Just Right Vehicle Network (Data Bus) Protocols

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ABSTRACT

This track presentation presents an improved Vehicle Network (Data Bus) Protocol Selection Process/Technique for Ground-based Military Vehicle Systems.

ABSTRACT (cont)

Vehicle network data bus protocols are analyzed/evaluated and selected to support the real-time control and information data gathering requirements for the Brigade Combat Team Platforms.

BACKGROUND

"ONE TEAM VISION –
EQUIPPING OUR JOINT WARFIGHTERS
WITH THE WORLD'S BEST CAPABILITY"

The selected Vehicle Network (data bus) protocol(s) can be installed into U.S. Army Ground-based Military and/or Commercial (COTS) Vehicle Systems

DoD Mission Goals / Army Vision

"… The technology that is at the center of Transformation is <u>Information Technology</u>"

"… a <u>network centric</u> capable force that is robustly networked … fully interoperable and <u>shares information and collaborates</u> by means of <u>communications and information infrastructure</u> that is global, secure, real time, reliable, internet based, and user driven"

Arrival Ceremony for the Secretary of the Army

"The lesson of this war is that effectiveness in combat will depend heavily on jointness – that is , the ability of different branches of our Military to <u>communicate and coordinate efforts</u> across the battlefield."…

Former Secretary of Defense
Donald Rumsfeld

…the Army still has a lot to learn on how to successfully build such an advanced <u>information network</u>.

(FCS/BCT) Former Program Manager
MG Charles Cartwright

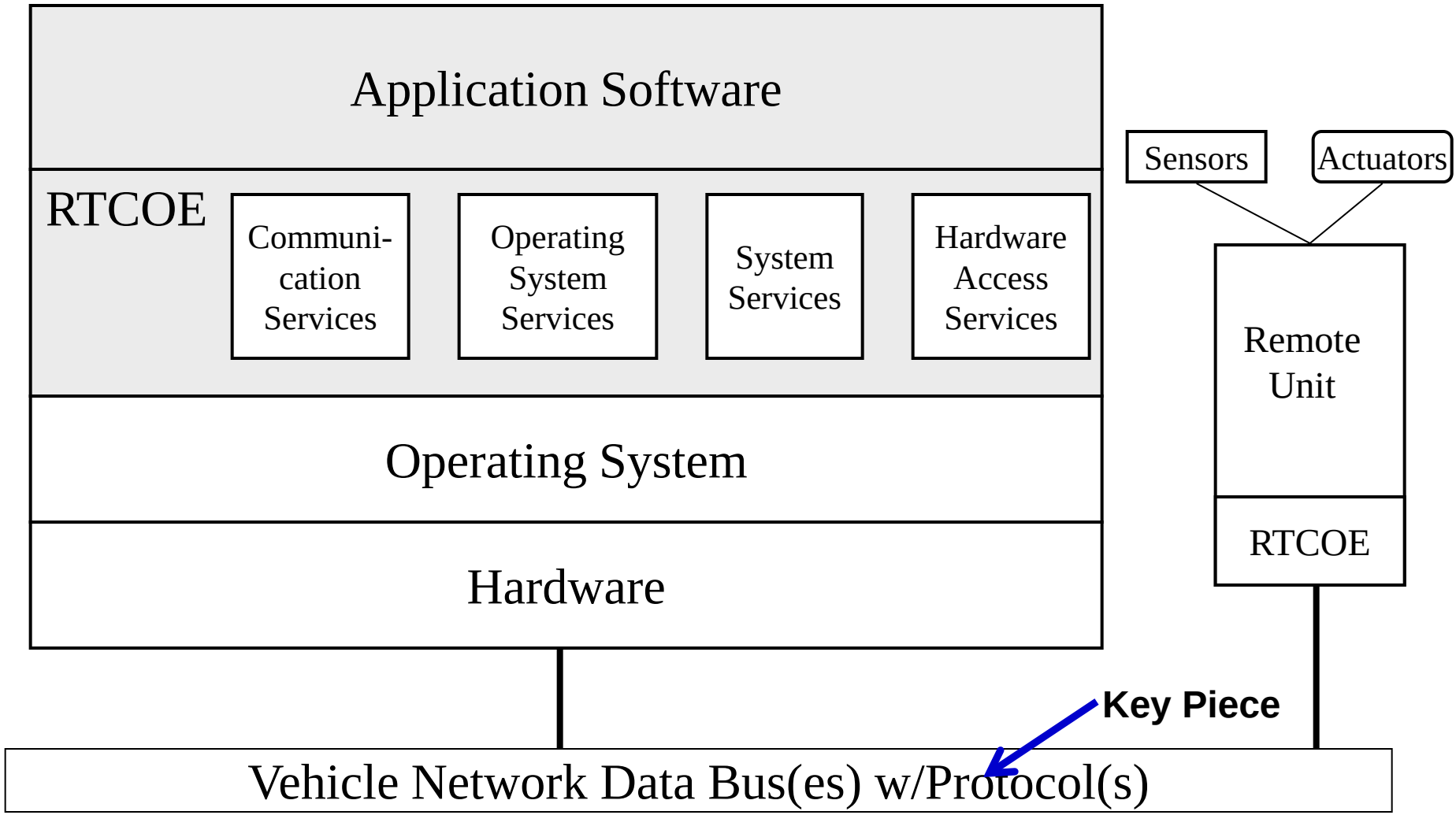
"We will become more sustainable. We look to reduce support demands by seeking common-platform / common-chassis / standard-caliber designs."

The Army Vision, by Gen. Eric K. Shinseki, Former Chief of Staff, USA

US Army Philosophy

- **US Army Transformation is required to meet the challenges of changing conditions across the spectrum of military operations and the evolution of military technologies**
- **US Army Transformation combines advanced technologies, organizations, people, and processes with concepts to create new sources of military power that are more responsive, deployable, agile, versatile, lethal, survivable, and sustainable**
  - using a system-of-systems (SoS), not a collection of platforms
  - is network-centric, not platform-centric

RealTimeCommonOperatingEnvironment (RTCOE)



INTRODUCTION

PROBLEM

There are many parts of this network to research; however, I shall concentrate on defining a precise method to define and assist in properly selecting the network (data bus) protocol pieces, especially within a BCT Platform (vehicle).

Data Bus / Protocol

In vehicle network architectures, a **data bus** is a subsystem that transfers data between computing devices/peripherals. Unlike a point-to-point connection, a data bus can logically connect several peripherals/devices over the same set of wires. Each data bus defines its set of connectors to physically plug devices, peripherals or cables together.

The data bus' **protocol** is a set of rules governing the format of messages that are exchanged between the computing devices/peripherals. Some data bus protocol designers employ excessive redundancy and parallel data paths as solutions for latency, large % utilization rates, throughput and survivability issues; still others are using proprietary protocols.

The WRONG Data Bus/Protocol Goal

- Vehicle manufacturers prefer their vehicle architecture employ their own developed data bus and protocol.
- **Case in Point – One Government contractor desired that ONE Data Bus type exist in the Vehicle's Electronic Architecture!**
  - They preferred GbE only.
  - Dictated and not arrived at scientifically.

Correct Data Bus/Protocol Goals

- Technical – Size, Weight and Power (SWaP)
- Cost – Lowest/Reasonable
- Schedule – Available/On Track
- Performance – Highest Technology Risk Level / Risk Free

Key Data Bus/Protocol Conundrum

General area is one where many people have less understanding than they think they do.

Mike Green - NPS

NO Data Bus / Protocol Usage Here

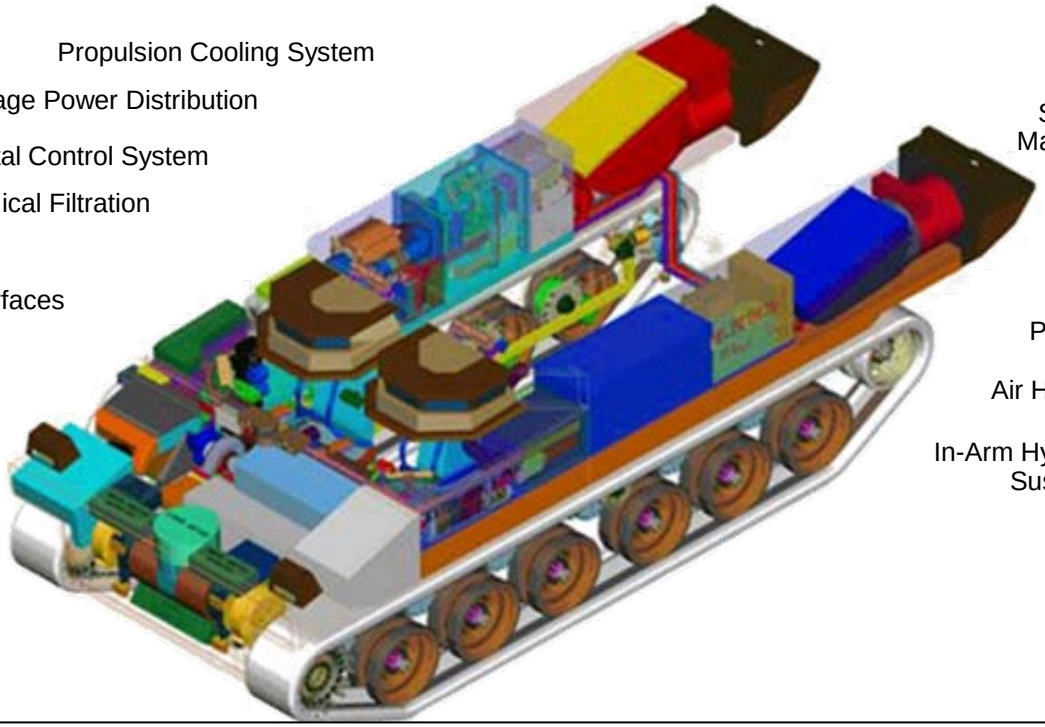
Program Manager's Vehicle Network Goal

To move infinite amounts of data

In no time

In thin air!

Vehicle Network (Data Bus) Protocol Reality



Vehicle Network(s)

SW Programmable Radio Suite & Antennas
Real-time Vehicle Control Data Buses
Information Exchange (Enterprise) Systems Data Buses
Decision Aids
Distributive Collaboration of Manned/Unmanned Platforms
Security Intrusion Detection

VEHICLE NETWORK (DATA BUS) PROTOCOL SELECTION PROCESS/TECHNIQUE

Previous Network Selection Iterations

Vehicle Network Selection Conducted 2002

– CAN Data Bus recommended
– Simple Mathematical selection method used

Vehicle Network Selection Conducted 2003-2005

– CAN Data Bus recommended for lower speed hard real time control
– IEEE 1394b Data Bus recommended for high speed hard real time control
– Formal Trade Study Process w/ software assisted method used
– Process conducted twice during contract period of performance

SOLUTION DEVELOPMENT METHODOLOGY 1

My NPS Software Engineering PhD Dissertation Research is centered on presenting an improved (new) Vehicle Network (Data Bus) Protocol Selection Process/Technique for Ground-based Military Vehicle Systems.

Worldwide standard (ISO/SAE) and emerging (industry/academia) Vehicle network (data bus) protocols are to be analyzed/evaluated and categorized by an all-encompassing, feature-based technique to define the (non)real-time control and information data gathering requirements for the BCT Platforms.

By feature-orientation, my goal is to make the mapping relationship between vehicle network (data bus) protocol requirements and the Vehicle Network Selection Process/Technique selected architecture straightforward and defendable.

SOLUTION DEVELOPMENT METHODOLOGY 2

A **Feature** can be defined as: A feature is “a coherent and identifiable bundle of system functionality that helps characterize the system from the user perspective”; A feature is “a prominent or distinctive user-visible aspect, quality, or characteristic of a software system or systems”; A feature is “an externally desired service by the system that may require a sequence of inputs to effect the desired result”; A feature is “a service that the system provides to fulfill one or more stakeholder needs”.

Dongyun Liu and Hong Mei of the *Institute of Software, School of Electronics Engineering and Computer Science* , *Peking University, Beijing, China* find that “**a feature is a higher-level abstraction of a set of relevant detailed software(/hardware/firmware) requirements, and is perceivable by users (or customers(/system developers**))”. These features (requirements) must somehow be categorized or processed (traded-off) to form a hierarchal feature (requirement) selection characterization method to classify/tradeoff requirements for my “best pick(s)” method for the “just right” vehicle network (data bus) protocol.

SOLUTION DEVELOPMENT METHODOLOGY 3

- The quantity and quality of network design features analyzed by previous network selection techniques/tools were insufficient to pick correct, mutually accepted vehicle network (data bus) protocols for the DoD's BCT Platform or its legacy programs that preceded it.
- Use previous selection methods as one of the best previous competing solutions to act as a starting point for the framework of my new feature-based vehicle network selection process/technique.
- Use all of the founding principles and merits of a BCT Common Operating Environment to act as the "most favored" features of the selection software and employ a fuzzy logic rules-based and/or simulation toolset that shall evolve into the best vehicle network protocol selection tool to date.
- The new vehicle network protocol selection process/technique shall employ over double the number of measures of network features to assess all candidate vehicle network protocols against previous selection methods.

SOLUTION DEVELOPMENT METHODOLOGY 4

First, conduct a survey of the **network requirements** of typical vehicle networks. These "**features**" shall then be used to help define the best feature-based architecture for the BCT Platforms.

Second, rather than use a handful or limited set of parameters to define a vehicle network (data bus) protocol for the purposes of supplying the inputs to a trade study, it is better to define the key features/requirements that represent all present day vehicle network (data bus) protocols and use them in an unified (automatic) **trade-off analysis** selection process to select the data bus protocol(s) needed by the developer to be used across all product line products, or in this case, vehicles.

Third, place these features into a **personally developed vehicle network protocol selection tool**, add a developer's specific requirements and observe the results. Repeat using another developer's requirement inputs as necessary to refine the tool for effective use in the ground-based military/COTS vehicle domain.

Vehicle Network Protocol Selection – My Iteration 1

New Key Feature-based Selection Criteria:

- Based on key features of a vehicle network (data bus)
- Based on vehicle network (data bus) protocol feature (requirement) characterization/tradeoffs
- Based on actual functionality of the vehicle network (data bus)
- Based on common sense and actual industry practice(s)
- Based on inherent Pit Stop Design/Engineering principles

Vehicle Network Protocol Selection – My Iteration 2

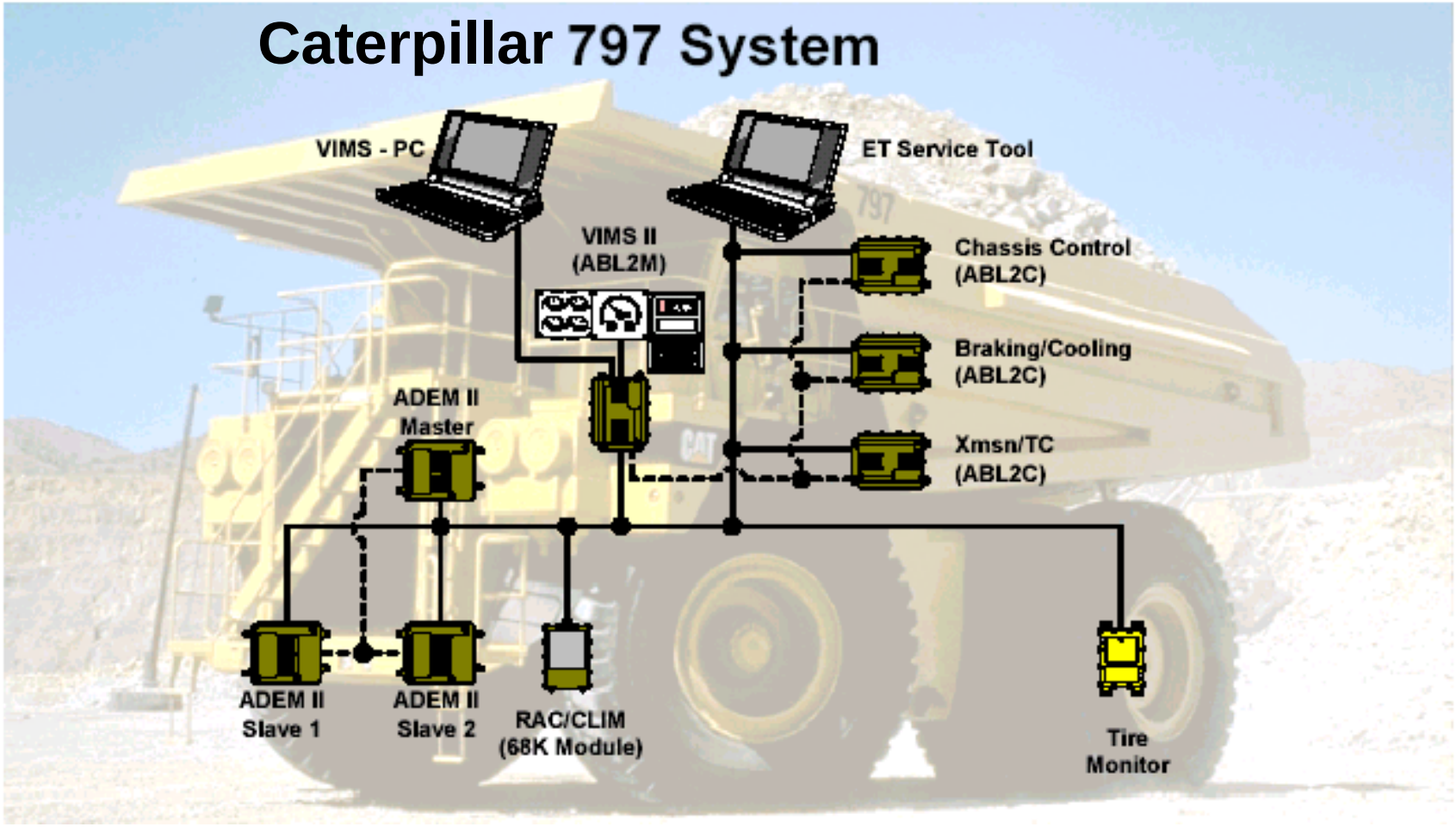
Research Requirements Characterization and Tradeoff Methods:

- Analyze Requirements Tradeoffs
  - **Systematic Tradeoff Analysis for Conflicting Imprecise Requirements**
  - **Architecture Tradeoff Analysis Method (ATAM)**
- Analyzing the Tradeoffs among Requirements, Architectures and COTS-Based Systems
- Tradeoffs in Weapon System Design
- Quantitative Methods for Tradeoff Analyses
  - **Figure of Merit**

Pit Stop Engineering Applied to Vehicle Network Protocol Selection Process/Technique

- **Simplified Architecture**
  - Follow Army Enterprise Architecture (JTA-Army) Guidance
- **High Use of existing Standards or**
  Promote Development of New SAE/IEEE/ISO Standards
- **Standard Naming Convention for RTCOE & Vetronics features**
- **Extensive use of Vehicle Network(s)/Data-Bus(es) for System Data Flow**
- **Generic Features/Attributes for High Reuse**
- **Achieve Lowest Cost/Highest Supportability/Maintainability/Reliability**

A Just Right Vehicle Network Protocol?



My Dissertation Partners (NPS Dissertation Committee)

- **Professor Valdis Berzins – Committee Chairman/Supervisor**
- **Professor Luqi**
- **Professor John Osmundson**
- **Dr. Satya Kodali (PM GCV colleague)**

My Dissertation Partners (Outside of NPS Relationships)

Other Academia

- MSU – Dr. Betty Cheng / EE Dept of Computer Science Engrg
- U of M – Dr. Paul Richardson / EE Dept
- ASU – Dr. David Cook (Unofficial SwE Humorist)

Industry

- GDLS – Mr. Antony Torre (Lead Engineer/Architect)
- GDLS – Ms. Suzanne Rydel (Vetronics Modeling & Simulation SME)
- GDLS – Ms. Hong Jiang (Vetronics Modeling & Simulation SME)
- Carlson Technology, Inc. – Mr. Dennis Carlson

SAE

- Vehicle Architecture for Data Networks Committee, including…
- Vehicle Network Protocols Task Force
- COTS Manufacturers (i.e., GM, Ford and Chrysler, Dearborn Group)

References 1

[1] Andrew S. Tanenbaum; Computer Networks; Englewood Cliffs, NJ: Prentice Hall, 1996.

[2] Buckstad, MAJ R., and C. Mushenski, Vehicle Control and Operating System (VCOS) Specification, U.S. Army TACOM, Warren, MI 48397-5000, 31 Aug (1990)

[3] C. Reid Turner e.tc, A conceptual basis for feature engineering, The Journal of Systems and Software 49 (1999)

[4] Carlson, Dennis, Pit Stop Design Philosophy - Carlson Technology, Inc., 27 May 2003.

[5] Crusader Data Bus Evaluation and Recommendation Trade Study; GDLS-SHC, Sterling Heights, MI; 1997

[6] DJ Ackerman; Preliminary Report: Data Acquisition and Control Bus (DACB) Selection for Crusader Self Propelled Howitzer Vehicle Electronics; 16 Jan 1995.

[7] Defense Acquisitions: Key Decisions to Be Made on Future Combat System, GAO-07-376T. Washington, D.C.: March 2007.

[8] DY 4 Systems Inc.; Preliminary White Paper on Local Area Network Options for Today's Vetronics Programs

[9] Gacek, C., Exploiting Domain Architectures in Software Reuse, University of Southern California, Los Angeles, California, 90089-0781, (1995)

[10] Institute of Electrical and Electronics Engineers. IEEE Recommended Practice for Software Requiements Specifications (IEEE Std 830-1998), New York, N.Y.: Institute of Electrical and Electronics Engineers, 1998

[11] Kang, Kyo C. etc. Feature-Oriented Domain Analysis Feasibility Study (CMU/SEI-90-TR-21, ADA235785), CMU-SEI, 1990.

[12] Kogut, P., and K. Wallnau, Software Architecture and Reuse: Senses and Trends, Tutorial for Tri-Ada Conference, 7 November (1994)

References 2

[13] Lamb, D., Software Engineering: Planning for Change, Prentice Hall, (1988)

[14] Leary, J., Information Architecture - an Architectural Basis for Evolution of Large Scale Software Systems, Software Engineering Institute (SEI) Paper for NPGS Workshop, 2 February (1994)

[15] Leffingwell, Dean, Managing Software Requirements: A Unified Approach, AT&T, 2000

[16] Liu, Dongyun, Mei, Hong, Mapping requirements to software architecture by feature-orientation, Institute of Software, School of Electronics Engineering and Computer Science, Peking University, Beijing 100871, P.R.China (2000)

[17] Maddux, COL Jonathan, FCS Integrated Network Overview, International Test and Evaluation Association Workshop, Ft. Monmouth, NJ, 10 May 2006

[18] Mushenski, Christopher B., Amy Mokzran, Myrvold, Gregory; SAE Paper # 2002-01-0442; Vehicle Network Selection

[19] Mushenski, Christopher B., Rydel, Suzanne, Folian, Michael; SAE Paper # 2005-01-0933, Military Vehicle (FCS MGV) Electrical Systems Modeling and Simulation

[20] Mushenski, Christopher B., Torre, Anthony J.; SAE Paper # 2008-01-0774, Analysis and Modeling of Servo Motor Control in Military Vehicle Control Systems Update

[21] Nada, N., Rine, D., Three Empirical Studies in Validating a Reuse Reference Model, The Annals of Software Engineering Journal, Vol. 10, (2000)

[22] Torre, Anthony J., Mushenski, Christopher; SAE Paper # 2006-01-1170, Analysis and Modeling of Servo Motor Control in Military Vehicle Control Systems

List of Acronyms

- ATAM - Architecture Tradeoff Analysis Method
- BCT – Brigade Combat Team
- CAN – Controller Area Network
- COTS – Commercial Off-the-Shelf
- DoD – Department of Defense
- GbE – Giga-bit Ethernet
- IEEE – Institute of Electrical & Electronic Engineers
- ISO – International Standardization Organization
- JTA-Army – Joint Technical Architecture - Army
- RTCOE – Real-Time Common Operating Environment
- SAE – Society of Automotive Engineers
- SoS – System-of-Systems
- SWaP – Size, Weight and Power
- Vetronics – Vehicle Electronics