **Manual operation**
  - **Hydraulics, reducing gunner workload**
  - **Electrical as power electronics became more capable**
  - **Rate commanded directors**
  - **Analog servos allowed combining the operator command with an inertial gyro input yielding inertial-stabilization**
  - **Digital servos made inclusion of other battlefield factor corrections easier to implement, reducing the gunner's workload again**
- **Technology Evolution – Weapon Control**
  - **Mechanical recharge on recoil**
  - **Electronic monitoring and control managing feeders and improving gunner convenience and safety**

Vehicle Capabilities – Survival

- **Redundancy**
- **Battle damage protection**

Vehicle Capabilities – Not Explored

- **Communication**
- **Transport**

Supportability – Current Levels of Maintenance

BAE SYSTEMS

- Unit Level (Organizational Level) – the Motor Pool
- Direct Support (Intermediate Level)
- Depot (typically the manufacturer)

Diagnostic Technology Evolution

- **Before 1981**
  - **Multimeters**
    - **Vehicle Schematics**
  - **Vehicle Test Meter (STE-ICE)**
    - **Automotive Diagnostic Connector Assemblies & Transducers**
    - **Technical Manual troubleshooting**
- **1981**
  - **Controllable Interface Box (STE-M1/FVS)**
    - **Weapon System Diagnostic Connector Assemblies**
    - **Maintainer-augmented fault isolation**
    - **Fault isolate to single LRU**
    - **Matured over next several years with data collected in Production**
  - **Direct Support Electrical System Test Set**
    - **Replicates vehicle interfaces on bench**
    - **Fault isolate to single SRU**
    - **Matured over next several years with data collected in Production**
- **1985**
  - **Weapon aiming subsystem**
    - **Conversion to digital enabled built-in fault isolation routines**
    - **Accessible via plug-in terminal**
- **2001**
  - **Turret upgrade**
    - **Systemic BIT requirement**
    - **Fault isolation performed by main system computer**
    - **Capabilities available statused to Commander**
    - **Degraded Modes**
    - **Improvements to Direct Support testing**

BAE SYSTEMS

Diagnostic Technology – Future

- **Near term**
  - **LRUs subject to obsolescence redesign include BIT and Fault Isolation to the SRU level, when possible based solely on monitoring internal LRU behavior only**
  - **Results saved to persistent memory and made available to a plug-in terminal, making the Direct Support plug-in test equipment that fault isolates to SRUs is no longer required for those LRUs.**
- **Longer term**
  - **Continue to include BIT and Fault Isolation to the SRU level in LRUs subject to obsolescence redesign**
  - **Include system wide enhancements so that LRUs external behavior can be stimulated and sensed and the results communicated so the LRU is able to react to external observations and perform a more complete fault detection and isolation**
  - **The results are saved to persistent memory and made available to a plug-in terminal.**

BAE SYSTEMS

Prognostics – A Definition

- **Implementation: Prognostics requirements are beginning to creep into contemplated and funded efforts, but still as a placeholder**
- **Purpose: To estimate remaining useful life when that life is nearing its end**
- **Technical Requirement: Predict when end-of-life will occur within the next mission, or the period of time the vehicle is away from the motor pool. More advance warning is needed if the replacement part is not on hand. Obviously, the duty cycle of each prognosed component is critical in determining remaining life in units of vehicle power-on time.**

Diagnostics Concept Design and Decomposition

BAE SYSTEMS

- **Initial diagnostics concept work should entail**
  - **assessing allocated realizable MTBF**
  - **projected mission reliability**
  - **development and unit production cost, weight, and volume**
- **When completed, that diagnostics concept work should result in**
  - **definitions**
  - **requirements**
  - **standardized interfaces**
  - **implementation suggestions**
- **Then the emerging system and subsystem design concepts can evolve to include**
  - **appropriate partitioning between the tactical and diagnostic functions**
  - **appropriate level of inherent fault detection algorithms and hardware to meet the fault isolation requirement and intended support interface**
- **The following are just a few examples of capabilities that can be realized with early availability of diagnostics requirements and concepts.**

Possibilities to Enhance Unit Level Diagnostics

BAE SYSTEMS

- Minimize suboptimal compliance with requirements by enabling planning, design, and review of compliance early in the subsystem design cycle.
- Assure that pass/fail limits, algorithms, and crew/operator messages are updatable separately from the tactical software, so diagnostics maturation can follow an independent path from tactical anomaly resolution and feature addition.
- Characterize abnormal behavior down to the chip level.
- Architect intrusive tests such that they may be executed without affecting the in-vehicle operation of the electronics assembly.
- Improve LRU interface integrity fault detection via boundary scan at the LRU's system interface.
- Include the ability to tailor diagnostic pass/fail limits conditionally to minimize false alarms and nuisance trips based on vehicle mode of operation.
- Include LRU degraded modes (such as reduced processor power consumption) to compliment system level degrade modes.
- Include tests of system interconnect media in selected LRUs to detect and localize breaks, degradation, and missing terminators.

Possibilities to Enhance Direct Support Diagnostics

BAE SYSTEMS

- **Include an LRU-level persistent memory to log timestamped pass-to-fail and fail-to-pass transitions in conjunction with data potentially important to a root cause analysis (input voltage, internal temperature, value of analog inputs, processor load, memory utilization, etc.). This supports bench level repair and engineering root cause analysis of failures.**
- **Include a standardized interface from the LRU to bench power and a USB or other standardized serial interface port to enable a general purpose computer to offload the fault detection log and fault isolation results, manage the persistent memory, and optionally accept software updates for the LRU or for the entire vehicle.**
- **Allow the system to augment LRU interface fault detection – with results reported to the LRU for storage in it's persistent memory for bench level repair.**
- **Include sufficient system level redundancy and partitioning to support reconfiguration to maintain full capability or introduce degraded modes in the presence of faults. Examples are maintaining full capability via alternate processing and communication resources, degradation by invoking less automated capabilities, reducing Crewstation access to capabilities, etc.**
- **Combine manufacturing test requirements with system and LRU test requirements and satisfy with a single solution.**

Possibilities to Enhance both Unit Level Diagnostics and Prognostics

BAE SYSTEMS

- **If sensor requirements for diagnostics/prognostics differ from those for tactical operation, select sensors suitable for meeting all requirements.**

Possibilities to Enhance Prognostics

BAE SYSTEMS

- **The follow-on to an agreement of additional transducers required for prognostics is to implement the interfaces and reserve processing power required to detect degradation (this approach may involve high frequency characterization of mechanical systems to determine degradation).**

- **Consider including board-resident test software to track component degradation over time.**

- **Include chip-level monitoring of temperature and input current if deemed pertinent for prognostics.**