A Modeling and Simulation Approach to Non-Line of Sight-Launch System (NLOS-LS) Control Cell (CC) Crew Performance Analysis

Briefing for ITEA LVC Conference

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Purpose and Agenda

Purpose: Provide insights into the performance envelope of Soldiers conducting NLOS-LS related fire mission processing tasks.

Agenda

- Introduction.
- C3HPM Overview.
- Model-Test-Model.
- Fire Mission Thread Development.
- Stressor Effects on Taxons.
- Experimental Design Factors.
- Final Run Matrix.
- Initial C3HPM Results and Analysis.
- Follow-on Efforts.
- Summary.

Introduction

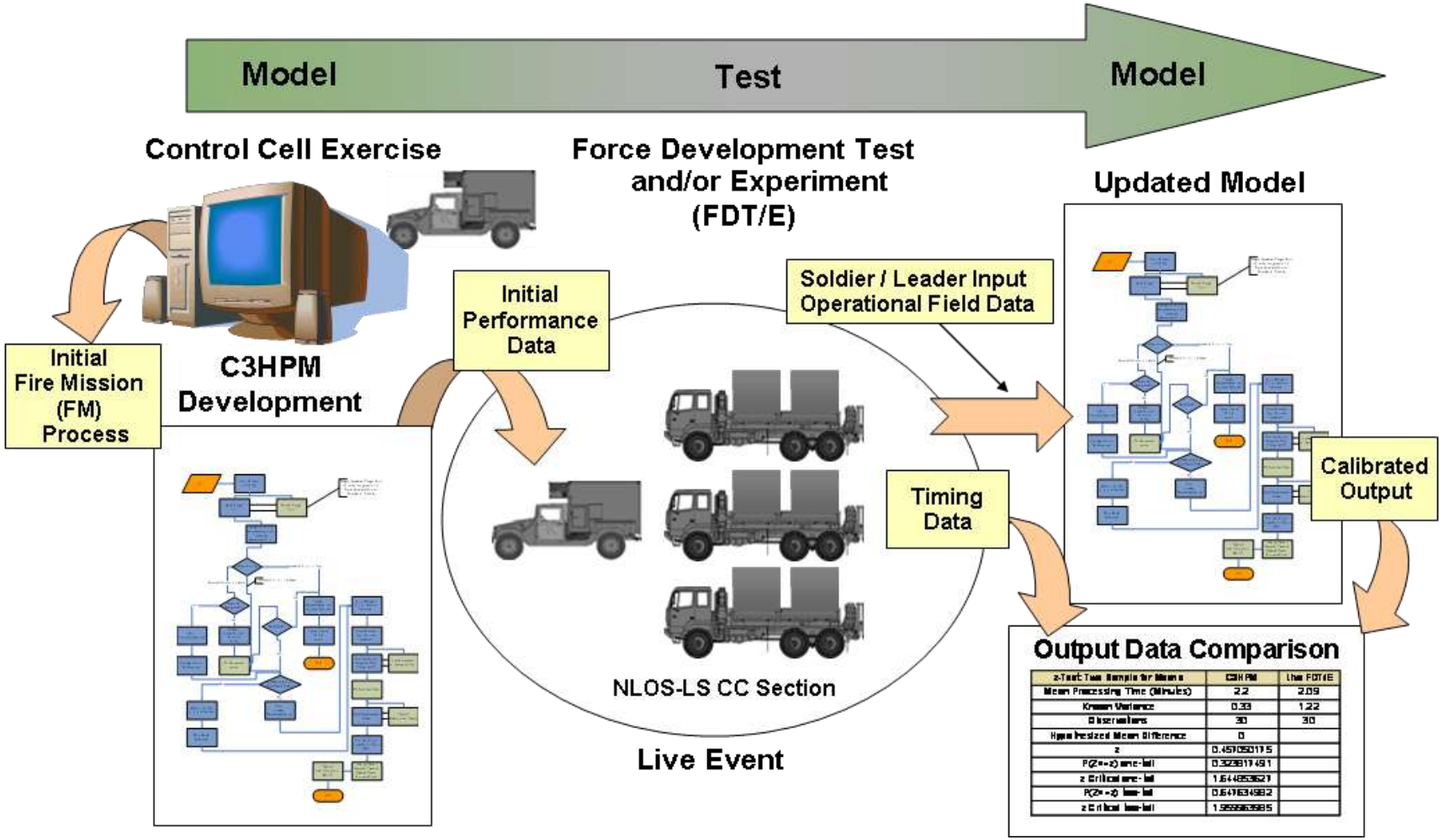
- Part of an on-going Future Combat Systems and Army modernization effort to analyze NLOS-LS CC operator workload over time.
- Developed a representation of the NLOS-LS CC in the Command, Control, and Communications Human Performance Model (C3HPM) using a model-test-model approach.
- Utilized C3HPM early results to assist in the design of live test events and identify human performance characteristics of interest.
- Team members included:
  - TRADOC Analysis Center-White Sands Missile Range (TRAC-WSMR).
  - Army Research Laboratory–Human Research and Engineering Directorate (ARL-HRED).
  - Modeling Architecture for Technology Research and Experimentation (MATREX) Human Centered–Network Enabled Battle Command (HC-NEBC).
  - TRADOC Capability Manager Rockets and Missiles (TCM RAMS).
  - Fires Battle Lab.
- Analysis results will support an NLOS-LS CC Milestone C decision in FY10.

C3HPM Overview

- A constructive, discrete event simulation that models human performance and human behavior in real-time.
- A tool to examine warfighter performance under dynamic stress conditions such as heat, cold, fatigue from continuous operations, vehicle motion, and environmental noise.
- A means to generate data on the effects of nominal and stress conditions likely to occur on the battlefield in an NLOS-LS CC in order to:
  - Examine operator task loading and workload performance.
  - Determine the workload limits of the control cell operators in terms of the number of fire missions they can process in a given time period given varied stress conditions.
  - Define the control cell operator's performance envelope.

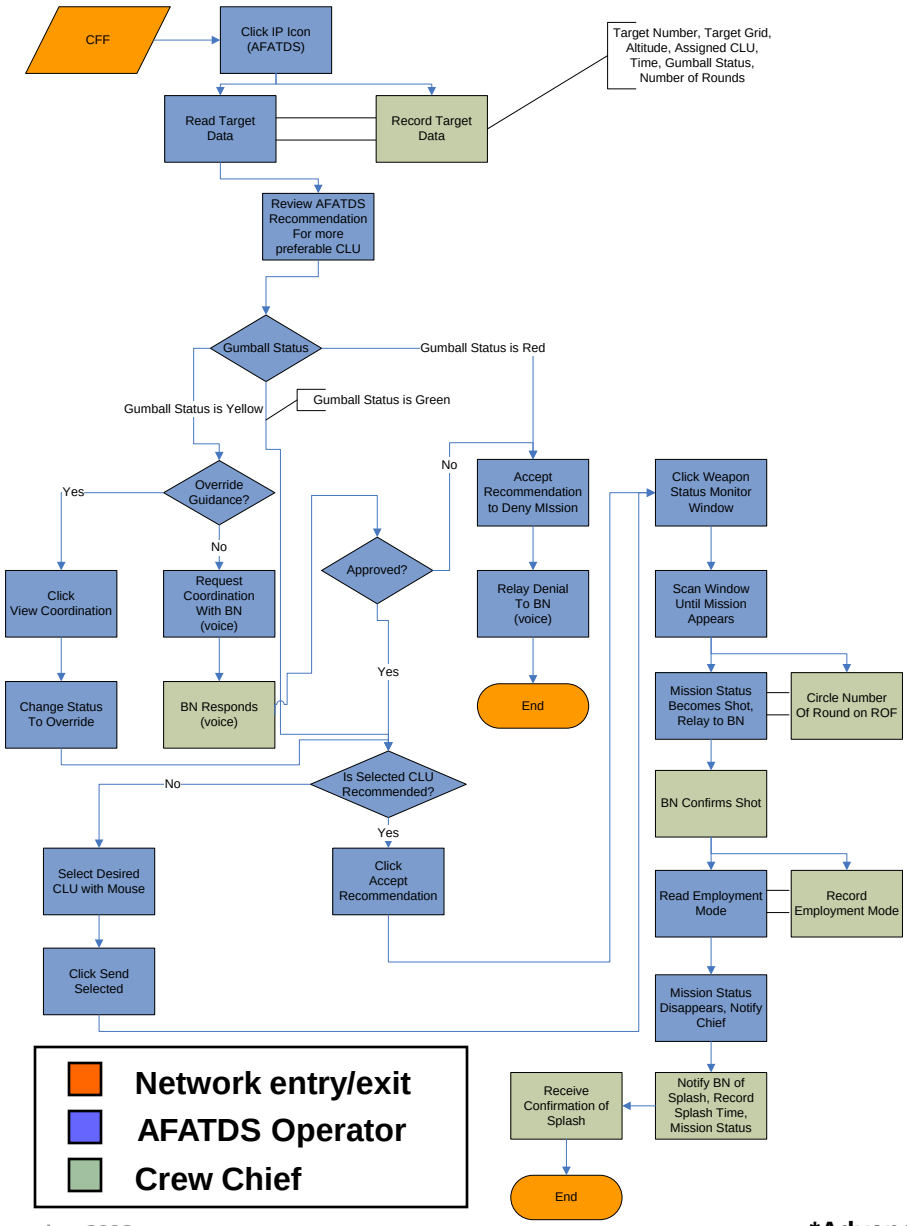
Model-Test-Model (M-T-M)

M-T-M used to develop representative NLOS-LS CC and other fire support functionality into C3HPM.



Accurate depiction of NLOS-LS CC fire mission process captured.

Fire Mission Thread Development



- Modeled NLOS-LS control cell FM process in C3HPM.
- Associated timing for completing each crewmember task.
  - CC Crew Chief.
  - AFATDS* Operator.
- Assigned a workload for each task in the following categories (if applicable).
  - Visual.
  - Auditory.
  - Cognitive.
  - Psychomotor.
- Identified environmental stressors impacting control cell operators.
  - Temperature.
  - Humidity.
  - Wind.
  - Noise.
  - MOPP.
  - Sleeplessness.
  - Continuous movement.
  - FM workload.

***Advanced Field Artillery Tactical Data System**

C3HPM Stressor Effects of Taxons

	C3HPM Stressors				
Taxons	MOPP Level	Temperature (Heat)	Temperature (Cold)	Noise	Sleepless Hours
Visual	T	A	T		
Numerical		A			TA
Cognitive		A			TA
Fine Motor Discrete	T	A	T		
Fine Motor Continuous					
Gross Motor Light	T		T		
Gross Motor Heavy					
Communication (Read/Write)		A			
Communication (Oral)	T	A		A	

Stressors impact taxons by *increasing the time* to complete the task (T) or by *decreasing the accuracy* of which the task is performed (A).

C3HPM Design Factors and Levels

Initial C3HPM run matrix consisted of *84,000 test cases*.

Stress Factors	Level 1	Level 2	Level 3	Level 4	Level 5
Workload (missions/hr)	5	15	22	30	37
Temperature (°F)	94 to 102	103 to 114	114+	NA	NA
Humidity (%)	21-30	41-50	51-60	61-70	NA
Sleeplessness (hr)	0-24	25-47	48-71	72-95	96+
Noise (dB)	50-60	70-80	NA	NA	NA
MOPP (level)	0	3	4	NA	NA
Movement (hr)	0				

9,000 cases

High Temperature and Humidity Experimental Design.

Humidity only affects high temperature.

9,000 cases

Low Temperature and Wind Experimental Design.

Stress Factors	Level 1	Level 2	Level 3	Level 4	Level 5
Workload (missions/hr)	5	15	22	30	37
Temperature (°F)	-40+	-21 to -4	15 to 32	NA	NA
Wind (knots)	0-10	21-30	31-40	50+	NA
Sleeplessness (hr)	0-24	25-47	48-71	72-95	96+
Noise (dB)	50-60	70-80	NA	NA	NA
MOPP (level)	0	3	4	NA	NA
Movement (hr)	0				

These groupings produced *18,750* test cases.

Wind only affects cold temperatures.

750 cases

Warm Temperature Experimental Design.

Humidity & wind do not affect warm temperatures.

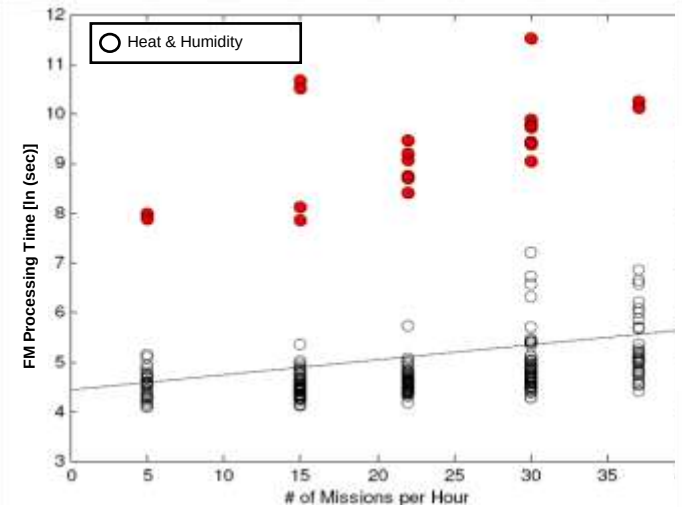
Stress Factors	Level 1	Level 2	Level 3	Level 4	Level 5
Workload (missions/hr)	5	15	22	30	37
Temperature (°F)	33 to 93	NA	NA	NA	NA
Sleeplessness (hr)	0-24	25-47	48-71	72-95	96+
Noise (dB)	50-60	70-80	NA	NA	NA
MOPP (level)	0	3	4	NA	NA
Movement (hr)	0	1	2	3	4

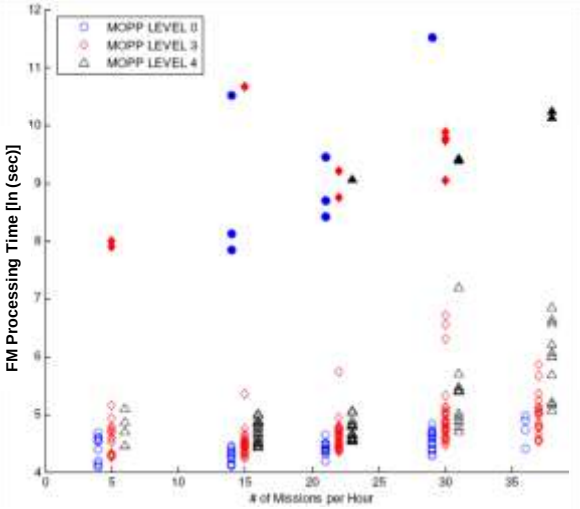
Final Run Matrix

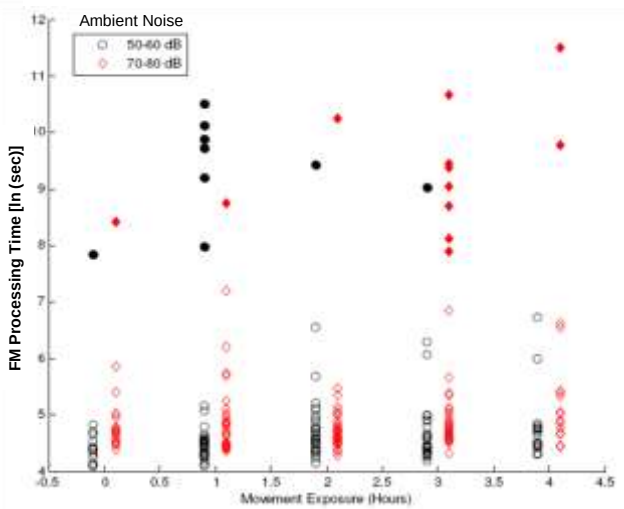
- Test cases from the three experimental design weather sets were further reduced by using the *Nearly-Orthogonal Latin Hypercube (NOLH)* statistical sampling method.
- NOLH ensures that each factor level is fully covered with only *n experiment runs* instead on *nm experiment runs*.
- The three experimental design weather sets can be sufficiently analyzed with a *minimum of 33 test cases for each weather set (99 test cases)*.
- To allow for greater confidence of statistical analyses performed after the C3HPM runs, *at least 65 test cases per weather set* must be executed *(195 test cases)*.
- Additional test cases were run to fill in gaps from the NOLH sampling method.

End Result: Initial set of C3HPM runs were *reduced to 259 test cases*.

C3HPM Initial Run Results







Main Effects on FM Processing Time

- Heat & Humidity.
  - 103 - 114 F with > 61% relative humidity.
  - > 114 F with 51% relative humidity.
- Workload (missions per hour).
- Ambient Noise.

Second Order Effects on FM Processing Time

- Workload & MOPP.
  - >20 fire missions per hour in MOPP 4.
  - >30 fire missions per hour in MOPP 3.
- Ambient Noise and Movement Exposure.
  - 70 - 80 dB with > 3 hours of movement exposure.

Effects of *high heat and humidity*, *heavy workload*, and *increased ambient noise* pushed fire mission processing times beyond an average of *4 hours*.

***Sleeplessness does not* make an impact on fire mission processing time because the majority of tasks are *not cognitive or do not require numerical calculations*.**

C3HPM Verification

z-Test: Two Sample for Means	C3HPM	Live FDT/E
Mean Processing Time (Minutes)	2.20	2.09
Known Variance	0.33	1.22
Observations	30	30
Hypothesized Mean Difference	0	
z	0.46	
P(Z<=z) one-tail	0.32	
z Critical one-tail	1.64	
P(Z<=z) two-tail	0.65	
z Critical two-tail	1.96	

FDT/E data *verifies* that C3HPM fire mission processing times are *representative of the live, manned NLOS-LS CC.*

C3HPM Excursion

z-Test: Two Sample for Means	2 Crew Members	1 Crew Member
Mean Processing Time (Minutes)	2.20	1.76
Known Variance	0.33	0.52
Observations	30	30
Hypothesized Mean Difference	0	
z	2.65	
P(Z<=z) one-tail	0.0040	
z Critical one-tail	1.64	
P(Z<=z) two-tail	0.0080	
z Critical two-tail	1.96	

One-man NLOS-LS control cell crew actually processed fire missions faster due to the *elimination of communications tasks* between the crew chief and the AFATDS operator.

Comparative Analysis

z-Test: Two Sample for Means	C3HPM (Post-FDT/E)	C3HPM (Pre-FDT/E)
Mean Processing Time (Minutes)	2.20	1.70
Known Variance	0.33	0.28
Observations	30	30
Hypothesized Mean Difference	0	
z	3.46	
P(Z<=z) one-tail	0.00027	
z Critical one-tail	1.64	
P(Z<=z) two-tail	0.00054	
z Critical two-tail	1.96	

The addition of the Battalion Fire Direction Center tasks created processing delays and *increased the NLOS-LS control cell processing time by an average of 30 seconds*.

Follow-on Efforts

- Focus on incorporating sustainment operations such as:
  - Preventive maintenance.
  - Reload and refueling operations.
  - Security operations.
  - Commander briefs/meetings.
  - Sleep rotations.
  - Meal rotations.
- Focus on sustainment operations impacts on control cell operations and fire mission processing.
- Expand runtime from an hour to a 24-hour period based on fire mission sets developed from TRADOC approved scenarios.
- Incorporate AETF Fires Battalion's battle rhythm from FDT/E FY08.
- Collect field data on NLOS-LS platoon tasks to increase C3HPM fidelity.
- Run C3HPM in conjunction with other combat/engineering models.
- Investigate only stressors of interest, such as battle fatigue.

Algorithms **on the effect of** ***battle fatigue and/or sleeplessness*** **on visual, fine motor, gross motor, and communications tasks** ***must be developed*** **for C3HPM.**

Summary

- C3HPM accurately depicts the fire mission processes and associated timing of an actual NLOS-LS control cell.
- Control cell operators' performance was defined with respect to workload and environment.
- C3HPM improvements for better NLOS-LS CC representation need to focus on the following areas:
  - Algorithms on the effect of battle fatigue and/or sleeplessness on visual, fine motor, gross motor, and communications tasks must be developed.
  - Fidelity of C3HPM needs to be increased by including additional processes of the fire mission thread external to the NLOS-LS CC.
  - Sustainment operations impacts on CC operations and fire mission processing needs to be addressed.

Glossary

- Visual Taxon. Requires using the eyes to identify or separate targets or objects (e.g., seeing something move and then recognizing it as an enemy tank).
- Numerical Taxon. Requires performing arithmetical or mathematical calculations (e.g., measuring an azimuth on a map with a protractor or estimating the distance between two points on a map).
- Cognitive Taxon (Problem Solving and Decision Making). Requires processing information mentally and reaching a conclusion (e.g., locating a fault in an electrical system after troubleshooting or selecting the best firing position for a machine gun).
- Fine Motor Discrete Taxon. Requires performing a set of distinct actions in a predetermined sequence mainly involving movement of the hands, arms, or feet with little physical effort (e.g., assembly and disassembly of the M-16 rifle or starting the engine of a truck).
- Fine Motor Continuous Taxon. Requires uninterrupted performance of an action needed to keep a system on a desired path or in a specific location (e.g., driving a vehicle or tracking a moving target).
- Gross Motor Heavy Taxon. Requires expending extensive physical effort or exertion to perform an action (e.g., lifting an artillery round or loosening a very tight bolt with a wrench).
- Gross Motor Light Taxon. Requires moving the entire body (i.e., not just the hands) to perform an action without expending extensive physical effort (e.g., getting into a prone firing position or evacuating a tank).
- Communications (Read and Write) Taxon. Requires either reading text or numbers that are written somewhere or writing text or numbers that can be read (e.g., reading a preventive maintenance check list for a vehicle or writing a letter home).
- Communications (Oral) Taxon. Requires either talking or listening to another person (e.g., giving a situation report by radio or receiving a password from someone while on guard duty).

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