Discovery Experimentation Campaign: Crafting the Future

S K Numrich, PhD, CMSP, Institute for Defense Analyses
Kevin Woods, PhD, Institute for Defense Analyses

IDA

THE FUTURE IS : NOW

Discovery Experimentation Campaign: Crafting the Future

or

How to use *simulation*

and human-in-the-loop capabilities of *training technology*, in particular,

to *reduce risk* in acquisition;

to assess military utility

of new technology;

or

revise tactics, techniques, and procedures

in the face of new technology (ours or theirs)

Outline of the Presentation

- What is meant by experimentation?
- What is discovery experimentation?
- Why use discover experimentation for military purposes?
- What is an experimentation campaign?
- How to execute a discovery experiment campaign – real example
- Tactical issues – stumbling blocks and work arounds
- Why experimentation campaigns are valuable for Multi-Domain Operations

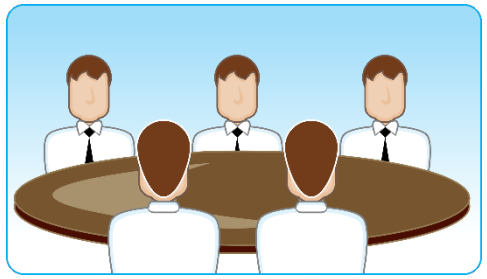
Learning Objectives

- Distinguish discovery experimentation from other forms of experimentation
- Define the flow of an experimentation campaign
- Explain why one might use discovery experimentation -- provide an example
- Describe how to develop a discovery experimentation campaign
- Explain the utility of an experimentation in exploring Multi-Domain Operations (MDO)

Why Experimentation at I/ITSEC

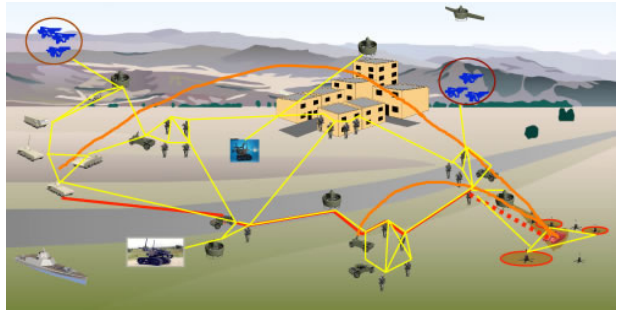
- Experimentation is a way of using simulation to support
  - Acquisition of new capabilities
  - Development of tactics in the face of new challenges, new technology
  - Development of and test of concepts for Joint Multi-Domain Operations
  - Exploring concepts for innovation
- Like a military campaign, the best tool depends on where you are in the effort

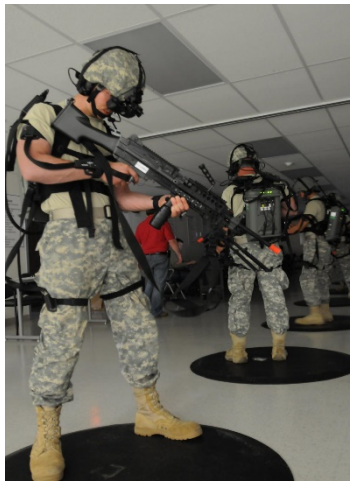
BOGSAT



Wargames

Constructive Simulation





Warrior in the Loop

Why Experimentation in the Military

"As the most powerful country on the planet, both economically and militarily, we should, without a doubt, **conduct aggressive experimentation** to not only learn what to do, but also actively seek to learn what not to do. We will benefit from both results, as we will develop future leaders and operators that are not afraid to take risks in pushing the edges of our own abilities."

Try and Try Again
(Military culture must embrace experimentation and failure)

Michael Tyson,
USNEWS,(2014)

Michael Tyson is the Marine Corps senior fellow at the Atlantic Council's Brent Scowcroft Center on International Security.

Criticality of Simulation and Experimentation

"I think modeling simulations is absolutely critical… We can save money, upfront, by modeling, simulating, whether it is designing prototypes and actually it is amazing what you can do, in a computer right now, before you actually build prototypes.

If you take a look at the strategy that we have right now… We are going to make competitors show us a detailed design, that we can actually model and simulate with before we go to prototype before we finalize our requirements, so we make sure we have the right requirements in place and we don't waste money along the way, in development.

And the same thing with training, and even testing on our systems. We are experimenting and simulating with the type of units that we are going to develop for multi-domain operations. So, we know whether they will be successful in combat or not. "

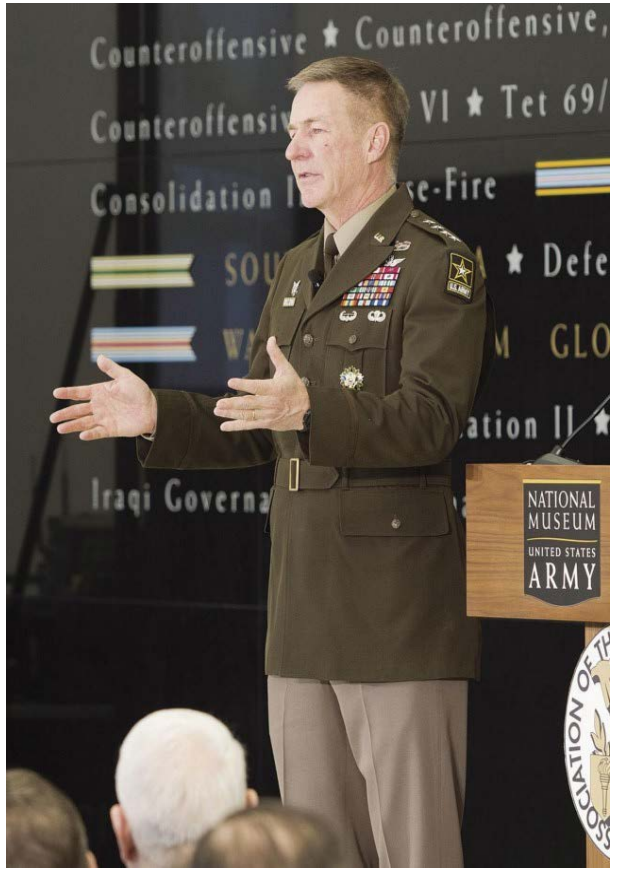


Photo: Paul Lara

GEN James McConville, Chief of Staff of the Army

House Armed Services Committee Holds Hearing on the Fiscal 2021 Budget Request for the Army

Mar 3 2020

Return of an Old Idea

This idea of **operational experiments**,

- for obtaining a **quantitative insight into the operation itself**,

is a new one and is capable of important results**.** (1946)

Properly implemented, it should make it possible for the military forces of a country

- to keep abreast of new technical developments during peace,
- rather than have to waste lives and energy catching up after the next war has begun**.**

Such operational experiments are of no use whatever if they are dealt with as ordinary tactical exercises…

Innovation in Peacetime ➔ Success in War

Philip M. Morse and George E. Kimball, Methods of Operations Research, Operations Evaluation Group Report 54, Washington, ***1946*** (p. 129) // cited in The Practice of Military Experimentation, Brian McCue, CNA (2003)

Experimentation:
Deemed Important in 1946
Confirmed in 2019
Deemed Critical in 2020

But what exactly is EXPERIMENTATION

Defining Experimentation

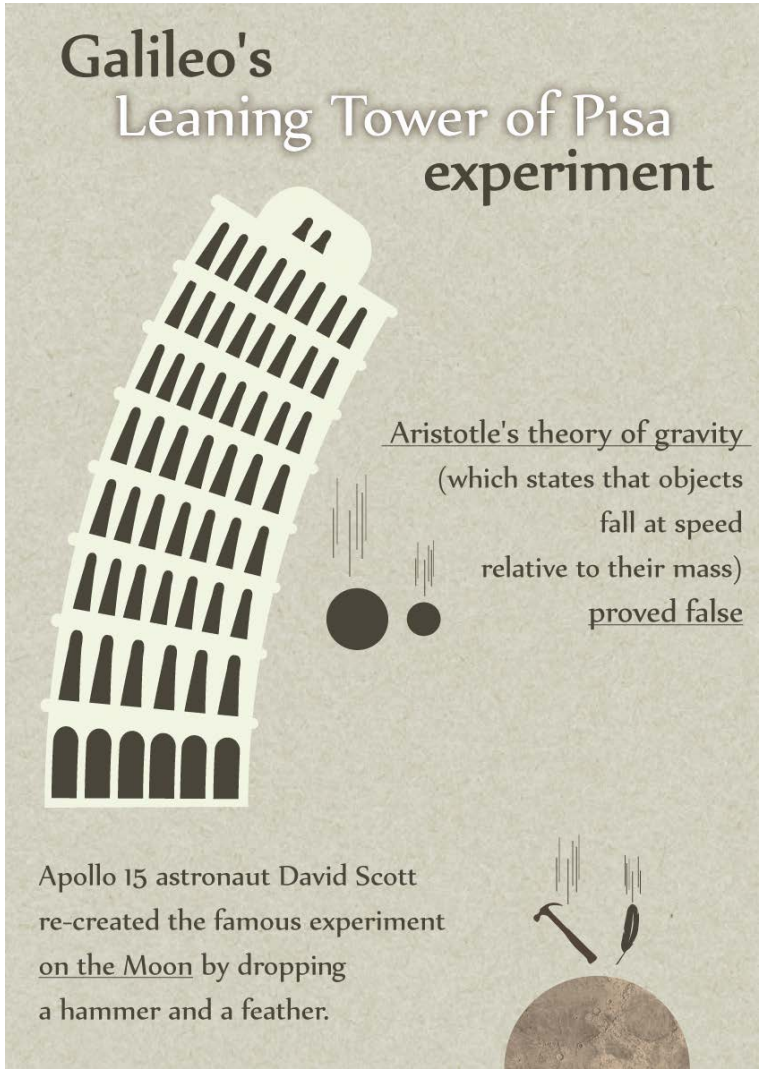
- DoD uses three primary types of experimentation (definitions used in following slides come from CCRP* Code of Best Practices: Experimentation (COBP)
  - Hypothesis testing experiments
  - Demonstration experiments
  - Discovery experiments
- Each type of experimentation
  - Has specific uses within DoD
  - Is characterized by the type of knowledge in hand at the outset
  - Makes different demands on data collection
- The different types of experiment can be combined into a campaign in the quest for increased capability for the military

*Command and Control Research Program (CCRP)

Hypothesis Testing Experiments (COBP)

- Hypothesis testing experiments are the **classic type** used by scholars to advance knowledge by seeking to falsify specific hypotheses (specifically if…then statements) or discover their limiting conditions.
- They are also used to **test whole theories** (systems of consistent, related hypotheses that attempt to explain some domain of knowledge) or observable hypotheses derived from such theories.
- In a scientific sense, hypothesis testing experiments build knowledge or refine our understanding of a knowledge domain

❖ Note: COPB uses a narrow definition. There are other ways to do hypothesis testing. However, this describes a particular type of experiment – what some would call a classical scientific experiment

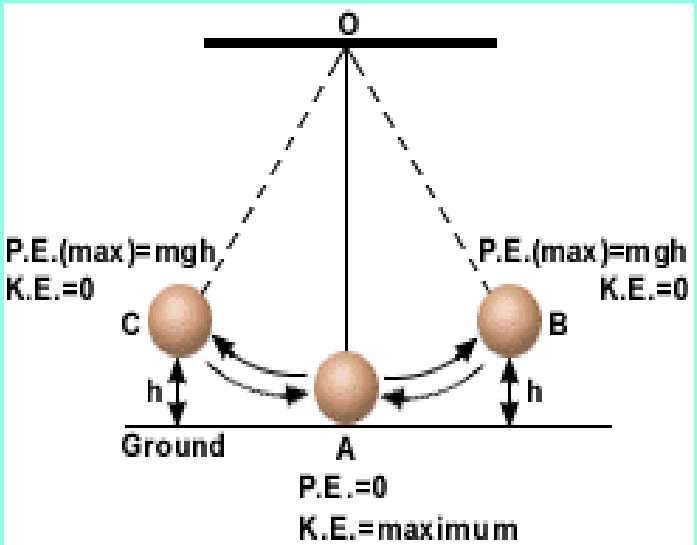


Yathis. Retrieved from http://yathish.deviantart.com/art/Galileo-s-Leaning-tower-of-Pisa-Experiment-358178208

Demonstration Experiments (COBP)

- DoD equivalent activities are **technology demonstrations** used to show operational organizations that some innovation can, under carefully orchestrated conditions, improve the efficiency, effectiveness, or speed of a military activity.
- In such demonstrations,
  - all the technologies employed are well-established and
  - the setting (scenario, participants, etc.) is orchestrated
  - to show that these technologies can be employed efficiently and effectively under the specified conditions.

Done initially as an Hypothesis Test, today the pendulum is a Demonstration



Discovery Experiments (COBP)

- Discovery experiments involve introducing novel systems, concepts, organizational structures, technologies, or other elements to a setting where their use can be observed and catalogued.

- Discovery experiments are similar to the time honored military practice by which
  - new military hardware (aircraft, tanks, etc.) was developed against a set of technical specifications (fly faster, turn tighter, shoot farther, etc.),
  - then given to technical user communities (typically Service test organizations or boards) to work out the concepts of operation, tactics, techniques, and procedure for effective employment.

Let's Summarize (1)

- Hypothesis Testing Experiments
  - Used to advance knowledge
  - Goal: falsify hypotheses (scientific theories – causal relationships) or seek to identify bounds or limitations in the hypotheses
  - Rely on the collection of **empirical data** (valid, reliable, repeatable)
- Demonstration Experiments (as used in DoD)
  - Goal: show that specific technologies can be efficiently and effectively used under the specific conditions of the demonstration
  - Employ well-established technologies (may be prototyped in new devices) in carefully orchestrated conditions (may be part of training exercises)
  - Empirical data collection changes to **observation**, recording of results and noting conditions under which innovations were demonstrated

Let's Summarize (2)

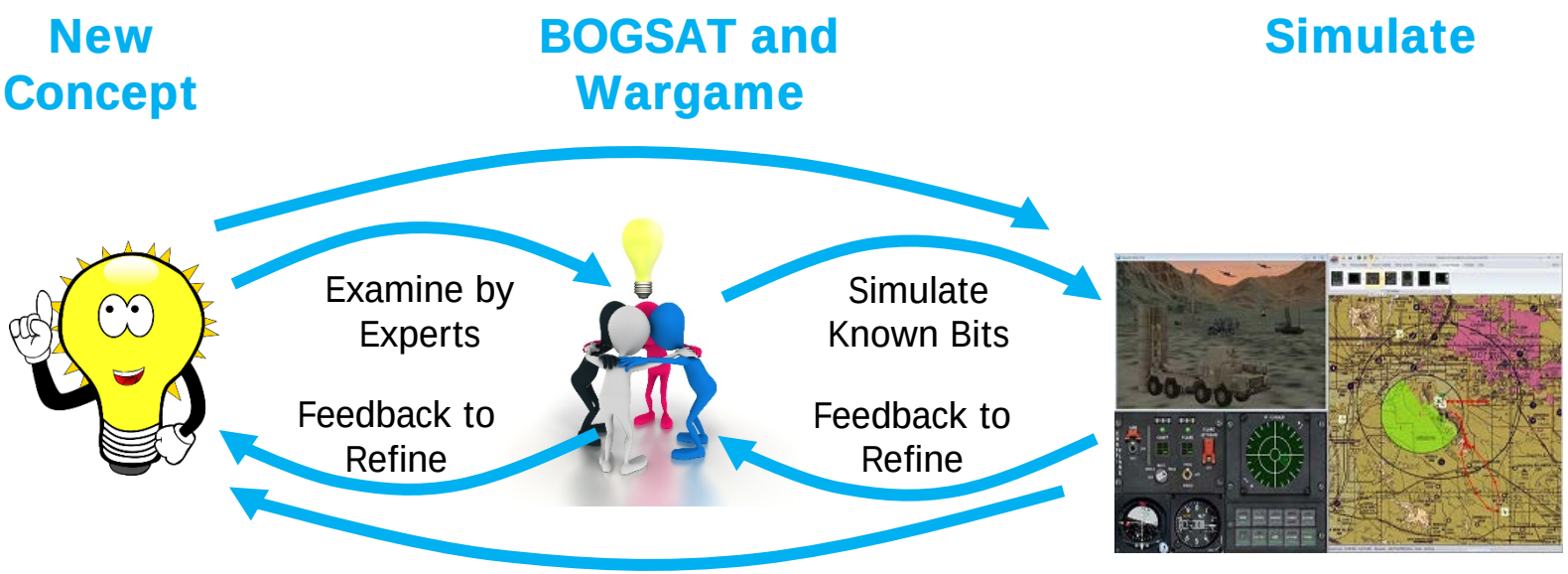
- Discovery Experiments (as used in DoD)
  - Goals: to identify potential military benefits, generate ideas about the best way for an innovation to be employed, and identify the conditions under which the innovation can be used
  - Results need not be validated or repeatable, but must be the result of informed and rigorous examination
  - Uses empirical data and observation to produce findings
  - Intent: Identify promising paths and dead ends, delineate further exploration and experimentation
    - force the community to ask rigorous questions about benefits sought,
    - generate hypotheses, and
    - lay the foundation for more rigorous types of experiments to test those hypotheses

Why Use Discovery Experimentation

- Discovery Experimentation: used prior to any decision to see if an innovation has military potential
- Innovations can be
  - New ways of using current capabilities
  - Exploring a new capability to discover whether or not it has military potential
  - Determining training requirement for new TTPs or new technologies
- A well-designed (discovery) experimentation campaign can reduce risk by
  - Examining a new concept before it is even prototyped to see if it lives up to the promised benefit
  - Exploring different ways of implementing a new capability as a way of refining design, particularly the user interfaces
  - Demonstrating early prototypes at a stage in development where change is far less expensive
  - Using the refined prototype to set the requirements rather than setting requirements and then creating the prototype

A Bit More on Discovery Experimentation

- Discovery experimentation is best used BEFORE deciding upon a course of action: buy something, change tactics, introduce new training
- Critical components of discovery experimentation
  - Best used in a “what if…”, or “suppose…” context – before a real hypothesis exists
  - Allow for failure – in fact, failure is an important means of refining a notional course of action
  - Use different types of simulation depending on issue
  - Always allow for Human-in-the-Loop investigation and *feedback*



Collect data at every step – observational and empirical

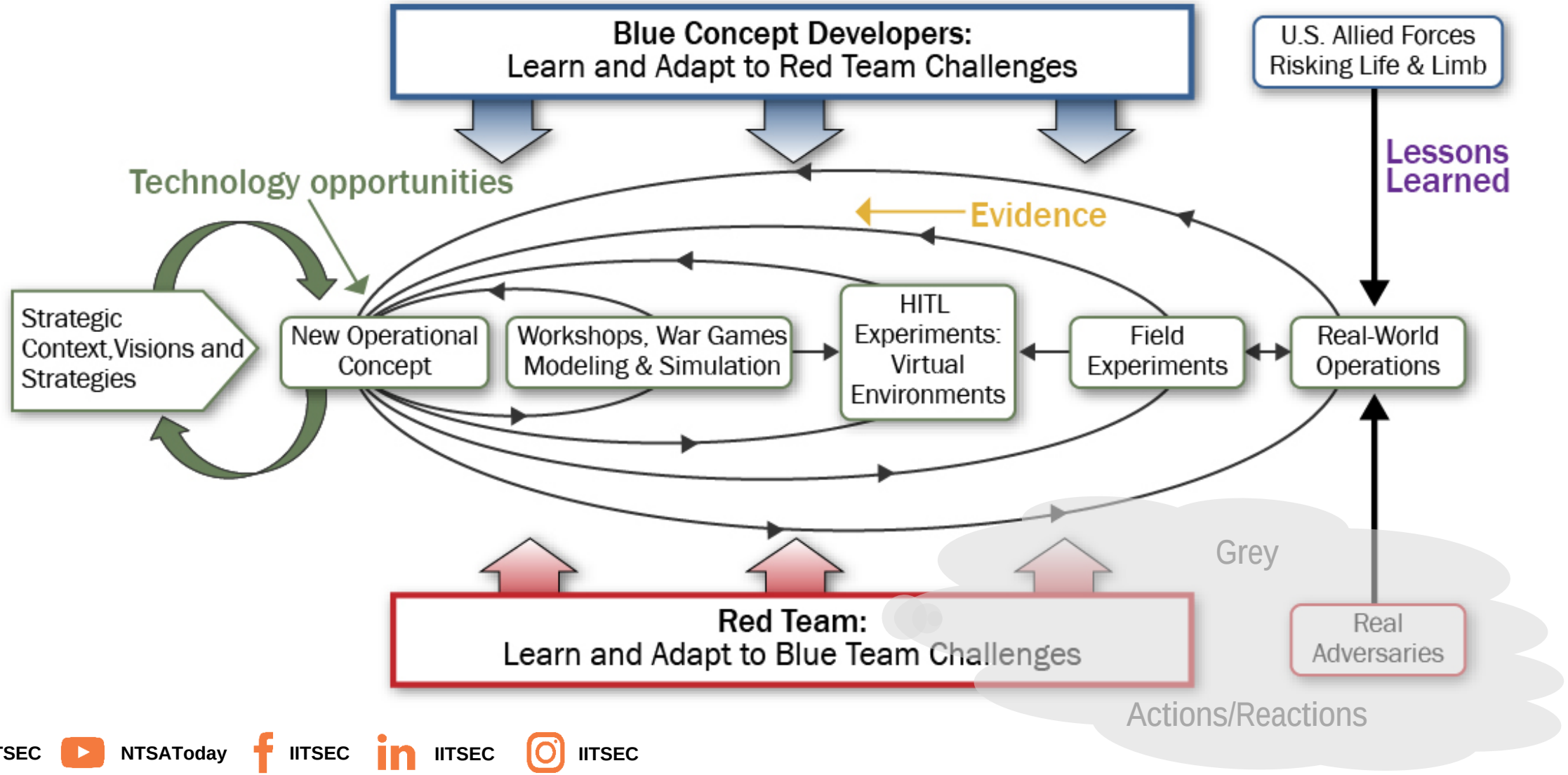
If the concept is new, simulation may not be able to capture all facets, but can be used to examine some of the “what ifs”

What About the Data?

- Refining the idea
  - Collect subjective data in a consistent manner – carefully designed questionnaires to collect results in a formatted manner.
  - Keep track of all refinements as it may be necessary to step back and regroup – not all refinements are likely to play out
- Wargaming the idea
  - Useful part of the refinement process
  - Collect results as above (observational) and include any computational outcomes (empirical)
- Simulating the idea in quick-turn, low granularity constructive simulations
  - Will likely have to work around missing pieces (keep track of the work-around details)
  - Collect results from performance runs
  - Experiment with diverse scenarios as appropriate

This is an Experimentation Campaign

The real power behind experimentation is development of an experimentation campaign



An Acquisition-Based Experimentation Campaign (COPB)

- Explore the military utility of the innovation (technology, TTPs, force structure, etc.)
- Refine the innovation via Discovery Experiment
- Refined innovation becomes an hypothesis
- Refine hypothesis – with discovered bounds (cost, maturity, priorities)
- Develop a demonstration-level prototype
- Refine requirements for actual production

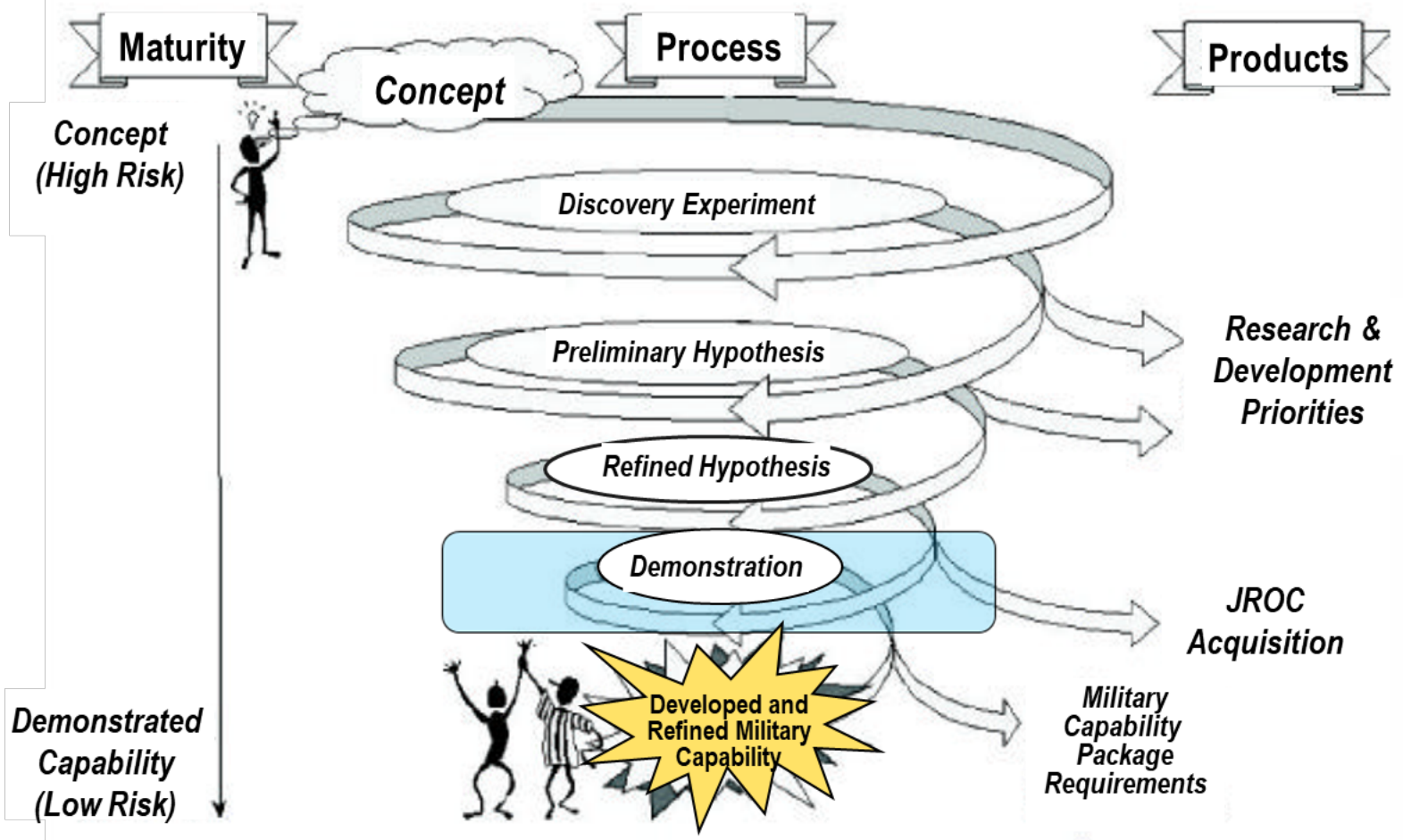


Figure 3-1. From Theory to Practice

26 Code of Best Practice for Experimentation

A carefully developed Experimentation Campaign can significantly reduce ***Risk***

Distinguishing Discovery and Demonstration

- Demonstrations: decisions and development are already done
  - Place new systems in the hands of warfighters often during training exercises
  - Are generally done by the prototyping offices of a single Service with their own exercises

- Elements of Discovery
  - Fielded and novel systems can be brought to bear on the problem (critical to MDO)
  - Joint question: Do the systems provided by several Services become a force multiplier?
  - Questions beyond just system performance:
    - Gaps, seams and redundancies
    - Institutional risks and opportunities
    - Complementary TTPs – do service TTPs work well together?
  - Can be used to explore which systems (current and proposed) would work best together (service or joint)
    - Which systems working together provided the best overall capability
    - What changes in TTPs would provide a significant improvement in the effectiveness of any individual system when working with other systems, particularly other service systems

Multi-Domain Operations: MDO
Multiple Definitions / Concepts
Adds to Land/Sea/Air
- *Cyber*
- *Space*
- *Electromagnetic Spectrum*
- *Human/cognitive*
- *Information …*

Planning and Executing a Discovery Experiment

It doesn't have to be complicated

It doesn't have to take years

It doesn't have to be extremely costly

Weapon-Centric Close Air Support (CAS) Concept Development and Experimentation

WCC Experiment

Stating and Refining the Concept

- General Military Problem Area (what keeps you awake at night)

How can the Joint Force Commander create CAS effects during the early phase (before US forces establish air superiority) of a major conventional operation or campaign without incurring unacceptable risks to the joint force or its mission?

- How to Use Discovery Campaign
  - State the problem space and define the concept
  - Refine the concept and seek a venue for experimentation
  - Add the missing pieces – future capabilities
  - Plan and execute data collection
  - Use feedback to change the environment of the experiment
  - Use feed forward to caveat findings and suggest further investigation

Refining the Concept

- Close Air Support (CAS)
  - CAS is defined as “air action by fixed- and rotary-wing aircraft against hostile targets that are in close proximity to friendly forces and that require detailed integration of each air mission with the fire and movement of those forces.” (JP3-09.3, p xi”)

- A ***contested environment*** is one where the adversary has the capabilities to deny US ability to operate or can restrict US freedom of action in air, space, or cyberspace.
  - In a *highly contested* environment, an adversary possesses the capabilities to interfere prohibitively in one or more domains that requires applying advanced warfighting techniques and capabilities to create desired effects.

US Air Force, *Air Force ISR 2023: Delivering Decision Advantage,* (Washington, DC: US Air Force Headquarters, 2013), 7.

Workshop and Seminars Clarified Need

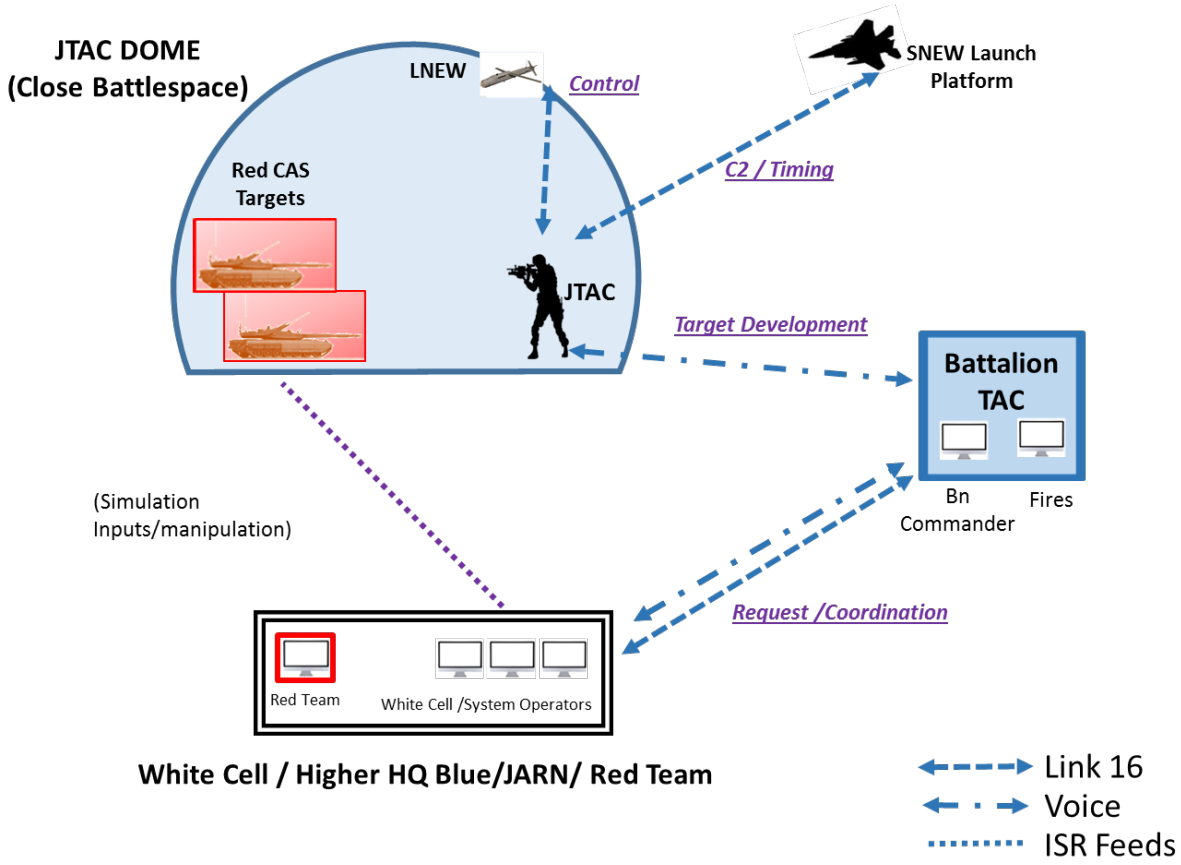
- Clarifying the Mission Need
  - A series of workshops and conferences with the CAS community (AF and USMC) confirmed the problem space
  - CAS mission must be accomplished when the airspace above the battlefield will likely be contested or highly contested, perhaps intermittently.
  - The necessity of conducting conventional ground maneuver with CAS support against a near-peer without first achieving air superiority is a significant and growing possibility.
- The Concept
  - Shift the mission burden of CAS from the platform delivering the munition to the control of the munition from the forward ground element, the Joint Tactical Air Controller (JTAC)
  - Weapon-Centric CAS became the concept
    - Allow the ground controller to direct smart weapons (not currently in the AF inventory)
    - Smart weapons: Standoff Network Enabled Weapon (SNEW) and Loitering Network Enabled Weapon (LNEW)
    - Why SNEW: released outside the major danger zone by any capable aircraft
    - Why LNEW: released outside the major danger zone, loiter anywhere including close to the front

Absent: Constructive Simulation

- Searches across Army and Air Force did not reveal any constructive simulation that included CAS specifically
  - Repeatable, aggregate simulations could not be run to refine the problem
  - Refinements had to be done in BOGSATs and with full-time participation of CAS professions (air and ground)
- Campaign had to skip the constructive simulation and move directly to Human-in-the-Loop simulation
  - Human-in-the-Loop simulation environment found at a CAS training site (Air Force Research Laboratory)
  - Army and Air Force provided operational warfighters with the credentials to provide realistic response to any simulated capabilities
- But there were additional shortcomings
  - The new concept involved operations not present in the simulation and not part of training for Joint Tactical Air Controllers
  - Communications, weapons, and operations were not part of traditional CAS

Battlespace Environment

- JTAC: Joint Tactical Air Controller is the individual usually positioned forward spotting the adversary for the pilot, coordinating airspace over the battle, passing situational awareness to the pilot, and doing battle damage assessment
- The need for air-delivered, precision fires is stated by the Battalion commander and coordinated if necessary with a Joint Air Request Net (JARN)
- Starting Point: New Weapons, Different Communications
  - LNEWs: loitering weapons, powered and controllable by the pilot (now the JTAC)
  - SNEWs: gliding weapons with maneuver ability under the control of the pilot (now the JTAC)
  - Both weapons have several technical means for locating a target – GPS and sensors



The Simulation Environment: HITL Trials

- AFRL provided the HITL facility for the Discovery Experiments (711th Human Performance Wing, Wright-Patterson Air Force Base, Dayton, Ohio)
- Integrated Combat Operations Training-Research Testbed (ICOTT): a virtual, human-in-the-loop, simulation environment—allowed real-world operators (JTACs) to employ platforms, sensors, and weapons that do not exist, but were represented in the simulated world that the JTACs used in everyday training..
- Simulation used: Modern Air Combat Environment (MACE). MACE is a largely physics-based, many-on-many simulation and threat environment with a large order of battle ideally suited for both stand-alone mission rehearsal and distributed mission simulation.
- *Needed:*
  - Simulations of LNEW and SNEW
  - Interface device for controlling LNEW and SNEW
- *Absent:* electromagnetic battlespace environment

As a training venue, the ICOTT facility was designed around a real-time, HITL construct with

- a core simulation capability,
- a semi-immersive visual environment for the individual being trained,
- specialized interface devices (e.g., a laser designator) for the trainee to use,
- a flexible C2 structure including radio and simulation interfaces, operator stations equipped with computer and radio interfaces, and
- a wealth of scenarios used for training JTACs and controllers of remotely piloted aircraft.

Image courtesy of Battelspace Simulations, Inc., http://www.bssim.com/

Metrics, Metrics, Metrics

- What we might want to know (hard data)
  - Number of weapons and targets one JTAC can handle
  - Success ratio: how many weapons were needed to kill/disable/delay a target
  - Second tries: how many times was a second try needed
  - What weapons were more successful against specific types of targets (moving, stationary)
- Contextual and performance data (soft data)
  - What tasks were difficult
  - What types of difficulties were experienced
  - How well a scenario went – was execution improved, tasks got easier, etc.
  - What skills would have been nice to have going into this
  - Was WCC viable, given their operational experience
- Subjects were all instructor level JTACs with multiple deployments in combat zones

Quest for Hard Data

- Data Collection
  - Compromise between what you want and what you can get
- Sometimes data you expect is not available
  - Training results are generally not shared or so heavily redacted that they are useless
  - Expected PDUs may not be available based on the way a modeled entity is designed
  - Human data collectors may not all focus on the same information
- Table at the right shows desired and available data for the WCC experiment

Desired Data Element	Source for Extracting Data				
	Scenario Description	PDU Data	Link-16 Message	JTAC Log	Radio Log
Start Time				10-30%	100%
Weapons Available	100%				
Time Target Assignment				10-30%	50-80%
Weapon-Target Plan				50-80%	10-30%
Time Weapon-Target Pairing			100%	50-80%	10-30%
Time Cleared Hot		100%	100%	10-30%	10-30%
Position in Flight		100% SNEW only			
Impact time		50-80%		10-30%	10-30%
Impact Location		50-80%			
Damage to Target		50-80%		10-30%	10-30%

Data Sources

- Hard data provides a sense for what happened
- Soft data can add context of how and why it happened
- Live observation is a critical part of the data collection – needed for piecing together diverse data sets
- HITL experiments can be frustrating, but they uncover facets of the concept not clear at the outset: change in C2 structure, training needs

Soft Data

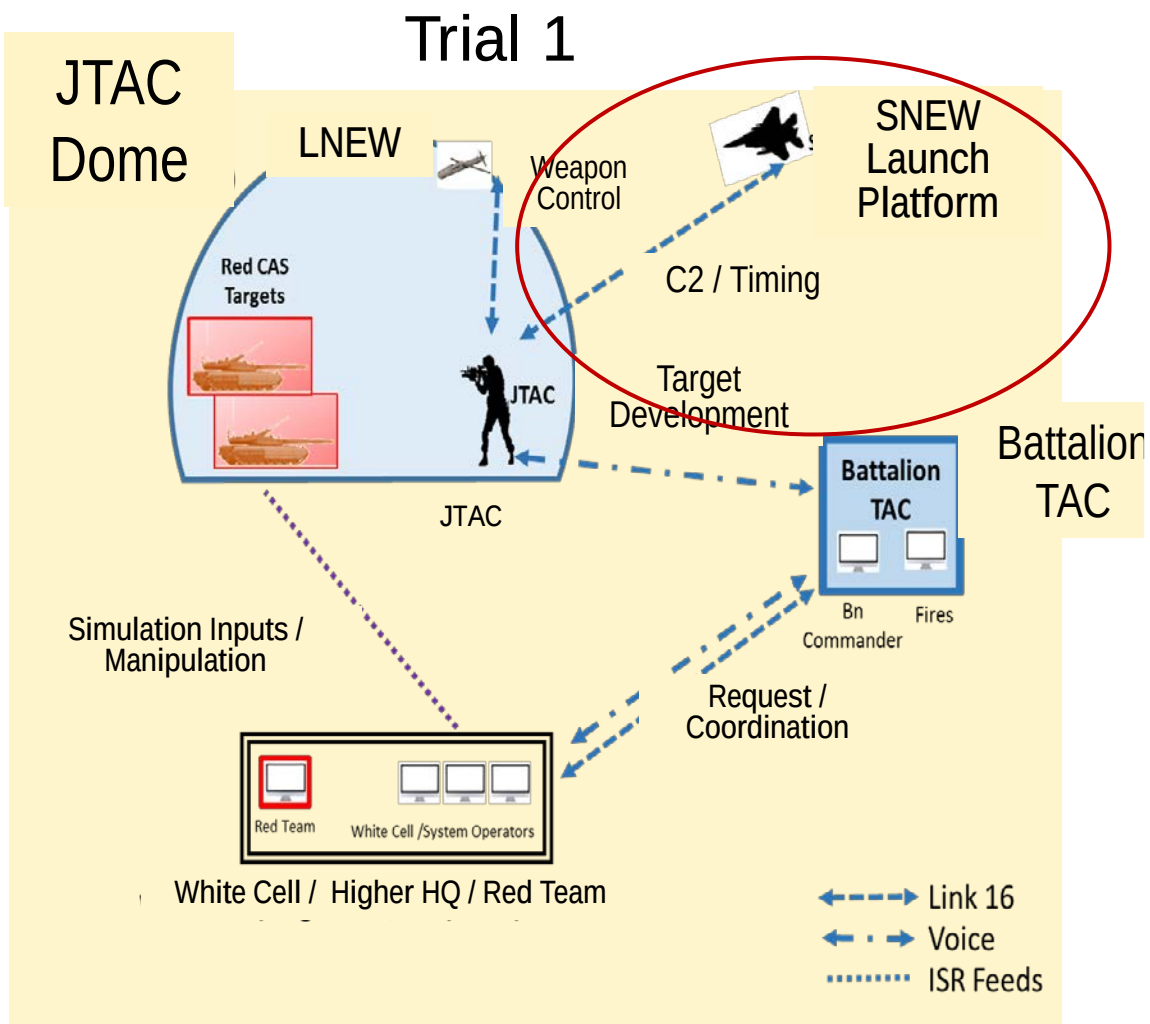
Instrument	Subject(s)	Collection	Total Samples
NASA Task Load Index	JTAC and Observer or JTAC1 and JTAC2	Each run in all Trials (31)	62
Part Task Difficulty Assessments	JTAC and Observer or JTAC1 and JTAC2	Each run in Trials 1 and 2	40
Elicited Response Survey (free text)	JTAC and Observer or combined JTAC1 and JTAC2	Each run in all three Trials	51
Outbrief Notes (IDA data collector)	JTAC and Observe or JTAC1 ad JTAC2 with Ground CDR and Fires Officer	Each run in Trials 1 and 2, after each set of 3 runs in Trial 3	24
After Action Review	JTACs	End of each Trial	12

Observational Data

Source	Information Provided
Radio Log: researcher notes	Time of radio messages, some identification of intended targets, planned weapons, damage assessments—targets and weapons not always identified in message log
JTAC Log	Recreation of planned and executed attacks, developed during outbrief (not all clock times were recorded)
Link-16 Messages	Computer file, included cleared hot (did not identify which weapon), when an entity was killed
Simulation State Messages	Time for cleared hot, state reports for SNEWs, usually impact time, usually impact location, damage to targets

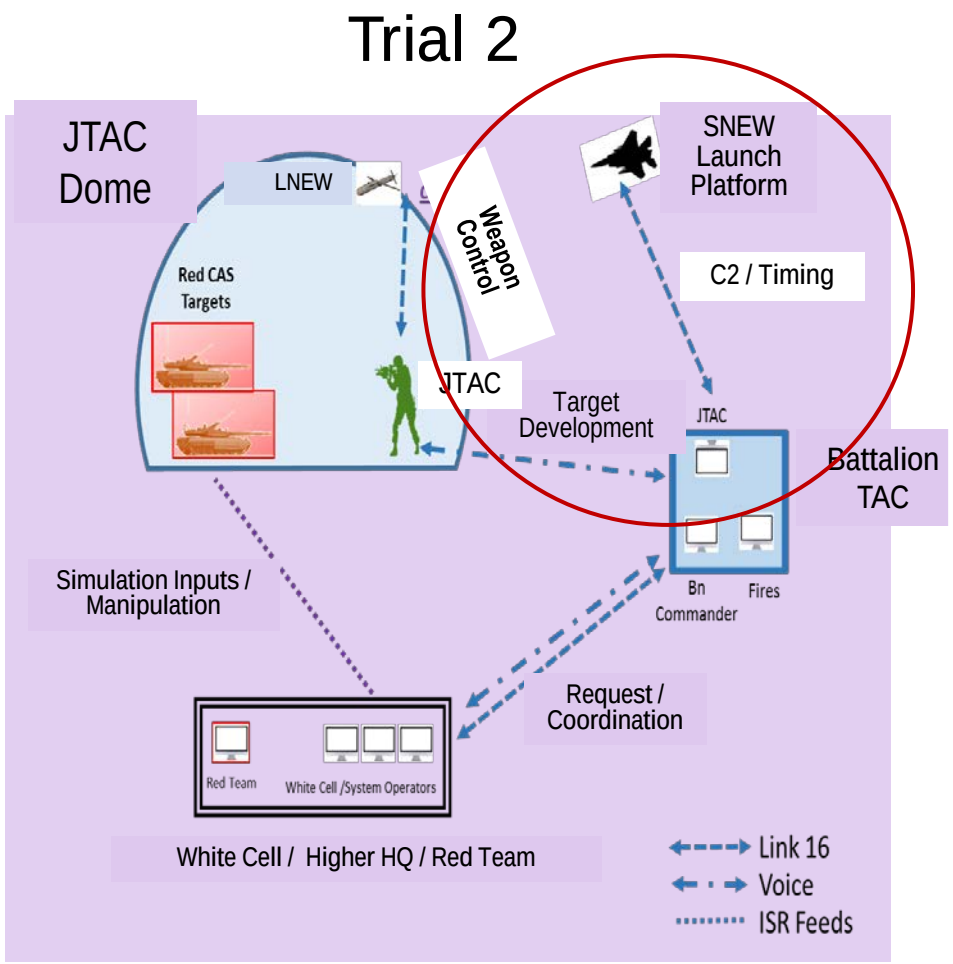
*Trial 1 did not have Link-16 messages.

WCC Experiment: Trial 1



- Initial Configuration
  - JTAC observes target
  - JTAC receives intel updated from Battalion Tactical Air Control (TAC)
  - TAC requests air support (deliver SNEW) from Higher HQ
  - JTAC develops plan of attack using SNEW or LNEW or both in combination
- JTAC's moves interact with the simulation in the dome
- JTAC communicates with TAC and controls weapons comms at the same times
- Bottom line: JTAC too busy with both sets of communication

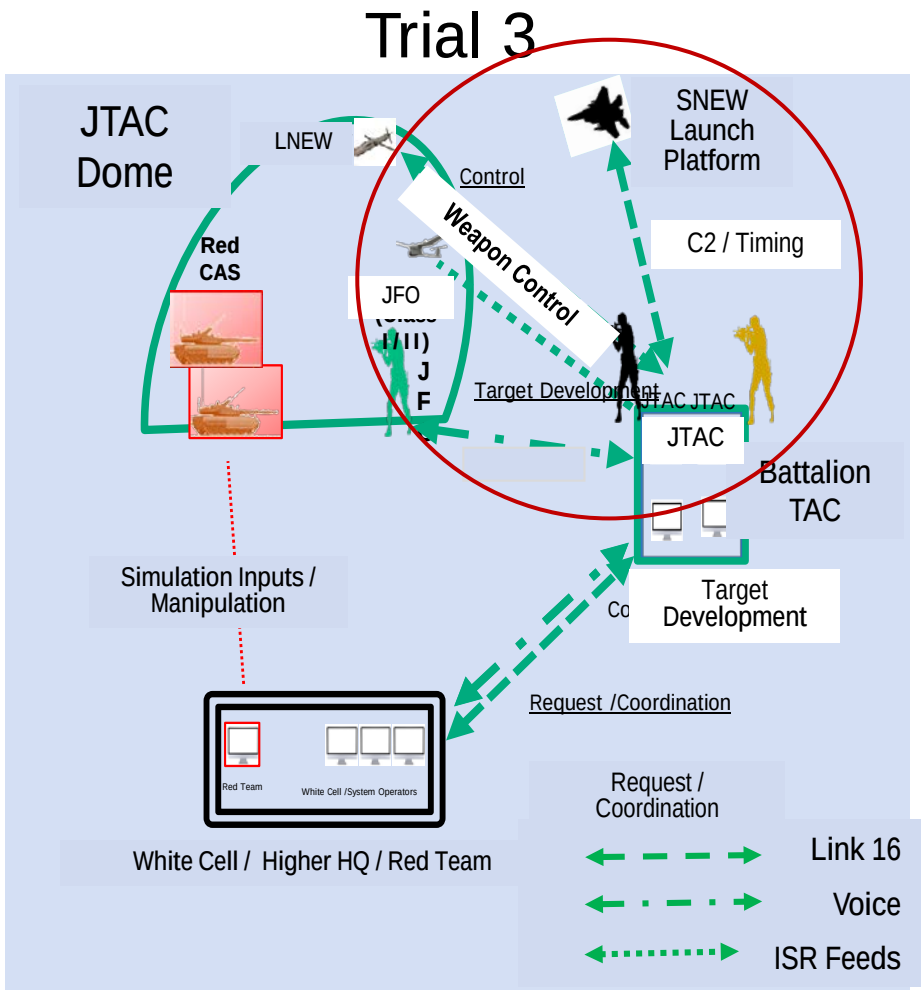
WCC Experiment: Trial 2



- Changes using feedback
  - JTAC already in TAC worked all communications not directly involved with the weapon
  - JTAC in the field handled weapon control
  - Planning done collaboratively between the JTACs
- Improved Performance
  - Needed closer coordination between communication and target plan development

WCC Experiment: Trial 3

- Using Feedback from Trial 2
  - Moved JTAC from field to TAC
  - Two JTACs
    - Coordinated communication
    - Received Intel
    - Developed targeting plan
    - Requested air support
  - JFO (Army, less training) in field
    - Spotted and communicated presence of targets
    - Controlled weapons once fired
    - Reported on damage
- Feed forward
  - JTACS need training in targeting
  - Set requirements for changes in JTAC control device



What Was Learned and Future Work Needed

- Experiment indicated potential military utility; however, total concept validity depends on technical capabilities not as yet measured, including
  - LNEW and SNEW performance (notional capabilities point to utility of potential systems),
  - Secure communications system (affect all battlespaces systems, not just CAS),
  - Timely and accurate targeting sources—especially for mobile/moving targets that may require multiple location updates (potential utility of advanced surveillance system).

- The WCC Experiment did not include the following elements that need closer examination in future studies
  - Realistic battlefield communications and networking
    - Questions remaining: stability and capacity of the overall network with typical loads
  - Representation of the end-game targeting of weapons
    - Would realistic end-game targeting capability change the effectiveness of the weapons and concept?
  - Representation of the adaptive adversary
    - What countermeasures would the adversary use?

What Constitutes Multi-Domain Operations

Multi-Domain Operations: Bridging the Gaps for Dominance

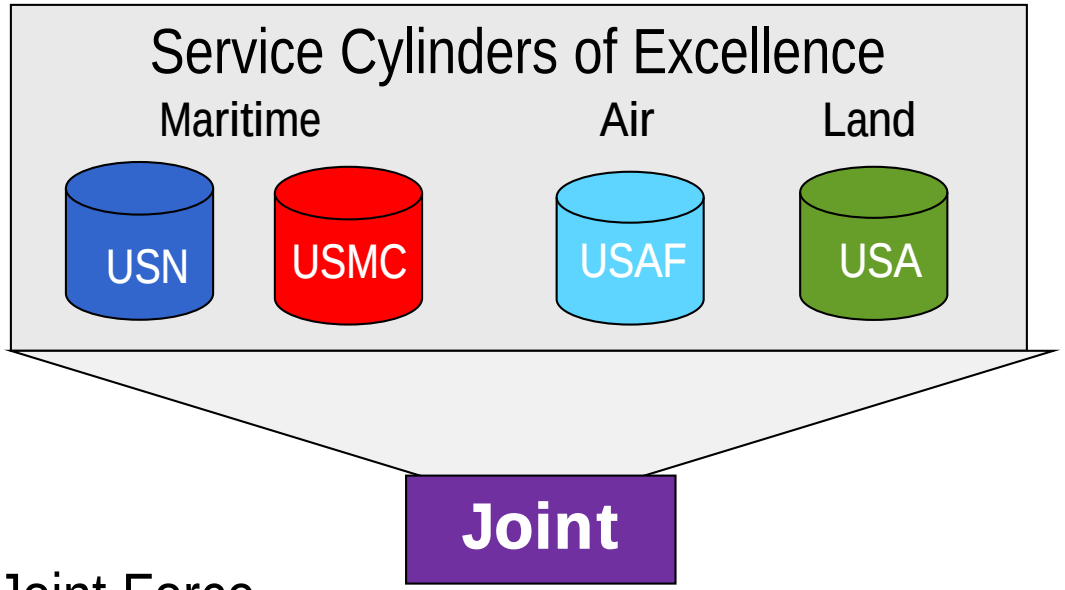
Congressional Research Service, "Defense Capabilities: Joint All Domain Command and Control, April 5, 2020

MDO Concepts

- Concept Stage: best time to begin an Experimentation Campaign to refine Joint operational concepts before Service concepts move is different directions
- Service Concepts Vary
  - Army: Extended and Expanded Sensor-to-Shooter
  - USAF: Focused on Command and Control (Joint All Domain Command and Control JADC2)
  - Navy: Fights MDO with undersea to space in net-centric operational concept
- Generally concepts revolve around
  - any sensor detects,
  - any capable weapon on any available platform engages,
  - any sensor detects damage –
  - any meaning any service across integrated communications

Experimentation – Foundational for MDO Development

- MDO at its best is inherently joint – critical domains are shared across the battlespace
- Service concepts and plans differ significantly
- *Within Services when numerous systems are integrated with only select platforms, communications, weapons, what are the best paths to success in near and long term*

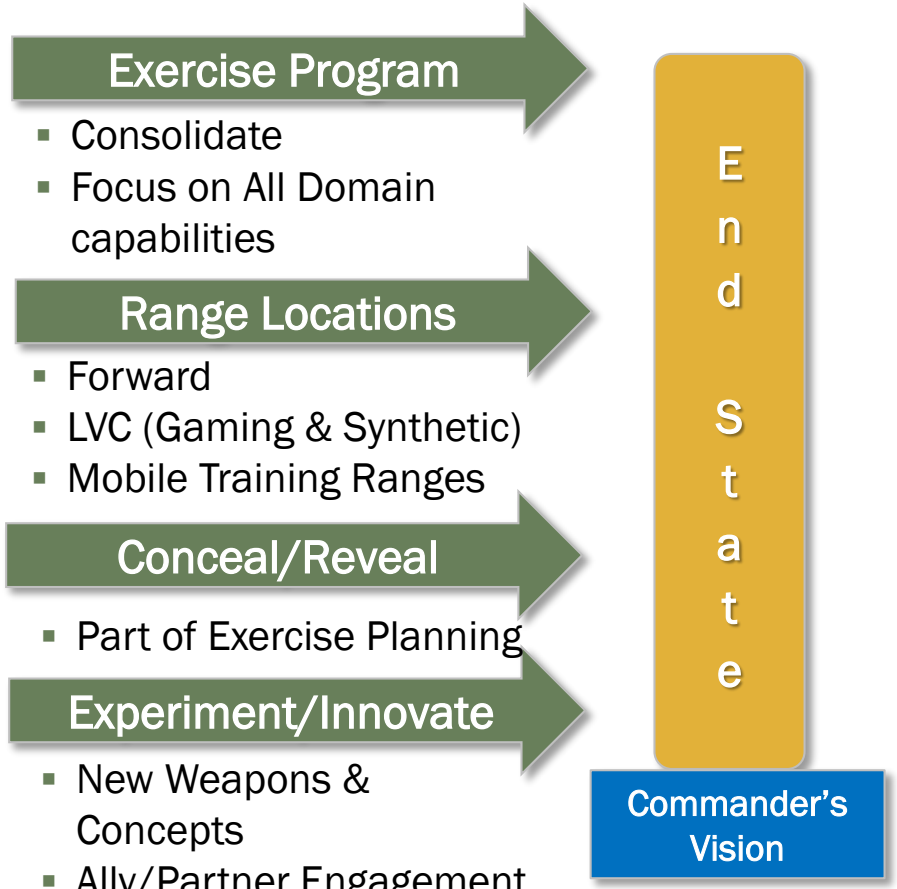


Gaps in Development of an MDO-Enabled Joint Force

- Wargames, training events, exercises, experiments, and modeling and simulation look to answer specific questions in isolation and rarely inform each other
- Joint concept-related activities are limited and isolated across the Department
- Missing: Integrated evaluations of solutions to challenges, leveraging strong operational experience and technical/analytical skills

How to Use Discovery Experimentation

Commander's Vision Forms the Basis for Experimentation Campaign



Abstracted from USINDOPACOM

- USAF Chief of Staff Gen. Goldfein: USAF, Navy Experimenting with Multi-Domain Operations*
  - Air Force and the Navy are trying to connect combat assets in new ways… to improve joint, software-driven warfare.
  - "We did
    - some pretty cool experimentation with space linked to [intelligence, surveillance, and reconnaissance] linked to [command and control] linked to shooter, and
    - then wrote the algorithms, put the common architecture in place, and
    - then worked the kill chain machine-to-machine, where the only human that was actually on the loop was the shooter."
- Joint experimentation is critical to uncovering gaps and capabilities in current force and remedy the gaps in the future force

*https://www.airforcemag.com/goldfein-usaf-navy-experimenting-with-multi-domain-operations/

Conclusion

- Discovery experimentation is not a free-for-all, but a carefully thought out and planned approach to addressing an issue long before it becomes a pressing problem.
- It allows humans to interact with new or potential concepts and capabilities and explore their military utility—something that is not often supported through traditional studies or experiments.
- It requires careful attention to the specification and collection of data that will provide solid evidence for the conclusions reached through executing the experiment.
- If all of these constraints are observed, discovery experimentation can be a valuable tool in the process of larger capability-to-concept campaign
- AND it is a critical need for developing a MDO-capable force, especially the joint force

Learning Objectives

- Distinguish discovery experimentation from other forms of experimentation
- Define the flow of an experimentation campaign
- Explain why one might use discovery experimentation -- provide an example
- Describe how to develop a discovery experimentation campaign
- Explain the utility of an experimentation in exploring Multi-Domain Operations (MDO)

Contact Information

Dr. S. K. Numrich (Sue): snumrich@ida.org

Dr. Kevin Woods: kwoods@ida.org

References

- Philip M. Morse and George E. Kimball, Methods of Operations Research, Operations Evaluation Group Report 54, Washington, 1946 (p. 129) // cited in
- McCue Brian, “The Practice of Military Experimentation,” CNA (2003)
- Alberts, David S., Hayes, Richard E., Code of Best Practices for Experimentation, CCRP Publication, 2002, PDF available http://internationalc2institute.org/codes-of-best-practice/ (last accessed 5/25/17)
- The Role of Experimentation in Building Future Naval Forces, National Research Council, 2004, (National Academy Press online)
- Jones, Anita, “Science, Technology, and Military Experimentation”, editorial, The Bridge, Volume 30, Number 3,4 (download PDF) https://www.nae.edu/File.aspx?id=7327 (last accessed 5/25/17)
- Budge, L., et al., “Future Joint Force I Experiment: Final Report,” (FOUO) IDA Paper P-3738, Oct. 2002.
- Tyson, Michael, “Try and Try Again: Military culture must embrace experimentation and failure,” https://www.usnews.com/topics/author/michael-tyson (last accessed 5/25/17)
- Woods, K.M., Kramer, S.D., Numrich, S.K., Resnick, J., Jackson, J.A., “Weapon-Centric Close Air Support: Concept Development and Experimentation Final Report”, IDA Paper P8290, Dec. 2016