INNOVATIVE TECHNOLOGY FOR DATA-CENTRIC, CAPABILITY FOCUSED APPROACH TO FACILITATE THE ARCHITECTURE, MODELING, AND INTEROPERABILITY OF CHALLENGING SYSTEM-OF-SYSTEMS, (SoS).

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ABSTRACT

A data-centric capability focused on meeting the strategic need for the rapid configuration of interoperability among and between different end-points such as applications, military vehicle onboard systems, modules and sensors represents a glaring capability gap facing the Army. This agile network layer is required for the standardization and interpretation of data into actionable intelligence. A capability that is essential for the Army to successfully facilitate complex "systems-of-systems" (SoS) engineering requirements for process improvement, superior products, and reduced cost.

INTRODUCTION

The design and management of complex systems over a product lifecycle require "System of System," (SoS) interoperability to achieve success. The Army has increased its emphasis on SoS for product engineering, process improvement, and reduced cost. The role of Systems Engineering, (SE) is expanding to the engineering of SoS capabilities to include products and vehicles that interconnect with networks to share data and learn from the shared experience of their operational environment. These complex environments are generally referred to as Cyber-Physical Systems, (CPS). CPS engineered systems allows the Army to apply an Internet-of-Things, (IoT) for data collection, from the manufacturing floor to the products and weapon systems they develop. As an emerging capability, CPS is most accurately defined by the transformative technologies that manage the data between interconnected systems such as Army End-User Devices, (EUDs) and the computational capabilities required to provide Command and Control, (C2) and Knowledge-Based Systems (KBS). Against this background, the ever-growing use of sensors, networked machines, and vehicle electronics has resulted in the generation of large volumes of data commonly known as Bid Data. Converting Big Data into actionable intelligence remains elusive. The

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generation of data for intelligent, resilient and self-adaptable systems must include a real-time data-centric framework that supports both CPS and Human Machine Interface, (HMI) architectures. The purpose of this white paper is to provide insight into modifiable Commercial-Off-The-Shelf capabilities that meet Army needs for complex SoS architectures without the need to re-engineer systems and rewrite software when requirements and end-points change.

OPERATIONAL NEED

Department of Defense, (DoD) defines a SoS as a set of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities[1]. Army End-User Device Reference Architecture[1] requires a rules-based capability or more specifically, a system that uses human rule sets as a programming requirement. Army defines EUDs as hardware components that contain and execute Human-Machine Interface, (HMI) solutions. Many use cases apply, but specific to TARDEC are three instances where data-centric applications are required for mission requirements already in development.

1. Emerging requirements that need to capture big data from disparate sources to improve business processes such as integrated logistics and Condition Based Maintenance Plus, (CBM+) projects.

2. A Universal Controller device that can support diverse data sets from Ground Vehicle Robotic, (GVR) applications, to leader-follower autonomy projects.

3. Army modernization projects where complex upgrade to equipment or maintenance of fielded vehicles require data-centric processing with logistic,

and Army Life- Cycle Management, (LCM) applications.

To address the unique data-centric requirements of these applications data-integration tools are required that are extremely flexible and operate the way the user works. In a paper titled, "A Cyber-Physical Systems Architecture for Industry 4.0 Based Manufacturing[2] a model is presented that applies to the above-referenced use cases. The balance of this white paper shall explore Synapse™, a framework that allows Army engineers to apply rules-based capability on a project by project basis to systems engineering requirements.

The following 5-C Architecture, where Connection, Conversion, Cyber, Cognition, and Configuration of data is required for operational success.
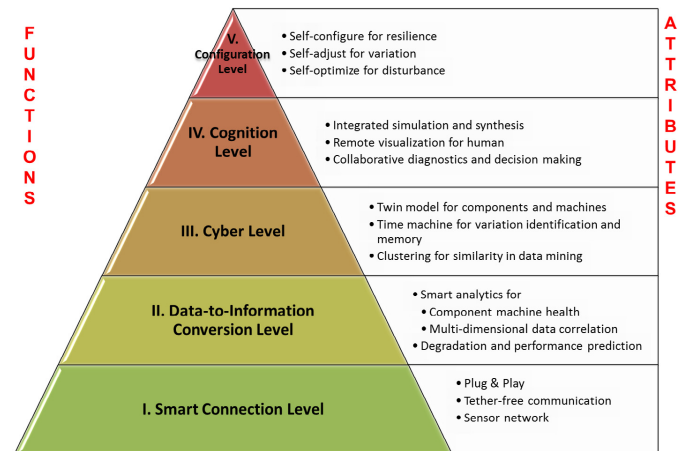
TECHNOLOGY DESCRIPTION

United States Patent number 7,243.120 titled "Transaction-based Enterprise Application Integration (EAI) and Development System approved July 2007 defines a data-centric framework in use in commercial healthcare. Specifically, the patent
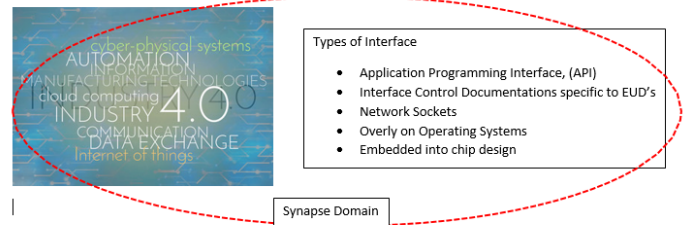
[1] U.S. Army End0User Device (EUD) Reference Architecture (RA) Version 2 dated 8 January 2016

[2] A Cyber-Physical Systems architecture for Industry 4.0-based manufacturing systems by Jay Lee, Behrad Bagheri , and Hung-An Kao

describes an architecture for a computing environment wherein transactions preferably model the enterprise and its business processes directly, allowing third-party systems, like ERP, supply chain and Web-portals to be more loosely coupled. The patent offers a system architecture where users model their particular enterprises in business terms so that disparate EUDs, databases, applications, sensors and electronic modules can be linked without custom programming.
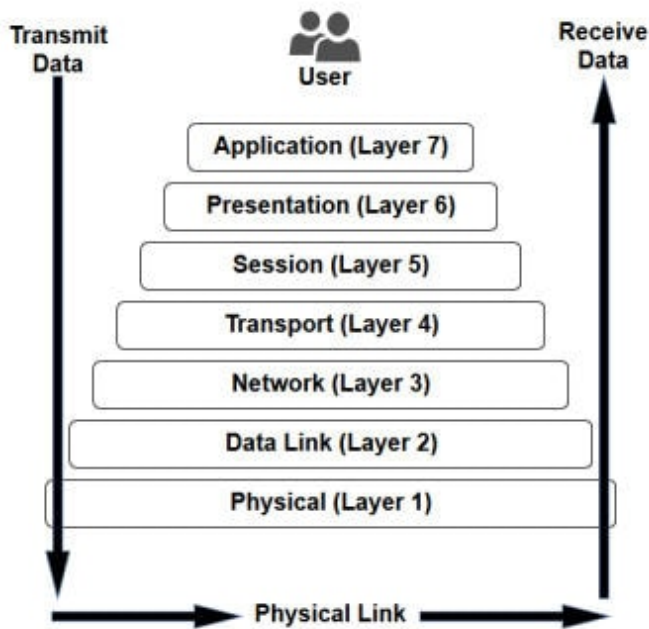
The Synapse™ framework is built on the Open Systems Interconnection (OSI) model allowing network end-points to establish preferred communications that model mission requirements. Army EUD's and networks are linked with a common language, so changes are easily managed from a central point of execution. Ad hoc integration of new EUD's, networks, and end-points at any level of the OSI model is accomplished using standard interface specifications and a flexible rules-based architecture that models the way the data is received and used. The model support:

The 7 Layers of OSI

Where the Physical Layer is responsible for the transmission and reception of data sets. The Data

Link Layer is responsible for the standardized transmission of data sets between two end-points. The Network Layer is responsible for multi-networked integration. The Transport Layer provides transmission of data sets between end-points including multiplexing of data between disparate EUD's. The Session Layers manages the communication sessions between end-points in a network. The Presentation Layer is the user interface, and the Application Layer is any programming interface to disparate systems end-points.

**Systems Viewpoint 1, (SV-1)**

COMMERCIAL USE CASE

Like the military, healthcare requires ad hoc integration of disparate end-points within a networked architecture to support surgery centers, care providers, patients and their families. Within this ecosystem, the use of disparate and different end-points range from machines, sensors, applications, and monitors to applications and databases, where operational and clinical data, such as patient records reside. Precise management of complex and highly variable processes are required for efficient, accurate and safe processing of the patient, the surgery, and the equipment. Within the operational environment interoperability and interconnectivity of a complete Physical-Cyber System, (PCS) includes connectivity with scheduling data, personal data, supply data, equipment data, sensor and monitor data and non-networked surgery kits adapted to the architecture using Radio Frequency Identification, (RFID) tags. A typical surgery center installation includes

integration at all 7 Layers of OSI and the integration of up to ten-thousand different end-points.
Software development is unable to keep up with an environment where change occurs frequently. Healthcare required real-time development environments where end-point integration could occur quickly from a single point of execution and distribute the change throughout the operational environment. The Synapse framework that provides the much-needed capability is built in ANSI C, a widely portable programming language. Systems integration and methods are straightforward and internally complete allowing implementation using a wide variety of programming languages, hardware interface designs, Operating Systems, (OS) overlays, and/or embedded on computational hardware as a complete OS. Once implemented, the framework provides the methods, without resort to additional programming, for describing the operating environment, including network and system topology, the description and distribution of services provided by or required by applications and devices in the environment, the configuration of connections and interfaces, including data formats and protocols, and rules for extending or coordinating existing functionality in the operating environment, or for defining new and/or independent functionality for the operating environment.

This provides a great deal of implementation latitude, in compensating for functional limitations of or incompatibilities among other endpoints, and maximizing their utility and the utility of the environment in the aggregate. Healthcare PCS solutions built on the Synapse framework have provided an average 50% improvement in surgery center efficiency while using data for continuous process improvement.

Project Viewpoint 1 (PV-1)
**Healthcare Surgery Centers**
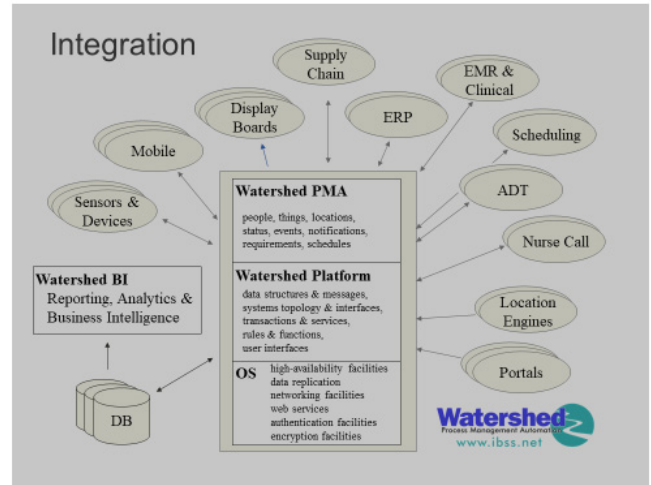
MILITARY VIEWPOINT

Today's military is increasingly connected in many diverse ways. Existing and yet-to-be-defined systems and vehicle platforms strongly challenge existing methods for data integration and systems engineering, (SE). In coming years, all vehicles and the onboard systems that support them have to integrate with external systems and networks to become "full mission capable. The ability of Army to manage rapidly changing requirements of the vehicles, onboard systems and unique informational data sets they develop will require a data-centric capability to support SoS requirements.

The Synapse framework is widely used in healthcare to network different End-User Devices, (EUDs), applications and databases into a Common Operating Picture, (COP). Adoption of modifiable COTS capabilities allows TARDEC engineers to test and evaluate net-centric capabilities without custom programming software on the project by project basis. The Synapse framework provides maximum design flexibility within reasonable constraints. System architecture, whether existing or under development benefit from rapid capability demonstrators that show great flexibility in

Systems of System Interoperability. TARDEC 30-year strategy commits to mission sets that are transformational. Developing new capabilities that are enabled by leap-ahead, innovative, modular, flexible, smart and adaptable technologies and architectures to demonstrate the art of the possible is critical to success.

The promise of transformational use of data in a networked environment depends on "un-isolating" disparate systems and devices and making information available to the people who need it most. At the center of this promise is the idea of interoperability and data sharing. There are thousands of different data standards in thousands of different application within the Army and DoD.

Operational Viewpoint 1 (OV-1)
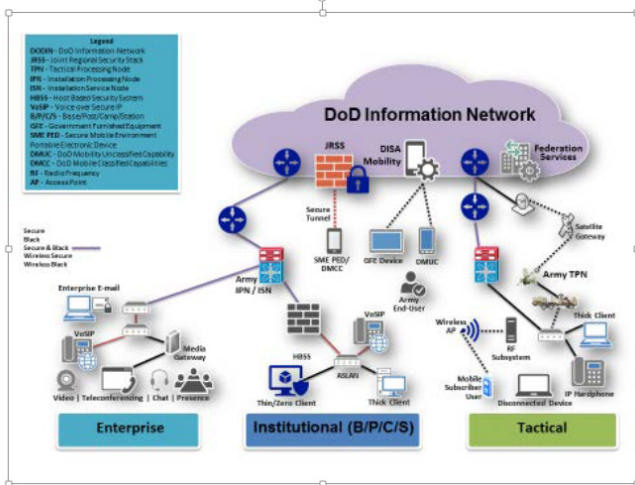
A framework for integration any data set or type creates the maximum amount of flexibility for system engineers for purposes of using the same components and architectures beyond strictly land vehicles, for example, Condition Based Management Plus, (CBM+) applications, universal controllers for robotics and leader-follower autonomy and others on a widespread basis. Ideally, the system shall be platform agnostic and shall incorporate holistic approaches, such as the ability to operate within complex operating environments. The goal of this planned, designed flexibility is to allow the TARDEC designed systems to lead the way toward the wide-ranging adoption of this technology, for purposes of maximum all-service flexibility and readiness.

Capability Viewpoint 1 (CV-1)

SUMMARY

Modifiable Commercial-Off-the Shelf, (COTS) items offer significant opportunities for Army TARDEC to reduced development time, provide faster insertion of new technology, and lower life-cycle cost. The program manager should pay particular attention to the intended product use environment and understand the extent to which this environment differs from (or is similar to) the commercial use environment. A data-centric framework exists to test and evaluate systems requirements for net-centric data integration