Push the Easy Button! Homogeneous vs. Heterogeneous Simulation Experiments

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ABSTRACT

As a part of Army's annual experimental campaign plan, an event named Talon Strike was planned for the spring of 2010 involving several of the US Army's Battle Labs and the United Kingdom (UK) as a coalition partner. It was not the specific intention to conduct Talon Strike as a homogeneous simulation experiment. In 2010, ARCIC, in an effort to conserve resources, combined both a Battle Command experiment with a pre-deployment training event using a single simulation driver. Talon Strike requires special security classification management. In order to comply with these security requirements and to reduce the complexity of the experiment, it was decided to use only OneSAF as the entity driver and the experiment's only constructive simulation. Talon Strike culminates a five year US/UK Future Land Operations Interoperability Study (FLOIS) staff effort for interoperability of coalition forces in battle command systems and staff operations. The experiment's architectural approach evolved into a model that supports the Common Interface level (High Level Architecture), the Common Data Level, the Common Architecture Level and the Common Application Level which together classify it as a Homogeneous Simulation Experiment, based on the Homogeneity Model proposed by Paul Hanover at I/ITSEC 2009. The Army's Omni Fusion series of heterogeneous experiments have traditionally been a collection of different battle labs each with their own proponent simulation and has required up to six months of detailed technical planning and integration to provide ten unique experiment runs. This paper compares the pros and cons of heterogeneous versus homogenous simulation federations, and presents the reduced effort need for integration compared with previous federations, while retaining entity model fidelity. This paper also contrasts and provides resource and workload insights into conducting both a homogeneous and heterogeneous experiment using empirical cost and manpower data.

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THE ENVIRONMENT AND HISTORICAL PERSPECTIVE

One of Modeling and Simulation (M&S) industry's major concerns of the past and present is how to fulfill customer requirements with minimal cost and time. The answer to this question becomes the motivation for most of the engineering activities in the M&S industry. With the recent increase in the design of multi-national experiments, a greater focus has been placed on enhancing the quality and efficiency and reducing cost. Today's distributed simulation techniques have great potential to fulfill the present demand and demonstrate efficiency in integrating existing simulation models. Reusability of metadata from previous experiments would reduce the cost. However, in practice, integrating diverse simulation systems and ensuring interoperability is still a significant challenge and the cost is not trivial.

The Army's Training and Doctrine Command (TRADOC) Battle Lab Collaborative Simulation Environment (BLCSE) experiments have traditionally comprised a collection of many different battle labs each with their own unique simulation systems. Each simulation system involves a tailored and diverse infrastructure that complicates integration of these simulations and consumes considerable resources in manpower, time and subsequently money.

In 2009, the Army Capabilities Integration Center (ARCIC) combined much of the integration work of three separate experiments using a common simulation federation, terrain, and data sets to reduce the expenditure of resources. This series of experiments consisted of Omni Fusion 09 (OF09), Earth Wind and Fire (EWF) 09, and Networked Brigade Combat Team (NetBCT). The designated Modeling and Simulation lead, Joint and Army Models and Simulation Division (JAMSD), implemented an effective preparation schedule and configuration management to retain all entity data, terrain, network configuration, etc., as much as possible, and to utilize them in the next event. Applying this effort to the federation's main entity driver and constructive simulation, OneSAF, was relatively easy, because JAMSD is OneSAF's model manager for BLCSE and has control of OneSAF within that community's federation environment. However, in addition to OneSAF, the BLCSE experiments can consist of twelve or more different simulation federates used by separate battlefield proponents. Each federate has its own data representations, terrain format and communication architecture. Thus, it was not easy for JAMSD to keep track of every simulation proponent's configuration control and data preparation. In these experiments, the BLCSE federation demonstrated a perfect example of a heterogeneous federation.

In a further effort toward efficiency in 2010, ARCIC combined a battle command experiment with a pre-deployment training event. The Talon Strike and Omni Fusion 2010 (OF10) events, conducted in May 2010 culminated a five year US/UK Future Land Operations Interoperability Study (FLOIS) focused on the interoperability of coalition forces in battle command systems and staff operations. The actual simulation event used US and UK brigade sized units as a training and preparation event for their deployment into the Afghanistan area of operations. As the staff effort matured and detailed planning for the simulation events began, the event director decided to use a common version of OneSAF played by both the UK and US forces at their home installations. This decision laid the foundation for the first multi-lateral exercise to be conducted using only one entity driver. Utilizing a single constructive simulation to create all entities and simulate all battle space activities was a new direction for the historically heterogeneous BLCSE federation. There were many unknowns including OneSAF models' fidelity, sufficiency of its entity resolution, terrain standardization, network configuration, and simulation data interoperability with ancillary C4ISR simulations and real-world equipment. The integration team, under the JAMSD's lead and technical support of PM OneSAF, set out to execute Talon Strike/OF10 as a multi-national, homogeneous experiment.

HETEROGEINITY IN BLCSE

We describe a heterogeneous simulation federation framework to be where several different simulation systems can be interoperable in a common communication environment. The framework conceptually consists of three layers: the model layer, the communication / architecture layer, and the data layer. The model layer has a collection of various simulation applications, such as OneSAF, FireSim XXI (FireSim), Advance Tactical Combat Model (ATCOM), Extended Air Defense Simulation (EADSIM), to name a few. In the BLCSE communication / architecture layer, various applications communicate using the High Level Architecture (HLA) and represent a complex system that we call a Federation. The data layer provides a common data description to enable simulation applications' models to communicate using the same data defined by the Federation Object Model (FOM). The HLA layer is employed as a communication infrastructure, which supports many valuable features for distributed simulation. A heterogeneous simulation federation includes many simulation systems that employ different simulation methodologies, and different hardware platforms. Often these high-fidelity systems are utilized to leverage their unique strengths or simply because they are readily available. Integrating applications and models to run in such a diverse environment, however, is a daunting task. Providing meaningful interoperability is an equally challenging task, as well. Additionally, implementing communication mechanisms between the simulation applications that are designed with different communication protocols or architectures such as DIS, TENA and HLA, unnecessarily increases integration time, often requiring a translator in between two different standards of communication. There are also other issues that should be taken under consideration. Simulation models represent objects at many different levels of fidelity and as a result, interoperability between models may require the use of a disaggregation process. Making the matter more complicated, in the data layer of the framework, all simulation systems have modeled their physical components to use AMSAA-provided data. The AMSAA physical data repository is often the source of behavior data for many of the real-world systems being modeled within BLCSE. The source data is produced in a manner that conforms to the Standard File Format (SFF), but not all systems use all the available data fields produced by AMSAA and not all systems have the same methodology of porting or ingesting the data for use by the simulation models. Data management and use across many of the systems can be as diverse as the systems themselves. Altogether, this diversity in models and data can and does cause modeled systems and effects of munitions to vary widely. In the homogeneous environment, all federates across the federation will be consistent in the use of models and the associated data. This environment also provides for a set of data that is consistently managed and utilized.

A typical BLCSE experiment is conducted in three phases: Planning Training and Execution, and Post Experiment Analysis and Reporting. Tables one, two, and three are a depiction of these three phases. The tables outline the usual schedule of major events within a phase. Within the Training and Execution Phase, there are subordinate federation integration and testing phases that are of interest to us. There is a consistent and understandable pressure on all staff involved with an experiment to compress the phase timelines and associated levels of effort. This is motivated by economy, of course, but also by the need to improve engineering processes to make the whole evolution more efficient and the outcomes more reliable and consistent.

For each experiment, the federation integration effort comprises three phases also, referred to as Integration Phases. During Integration Phase I, the input data is tested and validated within each of the simulations of the federation. Additionally, each of the simulation systems are tested with the primary entity driver, which in BLCSE is OneSAF. In Phase II, single instantiations of each simulation system are tested with each other and interoperability checks are performed for complex interactions. In Phase III, all systems are tested and the federation stressed under full load. The duration of these phases can vary depending on the experiment's entity count, number of simulations modeling entities, and the variety of simulations that use different communication architecture such as DIS, TENA and HLA. Table 4 depicts the duration of the three phases of integration of Omni Fusion 2009 (OF09), NetBCT and Talon Strike/Omni Fusion 2010 (TS/OF10). The Execution Preparation includes incorporating the last software drop, final force laydown guidance, role players' training, federation accreditation, scenario load and STARTEX position, SW/HW reset, rehearsal.

To illustrate the magnitude of hours we'll use the BESG Integration Section's (engineering group) historical data. During the OF09 experiment, the Integration Section consisted of ten people. Usually, the Integration Section becomes heavily involved with integration starting from the second half of the Phase I through the end of execution.

Table 1: Phase I - Planning Phase

Phase I:	Begins	Endstate	Required Action
Planning	Receipt of the experiment Mission	Ends with the experiment planning complete and the military role players beginning required training	All planning and coordination with ARCIC and across the TRADOC Experimentation Community of Practice (COP) for all associated experiment planning tasks to include: resources, manning experiment design, schedule, validation and verification (V/V), and roles and responsibilities
Phase Ia:	Begins	Endstate	Required Actions
Initial Planning Conference			Initial discussions on concepts for the following: Equipment and event design; Scenario and Operational environment; Classification; M&S Federation and collaborative simulation environment; Joint context and/or participation; Training and training support plan;
Phase Ib:	Begins	Endstate	Required Actions
Middle Planning Conference			Refine experiment initial concept results; discuss analysis plan, draft executable products and even directives.
Phase Ic:	Begins	Endstate	Required Actions
Final Planning Conference			Conduct a final review of Study Readiness, Expe Directives, Data Collection Management Plan (DCMP), Analysis Plan and Data Collections in o to resolve all outstanding issues/concerns and give a final confirmation and approval to move forward and execute the experiment.

Table 2: Phase II – Training and Execution Phase with Three Sub-Phases

Phase II:	Begins	Endstate	Required Actions
Training and Execution		Beginning of the first record run; validated and verified simulation; trained role players; verified communications and completed rehearsals	Federation Integration, Training/Rehearsals, Military Decision Making Process (MDMP), Pilot Runs and beginning of the Simulated Exercise (SIMEX)
Phase IIa:	Begins	Endstate	Required Actions
Validation and Verification (V/V)			During these phases the experiment Federation/Experimentation Community of Practice (COP) will conduct integration testing to ensure that the experimental environment is functioning as planned. Appropriate time is built into each phase to handle issues as they arise.

Table 3: Phase III – Post Experiment Analysis and Reporting

Phase III:	Begins	Endstate	Required Actions
Post Experiment Analysis and Reporting		ARCIC acceptance of Final report and Experiment to Action Plan (ETAP)	Simulation Experiment (SIMEX) coordinated over a distributed Battle Lab Collaborative Simulation Environment (BLCSE) with the TRADOC COP IAW with, SIMEX AAR, analysis of the data and the drafting of the post event analysis report and ETAP

The recorded work duration, including overtime, for OF09 was 4,450 hours, NetBCT was 3,512.5 hours and Talon Strike was 3,872.0 hours (Figure 1). If we add other BESG section hours which are Experiment Support Section (ESS); responsible for data (entity and terrain) creation; Technical Operations Support Section (TOSS) which provides onsite technical integration support to various battle labs and include the labs' own resources would increase the total number of hours by approximately 70%.

Figure **2** illustrates the number of weeks for each phase of OF09, NetBCT and TS/OF10. OF09 is typical example of a BLCSE heterogeneous experiment that the federation conducted on a regular basis. As we indicated above, in 2009 ARCIC implemented an experimental data reuse policy by placing experimental data under configuration control. This continuity of data was to be used in NetBCT, and other future experiments. This three to five weeks of integration time during Phase I. However, in TS/OF10 Phase I could not be skipped due to the increase of new coalition entity data.

Coalition events

Within the past few years ARCIC has began conducting events with allies with increased frequency and scope. These coalition events have been conducted with allies such as United Kingdom (UK), Canada, and Australia. In the ideal experiment environment, the simulation systems within our ally federates should be highly interoperable, easily configurable, and consistent with international development standards. The most effective method of achieving the required level of interoperability is to have all nations support the same simulation system or systems. Additionally simulation systems should conform to Army Battle Command System (ABCS) endorsed architecture, thus reducing the engineering burden of developing an acceptable level of interoperability for ABCS activities

Table 4 – Durations of Preparatory and Execution Phases of Recent BLCSE experiments

Phase	Phase Duration (in weeks)		
	OF09	NetBCT	Talon Strike/OF10
Integration Phase 1	5	-	3
Integration Phase 2	9	4	7
Integration Phase 3	4	3.75	3
Execution Preparation	2	0.25	4
Record Run-Week 1	1	1	1
Record Run-Week 2	1	1	1

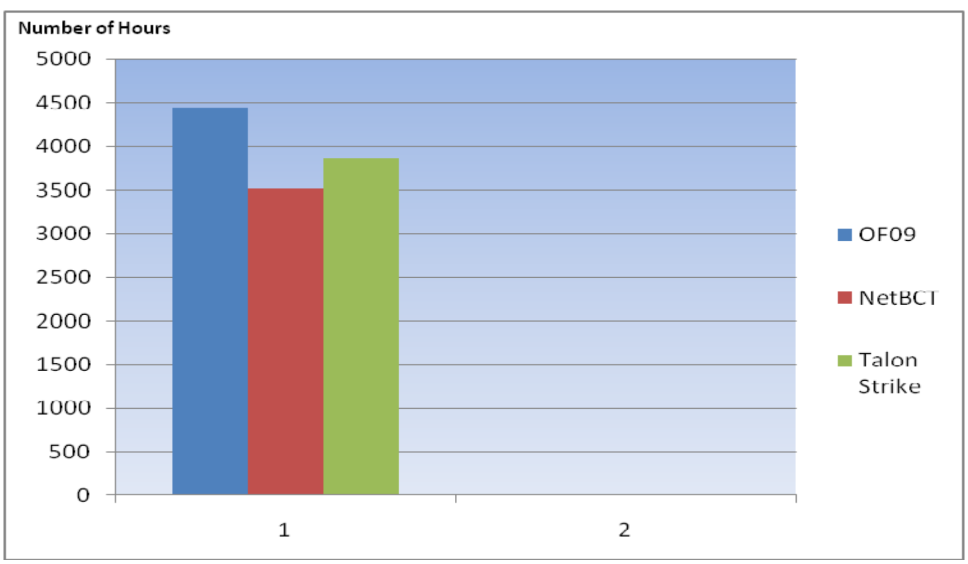

Figure 1: Integration Engineer Manpower

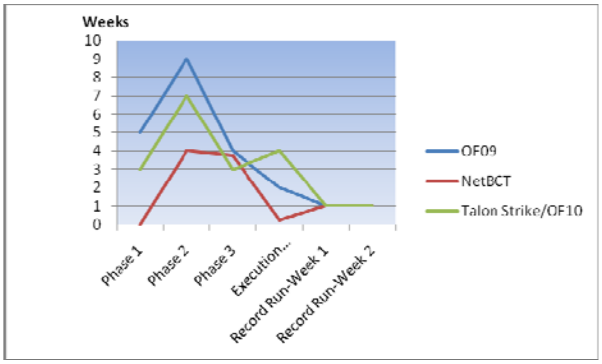

Figure 2: Duration of Integration phases of OF09, NetBCT and TS/OF10

HOMOGENEOUS 101

Hanover (2009) proposed a four-level the Homogeneous Model. He also discussed the differences between homogeneous and heterogeneous federations and the pros and cons in theory. He postulated, "The attainment of complete simulation application homogeneity is an essential, desirable and over time, attainable goal." He treated the concept of homogeneity as a way to refresh our community's efforts to work toward the concept as an end-state. He introduced four stages of homogeneity: Level One Homogeneity – Common Communications Interfaces, Level Two Homogeneity – Common Data, Level Three Homogeneity – Common Architecture, Level Four Homogeneity – Common Applications. This year, as a result of their chosen technical approach, TRADOC's BLCSE federation executed a training experiment that created a federation model that effectively attained Mr. Hanover's Level Four, an almost ideal homogeneous simulation federation environment. It was Talon Strike/Omni Fusi.

Talon Strike/OF 10 – The First Homogeneous simulation Federation in BLCSE

On 21 May 2010, the Combined Arms Center (CAC), Capability Development Integration Directorate (CDID), Battle Command Battle Laboratory completed the most complex, challenging, and significant experiment ever undertaken by the Experimentation Community of Practice. Talon Strike/Omni Fusion 2010 was not a Typical Army Experiment. What distinguishes TS/OF10 from other Army experiments is that it was designed to investigate UK-US battle command interoperability for a 2010 UK Joint Medium Weight Capability Brigade operating as part of a 2010 US Modular Force Division and provide an assessment of current force Battle Command capabilities to enable a more effective and interoperable UK-US coalition force.

TS/OF10 consisted of a single, integrated simulation, OneSAF, based experiment hosted at Fort Leavenworth (FLVN) and distributed to the LWC and across the United States. TS/OF10 was distributed on the Battle Lab Collaborative Simulation Environment (BLCSE) which, for the first time, includes the UK and National Simulation Center.

Unit participants include 12 Mechanized Brigade (UK) participating from the Land Warfare Center (LWC); 2nd Brigade Combat Team (BCT) / 1st Infantry Division (ID) participating from the National Simulation Center at Fort Leavenworth; 5th BCT/1st Armor Division (AD) Army Evaluation Task Force participating from Fort Bliss; support brigades and simulations operators participating from Fort Benning; and additional event support from Fort Monroe and Fort Gordon. The total number of entities in the experiment was 10000 – 15000.

The experiment's objective was to conduct an assessment of operating capabilities between US and UK units in the current 2010 timeframe and then transition to a future environment (2017) with the introduction of emerging technologies and their effect on operations. Over 600 US and UK, Soldiers, civilians and contractors were required to support this complex experiment from multiple locations. At Ft. Leavenworth, over 250 personnel were required to replicate the Division and Combined Joint Force Land Component Command (CJFLCC) command post and provide analyst support. The complex nature of the experiment guided the decision of the experiment director to use a single entity driver to model all entities in the experiment. This decision would somewhat simplify the integration and security aspects of the experiment. Accordingly, a common version of OneSAF was utilized by both the UK and US forces at their home sites. Conducting a homogeneous experiment provided a "Common Communication Interface", "Common Data", "Common Architecture", and "Common Applications" that would qualify Talon Strike/OF 10 experiment as a Homogeneous simulation experiment.

During the technical integration of the homogeneous federation, we have discovered contrasts in event run-up and execution compared to previous heterogeneous experiments. Integration complications were most evident in TS/OF10 during the integration of coalition entities. Many new entity and unit compositions had to be added to OneSAF (non-combatants, UK platforms/units, animals, etc). Due to objectives of the experiment, one of the main participants was ABCS. This included the Command Post of the Future (CPOF) and other UK and US Battle Command Systems in use today. However, providing the interoperability in the tactical communication/message format was an additional complication. Some of the OneSAF Command and Control logic had to be re-written and/or modified in order to provide interoperability between the tactical devices. Despite the difficulties, the integration testing phases (see Table 4 and Figure 2) duration were shorter than a typical heterogeneous BLCSE experiment integration duration. In addition, the number of people required for the phases of integration was less and duration of the integration was shorter (Figure 2).

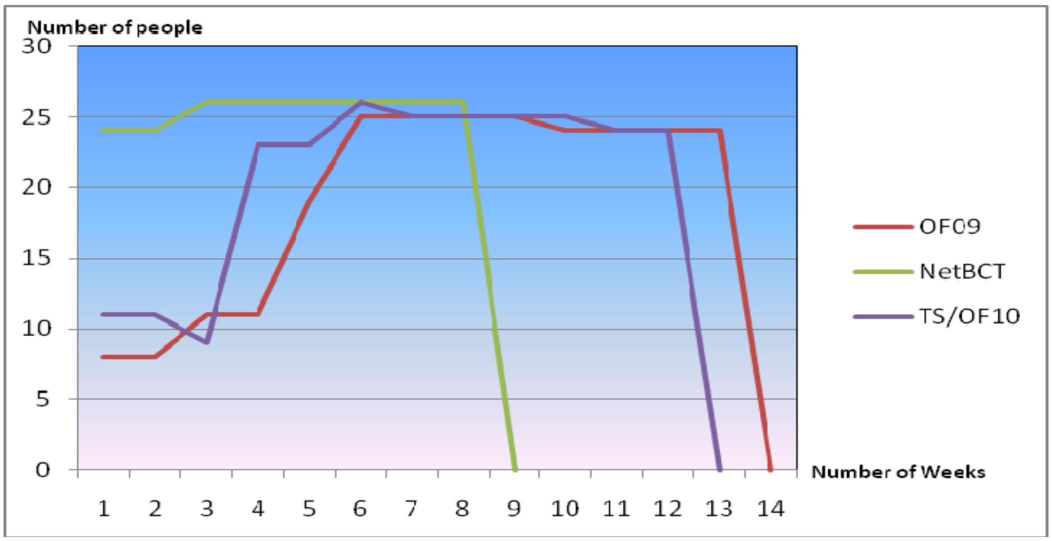

Figure 3: BESG Manpower Comparison

THE HETROGENOUS HOMOGENOUS COMPARISON

Daily event logs were maintained during pre-event testing and event execution for the events Omni Fusion 2008, 2009, and TS/OF10. Information was extracted from these daily logs to generate a categorized list of issues. Each log entry related to federate or federation problems were categorized into nine different types of issues. Two of the categories were specifically related to heterogeneous systems integration issues and system issues not related to the primary entity driver and simulation of test, OneSAF. These two categories were combined to provide a count of issues related to heterogeneous simulation integration labeled "Integration Issues Logged" in Figure 4. Also noted in Figure 4 is the total number of unique systems labeled "Unique Systems". The chart shows that as the greater number of unique systems involved in the simulation increases also does the number of issues related to integrating these systems. The more time and effort spent on resolving these types of integration issues can drive the cost and time spent in pre-event planning and testing.

Experiences of Run-Up to a Homogenous Event

Pre-event testing usually starts anywhere from three to six months prior to the start of the event.

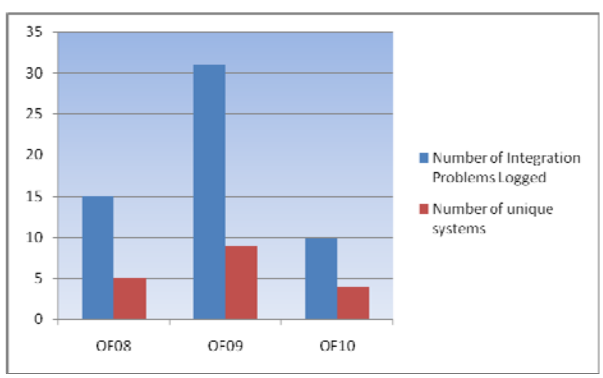

Figure 4: Logged Issues Compared to Number of Unique Systems

When conducting a heterogeneous event it is extremely important to have participating systems involved as early and as frequently as possible. Often times it is very difficult to coordinate and conduct participation of all system proponents due to scheduling conflicts, availability of resources, and development and configuration downtime. Filling in for some of the larger systems by operating a system on behalf of a proponent is often an unrealistic undertaking. Most of the systems operating in the simulation environment are hosted on specific or proprietary hardware, require operators who have dedicated skills and training, and usually need some specific configurations for any given event. These types of issues are not as critical for a homogeneous event. If the same system is used by all proponents and a single baseline is managed for all users, then substitution of a proponent becomes much easier and can be handled by any site that has the hardware to spare. Operating in a homogeneous environment also enables commonality of system operation across all proponents. Users and operators from one proponent can be easily transitioned across federates and be fully capable of operation with little to no training.

Capability, Complexity, and Performance

The three factors of capability, complexity, and performance are interesting factors to compare and contrast between a heterogeneous and homogeneous environment.

Capability: Simulation systems are often procured and developed with a narrow field of focus. Often times a simulation system is desired that fulfills a specific need for a particular vehicle or category of vehicles. These systems are of particular importance in that they model details that some of the more encompassing systems tend to ignore. In the pursuit of a homogeneous environment, the capability and fidelity analysis has to be conducted. What is the cost and will the end product be sufficient to capture the detail in a simulation system for use in a homogeneous environment. Or is the time and effort of integrating unique systems in a heterogeneous environment is not costly enough to warrant the cost of porting the fidelity to a new simulation system. Within the BLCSE is was determined that the simulation OneSAF contained sufficient enough capabilities to model all ground and air systems for the events Talon Strike and Omni fusion 2010. The goals and objectives for these events did not require the fidelity or capability provided by simulation systems like FireSim, EADSIM, and ATCOM.

Complexity: A trade-off analysis again has to be conducted for complexity as it was for capability. Complexity of federation integration, testing, and operation increase as the number of unique simulation systems increase. An increase in complexity will drive an increase in the time spent in development of new functionality and the addition of new system representations (weapon, munitions, and sensor). In the classic heterogeneous environment, this work has to be completed across all the unique systems. In a homogeneous environment, only the primary system is affected and work can be accomplished in a more coordinated effort.

Performance: In the past, model and data standardization efforts have been attempted with great intentions. Unfortunately, variances in the model performance and data based performance of physical components are still different across unique systems. When simulation based analysis is being conducted and data is being collected on physical components and resulting acquisition and vulnerability model calculations it is important to be consistent across the federation with respect to model logic and data usage. Legitimacy and consistency of model performance are very important to analysis. One without the other degrades the validity of results and can contribute to skewed analysis and inconsistent results during federation operation.

Event Execution

Frequently during the execution of an event, many problems and issues arise that require technical consultation and support. Fixes are often required and additional functionality is often desired during the execution of an event. It is inherently easier to analyze problems and introduce new functionality within the confines of a homogeneous event rather than a heterogeneous event. When a problem occurs that has a negative effect on the federation, eliminating variables that may contribute to the negative effect can be accomplished in a more linear manner when operating in a homogeneous environment. When sorting through variables in a federation in order to find the culprit of an issue, interrogating many "suspects" is more difficult and time consuming than interrogating one. The nature of the homogeneous environment lends itself to a more linear approach in reducing variables while troubleshooting federation issues and problems.

When conducting an event within a heterogeneous environment technical support tends to be organized by simulation system. The heterogeneous environment tends to segregate and isolate technical support into pockets of specialties grouped by system. Within the homogeneous environment, technical support can be applied across the whole federation, dedicating support in a more linear fashion reducing the isolated pockets of specialties.

Fidelity

The loss of fidelity can be a real possibility when conducting a homogeneous experiment or event. Consolidating an event into a common simulation system that will model all entities used in the event can result in a dilution of fidelity. A serious review of event expectations, goals, and objectives has to be made in order to understand the effects of possible fidelity loss. If the event of consideration's purpose and objective is to populate C2 systems for C2 training and evaluation then the loss of high performance flight characteristics for aviation assets is not a concern. More often, this analysis is not taken seriously and therefore fidelity overkill is preceded by months of needless and costly integration with a system that does not support the event goals and objectives. An early examination is required of needed fidelity. If high performance flight characteristics are needed, then it is important to identify this need as an input into the decision to conduct a homogeneous event. Whether there is a common simulation system that can meet the requirements of the event is subject to availability of a single simulation system.

Cost

In Figure 1 above, we compared total engineering hours spent in the integration efforts of OF09, NetBCT and Talon Strike (TS). NetBCT consisted of sixteen simulation applications and Talon Strike had one. We were able to obtain cost information of NetBCT and Talon Strike from one of the Battle laboratories. According to the information obtained, cost of NetBCT was $839,000 and cost of Talon Strike was $830,000 (Figure 5). If we consider that NetBCT included 16 different simulation applications and would have cost 16 times more than one Battle lab cost. However, even though the number may not be 16 times as much, but the difference still would not be trivial.

SUMMARY

In technical integration of our Talon Strike homogeneous federation, as mentioned in the text we discovered great contrasts in the run-up and execution compared to previous heterogeneous experiments which used as many as sixteen different simulation

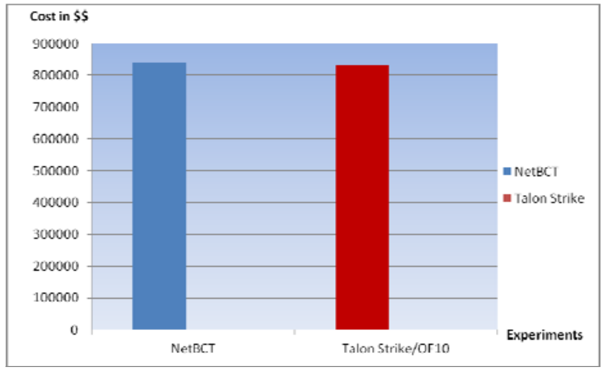

Figure 5: Cost comparison from of a Battle lab for Heterogeneous (NetBCT) and Homogeneous (TS) experiments

drivers. As we indicated above, integration was much less complicated. Therefore, the engineering team spent more time developing new functionalities that were required by the experiment objectives or enhanced the existing functionalities for the same reason and included into OneSAF baseline. Talon Strike was the first time BLCSE used a single simulation for a multi-national experiment. Many actions could have been done in advance instead of during the Execution Phase (Table 2). These would reduce the experiment's duration and cost drastically. Many lessons learned from Talon Strike will be applicable to the next homogeneous event and reduce the integration time and effort further. In contrast, the development of the functionalities that required to meet the event objectives can be done up front. Therefore, the cost of the event can be reduced further.

Talon Strike was a successful event. FT. Leavenworth, The Battle Command Battle Laboratory-Leavenworth (BCBL-L), and United Kingdom Land Warfare Center (LWC) experiment directors indicated "the most complex, challenging, and significant experiment ever undertaken by the Experimentation Community of Practice successfully completed". The experiment met the objectives and result was satisfactory. According to chief data analyst MBL (Maneuver Battle Lab.), the collected empirical data was good enough for analysts to analyze ground maneuver platforms.

This paper compared the pros and cons of heterogeneous versus homogenous simulation federations, and presented the reduced effort need for integration in contrast with previous federations, while retaining entity model fidelity. We also provided resource and workload insights into conducting both homogeneous and heterogeneous experiments using empirical manpower and cost data. In conclusion, we wish to iterate that Homogeneous simulation concept is path toward improving interoperability, efficient use of engineering resources, enhanced federation output validity, and further cost reduction. However, it will require advance planning, focused consideration and well defined experiment requirements to meet objectives and goals of the experiment properly. The decision on selection of experiment type, Homogeneous or Heterogeneous, still belongs to experiment director, since that is the level who knows how best to do so.

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