Closing the Gap of Standardized RAM Testing for Small Unmanned Robotic Systems

Presenter:

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Agenda

- Background
- Challenges
- Where are we now?
- Where do we need to go?
- How do we get there?
- Benefits

Background

Most small unmanned ground robotic systems have been fielded through rapid acquisition process intended to either improve existing capabilities or provide additional capability to fill a mission gap with limited budget. Current testing and evaluation is not providing a platform for comparative analysis without a significant increase in test scope and cost. Standardized test can create a targeted and concise test design while reducing budget.

Challenges

- Limited resources (cost, schedule, test items, etc).
  - Limited data and lack of confidence.
- Inconsistent test design and evaluation concept.
  - Unable to leverage historical testing for comparative evaluation.
- Lack of reliability requirement or associated failure definitions.
  - Educated guess on sample size and capability priority to test.
- Limited capability testing.
  - Poor/No system characterization.

Where are we now?

- 5 similar small unmanned ground robotic systems were tested over the last few years with limited budget and nominal test strategy.
- All 5 systems have common missions to investigate suspicious objects at a safe standoff distance and conduct reconnaissance and/or route clearance.
- All 5 systems have audio and visual sensors, gripper arm, track/wheels and an operator control unit.

Where are we now?

Robot	Endurance Test Criteria	Terrain Profile
1	No criteria.	No criteria.
2	30 RAM operating hours on each of 2 robots.	Gravel, smooth concrete, soil, grass, rough sand embedded concrete, saw tooth concrete and cubed concrete.
3	300 miles.	Gravel, paved, dirt, sand and mud.
4	22 RAM operating hours on 1 robot, 3 RAM operating hours on second robot, and 3 RAM operating hours on third robot.	Asphalt , grass, sand, and grave.
5	25 RAM operating hours.	No criteria.

Where are we now?

Robot	Design of Experiment	Capability Tested
1	6 iterations of 11 repetitions of LOS and NLOS communication.	LOS and NLOS communication over all sensors.
2	No criteria	No criteria.
3	60-80 deploy/recover repetitions.	Day and night operation. Deploy and recovery.
4	No criteria.	No criteria.
5	Repetition of target recognition.	Multiple mission based scenarios using key system tasks and capabilities. Multiple operators. Target recognition.

Where do we need to go?

Robust reliability test concept should include various scenarios to test capabilities and limitations in an operationally realistic environment.

- Terrains
- Temperatures
- Environmental conditions
- Operators of varying background and experience
- Threats of various shape, size and weight

Where do we need to go?

Rapid reliability test concept should include:

- Controlled variations
  - variations must be clearly defined and applied consistently across tests/systems such that a qualitative and/or quantitative comparison can be made between tests and systems.
- A concise test with an adequate scope
  - characterize the system by uncovering failure modes of essential functions.
- The evaluation should provide enough information for the Soldiers to understand the extent to which a certain system can aid him/her and any associated shortcomings or limitations.

How do we get there?

1. Scope test design by prioritizing essential capabilities.
   - High priority capabilities should be evaluated through testing, while low priority capabilities should be evaluated if resources permit.
2. Test resources.
3. Test procedures.
4. Data collection.

*Power curve for Gray-Lewis Test to Compare Two Exponential MTBFs

1. Scope

	Capability	Considerations	High Priority	Low Priority
Mobility	Provide power	Power source/type Power life Power re-chargeability Power replacement portability Power draw during operation	The loss of this capability can severely degrade the ability to successfully complete mission or can cause an increased risk of personal injury to the operator. This capability is a new capability compared to its predecessor. This capability was the focus of a previous test and documented corrective actions were implemented to resolve any surfaced failure modes. This capability is a safety concern.	The loss of this capability does not hinder mission completion. This capability was the focus of a previous test and no known corrective actions were implemented to resolve any surfaced failure modes. This capability was thoroughly tested under similar or identical test standards and procedures by previous non-government test facilities for which data can be provided and validated.
	Provide steering control	Tether/wireless Forward, back, left, right, up and down, etc Turning radii		
	Provide visual control	All types of cameras, laser range finder, etc Tether/wireless Non-line-of-sight (NLOS) vs. Line-of-sight (LOS)		
	Provide audio control	Tether/wireless Non-line-of-sight (NLOS) vs. Line-of-sight (LOS)		
	Provide speed regulation	Different speed control Max and min speed Stopping/braking distance through speed range		

1. Scope

	Capability	Considerations	High Priority	Low Priority
Lethality or Reconnaissance	Detect, acquire, observe target	Camera clarity Visual data capture & storage Day & night Illumination	System is intended to provide reconnaissance, surveillance and target acquisition and/or neutralization capability. This capability is a new capability compared to its predecessor. This capability was the focus of a previous test and documented corrective actions were implemented to resolve any surfaced failure modes. This capability is a safety concern.	The capability was inherited from its predecessor and remains unchanged. Valid test data can be provided by other sources. Legacy data can be used.
	Recognize, identify, and provide target distance information	Camera movement Camera field of view Camera range of motion GPS Laser range finder Camera color scale and contrast sensitivity		
	Gather visual, audio and electronic information	Information transfer Camera type Camera quality Information security Reporting accuracy & latency Max communication distance		
	Neutralize or incapacitate target	Accuracy Lethality		
Recovery and survive	Provide self diagnostic capability	Failure alerts Power consumption monitor Reboot	System will contain information which can't be abandoned. System must be retrieved at the end of a mission.	Valid test data can be provided by other sources. System is expendable at the end of a mission.
	Provide physical protection	External hardware Internal software safety Environment protection		
	Compatibility	Interoperability with other platforms/system Electronic interference		

1. Scope

	Capability	Considerations	High Priority	Low Priority
Control	Provide operator control interface	Data/audio/video link Wireless/tethered	System is intended to relay audio or visual information wirelessly/tethered. System must be retrieved at the end of a mission. System is intended to navigate various terrain profiles to include subterranean environments. System is intended to lift and/or various items. System is intended to have functionality of arm/gripper movement to a certain precision. System is intended to be utilized in missions across a range of environmental. System is intended to be part of a system-of-system or bigger platform. Software upgrades/changes. System is intended to relay sensitive information.	Valid test data can be provided by other sources. The capability was inherited from its predecessor and remains unchanged. Legacy data can be used. The loss of this capability does not hinder mission completion. Data from subcomponent testing can be provided and validated. System is not intended to perform in certain environment and/or terrains. System is expendable at the end of a mission.
	Command	Track/wheel/flipper control Self right capability Operation in wireless/autonomous mode		
	Interrogation arm/limbs/gripper	Range of movement Minimum & maximum force Maximum lift & carry weight		
	Environmental limitation & capability	Hot/cold Rain/sand/dust/water Terrain types Altitude/slopes Obstacle traversing Software performance Software reliability		
	Compatibility	Interoperability with other platforms/system Electronic interference		

2. Test Resources

Focus	Consideration	Recommendation and Rationale
Test Resources	Sample size Test time Test site User	Recommendation: Minimum of three test units. Rationale: To eliminate the possibility of having split data, where 50% of the sample population is highly reliable while the other 50% is not. Recommendation: Test units must be representative of final production products. Rationale: To eliminate possibility of introducing new and un-surfaced failure modes due to changes made post-testing. Recommendation: Test length should be determined by units of time and not distance. Rationale: To facilitate comparison to probability of completing a mission of a specific duration. Test time can also help gauge the adequacy of battery life and usage during operationally realistic missions. Recommendation: Test time should be in multiples of intended mission length or battery life. Rationale: To eliminate the possibility of overlooking failure modes due to wear and usage over a period of time meaningful to the intended user and mission (i.e., multiple missions or multiple battery recharges). Recommendation: Test site should contain all obstacles and terrain profiles and percentages necessary to test all high priority capabilities within test scope. Rationale: To surface failure modes associated with each tested capability under operationally realistic conditions. Recommendation: Operators should be varied throughout the duration of test. Rationale: To help analyze the transparency of failure mode(s) to users after fielding.

3. Test Procedures

Focus	Consideration	Recommendation and Rationale
Test Procedure	Design of Experiments Repetitions Measurement apparatus Reproducibility	Recommendation: Design of experiments should be utilized to optimize test events through controlled variations in test parameters. Rationale: It is crucial to incorporate an optimal design into a limited test plan to maximize the likelihood of uncovering failure modes. Recommendation: Replicate all iterations where a controlled variable was introduced multiple times. Rationale: Repetitions can produce more accurate data and increase test validity by decreasing experimental and human errors. Recommendation: Use verified and validated measurement tools per test standards. Rationale: Measurement tolerance should fall within the acceptable range of test and evaluation standards. Recommendation: Provide detailed documentation of all test procedure to ensure reproducibility of test. Rationale: Reproducibility can help failure review boards pinpoint failure modes and help evaluators analyze capabilities and limitations of the system under test.

4. Data Collection

Focus	Consideration	Recommendation and Rationale
Data Collection	Database management Database accessibility Database accuracy Data sensitivity Data collection procedure	Recommendation: Maintain a quick data turnaround time. Rationale: If data is quickly made available to evaluators, the analysis and report can be finalized much faster. Recommendation: Allow only the relevant users to access data for quick turnaround in evaluation and analysis. Rationale: Allowing only the relevant users to have access eliminates possible version control issues as well as expedites the data analysis schedule. Recommendation: Ensure both high quality and well detailed data. Rationale: For an accurate analysis, the content of the data must be detailed and accurate to avoid further delays due to requests for more information. Recommendation: Ensure accurate data sensitivity classification. Rationale: Not all data needs highly classified handling procedures. Accurate data classification can help reduce data turnaround time significantly. Recommendation: Ensure detailed documentation of all data collection procedures and personnel. Rationale: Detailed data collection procedures can help evaluators to analyze capabilities and limitations of system under test as well as reduce the time needed to answer requests for further information.

Benefits

- Improves test and evaluation guidelines when no reliability requirement and limited resources.
- Characterizes limitations via a test concept that focuses on uncovering failure modes for mission essential capabilities.
- Standardized data collection metrics allow for comparisons of system performance or reliability across test events.
- Increase the reusability of historical data.