Study Design to Assess the Autonomous Mobility of the Experimental Unmanned Vehicle

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Schedule				
	Course	Morning	Afternoon	Evening
Day 1	Gold		M-HMMWV (2 laps) Sdr-T1	M-HMMWV (2 laps) Sdr-T1
	Black		M-HMMWV (2 laps) Sdr-T2	M-HMMWV (2 laps) Sdr-T2
	Gold		M-HMMWV (2 laps) Sdr-T2	M-HMMWV (2 laps) Sdr-T2
	Black		M-HMMWV (2 laps) Sdr-T1	M-HMMWV (2 laps) Sdr-T1
Day 2	Gold	Tech-T1 (6 mission runs)	Tech-T2 (6 mission runs)	
	Black	Tech-T2 (6 mission runs)	Tech-T1 (6 mission runs)	
Day 3	Gold	Tech-T1 (6 mission runs)	Tech-T2 (6 mission runs)	
	Black	Tech-T2 (6 mission runs)	Tech-T1 (6 mission runs)	
Day 4	Gold	Tech-T2 (6 mission runs)	Tech-T1 (6 mission runs)	
	Black	Tech-T1 (6 mission runs)	Tech-T2 (6 mission runs)	
Day 5	Gold	Tech-T2 (6 mission runs)	Tech-T1 (6 mission runs)	
	Black	Tech-T1 (6 mission runs)	Tech-T2 (6 mission runs)	
Day 6	Gold	Tech-T1 (6 mission runs)	Tech-T2 (6 mission runs)	
	Black	Tech-T2 (6 mission runs)	Tech-T1 (6 mission runs)	
Day 7	Gold	Tech-T2 (6 mission runs)	Tech-T1 (6 mission runs)	
	Black	Tech-T1 (6 mission runs)	Tech-T2 (6 mission runs)	
Day 8	Gold		Tech-T1 (2 laps)	Sdr-T1 (6 subdesign runs)
	Black		Sdr-T1 (6 subdesign runs)	Tech-T1 (6 subdesign runs)
Day 9	Gold		Sdr-T1 (6 subdesign runs)	Tech-T1 (6 subdesign runs)
	Black		Tech-T1 (2 laps)	Sdr-T1 (6 subdesign runs)
Day 10	Gold			
	Black			
	Key:			
		Excursion 1 (Operational Baseline): Manned HMMWV runs using 2 soldier teams		
		Principal Experiment: site x terrain x xuv/team x speed x offset x mission		
		Excursion 2 (Continuous laps): terraine x speed		
		Excursion 3 (Soldier and Night Effects): team type x terrain x offset x speed x time		
		Open day to recover missing observations or augment data		
	Tech-T1	Technical Personnel Team 1		
	Sdr-T1	Soldier Team 1		
	subdesign	fixed distance (1000), fixed speed (high), 2 offsets x 3 replications		
	lap	one continuous run around the 3500 m course		
	mission run	a test condition involving 1 mission x 1 offset x 1 speed		
	course=	terrain difficulty		

Draft Study Design
Experimental Unmanned Vehicle

Excursion 1:

1. Purpose: Establish a baseline of soldier performance using manned HMMWVs over gold/black terrain and in day/night conditions.

2. Conduct: Each of 2 soldier teams would run 2 laps of 2 closed-curve, test courses at 2 times for 8 laps total on Day 1. At the conclusion of a clockwise lap, they would turn and travel the second lap counter clockwise, possibly with some initial displacement from the ending position.

3. Data: This would provide 16 laps of information upon which to establish performance baselines. Specifically each terrain/time pairing would have 4 laps of information for estimation of average miles per hour.

4. Critique: Not completely randomized, is balanced design with 2 teams x 2 terrains x 2 times x 2 replications. Laps quasi independent for a team through displacement of the origin and reversal of direction. A criticism is that manned runs do not occur on the same day.

Principal Experiment:

1. Purpose: Address performance from a military-operational standpoint by considering fixed distances consistent with envisioned scout missions. Focus is to see how mission distance (500m, 1000m, 2000m), speed (high, low), and offset (LOS, NLOS) alone affect the autonomous mobility measures, and how in combination with one another as interactions these factors affect mobility. Terrain difficulty (gold, black) and XUV/Team (Tech-T1, Tech-T2) effects will also be estimated.

2. Conduct: Each Tech team randomly assigned to its XUV throughout this portion of the test. On a day, Tech teams randomly assigned to start in the morning at gold or black. Each team performs the equivalent of 2 laps around the test course, but according to the test schedule that will be provided. In a morning session, teams would perform 6 test combinations from 3 mission distances x 2 speeds x 2 offsets. At the conclusion of a "mission," some random lateral displacement from the course path would be achieved, a random direction change would be chosen, a new offset would be assigned, and a new maximum speed would be set for the subsequent mission. In the afternoon, teams switch courses. 3 reps

Principal Experiment:

3. Data: Over 6 days, 144 missions will have been completed, 72 for each vehicle. These data support a split-plot design with (course x XUV/Team) serving as the whole plot and the other factors in the split or subplot). The purposes of the Principal Experiment can all be addressed.

4. Critique: Recognizes the restrictions on randomization and provides adequate data to support analyses. Added advantage that if implemented in the second site of testing may be viewed as a split-split-plot design, thereby increasing the sensitivity of the test to detect the influence of design factors. Fixed versus random factors? Pooling? Replicate block spanning 2 days? Confound days within a replicate with offset x speed interaction to mitigate damage to design from weather. Protects main effects.

Excursion 2:

1. Purpose: Excursion 2 provides information with a focus on continuous laps and different speeds than in the Principal Design. Augments data on speed to support at a minimum exploratory modeling of a quadratic or cubic model involving speed. Also, some continuous run information that was the subject of so much discussion would be provided.

2. Conduct: On the test course identified in the test design, Tech Team 1 would in the afternoon of Day 8 collect two laps of information. Offset would be fixed to one of (LOS, NLOS). At the conclusion of one lap, the speed would be adjusted to the next level, some random lateral displacement from the course path would be achieved, the direction would be changed, and a new maximum speed would be set for the subsequent lap. On Day 9, the second test course would be run.

Excursion 2

3. Data: The data collected is 4 continuous laps around test courses, each test course seeing each of two intermediate speeds. These laps may be regarded as augmenting the speed information to better support modeling and providing a partial answer to the question, how far can it go before E-stop.

4. Critique: If speed is an important factor as suspected, the intermediate speed information gathered should help us model more than a linear representation of that relationship, if it exists.

Excursion 3:

1. Purpose: This excursion focuses on soldier performance in the military-operational sense of the principal experiment, but applied to the use of the XUV. It corresponds to only a subset of the testing run in the Principal Design with the Tech teams.

2. Conduct: The mission distance is fixed to be 1000 m and the speed to be the higher of the two. Both offsets (LOS, NLOS) will be considered. Day/night conditions will be considered. Both terrains (courses) will be considered. Three replicates are planned. For the soldier team, all information requires 2 offsets x 2 times x 2 terrains x 3 replicates, or 24 mission runs. A course and time would be selected according to the test schedule. Then 6 mission runs would be made, 3 at LOS and 3 at NLOS. For Team 1, ½ of the information required is available from the Principal Experiment. Only ½ of the information (12 night runs) are required from Tech team 1.

Excursion 3:

3. Data: The resulting data loosely follows a factorial design with 3 replications of four factors at 2 levels: Offset (LOS, NLOS), Time (Day, Night), and Terrain (Gold, Black), Team (Tech-T1, Sdr-T1). In an exploratory context it could be analyzed as a factorial design.

4. This design does provide data to support the evaluation of soldiers using XUVs versus Technical personnel along with the impact of day/night conditions, offset, and a further look at terrain. Randomization will be done to the extent possible, but in this excursion we are severely constrained.—even borrowing 12 runs from the principal experiment and Tech –T1 to make it a complete factorial. That will have to be factored into the analysis.