



Defence Research and
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Recherche et développement
pour la défense Canada

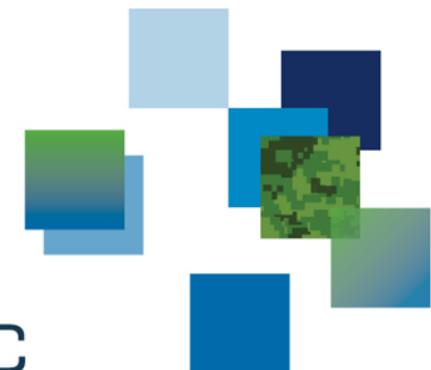
Blue Force Tracking: Effects of Spatial Error and Display Format on Soldier Performance

Justin G. Hollands

DRDC Toronto Research Centre

Contributions from:

Geoffrey Ho, Michael Tombu, Ken Ueno, and Matthew Lamb



DRDC | RDDC

Canada

Overview

- What is DRDC?
- What we do at the Toronto Research Centre
- Blue Force Tracking
 - Experiment 1. Effects of error
 - Experiment 2. Effects of display format

Defence Research and Development Canada (DRDC)



<http://www.drdc-rddc.gc.ca/>

DRDC | RDCD

What is Defence R&D Canada?

- Defence R&D Canada (DRDC) is an agency of the **Canadian Department of National Defence** that responds to the scientific and technological needs of the Canadian Armed Forces.
- DRDC is led by **Dr. Marc Fortin**, who is CEO and Assistant Deputy Minister of Science and Technology (**ADM (S&T)**) within the Department of National Defence.
- DRDC leads science and technology for **national defence and public security**.



DRDC Facts

- Birthdays
 - **67 years old** – Defence Research Board founded 1947.
 - **14 years as a special operating agency.**
- **1400 full-time personnel** of which ~800 are defence scientists & technologists.
- **Embedded teams** in major operational commands (national & international) and scientific counselors in two embassies.
- **S&T budget approximately \$300M,**
 - Half is delivered internally by defence laboratories and
 - Half directed towards external delivery of program (i.e. industry, academia and other partners) i.e. key part of national innovation system.
- **Specialized defence laboratory infrastructure valued at \$500M,**
- **Army, Navy, Air Force, Personnel, Joint**
- **Strong links to allied and national partners**
 - Other Government Departments
 - Int'l: TTCP, NATO, Bi-lateral and Tri-lateral agreements, etc.
 - In the US we work with: ARL, AFRL, SPAWAR etc.



Research Centres



Areas of Expertise

- Command and Control
- Communications Networks
- Intelligence, Surveillance, and Reconnaissance
- Complex Systems
- System Autonomy
- Mobile Systems
- Personnel Protection
- Protection of Assets
- Human Systems Integration
- Behavioural Effects

<http://www.drdc-rddc.gc.ca/en/science-tech.page?#a1>

Defence R&D Canada: Toronto Research Centre



DRDC Toronto's Capabilities

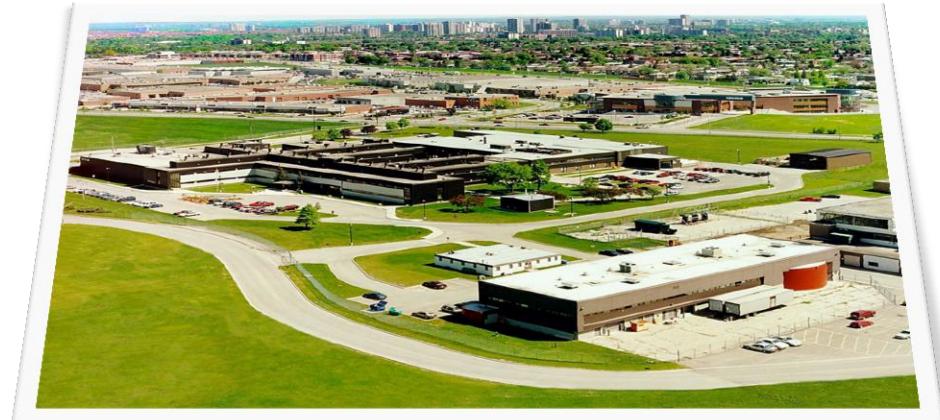
- People:
 - 120 (Civilians) + 40 (CFEME)
 - ~ 90 S&T workers (~ 50 DSs + 40 Technologists)
- Tools / Infrastructure:
 - Major facilities
 - Diving, Climatic, Centrifuge, SERF, etc...
 - Other facilities
 - Team research lab, soldier systems, advanced interface, etc...

DRDC Toronto Research Centre

■ Capability in 4 Sections:

- Individual Behaviour and Performance (IBP)
- Socio-Cognitive Systems (SCS)
- Human Systems Integration (HSI)

- Military Medicine (MED)

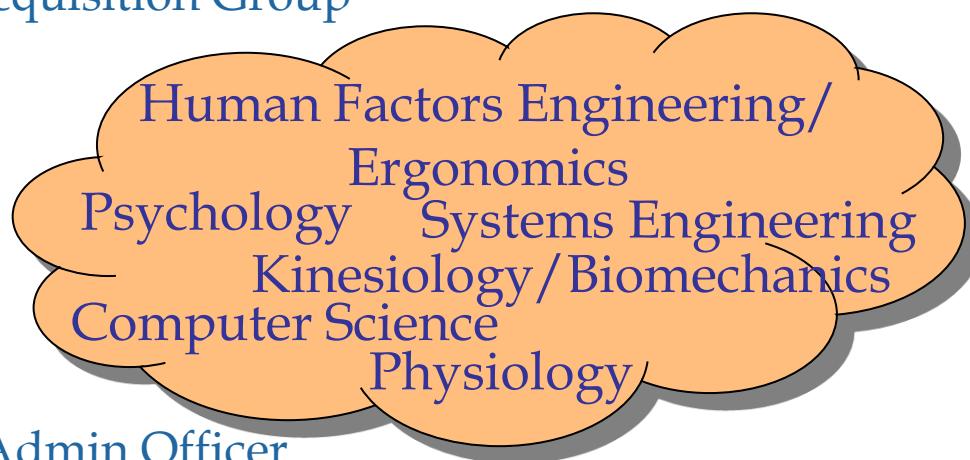


Human Systems Integration

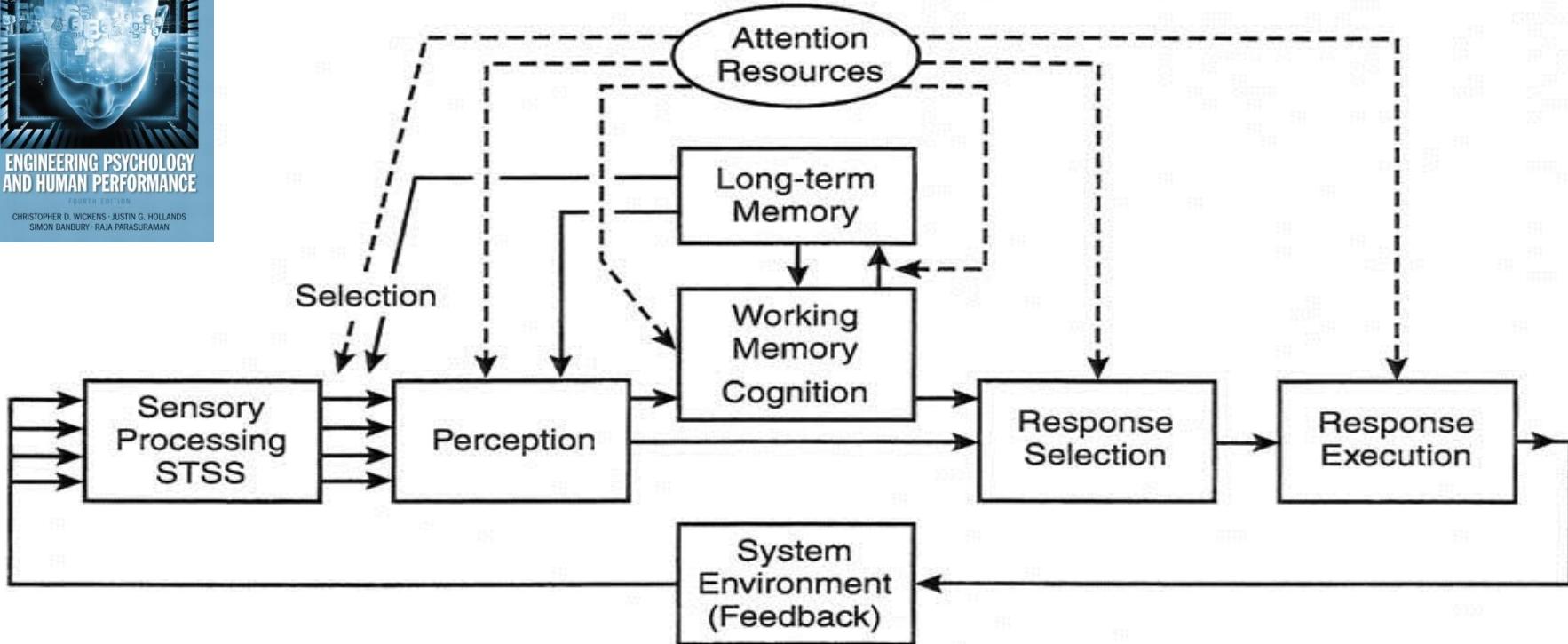
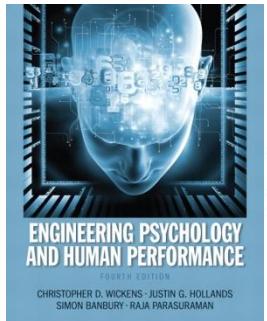


HSI Section Structure

- Three research groups:
 - Human Technology Interaction Group
 - Simulation and Modeling for Acquisition Group
 - Learning and Training Group
- Two Technical Groups:
 - Systems Engineering Group
 - Research Operations Group
- Section Management:
 - Section Head, Senior Scientist, Admin Officer
- Members:
 - Approx. 30 (incl. students, exchange staff, post docs, etc)



Information Processing Model





Blue Force Tracking: Effects of Spatial Error and Display Format on Soldier Performance

Ho, G., Hollands, J. G., Tombu, M., Ueno, K., & Lamb, M. (2013). Blue force tracking: Effects of spatial error on soldier performance. In *Proceedings of the Human Factors and Ergonomics Society – 57th Annual Meeting* (pp. 182-186). Santa Monica, CA: Human Factors and Ergonomics Society.



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Blue Force Tracking

- Knowing where friendly forces are
- Soldiers have used traditional methods; now GPS
- Purpose
 - Situation awareness (SA)
 - Reducing incidents of friendly fire
- U.S. FBCB2
- NATO Friendly Force Tracker
- Problems for BFT
 - Spatial and temporal error
 - 1-10 m error



Does BFT Help?

■ Armenis (2010)

- Section Commanders led four person teams to retrieve an asset
- Using paper map or BFT
- BFT better (but no diff in cognitive load)
- Did not examine spatial inaccuracies



■ Benford et al. (2006)

- Looked at spatial inaccuracy of GPS
- Online and live users played in a virtual world
- Users often unaware of GPS error

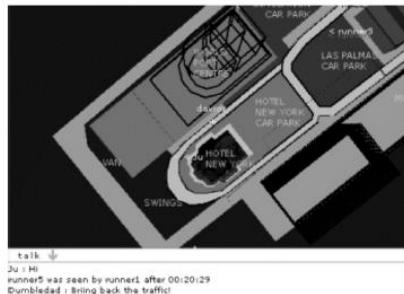


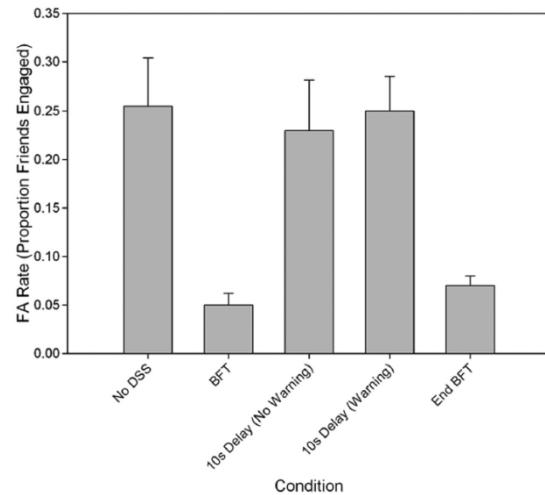
Fig. 3. Online player's interface—map view.



Does BFT Help (cont'd)

■ Bryant and Smith (2013)

- Civilian participants
- Friend and enemy bots (uniform, weapon, etc.)
- BFT available in some conditions
- 10 s delay
- False Alarm rate higher with delay
- BFT helps, but only if accurate



Bryant, D. J., & Smith, D. G. (2013). Impact of blue force tracking on combat identification judgments. *Human Factors*, 55, 75-89.

Unanswered Questions

- BFT can help; inaccuracies reduce or eliminate this advantage
- Questions
 - Military participants; unreliable data
 - How unreliable?
 - BFT useful in high-workload navigation
 - What is baseline?
 - What about SA?
 - What about display format: map or AR on head-up display?

Experiment 1 Approach and Hypotheses

- Using soldiers with combat experience as participants
- Realistic Scenario with navigation, “radio”, realistic BFT
- Friend/Enemy not distinguishable by appearance
- Examine BFT effects on both SA and target engagement
- Hypotheses
 - BFT better than no BFT
 - Reliable BFT better than unreliable

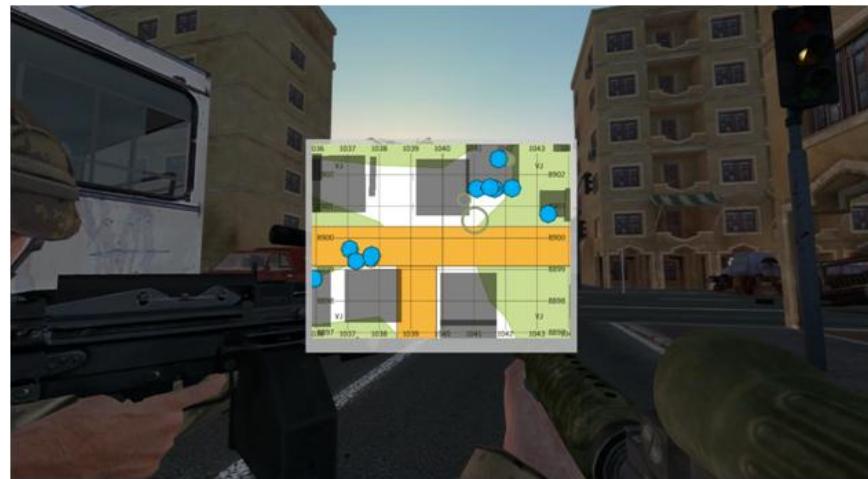
Experiment 1 Method

■ Participants

- 36 Canadian Army soldiers (male)
- Age 22-39 yrs
- Years of experience 6.35 yrs
- 8 mos experience in theatre
- No experience with BFT

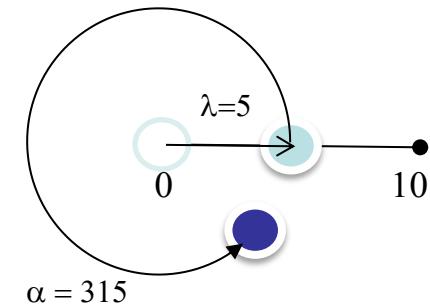
■ Apparatus

- Virtual Battle Space 2 (VBS2)
- Ran simulation, presented stimuli, recorded behaviour



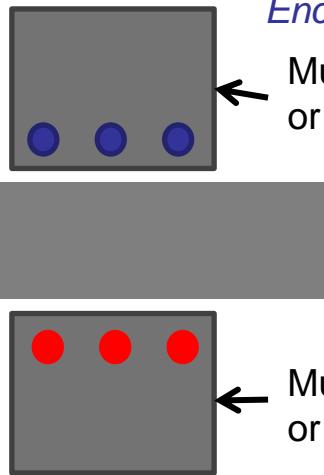
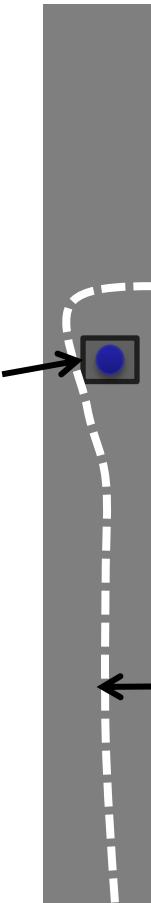
Design and Procedure

- One-way within-subjects design
 - No BFT, Reliable BFT, Unreliable BFT
 - Counterbalanced
- Unreliable BFT:
 - Each entity assigned random linear and angular offset
 - 0-10 m
- Informed consent, two training missions
- Mission required participant to lead a section through an urban area and then come to the aid of another section who had made contact with the adversary



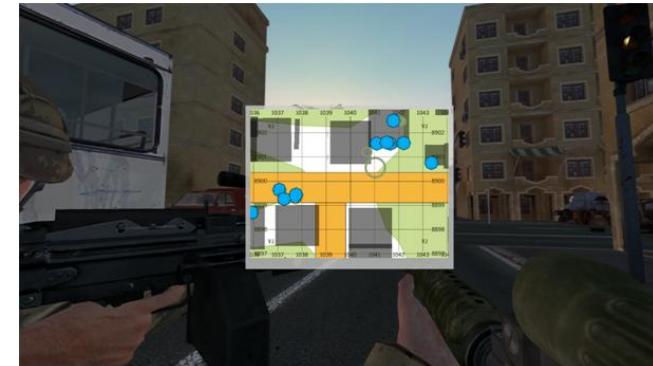
Overview of Mission

Encounter 1:
Single red or
blue shooter
at guard post

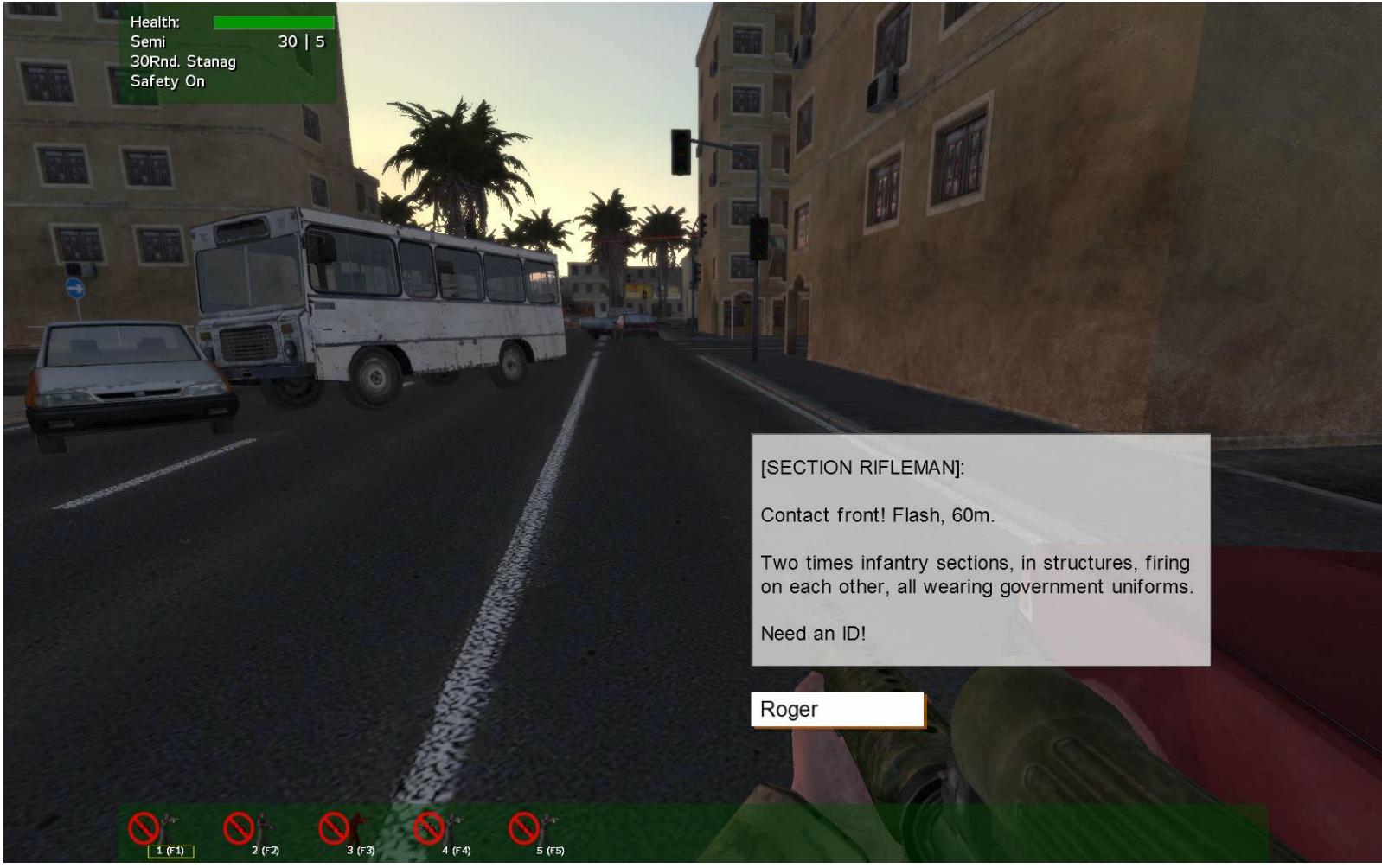


Encounter 2:

Multiple blue
or red forces







Encounter 2 w Inaccurate BFT

Dependent Variables

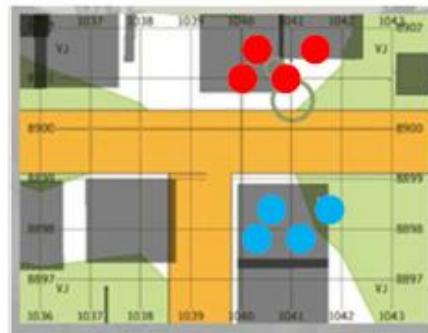
- Mission Performance
 - Time to complete (s), Hits, False Alarms, Time to fire
- BFT/Map interactions
 - Activation, panning, zooming
- Radio Communication
- Mental Workload
- Situation Awareness (measured after each mission)
 - Participants had to choose from a set of maps showing friendly and enemy positions

Situation Awareness – Encounter 2

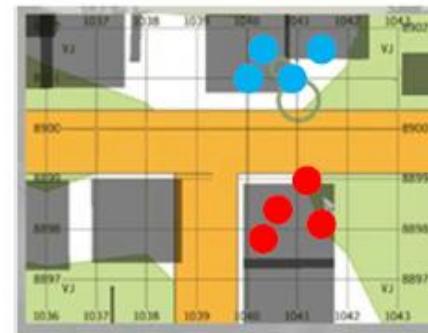
2. Please indicate the image that best shows the positions of other blue and red forces?

- A
- B
- C
- D

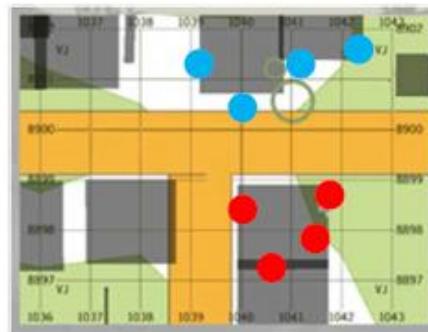
A



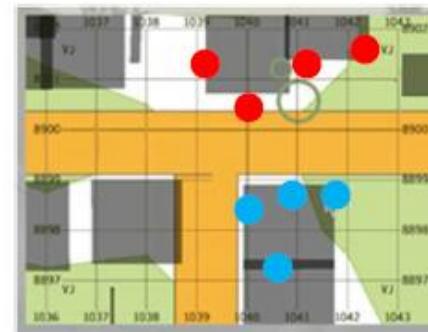
B



C



D



Results

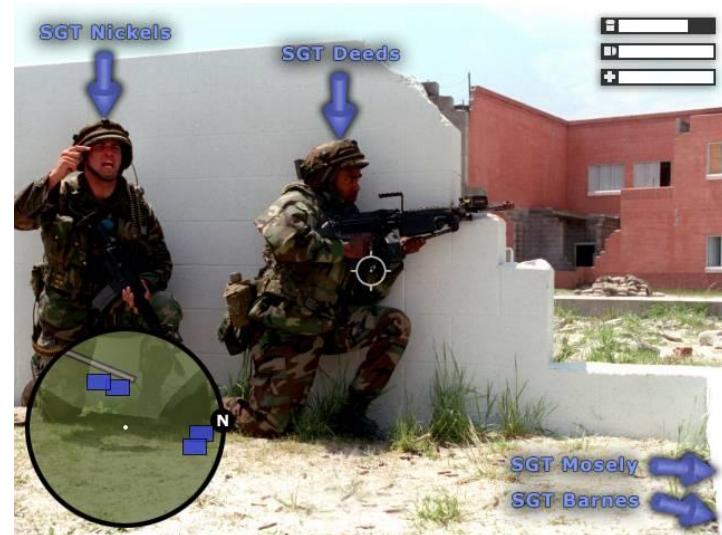
- Time to fire
 - Reduced (18 s Faster) with reliable BFT relative to no BFT; reliability had no effect
- Zoom out/pan
 - Reliable BFT opened more frequently than no BFT; reliability had no effect
 - More panning and zooming out with reliable BFT; reliability had no effect
- Workload
 - Greater workload for no BFT than reliable BFT; reliability had no effect
- Reliability and SA
 - SA greater for *reliable* BFT than for *unreliable* BFT (in Encounter 2 only)
- No difference in speed or accuracy for reliability

Experiment 1 Discussion and Summary

- With BFT, soldiers:
 - Were faster at making a decision to engage
 - Used BFT to see more of the battle space (zooming out, panning)
 - Reported lower workload
- Summary
 - For soldiers with operational experience...
 - When soldier navigates, uses a radio, and target appearance (uniform, weapon) do not indicate identity...
 - When reliability levels are realistic...
- **BFT does help,**
- **BFT reliability affects SA**

Experiment 2

- Augmented Reality
- Different display representations



Experiment 2: Method

- Participants
 - 40 soldiers
- Combat arms experience
- Experimentation campaign January 2015
- Session 3 hours; 30 min training
- 9 experimental “missions”, 5-10 min to complete
- Conditions
 - No BFT (map only)
 - BFT on map
 - BFT on AR: Boxes
 - BFT on AR: Floating (or Ornaments)
 - BFT on AR: Ribbon
 - BFT with and without error

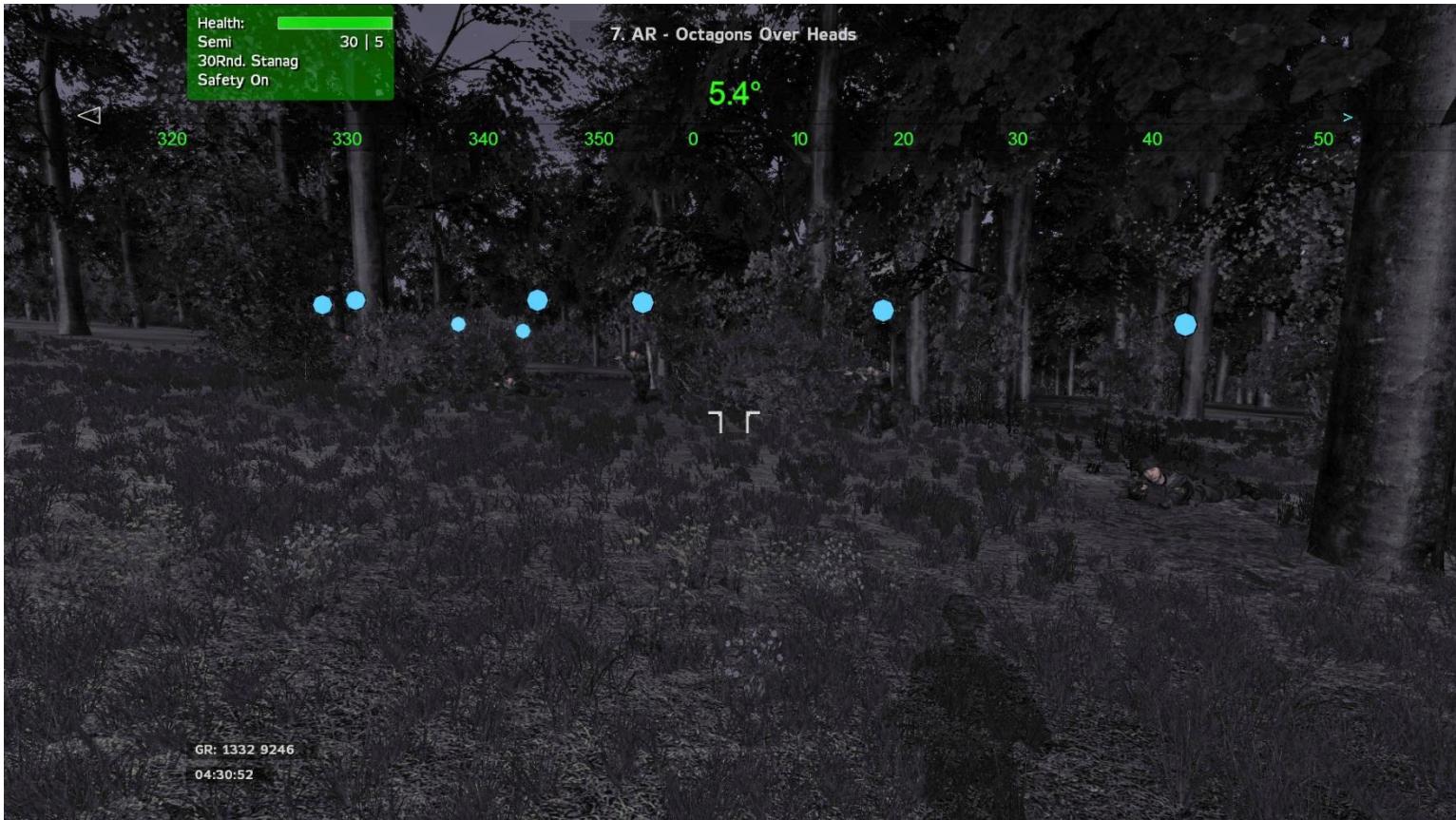
No BFT (map only)



BFT: Map



BFT: AR Floating Symbols



BFT: AR symbols on ribbon



BFT: Boxes

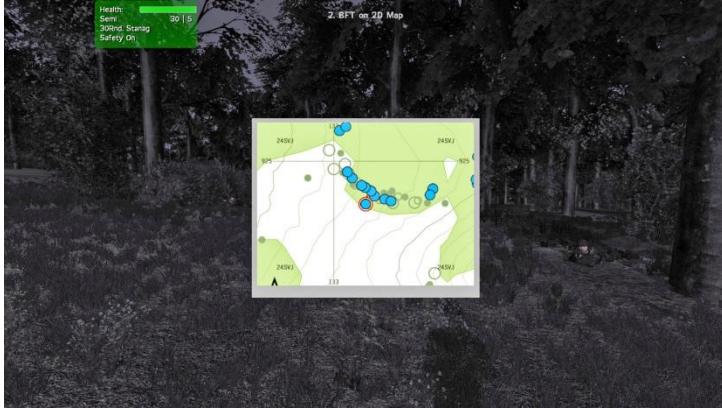


BFT: Ornaments

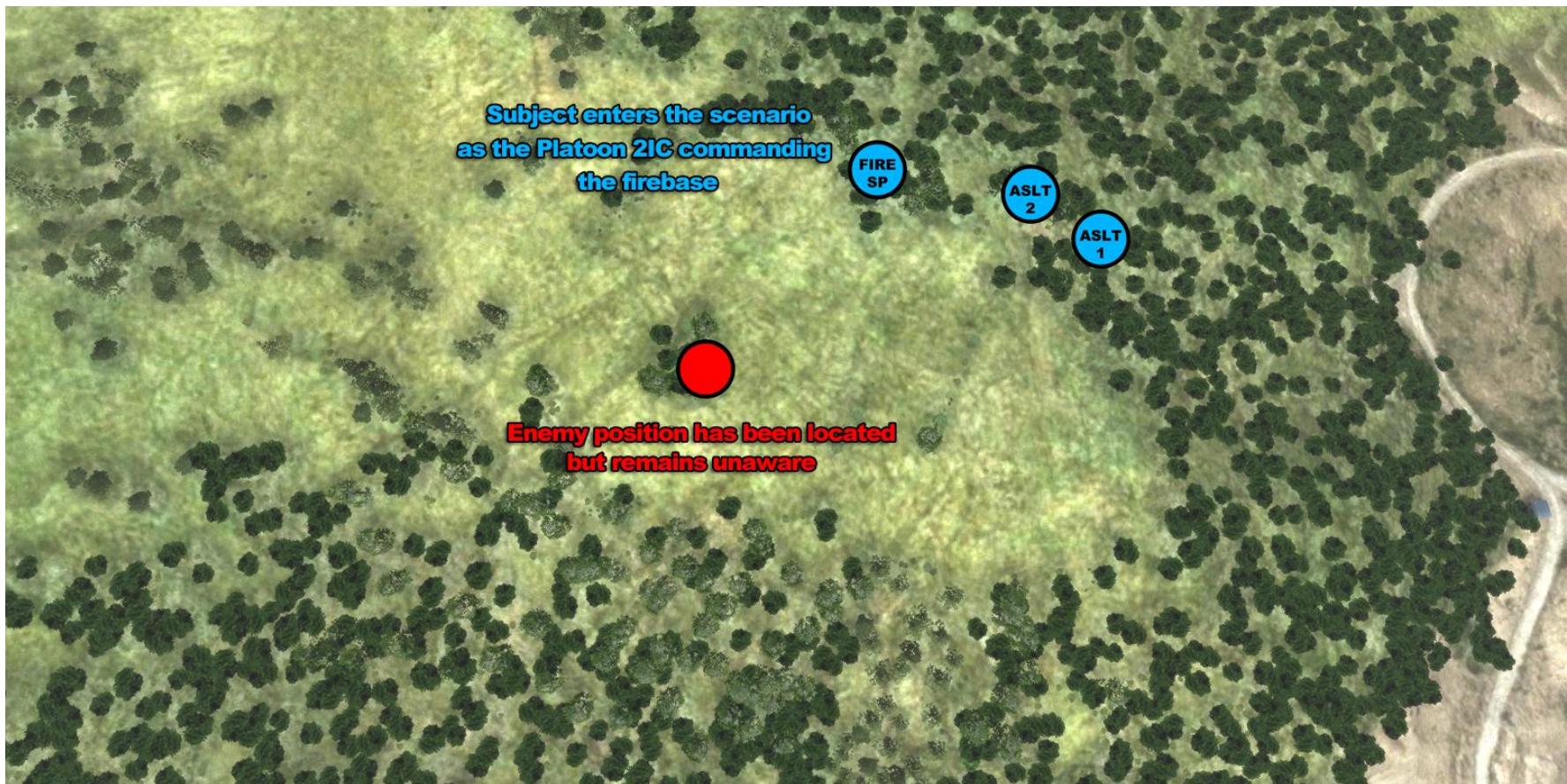


BFT Error

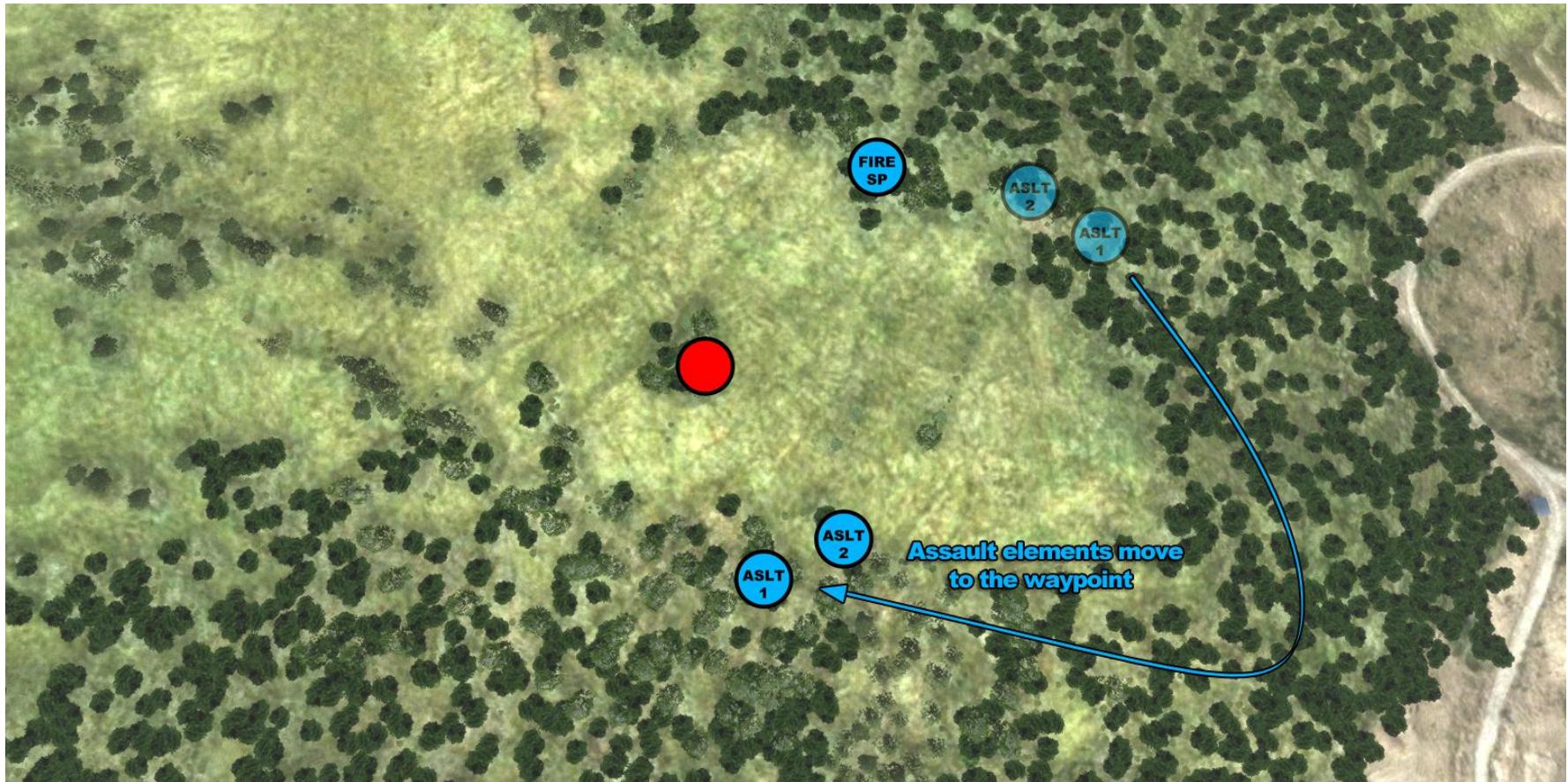
With error



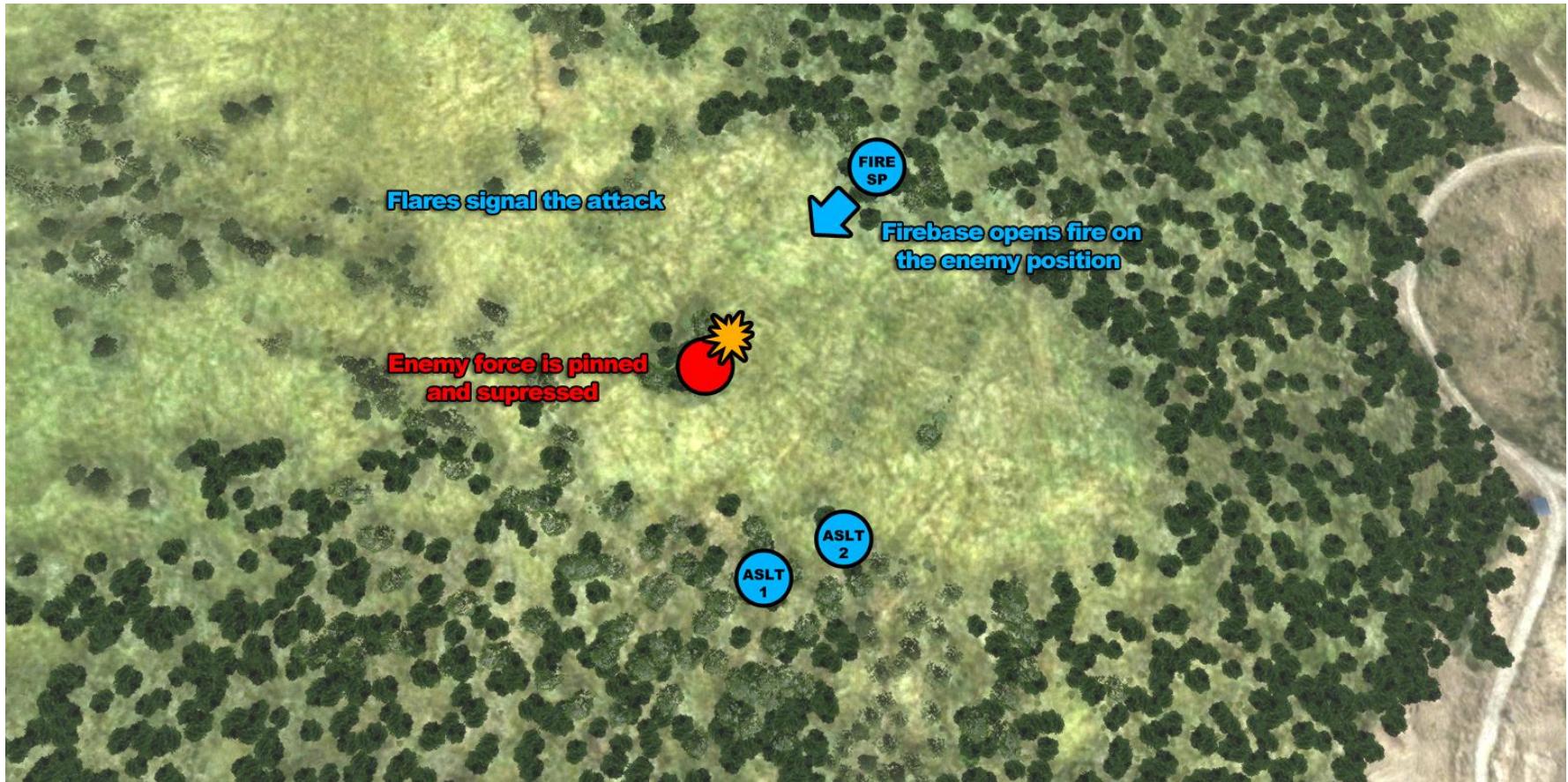
Scenario



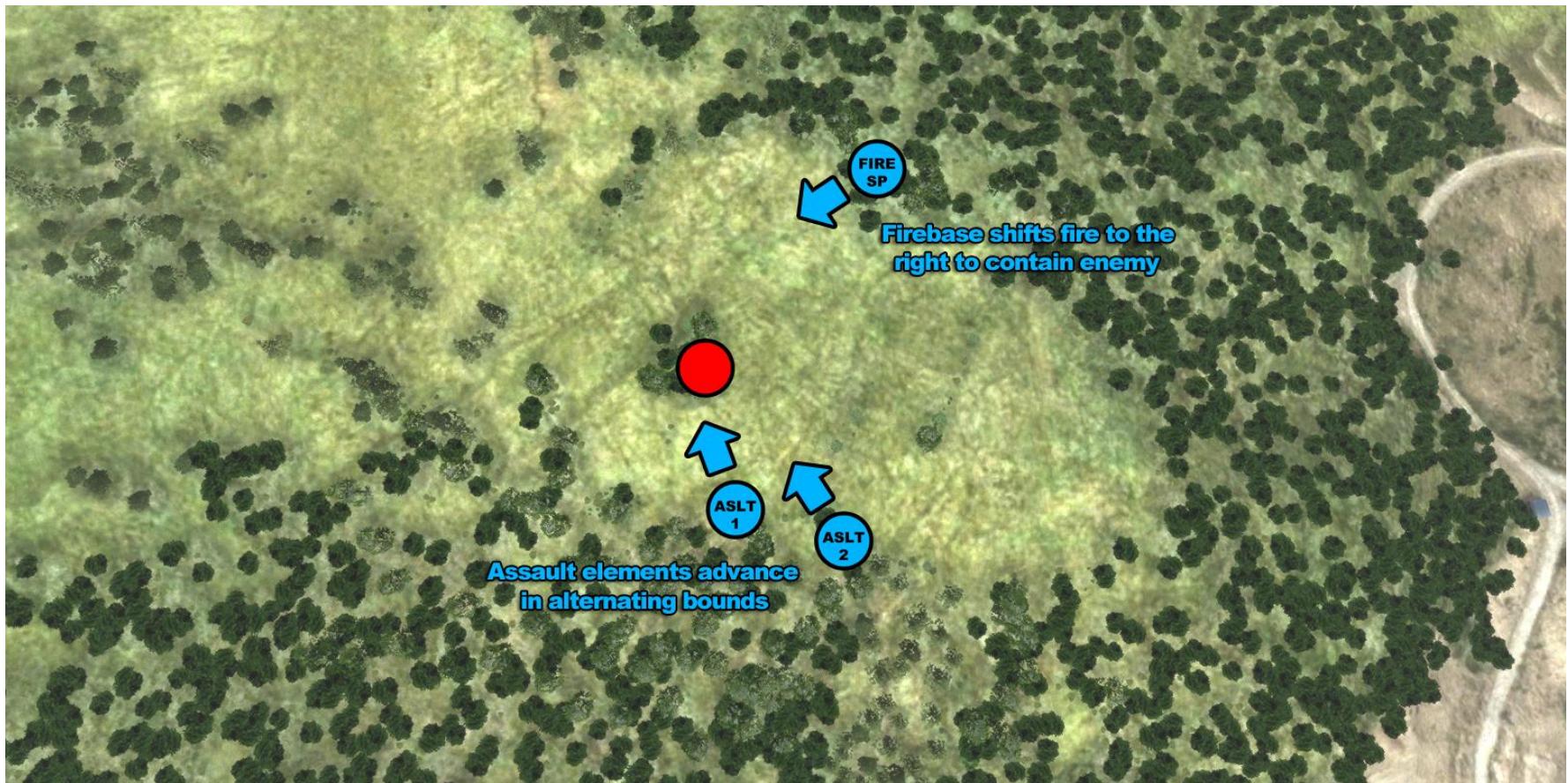
Scenario: Move



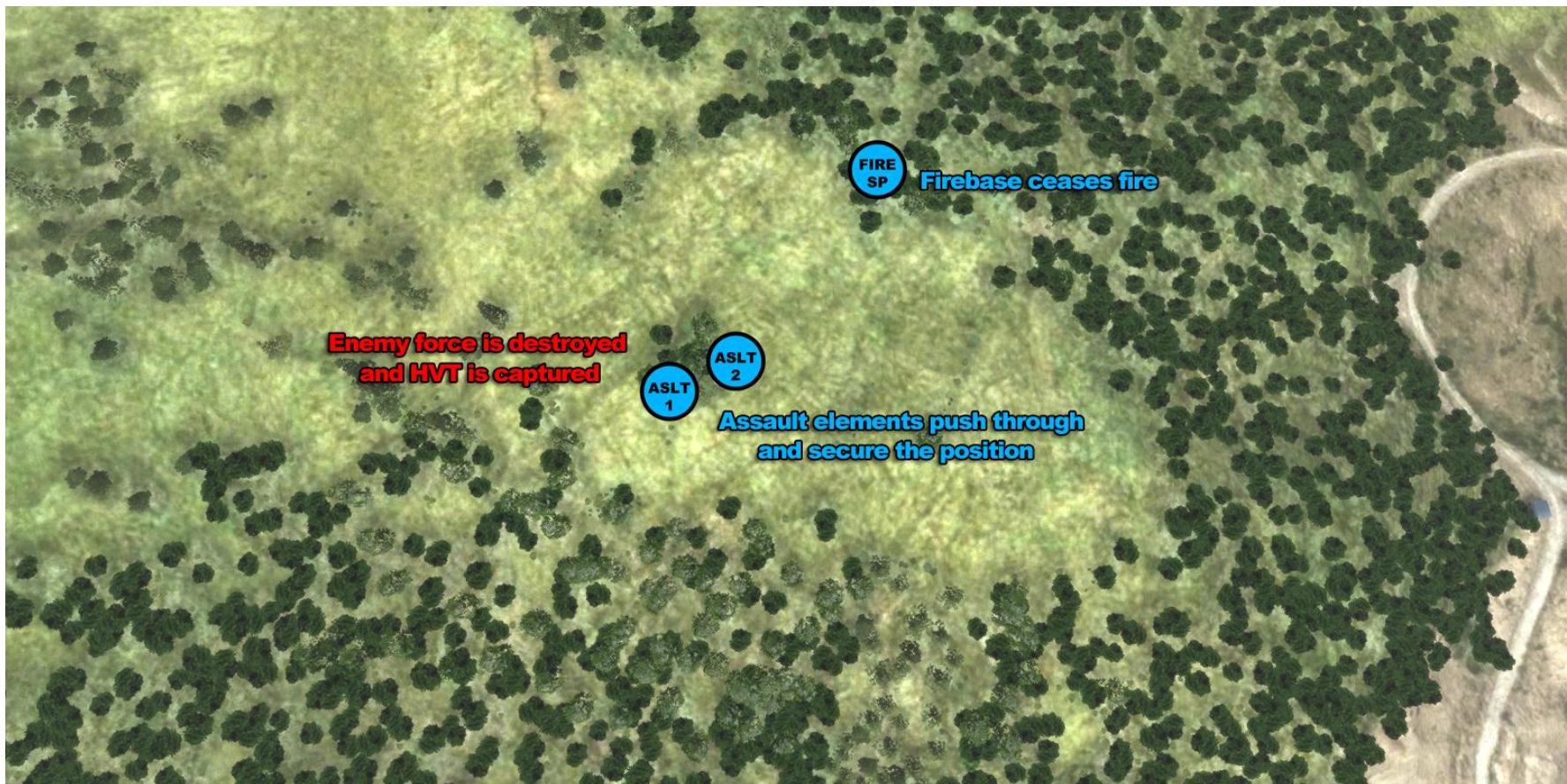
Scenario: Open Fire



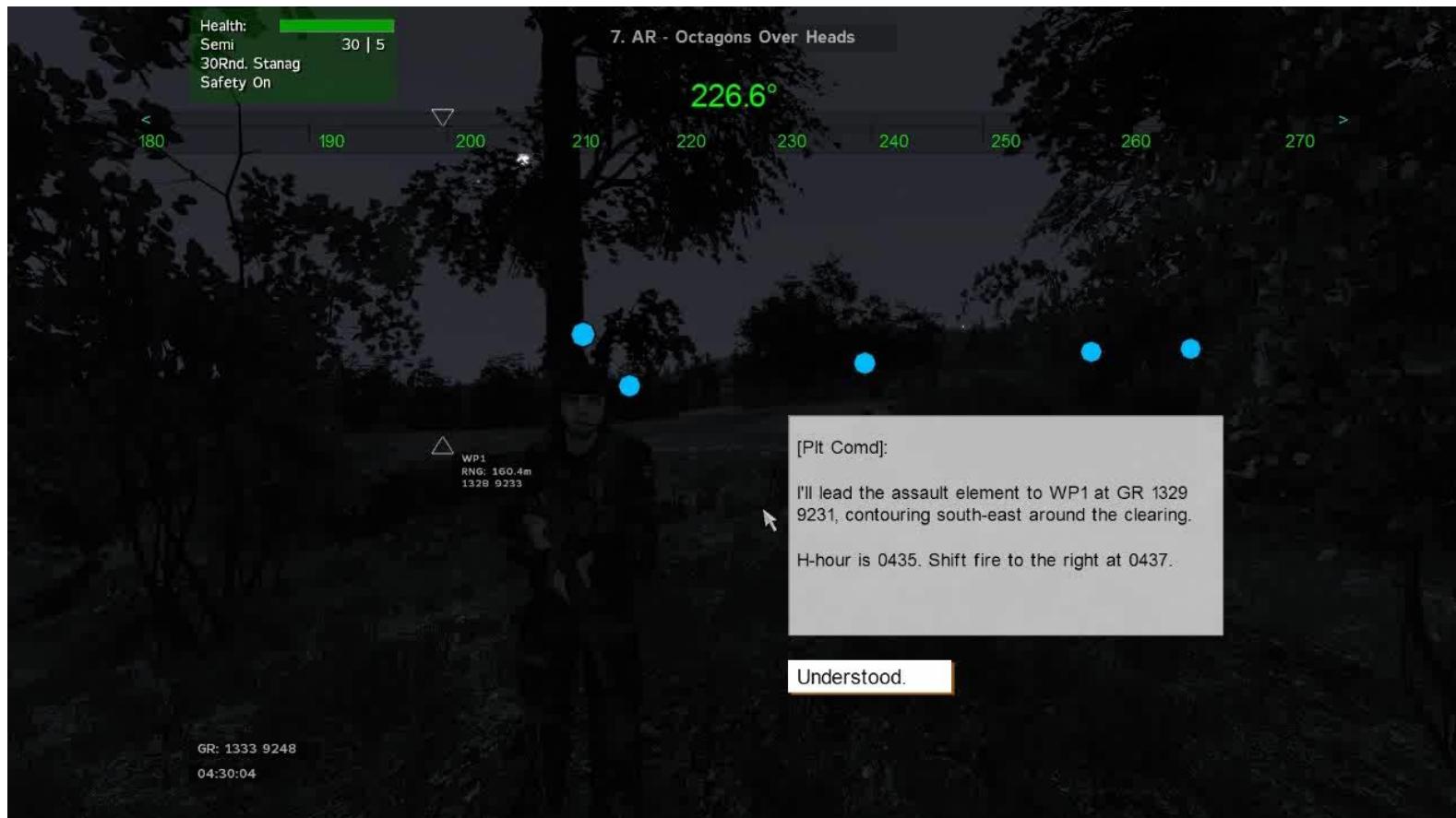
Scenario: Advance on Target



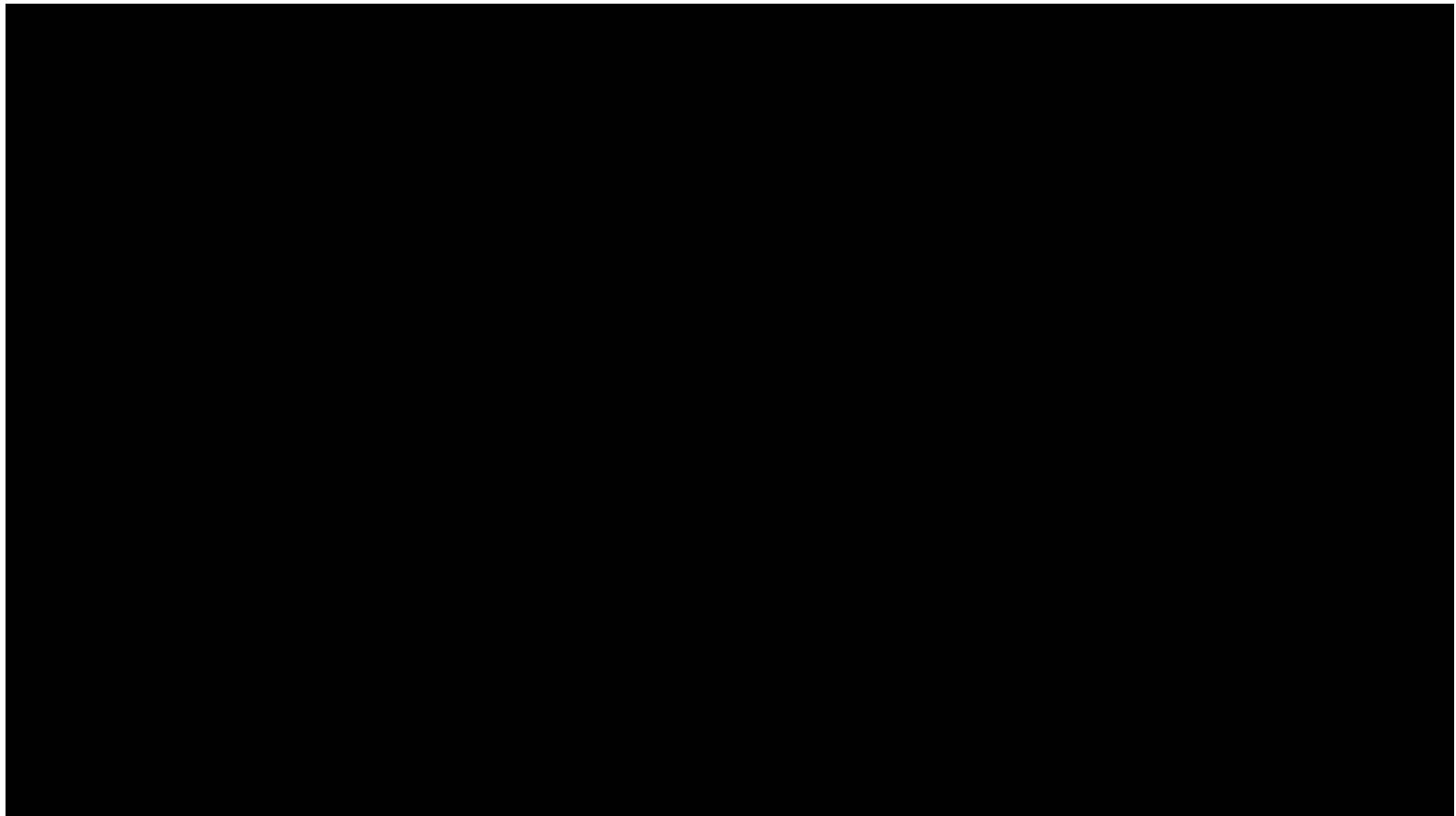
Scenario: Secure



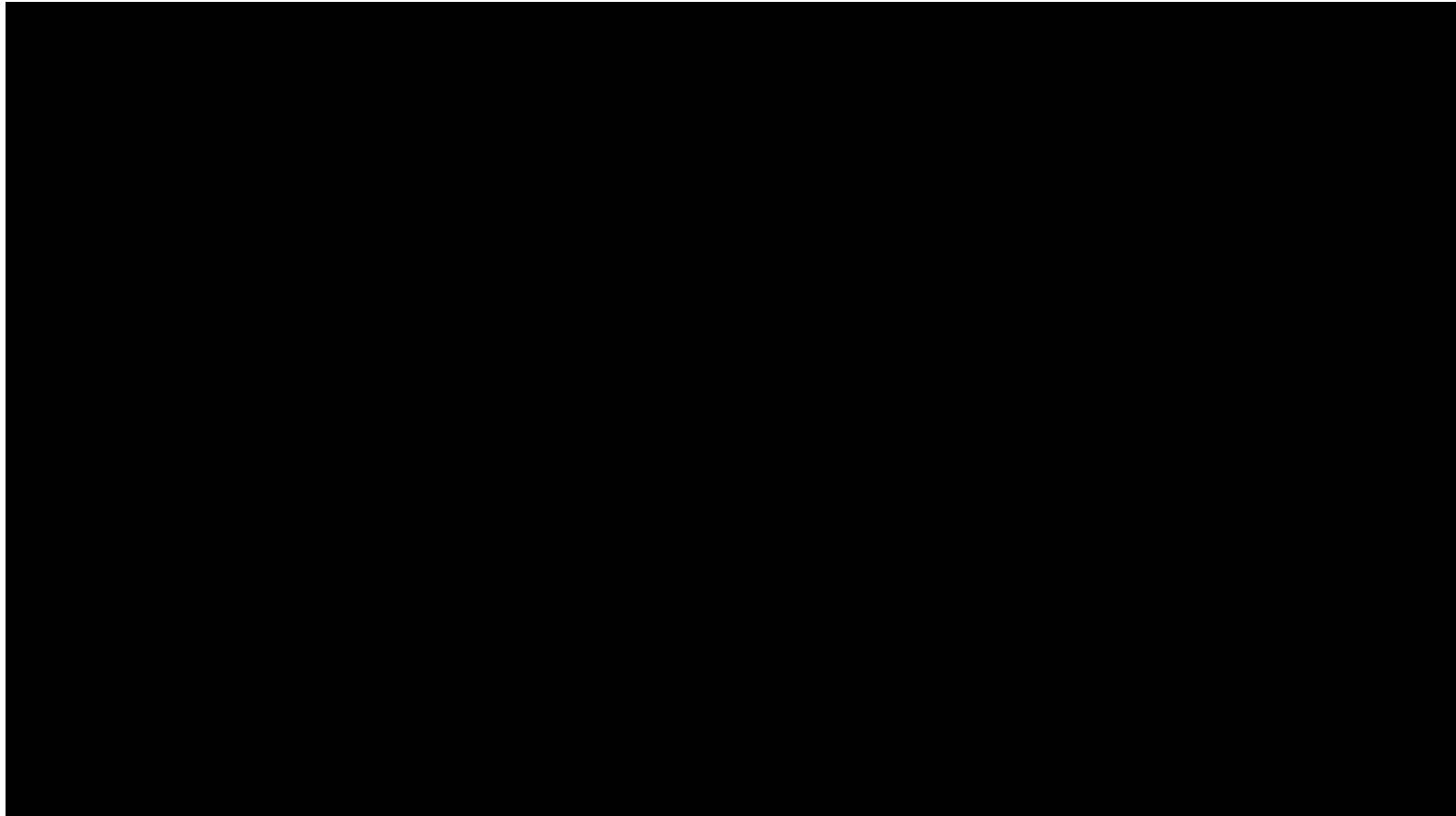
Scenario



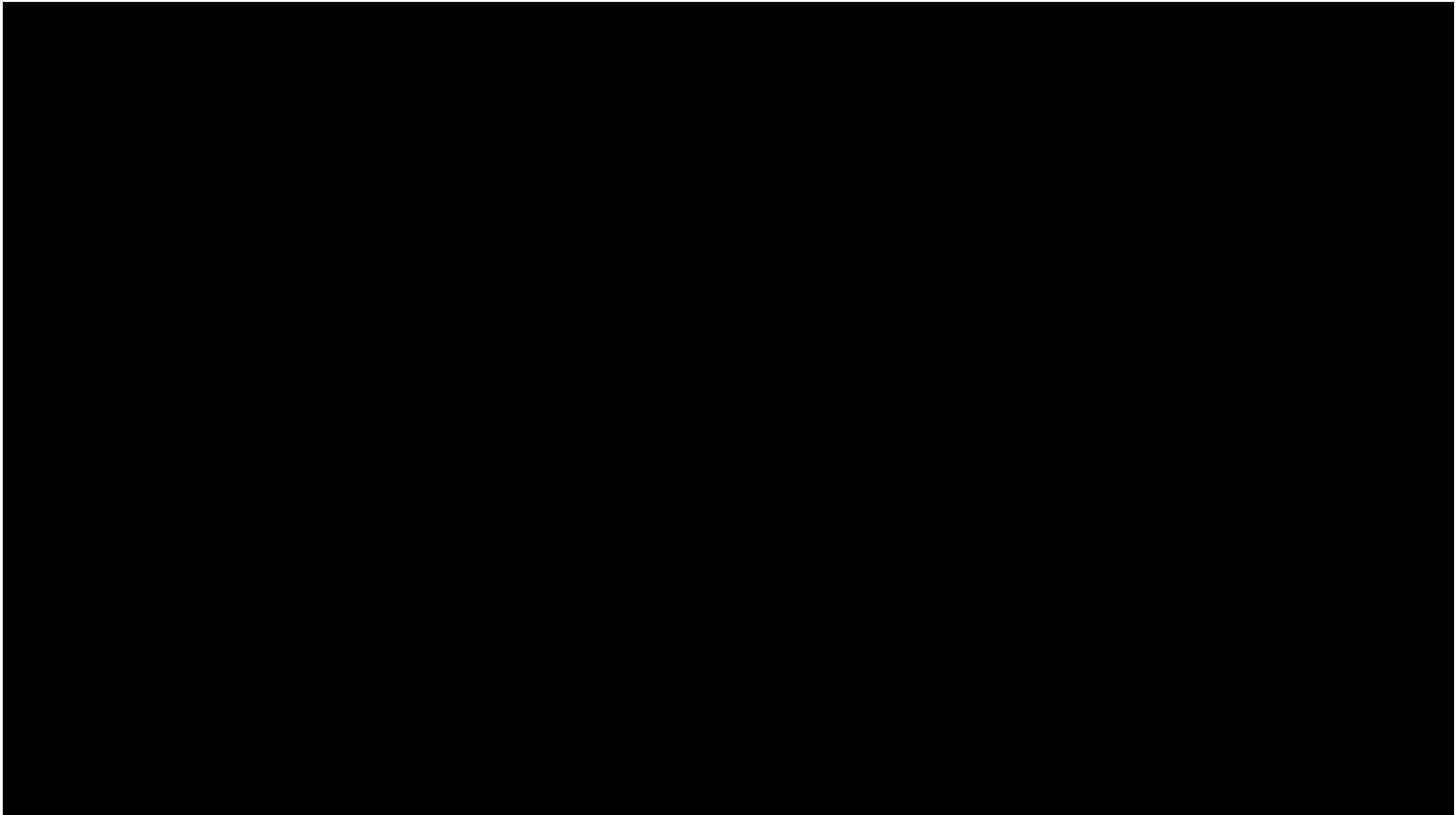
BFT Boxes



BFT Markers in Ribbon (unreliable)



Ornaments (unreliable)

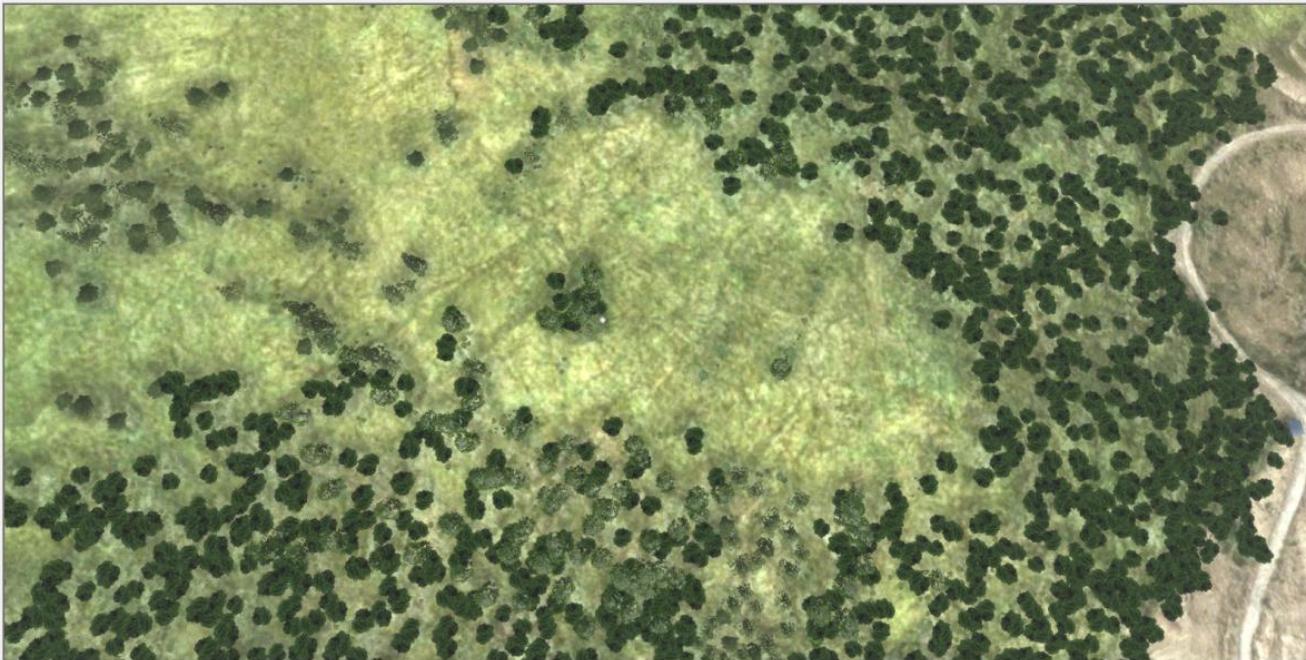


Scenarios

Scenario	Description	Event
1	Attack an enemy radio tower along a hedge-row	The attack succeeds as planned (no event)
2	Attack an enemy OP in a clearing circled by forest	The assault element ends up out-of-position
3	Attack a hill-top enemy OP from another hill-top	The assault element is ambushed by more enemy en route
4	Attack an enemy OP in a logging camp	Enemy patrols end up where the assault element is supposed to go
5	Attack an enemy checkpoint from a steep overlook	Mass enemy infantry and armour appear part-way through the attack
6	Attack an enemy OP at a farm	The assault element is late getting to the waypoint
7	Attack a small enemy encampment	The assault element gets lost in the woods and never appears
8	Attack an enemy OP on a hillside	The enemy packs up and leaves part-way through the attack
9	Attack an enemy OP in a logging camp	An unidentified blue force appears in the line of fire 46

Spatial Awareness Questionnaire

Place unit icons onto the map to represent their positions at the end of the scenario:



Self



Firebase



Assault 1



Assault 2



Other Blue



EN Inf



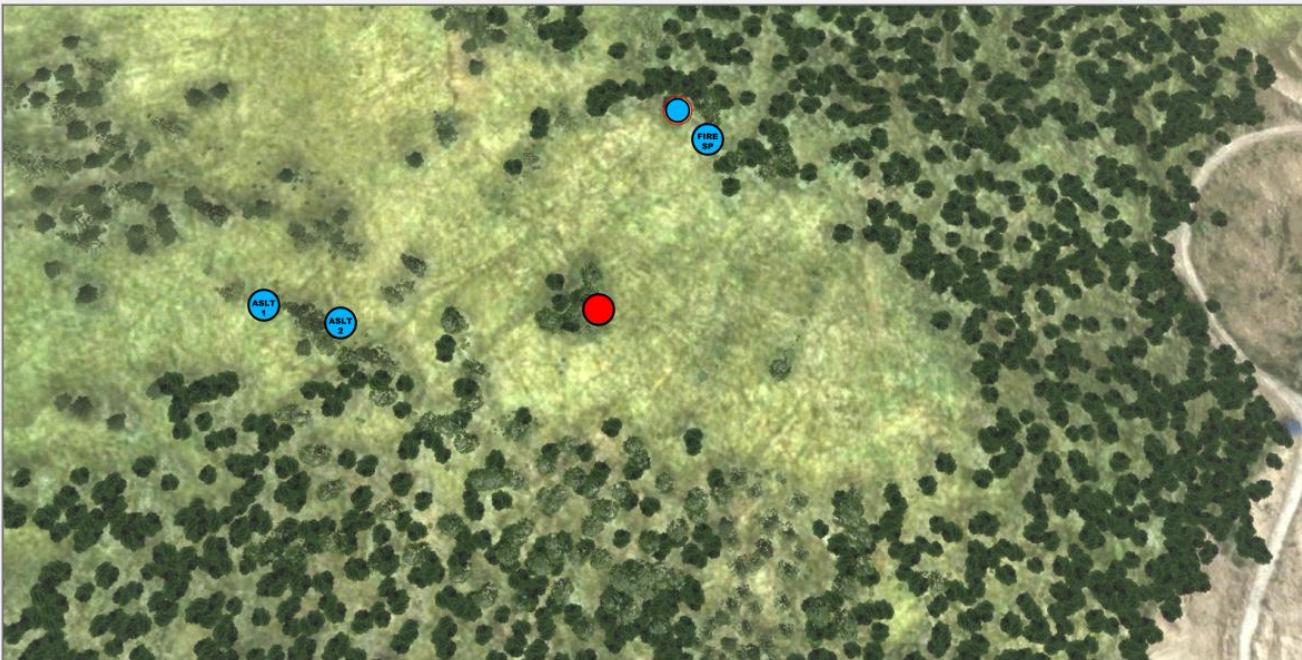
EN Veh



Submit

Spatial Awareness Questionnaire

Place unit icons onto the map to represent their positions at the end of the scenario:



Self



Firebase



Assault 1



Assault 2



Other Blue



EN Inf



EN Veh



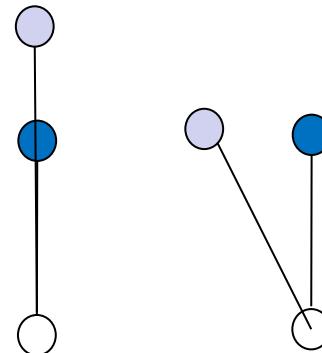
Submit

Dependent Measures

- Time to engage;
 - Time to complete task;
 - Number of blue on blue fire incidents (false alarms);
 - Number of blue on red incidents (hits);
 - Movement route;
 - Shots taken;
 - Shot accuracy;
 - Time referencing blue force tracker;
 - Number of times blue force tracker is referenced;
 - Spatial awareness
-
- **Data Analysis:** within-subjects ANOVA, MANOVA

Experiment 2: Hypotheses

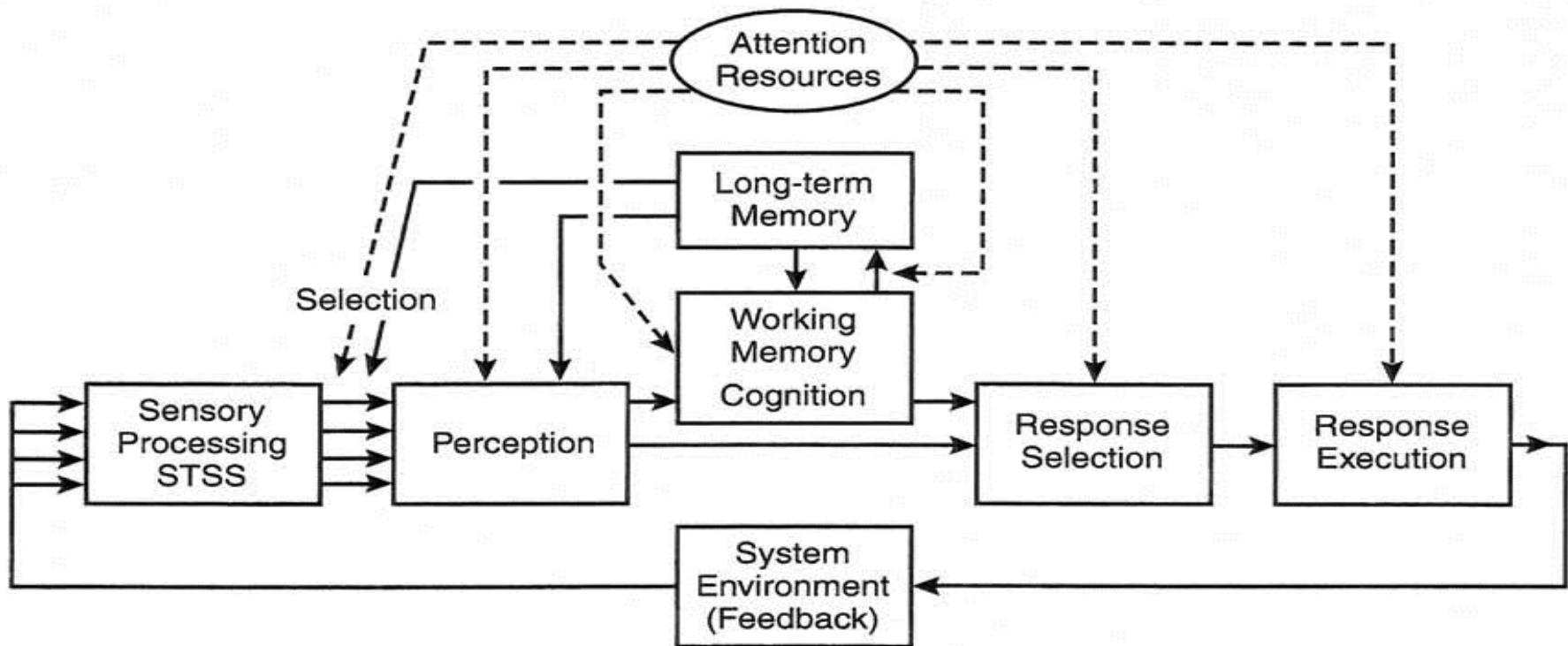
- BFT will beat no BFT (esp when there is deviation from plan)
- Error effects will be different for maps versus AR displays
 - Angular component of error becomes more salient with AR as compared to maps
 - Polar vs. Cartesian coordinates



General Summary

- In Experiment 1, soldiers with BFT:
 - Were faster at making a decision to engage
 - Used BFT to see more of the battle space (zooming out, panning)
 - Reported lower workload
 - Error (reliability) had little effect
- In Experiment 2, will look at display method
 - BFT should produce better mission performance
 - Augmented reality provides egocentric view
 - Error effects likely to differ with map and AR

Information Processing Model



Questions?

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FOR CANADA'S DEFENCE AND SECURITY

SCIENCE, TECHNOLOGIE ET SAVOIR
POUR LA DÉFENSE ET LA SÉCURITÉ DU CANADA



Table 1. Means and standard errors for each dependent measure in the No BFT, Unreliable BFT and Reliable BFT conditions.

		No BFT		Unreliable BFT		Reliable BFT	
		M	SE	M	SE	M	SE
Mission Performance							
	Time to Complete (s)	229.78	14.64	209.25	12.22	197.03	12.73
	Time to Fire (s)*	63.07	6.73	50.28	4.62	44.46	4.25
	Hits	10.22	0.47	10.17	0.41	10.58	0.35
	False Alarms	0.20	0.07	0.15	0.05	0.15	0.00
BFT / Map Interactions							
	BFT / Map Activation*	1.94	0.26	3.06	0.37	3.12	0.41
	Panning*	1.51	0.26	2.74	0.48	3.35	0.52
	Zooming In*	4.01	0.73	2.03	0.39	2.07	0.55
	Zooming Out*	1.64	0.39	5.35	0.82	3.94	0.92
Radio Communication		2.88	0.28	2.32	0.25	2.42	0.31
Mental Workload*		32.23	3.12	24.94	2.01	25.19	3.58
SA							
	Encounter 1 - Locate Sentry	0.88	0.05	0.81	0.06	0.83	0.04
	Encounter 2 - Locate Self	0.71	0.05	0.67	0.06	0.57	0.06
	Encounter 2 – Locate Friendly and Enemy Forces [°]	0.93	0.03	0.87	0.05	0.99	0.01

*Significant effect between No BFT and Reliable BFT ($\alpha=.05$)

[°]Significant effect between Unreliable BFT and Reliable BFT ($\alpha=.05$)