The Fully Integrated Architectural & Visualization Suite

IAC: Integrated Architecture Capability Tool

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ABSTRACT: *In support of its effort to design and create a fully integrated C4ISR (Command, Control, Communications, Computer, Intelligence, Surveillance, Reconnaissance) Network Centric based System-of-Systems architecture, the Army continues to grapple with creating a doctrinally correct, automated, robust and all inclusive database repository and methodology with 'gap analyses' capability traceable back to the underlying operational requirements of Joint Capabilities Integration and Development System (JCIDS) developed Department of Defense Architecture Framework (DoDAF) products. Given the lack of fully integrated products or applications to provide the doctrinally correct level of resolution necessary to design to most required standards, IAC—Integrated Architecture Capability—is offered as a relative solution. IAC is an automated, 'real time,' documented, JCIDS process that is modular in construct with 'cascading' links that provides a fully integrated and detailed high resolution approach for all legacy, current and future organizational structure DoDAF related Architectural Views. IAC is 'agnostic' in nature, meaning it is a methodology that can be applied to any service and/or organization with defined variables that can be linked. Designed to import data from DA Authoritative Sources, IAC 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. Furthermore, aside from its analytical, traffic profile/bandwidth and 'gap analysis' capabilities, IAC can be provided to the Warfighter for network Course of Action (COA) analysis and BDA, unit assimilation and unit SOP verification, as well as interface with a TRADOC AIMD supported visualization tool (CAVT) that will 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. IAC can not only provide exceptional cost savings as a function of reduced architectural resources, enhanced turnaround times and product leveraging across the architecture community of interest but it can also save considerable funding through the creation of a more streamlined and accurate systems acquisition process in support of Testing & Evaluation (T&E), Simulation Exercises (SIMEX) and optimized Vehicle-System configurations.*

Note: while this paper's focus will be on US Army Brigade Combat Team (BCT) related force structures, the IAC methodology is applicable to any service and/or organization with defined variables and associations.

OVERVIEW

IAC—Integrated Architecture Capability—is an automated, '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 Department of Defense Architecture Framework (DoDAF) related Architectural Views.

Designed with a robust methodology and all inclusive database repository, IAC has the capability to generate a fully integrated C4ISR (Command, Control, Communications, Computer, Intelligence, Surveillance, Reconnaissance) Network Centric based System-of-Systems architectural set of views that is not only doctrinally correct but has also been analyzed for architecture gaps with traceability back to the underlying operational requirements that are impacted by those gaps.

IAC is 'agnostic' in nature, meaning it is a methodology that can be applied to any service and/or organization with defined variables/parameters that can be linked. Initially designed to import data from Department of the Army (DA) Authoritative Sources, IAC 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.

Furthermore, aside from its analytical, traffic profile/bandwidth and gap analysis capabilities, IAC can be provided to the Warfighter for network Course of Action (COA) analysis and Battle Damage Assessment (BDA), unit assimilation and unit SOP verification, as well as interface (*future development*) with a US Army TRADOC AIMD supported Capability Architecture Development and Integration Environment (CADIE) Architecture Visualization Tool (CAVT) that will 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.

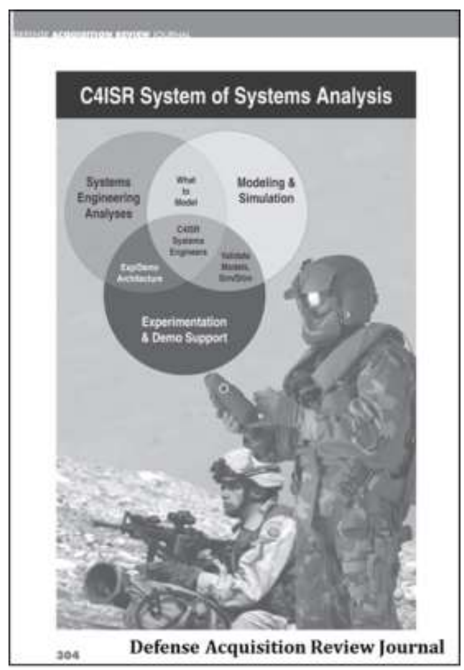
IAC can not only provide exceptional cost savings as a function of reduced architectural resources, enhanced turnaround times and product leveraging across the architecture community of interest, but it can also save considerable funding through the creation of a more streamlined and accurate systems acquisition process in support of Testing & Evaluation (T&E), Simulation Exercises (SIMEX) and optimized Vehicle-System configurations.

I. BACKGROUND

IAC is a proven and 'peered' Methodology (Figure 1). Though not credited, earlier versions of IAC (called 'TCAT' at the time) were used to develop operational and system Information Exchange Requirements (IERs) in support of PM WIN-T Milestone C, as well as traffic and bandwidth profiles for the 3rd Infantry and 101st Airborne Divisions' OIF deployments and CPOF evaluation.

Though IAC has an extensive number of capabilities, it was initially designed to support the development of DoDAF related products. Table 1 identifies the various Viewpoints associated with DODAF.

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.



Defense Acquisition University
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Figure 1

Furthermore, while the primary focus of this narrative discussion will be on US Army architecture, IAC is applicable to all services.

Viewpoint	Definition
All (AV)	An overview of the architectural effort including such things as the scope, context, rules, constraints, assumptions, and the derived vocabulary that pertains to the Architectural Description.
Capability (CV)	Describes capability taxonomy and capability evolution.
Data and Information	Provides a means of portraying the operational and business information requirements and rules that are managed within and used as constraints on the organizations business activities.
Operational (OV)	Description of the tasks and activities, operational elements, and information flows required to accomplish or support a military operation (information flows, information exchange requirements—IERs).
Project	Describes how programs, projects, portfolios, or initiatives deliver capabilities, the organizations contributing to them, and dependencies between them.
Services	Describes services and their interconnections providing or supporting, DoD functions. DoD functions include both warfighting and business functions.
Standards	Describes the set of rules governing the arrangement, interaction, and interdependence of parts or elements of the Architectural Description.
Systems (SV)	Description, including graphics, of systems and interconnections providing for, or supporting, warfighting functions (associates physical resources and their performance attributes to the operational view—platforms, nodes, speed of service, maintainability, availability, priority, security classification, etc).
Technical (TV)	Minimal set of rules governing the arrangement, interaction, and interdependence of system parts or elements, whose purpose is to ensure that a conformant system satisfies a specified set of requirements.

Table 1

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.

Unfortunately, for the most part, current Operational Views — and the generation of IERs in particular — lack a standardized methodology or doctrinal adherence to Legacy, Current or Future Force tactics, techniques and procedures (TTP). In addition, the IERs are never generated in the numbers required to truly replicate the exchanges of a complete Brigade Combat Team (BCT) or any other actual force structure/organization. Furthermore, if these products exist, they are generally bereft in detail and resolution to the point that they are of minimal value for simulation input thus forcing projects and programs to waste critical time and resources creating their own non-standardized OV-3's, OV-6c's, SV-6's and SV-10c's in order to perform System and Technical analysis.

II. CONCEPT

The overall concept of the IAC 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 C4ISR 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.

III. METHODOLOGY

The IAC methodology has two components, the 'Science of War' that is based on objective doctrine and the 'Art of War' that is based on Subject Matter Experts (SME).

The Science of War are derived from the operational concepts and relevant Force Structures that are obtained from the most current Department of Defense (DoD), Department of the Army (DA) and Training and Doctrine Command (TRADOC) Field Manuals—such as TOEs & MTOES, 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 IAC data set required to support C4ISR modeling and simulation.

- **Force Structure—Unit/Entity:** Current Force BCT force structures are readily obtained from unit specific MTOEs provided by the U.S. Army Force Management Support Agency (USAFMSA). And, while MTOEs and Future Force structures will continue to change and evolve, a major strength of the IAC methodology is that the model is designed to rapidly and easily integrate and update those changes. (see Paragraph V).

- **Army Universal & Universal Joint Task Lists—AUTLs & UJTLs:** The most current version of FM 7-15, Army Universal Task List, Change 10, dated 29 June 2012. TRADOC/AIMD has developed mapping of the six Warfighter Functions (Table 2) to the AUTL. In all, there are a total of 237 AUTLs (as defined down to the 'third level') that encompass every task that may be required to be accomplished in order to ensure mission success.

Army Universal Task List (AUTL) Warfighting Function			
ART1.0	Movement & Maneuver	ART4.0	Sustainment
ART2.0	Intelligence	ART5.0	Command & Control
ART3.0	Fires	ART6.0	Protection

Table 2

Regarding the Joint Tasks (UJTL), they are obtained from CJ CSM 3500.04C, Universal Joint Task List. In all, there are a total of 627 UJTLs categorized into seven functional areas (Table 3) that can serve as a link within IAC for all DoD/Joint services.

Universal Joint Task List (UJTL) Battlefield Functional Areas	
Deploy & Conduct Maneuver	Develop Intelligence
Exercise Command & Control	Protect the Force
Perform Logistics & CSS	Employ Firepower
Operate in a CBRNE Environment	

Table 3

Additional TRADOC architectural requirements seek to integrate Mission Command Essential Capabilities (MCEC) in DoDAF related documents. Based on the acquisition and integration of the following AIMD product, 'MCEC White Paper 31July Version 1.85,' IAC will be able to provide MCEC relationships within its DoDAF related outputs.

- **IEs—Reports, Messages, ISR, Telemetry:** IERs need to reflect all forms of information exchanges that take place. Not just current but also future and those not, necessarily, captured, yet, in doctrine and/or official documents. Towards that end and for the purpose of IAC, an effort was undertaken to identify a comprehensive list of reports, messages, ISR products and telemetry—both present and future.

The base documents that served as the foundation were 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. Additional research and analysis of Future Force doctrine and systems revealed other ISR platform and system telemetry information flows. Such additions are inclusive of robotic and unmanned air and ground vehicle command and control (C2), automated maintenance and supply status, combat identification and location, as well as bio med readouts, to name just a few.

All told, a total of 570 reports, messages, ISR, and telemetry information exchanges within thirteen functional areas have been identified and incorporated into IAC (Table 4).

NOTE: While these identified IEs are 'dated,' they serve as a good starting point until an updated list of IEs can be provided.

	Functional Area	# Remits		Functional Area	# Remits
1	Air Defense	18	8	Fire Support	116
2	Airspace C2	40	9	Intelligence	99
3	C2 Battle Command	104	10	Medical	23
4	CBNR	46	11	Service Support	62
5	Communications	23	12	Training	7
6	Electronic Warfare	16	13	Interoperability	TBD
7	Engineering (M/CM/S)	16			

Table 4

IV. IAC'S SQL-SERVER ALGORITHM

Currently, the IAC methodology involves a series of 'cascading matrices' to create a fully integrated Operational, System and Technical architecture with dynamic traffic/bandwidth profile and visualization capability (Table 5).

Note: given IAC's modular construct, additional matrices can easily be added by simply linking one of the new matrices' variables with a variable already included within the IAC database.

IAC Matrices Linkage

MATRIX	VIEW	RELATIONSHIP	Entity	AUTL	ReMIT	System	Waveform	SubNet	Protocol	Task/ Capability	Traffic/ Bandwidth	Coord
M1	OV	Entity x Task	X	X								
M2	OV	Task x IE		X	X							
M3	OV	Send Task x Rcvr Task		I (TxT)								
M4	OV	Send x Rcvr x IE (OV3)	X (SxR)		X							
M5	SV	Entity x Sys (MTOE/BOI)	X			**X**						
M6	SV	IE x Sys			X	X						
M7	SV	Sys x Sys (SV3)				I (SxS)						
M8	TV	Sys x DISR (TV1)				X			X			
M9	TV	IE x DISR			X				X			
M10	TV	DISR x DISR							I (PxP)			
M11	NWV	Network/Waveform	X				X	X				
M12	Format	IE			X							
M13	Profile	Dynamic IE M&S			X						X	
M14	Task Links	MCEC, UJTL, JCA		X						X		
M15	Long/Lat	Location/CAVT Interface	X									X

Table 5

Aside from the web based server application, the software prerequisites to run the IAC tool are as follows:

1. Java JRE 1.7
2. MS SQL Server 2008 R2 (or greater)
3. MS Excel 2010 (or greater) - Not required for execution but needed for opening generated files

SQL Server 2008 is used to manage the relationships represented by these matrices. The data represented in each matrix is normalized and stored as tables in a database. An SQL "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.

The SQL Query used to generate the View expresses the combination of all the matrix relationships required to generate the information exchange requirements. Some performance tweaks still need to be made to the database in order to optimize queries for large datasets.

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.

V. 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' (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 IEs (Paragraph III Table 4) have been assigned Formats and Modes as noted in Table 6.

FORMAT	MODE
Field Manual (FM)	Voice
USMTF	Data
VMF	Imagery
'X' - Undocumented	Streaming Video (1x)

1x: one-way transmission
Note: VTC would be 'Vidstream' going both ways

Table 6

As noted in Table 7, 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 one other aspect of IE Formats that must also be considered and that is 'Collaborative Planning'—implying a Sender to Receiver back and forth exchange of information. For analysis purposes, IAC models four variations of Collaboration (Table 7).

Collaborative Variations		
1	Collaborative Meeting 1	Colab Voice, Shared Desktop, No VTC
2	Collaborative Meeting 2	VoIP Voice, Shared Desktop, No VTC
3	Collaborative Meeting 3	Colab Voice, VTC
4	Collaborative Meeting 4	Chat

Table 7

The Properties (Administrative Data) such as Perishability, Criticality, Security Classification, and Precedence allow specific IEs to be 'assigned' to specific systems for transmission, such as 'Trojan Spirit' for Top Secret transmissions.

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 IAC 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, IAC generates the fully integrated IER Superset associated with the matrixed tables.

As to why we would want to do this, Figure 2 is a case in point.

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

Figure 2

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.

VI. INTEGRATED SV-10C/VIGNETTE DEVELOPMENT

A fully integrated vignette (Mission Thread/User Case) is another byproduct deliverable of the IAC process given IAC's Superset generation of all possible SV-6 system IERs permutations.

The IERs for such vignettes can be created by a filtering process (Table 8) that selectively sorts information exchanges as a function of:

1. Sender
2. Receiver
3. Message Type (IE)
4. Task/AUTL

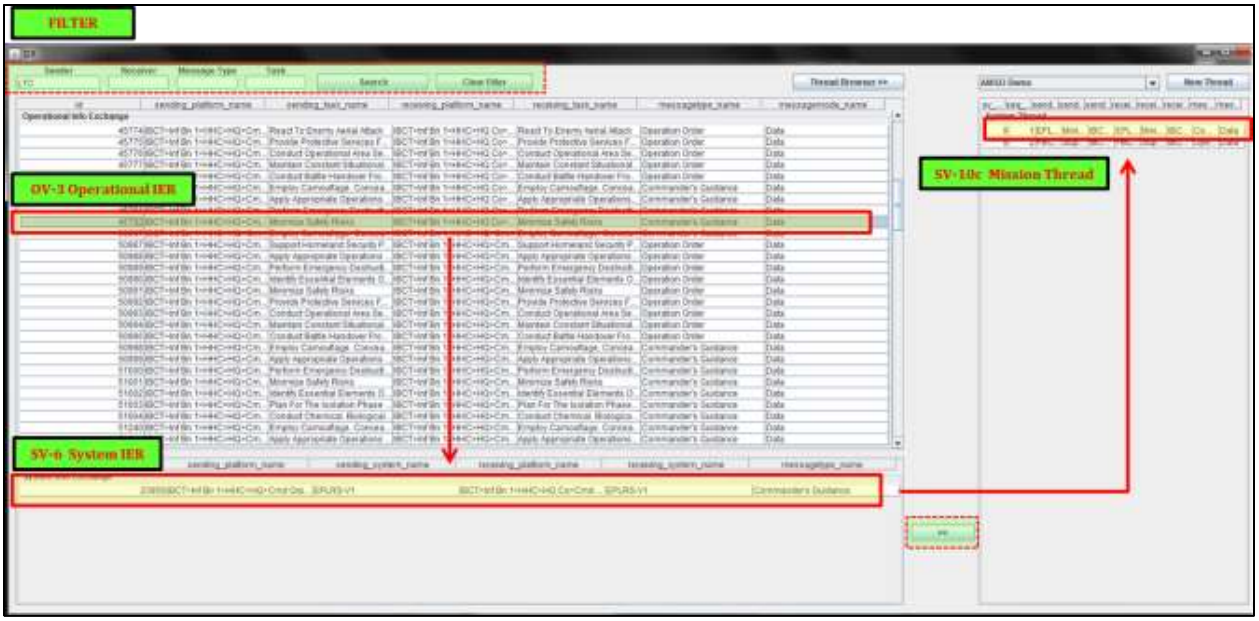

Table 8

Once these associated IERs are filtered, an SME can then take and order them in the proper sequence (or verify) to complete the vignette.

VII. 'REAL TIME' PRODUCT UPDATES, GAP MITIGATION/ ELIMINATION & 'WHAT IF?' ANALYSES

A key strength of the IAC 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*.

'MTOE' Tab

Row	SubS	UNIT/ELEMENTS	VEHICLE (Nomenclature)	A2C2S	A3BFIST	ACT-E	ADSI	AFATDS	AFATDS AN/GYK-56	AFATDS AN/GYK-56	AFATDS AN/GYK-57	AFATDS AN/GYK-58	AFATDS AN/GYK-59	AH-64D (Block II)	AH-64D (Block III)	AHRS AN/TYQ-116 (V)3	AKMS	AMDWS	AMG	AMPS	AN/GRC-193A +	AN/GYG-1(V)1	AN/GYK-37(V)4	AN/GYK-50A (ISYSCON)(V)4	AN/GYK-56	AN/MYQ-10(V)1	AN/PRC-126	AN/PRC-126AN/PLQ-8	AN/PYQ-6C	AN/TMQ-41 MMS	AN/TMQ-52 MMS-P	AN/TPQ-36 Firefinder
4		IBCT																														
5		IBCT/Inf Bn 2																														
6		IBCT/Inf Bn 3																														
7		LTC 11A00 (COMMANDER)	HUMMV 1																													
8		SSG 11B3O (OPNS SGT)	HUMMV 1																													
9		MAJ 11A00 (EXEC OFF)	HUMMV 2																													
10		CSM 00Z5O (CSM)	HUMMV 3																													
11	INT/S2	CPT 35D00 (S2)	HUMMV 4																													
12	INT/S2	LT 35D00 (ASST S2)	HUMMV 4																													
13	INT/S2	SFC 11B4O (SR INTEL SGT)	HUMMV 4																													
14	OPS/S3	MAJ 11A00 (S3)	HUMMV 5																									x			
15	OPS/S3	LT 74B00 (CHEM OFF)	HUMMV 6																						x						
16	OPS/S3	SGM 11Z5O (OPNS SGT)	HUMMV 6																						x						
17	OPS/S3	CPT 11A00 (S3 AIR)	Truck 1																													
18	FS	LT 13A00 (ASST EFFECTS COORD)	HUMMV Van 1					x													x	x										
19	FS	CPT 13A00 (EFFECTS COORD)	HUMMV 7																													
20	FS/TACP	CPT 01A00 (AIR FORCE STAFF OFF)	HUMMV 8																					x							
21	LNO	LT 11A00 (LNO)	HUMMV 9																													
22	S1	CPT 42B00 (S1)	HUMMV 10													x																
23	S1	SFC 42A4O (SR HUMAN RES SGT)	HUMMV 10													x																
24	S1	SSG 42A3O (HUMAN RES SGT)	HUMMV 10													x																
25	S1	SGT 42A2O (HUMAN RES SGT)	HUMMV 10													x																
26	S1	SGT 42A2O (HUMAN RES SGT)	HUMMV 10													x																
27	S4	CPT 11A00 (S4)	HUMMV 11																													
28	S4	SFC 92Y4O (SR SUPPLY NCO)	HUMMV 12																						x			x			
29	S4	SP4 92Y1O (SUPPLY SP)	HUMMV 12																													
30	S4	SGT 92Y2O (SUPPLY SGT)	Truck 2																													
31	UMT	CPT 56A00 (CHAPLAIN)	HUMMV 13																													
32	C4 OPS/S6	CPT 25A00 (S6)	HUMMV 14																													
33	C4 OPS/S6	SFC 25U4O (SR SGNL SPT NCO)	HUMMV 15																													

Table 9

Table 9 would be one such example where a change in the MTOE exchanges two systems assigned to a Battalion Commander…where one is 'deleted' by removing the assigned 'X' and another added by placing an 'X' in the corresponding cell. Once the updated matrix is imported into IAC a 'push of a button' will generate a new set of DoDAF related documents along with a corresponding set of associated 'gaps'…if any as a function of the change.

VIII. DOCTRINE X UNIT SOP EVALUATION

One beneficial byproduct associated with having both operational doctrinal and unit data in a matrix format is the ability to merge such matrices in a manner that creates the ability to contrast doctrinal operational concepts with a unit's actual Standing Operating Procedures (SOP) or 'business practices.'

Operational doctrine is defined by both the Unit/Force Structure x Task (AULT or UJTL) and Task x Information Exchange (IE or ReMIT) matrices while the Unit x IE/ReMIT matrix defines the operational unit's SOP/Business Practices. Both the doctrinal matrices can be joined through the Task parameter, which is common to both. Such a merge of the two matrices result in a Unit x IE/ReMIT product…which can then be contrasted with the unit SOP Unit x IE/ReMIT matrix (Figure 3). Where the two matrices do not match defines a 'gap' between proposed doctrine and a unit's operational SOP.

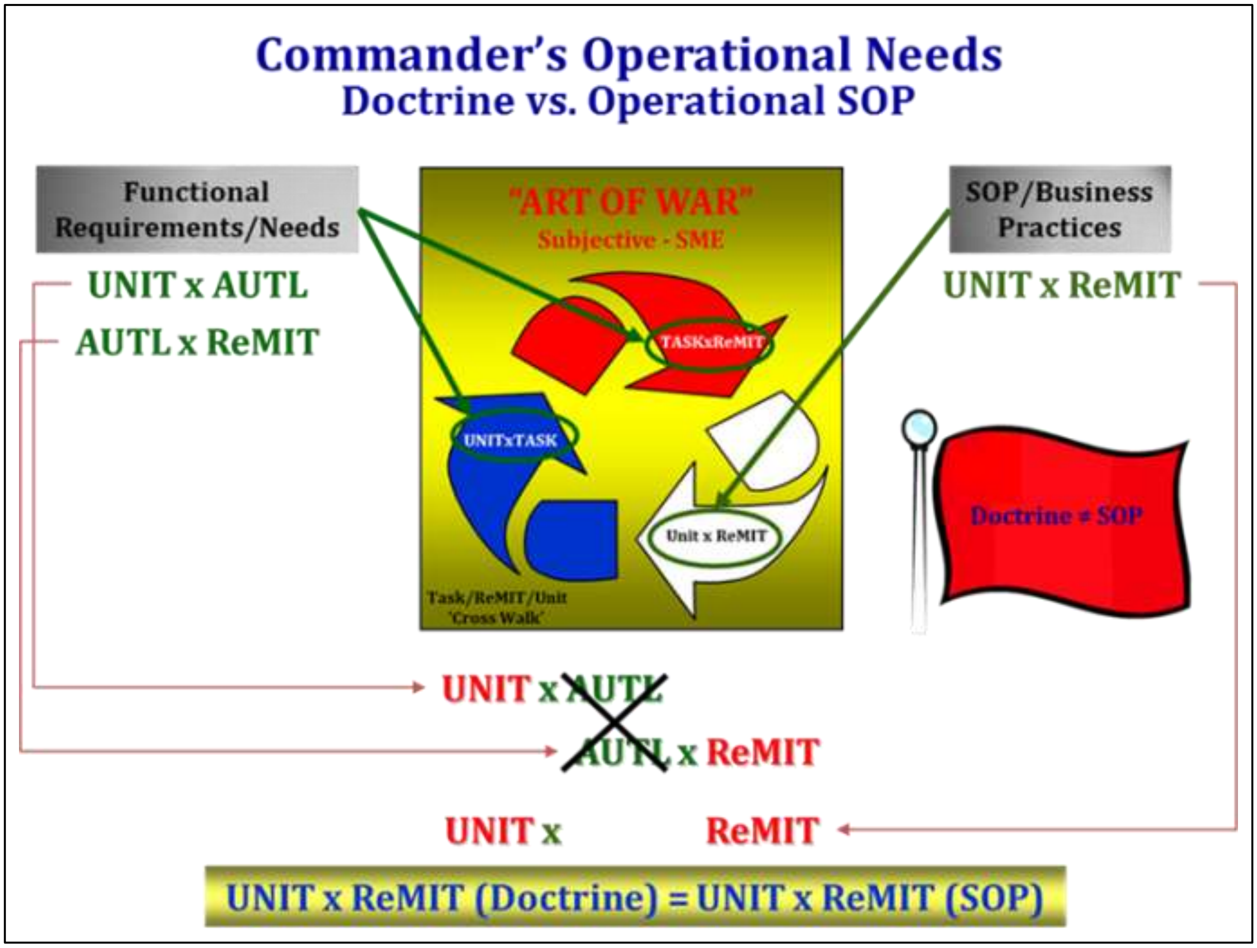

Figure 3

IX. CREATION OF AN INTEGRATED & DYNAMIC OPERATIONAL TRAFFIC /BANDWIDTH PROFILE

The generation of IERs are 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 Figure 2, *while 2,352 IERs were generated by the IAC 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 (Figure 4) 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.

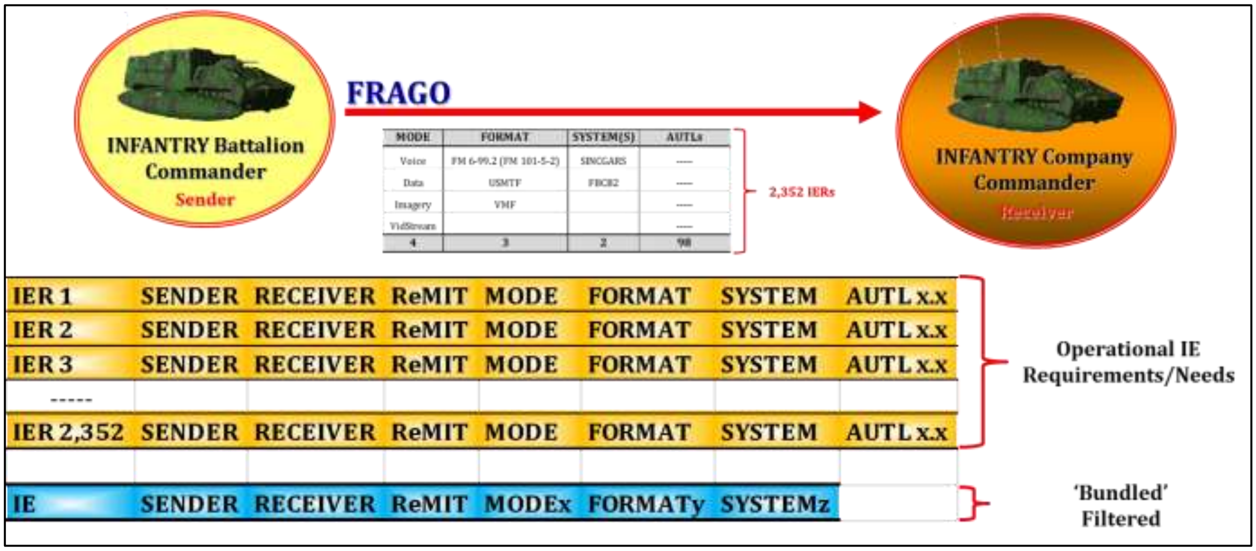

Figure 4

In addition to IE Mode and Format parameters, all 570 IEs have also been assigned, based on research, Data Rate and Property parameters as noted in Table 10.

DATA RATE	PROPERTIES
Frequency of Occurrence	Perishability
Speed of Service (SoS)	Criticality
Size	Security Classification
Duration	Precedence

Table 10

Thus, for each IE format, there is an associated data rate as it would apply to an infantry battalion (used by IAC as the 'baseline' unit): Frequency of Occurrence, Speed of Service, Data Size, Data Rate/Duration.

To increase the model's bandwidth fidelity, a 'C4ISR functional weight' has been assigned to each force structure unit/entity, the purpose being that as one increases in echelon of command and control (C2), generally the size or duration of a IE would correspondingly increase.

A case in point would be the Commander's Guidance IE. A VTC of such guidance between an infantry battalion commander and one of his company commanders may be five minutes in length, whereas a VTC of such guidance between a division commander and one of his IBCT commanders might be fifteen minutes in duration. Thus, if we establish a C4ISR Functional Weight of '1' for an infantry battalion, a C4ISR Functional Weight of '3' would be appropriate for a division force structure unit/entity. Consequently, as a function of this variable, the data rate values are increased or decreased, if necessary, as a result of the force structure unit/entity 'C4ISR Functional Weight.'

Having now taken the 'bundled' IE of Figure 3 and assigned to it the properties of Table 9 (adjusted by the 'C4ISR functional weight'), the IAC result is a fully integrated and unique set of information exchanges that can not only be used for operational, system, technical and network analysis but also 'adjusted' as required to create, in near real time, new outputs.

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.

X. CONDITIONAL BASED MAINTENANCE PLUS (CBM+)

Condition Based Maintenance Plus (CBM+) is the application and integration of appropriate processes, technologies, and knowledge-based capabilities to improve the reliability and maintenance effectiveness of DoD systems and components. At its core, CBM+ is maintenance performed based on evidence of need provided by Reliability Centered Maintenance (RCM) analysis and other enabling processes and technologies. CBM+ uses a systems engineering approach to collect data, enable analysis, and support the decision-making processes for system acquisition, sustainment, and operations.

The Services have been directed to incorporate their CBM+ strategies into appropriate guidance and directives to ensure implementation in organic (i.e., DoD in-house) maintenance capabilities and operations as well as in commercially supported DoD systems and programs for both new and legacy weapon systems.

The envisioned CBM+ operational environment will occur from the individual component to the platform level, in training courses, and the deployed environment.

Initially, Defense Acquisition Programs will exploit CBM+ opportunities as elements of system performance requirements during the design and development phase and throughout the life cycle.

CBM+ related studies and analyses should have three components:

1. Data – vehicle & system modeling
2. Operations
3. Transport

Overall, there are four primary assumptions that impact CBM+ Bandwidth:

1. MTTF = 'Deadline' (no CBM+ data)
2. MTTR = 'Deadline'
3. 'Normal Maintenance' = max CBM+ data
4. Battle Damage = 'Deadline' = Reduced CBM+ data

Figure 5 represents how CBM+ data could be generated to serve as IAC data input.

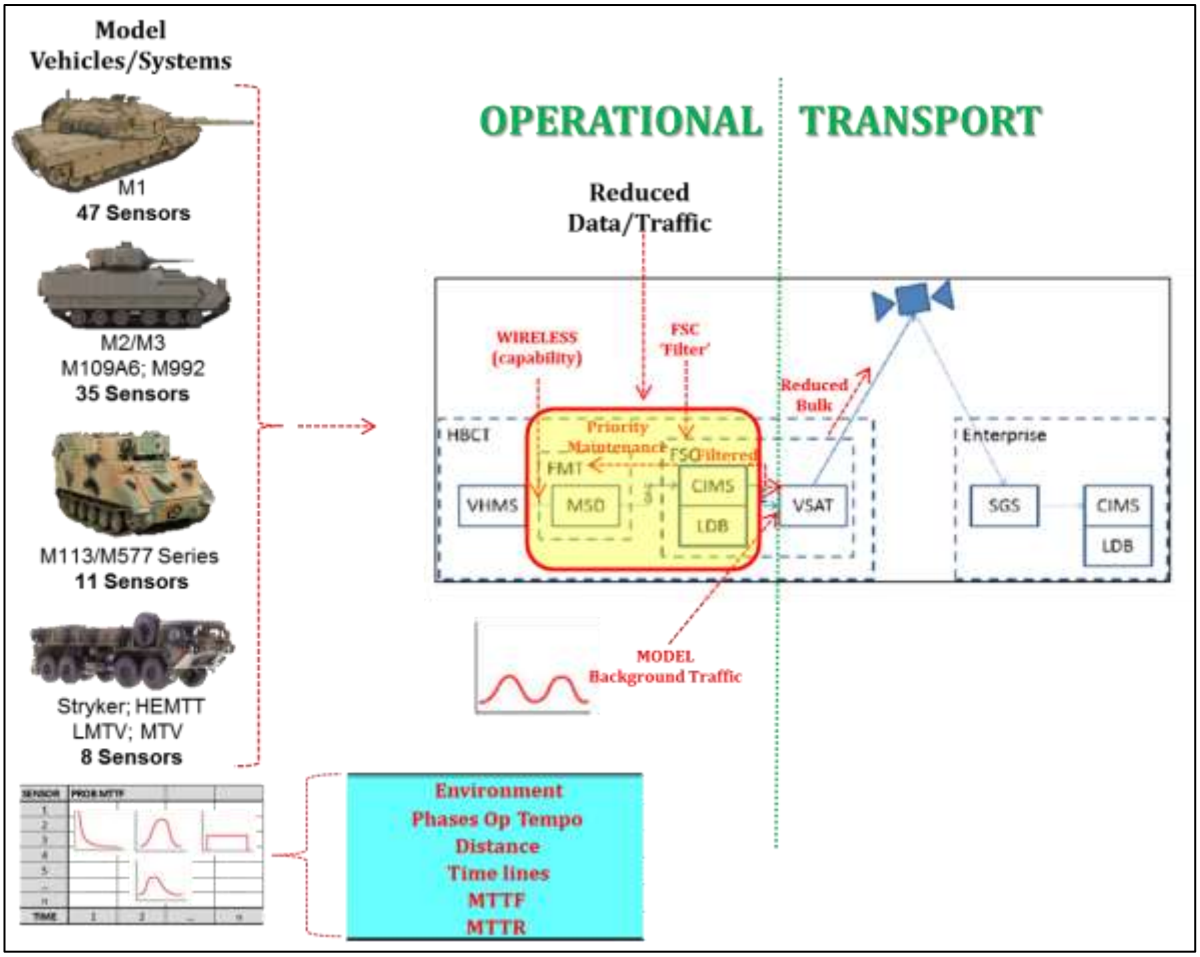

Figure 5

XI. FS 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 (Table 11).

UNIT/ELEMENTS	SubNET VEHICLE	Squad	Section	Platoon	Company	Company	Company Fires	Company Sensors	Battalion Command	Battalion Operations & Intel (O&I)	Battalion Admin & Log (A&L)	Battalion Fires	Battalion Mortars	Battalion Medical	CALL GROUPS	Brigade Upper Tier	Brigade Lower Tier	Brigade Command	Brigade Operations & Intel (O&I)	Brigade Admin & Log (A&L)	Brigade Fires	Brigade Medical	METT	Brigade Command	TBD1	TBD2
	Waveform	SRW	SRW	SRW	SRW	SINCGARS	SRW	SRW	SINCGARS	SINCGARS	SINCGARS	SINCGARS	SINCGARS	SINCGARS	SINCGARS	ANW	ANW	SINCGARS	SINCGARS	SINCGARS	SINCGARS	SINCGARS	MUOS	HF	LINK16	UHF/VHF
IBCT																		1	1	1	1	1				
IBCT/Inf Bn 2																		1	1	1	1	1				
IBCT/Inf Bn 3																		1	1	1	1	1				
LTC 11A00 (COMMANDER)	HUMMV 1		BnCP						1						BnC			1								
SSG 11B30 (OPNS SGT)	HUMMV 1								1	1								1	1				1			
MAJ 11A00 (EXEC OFF)	HUMMV 2		BnCP						1		1							1	1				1	1		
CSM 00Z50 (CSM)	HUMMV 3		BnCP						1						BnC					1			1			
CPT 35D00 (S2)	HUMMV 4		BnCP												BnC											
LT 35D00 (ASST S2)	HUMMV 4		BnCP						1	1						UT			1							
SFC 11B40 (SR INTEL SGT)	HUMMV 4		BnCP												BnC											
MAJ 11A00 (S3)	HUMMV 5		BnCP						1	1					BnC	UT		1	1				1	1		

Table 11

XII. 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, $cost, etc, IAC can execute a '**Trade off**' Study to evaluate optimization of various vehicle configurations (Figure 6).

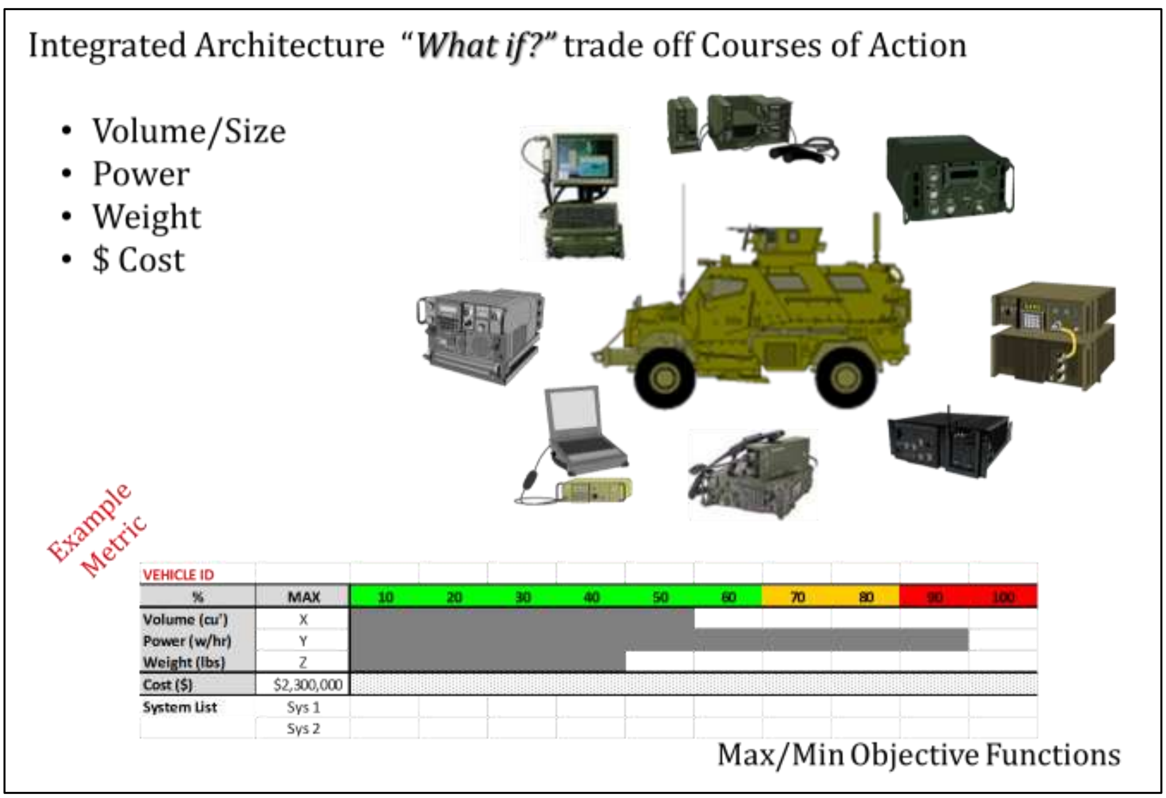

Figure 6

XIII. VISUAL REPRESENTATION OF THE IAC INTEGRATED ARCHITECTURE

With the completion of a fully integrated, overarching architecture, the next step would be to geospatially display that architecture (Note: entity coordinates can be linked through a matrix in IAC) for connectivity and range analyses. A TRADOC AIMD application called CAVT—CADIE Architecture Visualization Tool—does just that.

Note: CAVT is an AIMD tool and it is only the intent of this paper to highlight that IAC has the capability to interface with CAVT to perform as described below.

CAVT started as a laptop based interactive visualization and analytical tool (Windows .NET application) designed to express the details of an architecture's force structure transport communication infrastructure and provide short term analysis based on distance and geography to aid in resource management decisions. CAVT does not create architectures, it can only visualize an input architecture.

Along with a fully integrated architecture development process, IAC was specifically designed to interface directly and seamlessly with CAVT. This allows CAVT's transport communication infrastructure analyses to be accomplished at any level, be it singular entity (Soldier, platform) or node consolidation (CP—command post, TOC—tactical operations center, HHQ—higher headquarters).

CAVT focuses on the needs of the architecture, analysis, network management, M&S and testing communities:

- Provides the design details of the waveforms down to a specified level of granularity.
- Outputs data statistics associated with resource distributions for a variety of architectures:
  - Waveform assignments
  - Hardware distributions
  - Frequency Plans
- Provides capability to import current force communications infrastructure to compare and contrast with Future Force resource allocations.
- Can add additional resources to provide alternate CoAs (courses of action) to resolve connectivity gaps or excess capacity demands.
- Provides "Back of the Envelope" calculations and/or analysis for performance context:
  - Range
  - Connectivity btw Sender/Receiver Nodes
  - Routing Paths
  - Convergence Points
  - Capacity ('Pipe size')
  - Network Affiliations ('Subnets')
  - Operational Requirements ('Need lines')
- Is capable of post-processing data collected during test events to visualize the network dynamics that occurred.
- Is a living architecture artifact that evolves with a Program's baseline.

For each force structure represented by the architecture, there are four architecture views:

1. Deployment view: provides operational context to aid in understanding waveform connectivity and waveform behaviors.
2. Waveform view: shows high level attributes of waveform behaviors and their interconnectivity.

3. Focused view: isolates the specific waveform in question; provides greater operational context.
4. Description view of specific waveform behaviors taken from waveform specifications.

CAVT includes a Resource Allocation section to quantify resource allocations for a chosen subset of operational platforms:

- Channel assignments
- Frequencies
- Hardware

CAVT includes an Analysis Area to perform "back-of-the-envelope" calculations and to re-examine captured data from test events:

- Short term performance analysis aids in understanding network behaviors and can influence resource distribution decisions.
- Output from CAVT has been used in performance assessment reports on the 30-node WNW Test event in Charleston SC.
- Provides the capability to import other current force communication infrastructure data for resource allocation comparisons by maintaining a large library of infrastructure data available for comparisons.

Current CAVT limitations are as follows:

- Currently employs Google Earth as its data source; must eventually be transferred to Google Earth Enterprise for placement on the SIPRNET if it's to be used for operational analyses.
- Analysis calculations intended to aid the design of resource distribution and location, and not intended for detailed modeling and performance analysis of network (a feature that can be added later with the development of an interface with higher order network simulation models):
  - Link Margin calculations do not include losses due to foliage, atmosphere, urban structures, and fast fading effects.
  - Utilization and capacity estimates do not take into account the highly dynamic nature of the network. Estimates are based on burst rate and route probabilities.
  - Routing heuristics are simplified and are not representative of explicit protocol behaviors.
- Given the lack of any architectural community wide methodology that provides a degree of standardization between architectural process, the seamless integration of authoritative data sources (beyond IAC) is limited.

Figure 7 is a CAVT screen capture example of connectivity links and system identification.

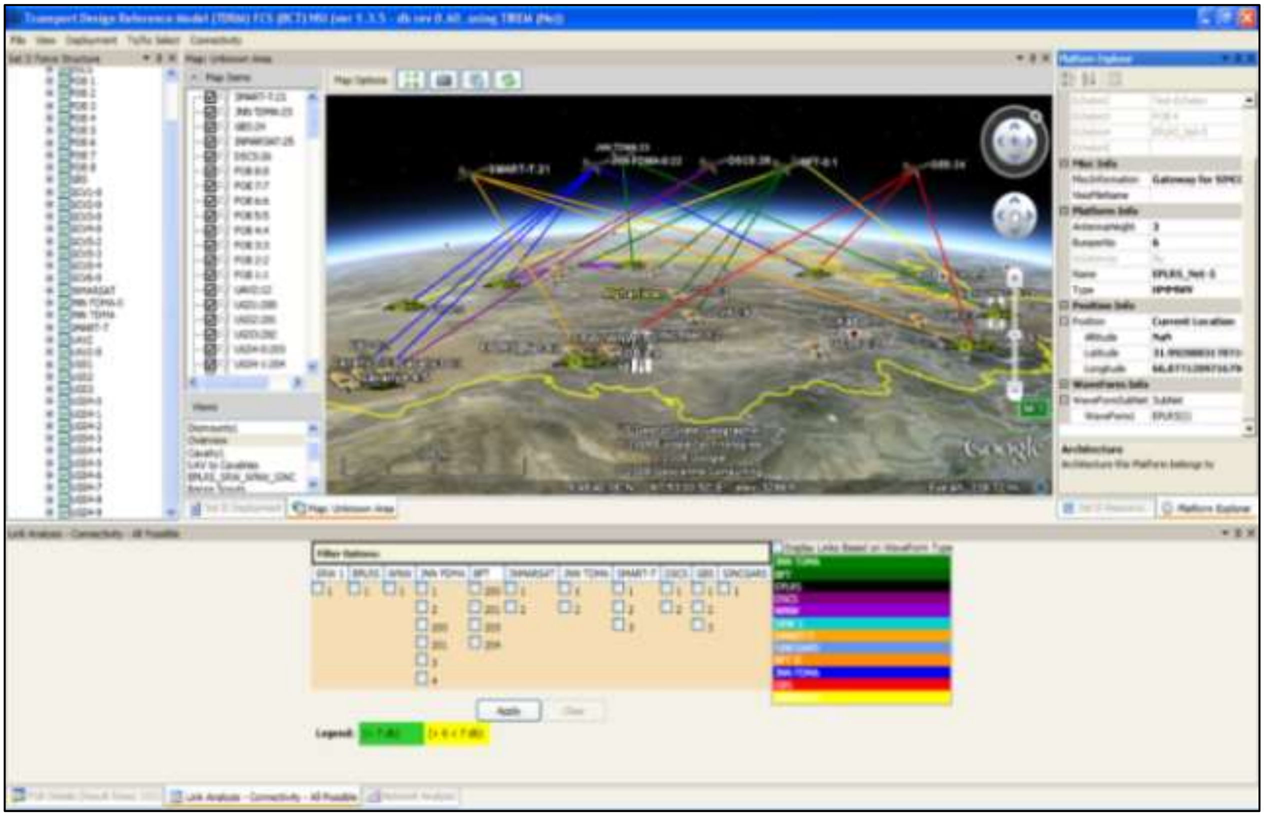

Figure 7

XIV. ADDITIONAL APPLICATIONS OF THE IAC/CAVT SUITE

While it has been clearly demonstrated to create an integrated architecture, IAC can also be used to 'reverse engineer' collected data to either validate the architecture modeling process or to improve upon it. Programs such as CERDEC's S&TC ASEO ODCA (Operational Data Collection Analysis) or even special organizations such as Task Force ODIN (Observe, Detect, Identify, and Neutralize). Data collected from such operations could be parsed and inputted into IAC to not only create a more realistic C4ISR model but such a model could then be used to improve on the structure and integration of said operation.

Furthermore, the IAC/CAVT suite extends well beyond the purely engineering realm of architectural modeling and system analyses. More importantly, this suite, given it is a Windows based application that runs on laptops, can literally be fielded to the Warfighter to execute a number of critical supporting operational tasks:

- Task Organization Integration
- C4ISR Resource Management
- 'Real Time' Architecture Analysis
- COA Analysis
- Battle Damage Assessment
- 'Work Around' Analysis
- Coordinates can either be directly inputted through a matrix…or, even applied through BFT.
- Electronic SOP: the Sender x Receiver x IE' IAC OV matrix is, in essence, a unit's SOP (Standing Operating Procedures).
- 'Automated' Reporting System

Simulation Exercises (SIMEX) and Testing & Evaluation (T&E) are two other areas of IAC value. Central to SIMEXs 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 IAC SV-6s which, if linked to CAVT and Blue Force Tracking (BFT), would provide for an exceptionally powerful execution, tracking and evaluation and analysis tool (Figure 8).

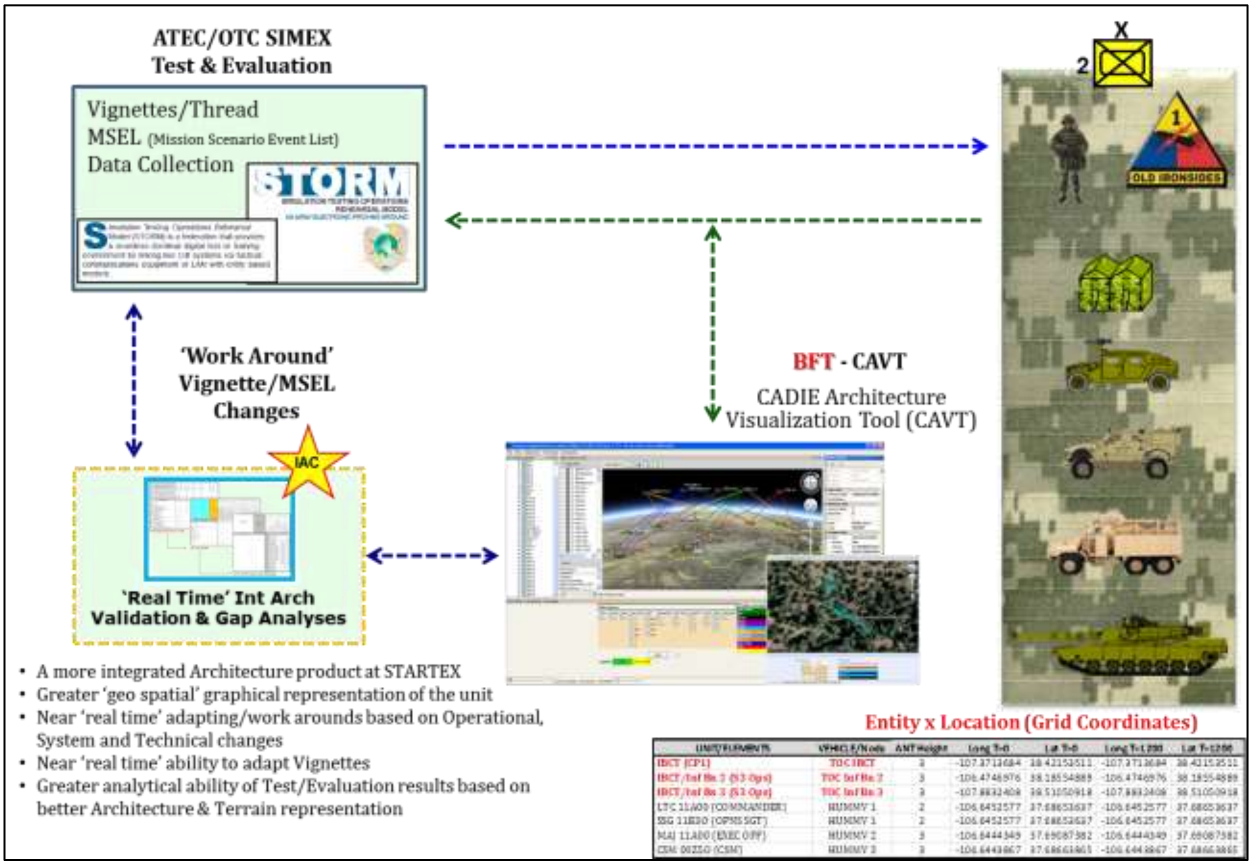

Figure 8

In the end, ***fielding this suite to the Warfighter*** would be a 'win/win' for both them and the architectural/system/network engineer for the Warfighter obtains an application from the engineer with direct BC and operational network relevancy while the engineer obtains from the Warfighter the SME expertise of timely, direct data entry to perform more relevant analyses in support of the Warfighter.

XV. SUMMARY

The IAC-CAVT Initiative—addresses not only customer architectural analysis needs but also has operational warfighter potential:

1. Verify **Architecture compatibility** between ALL legacy and capability sets (CS).
2. Identify '**gaps**' between: Operational Requirements, O/S and S/T architectures.
3. Create **Integrated O/S/T Architectural Views.**
4. Capability to create a **Traffic Profile** (Background traffic).
5. Capability to create a 'dynamic **Bandwidth Profile**' based on the Traffic Profile [note: this profile is not inclusive of Network 'overhead' and thus is not an overall 'Network Load' profile].

6. Overarching Battlespace '**visualization**' of OA/SA/TA **C4ISR Functions.**
7. Display **time sequenced** integration of **information flow** over network… 'pipelines pulse' (based on IE Matrix).
8. Display **Connectivity** between Sender/Receiver Nodes.
9. Display **Capacity** ('Pipe size').
10. Display **Network Affiliations** ('Subnets').
11. Capability to tie in **Operational Requirements/Needs** as a function of the **Traffic Profile.**
12. Can be inclusive of **CBM+** related Traffic/Bandwidth profiles.
13. A Dynamic Traffic/Bandwidth Profile with integrated operational requirements will provide a **'what if?' analytical capability** to determine 'good enough' and 'cost associated' impacts on operational needs given associated architectures.
14. Incorporate as part of a '**visualization suite**' to support **operational**, **SIMEX** and **T&E**.
15. Commo/System '**range fans**' – support CoA analysis.

Eventually, it is envisioned that IAC could be part of a suite of four components that will create a truly overarching and integrated architectural process (Figure 9) to perform the following:

1. IAC to generate fully integrated DoDAF related Views that will create a dynamic Operational Load Traffic/Bandwidth Profile—in essence the 'Operational Load.'
2. Higher Order communications effects Network M&S to develop Network Load.
3. CAVT (or similar) for Connectivity visualization.
4. Seamless (relatively speaking) Data transfer in/out of CADIE which will serve as the Army's architectural data repository.

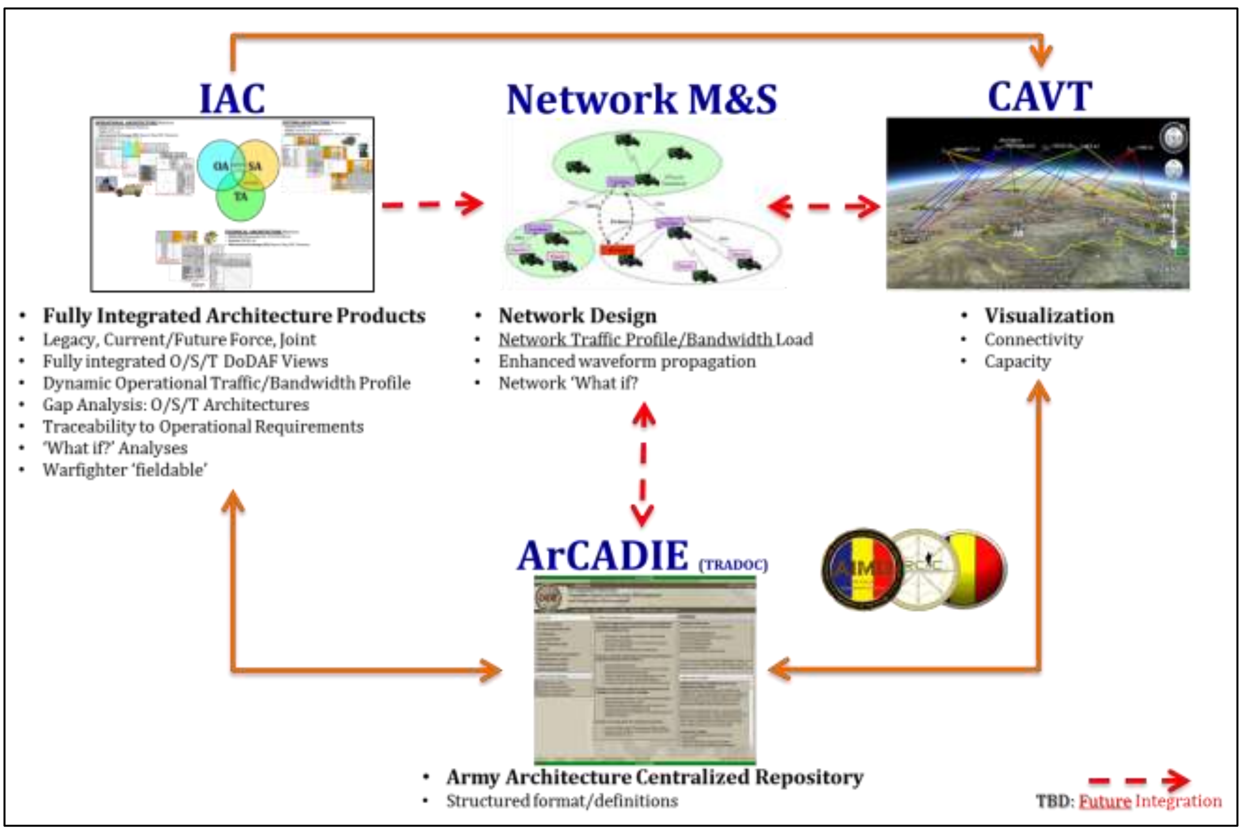

Figure 9