History and Basics of M&S[1]

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Everything has a history. What few realize is that Modelling and Simulation or M&S predates the computer. Many of you are familiar with the concepts of chess. What makes chess significant? For one it represents rules. It also contains a strategy with infinite possibilities. While today most regard it as a commonplace game, strategic prowess was taken very seriously in the ancient world where reputations, not to mention kingdoms were won and lost to military campaigns. Figurine warriors replicating the art of battle have been dated as far back as 2500 BC in Egypt. As best as can be determined, these figurines offer us the earliest known example of formation and manoeuvre. The Chinese were no exception. Sun Tzu, Chinese strategist and military philosopher wrote about the game Wei Hei or *encirclement* around 500 BC. India circa 700AD added pieces, moves and strengths to Shataranja, the closest predecessor to the chess we play today.

We fast forward to the 1600's to Germany where more military detail was added to a larger board and additional pieces. This larger board now sported rivers, forest and other terrain features. The enhanced version of war-gaming called Königspiel or *the King's Game* advanced a notion that war can be 'reduced' to distinct concepts and formal rules. In 1824, Prussian Baron von Reisswitz published a book called Kriegspiel or *wargame.* Instead of a flat board, another revolutionary addition was made in the form of three-dimensional terrain. Dice decides the outcomes of fires, introducing both abstraction and quantification. While Königspiel fostered the concept of *reductionism*, Kriegspiel gave us in due time topographical maps and the stirrings of battle calculus. If the field of M&S can claim its rightful origin chronologically, it is the 1800s where the basic concepts of M&S as we recognize them become evident.

Now we go to another continent – North America. In 1879**,** Army Major James Livermore, felt there was more to war than just battle. The new twists he added were logistics and the quantification of fatigue. A few years later, another Army Officer, Lt Totten, felt that Kriegspiel had an anomaly that prevented it from being played in a political context. His insight was that one should not jump into Kriegspiel immediately but instead proceed from the simple to the complex; adding layers to the game depicting the different facets or levels of war: tactical, operational, and strategic**.** This is the first time we see a 'hierarchy' in modelling. By 1887,

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Little, D. (2006) History and Basics of M&S. In *Integration of Modelling and Simulation* (pp. 1-1 – 1-4). Educational Notes RTO-EN-MSG-043, Paper 1. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
01 SEP 2006	**N/A**	**-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
History and Basics of M&S1	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Battle Command, Simulation & Experimentation Directorate (BCSE) HQDA, DCS G-3/5/7 400 Army Pentagon Washington, D.C., 20310 USA**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM001943., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**UU**	**34**	

wargaming becomes a permanent part of the curriculum at the U.S. Naval War College due to the efforts of William McCarty-Little.

The beginning of the 20th Century witnessed a proliferation of techniques. In Berlin, wargaming developed the WW I mobilization plan. In Great Britain, Colonel Lanchester originated equations that translate the effects of battle on an area. Prior to WWII, Japan wargamed its incursions into Manchuria and China. By the 1930s, a Live-Virtual simulation carried Japanese pilots suspended from the ceiling over the mock topography that would later become the attack on Pearl Harbor, Hawaii. The effect of this technique also added to their misfortune at the Battle of Midway, signalling the beginning of the end.

While the first 50 years of the 20th Century overshadowed a preponderance of design constructs and analysis, the Cold War was still what we now consider manual…analogue…primitive. By 1950, it is still large boards, playing pieces and push pins. While still a novelty for many in the military community, the research industry continually improved their methods of quantitative analysis, bringing the two ever closer into a discipline.

Three significant occurrences changed the status quo: the transistor, integrated circuitry and commercially obtainable computers. Once this became available to the analysis community, M&S increased exponentially. Imagine if you will the notebook computer or personal computer that allows you to read this. Your operating system was only dreamed of in the 1950s. While the large wargaming rooms had mock terrain and push pieces, an equal amount of room was needed for our early models. The logic behind this impetus of modernization was simply one of global political-military competition. In 1958, the Cold War took on a new twist when Russia launched Sputnik. In response, President Eisenhower created a host of organizations in response. One of them is the Defense Advanced Research Projects Agency which played a role in our field as well as the precursor of the internet.

The Naval War College by this time has a computer-assisted wargame taking up three floors of an academic building. Built to accommodate a single wargame, it is torn down completely and reassembled from the very beginning for a subsequent effort. This capability was the natural progression of the wargames developed there by William McCarty-Little in the 1880's. In spite of its obvious drawbacks, this gets the attention of U.S. Navy fleet commanders, who send their staffs to train on it.

During the 1960's, IBM roles its mainframe computer called the '7070.' This is the first computer capable of supporting simulations; again a far cry from what you are using now. By 1964, the Naval War College replaces analogue technologies with digital and conducts its first remote wargaming. This is what we in the U.S. call the 'McNamara Era'[2] During Vietnam, the overemphasis of quantification distorts decision-making at the highest levels and M&S suffered for some years afterwards.

Finally in the late 1980s, a prototypical simulation standard was developed linking technology with Division and Corps computer-assisted exercises. Additionally, the conceptual design of physical or virtual simulators is to link them or become *networked*. Terrain maps and overlays are now added to the screens and the Department of Defense (DoD) codified simulation policy through the 5000-series directives, thus establishing a formal policy in acquiring expensive M&S technology. For those that remember this era, the solitary computer was still prohibitively expensive – the prospect of computer commoditization still afar off.

Having given the history of M&S in rapid fashion, the question that deserves to be answered is 'so what?' If nothing else, the history of M&S provides a path-dependency to what it is now. It is through historical

[2] The McNamara Era is best understood by Secretary McNamara himself in the documentary film, 'The Fog of War.' (2003).

necessity that M&S allows us today an 'arms-length' analysis as an enabler of decision-making. M&S more often than not, affords a meeting of minds not only vertically within a given service but horizontally between all of them. This is far better than learning 'on-the-spot' within theatre, a prospect with disastrous implications. Thus defined, computer-based simulation attempts to place military decision-makers into recognizable dilemmas bearing an uncanny resemblance to: processes, facilities, systems, organisational behaviour, environments and activities embodied by weapons systems, airframes and vehicles not to mention individual capabilities.

One of the spill-over effects of M&S was its contribution to 'Jointness.' The Aggregate-Level Simulation Protocol (ALSP) linked service wargames such as the Army's Corps Battle Simulation (CBS) and the Air Force's Air Wargame Simulation (AWSIM) long before the notion came into vogue. While the notion of Combined Arms Tactical Trainers (CATTS) seeks horizontal integration of branch-specific simulations such as artillery or air defence, a Marine Corps aviation unit can go to any Army Aviation Combined Arms Tactical Trainer (AVCATT) and fly a mission without raising any eyebrows.

This is not to say that the relationship is always smooth. Military-sponsored M&S it is fair to say is ahead in areas and well behind in others. The Army for example is pushing for the complete digitization of its communications and linking it to M&S. Also major commands purchase commercial software off-the-shelf or *COTS* because the government can only forecast and project expenditure for known requirements well in advance. Just when we thought the military community approached saturation, we found ourselves closer to square one after 9-11 than before. Due to the fungibility of the open market, niche programming in human agency is equally sought after.

Many then ask what if any the similarities and differences are between military and civilian simulations. We define simulations as a "model able to repeat the same events over time"[3] which appears to hold true for both. It is the military analyst not the simulationist with more in common with economists and political scientists. Again the simulationist serves a commander seeking training value available due to the evolution of gaming through history. The analyst on the other hand shares a common goal with the economist or political scientists through the isolation of a particular or singular phenomenon. One prime example is called Monte Carlo Simulations. Monte Carlo simulations approximates solutions to mathematical or physical problems by offering a range of values possessing a calculated probability of being the solution.[4]

More often than not, the military simulation is stochastic in nature. When you left the hotel room, a taxi could have struck you crossing the street, the entrance could have been blocked or an attractive lady could have asked you for directions. As opposed to Kriegspiel, events are not bad if you roll a one versus a six or as mundane if you have a 90-plus percent chance in Monte Carlo of being here on time. Figuratively speaking, a stochastic simulation is not one knob that can transform training events from easy to hard but several.

In this particular context, when a military-oriented simulation can act out a variety of behaviours conducive to combined-arms operations on a computer screen, we might say that we are witnessing a constructive simulation. There is also a situational dependency to combat power in constructive simulations, setting it apart from the others. When we dismount infantry crews from tracked vehicles in the simulation to attack terrain only navigable by foot, we have 'disaggregated' from the total combat value of the crew system. When we place them back in the vehicle, they are an aggregate once again. While these response cells (units) fight the

[3] Paraphrasing the DOD M&S Glossary.

[4] Monte Carlo has multiple variables with a range of probability spread along on a 'bell-shaped' curve.

war via computer, the reporting, maps, overlays, orders processes for the staff or primary training audience remains overall equally stressful as under real conditions.

If the simulation is weapon or crew-centric requiring navigation, acquisition or engagement inside a setting that is an imitation of the real thing, it is most likely a virtual simulation. Some competencies are impractical or impossible to replicate through technology. The best way to integrate manoeuvre using live ammunition, negotiating with warlords or coordinating with another service is best done live. While it is impractical or too expensive to do everything live, the sum of its parts called *Live, Virtual and Constructive* simulations or L-V-C for short provides a matrix of values in obtaining the best training possible.

Considering the exposure to crews, line units, staffs and commanders, it is no exaggeration that the M&S professional maintains a finger on the pulse of readiness.

History and Basic Concepts of M&S

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Learning Objectives

Identify Model and Simulation key concepts from a historical perspective.

Explain model and simulations historical concepts that are applicable for today's simulations.

Describe the fundamentals of modeling and simulation concepts.

Describe the concept of modeling.
Describe the attributes of physical models, mathematical models, and process models.
Describe the terms fidelity and resolution.
Define live, virtual, and constructive simulations.
Define classes of simulations.

Antiquity to Modern Era

~2,500 BC - Sumeria/Egypt: figurine warriors

~500 BC - China: First war game (*Wei Hei*, Sun Tzu)

1800s Germany: *Kriegspiel* (“military chess”)

Birth of “modern” M&S

Antiquity to Modern Era

1780s - Basic M&S concepts evident

Aggregation (few playing pieces = many entities)

Terrain representation (multi-colored hex grid)

Rules of movement

Umpires adjudicate player actions

War reduced to basic concepts and rules

Reliance on simplifying assumptions

Differences in modeling naval & land warfare

Early 1800s - German *Kriegspiel*

Reisswitz replaces war chess game board (1824)

- 6'x6' ***portable sand table*** that modeled terrain in relief
- Detailed topographic maps

New concepts introduced

- Scaled blocks represent units & frontages
- ***Scenario; time/distance considerations***; moves
- Qualitative aspects of military strength
- ***Codifying military experience & effects of combat ("VV&A")***
- Rules for a wide range of contingencies
- Effects of combat calculated; dice decide effects of fire

Late 1800s - US "*Kriegspiel*"

MAJ Livermore introduces U.S. to modified *Kriegspiel* (1879)

- More sophisticated symbology; ***tracking consumables***
- Attempts to ***account for human element*** (time, fatigue)
- Growth in complexity, ***artificiality***, time & ***cost to set up & run***

LT Totten includes different levels of war
("hierarchy of models")

Naval War College created (1884); adopts wargaming (1887)

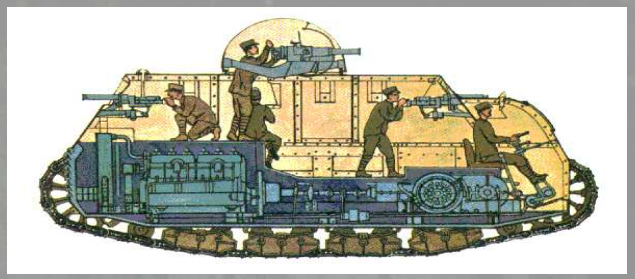
William McCarty Little influenced by Livermore & Germans

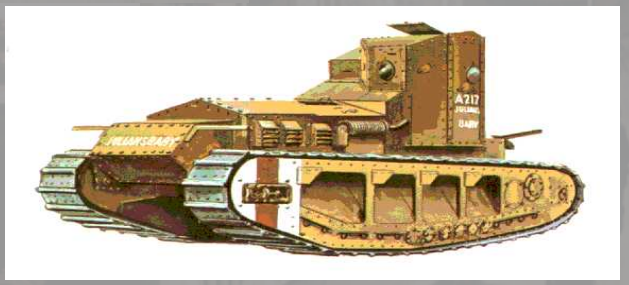
"Complete preparedness against all possible contingencies"

Dual, tactical & strategic board games used (to WWII)

1900 - 1950

Prussian strategic simulation (mobilization planning for WWI)





Lanchester equations codify firepower relationships (1916)

1900 - 1950

Japan used analytical M&S in research & planning (1930s)

Germany elaborate pol-mil gaming; use diverse forms of M&S (1930-1945)

US Louisiana Maneuvers (1940)

Operations research supplants wargaming (mid-1940s)

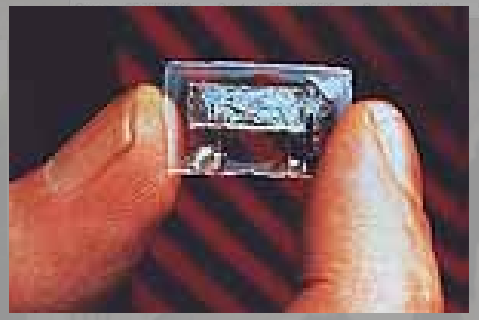
Post WWII Through 1950s

Electronic computer invented ENIAC, 1946

First commercially available computer UNIVAC-1, 1952

First silicon transistor Texas Instruments, 1955

First mini-computer PDP-1,1959



Integrated circuit invented, 1957

Post War Through 1950s

SPUTNIK

Pres. Eisenhower creates DARPA (1958)

First electronic fighter aircraft simulator (Link, 1950)

SAGE System (live/virtual simulations of air defense) (1959)

1960s

IBM 7070 computer (1961)

CARMONETTE Analytic Model (1961): Cost and operational effectiveness analyses in support of acquisition
http://www.modelbenders.com/foundation/preview/sld011.htm

Line-of-sight Algorithms developed (1961)

Early Digital Terrain (1963):
developed for the space program to train astronauts

ARPANET Advanced Research Projects Agency (ARPA) Network (1969)

McNamara era: OSD & JCS had a negative impact on M&S
M&S was used during Vietnam, but it was a disaster

1980s

First FTX driven by a simulation (JESS)
TOC Environment (CATTS)
1987

Late 1980s - 1990s

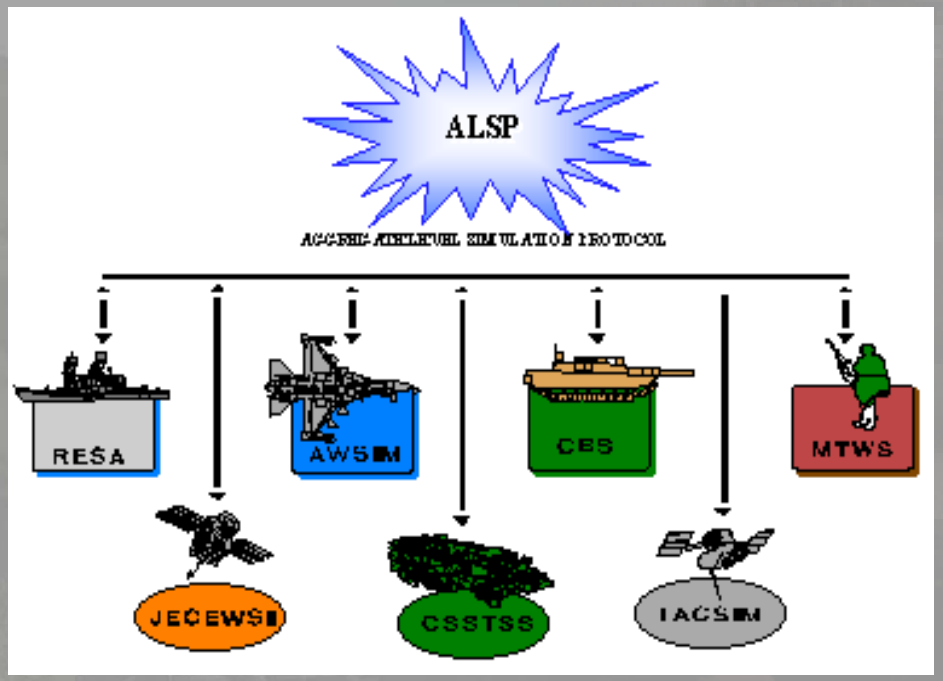
First REFORGER driven by a simulation
DoD Simulation Policy Study
DIS standards

1990s

M&S in Operation Desert Storm

- Constructive simulations for operational wargaming
- Virtual simulation linked to operational systems (ODIN)
- Gulf War battle of “73 Easting” catalogued using SIMNET
- Semi-Automated Forces (SAF) for COAA

1990s

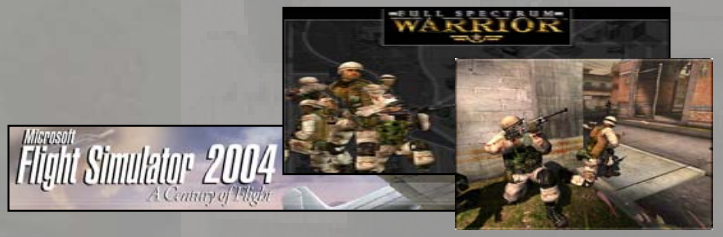


ALSP Links Service Wargames (Army CBS + AF AWSIM)
REFORGER 92 & Ulchi Focus Lens 92
DSB Codifies 3 Types of Simulations (Live, Constructive, Virtual)
CCTT Development Begins
Zen Regard Exercises

2000s

The rise and fall of JSIMS

Use of COTS

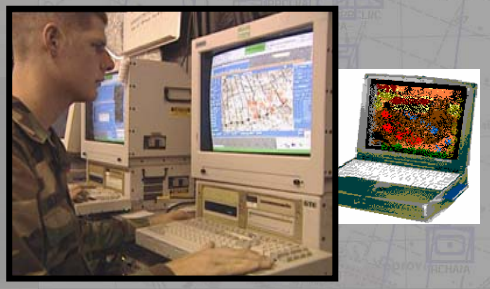


New federations

JNTC and ACTF

Digital battlefield

ABCS



Experimentation (DCX I and II)

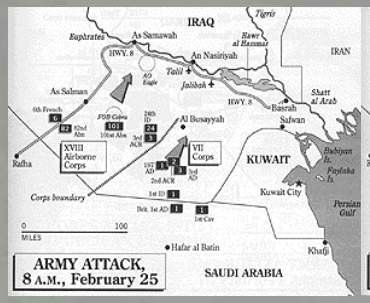
- Demonstrate warfighting capability
- Assess progress in meeting Force XXI DTLOMS reqts
- Integrate C4ISR at all levels
- Army contributions to Jt Cbt Opns.

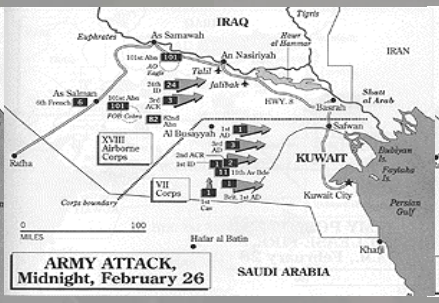
Simulation of “brown out” to prepare AH-64 pilots for OIF and Afghanistan

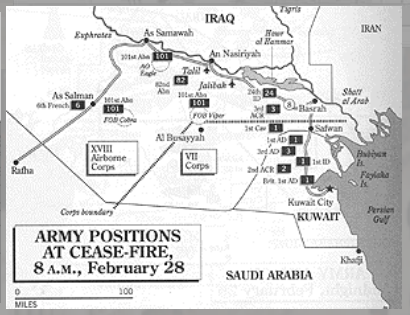
Future Prediction

Nor have models done well predicting outcomes of <u>future</u> conflicts.

Models said Gulf War would last longer and result in far more allied casualties than actually occurred.







The Human Element in War

Clausewitz:

"The difference between real war and war on paper is friction" (i.e., the *human element*).

Napoleon:

"The moral is to the physical as three is to one."

In general, a model or simulation that fails to account for the human aspect of conflict is artificial and unrealistic.

Why Is M&S Important to Me?

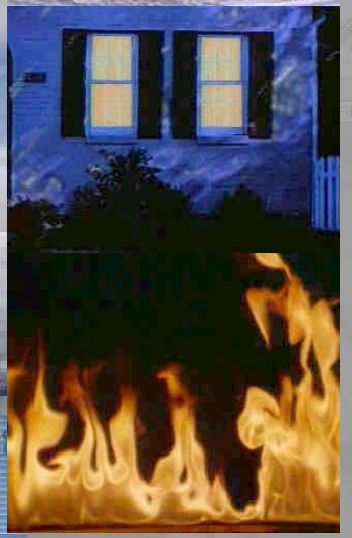
M&S can:

- *Improve* capabilities and enhance *decision making* and *readiness*
- *Allow* warfighters and military planners to *rehearse* joint *missions*
- *Provide training* for the complete spectrum of military operations
- *Allow* testers to create *realistic developmental* and *operational test* scenarios
- *Enhance information-sharing* among designers, manufacturers, logisticians, testers, and users

What Is Modeling and Simulation?









An attempt to imitate real world

- **processes**
- **facilities**
- **systems**
- **humans and organizations**
- **environments**
- **activities**

What Is a Simulation?

Simulation - A method for implementing a model over time.

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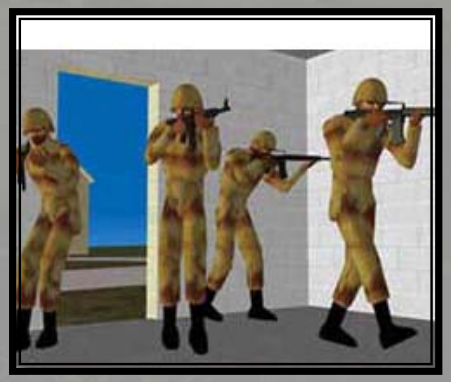
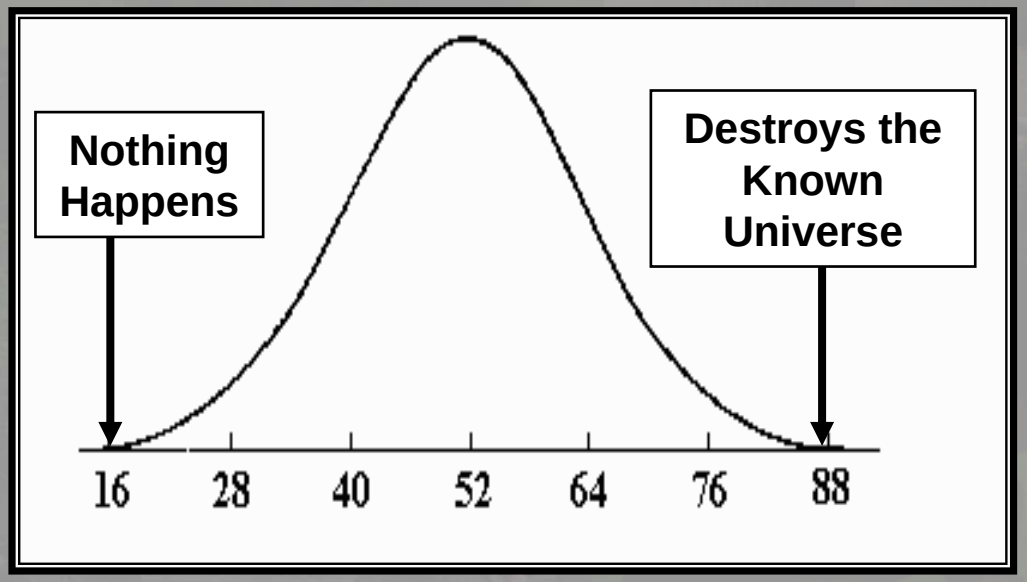


Classes of Simulations

Monte Carlo Simulation - the use of computer simulation to obtain approximate solutions to mathematical or physical problems, especially in terms of a range of values, each of which has a calculated probability of being the solution

Multiple variables; probability based on Bell Curve



Example: Simulations of Atom Bomb in WWII

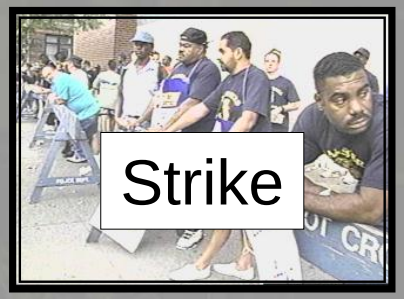
Classes of Simulations

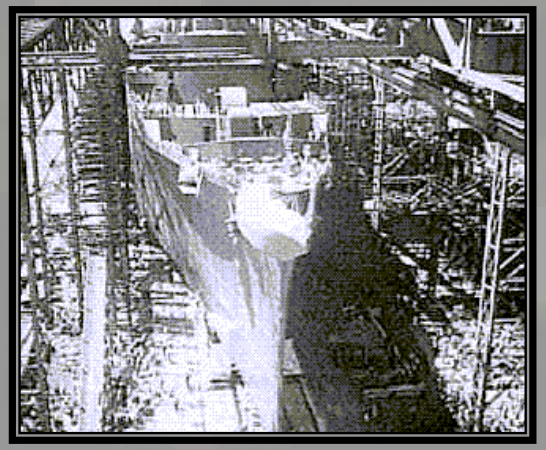
Deterministic Simulation - a simulation that does not contain any probabilistic (i.e., random) components

Example: Simulation of a chemical reaction

Classes of Simulations

Stochastic Simulation - a collection of random variables ordered over time, which are defined on a common sample space. Random events can throw the simulation off.





Example: Simulation of a shipyard

Types of Simulation

Live Simulation - Simulation involving real people operating real systems.

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Live simulations:

- involve individuals or groups
- may use actual equipment
- may provide a similar area of operations
- may not fully replicate actual activity

Types of Simulation

Example of a Live Simulation

Advantages

- *Train under realistic conditions*
- *Human factors*
- *Allows you to experience capabilities and limitations.*

May result in:

- *Large resource expenditure*
- *Safety hazards*
- *Maneuver damage*

Types of Simulation

Virtual Simulation -

- A simulation involving *real people operating simulated systems*.
- Virtual simulations inject human-in-the-loop in a central role by exercising:
  - *motor control skills*, e.g.,flying an airplane
  - *decision skills* (e.g., committing fire control resources to action)
  - *communication skills* (e.g., as members of a C4I team).

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Types of Simulation

Examples of a Virtual Simulation

Virtual simulations:

- Have *various degrees* of equipment *realism*
- Exercise *decision/communication skills*
- Enable performance of *high risk* or expensive tasks
- May cause a negative human response
- May cause *virtual sickness*

Types of Simulation

Constructive Simulation -

• Simulations that involve simulated people operating simulated systems.

• Real people stimulate (make inputs) to such simulations, but are not involved in determining the outcomes.

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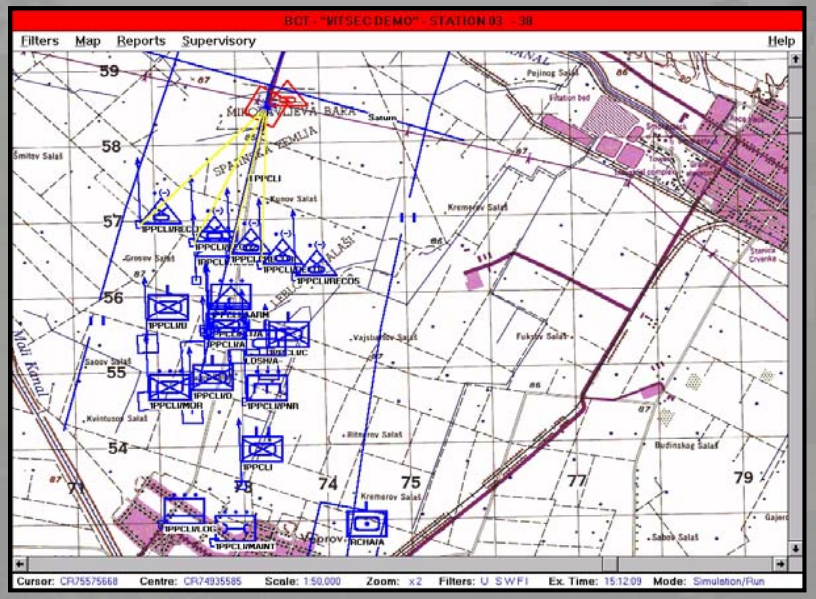
Types of Simulation

Example of a Constructive Simulation

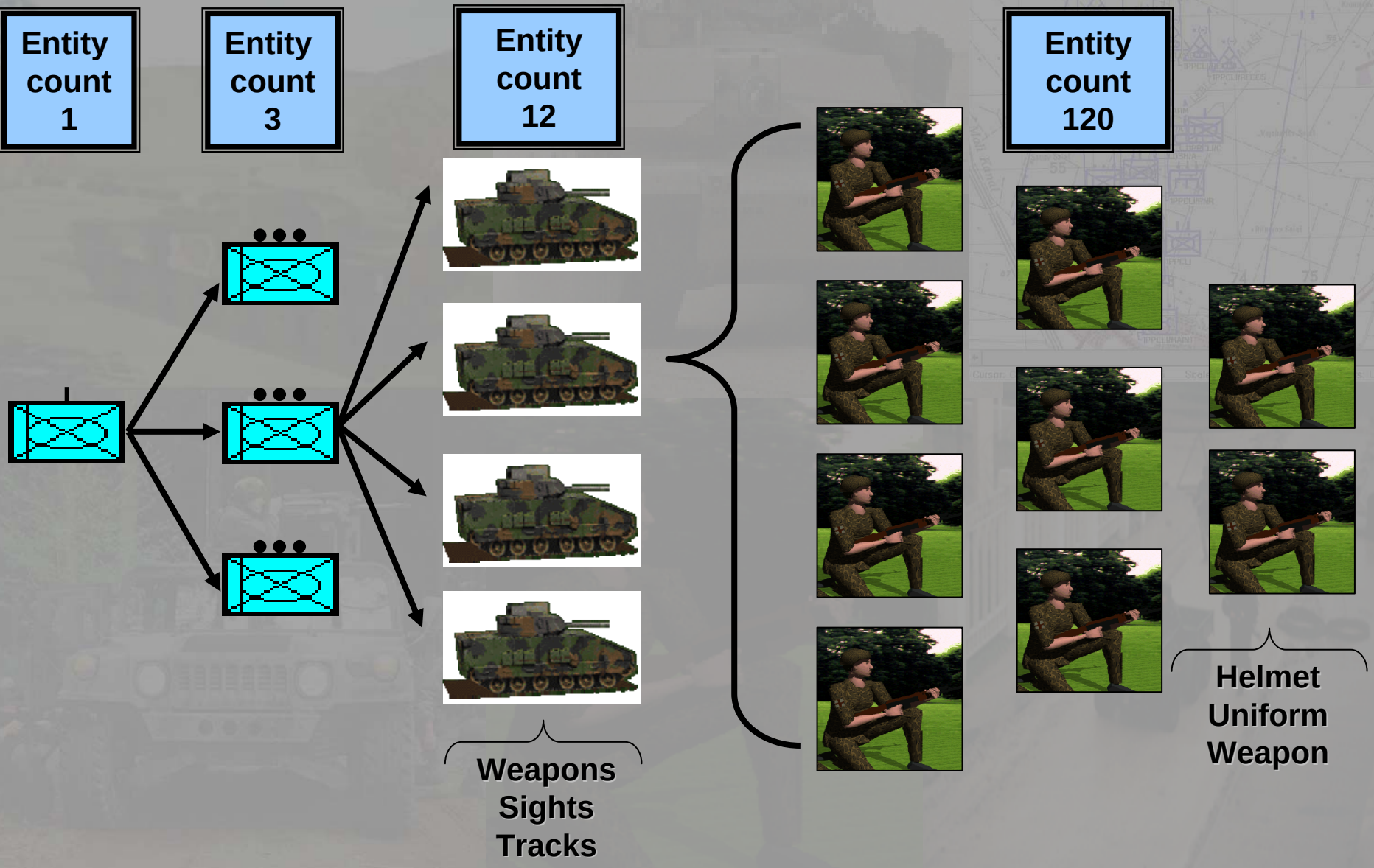


Constructive simulations:

- make measurements
- generate statistics
- perform analysis
- predict possible outcomes
- stress large organizations

- Many constructive simulations use a large number of established, existing models.
- Most provide a valuable service, but may not be designed to share information, thus making information sharing between them more difficult.

Aggregation and Disaggregation



Distributed Simulation (DS)

Connected simulations, sharing information through state-of-the-art communication systems.

Live

Constructive

Virtual

Can be across the room or across the world!

Virtual

Constructive

Live