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CAGE IIIA Distributed Simulation Design Methodology

Dave Bowen, Michael Galister, Michael Slade and John O'Neill

Joint and Operations Analysis Division
Defence Science and Technology Organisation

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ABSTRACT

While there is a considerable body of scientific knowledge on the principles for designing simulations, there is a gap in translating these principles into the pragmatics for designing large-scale, distributed, peer-to-peer federated simulations at the coalition level. CAGE IIIA successfully implemented a fully distributed, federated simulation environment that stimulated each Nations C2 systems. This report describes the Distributed Simulation Design methodology that was developed and trialled by DSTO during the CAGE IIIA experiment to enable the pragmatics of designing and implementing a fully distributed, federated simulation environment.

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DSTO Defence Science and Technology Organisation
506 Lorimer St
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Telephone: 1300 333 362
Fax: (03) 9626 7999

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Executive Summary

The Coalition Attack Guidance Experiment (CAGE) IIIA is the third in an ongoing campaign of coalition human-in-the-loop experiments. The CAGE Campaign Objective 6 is to "Improve the methodology and analysis tools for scientific analysis of cross-boundary issues in distributed experimentation". In addition Technical Panel 8 of the Joint Systems Analysis group under The Technology Cooperation Program (TTCP JSA TP8) have been tasked to leverage the CAGE campaign to develop an addendum to the Guide to Experimentation (GUIDEX) that focuses on the pragmatics of distributed experimentation and to develop a distributed simulation design methodology.

While there is a considerable body of scientific knowledge on the principles for designing simulations, *there is a gap in translating these principles into the pragmatics for designing large-scale, distributed, peer-to-peer federated simulations at the coalition level* [Jessee, S. et al., 2013d].

The distributed simulation design problem confronting a fully distributed, federated simulation environment as represented by the CAGE campaign of experiments is that there is no central design authority, but rather a federation of systems owned, developed and operated by each nation with an agreed upon purpose, i.e. an Acknowledged System of Systems (SoS) [DoD OSD 2008]. Standards such as Federation Development and Execution Process (FEDEP), Synthetic Environment Development and Exploitation Process (SEDEP), Distributed Simulation Engineering and Execution Process (DSEEP) and Kweley and Wood [Andreas Tolk et al. (2012)] all assume a central design authority and thus full control of the system of systems (i.e. a Directed SoS [DoD OSD 2008]) that result from the federation.

CAGE IIIA successfully implemented a fully distributed, federated simulation environment that stimulated each nation's C2 systems. Each nation was responsible for building their own simulation environment for their area of operation. The national simulations environments were then federated together enabling entities to move across areas of operation and to be available in the other nation's simulations. The advantage of designing a distributed, federated simulation environment is that there are no dependencies between nations for simulation services. In situations where a nation is off the network during experiment conduct, the other nations can continue functioning. As a result within the CAGE environment "*there is a fundamental requirement to ensure each nation retains control of their simulations, while federating at execution time in a peer-to-peer manner*".

Recommended way forward

The distributed simulation design methodology developed through CAGE IIIA and presented in this report has demonstrated sufficient utility and robustness that it should continue to be used and developed in both the CAGE campaign of experiments and similar exercises/experiments that exploit distributed federated simulations.

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Jessee, S., Hill, A., Flahive, A., *The TTCP Coalition Attack Guidance Experiment (CAGE II) Final Report,* TR-AER/JSA-1-2013, 2013.

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Acronym List

Acronym	Definition
ACE	Airspace Coordination Element
ACO	Airspace Control Order
ACSO	Air Control Support Officer
AD	Active Directory
ADA	Air Defense Artillery
ADF	Australian Defence Force
ADSI	Air Defence Systems Integrator
AEW&C	Airborne Early Warning and Control
AFATDS	Advanced Field Artillery Tactical Data System
ALI	Air Land Integration
ALIC	Air Land Integration Cell
AMACE	Amphibious Airspace Coordination Element
AMALO	Amphibious Air Liaison Officer
AMD	Air and Missile Defense
AMDWS	Air and Missile Defence Work Station
AMHS	Automated Message Handling System
AMO	Air Mobile Operations
Analyst Notebook	Data analysis environment that allows analysts to quickly collate, analyse and visualise data from disparate sources
AO	Area of Operations
AOD	Air Operations Division
AOR	Area of Operational Responsibility
ArcGIS	Mapping and Geospatial mapping and visualisation tool
Arty	Artillery
AS	Australia
ASC	All Source Cell
ASCII	American Standard Code for Information Interchange
ASIC	All Source Integration Cell
ATO	Air Tasking Order
AWG	Analyst Working Group
AWS	Analyst Work Station
BALO	Brigade Air Liaison Officer
BC	Battle Commander
BDA	Battle Damage Assessment
BFT	Blue Force Tracking
BHQ	Brigade Head Quarters
BK	Battle Captain
Bk2	Block 2
BSC	Battle Simulation Centre
C2	Command and Control
C2I	Command, Control, and Intelligence

Acronym	Definition
C2PC	Command & Control Personal Computer
CA	Canada or Canadian
CAGE	Coalition Attack Guidance Experiment
CAOC	Combined Air Operations Centre
CAP	Close Air Patrol
CAS	Close Air Support
CASEVAC	Causality Evacuation
CBF	Counter Battery Fire
CCA	Close Combat Attack
CFF	Call For Fire
CFWC	Canadian Forces Warfare Centre
CMD	Commander
CNRSIM	Command Net Radio Simulator
COA	Course of Action
COP	Common Operating Picture
COY	Company
CPAS	Collective Performance Assessment System
CRAM	Counter-Rocket, Artillery, Mortar
CSD	Coalition Shared Database
CSV	Comma Separated Value
DDG	Guided-Missile Destroyer
DIA	Defense Intelligence Agency
DIS	Distributed Interactive Simulation
DISA	Defense Information Systems Agency
DivX	DivXNetworks, Inc. media player
DHCP	Dynamic Host Configuration Protocol
DMT	Distributed Mission Thread
DNS	Domain Name Server
DODIIS	Department of Defense Intelligence Information System
DP	Decision Points
DRDC	Defence Research and Development Canada
DSN	Defence Secret Network
DSTO	Defence Science and Technology Organisation
DTED	Digital Terrain Elevation Data
ELIIXAR	Evolutionary Layered Integrated ISR Exemplar Architecture
EMT	Effects Management Tool
ESG	Executive Steering Group
EW	Electronic Warfare
EWRD	EW Research Division
EXCON	Exercise Control
FAADC2	Forward Area Air Defence - Command and Control
Falconview	Mapping software with geo-referenced overlays
FIREFOX	Web Browser
FFG	Guided-Missile Frigate

Acronym	Definition
FLEWSE	Force Level Electronic Warfare Synthetic Environment
FMV	Full Motion Video
FSR	Field Service Representatives
FW	Fixed Wing
Gb	Giga Bit
GBAD	Ground Based Air Defence
GCC	Ground Component Commander
GCCS-I3	Global Command and Control System - Intelligence
GCCS-J	Global Command and Control System - Joint
GCCS-M	Global Command and Control System - Maritime
GCS	Ground Control Station
GIA	Geomatics
GMT	Greenach Mean Time
GOTS	Government Off The Shelf
GPS	Global Positioning System
GW	Gate Way
HD	Hard Drive
HICON	Higher Control
HOA	Horn of Africa
HQ	Head Quarters
HUMINT	Human Intelligence
IA	Image Analyst
iBase	Intelligence data management application that enables collaborative teams of analysts to capture, control and analyse multisource data
ICCE	International Command & Control Enterprise, A C2PC like client for the TMS
IE	Internet Explorer web browser
IED	Improvised Explosive Device
IIR	Imagery Interpretation Report
IO	Information Operations
INTREP	Intelligence Report
IP	Internet Protocol
IPB	Intelligence Preparation of the Battlefield
IR	Infra-Red
IS	Integration Spirals
ISDS	Intelligence Shared Data Server
ISM	Immersive Mission Simulator
ISRD	Intelligence, Surveillance, Reconnaissance Division
ISR	Intelligence, Surveillance, Reconnaissance
ISREW	Intelligence, Surveillance, Reconnaissance and Electronic Warfare
ISTAR	Intelligence, Surveillance, Target Acquisition and Reconnaissance
iTRACKS	International Track Server, A C2PC like client for the TMS
J2	JTF Intelligence Officer
J3	JTF Operations Officer

Acronym	Definition
JADOCS	Joint Automated Deep Operations Coordination System
JAISREE	Joint Airborne ISR Exploitation Environment
JASAE	Joint All Source cell Analytical Environment
JCATS	Joint Conflict and Tactical System
JFA	Joint Fires Area
JFBL	Joint Fires Battle Lab
JFECC	Joint Fires and Effects Coordination Centre
JFO	Joint Fires Observer
JHU/APL	John Hopkins University and the Advance Propulsion Lab
JIPTL	Joint Integrated Prioritised Target List
JMHS	Joint Message Handling System
JMT	Joint Mission Thread
JOR	Joint Operations Room
JPR	Joint Personnel Recovery
JSA	Joint Systems Analysis
JSAF	Joint Semi-Automated Forces
JTF	Joint Task Force
JTT	Joint Targeting Tool box
Kts	Knots
LCC	Launch Control Center
LCC	Land Component Commander or Land Component Command
LHA	Landing, Helicopter, Assault
LHD	Landing Helicopter Dock
LO	Liaison Officer
Mb	Mega Bit
MIDB	Modernised Integrated Data Base
MOR	Mortar
M&S	Modelling and Simulation
MS	Microsoft
MS Exchange	Microsoft email Exchange Server
MS Office	Microsoft Office suite of products
MS Project	Microsoft Project server and client
MS SharePoint	Microsoft SharePoint Server
MUAV	Maritime Unmanned Aerial Vehicle
NAI	Named Area of Interest
NATO	North Atlantic Treaty Organisation
NAS	Network Attached Storage
NFCS	Naval Fires Control System
NG	Northup Grumman
NGS	Naval Gunfire Support
NLO	Navy Liaison Officer
NSFS	Naval Surface Fire Support

Acronym	Definition
NTP	Network Time Server
OBREP	Order of Battle Report
OIC	Officer In Charge
OneSAF	One Semi-Automated Forces
OO	Other Operations
Op	Operation
OpenFire	XMPP compliant Chat Server
ORBAT	Order of Battle
ORM	Operations Room Manager
OPSO	Operations Staff Officer
OS	Operating System
OTH-G	Over The Horizon Gold Messages
PDU	Protocol Data Unit
PED	Processing, Exploitation and Dissemination
PIMS	Portable Immersive Mission Simulator
POO	Point of Origin
POI	Point of Impact
PPLI	Precise Participant Location and Identification
R&D	Research and Development
RADAR	Radio Detection And Ranging
RAM	Random Access Memory
RLP	Recognised Land Picture
RW	Rotary Wing
SA	Situational Awareness
SACC	Supporting Arms Coordination Centre
SAN	Storage Area Network
SIMDIS	Simulation Display System
SIMRADIO	Simulated Radio
SITREPS	Situation Reports
SISO	Simulations Interoperability Standards Organisation
SF	Special Forces
SME	Subject Matter Expert
SOCET GXP	SOCET GXP is a geospatial-intelligence software package that uses imagery from satellite and aerial sources to identify, analyse, and extract ground features quickly, allowing for rapid product creation
SOP	Standard Operating Procedure
SOPSO	SACC Operations Observer
SOF	Special Operations Force
SoS	System of Systems
Spt	Support
SQL	Structured Query Language
SV	Systems View
TA	Target Acquisition
TACP	Tactical Air Control Party

Acronym	Definition
TAI	Target Area of Interest
TAP	Tactical Air Picture
TB	Tara Byte
TCP	Transmission Control Protocol
TDL	Tactical Data Link
TMS	Track Management System
TOC	Tactical Operations Centre
TORC2H	Tactical Operational Command and Control Headquarters
Transverse	XMPP compliant Chat Client based upon NATO's JCHAT
TP	Technical Panel
TP8	TTCP Joint Systems and Analysis Group Technical Panel 8 Combined Fires Demonstration and Experimentation
TST	Time Sensitive Target
TTCP	The Technical Cooperation Program
TTP	Tactics, Techniques and Procedures
TUAV	Tactical Unmanned Aerial Vehicle
TWG	Technical Working Group
UAS	Unmanned Aerial System
UAV	Unmanned Aerial Vehicle
UDP	User Datagram Protocol
UHF	Ultra High Frequency
UK	United Kingdom
US	United States
VBS2	Virtual Battlespace 2 Simulation
WK	Watch Keeper
Wyvern	Data repository and visualisation tool used by ADF Special Forces
VBS2	Virtual Battlespace 2
VHF	Very High Frequency
VLC	Video LAN Codec – an Open-source cross-platform multimedia player and framework
VM	Virtual Machine
VOIP	Voice Over Internet Protocol
VMF	Variable Message Format
XML	Extensible Markup Language
XMPP	eXtensible Messaging and Presence Protocol

1. Introduction

The Coalition Attack Guidance Experiment (CAGE) IIIA is the third in an ongoing series of coalition human-in-the-loop experiments[1]. CAGE IIIA was a coalition supported, Australian led activity conducted 28 October - 8 November, 2013 with distributed *in situ* military participation from Australia with limited participation from Canada and the UK.

The CAGE problem domain is focused on a joint and coalition task force facing battlespace integration, synchronisation, coordination and deconfliction, joint fires system interoperability, and cross-boundary control issues in the prosecution of dynamic targets and emergent targets[2].

The CAGE II and IIIA experiments were designed and conducted as large-scale, distributed, peer-to-peer federated experiments across Australia, Canada, United Kingdom, and the United States. While there is a considerable body of scientific knowledge on the principles for designing simulations, there is a gap in translating these principles into the pragmatics for designing large-scale, distributed, peer-to-peer federated simulations at the coalition level [Jessee, S. et al., 2013d].

1.1 Purpose of the Report

This report documents the distributed simulation design methodology (DSDM) being developed and used in the CAGE campaign of experiments.

Within CAGE there is no central design authority, but rather a federation of systems owned, developed and operated by each nation with an agreed upon purpose, i.e. a directed System of Systems (SoS) [DoD OSD 2008]. Standards such as Federation Development and Execution Process (FEDEP)[3], Synthetic Environment Development and Exploitation Process (SEDEP)[4], Distributed Simulation Engineering and Execution Process (DSEEP)[5] and Kweley and Wood[6] all assume a central design authority and thus full control of the system of systems (i.e. a Directed SoS [DoD OSD 2008]) that result from the federation. Within the CAGE environment "*there is a fundamental requirement to ensure each nation retains control of their simulations, while federating at execution time in a peer-to-peer manner*".

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[1] Australia observed CAGE I and fully participated in both CAGE II and IIIA

[2] Emergent targets are targets on the Joint Integrated Prioritized Target List (JIPTL) that cannot be targeted until they emerge above the detection threshold. The use of the term emergent targets was defined and agreed across the CAGE stakeholder community due to differences in interpretation for dynamic targets and time sensitive targets.

[3] IEEE 1516.4 April 2003 HLA FEDEP Standard

[4] http://www.euclid1113.com

[5] IEEE 1730-1010 Recommended Practice for Distributed Simulation Engineering and Execution Process (DSEEP)

[6] Engineering Principles of Combat Modeling and Distributed Simulation, Edited by Andreas Tolk, Wiley Press, 2012

The attributes for a DSDM to develop a CAGE-like simulation environment are:

- Each nation has simulation requirements that are unique to the nation and are not shared in the federation.
- A collegial system of systems with decentralised development and control.
- Experimental objectives drive the design of both the scenario (script) and the simulation. As a result the simulation designers are not in control of the complete end system but are only responsible for a portion of the architecture; the design must respond to requirements which are driven by the experiment design and experiment execution control process.
- The need to stimulate a selection of C2 systems with realistic data and communication interfaces which are being designed and integrated by different teams through other efforts.
- Different requirements for model fidelity across the various simulations and sites.
- Heavy reliance on Government Off The Shelf (GOTS) Software Simulation environments (Joint Semi-Automated Forces (JSAF), One Semi-Automated Forces (OneSAF), Joint Conflict and Tactical Simulation (JCATS) and commercial products like Virtual BattleSpace 2 (VBS2).

Constraints on the DSDM are:

- A constrained bandwidth which leads to the requirement for filtering of information exchange between nations and within national sites; and the potential to introduce novel capabilities such as the local construction of Full Motion Video (FMV) being created from other nation simulations.
- The lowest common means for federation across the nations is Distributed Interactive Simulation (DIS)[7] and the High Level Architecture Real-time Platform Reference Federate Object Model (HLA RPR-FOM)[8].
- Trading off the use of HLA and DIS within clusters of simulations to enable/disable features required by the larger federation.
- Capabilities for visualisation of simulation entities across countries and simulation platforms are different and require rationalisation.
- Differing levels of knowledge and experience in distributed simulation design and implementation.

While there is a considerable body of scientific knowledge on the principles for designing simulations, there is a gap in translating these principles into the pragmatics for designing large-scale, distributed, peer-to-peer federated simulations at the coalition level [Jessee, S. et al., 2013d].

This methodology expands upon accepted standards while integrating simulations into a larger decentralised system of systems design. This section addresses: the problem statement, the aim of the distributed simulation design methodology, an overview of the methodology, the preliminary design aspects, the detailed design aspects, the

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[7] Simulation Interoperability Standards Organization (SISO) Enumerations for Simulation Interoperability, SISO-REF-010-2011, 19 April 2011

[8] RPR-FOM Version 1.0 SISO-STD-001.1-1999

implementation aspects, the validation and verification aspects, and the assessment of the utility of the methodology in CAGE IIIA.

2. Distributed Simulation Methodology

2.1 Aim of the Distributed Simulation Design Methodology

The aim of this effort, to develop and trial a distributed simulation design methodology, is to extend the existing standards approach from addressing an Acknowledged system-of-systems to addressing a Directed system-of-systems. This extension is being achieved by incorporating appropriate systems of systems engineering approaches and extending the methodologies with systems engineering activities from the International Standards Organization (ISO) Standard 15288 and by ensuring that the methodology aligns with the experiment design methodology being developed to address the principles of The Technology Cooperation Program (TTCP) Guide for Understanding and Implementing Defence Experimentation (GUIDEx).

The key challenges for this methodology are with understanding how to:

- design it
    - define the entities; determine in which simulation the entity is implemented and determine what it is doing
    - determine which entities need to know what information about which other entities
    - determining how to apportion simulation development across the coalition
    - ensuring that entities implemented across the coalition, line up and behave correctly for mission threads.
- verify it
- manage its design and development
- integrate real C2 systems with the simulation systems
- avoid the requirement for hard specifications too early
- support the activity streams for designing an experiment
    - scenario development
    - experiment management
    - technical
    - data collection analysis.

2.2 Overview of Distributed Simulation Design Methodology

The four key steps in the methodology are: develop a preliminary design; develop a detailed design; implement a solution, and verify the design and implementation. For each of these steps we show the relationship between the process, information requirements and simulation design products. The proposed Distributed Simulation Design Methodology expands the DSEEP leveraging ISO 15288 methods to account for the distributed design aspects by adding additional control points, formal verification and validation processes and simulation design products. In addition the experience of conducting the CAGE experiments has provided lessons and issues that have influenced the methodology design.

2.3 Preliminary Design

This section presents the preliminary design stage of the proposed methodology. The preliminary design enables the developers to understand:

- stakeholder requirements
- the entities required
- the behaviours and types of interactions required
- entity allocation across simulations and nations
- entity information exchange requirements across simulation
- filtering requirements
- data requirements to support the simulation
- C2 interface requirements
- requirements for supporting the experiment objectives, and the experiment analysis activities
- Where and how it is executed. In particular:
    - Who is responsible for which portions of the overall simulation?
    - allocation of entities and behaviours to nations and simulations
    - the reporting of simulation events, actions, etc. to the C2 systems
- What validation is required and how it is validated. In particular:
    - ensuring the entity alignment and interactions
    - verifying that the visualisation meets the experimental goals
    - verifying the sensor interaction with entities
    - the latency associated with information flows within the federation and interfaces to the C2 systems is acceptable to the experiment designers
    - verifying the correlation of time, space and behaviour across simulations.

2.3.1 Overview of the Preliminary Design

The ability to execute the preliminary design is extremely dependent upon information being made available from other parallel processes associated with experiment design and scenario development. Figure 1 shows the information flows from the parallel processes and the interactions required, supporting the preliminary design, within the context of the distributed simulation design methodology. Figure 2 shows the process flow for the preliminary design step, mapping the information requirements and the simulation design products that are generated. This process was trialled in the CAGE IIIA simulation design activities. The remainder of Section 2.4 elaborates each design step.

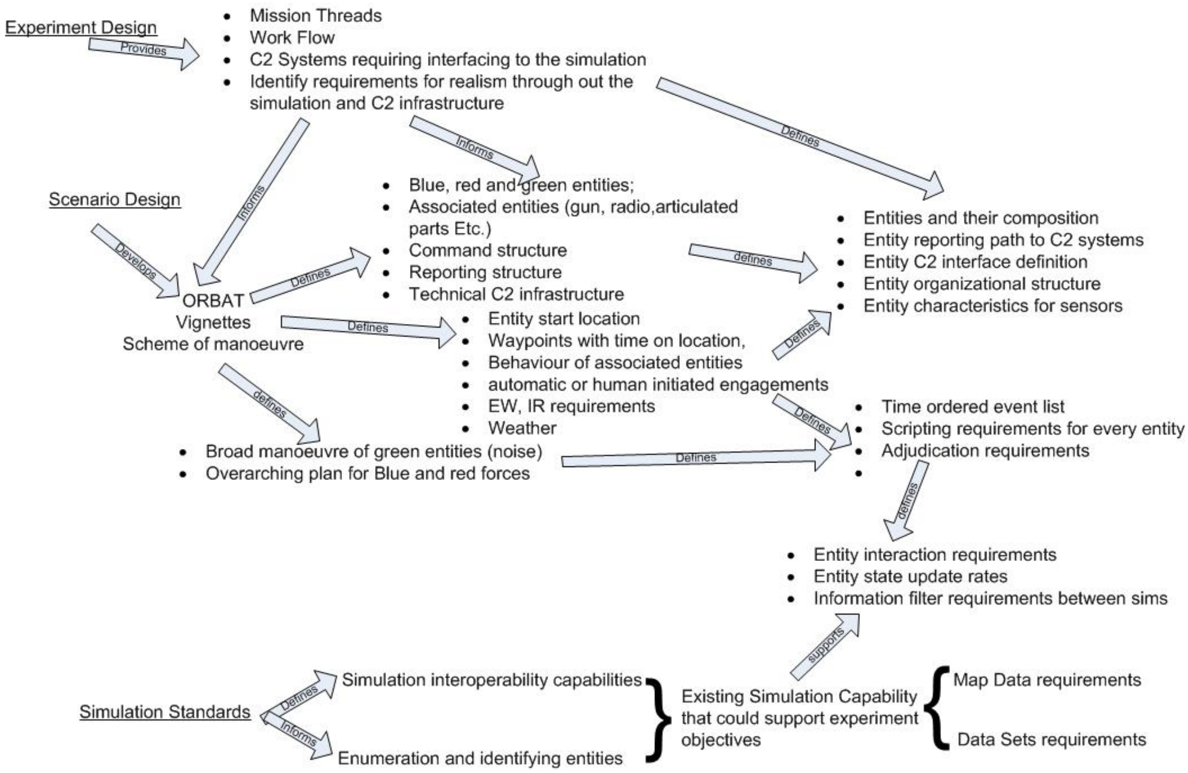

Figure 1: Preliminary Design Information Requirements

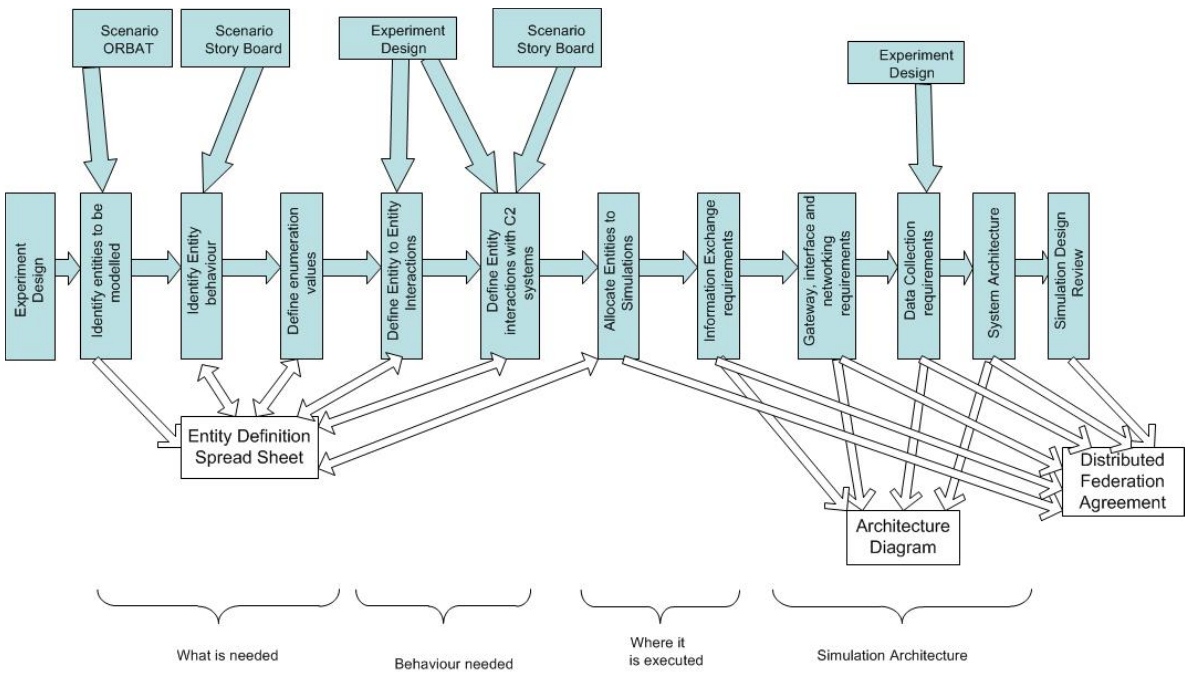

Figure 2: Preliminary Design Process

2.3.2 Driving and Eliciting Simulation Design Requirements from the Scenario Design Process

The scenario design methodology applied in CAGE IIIA consisted of four phases: Scenario Guidelines; Scenario Story board (SSB); Scenario Writing board (SWB) and Scenario Review. Each phase includes several activities that refined the scenario and increased the level of detail. The output of these activities is used as requirements for a number of internal actions within the overall experiment design. In particular the scenario script is used in the generation of the simulations.

Figure 3: Scenario Design Method shows the distributed simulation design methodology used for the CAGE experiment campaign.

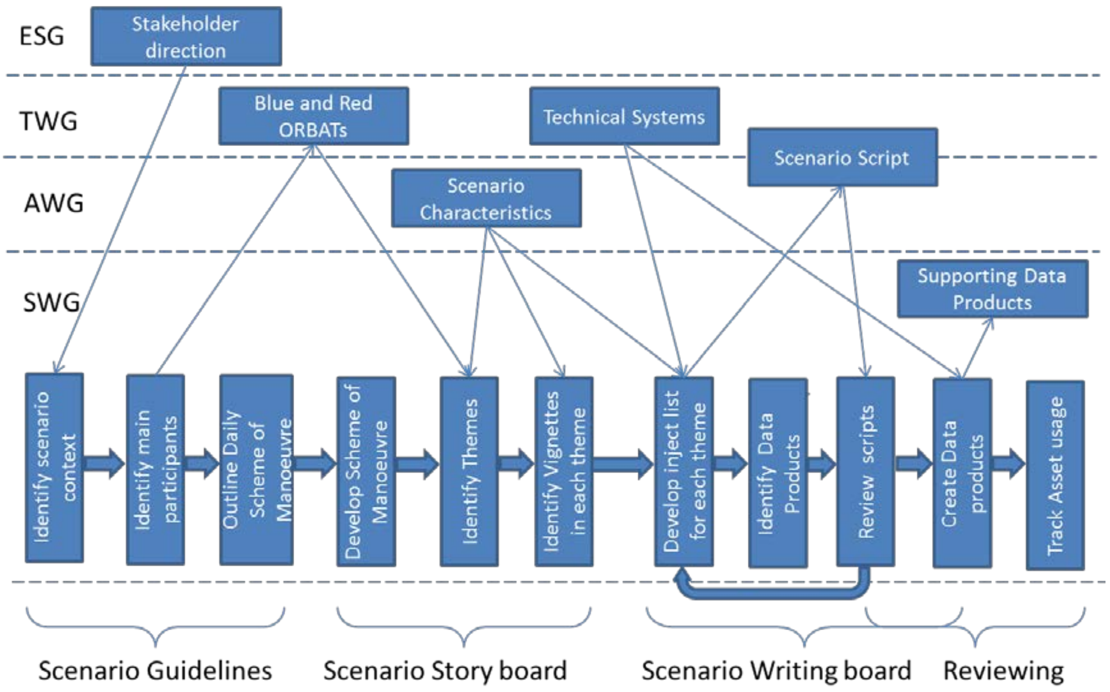

Figure 3: Scenario Design Method

The top half of Figure 3: Scenario Design Method shows the products interfaces between the SWG and the other working groups. The lower half of the figure shows the steps of the methodology over the four phases of development.

2.3.2.1 Scenario Design Products

This section describes the products that are created and then how the products inform the scenario development process.

Between the concept design conference (CDC) and the initial planning conference (IPC) several products were created to guide the design of the experiment including the scenario. These products were agreed upon at the National and Coalition levels and include:

- Experiment Objectives
- basic C2 nodes
- areas of responsibility for each country
- any national internal Areas of Responsibility (AOR)
- high level Blue/Red Scheme of Manoeuvre (SoM)
- Red ORBAT
- Blue ORBAT from each nation
- an indication of which assets are participating or being simulated.

The output products of this phase include: a detailed SoM, theme overview sheets with missions threads identified and a rough event flow chart of themes and missions.

Figure 4: Basic Scenario SoM shows the basic outline of a Scheme of Manoeuvre as well as indicating the main objectives or end-states of each day, these guidelines indicate the desired intensity as the scenario progresses.

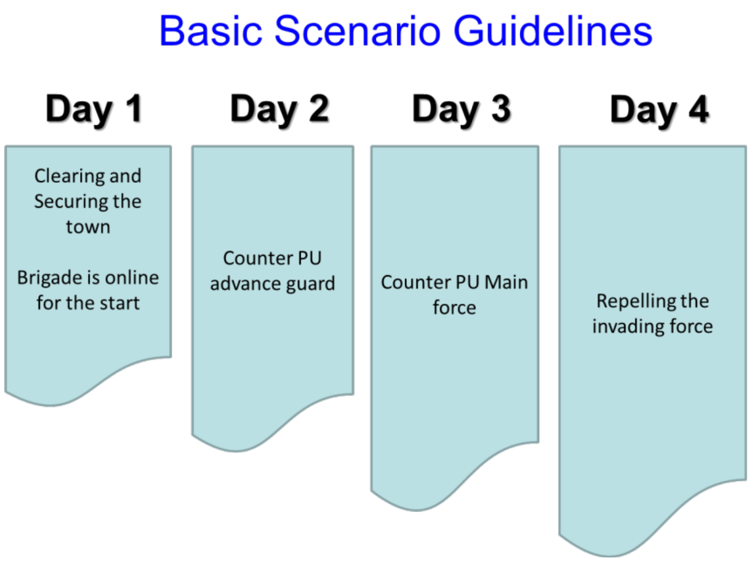

Figure 4: Basic Scenario SoM

The guidelines for the scenario also include approximate Areas of Operation (AO) or Areas of Responsibility (AOR) for each nation. This provides the simulations with the area for the simulations to interact and allows the SSB to be informed of the ability of the simulation terrain, entity and mapping capabilities to support the scenario. Figure 5: An example of a SoM for a particular scenario day in CAGE IIIA. It shows the Red force coming in from the east with Blue forces moving out from the centre. It also shows several skirmishes with red entities to the south and west. This scheme of manoeuvre provides the approximate locations of blue force elements, red force elements and civilian traffic for the start of day and the individual trials and DMTs.

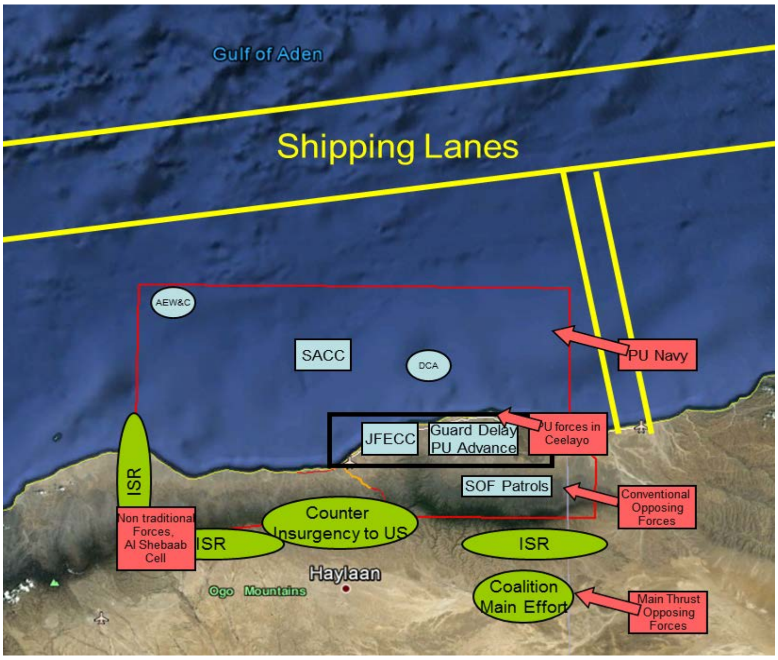

Figure 5: An example of a SoM for a particular scenario day

Figure 6 shows the linkages between themes in CAGE IIIA. The linkages enable the simulation designers to understand both the necessary and the supporting entity behaviours. Entities whose behaviour supports the identified themes are necessary but all other entities behaviour specified in the scenario design are supporting and therefore of lower priority with regard to ensuring behaviour is correct and verified.

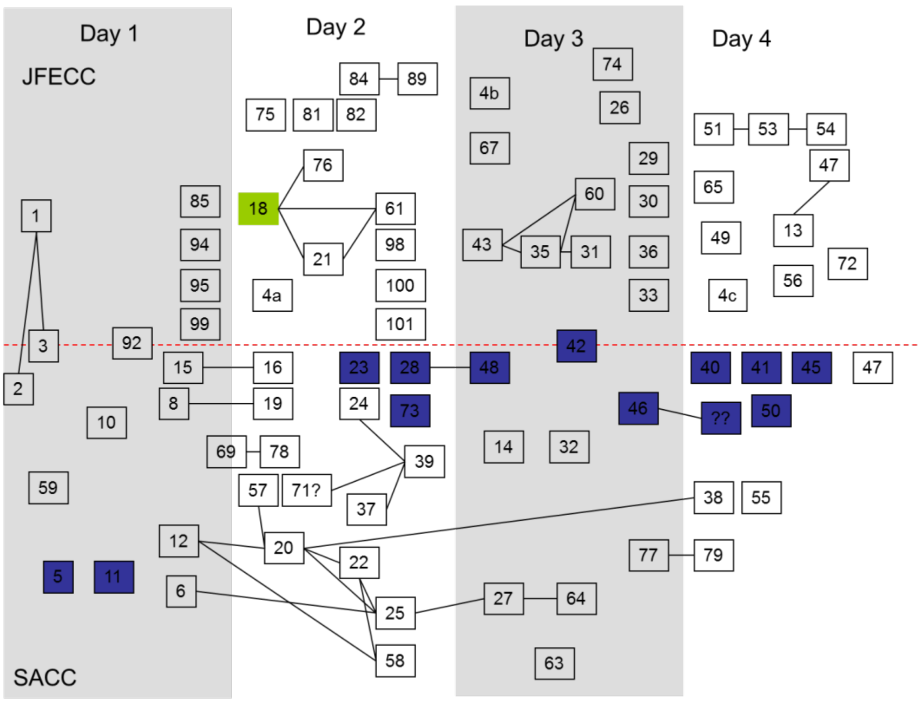

Figure 6: Shows the linkages between themes in CAGE IIIA

Injects are the external stimulus applied to the experiment participants in order to trigger certain participant behaviour. Injects include exact location, time, entities involved, and the inject source. The structure of the inject sheets produced in the SWB are driven by the needs of the simulation team who are required to translate the script into detailed simulations. The design of the inject sheets is provided below.

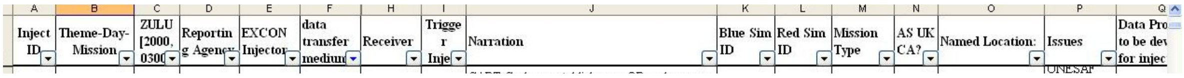

Figure 7: The template for creating the scenario script

Figure 7 shows the template for creating the scenario script with the column headings of the inject sheet for each theme. The headings read from left to right:

- Inject ID: a unique number for that inject for that day (auto assigned, for scenario control)
- Theme–Day–Mission: The mission identifier that links to the day and theme
- ZULU: the time to the minute of when the inject occurs (for scenario control, analysts, simulation design).
- Reporting agency: this is the simulation entity or other entity that is responsible for reporting this inject (i.e. a combat team, forward observer, pilot, Intel source) (For scenario control, analysts, simulation design)
- EXCON injector: this is the role within EXCON who is acting on behalf of the reporting agency to make the inject (For scenario control, technical team, simulation team).
- Data transfer medium: specifies by what means the inject is provided to the participants. For example voice, chat, email, AFATDS, TORC2H message, FMV, Link 16, VMF, DCTS. (for scenario control, technical team, simulation team, analysts)
- Receiver: The participant who is expected to receive this information. (Scenario control, technical team, analysts, simulation design)
- Trigger Inject: Specifies whether this inject must be inserted at exactly this time or dependent on other events before injecting. (Scenario control)
- Narration: This is a description of the situation and what needs to be injected. This does not specify the exact wording of the inject, this narration should be scenario relevant and use military language or properly formatted messages depending on the transfer medium. (Simulation team, scenario team). This narrative also needs to indicate what is pre-scripted and what is indicative, as well the narrative needs to provide the expected outcomes versus the desired outcomes
- Blue sim ID: used to specify which blue unit the inject is from/involves. (Simulation team)
- Red Sim ID: used to specify which red target is involved/targeted in this inject. (Simulation team)
- Mission type: used to specify which mission type this inject should trigger. (Analysts)
- AS/UK/CA: Used to indicate which nation is responsible for inserting this inject to the participants. (Scenario Control)

- Named Location: Used to specify the location of the inject or entities in the inject. If the location is well known, just a name is enough. (Scenario Control, simulations)
- Issues: Used to flag possible issues with the inject. (Scenario Control, tech team, simulation team, analysts)

Figure 8 shows asset tracking across themes and time shows an example of the blue force assets used on one particular day of the CAGE IIIA scenario. Asset tracking allows the identification of resource conflicts across mission threads; or the identification of resources that are not being used (such as MRH-4 in Figure 8) that can be applied to the mission threads or deleted from the ORBAT. This Spreadsheet is reused in the detailed design as the input for the entity behaviours as described in section 2.5.2.

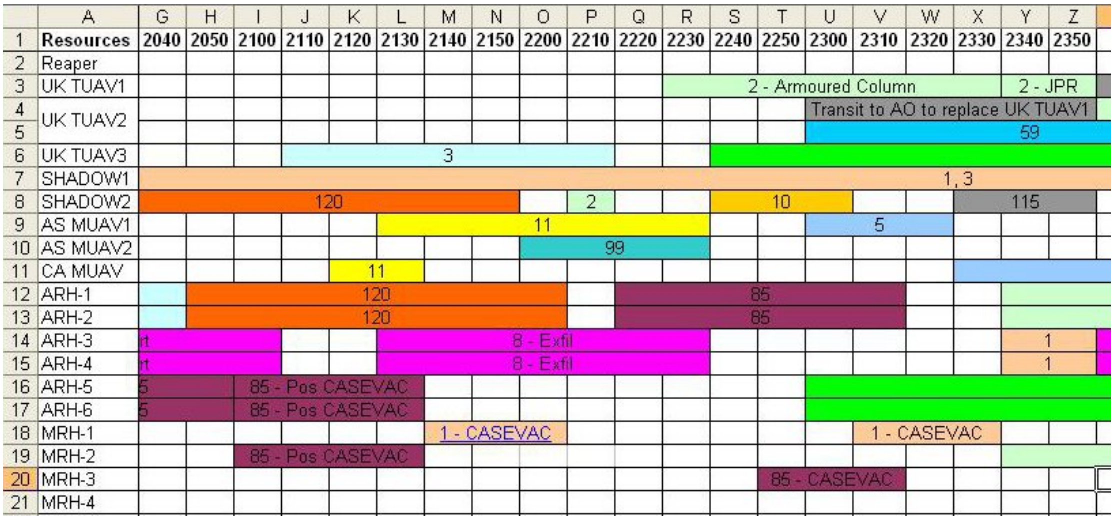

Figure 8: Asset tracking across themes and time

Once all of the individual scripts for each theme have been finalised they are combined to create a single list of injects in chronological order for each day of the scenario. This is where each theme is interwoven with all other themes for the day.

2.3.2.2 How the products inform the Scenario Development Process

At this point the single list of injects in the chronological order for each day represent the ground truth of the scenario and the products discussed in section 2.4.2.1 are used to inform the following steps in the scenario development process.

Identify Entities to be Modeled

This step involves assessing the Order of Battle developed by the scenario writers for the blue force, red force, insurgents and non-combatants, the level of background activity required to create a realistically cluttered environment, etc.

Identify Entity Behaviour

Leveraging the scheme of manoeuvre defined in the scenario the individual entities are assessed with respect to required manoeuvre and behaviours. This assessment results in a set of characteristics that the simulation will require in delivering the anticipated scenario.

This could include visualisation, articulated parts, electronic signatures, realism of movement, etc.

Define Entity to Entity Interactions
In this task the interactions between entities is assessed with respect to the scenario and scheme of manoeuvre. This identifies entities that will never interact and do not need to receive information about each other. This will feed into the filter design task later on. In addition this task will identify visualisation requirements or EW and IR signature requirements. It will identify the potential for weapon engagements between entity pairs, potential for aggregation of entities for group behaviour, etc. This analysis will provide simulation characteristics for the selection of simulations and for the allocation of entities to simulations task.

Define Entity Interactions with C2 Systems
Each of the entities are assessed to determine which C2 systems should be provided data from the entity, the type of interaction, the Tactical Data Link and associated messages that should be used, the update rates, how the interaction is initiated, how it continues, frequency requirement, etc.

The types of C2 interaction can be a blue entity self-reporting its location, an entity being sensed by entities (for example a RADAR site), reporting events that are occurring inside the simulation (significant event reporting), firing weapon systems, weapon system status, full motion video (FMV) feeds, etc. This analysis is used in selecting which simulations are required in the federation and allocating an initial set of entities to the simulations.

For each entity the appropriate C2 identifiers associated with the entity such as the Unit Resource Number (URN), 2525B symbol, call sign, IFF code, etc. are acquired from the scenario design documentation, national registries or created and associated with the entities. This data will need to be coded into the entities during the implementation phase.

Allocate entities to Simulations
In this step the information from the previous steps are used to identify which simulation environments will be federated in each country and which entities will be modeled in each of these simulations. The entity to simulation allocation will as a minimum be a function of geographic coverage, C2 interface capabilities, entity interactions, computational load, and model characteristics.

Define Enumeration values
Using the list of entities for each simulation, their nationalities (birth or manufacturing), etc. the most appropriate enumeration is identified for the entity. Once this has been done then a mapping of the entity enumeration for each type of simulation in the federation is compiled. Where holes exist in this mapping (i.e. a simulation does not have the appropriate model then the best fit model is identified and mapped to the entity. This list is used to create the HLA/DIS gateways and to map entities within simulations.

Identify Information Exchange Requirements Between Simulations
In this step identify an initial information exchange requirement from simulation to simulation and from site to site. This understanding is intended to identify simulations that do not have to interact (for example a UAV simulator may not need to interact with an EW simulator). As well, simulators that have a large geographic separation between entities and no way to sense each other's entities may not have to interface.

Define Gateway Interfaces and Networking Requirements
In this step the task is to identify the requirement to have Gateways, and filters between simulators and sites. Gateways that may be required will interface:
- HLA simulations with the DIS backbone
- simulations to C2 systems
- site to site
- nation to nation.

In addition as this assessment is performed and the Gateways identified the characteristics of the long-haul network between sites in the federation may require the Gateways to convert the network transmission from broadcast to multicast and back, change IP and ports used, block entity or PDU type transmissions.

Ensure Data Collection Plan requirements are Designed into the System
Leveraging the developing data collection plan and the EXCON requirements identify the requirement for data loggers, "god's eye view' tools, etc. within the simulation architecture. Identify the requirement for interactors and to provide EXCON with access to portions or all the simulation. Define the interaction between the simulation federation and the execution of the experiment.

Develop an Overarching Architecture of the Simulations
The preceding tasks provide the material necessary to develop a high level architecture of the simulations in the federations and their interaction with other systems and users.

Simulation Preliminary Design Review
Exiting this Stage of the design occurs through the successful execution of a Preliminary Design Review (PDR). This review assesses the outputs of each step using a walk-through of the Federation Agreement Document and the Entity Identification Spreadsheet which are used to record the data products of these steps. This step should align with the Main Planning Conference.

2.3.3 Distributed Simulation Design Products

The following section presents examples of the data products that are developed during the preliminary design process. The Data products are:
- Entity Definition Spread Sheet
- Federation Agreement
- Architecture Diagrams.

2.3.3.1 *Entity Definition Spread Sheet*

A key repository of information developed, in the various steps in the preliminary design, is the Entity Definition Spread Sheet. This spreadsheet has several tabs used to collect and correlate the different information. The tabs are:

- Blue Nations Land DIS List
- Blue Nations AIR DIS List
- Blue Nations Maritime DIS List
- Red List
- Green Entity DIS List
- Green ORBAT
- Munitions List
- URN Look up Table & C2 Interfaces.

Depending on the design some or all of these tabs would be used and it is possible that additional tabs would be required. These tabs are described below with an example of the type of data that was captured during CAGE IIIA.

Blue Nations Land DIS List

This tab of the spreadsheet records the Blue Land Order of Battle (ORBAT) and applicable information about the entities. This data is compiled from an assessment of the scenario information and then augmented through an understanding of the requirements for associated command structures to enable the simulations to link the entities into units.

Entity Short Name (green Font lifeform)	DIS ENU	ShortName	Notes	Symbol
ADA_ADAGenericLauncher_4_Engagement_Control_Station	1.1.225.28.2.2.1	CRAM		SFG*EWMA--*****
ADA_Radar_Giraffe	9.1.205.2.5.1.0	Giraffe		SFG*UUMRG-*****

Figure 9: Template spreadsheet to record blue land entities

Blue Nations AIR DIS List

This tab of the spreadsheet records the Blue Air Order of Battle (ORBAT) and applicable information about the entities. This data is initiated by an assessment of the scenario information and then augmented through an understanding of the requirements for associated command structures to enable the simulations to link the entities into units.

Air Unit	Number of Units	Type	Component Units/Entities	ENU	URN	Equipment DIS-ENU	Attachment DIS-ENU
ARH-SQN	6	Entity	ARH1	1.2.13.20.1.1.0			
			ARH2	1.2.13.20.1.1.0			

Figure 10: Template spreadsheet to record blue air entities

Blue Nations Maritime DIS List

This tab of the spreadsheet records the Blue Maritime Order of Battle (ORBAT) and applicable information about the entities. This data is initiated by an assessment of the scenario information and then augmented through an understanding of the requirements for associated command structures to enable the simulations to link the entities into units.

		Marking	Component Units/Entities	ENU	URN	SIM Allocation	One SAF Ineraction	C2 Interaction	FLEWSE Model	VBS2 Model	PIMS	Equipment DIS-ENU	Attachment DIS-ENU
AS_CAGEIII_ARG_MARITIME	LHD	Canberra	AS_MARITIME_LHD_Landing_Helicopter_Dock	1.3.13.54.1.1.0	XXXX186	One SAF	N	AFATDS	N	N	N		
		Adelaide	AS_MARITIME_LHD_Landing_Helicopter_Dock	1.3.13.54.1.1.0		JSAF	N		N	N	N		
	AWD	Hobart	AS_MARITIME_AWD_Air_Warfare_Destroyer	1.3.13.4.1.1.0		JSAF	N	AFATDS	N	N	N		
		Brisbane	AS_MARITIME_AWD_Air_Warfare_Destroyer	1.3.13.4.1.2.0		JSAF	N	AFATDS	N	N	N		
	ANZAC	Anzac	AS_MARITIME_FFH_ANZAC	1.3.13.6.2.1.0	XXXX188	One SAF	N	AFATDS	N	N	N	NGF	
		Arunta	AS_MARITIME_FFH_ANZAC	1.3.13.6.2.2.0	XXXX187	One SAF	N	AFATDS	N	N	N	NGF	
		Sydney	AS_MARITIME_FFG	1.3.13.6.1.1.0		JSAF	N		N	N	N		
		Darwin	AS_MARITIME_FFG	1.3.13.6.1.2.0		JSAF	N		N	N	N		
	L100	Choules	AS_MARITIME_Choules	1.3.13.16.2.1.0		JSAF	N		N	N	N		
	Helo	SH-60	AS_MARITIME_SH-60R	1.2.13.22.2.1.0		JSAF	N		N	N	N		
			AS_MARITIME_SH-60R	1.2.13.22.2.1.0		JSAF	N		N	N	N		
			AS_MARITIME_SH-60R	1.2.13.22.2.1.0		JSAF	N		N	N	N		
			AS_MARITIME_SH-60R	1.2.13.22.2.1.0		JSAF	N		N	N	N		
			AS_MARITIME_SH-60R	1.2.13.22.2.1.0		JSAF	N		N	N	N		
			AS_MARITIME_SH-60R	1.2.13.22.2.1.0		JSAF	N		N	N	N		
			AS_MARITIME_SH-60R	1.2.13.22.2.1.0		JSAF	N		N	N	N		
	UAV	UAV	AS-MARITIME_UAV	1.2.225.50.8.10	XXXX026	PIMS	N		N	N	N		

Figure 11: Template spreadsheet to record blue maritime entities

Red List

This tab of the spread sheet records the RED Order of Battle (ORBAT) and applicable information about the entities. This data is initiated by an assessment of the scenario information and then augmented through an understanding of the requirements for associated command structures to enable the simulations to link the entities into units.

Short Name	Side	DIS#:Puntland-300, Alshebaab-195	SIM Allocation
60mm_Motor_Gunner	PUNTLAND	3.1.300.1.228.103	OneSAF
BTR-70-Generic	PUNTLAND	1.1.222.2.12.1.0	OneSAF
BTR-70BREM-Repair	PUNTLAND	1.1.222.2.12.8.0	OneSAF
BTR-70KshM-Command	PUNTLAND	1.1.222.2.12.7.0	OneSAF
BTR-70MS-Comms	PUNTLAND	1.1.222.2.12.6.0	OneSAF
BTR-70SPR-2-Jammer	PUNTLAND	1.1.222.2.12.5.0	OneSAF
D30 - HOW	PUNTLAND	1.1.222.5.4.0.0	OneSAF

Figure 12: Template spreadsheet to record red entities

Green Entity DIS List

This tab of the spread sheet records the non-combatant (Green) Order of Battle (ORBAT) and applicable information about the entities. This data is initiated by an assessment of the scenario information.

Entity Type	Nationality	*Number of entityies*	Type	Component Units/Entities	ENU	URN	Equipment DIS-ENU	Attachment DIS-ENU
Container Ship	Country1	300	Entity	CTSHIP1	1.3.222.61.1.0			
				CTSHIP2	1.3.222.61.1.0			

Figure 13: Template spreadsheet to record green entities

Munitions List

This tab of the spread sheet records the munitions to be deployed during the simulation.

Ammunitions	DIS Enumeration
projectileFA105mmDPICMM916	2.9.225.2.10.20.0
missileSCUDNuke3Kt	2.11.222.2.2.6.0
projectileFA155mmHeM1Denel	2.9.197.2.1.1.0

Figure 14: Template spreadsheet to record munitions

URN Look up Table and C2 Interfaces
This tab of the spread sheet records the C2 interfaces and applicable information required for the interface to work by entities.

URN	Unit Short Name	Unit Long Name	Nation	Service	Symbol	DIS marking	c2 Interface
5811717	SF_PL/FT3/	SF_PL/FT3/	AS	A	SFGPEWRR--*****	ASA-5811717	TMS-2
5811711	SF_PL/FT2/	SF_PL/FT2/	AS	A	SFGPEWRR--*****	ASA-5811711	TMS-2

Figure 15: Template spreadsheet to record the C2 interface information for entities

2.3.3.2 Federation Agreement

The second distributed simulation design product is the Federation Agreement. It provides a repository for the descriptive data developed and compiled during the preliminary design as well as agreements between the sites and nations. The following table of contents provides an example of the topics covered in this document for the CAGE IIIA simulation.

Distributed Federation Simulation Agreement
Table of Contents

1. PURPOSE
2. DOCUMENT VERSIONS AND UPDATES
3. REFERENCES
4. EXPERIMENT OVERVIEW
4.1 General
4.2 Scenario Location
4.3 Scenario
5. SIMULATION INFRASTRUCTURE
5.1 Overall Network Environment
5.2 Australia Simulation Environment Overview
5.3 Canada Simulation Environment Overview
5.4 UK Simulation Environment Overview
5.6 RTI
5.7 DIS
5.8 FOM
6. RTI SERVICES
7. SIMULATION MANAGEMENT
8. TIME OF EVENTS
9. OPTIONAL ATTRIBUTES AND PARAMETERS
10. UPDATES AND QUERIES
11. IDENTIFIERS
11.1 Internal Federation Name
11.2 RTI and Application ID
11.3 Site ID
12. COORDINATE SYSTEMS
12.1 JSAF Terrain (ALL)

12.2 VBS2 Terrain (ALL)
12.3 CAMX (Canada)
13. KINEMATIC ATTRIBUTES
14. DEAD RECKONING
15. UPDATE THRESHOLDS
16. ENTITY COORDINATES
17. GROUND CLAMPING
18. USER DEFINED TAGS
19. DATA TYPE REPRESENTATION
20. ENDIANESS
21. ALIGNMENT AND PADDING
22. TRANSPORT MECHANISMS
23. TIMEOUTS
24. ENTITY REPRESENTATIONS
25. COMBAT INTERACTIONS
26. ENTITY ENUMERATIONS
27. AGGREGATE ENUMERATIONS
28. COUNTERMEASURES
28.1 Concealment
28.2 Decoys – Chaff
29. OBJECTS AND INTERACTIONS
30. VV&A
31. OPERATIONAL SCENARIO

2.3.3.3 *Architecture Diagrams*

The third distributed simulation design product developed in the Preliminary Design phase is the initial System View of the federation and its interfaces. The following diagram shows the federated systems view for the CAGE IIIA experiment.

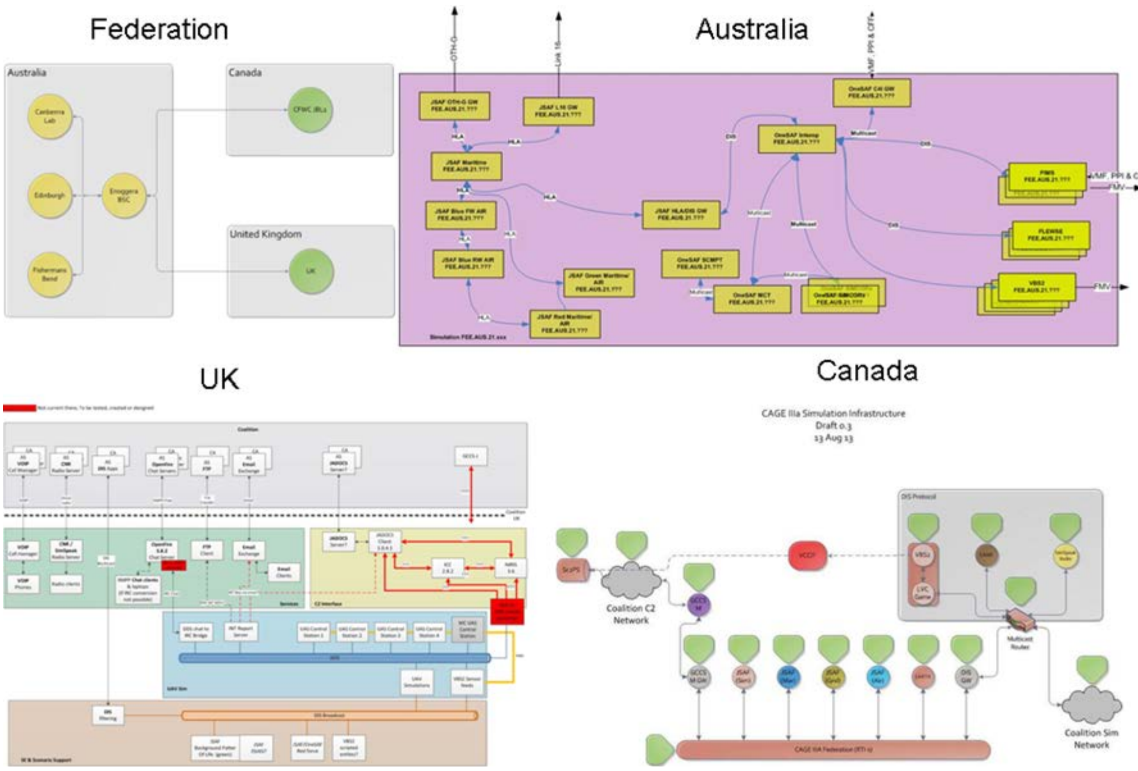

Figure 16: Preliminary Federation System View

2.4 Detailed Design Phase

The detailed design enables the developer to:

- identify the script-ability of experiment threads verse requirement for interactor to implement entity behaviour and actions in real time to respond to events
- determine the entity aggregation and de-aggregation requirements
- develop the detailed C2 interfaces
- identify the data collection points and ensure the data will be recordable
- identify experiment control points for managing the execution of the simulation and varying the tempo if required
- further development the details of the architecture
- determine the verification requirements for the behavioural allocation across the architecture.

The following diagram demonstrates the interaction between the various design processes and this stage of the simulation design. Information from the preliminary design stage as well as information from the scenario design and the experiment design is used in this stage. The results of the work performed can have significant impact in the details of the scenario and the implementation of the experiment plan as shown in the centre and right hand parts of the figure.

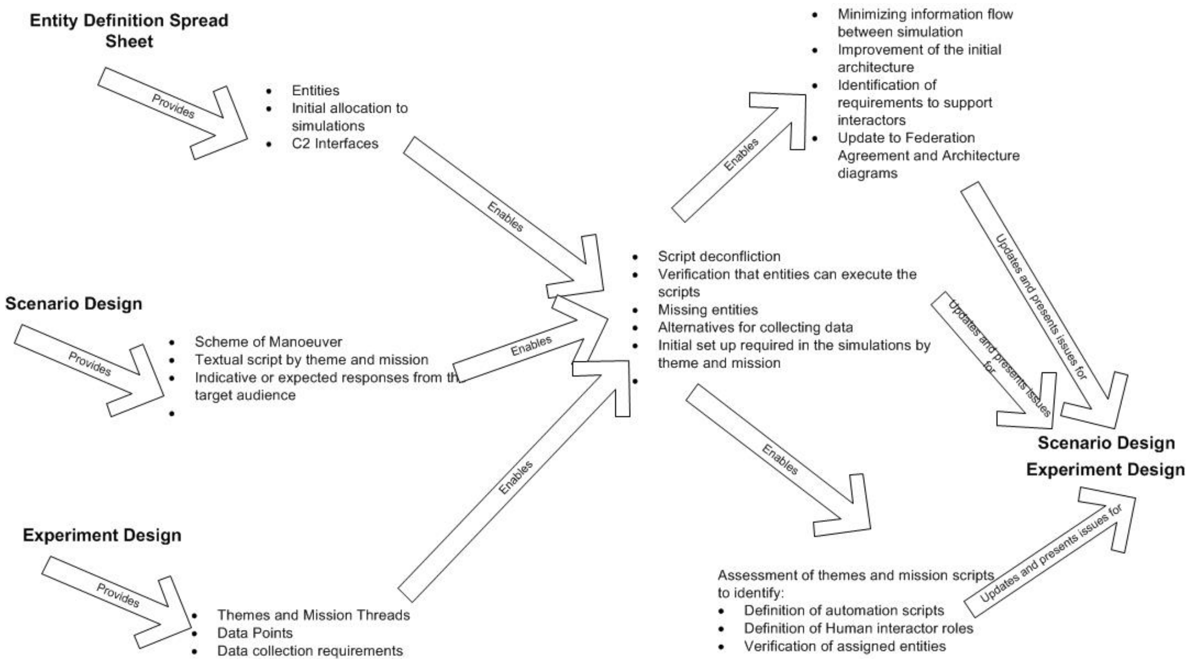

Figure 17: Detailed design information flow

2.4.1 Detailed Design Process

This section describes each step of the detailed design process shown in Figure 18 mapping the information requirements and the simulation design products that are generated.

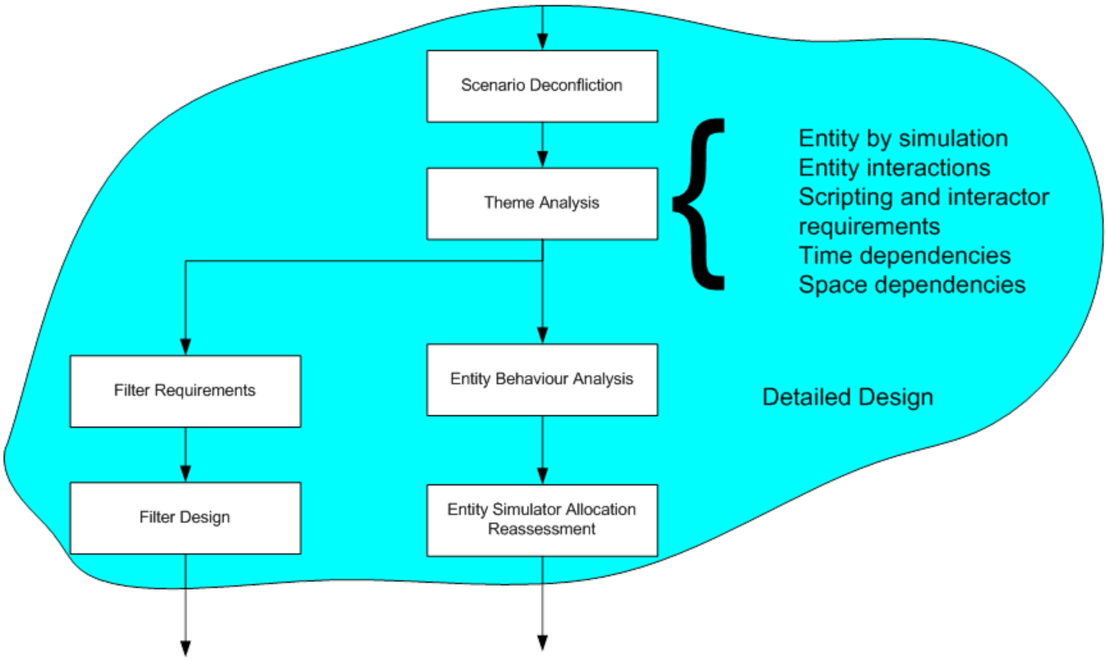

Figure 18: Detailed design process steps

Scenario Deconfliction
In this step the scenario description provided by the scenario writing board is deconflicted in time and space. The intent is to ensure that the script envisioned can execute in the time frames required, that there are sufficient entities in the Order of Battle, and the modelled characteristics and real life behaviour can achieve the desired outcomes of the script. Conflicts identified are provided to the experiment design and scenario writers to redress. This task repeats until a deconflicted scenario is achieved. The results of this activity are recorded in the Script Entity Behaviour Spread Sheet [see section 2.5.2].

This step informs the scenario development board and the experiment design of conflicts in the scenario script including:

1. location discrepancies
2. gaps in capability
3. timing issues.

In an iterative process these discrepancies are removed through clarification of intent for the theme/mission, adjustments to theme and mission timings, adding entities to the ORBATS, and either rewriting of scripts or accepting the conflicts as being required features to test the experimental objectives.

This step ends when there is a script that can be executed in a fashion that will achieve the experimental play expected. This deconfliction only assures that for a single path and with the anticipated player decisions there are sufficient entities, tasking, and time and space coordination to achieve the anticipated outcomes. It does not ensure that every execution path can be performed; nor that their mission objectives can be achieved if different choices are made during the scenario play.

Theme Analysis
In this step the Script Entity Behaviour Spread Sheet [see section 2.5.2.] is assessed with respect to the individual experimental themes and missions. The deconflicted scripts are separated into the individual themes that are intended to deliver the desired experimental data points to be used by the analysts. Each theme is then assessed to ensure that the intent of the theme can be achieved. The experimental data points are identified along with critical set up conditions that are required for the data point to achieve a useful result.
The results of this activity include identifying the following:

- Potential for entity aggregation and de-aggregation during the theme.
- Define the DIS Enumeration of the aggregated entity representing the individuals when aggregated.
- Identification of the data collection points within the individual themes and associated missions.
- Entity initial conditions required to achieve the desired theme outcomes
- Alternative opportunities to achieve the desired set of data points associated with the theme and missions.
- Entities central to experimental goals and those providing background noise, extra work and ones that could be scripted without impact of time and space adjustments to the theme and missions. For example shipping traffic through which the entity moves while being tracked and ultimately engaged could be scripted to have a defined behaviour.

Entity Behaviour Analysis
For each theme and mission the entities are assessed with respect to the ability of the model in the selected simulation to provide the necessary behaviours, the entity interactions and the ability to publish required information and created the desired effect on other entities. In addition the requirement for interactor control of the entity verse scripted control of the entity is assessed. The result of this analysis is an understanding of the entity behaviours that can and should be scripted and which behaviour needs to be initiated and directed by an interactor. For example if a group of entities need to go from point a to point b in order to be in a location that enables an event in the mission or theme a time initiated script may work. In another case a series of actions may occur for a single or group of entities, depending on the outcome of actions taken by the target audience. This analysis may result in several scripts being created that can be initiated if and when required or it may need the interactors to react appropriate to the response. The following diagram demonstrates how the theme and its associated missions are examined with respect to the entities assigned and the time activities with the intent of determining how time and position independent of the various themes and missions can be made.

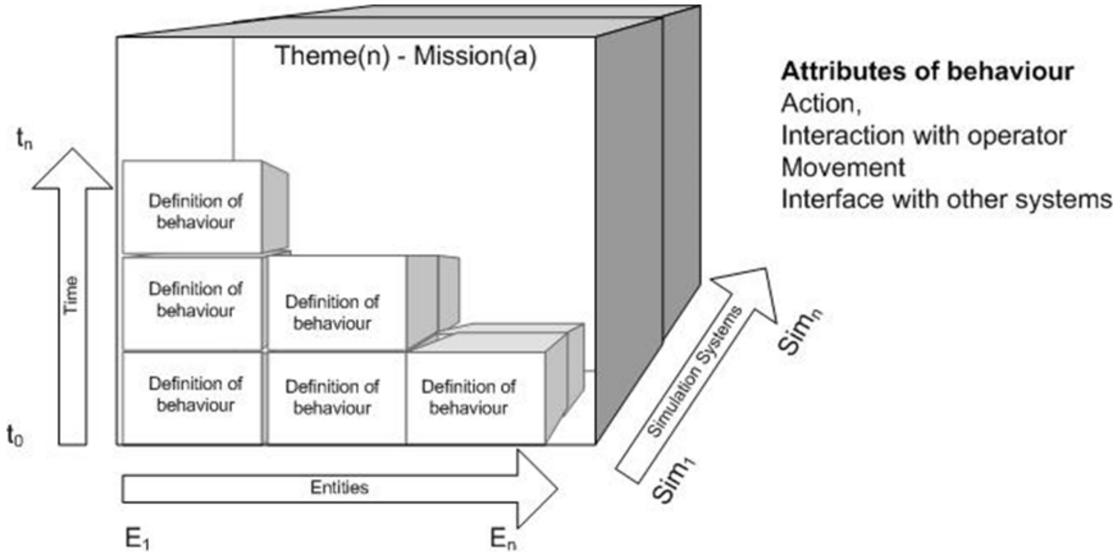

Figure 19: Assessment by theme for time and space independence

Where command and control interaction is required of the entity this relationship is identified and defined. For example if a gun battery in the simulation is to be fired by a command and control system the command relationship that enables the simulation to execute this is defined as well as the interface behaviour (messaging) required by the C2 system.

The types of issues that might be identified through this step include:

- No munition in the simulations with the flight characteristics to achieve the anticipated goal during the scenario being modelled.
- Intended information exchange with the C2 system specified will not work as there is a problem with the capabilities of the simulation or the C2 system with respect to the intended exchange (a message type has not been implemented, a data value for a field of data required for the message does not exist, etc.)
- Requirement for EXCON staff to interact with the simulation to achieve the requested free play behaviours.
- Undesirable effects of entity re-tasking across mission and themes.

Entity Simulator Allocation Re-Assessment
Section 2.4.2.1 defined an initial entity to simulation allocation in the preliminary design stage. The entity to simulation allocation is reassessed at the conclusion of the detailed design of the entity scripts and entity behaviour.

Filter Requirements
Fundamental to the constrained nature of the communications between nations and the requirement to separate national and coalition scenario activities is a requirement to implement filters between the national simulation federation and the coalition federation. The mission and themes are analysed to identify information flow between simulations that are critical to the execution of the distributed simulation. Augmenting the efforts made in the preliminary design the following types of analysis are made: if only one nation is using a type of information (e.g. EW emissions) from entities then the other

nations do not require this information in their simulations and it can be filtered from the site to site communications; if the information about emissions can be retained local to a site then a filter could reside at the site; if emissions are required in multiple but not all sites then a filter could occur on a site-by-site bases.

The outcome of this assessment should identify where filters are required, the information being filtered by each, the reason/justification for the filtering of the information, the impact of not filtering the data, and the conditions that can be used to drive the filter.

The following diagrams demonstrate the various considerations when setting up the filtering criteria between simulations and between sites. In the first diagram the entity interaction is examined in the context of the potential that entities would sense each other or would move about each other. In the second diagram the entities are examined with respect to influence between entities as they support themes. For example if one simulation is leveraging EW emissions and another is not then their entities could be in the same time and space and have no influence across simulations enabling the filtering.

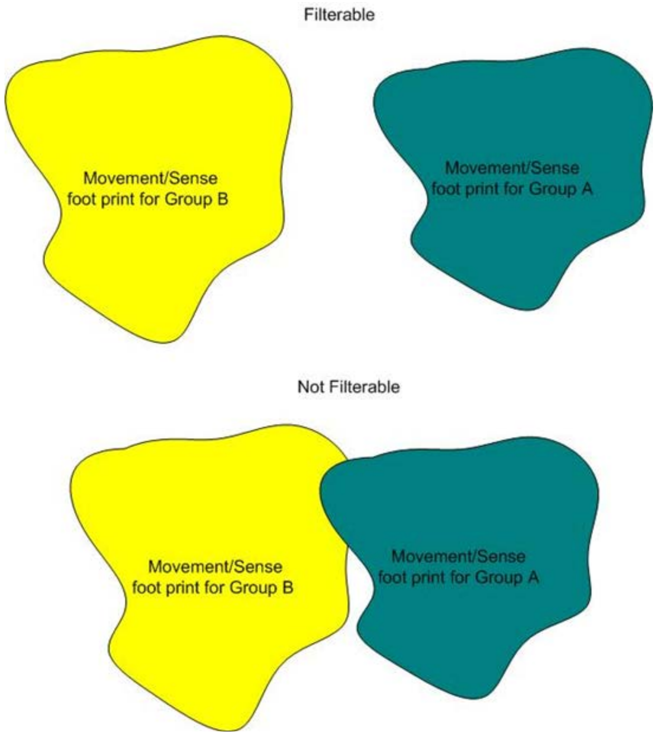

Figure 20: Using entity sense and movement footprints to determine if filtering can occur

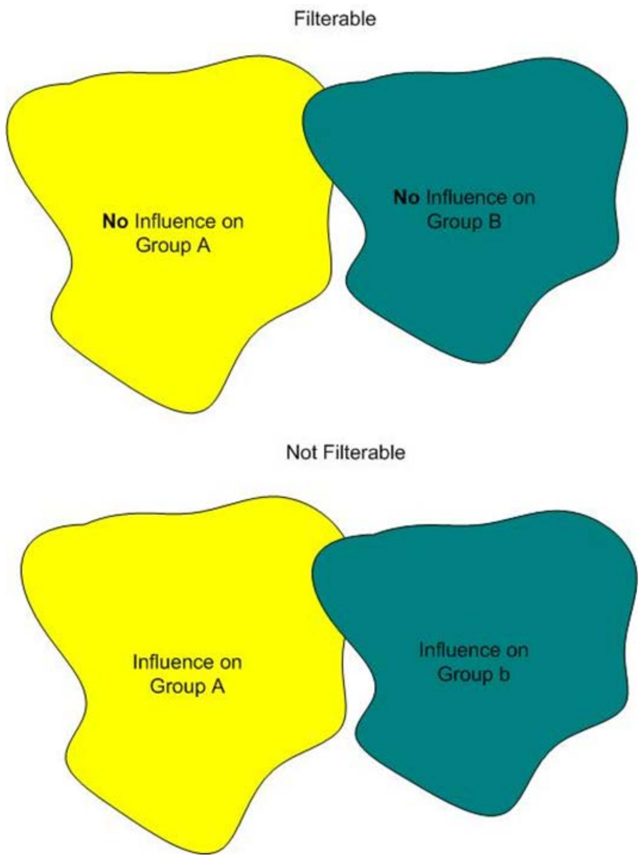

Figure 21: Using Entity influence to determine if filtering can occur

Filter Design
In this stage the applicable filter tool (e.g. the Canadian tool Bender) is designed to address the filter requirements identified earlier. For each identified filter in the architecture there is a list of entities or portions of the information being shared about entities, the filter tool being used and how the entity information is used to implement the filter in the tool.

Test Plan
In this step the plan for testing the simulation federation and the simulations ability to support the scenario created and the experimental objectives is written. This plan should identify the methods to be used for testing, the schedule and scope of testing, the objectives for the testing and the anticipated results.

Critical Design Review
Completing this phase of the design occurs through the successful execution of a Critical Design Review (CDR). The CDR assesses the outputs of each step of the detailed design through a walkthrough of the Final Federation Agreement Document, the Entity Identification Spreadsheet, the Script Entity Behaviour Spread Sheet and simulation design document as described in Section 2.5.2. This step should occur after the Mid Planning Conference and before implementation of the simulations begins.

2.4.2 Distributed Simulation Detailed Design Products

The Detailed Design stage updates and augments the following products:

- Distributed Simulation Federation Agreement
- Entity Definition Spread Sheet
- Systems Architecture.

The following products are created during this stage:

- Script Entity Behaviour Spread Sheet
- Detailed Design Document
- Test Plan.

The following sections present examples of the two data products that are developed during the detailed design process.

Script Entity Behaviour Spread Sheet

The Asset Tracking Spread sheet shown in Section 2.4.2.1 Figure 8, the scenario description and the DIS enumeration list are used to develop an entity behaviour spreadsheet. The state change column refers to the point in time when a mission theme begins. Start position refers to the location is at when the state change occurs. Movement is a description of the movements and behaviours anticipated for the entity. The action is a description of what is expected to occur with respect to the entity.

Table 1: Entity Behaviour spreadsheet

Mission Threads	Entities	State Change 1	State Change 2	State Change 3	State Change 4
Mission Thread 1	Entity 1	Start Position; Movement; action	Start Position; Movement; action	Start Position; Movement; action	Start Position; Movement; action
	Entity 2	Start Position; Movement; action	Start Position; Movement; action	Start Position; Movement; action	Start Position; Movement; action
	Entity 3	Start Position; Movement; action	Start Position; Movement; action	Start Position; Movement; action	Start Position; Movement; action
	Entity 4	Start Position; Movement; action	Start Position; Movement; action	Start Position; Movement; action	Start Position; Movement; action
Mission Thread 1	Entity 5	Start Position; Movement; action	Start Position; Movement; action	Start Position; Movement; action	Start Position; Movement; action
	Entity 6	Start Position; Movement; action	Start Position; Movement; action	Start Position; Movement; action	Start Position; Movement; action

Mission Threads	Entities	State Change 1	State Change 2	State Change 3	State Change 4
	Entity 7	Start Position; Movement; action	Start Position; Movement; action	Start Position; Movement; action	Start Position; Movement; action

Detailed Design Document
The following table of contents provides an example of the topics covered in the Detailed Design Document. This document provides a repository for the description of the scripts, filters and changes to the simulations required to implement the scenario. In addition this document records issues identified during the design that will impact the experiment design or scenario execution. This document covers the design created to allow the interactors to interface with appropriate entities to achieve the desired effects. The following is an indicative Table of Contents:

Detailed Design Document
Table Of Content

1. PURPOSE
2. DOCUMENT VERSIONS AND UPDATES
3. REFERENCES
4. EXPERIMENT OVERVIEW

4.1 General
4.2 Scenario Location
4.3 Scenario

5. SIMULATION INFRASTRUCTURE

5.1 Overall Network Environment
5.2 Australia Simulation Environment Overview
5.3 Canada Simulation Environment Overview
5.4 UK Simulation Environment Overview
6.0 Script Analysis
7.0 Theme by Theme Script Design
7.1 Automated Entity Behaviour - across time and space
7.2 Interactor interfaces and expectations
7.3 Allocation of Entity to Simulations
7.4 Changes to Simulators
7.5 Maps, Visualization and other Data Sets
8.0 Filter Requirements & Design
9.0 Simulation Management
10.0 Recovery
11.0 Start states
12.0 Implementation management
12.0 Verification and Validation Requirements

2.5 Implementation

The following diagram presents the implementation activities and the linkages to the verification activities.

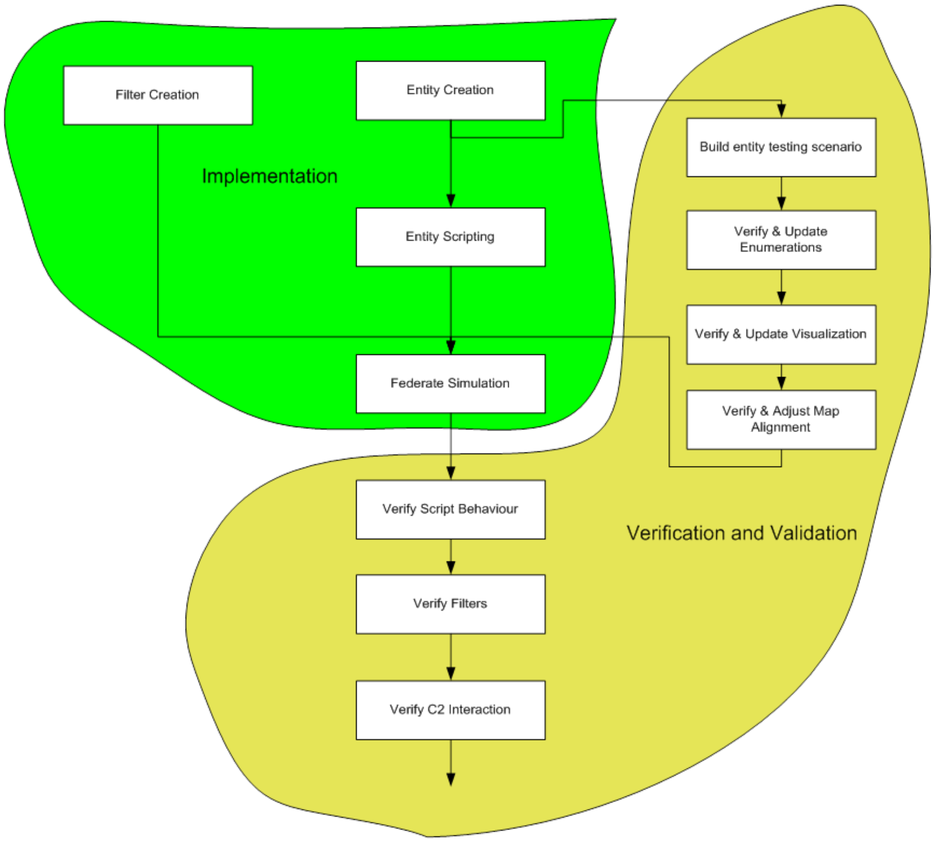

Figure 22: Implementation activities (shown in green) and the linkages to the Verification Activities (shown in yellow)

Entity Creation

In this step the detailed design is implemented in the simulation entities. The entity enumerations, organisational relationships, URNs, organisation names, IFF codes, range and bearing of detection, etc. are coded for every entity in all simulations. The result of this step is a complete set of entities in all simulations that have all the appropriate characteristics required to support the scenario and the experiment. This set of models can then support the entity verification activity defined in the Verification and Validation stage.

Entity Scripting

The scripts defined for each entity, in the earlier step, are coded in the various simulations. As part of the implementation the individual behaviour of the entities in executing the script is tested to verify it behaves as specified in the design documentation.

Filter Creation

The filter design is implemented in each of the identified filters. The filters are tested against the identified information flows.

Simulation Federation
The individual simulations are federated as a national federation tested. The National federations are then federated into a coalition federation.

2.5.1 Distributed Simulation Implementation Products

The principal result of this stage of the development methodology is to have a working Federation; working simulation scripts; working entity Behaviour and interactions; working Interfaces; working filters; working tools to support the scenario Interactor; and finally all developed code should have inline documentation describing the mapping of the code to the design and any special coding performed to make the system work.

2.6 Verification and Validation

The following diagram presents the verification and validation activities (shown in Yellow) as well as their interaction with the implementation process.

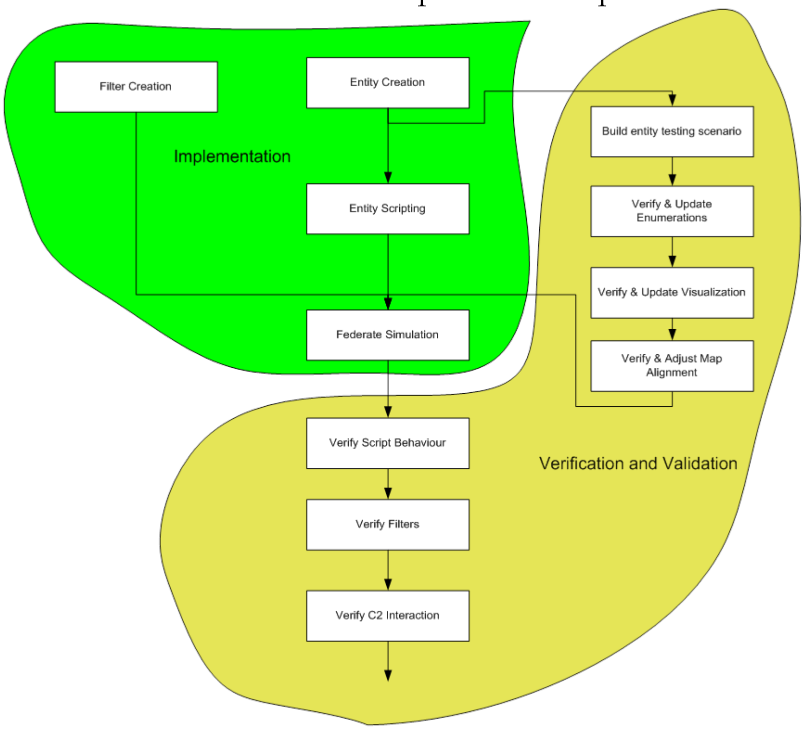

Figure 23: Verification and Validation Activities (shown in yellow)

Build Entity Testing Scenario
In this step a simulation scenario is created for each simulation that has all of the entities that will be used in the simulation. This scenario is designed and constructed to allow the verification that the other simulations see the entities correctly, that their behaviour is correct, that they are not generating information that affects the other simulations entities (i.e. PDU's of death (PDUs that result in a Simulation crashing or an entity to die unexpectedly), or AI behaviour that will affect the simulation if not over ridden).

Verify and Update Enumerations
Leveraging the test scenario and beginning with a site simulation federation, progressing to a national and ultimately a coalition federation verify for each simulation that it properly displays all the entities from the other simulations, has compatible performance models for the entity, does not have problems from information being received from a simulation, etc. The outcome is to verify that the model to model behaviour required by the scenario can properly execute and deliver the desired behaviour across the federation. In executing this activity the selected models for every entity will be validated and any necessary changes made. This test will also verify that entity interactions such as shooting at each other works as expected and that the results are properly represented in all appropriate simulations.

Verify and Update Visualisation
In this step the scenario for testing will be leverage to ensure that the mapping of a model to its visualisation and other characteristics is correct across the simulations. The outcome of this test will be an agreement that the visual models, EW models etc. being used in all the simulators are the same or close enough for the purposes of the event.

Verify and Adjust Map Alignment across Federation
In this step the test scenario is used to ensure that the maps being used across the simulation federation are properly aligned, and have sufficient detail to constrain entity behaviour appropriately and are same across simulations. This test is verifying that an entity on the surface in one simulation is not underground or flying in another simulation. It is verifying that an entity in one simulation is in the same location in all other simulations. It verifies that the elevations and blockage of physical structures are properly handled by all entities requiring this behaviour. The outcome is a verification that the entities properly interact with the maps in all simulations and that the simulations all properly understand the world the same (or close enough to achieve the desired results).

Verify Script Behaviour
In this step the script behaviour is verified. Simulation by simulation the scripts defined in the detailed design are tested to ensure that the times to execute are correct, that entities end up in the correct locations, that expected interactions can take place between entities within and across simulations based upon the results of the scripts. The scripts are tested within the simulation and then across all simulations required to execute a mission and theme. The final testing is to verify that each mission thread can be executed, that themes and mission exhibit the appropriate amount of capability for free play and that the data collection points can be realized.

Verify Filters
In this step the filters are tested in the context of a fully federated simulation to ensure that the filters provide the desired behaviour.

Verify C2 Interactions
This step involves testing that each of the C2 interfaces work as required by the scenario. It needs to verify that RADARS pick up only the objects that should be seen, control loops between C2 and simulated entities function, etc.

Verification Review
The outcome of the verification and validation is an assessment of the readiness for the simulation to support the experimental objectives. This review should occur before the Experiment Readiness Review.

2.6.1 Distributed Simulation Verification and Validation Products

The Verification and validation activities generate the following products: a detailed set of test procedures that describe how to execute the test plan developed in the detailed design stage; all necessary test scripts and scenarios required to execute the tests; the test results and any remediation's and retesting that resulted from executing the tests; any updates to the various configuration files and finally a statement of simulation readiness.

2.7 Summary

The coalition implemented the preliminary design [section 2.4] portion of the method during CAGE IIIA. Australia implemented the preliminary design [Section 2.4] and an initial pass through the detailed design, implementation and V&V phases focusing on execution and not product development due to time and resource constraints.

The simulation infrastructure developed for CAGE IIIA represented a quantum improvement over the CAGE II implementation. This was the result of significant fault finding and debugging along with the more mature design approach leveraged for the simulation.

3. Conclusions and Recommendations

Technical Panel 8 of the Joint Systems Analysis group under The Technology Cooperation Program (TTCP JSA TP8) has been tasked to leverage the CAGE campaign to develop an addendum to the Guide to Experimentation (GUIDEX) that focuses on the pragmatics of distributed experimentation and to develop a distributed simulation design methodology. The aim of this effort, to develop a distributed simulation design methodology, is to extend the existing standards approach from addressing an Acknowledged System-of-Systems to addressing a Directed System-of-Systems.

Within CAGE there is no central design authority, but rather a federation of systems owned, developed and operated by each nation with an agreed upon purpose, i.e. a Acknowledged System of Systems (SoS) [DoD OSD 2008]. Standards such as Federation Development and Execution Process (FEDEP), Synthetic Environment Development and Exploitation Process (SEDEP), Distributed Simulation Engineering and Execution Process (DSEEP) and Kweley and Wood all assume a central design authority and thus full control of the system of systems i.e. a Directed SoS [DoD OSD 2008] that result from the federation.

"there is a fundamental requirement to ensure each nation retains control of their simulations, while federating at execution time in a peer-to-peer manner".

CAGE IIIA successfully implemented a fully distributed, federated simulation environment that stimulated each nation's C2 systems in the form of an Acknowledged System of Systems. Each nation was responsible for building their own simulation environment for their area of operation. The national simulations environments were then federated together enabling entities to move across areas of operation and to be available in the other nation's simulations.

The challenge for the CAGE campaign of experiments is to continue to build upon this methodology both refining the deliverables but building templates for the deliverables and remediated simulation environments that will result in better and faster implementation of the simulation federation. The linkage between the other streams of work associated with building an experiment requires significant improvement. This methodology is principally based upon a waterfall approach whereas the experiment design is based on an iterative wave model. Getting the right linkages and in a timely manner is a work in progress.

Another challenge is the development of an optimal level of scripting and allocation of entities to simulations to enable the evolving concept of trail based approach to CAGE events.

The distributed simulation design methodology developed through CAGE IIIA and presented in this report has demonstrated sufficient utility and robustness that it should continue to be used and developed in both the CAGE campaign of experiments and similar exercises/experiments that exploit distributed federated simulations.

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Dave Bowen, Michael Galister, Michael Slade and John O'Neill

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DSTO Defence Science and Technology Organisation
506 Lorimer St
Fishermans Bend Victoria 3207 Australia

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19. ABSTRACT

While there is a considerable body of scientific knowledge on the principles for designing simulations, there is a gap in translating these principles into the pragmatics for designing large-scale, distributed, peer-to-peer federated simulations at the coalition level. CAGE IIIA successfully implemented a fully distributed, federated simulation environment that stimulated each nations C2 systems. This report describes the Distributed Simulation Design methodology that was developed and trialled by DSTO during the CAGE IIIA experiment to enable the pragmatics of designing & implementing a fully distributed, federated simulation environment.