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Exploratory Study of STK Towards an Integrated Visualization Architecture for Capability Engineering

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Abstract

Within Capability Engineering, there is an increasing need to provide visualization as part of addressing capability conception, generation and engagement. By employing visualization technologies within a collaborative synthetic environment, the immediate impact of decisions and actions on an entire capability can be investigated and explored by the broad range of participants involved within the Capability Engineering effort.

To this end, the CapDEM (Collaborative Capability Definition, Engineering and Management) TDP initiated an explorative study to evaluate the potential of currently available tools and technologies that can suitably aid in capability visualization and analysis. This report explores the potential of Satellite Tool Kit (STK) to visualize scenarios pertinent to C4ISR – "the Capability Area" selected due to its relevance to the DND/CF. The study also assesses the ability of STK to serve as a "visualization hub," leveraging the potential of other Capability Engineering tools within a proposed Integrated Visualization Architecture (IVA).

The explorative study revealed that STK can provide a reasonable "As-Is" standalone visualization capability. A potential difficulty, however, is the complexity, learning curve and high cognitive load associated with detailed model development within STK in order to produce accurate and appropriate visualizations. Issues pertinent to being fully compliant with the military intelligence cycle and how to move towards developing a full-fledged "To-Be" IVA, including interface and developmental efforts relative to the broader Capability Engineering tools, were also examined.

Résumé

Dans l’ingénierie des capacités, il devient de plus en plus nécessaire de fournir des moyens de visualisation pour permettre de concevoir, de générer et d’engager les capacités. Grâce à l’utilisation des techniques de visualisation dans un environnement collaboratif synthétique, les conséquences immédiates des décisions et des actions sur une capacité totale peuvent être examinées et explorées par toute la gamme des participants concernés par le travail d’ingénierie des capacités.

À cette fin, le PDT DIGCap (définition, ingénierie et gestion collaboratives des capacités) a lancé une étude d’exploration dans le but d’évaluer le potentiel des technologies et des outils actuellement disponibles, adéquats pour faciliter la visualisation et l’analyse des capacités. Ce rapport explore le potentiel de la boîte à outils STK (Satellite Tool Kit) pour visualiser des scénarios pertinents au C4ISR – le domaine de capacités choisi en raison de sa pertinence pour le MDN et les FC. Cette étude évalue également la capacité de STK à servir de « centre de visualisation », et ainsi à exploiter le potentiel des autres outils d’ingénierie des capacités dans une architecture de visualisation intégrée (AVI) proposée.

Cette étude exploratoire a révélé que STK permettait d’offrir, dans son état actuel, des capacités de visualisation autonomes raisonnables. Cependant, la complexité de cet outil, sa courbe d’apprentissage ainsi que la forte charge cognitive associée au développement d’un modèle détaillé dans STK afin de produire des visualisations exactes et appropriées constituent une difficulté potentielle. Les problèmes reliés à la conformité intégrale au cycle du renseignement militaire et au développement d’une AVI complète ultérieure, y compris une interface, ainsi que les travaux de développement rattachés aux outils d’ingénierie des capacités généraux, ont également été examinés.

Executive summary

Visualization constitutes one of the key components within Capability Engineering that has the potential not only to facilitate, but to significantly enhance the understanding, communications and exploration of capability-based solutions. Employable at both strategic and tactical levels, visualization offers a means to address the operation and management of a capability and its underlying systems, be they data or platform-centric, physical or logical. Such an approach therefore enables an easier and more direct representation of the problem space in a way that stake holders and decision-makers can focus and extract elements that are capability critical. The result is a more straight-forward, understandable and consequently more powerful way of exploring how to address potential solutions as they are identified through the application of Capability Engineering.

To this end, as the originator of the Capability Engineering construct, the CapDEM (Collaborative Capability Definition, Engineering and Management) TDP engaged C4ISR as a candidate “Capability Area” to explore and demonstrate the potential of visualization in terms of current and future DND capabilities. An exploratory study was initiated in working towards a visualization architecture by first exploring a stand-alone “As-Is” capability followed by a plan to incrementally migrate towards an eventual “To-Be” capability. For this initial effort, a software package known as the Satellite Tool Kit (STK) was chosen as the initial “visualization hub”.

To evaluate STK’s stand-alone “As-Is” visualization capability, a typical C4ISR scenario was developed to demonstrate and display situational awareness at the theatre level. The scenario demonstrates several currently operational Intelligence, Surveillance, and Reconnaissance (ISR) platforms. It showed AWACS, JSTARS, U-2, Global Hawk UAV, reconnaissance satellites, various target aircrafts and a variety of ground segments representing relay stations. The imaging satellite was represented by “Surveillance Atlantic”, a Low Earth Orbit (LEO) space asset to augment reconnaissance on-demand. The representative C4ISR scenario had approximately ten different views, each providing strategic vantage points of the theatre battle space.

As a standalone software package, STK provided acceptable and reasonable “As-Is” visualization capability. It was found, however, that STK’s standalone execution of the C4ISR scenario only partially conformed to all the phases within the military intelligence cycle. This cycle is used to measure the impact of C4ISR systems within a given operational context, including aspects of communications survivability, resistance to countermeasures, and the ability to formulate distribution plans and create/provide a Common Operating Picture (COP). However, model enhancements and external plug-ins could be developed and integrated to make STK fully compliant.

It was also concluded that in order to progress from “As-Is” standalone visualization architecture towards a more encompassing “To-Be” Integrated Visualization Architecture (IVA), STK must be capable of functioning within a joint environment consisting of various Capability Engineering tools. Each tool would need to interact with STK in a distributed fashion over a network, receiving and sending relevant data about entities in the scenario, with

the goal to provide enhanced informational awareness. The principle would be to augment STK with other tools that provide domain-specific visualization and analytical functionalities that enable end users to observe and interact with a broader picture of the scenario and the capabilities realized via its component entities.

In addressing above options, the exploratory study encountered several software adaptation issues. STK is a COTS product and does not support out-of-the-box “plug-in” interfaces. This limitation means that a fairly large subset of desirable Capability Engineering tools do not readily connect to STK in a simple “out-of-the-box” manner. Rather, in order to integrate such tools, appropriate interfaces need to be designed and implemented within a larger capability visualization architecture.

Finally, it can be said that STK offers reasonable capability to support situational awareness animation via cross application data exchange, through usage of a plethora of “data transfer” commands, domain-specific add-on modules, and ready-to-integrate interfaces. Consequently STK can be seen to easily evolve as a key capability visualization tool within IVA. As CapDEM and the application of Capability Engineering continue to advance, IVA’s interoperability with the other services will need to improve. Such improvements should be balanced by IVA’s ability to interface with more collaborative joint intelligence processing systems at national, theatre, and tactical levels to make the best use of the additional data.

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La visualisation constitue une des principales composantes de l'ingénierie des capacités; elle possède le potentiel de faciliter et d'améliorer de façon significative la compréhension, les communications et l'exploration des solutions axées sur les capacités. Exploitable aux niveaux stratégique et tactique, la visualisation constitue un moyen de prise en charge de l'exploitation et de la gestion des capacités et de leurs systèmes sous-jacents, que ces derniers soient centrés sur les données ou la plate-forme, physiques ou logiques. Une telle approche permet par conséquent de représenter plus facilement et de manière plus directe l'espace des problèmes, de sorte que les acteurs concernés et les décideurs peuvent se concentrer sur les éléments qui sont critiques du point de vue des capacités, et les isoler. Il en résulte une façon plus simple, mieux compréhensible et par conséquent plus puissante d'explorer la façon d'aborder les solutions potentielles révélées par l'application des techniques de l'ingénierie des capacités.

À cette fin, à titre de parrain de la structure d'ingénierie des capacités, le PDT DIGCap (définition, ingénierie et gestion collaboratives des capacités) a choisi le C4ISR comme « domaine de capacités » candidat pour explorer et démontrer le potentiel de la visualisation en termes des capacités actuelles et futures du MDN. Une étude exploratoire a été amorcée dans le but d'élaborer une architecture de visualisation, en explorant tout d'abord un outil « existant » autonome, puis en mettant au point un plan visant une migration incrémentielle vers une éventuelle capacité « ultérieure ». Pour ce travail initial, le logiciel STK (Satellite Tool Kit) a été choisi comme « centre de visualisation » initial.

Afin d'évaluer les capacités de visualisation de l'outil STK autonome « existant », on a mis sur pied un scénario de C4ISR typique afin de démontrer et de présenter la connaissance de la situation au niveau du théâtre des opérations. Ce scénario permet de faire la démonstration de plusieurs plates-formes de renseignement, de surveillance et de reconnaissance (RSR) actuellement opérationnelles. Il fait intervenir des AWACS, des JSTARS, des U-2, des UAV Global Hawk, des satellites de reconnaissance, divers aéronefs cibles et une variété de segments terrestres qui représentent des stations relais. Le satellite d'imagerie était représenté par « Surveillance atlantique », un satellite sur orbite basse qui vise à compléter la reconnaissance sur demande. Ce scénario représentatif du C4ISR comportait environ dix vues distinctes, chacune offrant un point de vue stratégique sur l'espace de combat du théâtre des opérations.

STK, un logiciel autonome, offrait des capacités de visualisation « existantes » acceptables et raisonnables. Cependant, on a constaté que la mise en œuvre autonome par STK du scénario C4ISR ne se conformait pas totalement à toutes les phases du cycle du renseignement militaire. Ce cycle est utilisé pour mesurer les impacts des systèmes C4ISR dans un contexte opérationnel déterminé, et notamment les aspects de la survivabilité des communications, de la résistance aux contre-mesures ainsi que la capacité de formuler des plans de distribution et de créer/fournir une image commune de la situation opérationnelle (ICSO). Cependant, on pourrait rendre STK entièrement conforme en apportant des améliorations au modèle et en lui ajoutant des programmes complémentaires externes.

On est également arrivé à la conclusion que, afin de passer d’une architecture de visualisation autonome « existante » à une architecture de visualisation intégrée (AVI) « ultérieure » plus globale, il fallait que STK puisse fonctionner dans un environnement interarmées constitué de divers outils d’ingénierie des capacités. Chaque outil devrait pouvoir interagir avec STK de manière distribuée en réseau, en recevant et en envoyant des données pertinentes sur les entités dans le scénario, dans le but d’établir une connaissance améliorée de la situation. Le principe consisterait à compléter STK avec d’autres outils dotés de fonctionnalités de visualisation et d’analyse propres au domaine et permettant aux utilisateurs finals, grâce aux entités constitutives du système, d’observer une image plus étendue du scénario et des capacités réalisées et de réagir avec elle.

Dans l’examen des solutions évoquées ci-dessus, l’étude exploratoire s’est heurtée à divers problèmes d’adaptation du logiciel. STK est un logiciel commercial standard qui ne supporte pas des interfaces « complémentaires » directement. En raison de cette limitation, il est impossible de relier directement à STK, de façon simple et immédiate, un sous-ensemble passablement important des outils d’ingénierie des capacités. Pour intégrer ces outils, il faut plutôt concevoir et mettre en œuvre des interfaces appropriées, dans le cadre d’une architecture de visualisation des capacités plus globale.

Enfin, il convient de mentionner que STK offre des capacités raisonnables permettant d’animer la connaissance de la situation, grâce à des échanges de données entre les applications, et par l’utilisation de toute une pléthore de commandes de « transfert de données », de modules complémentaires propres à un domaine, et d’interfaces prêtes pour l’intégration. Par conséquent, on estime que STK pourra facilement évoluer et constituer un outil clé de visualisation des capacités à l’intérieur de l’AVI. À mesure de l’évolution du projet DIGCap et des applications de l’ingénierie des capacités, il faudra améliorer l’interopérabilité de l’AVI avec les autres services. Ces améliorations devront s’accompagner de la capacité d’interfacer l’AVI avec des systèmes interarmées de traitement du renseignement plus collaboratifs, au niveau national, du théâtre et tactique, afin d’exploiter au mieux les données additionnelles ainsi acquises.

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1. Introduction

To facilitate Capability-Based Planning (CBP) [1], the Department of National Defence (DND) initiated the Collaborative Capability Definition Engineering and Management (CapDEM) TDP to demonstrate and validate Capability Engineering [2] as part of introducing engineering rigor to the development/procurement of system-of-systems based capabilities. To illustrate the potential of Capability Engineering via systematic linkages between capability conceptualization and system/component functionalities, C4ISR was chosen as a candidate "Capability Area" to explore, demonstrate and refine current and future DND capabilities.

Within the chosen "Capability Area", Maritime ISR was chosen as a "Capability Demonstration Context" to illustrate traceable links between capability generation, engagement and sustainment. As shown in Figure 1, "ISR Visualization" was identified as one of the key functional components that facilitate analysis, annotation, visualization and collaboration within a scalable synthetic computing environment that could potentially extend and integrate various Capability Engineering tools [3]. Such a visualization facility is expected to enable interactive collaboration and leverage broader perspectives on relevant capabilities.

Satellite Tool Kit (STK) [4], a Commercial Off-The-Shelf (COTS) software product developed by Analytical Graphics Inc. (AGI), was chosen as the "hub" for CapDEM's initial effort to provide visualization within Capability Engineering. To this end, an exploratory study was initiated to assess the prospects of STK's potential to visualize C4ISR scenarios, its ability to integrate with other Capability Engineering tools and its suitability to support standard ISR methodologies, such as the military intelligence cycle [5].

The ultimate goal of such an effort is to achieve, both by design and conceptual prototype, an "Integrated Visualization Architecture" (IVA) whereby the (existing) "best of breed" Capability Engineering tools can be combined to provide interactive experimentation rather than mere visual "eye candy". When executed in a networked environment, such distributed processing allows experimentation data from different sources to be "computationally steered" to produce a high-level visualization capability. With such a net-centric control schema, interactively changing any pertinent simulation parameter would immediately update the visualization, consequently enabling designers and decision makers to see the immediate impact of such decisions on the entire capability.

This process of "computational steering" promotes collaboration at the information object level, providing a resilient simulation environment that can easily adapt to advances in technologies, readily allowing new capabilities from third-party sources to be integrated into IVA. A visualization "common ground" can therefore be created in which wider participation focuses on getting a grasp of an overall picture, setting new directions and discovering possible synergy between existing and new capabilities as well as the engineering tools used to do such an analysis.

The scope of this report is to:

- Explore the issues and potential effectiveness of native STK towards capability visualization.
- Explore the design, integration and implementation issues underlying an executable architecture approach to capability visualization that which conforms to CapDEM's incremental and evolutionary approach based on spiral development.
- Evaluate this pilot-study by providing near-time conclusions and forward-looking recommendations, both for native STK and in terms of an Integrated Visualization Architecture.

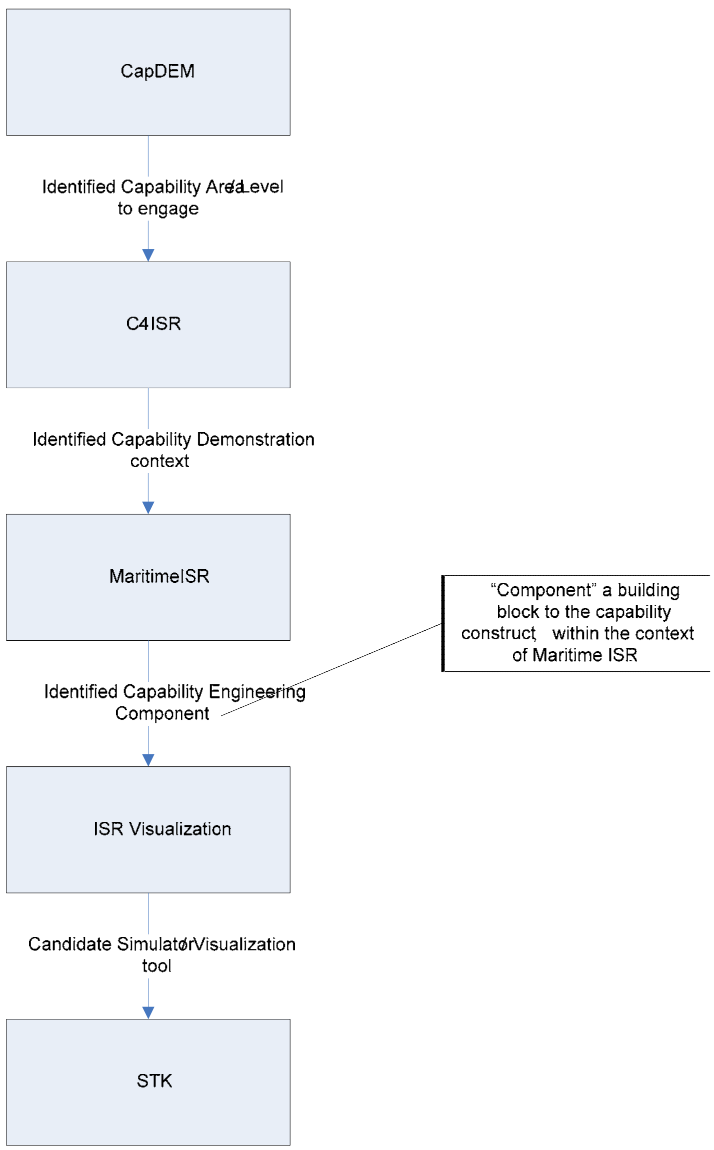

Figure 1. *Visualization Selection Roadmap*

2. Exploring Visualization: Current and Future Capability

Visualization provides Capability Engineering the flexibility to explore answers to both strategic and tactical questions about the operation and management of underlying systems, be they data or platform-centric, physical or logical. An example would be the use of communication systems by CF-18 in a reconnaissance mission. Furthermore, capability-based visualization offers the ability to observe the inter-relationships between entities during scenario animation, thus illustrating both the complexity and value added through interactions within a capability-based, system-of-systems context.

Towards this end, STK is the central “hub” of the current effort to provide capability visualization. This section will first look at the existing stove-piped “As-Is” capability of STK in a standalone mode. Using a mix of ground, airborne and space ISR assets, a representative scenario is developed, and STK’s basic capability to support Tasking, Processing, Exploitation and Dissemination (TPED) within the military intelligence cycle is also explored.

To fully realize the potential effectiveness of STK, the introduction of the CapDEM CEE tool suite to augment distributed scenario execution will form the basis of a “To-Be” Integrated Visualization Architecture. The essential building blocks of such an integrated architecture are examined in an upcoming section.

Capability Engineering mandates the use of spiral development to progress iteratively towards a comprehensive and collaboratively engineered capability. Figure 2 depicts the migration path towards full implementation of the proposed IVA. The refinement loop illustrates the use of constant on-going exploration and the integration of new and emerging systems and technologies to maintain information accuracy while simultaneously reducing the capability gap.

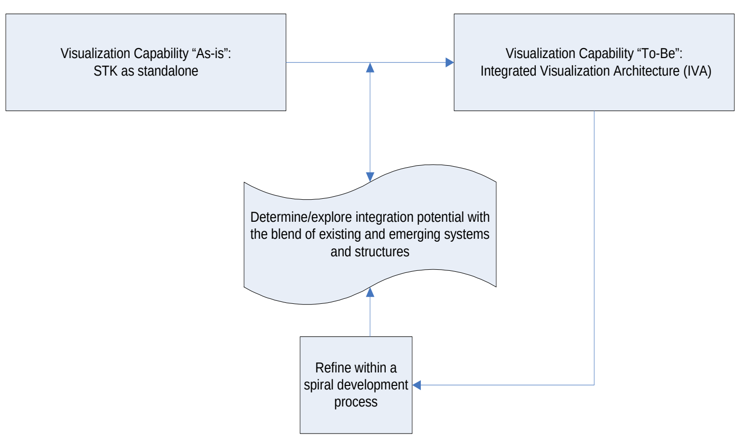

Figure 2. *Visualization Capability Evolution*

2.1 "As-Is" Visualization Architecture

The "As-Is" visualization architecture is represented via the use of STK to simulate a typical C4ISR scenario in stand-alone mode. Current STK modules provide modelling templates for entities such as Aircraft, Satellite, Sensor, Target, Area of Interest (AOI) and Coverage. These templates are individually configured to model various C4ISR assets and are integrated to animate the representative scenario. This scenario animation is not influenced by any external Capability Engineering tools and currently executes on a standalone desktop computer. STK provides the analytical engine to calculate instantaneous scenario data and dynamically display 2-Dimensional and 3-Dimensional ISR assets overlaid on maps, giving a reasonably realistic look and feel to the scenario's environment.

Some of the core capabilities relevant to modelling and scenario development that prompted the selection of STK as a "one-stop visualization tool" includes:

- The user can generate scenarios that reflect situational awareness and view the battle space with land, sea, air and space assets from any viewpoint combined with the ability to store these vantage points for later playback and analysis;
- STK's functionality to connect and communicate with third-party applications via TCP/IP socket or Microsoft's Component Object Model (COM) [1];
- Ephemeris data generation using various propagators. Note: Ephemeris data refer to the basic Keplerain elements used to define satellite orbital parameters;
- Configure Aircraft and Unmanned Aerial Vehicle (UAV) platforms and provide the ability to attach sensors with customizable terrain-following Field of View (FOV);
- Defining the boundaries and spatial resolution of the coverage area, either globally or by latitude bounds;
- Incorporate all assets of an ISR infrastructure;
- Configure the engineering attributes of each ISR asset;
- Configure the entities being observed, such as Targets within an AOI;
- Enable the events that cumulatively trigger the state transitions of all players within the modelled surveillance scenario;
- Ability to control/adjust aspects of visualization during scenario execution; and
- Generate statistically quantifiable measures of coverage and detection performance.

Table 1 captures and organizes the overarching modelling requirements matrix for the candidate Capability Demonstration Context (i.e., Maritime ISR). The resolution matrix can be used as a guideline in developing requirements and identifying whether the corresponding STK module and its functionality is capable and licensed to satisfy the said requirement.

[1] Information on TCP/IP and COM can be found at the MSDN website (http://msdn.microsoft.com).

Table 1. STK Requirements Resolution Matrix

	Entity Type: Scenario Objects, Data Feeds, Modules	STK Support	License Status	Part of Representative Scenario	Maritime ISR Requirement
		As of January 2005			
Scenario Objects	**Fixed Wing Airborne Surveillance and Targeting Platforms**				
	AWACS	Y	Y	Y	TBD
	Global hawk	Y	Y	Y	TBD
	Guardrail	Y	Y	Y	TBD
	JSTARS	Y	Y	Y	TBD
	U-2	Y	Y	Y	TBD
	Interceptors	Y	N	N	TBD
	Missile	Y	Y	N	TBD
	Rotary Wing Airborne Surveillance Platforms				
	Maritime Helicopters	N	N	N	TBD
	Airborne and Ground Targets				
	Gulf-4	Y	Y	Y	TBD
	F-16/18	Y	Y	N	TBD
	Halo	Y	Y	Y	TBD
	Area Target Object (Area of Interest)	Y	Y	Y	Y
	Airborne and Ground - Fixed Sensor: Type/Pointing				
Scenario Objects	Complex Conic/Fixed	Y	Y	Y	Y
	Simple Conic/Targeted	Y	Y	Y	Y
	Rectangular/Spinning	Y	Y	Y	Y
	Constellation	Y	Y	Y	TBD
	Facility (Ground Segment)	Y	Y	Y	Y
	Ground Moving Target Vehicle	Y	Y	Y	Y
	Radar				
	Pulse Doppler	Y	Y	Y	Y
	High Frequency Surface Wave	N	N	Y	TBD
	Synthetic Aperture	Y	Y	N	TBD
	Space-Based Radar	Y	Y	Y	TBD
	Ship				
	General Supply Ship	Y	Y	N	Y
	Submarine	Y	Y	N	Y

	Dipping Sonars	N	N	N	Y
	Globe Maps				
	High Resolution Maps	Y	Y	N	Y
	Joint Mapping Tool Kit	Y	N	N	Y
	VO Earth Imagery	Y	Y	Y	Y
	Terrain	Y	Y	N	Y
Data Feeds	**External Data Feed into STK**				
	DIS	Y	Y	Y	N
	HLA	N	N	N	Y
	OpNet ▪ Middleware that converts from time step to event driven messages	N	N	N	Y
	STK/X ▪ COM & DCOM Interface	Y	Y	N	Y
	ELINT ▪ TRAP Broadcast (National) ▪ TIBS Broadcast (Theater)	Y	Y	N	TBD
	SIGINT ▪ NRTD ▪ NRTI	Y	Y	N	TBD
	GCCS and C2PC	Y	Y	N	TBD
	External Database ▪ ODBC Databases	N	N	N	TBD
	External Air tasking Order	Y	Y	N	TBD
	Ground Moving Target Indicator (GMTI) data	Y	Y	N	TBD
	Air Moving Target Indicator (AMTI) data	Y	Y	N	TBD
	Moving Target Indicator Exploitation Data (MTIX)	Y	Y	N	TBD
	Link-16	N	N	N	TBD
	Data Feed out of STK				
	DIS	Y	Y	Y	N
	HLA	N	N	N	Y
	OpNet	N	N	N	Y
	STK/X ▪ COM & DCOM Interface	Y	Y	N	Y
	STK Movie Maker	Y	Y	N	Y
Modules	**Algorithms**				
	Detection and Tracking	N	N	Y	TBD
	Electronic Warfare Suite (EW)	N	N	N	TBD

	Electronic Warfare Support Measures (ESM)	N	N	N	TBD
	STK Chain	Y	Y	Y	TBD
	Comms System	Y	Y	N	TBD
	Coverage Definition	Y	Y	Y	TBD

2.1.1 Representative C4ISR Scenario Generation

A typical C4ISR scenario was developed to demonstrate STK's ability to display situational awareness at the theatre level. The scene shows several currently operational Intelligence, Surveillance, and Reconnaissance (ISR) platforms. It shows AWACS, JSTARS, U-2, Global Hawk UAV, reconnaissance satellites, various target aircrafts and a variety of ground segments representing relay stations. The imaging satellite is represented by "Surveillance Atlantic" a Low Earth Orbit (LEO) space asset to augment reconnaissance on-demand.

The following provides a brief overview of the sensor modelling parameters within the representative scenario to obtain requisite swath over predetermined AOIs. "Sensor Type" defines its FOV while "Pointing" and "Scan Mode" parameters further refine the FOV pattern. The "Pointing" parameter defines sensor orientation and "Scan Mode" defines the search pattern. One should note that it is very important to explain the following sensor parameters in detail since they are the building blocks for modelling and simulation within STK (by providing requisite FOV and situational awareness in the representative ISR scenario):

- Simple Conic Sensor – The sensor modelling of a Simple Conic type is based on a fixed pointing cone angle that the users enters to define the conical FOV.
- Fixed Pointing Type – The sensor is constrained to point in the same direction as the parent.
- Complex Conic Sensor – A set of "Inner and Outer Half Angles and Minimum and Maximum Clock Angles" define the sensor modelling of a complex conic type. The former angular set defines the angular radius of the cone measured from the bore-sight and the latter defines the range of rotation about the bore-sight relative to the "up-vector".
- Targeted Pointing – Sensor is constrained to aim at one or more assigned targets. The visualization effect would be that the sensor's footprint appears in the graphics window only when the target is in the FOV. Additionally, by configuring a "Targeted" orientation to "Track", the sensor will slew on an assigned target as soon as it appears over the horizon.
- Rectangular Sensor – A set of "Vertical and Horizontal Half Angles" defines the sensor modelling of a rectangular sensor type. Within the

sensor coordinate system the former angular set specifies the angle from the bore-sight (Z) direction to the edge of the sensor in the YZ plane and the latter specifies the angle from the bore-sight (Z) direction to the edge of the sensor in the XZ plane.

- Spinning Pointing – Often used to model radar antennas, push broom sensors and other instruments that spin, scan or sweep over time. The options available for spinning sensors allow the user to define the sensor as spinning on its axis or sweeping in a defined pattern.
- Continuous Scan – Uninterrupted search about the spin axis.
- Bidirectional Scan – Scan back and forth from a specified start angle to a specified stop angle

The following provides a brief overview of some the key air and space-borne assets modelled within the representative C4ISR scenario [6] [7] [8].

1. Airborne Warning and Control Systems (AWACS) is an airborne asset, modelled to simulate all-weather surveillance, command, control and communications (C3) needed by commanders of any Air Defence Forces. The radar and computer subsystems on AWACS can gather and present broad and detailed battlefield information. AWACS modelled with-in the representative scenario has six sensors and Table 2 details their design parameters.

Table 2. *AWACS Sensor Data*

Sensor	Type	Pointing Data	Targeted to
Radar_Down	Complex Conic: ▪ Inner Angle = 60^0 ▪ Outer Angle = 90^0	Fixed at: ▪ Azimuth 0 ▪ Elevation -90	None
Radar_Up	Complex Conic: ▪ Inner Angle = 60^0 ▪ Outer Angle = 90^0	Fixed at: ▪ Azimuth 0 ▪ Elevation 90	None
Scanning_Beam	Rectangular: ▪ Vertical ½ angle 2.5^0 ▪ Horizontal ½ angle 30^0	Spinning Continuous	None
To_GuardRail	Simple Conic: ▪ Cone angle 0.1^0	Targeted & set to tracking	To GuardRail
To_JSTARS	Simple Conic: ▪ Cone angle 0.1^0	Targeted & set to tracking	To JSTARS
To_U2	Simple Conic: ▪ Cone angle 0.1^0	Targeted & set to tracking	To U2

2. Joint Surveillance and Target Attack Radar System (JSTARS) is an airborne asset, modelled to simulate long-range air-to-ground surveillance system designed to detect ground targets. As modelled within the representative scenario, JSTARS has two sensors and Table 3 details their design parameters.

Table 3. JSTARS Sensor Data

Sensor	Type	Pointing Data	Targeted to
Left_Side	Rectangular: ▪ Vertical ½ angle 45^0 ▪ Horizontal ½ angle 45^0	Fixed at: ▪ Azimuth 90 ▪ Elevation -45	None
Right_Side	Rectangular: ▪ Vertical ½ angle 45^0 ▪ Horizontal ½ angle 45^0	Fixed at: ▪ Azimuth -90 ▪ Elevation -45	None

3. UAVs are an airborne asset, contributing towards Wide Area Search (WAS) for situational awareness and threat assessment, as well as narrower focus on specific targets for prosecution and battle damage assessment. The Global Hawk UAV provides rapid and detailed reconnaissance and surveillance information of areas up to 138,000 km^2. Global Hawk modelled with-in the representative scenario has four sensors and Table 4 details the sensors design parameters.

Table 4. Global Hawk Sensor Data

Sensor	Type	Pointing Data	Targeted to
GlobalHawk_Main	Rectangular ▪ Vertical ½ angle 28^0 ▪ Horizontal ½ angle 4.4^0	Fixed at: ▪ Azimuth 0^0 ▪ Elevation -34.3^0	None
GHawk_Scanner	Rectangular ▪ Vertical ½ angle 1^0 ▪ Horizontal ½ angle 1^0	Spinning Unidirectional	None
GPS_FOV	Complex Conic ▪ Inner Angle = 0^0 ▪ Outer Angle = 80^0	Fixed at: ▪ Azimuth 0 ▪ Elevation -90	None

4. GuardRail, a special purpose signal detection system, has four major subsystems: the ground based Integrated Processing Facility (IPF), the Airborne Relay Facility (ARF), the Auxiliary Ground Equipment (AGE) and the Commanders Tactical Terminal (CTT). It also has certain associated support equipment that includes maintenance facilities, storage vans and a power distribution system. A typical Guardrail mission is tethered to one, two or three special mission equipped aircraft deployed in standoff flight tracks that are within line of sight to the targeted area of interest. The system mission is to collect and locate and to analyze the collected SIGINT (Signal Intelligence and Threats) in response to higher level tasking. The system relays tactical intelligence reports to its users. The GuardRail modelled within the representative scenario has two sensors and Table 5 details its design parameters.

Table 5. GuardRail Sensor Data

Sensor	Type	Pointing Data	Targeted to
Left_Side	Rectangular ▪ Vertical ½ angle 85^0 ▪ Horizontal ½ angle 20^0	Fixed at: ▪ Azimuth 90^0 ▪ Elevation $–23^0$	None

Sensor	Type	Pointing Data	Targeted to
Right_Side	Rectangular ▪ Vertical ½ angle 85^0 ▪ Horizontal ½ angle 20^0	Fixed at: ▪ Azimuth -90^0 ▪ Elevation $–23^0$	None

5. Incorporating a Space Based Radar (SBR) into a C4ISR scenario enhances its surveillance capability by the satellite's ability to generate near-real time broad area pictures of moving vehicles throughout a large area of operation. SBR-rendered information can be further exploited for intelligence, battle management and targeting at multiple levels of command. The representative scenario has a "Surveillance Atlantic Satellite" as a space asset, modelled as an earth imaging satellite with sun-synchronous orbit and orbital elements as outlined in Table 6. The modelled surveillance satellite orbits at a speed of 17,500 miles per hour. It is modelled as a high-resolution remote sensing satellite that can see objects on the ground as small as one-meter square. The SBR modelled within the representative scenario has two sensors and Table 7 details its design parameters.

Table 6. *SBR Ephemeris Data*

Orbital Element	Value
Semi-major Axis	7054 km
Eccentricity	0.0000899
Inclination	98.19^0
Argument of Perigee	127.71^0
Right Ascension of Ascending Node (RAAN)	195^0
True Anomaly	205^0

Table 7. *SBR Sensor Data*

Sensor	Type	Pointing Data	Targeted to
Common Beam	Simple Conic ▪ Cone Angle 0.1^0	Targeted & set to tracking	Facility Ground Segment
Surveillance Camera	Rectangular ▪ Vertical ½ angle 1^0 ▪ Horizontal ½ angle 1^0	Targeted & set to tracking	Hijacked_Target, Striker_Target & Facility Ground Segments

2.1.2 Representative Scenario Execution

This section provides step-by-step instructions to execute and visualize the C4ISR-based situational awareness scenario. One should note that STK is a constructive simulator that pre-processes all the satellite orbital propagation data and aircraft's route before the scenario animation, based on user configured ephemeris and waypoint data. The representative scenario has around 10 different views each providing strategic vantage points of the theatre battle space.

1. Activate the 3-D window and click the *animate forward* button. As shown in Figure 3, one can see a Theatre-wide view along with a variety of assets and their sensor packages covering the AOI. When finished, click the *reset* button.

2. Open *Stored Views* , select `AWACS_close_up` from the list, and click *Apply* (or you could locate the view and click the button in the 3-D stored views table below). Animate the scenario. The AWACS aircraft has two sensors attached. One represents the FOV that covers the entire area the AWACS radar covers. This is a static, Complex Conic sensor with a range constraint to create a dome. The other sensor represents the Field of Regard. It shows the rotation of the sensor and can represent the true position of the beam at any instant in time. When finished, click the *reset* button.

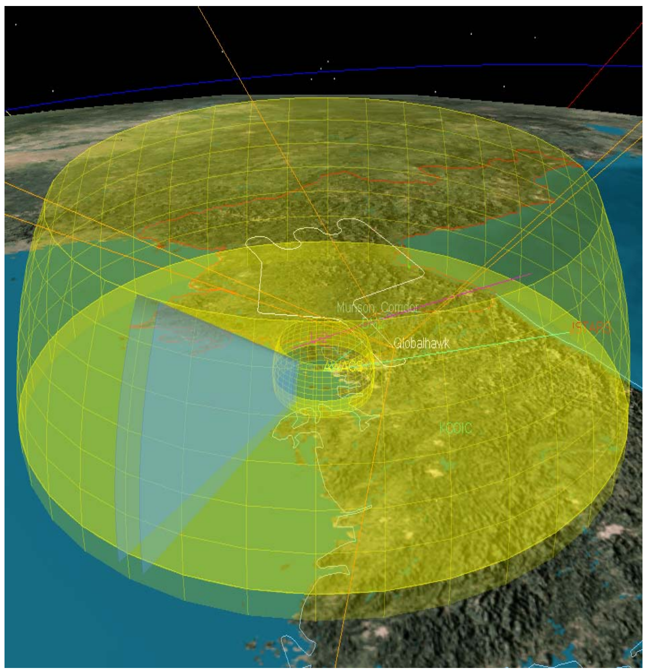

Figure 3. *ISR Theatre-Wide View*

3. To see other aspects of this scenario more clearly, turn off the AWACS radar sensors. In the *Object Browser* select the `AWACS Radar_Down` sensor. Right-click and select *Properties Browser*, and go to the *2D Graphics/Display Times* page. Change the *Display Status* to `Always Off` and click *OK*. Repeat this step for the AWACS `Radar_Up` and `Scanning_Beam` sensors. Select `Storyline1` from the Stored Views list, click *Apply*, and then animate again. Notice this Stored View not only moved us to a different vantage point, but the animation time has also jumped forward about a minute. “Threat Domes” will pop on as the Surface to Air Missile (SAM) sites is detected. Their notional sensing

ranges are represented with Sensors. Applying a “Range Constraint” to the sensor creates the sensor FOV domes. They appear when the Display Times are reached. Sensor Display Times can be set in the *Properties Browser* --> *2D Graphics/Display Times* page. When finished, click the *reset* button.

4. Select `Atlantic_Surveillance_Single_Snaps` from the Stored Views list, click *Apply*, and then animate again. As it passes overhead, shown in Figure 4, the satellite does a raster scan of targets on the ground. To collect a large area, the satellite has to slew its attitude to cover the entire area. In this particular example, a moving aircraft object is used to act as an object to point at. The satellite aligns its Z-axis with the vector to the target and follows its motion. As the satellite images a target, one can see an outline appear. Images can be added in the Globe File Editor, each image belonging to an Image Set. The Image Sets for the targets can be setup to appear at specific times, which correspond to the imaging times. When finished, click the *reset* button.

5. Select `Globalhawk_turn` from the Stored Views list, click *Apply*, and then animate again. The GlobalHawk UAV has a rectangular FOV. Four rectangular sensors represent the scanning sensor. Each of these sensors is setup as a Unidirectional Spinning Sensor, with display times set to display each sensor one at a time. The times are synchronized to look like the sensors are scanning back and forth, up and down. When finished, click reset.

6. Select the `Globalhawk_to_GPS` chain in the Object Browser, right-click, select *Properties Browser***,** and go to the *2D Graphics/Attributes* page. Under *Animation Graphics* turn *Show Line ON* and click *OK*. Select `Globalhawk_close_up` from the Stored Views list, click *Apply*, and then animate again. One should see access lines to the GPS constellation turn on. The red disk represents the minimum angle for GPS signal reception based on the antenna position on the vehicle. GPS guided UAVs will have to handle changing visibility to GPS as they maneuver through turns and encounter changing terrain. When finished, click the *reset* button.

At this point, STK will start the animation of the representative scenario as illustrated in Figure 4.

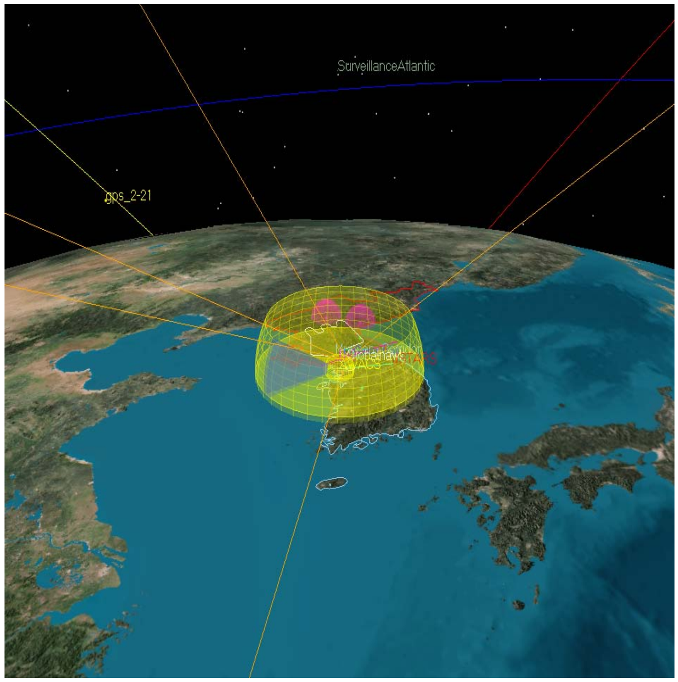

Figure 4. *ISR Space-Based Surveillance View*

2.1.3 Intelligence Cycle Overlay

The military intelligence cycle measures the impact of C4ISR systems within a given operational context. Examples include: communications survivability, resistance to countermeasures, and the ability to formulate distribution plans and create/provide a Common Operating Picture (COP).

As shown in Figure 5, TPED is an ISR infrastructure capability breakdown that overarches the intelligence cycle. Each phase of the TPED straddles the two adjoining phases of the underlying intelligence cycle. The suitability of STK in meeting the needs of these various phases are detailed below.

STK's suitability to "Tasking": The "Planning and Direction" and "Collection" phases leverage the "Tasking" capability within the intelligence cycle. This initial phase of the intelligence cycle involves drawing up specific collection requirements, the actual gathering of the raw information needed to produce finished target specific intelligence. The "Surveillance Atlantic Satellite" modelled within the representative scenario satisfies this "Tasking" capability as it images the area of interest assigned for surveillance and detects any ground moving targets. With the exception of Sensor-to-Target Line of Sight (LOS), no other detection criteria are clamped during this phase.

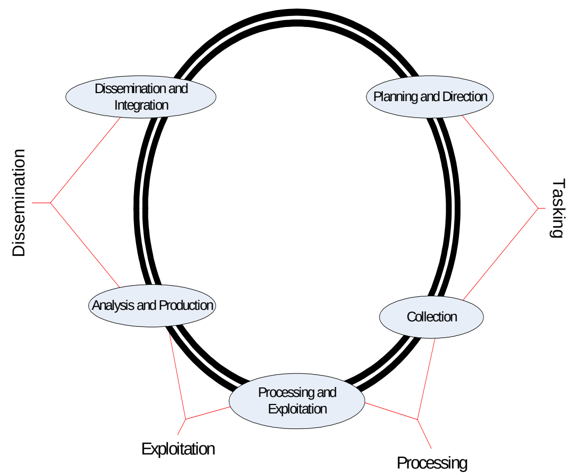

***Figure 5.** Intelligence Cycle*

STK's suitability to "Processing": The "Collection" and "Processing and Exploitation" phases leverage the "Processing" capability within the intelligence cycle. This phase involves processing the vast information of raw data collected and converting them into a form usable by analysts. This may include decryption, translations and reduction leading to "data fusion" as obtained from several disparate sources. The "As-Is" visualization architecture partially models the "Processing" capability of the intelligence cycle. Specifically, AWACS and Global Hawk UAV are modelled within the representative scenario to support this phase by providing situational awareness of the theater battle-space. Detection evaluation done on-board AWACS, fusion of raw detection data by one or more SBR or SAR sensor's respective Ground Segments, all of which are part of the "Processing" capability, are not currently modelled within the representative scenario.

STK's suitability to "Exploitation": The "Processing and Exploitation" and "Analysis and Production" phases leverage the "Exploitation" capability within the intelligence cycle. Analyzing processed data essentially means evaluating and integrating often-fragmented data into an intelligence product. The data is analyzed for its validity, reliability and relevance within the context of "Sensor-to-Shooter" objectives. This phase tracks any movement of a detected and validated target, thus providing updated information. The underlying phases of "Exploitation" capability are not currently modelled within the representative scenario.

STK's suitability to "Dissemination": The "Analysis and Production" and "Dissemination and Integration" phases leverage the "Dissemination" capability within the intelligence cycle. Such a capability is responsible for distributing "mission executable data" including mission and combat specific data such as "Desired Mean Point of Impact", attack timing, and combat tasking to the lower units. For example, a combat tasking, which would include actual routing of an interceptor towards the target, its axis of attack and weapons release settings, would be distributed to end units. The underlying phases of "Exploitation" capability are not currently modelled within the representative scenario (due to module licensing issues).

2.2 "To-Be" Visualization Architecture

The "As-Is" visualization architecture presented in the previous section is based solely on the capabilities offered within the STK software package. As such, it takes advantage of the numerous features and capabilities within that package that map well to the C4ISR domain. While facilitating a demonstration of the potential of visualization, the expectations of what could be achieved within this initial effort had to be adapted to fit the limitations of the tools available, their relative state of development and time constraints. In particular, the focus of the initial effort was on the required modelling to provide appropriate visualization of the various assets, systems and techniques used within the representative scenario. Categorized as the "As-Is" visualization architecture, this approach provided a limited degree of capability visualization, but did not offer the breadth and versatility of representation which is ultimately desired. The "To-Be" visualization architecture is intended to address a broader, more complex, adaptive and flexible approach to representing and visualizing capabilities.

Consequently, in order to progress from the "As-Is" standalone visualization architecture towards a broader, more encompassing "To-Be" visualization architecture, there is a need to provide the ability to integrate functionalities and capabilities from disjoint tools and technologies together. Therefore, in evolving from the "As-Is" towards the desired "To-Be" Integrated Visualization Architecture (or IVA), STK must be capable of functioning within a complex, multiple application environment made up of various Capability Engineering tools such as shown in Figure 6. Each tool would interact with STK in a distributed fashion over the network, exchanging relevant data about entities in the scenario, with the goal to provide enhanced information presentation and analysis of the systems and components. The premise is to augment STK with tools that provide domain-specific visualization and analytical functionalities to enable end users to observe and interact with a broader picture of a scenario and its capabilities.

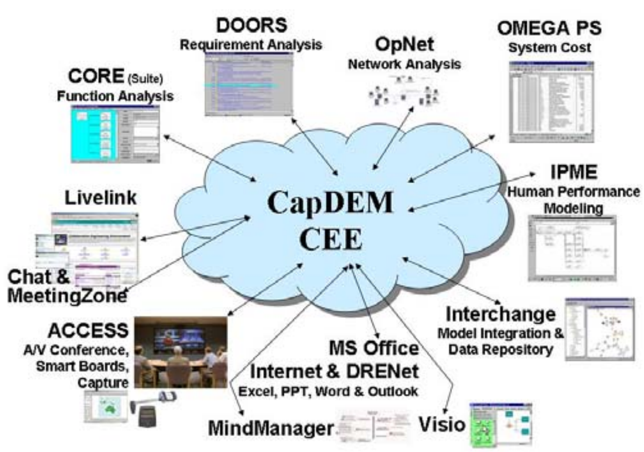

Figure 6. *Capability Engineering Tools – The CapDEM Collaborative Engineering Environment*

The anticipated structure of the IVA would embed STK (as an ActiveX control via the "STK/X" module) within a Windows application that itself would serve as an augmented "visualization hub" for all IVA tools and technologies (see top half of Figure 7). Such an application would internally launch STK, prompting the user to load a scenario from a repository (or author one from scratch). As a minimum requirement, the "first generation" IVA should be able to load the scenario initialization parameters from the shared repository (e.g., InterchangeSE), interactively animate the scenario and communicate scenario specific parameters with domain-specific Capability Engineering tools. This connectivity would allow the additional tools to provide auxiliary visualization and/or analysis functionality (via end user interaction) or serve as additional domain-specific "compute engines" within the IVA. The increased availability of inter-application communication results from developing COM-aware interfaces supported by the "STK/X" module. As a result, various Capability Engineering tools, as represented by the CapDEM CEE, could be more easily connected to STK via industry standard interfaces.

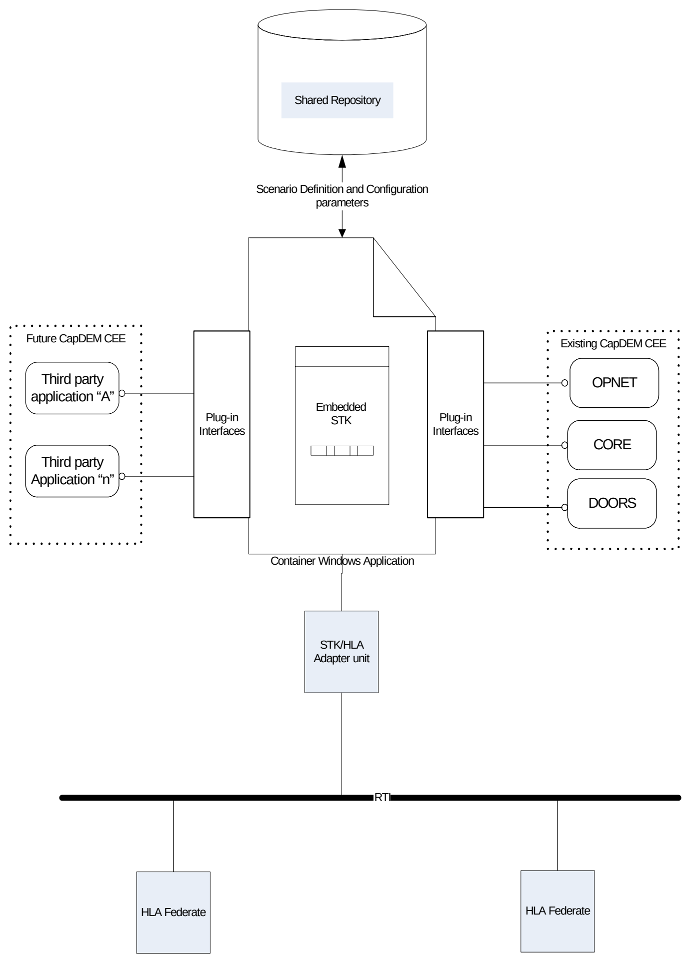

Figure 7. *"To-Be" Integrated Visualization Architecture*

Notwithstanding the specifics of which additional Capability Engineering tools or systems could eventually become part of the IVA, the simple inclusion of these additional technologies creates a broader and more informationally diverse scenario. Consequently, there will be a need to provide additional definition and descriptive information on what elements constitute a scenario within the “To-Be” architecture. For example, the relationship between an OpNet representation of an entity vs. its STK description, and the data/relationships to be modelled would need to be identified and represented. This additional information would require the definition of an IVA scenario description methodology, such as the use of a markup language (e.g., an XML-based derivative) to define the relationships and complex meta-systems (i.e., systems of systems) that would result. While identified as a necessary aspect of IVA, further investigative and developmental efforts in this area are required.

In terms of structure and user interaction, the initial IVA would likely be designed as a standalone application. While this approach would facilitate easier and more stable development, the eventual goal is to provide a browser-based interface (e.g., one which could run inside Internet Explorer or equivalent). Doing so would significantly increase availability and accessibility to the IVA via a light-weight interface, ensuring it could be used and controlled more easily on and/or across different network environments. This style of user interface would also promote integration into increasingly common portal-based systems, like that used by the CapDEM CEE. Such an approach would also more easily fit within and adapt to current and future trends in user interface and application design.

A “second generation” IVA is intended to further augment the computational, functional and visualization potential of such an environment through integration with HLA-based simulation systems (see the lower half of Figure 7). Through the use of an “adapter” [9] between STK and an HLA-based federation, IVA could serve as a combined control, analysis and visualization hub, linking the HLA-based simulation environment to the functionality provided by the Capability Engineering tools (since most of them are not HLA-based). From an HLA perspective, the STK/Capability Engineering tool hub would serve as a federate (albeit a complex one) within the federation. Such an approach would provide the potential to utilize the simulators’ functionalities in support of the Capability Engineering tools as deployed within the IVA. Consequently, such an approach offers the potential to provide a truly integrated and synergistic collaboration between the traditional “world” of simulation and Capability Engineering.

3. Advancing Visualization: Issues and Considerations

This section provides a brief overview of the issues that arose during this initial exploratory study in providing capability visualization. Several problem areas that may arise along the migration path from an “As-Is” to “To-Be” visualization architecture are also presented.

Most notably, STK is a COTS product that does not support out-of-the-box “plug-in” interfaces. This limitation means that a fairly large set of desirable Capability Engineering tools do not readily connect to its “out-of-the-box” configuration. In order to integrate such tools, interfaces need to be designed and implemented within a more broadly designed capability visualization architecture. From a long-term developmental and maintenance perspective, each version upgrade for a given tool could impact the suitability of such interfaces, possibly necessitating changes to ensure continued interoperability and functionality. Efforts must therefore be made to minimize such extra effort through comprehensive and well thought-out upfront design.

The following are some of the current adaptation issues. By highlighting them, constructive analysis, recommendations and solutions can then be considered in moving towards an IVA.

- Users need to be familiar with a significant amount of low-level detail with respect to the creation, use and manipulation of various types of STK objects; these include: sensors, radars, coordinate systems (and pertinent transformations using “Vector Geometry Tool”), various types of terrain and image data and their transformations to provide reasonable animation of the battle space.
- Data formats come in a wide variety of types. Even though data types are conceptually structural representation of byte sequences, the “data transfer” interface commands used for STK network communications in client/server mode only work with string formats (i.e., series of ASCII characters). In moving towards IVA, data formats and their conversion towards “Connect Module compliance” could become very critical in order to integrate third-party applications. At the time the original “As-Is” architecture and representative scenario were constructed, there was no strategy in place to handle this diversity. Subsequent awareness of an STK add-on module known as “Flight Control” from Simulyze [10] may be useful in addressing this issue. In either case, however, further investigation is required.
- In order to develop a scaleable visualization architecture that permits interactive exploration of large volumes of data, a high-performance storage and networking infrastructure is essential. Additionally, a large high-performance repository would be required to address not only the storage but the management (e.g., on-demand access) of the large graphic datasets used for scenario rendering. For example: Digital Elevation Terrain Data (DTED) and geo-referenced geo-TIFF images. The potential of additional multimedia content, such as video and audio, also requires these issues be addressed properly.

- As a self-contained standalone tool, STK is not equipped with a central module to handle a multiplicity of incoming detection data from different sensors and then provide further "global" processing such as cross-cueing, tasking, data fusion and track fusion. This limitation directly impacts on STK's ability (or lack thereof) to comply with all phases of the military intelligence cycle and its support of TPED.
- EO/IR imagery, ISAR/MTI and acoustic sensors are not currently supported by STK. They are, however, required as part of providing the kinds of intelligence essential for "information dominance" within military intelligence cycle.
- The cells marked "undetermined" within the "STK Requirement Resolution Matrix" (see Table 1), need to be addressed. Since different scenarios will require different STK module support, resolving undetermined requirements would define the path for what is needed to demonstrate Capability Engineering in a particular capability context. This need to map STK modules to support scenario requirements illustrates the need to map capabilities to the functional support with STK and any other such tools which may be employed within an IVA.
- Many of the Capability Engineering tools by themselves are functionally complex and often informationally voluminous. In order to correlate the use of different tools "Contextual Determinants", as defined by Canadian Space Agency (CSA), can help build mission-centric and interface-friendly data. CSA adopted the concept of "Contextual Determinants" in order to piece together functionally disparate but contextually convergent software modules in-to one large cohesive system. Each Contextual Determinant, as a common binding factor, not only bifurcates functionally different subsystems and modules, but also guides interface development and deployment. Such correlation components that can interface and provide traceable links across desirable Capability Engineering tools needs to be identified. For example:
  - A "communication parameter" could be viewed from STK's perspective as an "asset-to-jammer" visualization, utilized by OpNet for network analysis and evaluated in DOORS/CORE as to its satisfying a particular functional or system requirement.
  - A "Fire Mission" could be viewed from STK, Joint Semi-Automated Force (JSAF) and OpNet, with each tool providing its own view(s) of the determinant while supplementing the capability of the other tool.
- To enable a higher level of fusion and to enhance all-source analysis, the visualization architecture needs a robust and widely-supported network communication architecture. To this end, HLA is a candidate for further study due to its ability offer connectivity with numerous simulation packages that are of potential interest.
- Each refinement phase of "To-Be" visualization capability needs to be version-controlled and documented. That is, an appropriate amount of "configuration management" needs to be applied to the development of the architecture due to its complex, multi-system nature. To this end, the spiral development methodology adopted by CapDEM needs to be supplemented by a robust software development practices that allows structured implementation of IVA while it evolves.

- Measurements of the capabilities being visualized, experimented with and/or evaluated need to complement the measures applicable to the specific component entities within the capabilities themselves. Consequently, appropriate Measures of Effectiveness (MOE) and Measures of Performance (MOP) must be defined for both the capabilities and their component systems. In concert, how such measures are to be presented to the users, both visually as well as for analytical purposes, must be addressed. Such methods must consider how to do so both in a tool-independent manner as well as in terms of the specific technologies being used within the IVA.

4. The Way Ahead: Conclusions and Recommendations

The intent of this work was to address the potential of visualization within and as applied to Capability Engineering. To illustrate such potential, Maritime ISR was chosen as the "Capability Demonstration Context" within the C4ISR "Capability Area" to demonstrate the utility of systematic linkages between capability conceptualization and system/component functionalities. In doing so, "ISR Visualization" was identified as one of the key functional components to facilitate analysis, annotation, visualization and collaboration within a scalable synthetic computing environment.

Towards that end, this document reported on the results of an initial exploration of STK towards capability visualization, including its effectiveness and issues resulting from its use as a standalone application. Also included was an exploration of the design, integration and implementation issues underlying an executable architecture approach to capability visualization, based in part on CapDEM's incremental and evolutionary methodology. The result was a two-stage approach to capability visualization, namely the "As-Is" STK-only visualization architecture and the proposed "To-Be" Integrated Visualization Architecture, or IVA.

Within both cases, STK served as the primary means of visualization – i.e., the "visualization hub". Initially, the effort looked at the existing stove-piped "As-Is" capability of STK in standalone mode. Using a mix of ground, airborne and space ISR assets, a representative scenario was developed and used to illustrate the ability of STK to visualize specific capabilities. Additionally, STK's "out-of-the-box" capability to support Tasking, Processing, Exploitation and Dissemination (TPED) within the military intelligence cycle was also explored.

To more fully realize the potential effectiveness of STK in terms of capability visualization, the CapDEM CEE tool suite was introduced to provide broader, more rigorous and more informed perspective of the capabilities being visualized. As such, it formed the basis of the "To-Be" Integrated Visualization Architecture. The realization and evolution of the IVA concept proposed within this document will best be developed using a number of iterations. As part of doing so, the following steps need to be taken into account:

- Formulation of a methodology for information exchange/sharing between the IVA and each of its components. That is, for each known Capability Engineering tool (i.e., the CapDEM CEE), determine how best to interface the desired tool to the visualization architecture. Doing so would include identifying the kinds and formats of information each tool would need to exchange, based in part on what the capability/functionality it brings to the IVA.
- Formulation of a strategy to support connectivity to and information exchange/sharing with both current and future tools, including those in the CapDEM CEE. Such a strategy would need to consider the reality of the above methodology

as well as the general trends in application integration (ranging from specific technologies to enterprise architectural approaches).

- Design and implementation of appropriate adapter interfaces to enable broader distributed connectivity; for example, connection to HLA-based systems to utilize real-time ISR visualization data from (simulation) systems at geographically distant locations.
- Investigation and formulation of a scenario description methodology. Such an approach must support the specification of complex system-of-systems relationships (which constitute the basis of capability definition) along with taking into account the extensible nature of the IVA and how its different components would play a role in capability visualization.
- Investigation of how to provide flexible and adaptive user interface integration for the multiple tools that are likely to constitute the IVA. Exploration of various user interface designs with due consideration to the constraints of the component applications would be prudent.
- Investigation and identification of appropriate MOEs and MOPs relevant to a "Capability Demonstration Context" and a roadmap for their exploitation within the IVA.

Based on this initial effort, STK was deemed to offer a good basis for situational awareness animation while facilitating cross application data exchange through the use of a plethora of "data transfer" interface commands, domain-specific add-on modules, and ready-to-integrate interfaces. Concern over STK's complexity of use is primarily due to the need to sufficiently understand the details of individual components as part of providing accurate component behaviour for analysis and visualization purposes. Further work on how to simplify this aspect would be beneficial to future IVA development.

STK can therefore be seen to easily evolve as a key capability visualization tool within IVA. As the application of Capability Engineering continues to advance, IVA's utilization of various technologies and interoperability with the other services will need to expand, including the use of interactive multimedia and collaborative technologies such as animated scenarios, high-resolution imagery and shared, multi-application environments. Ultimately, such improvements should be balanced by the architecture's ability to interface with more collaborative joint intelligence processing systems at national, theatre, and tactical levels to make the best use of the additional data. Through the resulting breadth of representation, IVA's users, be they operators, analysts, scientists or decision makers will be able to more easily digest a wide array of highly interdependent information. As a result, Capability Engineering will play an increasingly powerful role within scalable synthetic computing environments through the provision of an interactive, collaborative and knowledge-based approach to network-centric simulation.

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List of symbols/abbreviations/acronyms/initialisms

AMTI	Air Moving Target Indicator
AGE	Auxiliary Ground Equipment
AOI	Area of Interest
ARF	Airborne Relay Facility
ASCII	American Standard Code for Information Interchange
AVI	Architecture de visualisation intégrée
AWACS	Airborne Warning and Control Systems
C2PC	Command and Control for the Personal Computer
C3	Command, Control and Communications
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
CapDEM	Collaborative Capability Definition Engineering and Management
CBP	Capability-Based Planning
CEE	Collaborative Engineering Environment
COM	Component Object Model
COTS	Commercial Off-The-Shelf
CSA	Canadian Space Agency
CTT	Commanders Tactical Terminal
DCOM	Distributed Component Object Model
DIGCap	Définition, ingénierie et gestion collaboratives des capacités
DIS	Distributed Interactive Simulation
DND	Department of National Defence
DTED	Digital Terrain Elevation Data

ELINT	Electronic Intelligence
EO	Electro-optical
ESM	Electronic Support Measures
EW	Electronic Warfare
FC	Forces Canadiennes
FOV	Field of View
GCCS	Global Command and Control System
GMTI	Ground Moving Target Indicator
HLA	High Level Architecture
ICSO	Image commune de la situation opérationnelle
IPF	Integrated Processing Facility
IR	Infrared
ISAR	Inverse Synthetic Aperture Radar
ISR	Intelligence, Surveillance, and Reconnaissance
IVA	Integrated Visualization Architecture
JSAF	Joint Semi-Automated Forces
JSTARS	Joint Surveillance and Target Attack Radar System
LEO	Low Earth Orbit
LOS	Line of Sight
MDN	Ministère de la Défense nationale
MOE	Measure of Effectiveness
MOP	Measure of Performance
MSDN	Microsoft Developer Network
MTI	Moving Target Indicator

MTIX	Moving Target Indicator Exploitation
NRTD	Near Real-Time Dissemination
NRTI	Near Real-Time Intelligence
ODBC	Open Database Connectivity
PDT	Programme de démonstration de technologies
RSR	Renseignement, de surveillance et de reconnaissance
RTI	Run-Time Infrastructure
SAR	Synthetic Aperture Radar
SBR	Space-Based Radar
SIGINT	Signal Intelligence
STK	Satellite Tool Kit
TBD	To Be Determined
TCP/IP	Transmission Control Protocol / Internet Protocol
TDP	Technology Demonstration Program
TIBS	Tactical Information Broadcast System
TIFF	Tagged Image File Format
TPED	Tasking, Processing, Exploitation and Dissemination
TRAP	Tactical Related Applications
UAV	Unmanned Aerial Vehicle
VO	Visualization Option
WAS	Wide Area Surveillance
XML	eXtensible Markup Language

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(U) Within Capability Engineering, there is an increasing need to provide visualization as part of addressing capability conception, generation and engagement. By employing visualization technologies within a collaborative synthetic environment, the immediate impact of decisions and actions on an entire capability can be investigated and explored by the broad range of participants involved within the Capability Engineering effort.

(U) To this end, the CapDEM (Collaborative Capability Definition, Engineering and Management) TDP initiated an explorative study to evaluate the potential of currently available tools and technologies that can suitably aid in capability visualization and analysis. This report explores the potential of Satellite Tool Kit (STK) to visualize scenarios pertinent to C4ISR – the "Capability Area" selected due to its relevance to the DND/CF. The study also assesses the ability of STK to serve as a “visualization hub,” leveraging the potential of other Capability Engineering tools within a proposed Integrated Visualization Architecture (IVA).

(U) The explorative study revealed that STK can provide a reasonable “As-Is” standalone visualization capability. A potential difficulty, however, is the complexity, learning curve and high cognitive load associated with detailed model development within STK in order to produce accurate and appropriate visualizations. Issues pertinent to being fully compliant with the military intelligence cycle and how to move towards developing a full-fledged “To-Be” IVA, including interface and developmental efforts relative to the broader Capability Engineering tools, were also examined.

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Capability Engineering
Collaborative Engineering Environment
CEE
Satellite Tool Kit
STK
Visualization
Integrated Visualization Architecture
IVA
Capability Visualization
C4ISR

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