Paratus Associates LLC
SDVOSB

The Complete C5ISR Architecture Tool (TC²AT)

Improving Department of Defense Architecture Framework (DoDAF) Processes via an Integrated Architecture Capability

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ABSTRACT: The DoD continues to grapple with trying to develop an automated and fully integrated C5ISR System-of-Systems architecture and database repository process with a gap analyses capability that is doctrinally correct and can trace back to a force structure's underlying operational requirements.

Significant progress can be made in that direction with adoption and continued development of TC2AT. Built from the individual Warfighter – platform up, TC²AT is an automated JCIDS process that is modular in construct with cascading matrix links that provides a high-resolution detailed approach for all legacy, current and future organizational structure DoDAF related architecture from singular entity or platform to composite Enterprise level.

A core function of the TC²AT methodology is its ability to generate a 'super set' of all Sender x Receiver permutations of information exchange requirements (IER – OV3) as a function of operational requirements and systems. In the event there are no interoperable systems associated with the Sender x Receiver IER, TC²AT will identify the operational requirements that cannot be met as a function of that gap.

TC²AT is a peered methodology that has already proven its ability in the past to develop operational (OV3) and system (SV6) IERs in support of Army programs, GWOT combat division deployments and even a MITRE program evaluation.

As TC²AT's capabilities are expanded, the tool will provide real world analytical, traffic profile/bandwidth and gap analyses capabilities to identify C5ISR architectural operational impacts and a myriad of other applications. Not only can TC²AT enhance unit mission accomplishment and cost savings as a function of architectural efficiencies, it can also save considerable funding through continuous C5SIR architecture 'trade off' and gap mitigation studies.

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JD LOCK, Lieutenant Colonel, US Army (Retired), is a graduate and former Department of Systems Engineering assistant professor/director of Stochastic Modeling & Simulation of the United States Military Academy, West Point, who among other assignments, served with the 1st Armored and 82nd Airborne Divisions, as chief NATO/SFOR engineer of the Balkans during the Kosovo campaign, and as the senior director of a simulation exercise group (SEG) that executed high, mid & low-level intensity conflict scenarios. In addition, Lock served as an advisor for U.S. Army "Warfighter" exercises, the U.S. First Army's General Officer "Senior Mentor" Program, and as a DoDAF subject matter expert in support of the Army Science Board, along with extensive involvement with operational, system and technical C5ISR DoDAF related architectures in support of the US Army and Joint J6 Staff, to include the NIE, FCS, AAEF, MRAP and WIN-T. Lock currently supports the Army's AI Integration Center (AI2C).

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1. OVERVIEW – THE PROBLEM

The modeling community continually strives to design and create fully integrated applications in support of all levels of Network Centric based System-of-Systems architecture. Towards this end, the U.S. armed forces continue to grapple with building a doctrinally correct, automated, robust and all-inclusive methodology and database repository with gap analyses capability traceable back to the underlying operational requirements in support of Joint Capabilities Integration and Development System (JCIDS) developed Department of Defense Architecture Framework (DoDAF) products. Current DoDAF related processes have significant contrasts between current capabilities vs real needs, the following (Table 1) to highlight just a few:

Current Capability	Real Need
Time consuming	Automated; 'real time' updates
No centralized dBase that all views draw on	No naming convention errors
No/limited integration	All view Gap Analysis; 'What if?' assessment
Mission Thread focus	Singular fidelity to Enterprise level

Table 1

Why is this? To resolve any issue, one must first define the problem. A review of the community's discussion indicates two problems that clearly stand out:

1.1 Problem I – The WHY (Requirements): There currently exists within the DoDAF community no (or at best limited) automated, open architecture, model-based process or tool that meets DoD needs to create and analyze products based on Warfighter requirements.

1.2 Problem II – The WHAT: Current DoDAF focus is on Mission Threads, SV-10cs (aka Vignettes, Needs and Use Cases) which are comprised on sequenced OV-3s (operational information exchange requirements) and SV-6s (system information exchange requirements) which are only a minor subset snapshot of the overall C4ISR/C5ISR enterprise architecture. At a minimum, a true enterprise architecture must:

- Model a fully integrated and capable all view Traffic & Bandwidth profile.
- Provide gap analyses traceable back to operational impact(s).

Ultimately, a true Enterprise architecture will address and satisfy specified and implied requirements (Table 2):

Stated or Implied Requirements/Needs	
Authoritative Sources	OA - OV3 & OV6c
Standards	SA - SV6 & SV10c
Requirements based	TA - TV1
Open architecture	Gap Analysis w Traceability
Model Based process	Bandwidth & Traffic Profiles
Fully Integrated	Architecture Analyses
Automated	Acquisition Analyses
Enterprise to System Level	Testing & Evaluation
Cross Discipline	Life Cycle Management
Central dBase - Naming	SIMEx Support w GeoSpatial
Data Integration & Exchange	Tool Agnostic
Interoperability Matrices	**Agile Approach**

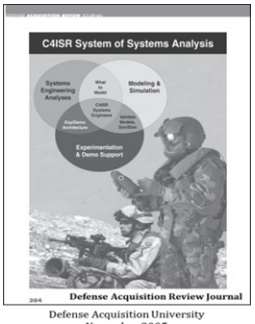
Table 2

1.3 The Real Problem – To date, there's been plenty of discussion as to the WHY and the WHAT but little, if any, as to the HOW. It's time to go beyond the pure talk of Why and What and execute the How as a function of defining a process that addresses the Why and What and builds a tool to execute that process. TC^{2}AT is the HOW.

2. OVERVIEW – A SOLUTION

To address this issue, Paratus Associates has created what we call The Complete C5ISR Architecture Tool (TC^{2}AT) that produces fully integrated architecture and analyses products that can additionally serve as inputs to other applications.

2.1 Background – TC^{2}AT is a peered and proven Methodology haven been published in an edition of the Defense Acquisition University's Defense Acquisition Review Journal (Graphic 1) and, though not credited, earlier versions of TC^{2}AT were used to develop operational and system DoDAF deliverables in support of major US Army initiatives to include:



Defense Acquisition University
November 2005

Graphic 1

- PM WIN-T: OV-3 Information Exchange Requirements (IER) for Milestone C.
- 3rd Infantry Division: OV-3 Information Exchange Requirements (IER) to create traffic and bandwidth profiles to exercise the Joint Node-Network (JNN) pre OIF deployment.
- 101st Airborne Division: OV-3 Information Exchange Requirements (IER) to create traffic and bandwidth profiles to exercise the Joint Node-Network (JNN) pre OIF deployment.
- CPOF – Command Post of the Future (MITRE): OV-3 Information Exchange Requirements (IER) to create traffic and bandwidth profiles to evaluate system performance during Battle Update Briefs (BUB).

2.2 Fundamental Modeling Approach – Though TC^{2}AT has an extensive number of capabilities, it was initially designed to support the development of DoDAF related products. And, while all of the Viewpoints are relevant to one degree or another, for the purpose of addressing and describing a fully integrated and automated architectural approach our focus, for discussion purposes, will be on the Operational (OV), System (SV) and Technical (TV) viewpoints. Furthermore, while the primary focus of this narrative discussion will be on US Army architecture, TC^{2}AT is applicable to all services (or agencies). As architecture modelers, it is import to ensure we are clear not only with the process but, also as importantly, term definitions. From our perspective, we see modeling (aka architecture) as a three-step process:

1. Defining and creating a full integrated Methodology/Process.
2. Defining and creating rules and standards, especially in regards to variable/parameter naming conventions.
3. Locate and facilitate with Subject Matter Experts (SME) data input.

In support of this three-step process, it's equally important to clearly define modeling/architecture terms as they relate to DoDAF related data:

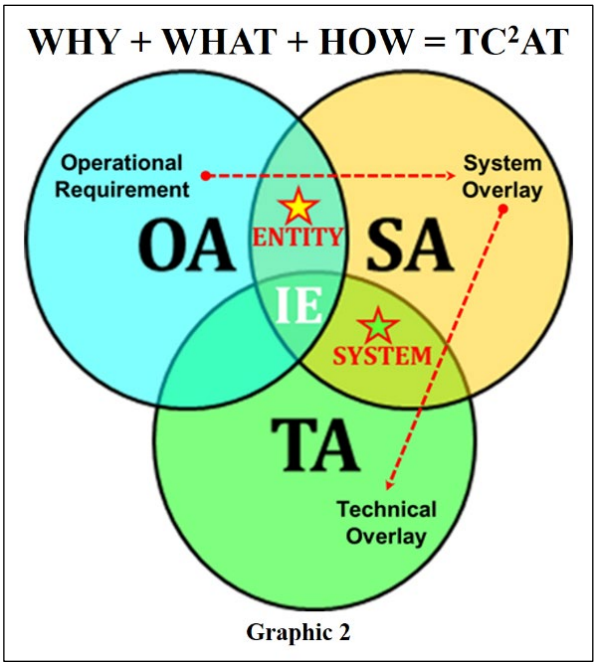
1. Operational Architecture is defined as:
   a. Entity = Platform = Individual = Force Structure = Node which represent Operational elements that have Systems that send/receive Information Exchanges in support of Tasks.
   b. Tasks which represent the Requirement/Need for the Information Exchange.
   c. ReMITs (Reports, Messages, ISR, Telemetry) which represent the type of Information Exchanged.
2. System Architecture is defined as:
   a. System represents the physical hardware (HW) that sends/receives ReMITs
   b. Note: In some instances, Platform & System may be the same (ie. Predator).
3. Technical Architecture:
   a. Technical = SW = Waveform = Protocols that represent, in broad terms, the System Operating System (OS).

2.3 Enterprise Approach – In order to properly create and analyze SVs and TVs, one needs doctrinally sound and data friendly OVs, in particular, OV-3 IERs that identify information exchanges between operational entities/nodes. In addition, it is imperative that for each IER, the relevant attributes of that exchange (media type, size, duration, etc.) be included. This will allow for the development and creation of a dynamic 'traffic/bandwidth profile' in support of network bandwidth analysis. Furthermore, these OV-3 related IERs and the matrix methodology used to create them can be used to facilitate the development of other OVs, to include the OV-6c Operational Event/Traces, better known as 'Mission Threads' (aka 'Vignettes' or 'User Cases') that describe operational activity sequence and timing.

3. TC^{2}AT – The Complete C5ISR Architecture Tool

3.1 Concept – TC^{2}AT is an automated, relatively real time, documented, Joint Capabilities Integration and Development System (JCIDS) process that is modular in construct with cascading links between variables/parameters that provides a fully integrated and detailed high-resolution approach for all legacy, current and future organizational structure DoDAF related Architectural Views. Designed with a robust methodology and all-inclusive database repository, TC^{2}AT has the capability to generate a fully integrated C5ISR (Command, Control, Communications, Computer, Intelligence, Surveillance, Reconnaissance) Network Centric based System-of-Systems architectural set of views that is not only fully Operational, System and Technically integrated (Graphic 2) and doctrinally correct but has also been analyzed for architecture gaps with traceability back to the underlying operational requirements that are impacted by those gaps. TC^{2}AT is agnostic in nature, meaning it is a methodology that can be applied to any service and/or organization (federal, state or commercial) with defined variables/parameters that can be linked. Initially designed to import data from Department of the Army (DA) Authoritative Sources, TC^{2}AT is 'CON'd' (Certificate of Networthiness) given it's built

on a series of algorithms and scripts in association with the DoD approved MS SQL Server relational data base. Future upgrades will also make TC²AT a Cloud based application.



Graphic 2

The overall concept of the TC²AT process is relatively simple and built from the Warfighter up. After all, if an architecture is not built to support the Warfighter, why is it being built in the first place? The battlefields of Today, Tomorrow and the Future will always involve certain fundamentals of warfighting processes that are focused on a Force Structure (FS) - Entities (Table of Organization & Equipment - TO&E/Modified TO&E - MTOE), that Force Structure performing Tasks (Army Universal Task List - AUTL/Universal Joint Task List - UJTL) and those Tasks producing or requiring information flow (sending/receiving) in order to be accomplished. Every element/entity within a Force Structure performs a series of Tasks that requires either the sending (producer) or receiving (consumer) of C5ISR related Information Exchanges (IEs in the form of Reports, Messages, ISR, or Telemetry). It is the relationship between these three variables—Force Structure, Task, and IE—that provides the foundation to automate and generate doctrinally correct operational IERs that are then built upon for System and Technical views.

3.2 Methodology – The TC²AT methodology has two components, the 'Science of War' that is based on objective doctrine and the 'Art of War' that is based on subjective Subject Matter Experts (SME). The Science of War are derived from the relevant Force Structures and the operational concepts associated with that force structure. Each service has its own documentation. For example, US Army force structure can be obtained from the most current Department of Defense (DoD), Department of the Army (DA) and Training and Doctrine Command (TRADOC) Field Manuals—such as Tables of Organization and Equipment (TOEs & Modified – MTOES) that can be found in the US Army Force Management Support Agency (USAFMSA), Doctrine for the Armed Forces of the United States (Joint Publication 1), FM 3-0, Operations, FM 5-0 (formerly FM 101-5 Staff Organization and Operations, Army Planning and Orders Production, as well as Future Force transformation documents, to include Operational and Organizational (O&O) and Operational Requirements Documents (ORD). Research and analysis of these manuals and documents provide the relevant information required to determine and define the Force Structure, Tasks and IEs necessary to create an TC²AT data set required to support C5ISR modeling and simulation. (Note - corresponding US Air Force, US Navy and US Marine Corps documentation similar to Army documentation are also available. Furthermore, in many instances, in the absence of any such documentation, all services have cross references and ties through Joint Service documentation. In the end, there is one simple and key factor to keep in mind regarding architecture which, essentially, can be referenced as 'Modeling 101' – without the use of authoritative sources which establish the underlying naming conventions and definitions, attempts to create fully integrated DoDAF related deliverables will fail. For the sake of our TC²AT proof of concept demonstration, we availed ourselves of the following documentation to serve as inputs for our data base:

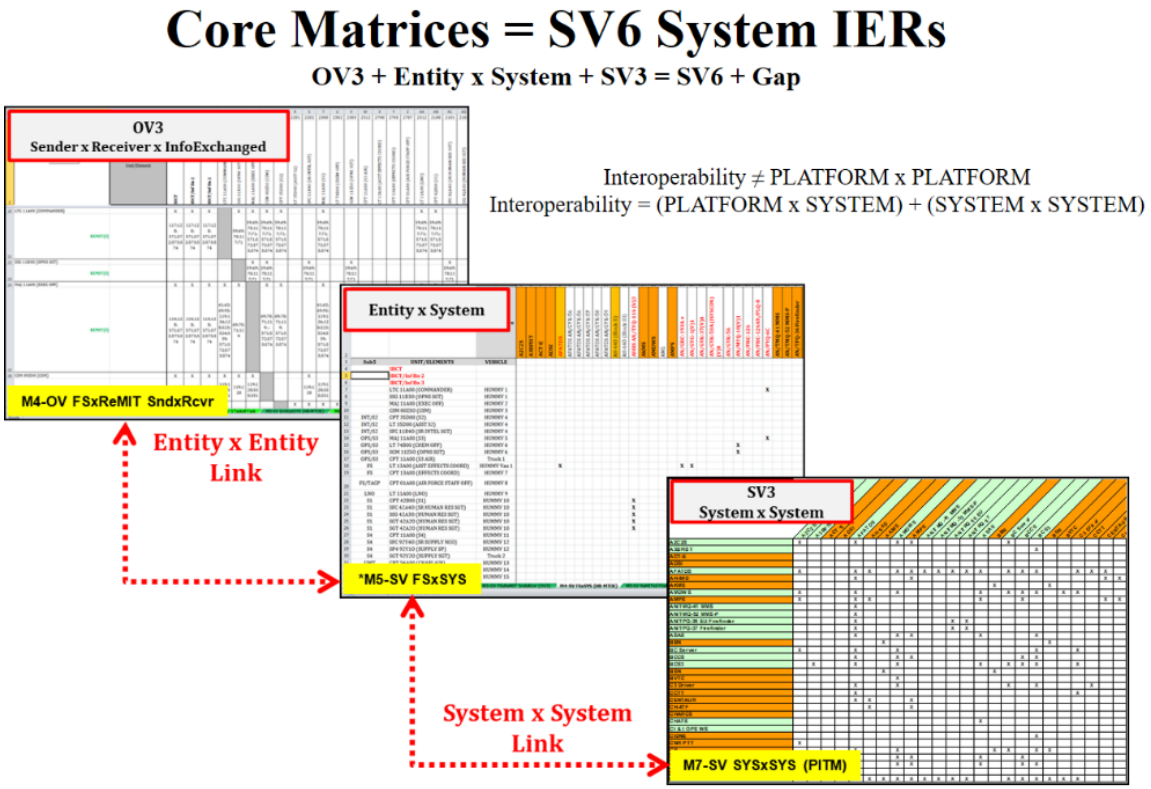
- **Force Structure – Unit/Entity & Systems:** Unit specific MTOEs provided by the U.S. Army Force Management Support Agency (USAFMSA) which identifies which specific Systems are assigned to each individual operational entity thus providing a direct link between Operational and System architectures.
- **Army Universal, US Air Force & Universal Joint Task Lists (AUTLs, AFTLs & UJTLs) –** FM 7-15, Army Universal Task List, CJ CSM 3500.04C, Universal Joint Task List.
- **ReMITs (Reports, Messages, ISR, Telemetry) – Information Exchanged –** FM 6-99.2 (formerly FM 101-5-2) U.S. Army Report and Message Formats, 2004 US Message Text Formats (USMTF) and 2004 MIL-STD and

Joint Variable Message Format (JVMF) Baselines (Note – USMTF, MIL-STD and JVMF messages are common to all services).

3.3 Core Components – While there are a number of linked matrices associated with the TC^{2}AT process, three in particular serve as the fundamental core process, the heart, of DoDAF related architecture products and they are the following:

1. Sender x Receiver x Information Exchanged (ReMIT) – in essence, the OV-3 IER product
2. Entity x System – in the Army referenced as TOE/MTOE; Systems assigned to Platforms
3. System x System Interoperability – an SV-3 depicting which Systems can interface with each other

The TC^{2}AT methodology takes and integrates these three matrices into a central DoDAF product (Graphic 3) – an SV-6, System IERs.



Graphic 3

3.4 TC^{2}AT'S SQL-Server Algorithm – Currently, the TC^{2}AT methodology involves the linkage of a series of cascading matrices to create a fully integrated Operational, System and Technical architecture with dynamic traffic/bandwidth profile and visualization capability (Table 3). One invaluable aspect of using linked matrices and making TC^{2}AT a modular construct is that additional matrices can easily be added by simply linking one of the new matrices' variables with a variable already included within the TC^{2}AT database.

VIEW	MATRIX	FUNCTION	REMARKS
OV	**M1**	**ENTITY x TASK**	**Entity =Ind or Platform that xchange Info**
OV	M2	TASK x ReMIT	ReMIT = Reports, Messages, ISR, Telemetry
OV	M3	TASK x TASK	Task = AUTL (Army Universal Task List)
OV	M3x	TASK x TASK	Sends, Receives or Both
OV	M3a	AUTL x UJTL	Universal Joint Task List
OV	M3b	AUTL x MCEC	Mission Command Essential Capabilities
OV	**M4**	**ENTITY x ReMIT**	**OV3 - Sender x Receiver**
SV	**M5**	**ENTITY x SYS**	**Force Structure - *Mod Table Org & Equip (MTOE)**
SV	M6	SYS x ReMIT	Mode - Voice, Data, Image, Stream or All
SV	**M7**	**SYS x SYS**	**SV3 - Prgm Interop Traceability Matrix (PITM)**
SV	M7a	SYS x SYS - USMTF	U.S. Message Text Format
SV	M7b	SYS x SYS - VMF	Variable Message Format
SV	M7c	SYS x SYS - XML	Extensible Markup Language
TV	M8	SYS x DISR	Program Interoperability Standards Matrix (PISM)
TV	M9	ReMIT x DISR	DoD Info Tech Standards & Profile Registry
TV	M10	DISR x DISR	

Table 3

The data represented in each matrix is normalized and stored as tables in a database. A "View" is created for each level of information exchange requirements we wish to generate (Operational, System, and Technical), and the results of each query are stored in separate tables. Currently, transcribing the matrices into the database tables is largely a manual process. As we progress, we will develop a user interface which would allow a subject matter expert to interact with the matrix relationships in an intuitive manner, and store that data directly into the database tables. The challenge lies in representing a series of complex relationships as an intuitive point and click interface.

3.5 Creation of an IER 'Superset' For Operational Needs/Requirements Analysis – While integrated, these singular IERs do not constitute the full architectural picture, for with any given series of FS-Unity/Entity, IE, Task and System relationships, there may be a series of combinations by which that specific information can be exchanged along with a series of operational needs (Tasks/requirements) that must be met. Thus, to ensure a fully inclusive integrated architecture, it is imperative that all combinations of relationships be generated. As a result of significant past research, each of the 570 noted ReMITs have been assigned Formats and Modes. There are four specific forms an information exchange can take: free form, USMTF, VMF and "Undocumented" exchanges that have yet to be categorized. There is another degree of increased fidelity that can be gained as a function of the IE format parameters in that 'one size does not fit all.' Citing the *Commander's Guidance* IE, once again, as an example, a commander may wish to call a subordinate commander by radio, send a text email, draw a graphic and send it as an image, or conduct a VTC. A multitude of options must be captured which allows for multiple formats for each specific IE being generated. Based on these formats, modes and assigned systems, the TC^{2}AT algorithm generates all combinations of IERs possible for each associated FS-Unity/Entity in support of all identified tasks that may be executed on the field of battle. Thus, in the end, TC^{2}AT generates the fully integrated IER Superset associated with the matrixed tables (Graphic 3). As to why we would want to do this, Graphic 4 is a case in point.

An *Infantry Battalion Commander* issues a *Fragmentary Order* (FRAGO) to one of his Infantry *Company Commanders*. This FRAGO can be transmitted in four different *modes* (Voice, Data, Imagery, VidStream), three different *formats* ('Free Form,' USMTF, VMF), over two *systems* in support of 98 different *AUTLs*. All told, 2,352 'Super Set' IERs are generated. Ultimately, this IER SuperSet serves as an integral tool to (1) identify operational impacts in the event of operational, system or technical gaps and (2) identify system combinations that can execute information exchanges.

3.6 Integrated SV-10c/Vignette Development – A fully integrated vignette (Mission Thread/User Case) is another byproduct deliverable of the TC2AT process given TC^{2}AT's Superset generation of all possible SV-6 system IERs permutations. The IERs for such vignettes can be created by a filtering process that selectively sorts the 'Super Set' of SV-6s as a function of Sender, Receiver, ReMIT – Message Type (IE), Task – UJTL, AUTL, AFTL and/or System. Once these associated IERs are filtered, an SME can then take and order them in the proper time sequence (or verify) to complete the vignette.

SV6 + Gap Analysis + Operational Requirements Traceability

MODE	FORMAT	SYSTEM(S)	AUTLs
Voice	FM 6-99.2 (FM 101-5-2)	SINCGARS	-----
Data	USMTF	FBCB2	-----
Imagery	VMF		-----
VidStream			-----
4	3	2	98

2,352 IERs

- Only Integrated SV6s created
- Disconnects between Operational & System Architectures ID'd as Gaps
- Created SV-6 of all possible events

Graphic 4

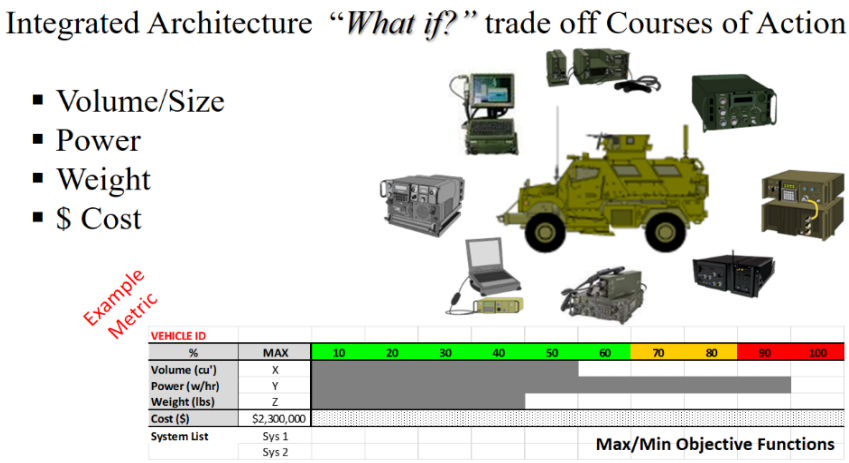
3.7 'Real Time' Product Updates, Gap Mitigation/ Elimination & 'What If?' Analyses – A key strength of the TC^{2}AT process is the fact that should any of those matrix relationships change as a function of task organization, procurement or, simply, as a function of gap mitigation or 'what if?' analyses, *all one needs to do is change the relationships within the matrices*—or, in the case of added systems, add the new systems to the 'end' of the list—and *a new, complete set of OV, SV and TV products will be automatically produced, complete with gap analysis output*. To do so, one need only make changes to any of the matrices, primarily those of Graphic 3 – add/delete 'X's, add and link additional parameters/variables – then generate a new set of DoDAF related documents along with a corresponding set of associated 'gaps'…if any as a function of the change.

3.8 Creation of an Integrated & Dynamic Operational Traffic /Bandwidth Profile – The generation of IERs is essential to ensure that all doctrinal commander's operational needs/ requirements have been identified but once that has been accomplished, IERs no longer have any real relevancy and must thus be 'converted' into a singular 'IE'—information exchange—to create an operational traffic/bandwidth profile for true System and Network analysis. As defined, an IER identifies the information exchanges that must be executed to meet the commander's needs/requirements. That does not, however, mean that an IER is the actual information exchanged. As noted in the previous example of Graphic 4, *while 2,352 IERs were generated by the TC^{2}AT algorithm to ensure all operational needs/requirements were met (with traceability back to the operational requirements impacted by gaps) and to identify all system combinations for information exchanges, only one FRAGO would actually be transmitted and received, not 2,352.*

Thus, from an operational traffic/bandwidth profile perspective, 2,351 of the SuperSet IERs are 'redundant.' These redundancies can easily be eliminated by 'bundling' the IERs by Sender/Receiver/IE/Mode/Format/ System/AUTL and 'collapsing' it into the single 'Information Exchanged' (IE) element where a single Sender x Receiver exchange of a specific IE made in a specific Mode, in a specific Format over a specific System will serve to meet multiple Task needs/requirements. In addition to IE Mode and Format parameters, all 570 IEs have also been assigned, based on research, Data Rate and Property parameters. Thus, for each IE format, there is an associated data rate as it would apply to an infantry battalion (used by TC^{2}AT as the 'baseline' unit): Frequency of Occurrence, Speed of Service, Data Size, Data Rate/Duration. Note: It is emphasized that, at this point of development, *the Traffic/Bandwidth Profile is 'Operational' and not 'Network' in design*; ie. the current IER parameters will assign size, duration and frequency values associated with specific operational products—OPORDs, images, VTCs—but will not include additional system or network 'add ons' such as system synchronization, security/encryption, tunneling, etc.

3.9 FS/Platform x Subnet x Waveform – An additional architectural modeling feature that can be added is the inclusion of grouping the Force Structure by Subnets, along with assigning waveform functions to those Subnets.

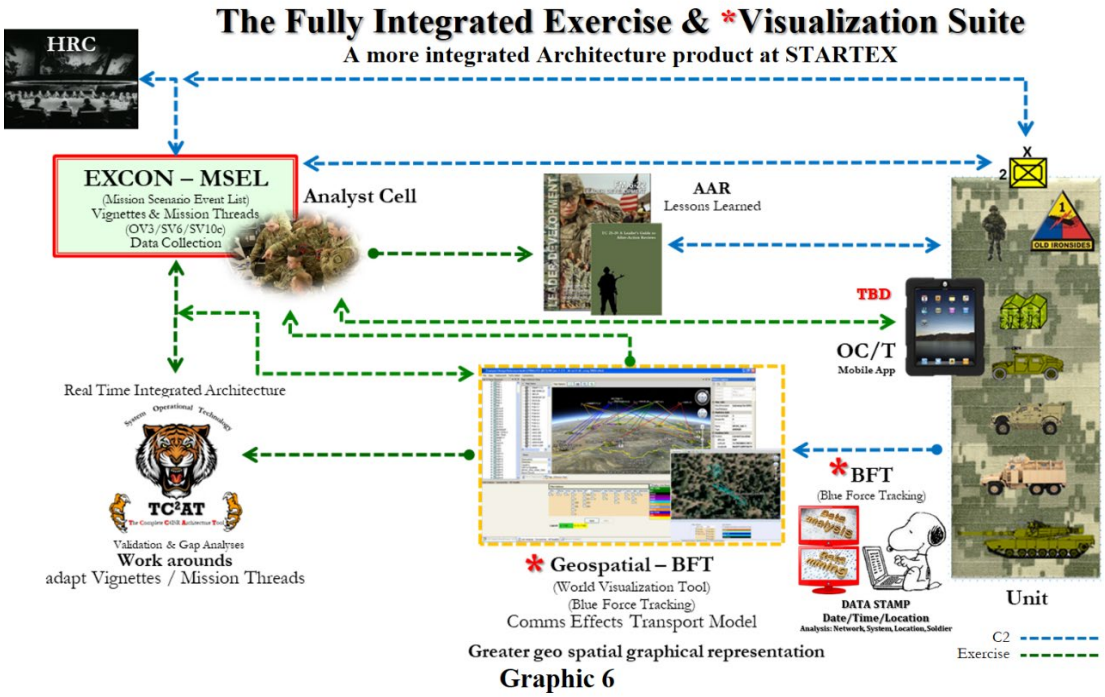
3.10 Platform/Vehicle Configuration – Architectures not only have an impact on a unit's ability to meet its mission requirements but, also, on organizational budgets and vehicle capabilities. Provide an underlying system dbase of antenna, size, power, LIN (Line Identification Number), $cost, etc, TC^{2}AT can execute a 'Trade off Study' to evaluate optimization of various vehicle configurations (Graphic 5).



Graphic 5

4. Mission Analyses Suite (MAS):

While TC^{2}AT is a stand-alone tool, it is intended to eventually be the core component of a 'Mission Analyses Suit' that can be linked to a 'Google Earth' type of geo-spatial visualization tool that would allow for architectural entities and nodes to be accurately displayed in a specific geo-spatial terrain scenario for additional connectivity, network, wave propagation and 'what if' analyses. By assigning coordinates to the TC^{2}AT architecture entities, one can conduct transport communication infrastructure analyses at any level, be it singular entity (Soldier, platform) or node consolidation (CP—command post, TOC—tactical operations center, HHQ—higher headquarters).



Graphic 6

In addition, such an architecture suite would also prove to be of exceptional value to the Simulation Exercise (SIMEX) / Synthetic Environment (SE) and Testing & Evaluation (T&E) communities. Central to SIMEX/SEs and T&Es are Mission Scenario Event Lists (MSEL) that essentially serve as 'blueprints' for how they are to be executed and evaluated. Such MSELs can be designed with TC^{2}AT SV-6s which, if linked to a visualization tool and Blue Force Tracking (BFT), would provide for an exceptionally powerful execution, tracking and evaluation and analyses tool (Graphic 6).

5. Summary

In the end, TC^{2}AT is a 'win-win' for both the Warfighter and architectural/system/network engineer. Whether Cloud based or a laptop application (or both), the tool can be fielded to the Warfighter for network Course of Action (COA) analyses, Battle Damage Assessment (BDA) and unit assimilation while the engineer can obtain from the Warfighter the SME expertise of timely, direct data entry to perform more relevant training and testing analyses in support of the Warfighter.

TC^{2}AT addresses not only customer architectural analysis needs but also has operational warfighter potential that is inclusive of and can meet a myriad of requirements. Previously, per Table 2, it was noted that the DoDAF and architecture community, in general, have laid out a number of specified and implied requirements (the WHAT and WHY) that need to be met.

The TC^{2}AT initiative (the HOW) currently meets most of these requirements and can eventually meet all. Add to that the potential to include Artificial Intelligence (AI) enhancements and applications in time, is there another DoDAF/architecture tool that can claim the same?