

# Tactical Tomahawk Interface for Monitoring and Retargeting



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# Tactical Tomahawk Human-in-the-Loop Issues

- UVA FNC grant to look at human performance issues for the Tactical Tomahawk
- New generation of cruise missiles
  - Loiter concept
- Initial Navy Goals
  - Potentially 128 missiles launched per strike
  - 10 minute loiter response time
- Navy needs a system for monitoring and retargeting
  - Interface development
    - *Tactical Tomahawk Interface for Monitoring and Retargeting (TTIMR)*
  - Analysis of human-in-the-loop elements
  - Personnel requirements



# Typical Profile of Tomahawk Mission



Tactical Tomahawk Interface  
for Monitoring and Retargeting



# Proposed Tactical Tomahawk Missions

Default Mission  
Flex Mission  
Emergent Mission

Primary (Default) Target

Preplanned Health and Status points

Guidance Waypoint

Branch Point

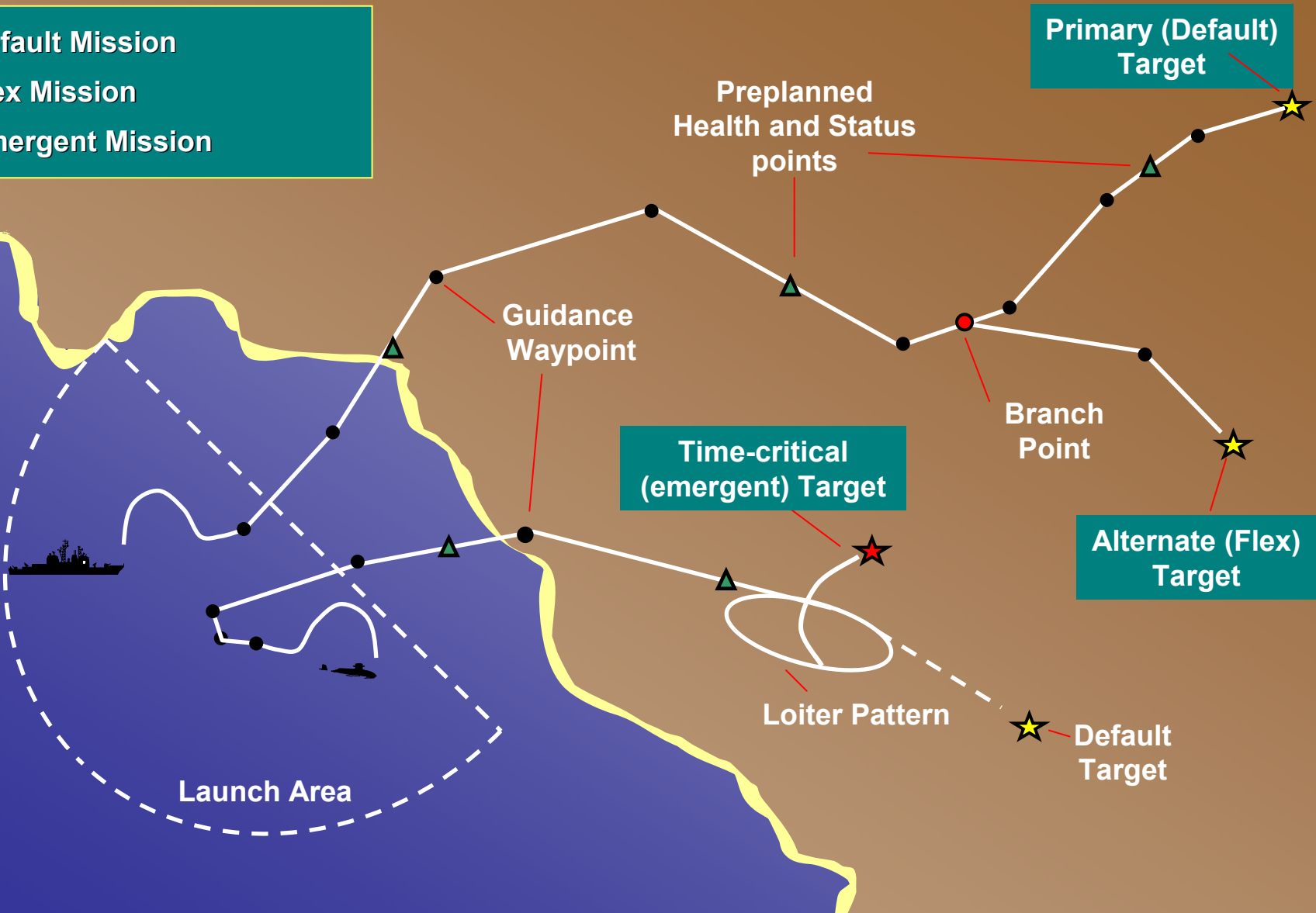
Time-critical (emergent) Target

Alternate (Flex) Target

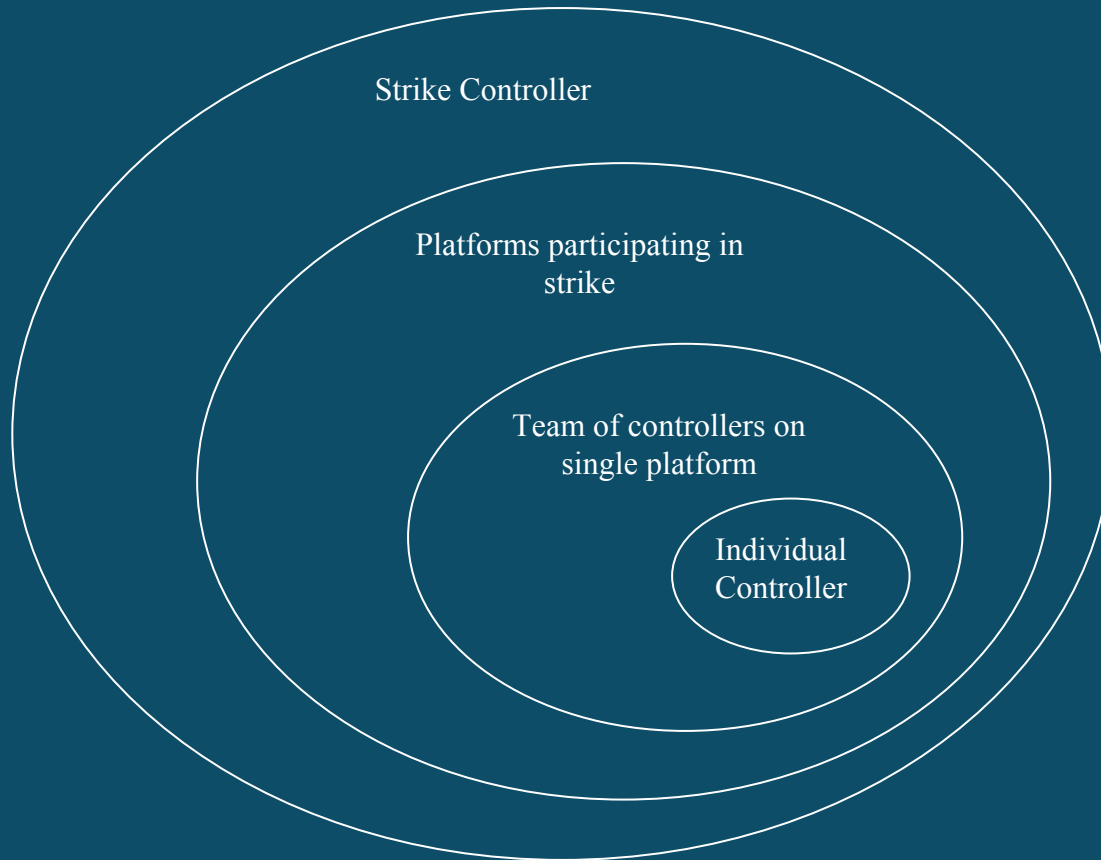
Launch Area

Loiter Pattern

Default Target



# Players for a Single Strike

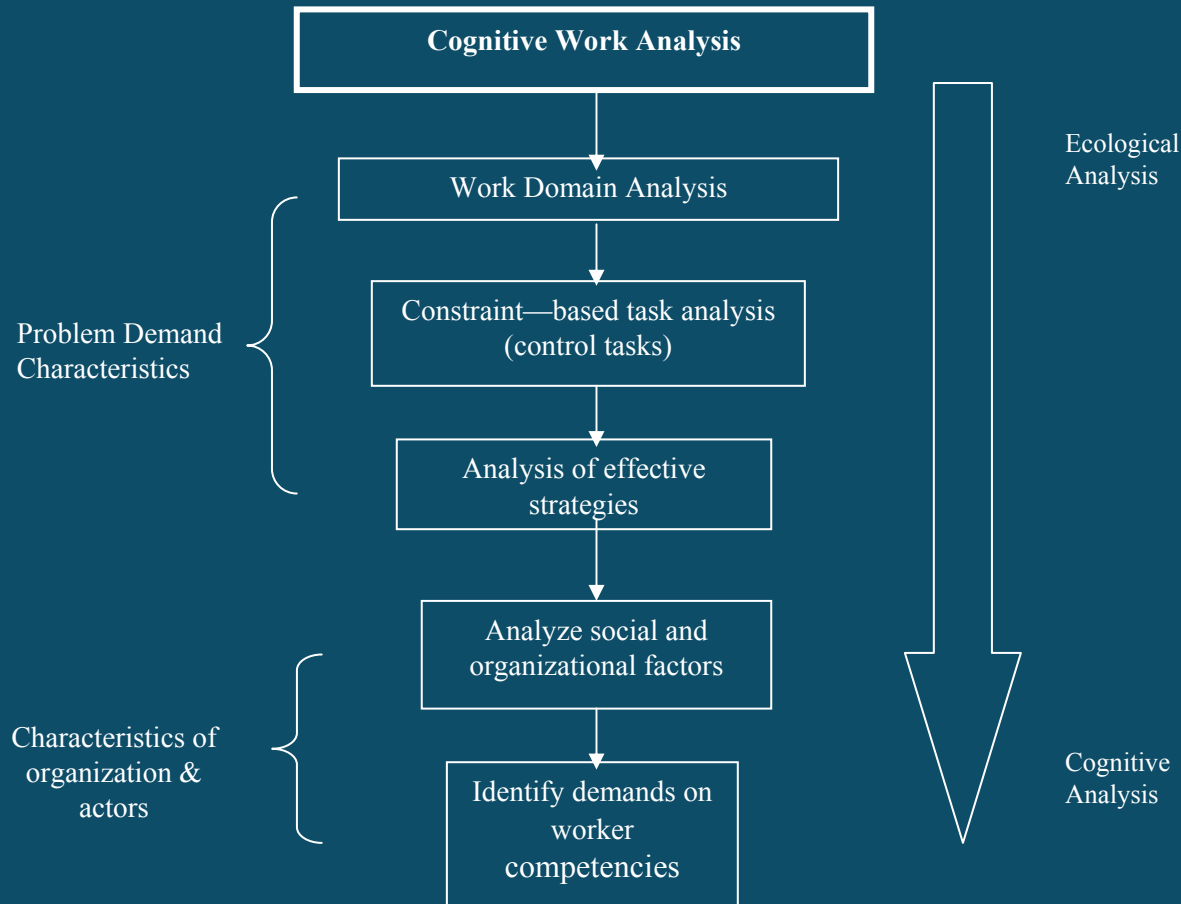


# Cognitive Work Analysis

- Provides a map instead of directions
  - Allows for more flexible decision tools
- The ecological approach to understanding a domain
  - Initial focus on external constraints as opposed to human-centered
  - As compared to a more traditional task analysis
- Primarily conducted for causal domains
  - Command & control systems are in the intentional domain classification
- Difficult because the domain does not exist



# Task Analysis v. Cognitive Work Analysis







# TTIMR

Strike: BB UTC: 0659:37Z

	Munitions Depot	Truck Park	Barracks	Electric Grid	Training Camp	SAM Site	Oil Storage	Fuel Depot	Reactor Facility	Factory
	0700 0726	0713 0741	0729 0744	0707 0732	0707 0737	0700 0721	0700 0725	0706 0736	0706 0736	0719 0749
	T021U-DH	T022S-DL	T023S-DM	T024S-DH	T026S-DH	T027U-DH	T030U-DH	T031U-DM	T032U-DH	T033U-DL
LM029U-DL	14:29					15:33	7:44	19:13	12:42	22:08
RM030S-DM		34:01	29:04	19:35	18:58					
LM031S-DL				14:32	24:42					
RM032U-DM						0:01		D 07:21Z		19:18
RM033S-DL		D 07:25Z	8:11F	4:50						
RM034S-DM		1:36F	D 07:28Z	1:41						
RM035U-DM	17:38					11:11		19:33	16:23F	25:29
RM036U-DL	17:42					10:54	13:19	22:44	20:20	D 07:33Z

FF Alloc	2	0	0	1	1	1	1	0	1	0
RTG Alloc	0	1	1	0	0	0	0	1	0	1
Total Required	2	1	1	1	1	1	1	1	1	1
Shortage	--	--	--	--	--	--	--	--	--	--

Show:  Action Messages  Information Messages  Health/Status Warnings

Last message received @ 0645Z

**Target: T031U-DM**

Fuel Depot  
Lat: 33.80N  
Long: 55.10E  
Elevation: 181ft

Missile(s) targeting:  
RM032U-DM (24m18s/07:21Z)

**Missile: LM029U-DL**

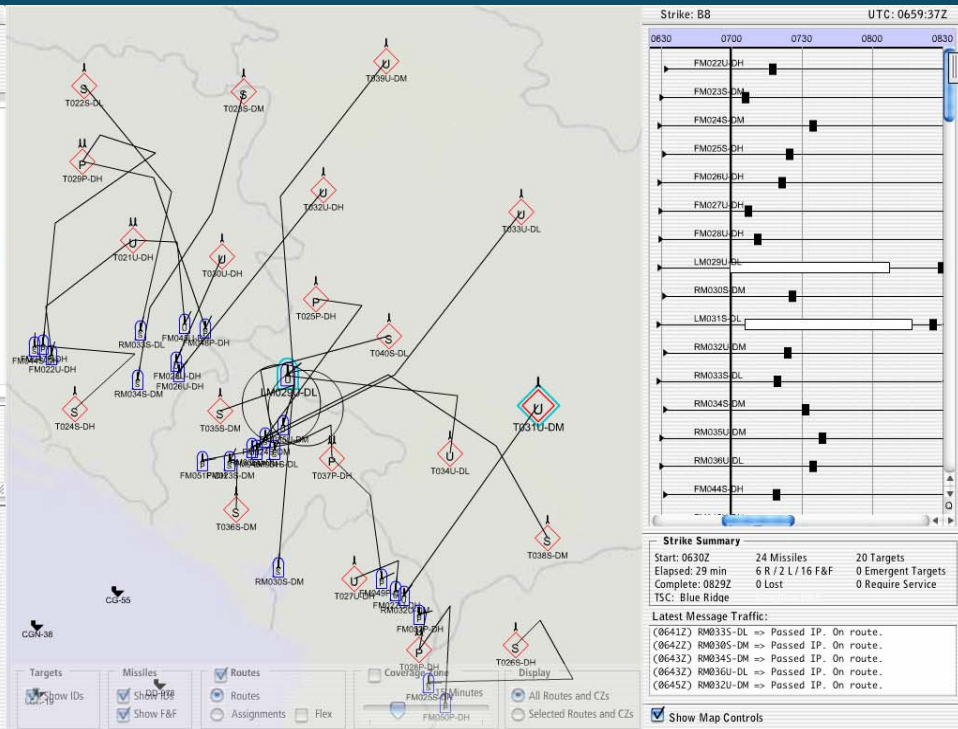
Type: Block IV -- GPS Only  
From: USS Levte Gulf (CG-55)  
Launch: 06:30Z  
Mission # 000015

Estimated Position  
Lat: 34.17E  
Long: 51.75W  
Altitude: 4853.56 MSL

Current Target: T034U-DL  
TTI: 89m57s (08:29Z)  
TOIR: 91 min

Loiter:  
Loiter Pattern Complete  
Not flex capable

Retarget:  
 Retarget Missile



## Retargeting Display

## Monitor Map

Tactical Tomahawk Interface  
for Monitoring and Retargeting



# Retargeting Display

- Primary element - the Decision Matrix
  - *Missile/target pairings*
  - *Decision times are primary focus- not TOTs*
  - *The WOO (Window of Opportunity)*
    - *A flexible decision space*
- Comm box
  - *A chat tool*



	Oil Storage	Fuel Depot	Reactor Facility	Factory	Supply Depot	Bridge	Truck Park	Troop Camp	Chemical Plant	Barracks
	0706 H□□ 0701 0721	0724 H□□ 0709 0739	0708 H□□ 0701 0723	0826 H□□ 0811 0830	0707 H□□ 0701 0722	0721 H□□ 0706 0736	0701 H□□ 0701 0716	0826 H□□ 0811 0830	0814 H□□ 0759 0829	0711 H□□ 0701 0726
	T010U-DH	T011U-DM	T012U-DH	T013U-DL	T014U-DL	T015U-DM	T016S-DM	T018S-DL	T019U-DM	T020S-DM
RM015U-DM	12:26	D 07:23Z	4:49	---	---	3:14	---	---	---	---
LM017U-DL	12:35	16:46	3:54	D 08:25Z	7:33	5:16	---	---	---	---
RM018U-DM	---	15:47	14:41	---	11:29	D 07:20Z	---	---	---	---
RM019S-EH	---	---	---	---	---	---	---	---	---	---
RM021U-DL	---	4:04	---	---	D 07:06Z	4:04	---	---	---	---
RM022S-DL	---	---	---	---	---	---	---	---	---	16:39
RM023S-DM	---	---	---	---	---	---	---	---	---	6:49F
RM024U-DM	10:46	---	---	---	---	17:40	---	---	D 08:14Z	---

FF Alloc	1	0	1	0	0	0	1	0	0	1
RTG Alloc	0	1	0	1	1	1	0	0	1	0
Total Required	1	1	1	1	1	1	1	1	1	1
Shortage	--	--	--	--	--	--	--	>> 1 <<	--	--

Show:  Action Messages  Information Messages  Health/Status Warnings

(0656Z) RM019S-EH => Has been successfully retargeted to T021S-EH  
 (0657Z) **Blue Ridge => EMERGENT TARGET IN NORTH CENTRAL SECTOR**  
 (0657Z) TTIMR => Retargeting RM022S-DL to T022S-EH  
 (0658Z) **Blue Ridge => How many targets can RM021U be retargeted to in 20 minutes?**  
 (0659Z) FM011S-DM => Missed a reporting waypoint.  
 (0700Z) **Blue Ridge => How many minutes do you have left to flex RM023s to T020S?**

Last message received @ 0700Z

Clear

Send

#### Target:

None selected  
 Lat: --  
 Long: --  
 Elevation: -- ft

Missile(s) targeting:

None

#### Missile: RM023S-DM

Type: Block IV -- GPS Only  
 From: USS Fife (DD-991)  
 Launch: 06:32Z  
 Mission # 000015  
 Current Target: T003S-DM  
 TT: 26m43s (07:24Z)  
 TOFR: 93 min

*Estimated Position*  
 Lat: 34.71E  
 Long: 49.88W  
 Altitude: 584 MFL

*Loiter:*  
 Not Loiter Capable  
 2 flex targets

#### Retarget:

Retarget Missile  Flex Missile  New Target

Retargeting command sent

# A Flexible Decision Space: The WOO

A candidate missile exists for another TOT outside the pre-established window

Preplanned TOT

The current window limits

A candidate missile exists for the current window around the TOT

	Bridge	Training Camp	Runway
	0825	0819	0736
	0810 0830	0804 0830	0721 0751
	T001U-DL	T002S-DL	T003U-DH
LM001U-DL	D 08:25Z		26:11
RM002S-DM		---	
RM003U-DM	---		
RM004U-DH	0:45F		D
LM006S-DL		D 08:19Z	
RM007S-DH			
RM009S-DH		---	

	Bridge	Training Camp	Runway
	0825	0819	0736
	0810 0830	0807 0830	0721 0751
	T001U-DL	T002S-DL	T003U-DH
LM001U-DL			26:07
RM002S-DM		15:48	
RM003U-DM			24:14
RM004U-DH			D 07:36Z
LM006S-DL		D 08:19Z	
RM007S-DH			
RM009S-DH		6:32	

When the WOO is enlarged, more missiles become available and the decision time remaining is shown

Strike: AB

	Oil Storage	Fuel Depot	Reactor Facility
	0706	0724	0708
	0701	0721	0709 0739 0701 0723
	T010U-DH	T011U-DM	T012U-DH
RM015U-DM	12:26	0 07:23Z	4:49
LM017U-DL	12:35	16:46	3:54
RM018U-DM		15:47	14:41
RM019S-EH			
RM021U-DL	---	4:04	---
RM022S-DL			
RM023S-DM			
RM024U-DM	10:46	---	---

FF Alloc	1	0	1
RTG Alloc	0	1	0
Total Required	1	1	1
Shortage	---	---	---

Show:  Action Messages  Information Messages  Health/Status Warnings

(0656Z) RM019S-EH => Has been successfully retargeted to T021S-EH

(0657Z) **Blue Ridge => EMERGENT TARGET IN NORTH CENTRAL SECTOR**

(0657Z) TTMR => Retargeting RM022S-DL to T022S-EH

(0658Z) **Blue Ridge => How many targets can RM021U be retargeted to in 20 minutes?**

(0659Z) FM011S-DM => Missed a reporting waypoint.

(0700Z) **Blue Ridge => How many minutes do you have left to flex RM023s to T020S?**

Last message received @ 0700Z

Clear

Send

Show:  Action Messages  Information Messages  Health/Status Warnings

(0656Z) RM019S-EH => Has been successfully retargeted to T021S-EH

(0657Z) **Blue Ridge => EMERGENT TARGET IN NORTH CENTRAL SECTOR**

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(0700Z) **Blue Ridge => How many minutes do you have left to flex RM023s to T020S?**

Last message received @ 0700Z

Clear

Send

Target:

None selected

Lat: --

Long: --

Elevation: -- ft

Missile(s) targeting:

None

Missile: RM023S-DM

Type: Block IV -- GPS Only

From: USS Fife (DD-991)

Launch: 06:32Z

Elevation: -- ft

Mission # 000015

Current Target: T003S-DM

TTI: 26m43s (07:24Z)

TOFR: 93 min

Estimated Position

Lat: 34.71E

Long: 49.88W

Altitude: 584 MFL

Loiter: Not Loiter Capable

2 flex targets

Retarget:

Retarget Missile

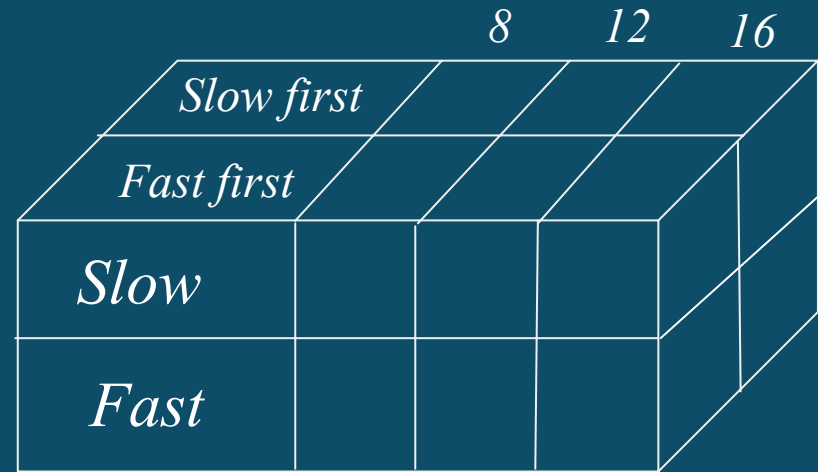
Retargeting command sent



# Human-in-the-Loop Testing

- A 3 X 2 X 2 design:

- Missiles
- Arrival rate (Tempo)
- Order of test sessions



- 42 Navy subjects

- 26 active duty, 16 retired

- Dependent variable: overall performance score

- Repeated measures mixed factorial ANOVA

- *Single covariate: age (retired mean = 47, active duty mean = 32)*



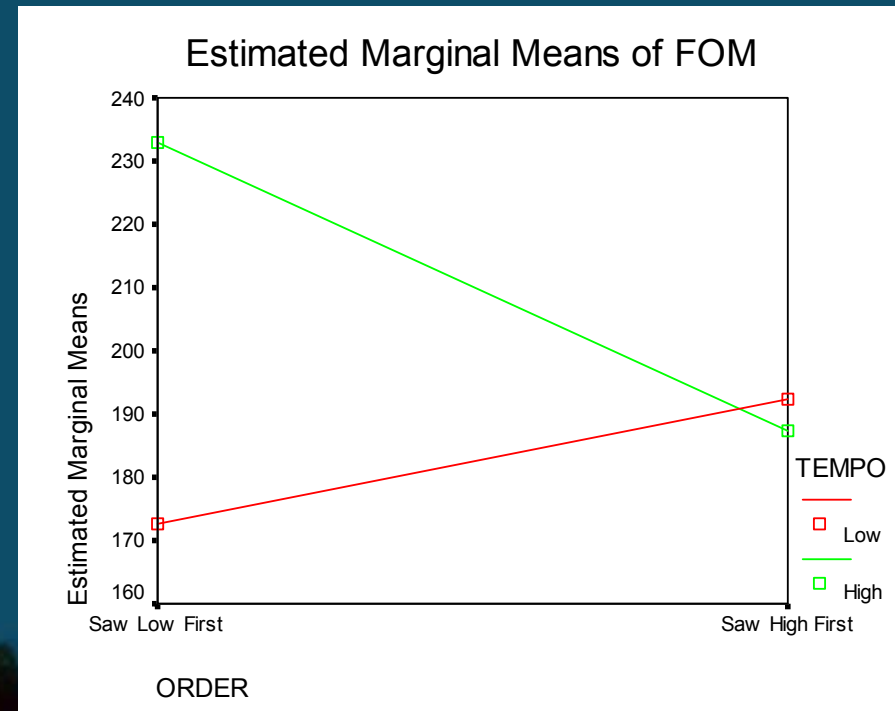
# Results

- Main Effects

Factor	F	DOF	p
Tempo	6.943	1, 35	.012
Order	.076	1, 35	.784
Missiles	2.802	2, 35	.074
Age	8.023	1, 35	.008

- Tempo\*order interaction

- $p < .001$  ( $F = 18.457$ ,  $DOF (1,35)$ ,  $power = .987$ )
- Some learning took place





# Post Hoc Analysis of Data

- Two emergent trends during testing and data analysis
  - Chat box fixation
  - Parallel versus serial decision making in retargeting
    - Despite training, only 25% executed parallel strategy
  - Post hoc 3 X 2 X 2 X 2 repeated measures ANOVA
    - IVs: missiles, tempo, chatty, parallel
    - Parallel decision process: marginally significant ( $p=.070$ ,  $DOF(1,70)$ ,  $F=3.384$ )
    - Chat box fixation: significant ( $p=.007$ ,  $DOF(1,70)$ ,  $F=7.709$ )
    - Can only be considered exploratory





# Conclusions

- How many missiles a person can effectively control is significantly influenced by the operational tempo.
- The current decision matrix design poses a problem for parallel decision making.
- The chat box approach to communications could be significantly degrading primary job performance.
  - More research needed
- The Navy's original estimate that one person can only effectively control four missiles is low.

