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Initial Experiment in Using a Powered Parafoil for Employment of Intelligence, Surveillance, and Reconnaissance (ISR) Unattended Ground Sensors (UGS)

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14. ABSTRACT

Experiments were run by the U.S. Army Research Laboratory at Yuma Proving Ground, AZ, on 10 and 12 June 2004 to obtain an initial assessment of the viability of using a powered parafoil as an unmanned air vehicle for employment of Future Combat System intelligence, surveillance, and reconnaissance unattended ground sensors (UGS). These experiments were conducted as an adjunct to the testing of the parafoil for the Special Operations Command Wind-Supported Air Delivery System program. Three flights were flown which dispensed UGS mass mock-ups. Two of the flights used manually released UGS while the third flight was operated autonomously. The experiments were designed to give an initial quick look assessment of the dispersions that might be expected in UGS parafoil employment.

The initial assessment indicates that the powered parafoil is a viable air delivery platform. Control of the UGS release is good and dispersions in landing areas are minimal. Maximum dispersion for a drop of three nodes was about 7 m from the centroid of the landing locations. Dispersions were typically less than 3 m.

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Disclaimer

The perspectives expressed in this report are those of ARL and may not reflect the positions of TRADOC, PMs, or the Army.

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Executive Summary

Experiments were run by the U.S. Army Research Laboratory at Yuma Proving Ground, AZ, on 10 and 12 June 2004 to obtain an initial assessment of the viability of using a powered parafoil as an unmanned air vehicle for employment of Future Combat System intelligence, surveillance, and reconnaissance unattended ground sensors (UGS). These experiments were conducted as an adjunct to the testing of the parafoil for the Special Operations Command Wind-Supported Air Delivery System program. Three flights were flown which dispensed UGS mass mock-ups. Two of the flights used manually released UGS while the third flight was operated autonomously. The experiments were designed to give an initial quick look assessment of the dispersions that might be expected in UGS parafoil employment.

The initial assessment indicates that the powered parafoil is a viable air delivery platform. Control of the UGS release is good and dispersions in landing areas are minimal. Maximum dispersion for a drop of three nodes was about 7 m from the centroid of the landing locations. Dispersions were typically less than 3 m.

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1. Background

The Army's Future Combat Systems (FCS) and Future Force Warrior (FFW) programs have a requirement for intelligence, surveillance, and reconnaissance (ISR) unattended ground sensors (UGS). The Air Force, Marines, and Special Operations Command (SOCOM) likewise have requirements for ISR UGS. FCS ISR UGS are a core component of the FCS unit of action (UA) and are a critical asset to provide situational awareness. The fundamental operational requirements are as follow:

- Employment: UGS must be employed as far as 150 km. This long-range employment requirement precludes hand emplacement or ground vehicle emplacement and makes air drop employment highly desirable during many conditions.
- Information and persistence: UGS must provide persistent surveillance and useful ISR information about targets (classification, location, and direction of movement) and communicate this information 150 km back to the UA. Detailed UGS ISR operational requirements document (ORD) requirements are given in annex E of the FCS ORD.

Currently, no air delivery platform is identified for UGS in FCS. A delivery platform is needed which is practical and will be an FCS available asset. The UA Mounted Battle Lab (UAMBL) at Ft. Knox, KY, has stated that the class IV-B unmanned air vehicle (UAV) (which includes the powered parafoil), high mobility artillery rocket system (HIMARS) (rocket), and the FCS non-line-of-sight (NLOS) cannon are the acceptable air delivery platforms. There are the obvious issues with the sensor hardware configuration and hardening for air delivery, development of the dispensing mechanism, variances in dispersion patterns of the nodes in the UGS field, etc. These issues are just beginning to be examined.

ARL and others have considered the use of a powered parafoil as an employment platform for FCS ISR UGS. The parafoil is not currently a core asset to the UA or unit of employment (UE), and is not a complete solution to the long-range employment requirement. Using the parafoil in high winds will be a concern. The preference for the powered parafoil is based on several considerations as follows:

- Already developed and commercially available from MMIST, (Mist Mobility Integrated Systems Technology, Inc.)
- Heavy payload of close to 600 lb with round trip range of 50 km,
- Round trip range of 650 km with 100-lb payload,

- Development of an UGS dispenser system relatively easy and inexpensive,
- Can give controlled dispensing of UGS nodes, if needed.

2. UGS Employment Concepts

The employment concept envisioned is to use the unmanned powered parafoil to employ far ISR UGS. Employment of an UGS field may be as far as 150 km—the maximum range of the UA area of interest. The mission of the parafoil would be to fly and air drop UGS in predefined area and then return to the employing unit (or some other unit). Multiple UGS fields could be dispensed on a single flight. MMIST's powered parafoil has six cargo bins, each capable of carrying cargo or fuel tanks. If five of the six bins were used for fuel tanks, leaving a single bin with a 100-lb payload, the round trip range would be 650 km, assuming an average headwind speed of zero. Head or tail winds add directly to the ground speed as with a powered aircraft. Flights can be autonomous or controlled via a radio or Iridium satellite communications (SATCOM) link. Autonomous operation of the parafoil would require the UGS to be dropped at a minimum altitude above ground of approximately 800 to 1000 ft. A dispenser would need to be designed that has the capability to dispense one node at a time. MMIST engineers have indicated that this would not be difficult.

The powered parafoil is ground launched from a pickup truck or high mobility multipurpose wheeled vehicle (HMMWV) with a 35-mph head wind required for launch. The parafoil flies at approximately 50 km/hr air speed. The payload dispenser consists of six bins, each capable of carrying a payload of 100 lb with a total payload limit of 573 lb. Any (or all) of the bins may be used for fuel tanks, trading payload for range. The maximum range is 942 km with an average head wind of 0 mph. With three bins of fuel, the range is about 350 km, still leaving a payload of 300 lb. The flight ceiling is 14,500 ft above mean sea level, allowing employment missions to be flown over all but the tallest mountains. The minimum launch time is 14 seconds and launch and recovery can be accomplished with a three-person crew.

Figures 1 through 4 show the powered parafoil in operation.

Figure 1. Launch of powered parafoil.

Figure 2. Airborne powered parafoil.

Figure 3. In-flight opening of payload dispensers.

Figure 4. Powered parafoil landing.

There are several concepts for deployment of UGS which use the powered parafoil. One is to have the UGS nodes dropped and then let them free fall. This would require the nodes to be hardened to survive impact, and issues ensuring a controlled vertical landing would have to be addressed. An alternate scheme would have either guided or unguided secondary mini-parafoils attached to the UGS. The guided mini-parafoil would allow for a more precision emplacement of the nodes but at added significant cost per node. Both schemes would allow for a soft landing with the potentially undesirable result of having each node's location flagged with the parafoil. Trade-offs of employment dispersions versus the number of nodes required versus the cost of the secondary parafoils would have to be assessed.

3. Experiment Design

The Snowgoose powered parafoil was developed for SOCOM by MMIST, Ottawa. The tests conducted at the Yuma Proving Ground (YPG), AZ, were for the SOCOM WSADS program, which uses the parafoil for leaflet delivery and parachute re-supply. The flight scenarios and embedded mission software were designed for these SOCOM missions. The dispensers, which were designed to have the bottom open and to simply drop everything from the bin, were also tailored to the WSADS program.

SOCOM and MMIST allowed ARL to place mass mock-ups of UGS in the four or five unused bins of the Snowgoose. Twelve aluminum mass mock-ups were built to simulate the approximate size and weight of an UGS node. The node model was based on the ARL affordable ISR UGS concept, a 3.5-inch tall, 4-inch diameter family of scatterable mines (FASCAM) cylindrical package with sensors, batteries, and a two-board electronics set for short haul communications, long haul SATCOM "reachback," and sensor processing and signal conditioning. This size and shape also closely align with the proposed production-envisioned massively deployed UGS (MDUGS). Figure 5 shows the UGS mass mock-ups used for the experiment.

Figure 5. UGS mass mock-ups.

The purpose of the experiment was to get an initial indication for the UGS node dispersions that might be expected from a powered parafoil employment. UGS were placed on three mission flights. The first two were manually controlled flight with drops from an altitude of approximately 300 to 500 ft above ground level. The UGS had a "target" on the ground. A single dispensing bin was opened during each pass over this target. The Snowgoose operator piloted the parafoil toward a targeted release point displayed on the ground station and pushed the release button. On the two manually controlled flights, three bins contained two UGS nodes each and two of the bins contained three nodes each for a total of 12 on-board nodes.

The third flight was an autonomous flight with autonomous UGS dispensing. This flight had three nodes placed in a single dispensing bin. The parafoil was programmed with a "target" on the ground. The Snowgoose autonomously flew to the drop point that it calculated for the payload to land on the target. Pinpoint accuracy was not expected on these flights. Since the Snowgoose navigation and dispensing software was designed for dispensing parachute payloads that would be affected by the local winds, it was not optimal for the node mock-ups which fell straight down to the ground.

For all flights, the coordinates of the UGS landing points were surveyed. In addition, post-flight data of the actual release points and altitude above ground were retrieved from the Snowgoose flight data. This allowed for a determination of the dispersions and the "error" of the autonomous drop.

4. Test Data and Results

The flights produced the following dispensing of the UGS:

Table 1. UGS dispensing summary.

Flight No.	Bin No.	Quantity UGS Dispensed	Drop Mode
1&2	2	3	Manually controlled drop
1&2	3	3	Manually controlled drop
1&2	4	2	Manually controlled drop
1	5	2	Manually controlled drop
2	5	0	Bin door stuck
1&2	6	0	Bin door stuck
3	2	3	Autonomous drop

Bins 5 and 6 had been damaged in earlier tests and had problems in the release lever. The bin 5 door stuck in the second flight and the bin 6 door stuck in the first two flights. These bins had two UGS each that were not dispensed. After each flight, the UGS were recovered and the landing position of each node was global positioning system (GPS) surveyed. The drop area on the ground was very flat for the first two drops and consisted of a mix of sand with many stones and large pebbles. The ground was hard with about 0.5 inch of loose sand on top. Of the total of 21 UGS dropped, 18 landed on their sides. The significance of this, if any, is not clear. The drop area for the autonomous drop was rough and uneven. Table 2 tabulates all the data taken and calculated, including drop coordinates, landing coordinates, and calculation of the dispersions.

UGS that landed within 3 to 5 ft of each other were treated as the same point, taking into consideration of GPS accuracy. We calculated the dispersion by determining the distance that a node was from the centriod of the landing positions. The maximum dispersion distance was 7.2 m, with 2 to 3 m more typical. Contributing to the dispersions is the fact that the UGS were lying in the floor of a big bin, which is about 3 ft by 3 ft, and were sliding around during flight. When the floor drops open, the UGS fall from different spots within the bin and leave at slightly different times. With a dispenser designed for UGS, this would not happen. Figure 6 shows a typical landing dispersion.

Table 2. YPG UGS drop data.

	Bin No.	UGS No.	Height (meters)	North Delta Landing (degrees)	East Delta Release (degrees)	North Delta Landing (meters)	East Delta Release (meters)	Offset (meters)	Drop Dispersion Distance from c.g. (meters)
Flight 1 - Manual Drop									
Drop 1	2	1	107	0.000294	-0.000775	32.72	-72.32	79.38	2.69
Drop 1	2	2	107	0.000322	-0.000803	35.81	-74.91	83.03	1.34
Drop 1	2	11	107	0.000322	-0.000803	35.81	-74.91	83.03	1.34
Drop 2	3	3	93	0.000155	-0.000224	17.21	-20.91	27.08	0
Drop 2	3	7	93	0.000155	-0.000224	17.21	-20.91	27.08	0
Drop 2	3	12	93	0.000155	-0.000224	17.21	-20.91	27.08	0
Drop 3	4	4	170	-0.000604	-0.000666	-67.13	-62.09	91.45	3.02
Drop 3	4	8	170	-0.000631	-0.000721	-70.22	-67.27	97.25	3.02
Drop 4	5	5	81	-0.000624	-0.000977	-69.34	-91.19	114.56	3.02
Drop 4	5	9	81	-0.000651	-0.001033	-72.43	-96.37	120.56	3.02
Flight 2 - Manual Drop									
Drop 1	2	1	98	-0.000091	-0.000944	-10.16	-88.06	88.64	3.09
Drop 1	2	2	98	-0.000036	-0.000944	-3.98	-88.06	88.15	3.09
Drop 1	2	11	98	-0.000064	-0.000944	-7.07	-88.06	88.34	0
Drop 2	3	3	89	-0.000923	-0.000052	-102.65	-4.85	102.76	2.69
Drop 2	3	7	89	-0.000979	0.000031	-108.82	2.92	108.86	7.32
Drop 2	3	12	89	-0.000923	-0.000080	-102.65	-7.44	102.91	4.78
Drop 3	4	4	86	-0.000347	-0.000636	-38.59	-59.32	70.77	1.54
Drop 3	4	8	86	-0.000375	-0.000636	-41.68	-59.32	72.50	1.54
Flight 3 - Autonomous Drop									
Drop 1	2	1	247	n/a	n/a	-94.00	-27.00	97.8	0
Drop 1	2	2	247	n/a	n/a	-94.00	-27.00	97.8	0
Drop 1	2	11	247	n/a	n/a	-94.00	-27.00	97.8	0

Note: Above ground levels for flights number 2 & 3 were estimated with a nominal ground elevation of 250 m ~ 820 ft derived from flight #1.

Figure 6. Typical drop dispersion.

Two-dimensional offsets (north and east) of the landing points from the drop point varied from 27 to 120 m. The post-drop wind factor is negligible on the UGS mass mock-ups. The offset is a result of the initial forward velocity imparted on the nodes by the velocity of the parafoil. The greater the drop altitude, the larger the expected offset because of the forward speed of the parafoil. However, the ground speed is directly increased or decreased by the headwinds or tailwinds. Looking at the data in table 2 and using the offset and height of drop, one can derive the head wind or tail wind. It appears that the winds at the drop altitudes were running between 0 and 20 mph.

The autonomous drop was most interesting since it is more representative of the operational manner in which UGS would be employed. Three UGS were dropped from one bin on the autonomous flight. The parafoil was programmed with the coordinates of the ground “target” spot and flew to a release point that would allow the measured winds to carry the presumed parachuted payload to the target spot as is the case with the SOCOM scenarios programmed. Therefore, the UGS were going to predictably land up wind from the desired landing spot. Figure 7 shows the relative two-dimensional release, target, and actual landing spots.

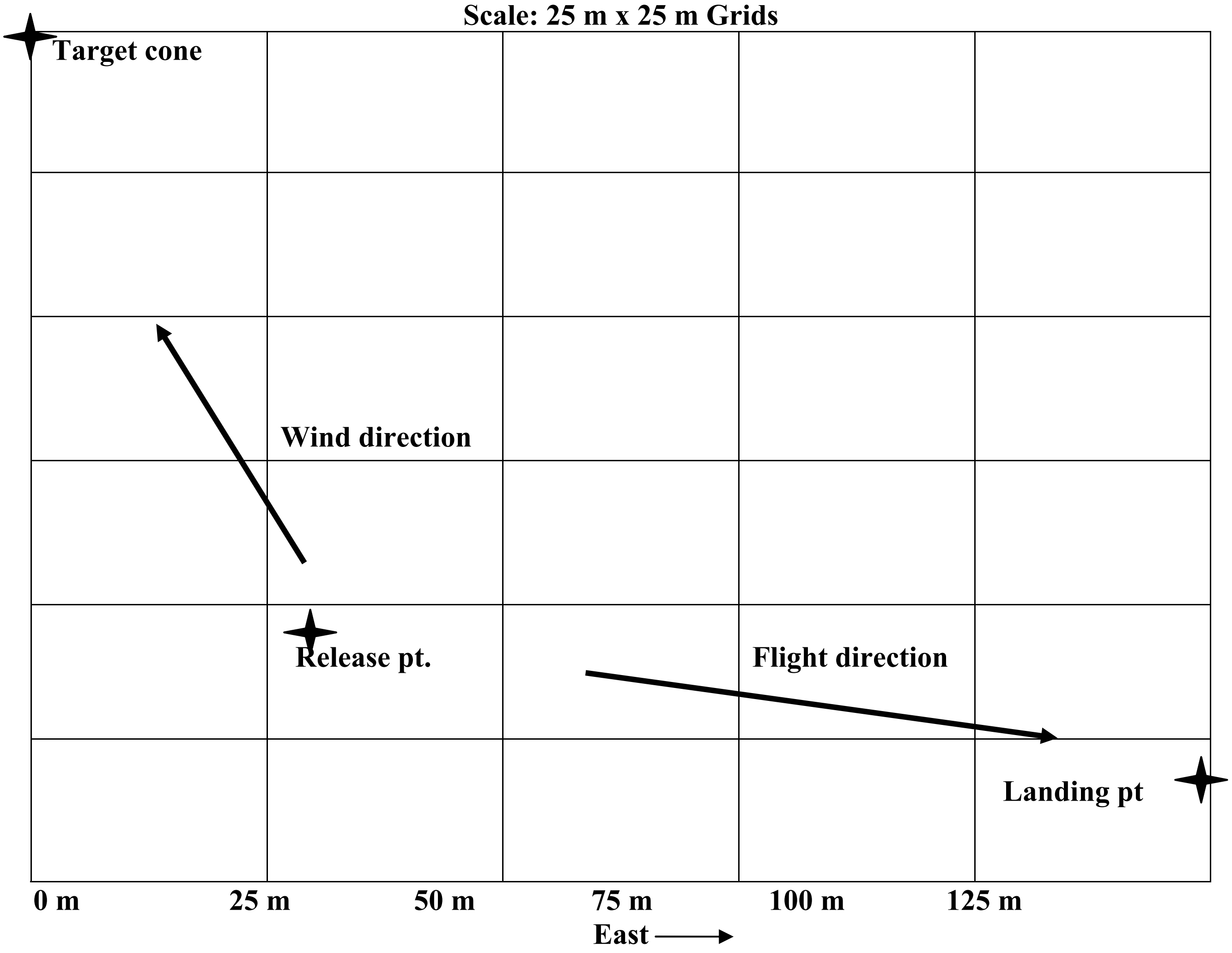

Figure 7. Autonomous flight relative coordinates.

As figure 7 indicates, the parafoil flew upwind past the target and then properly released the UGS payload upwind from the target in the expectation the wind would carry the payload back to the ground target spot. Post-flight calculations using the wind and altitude data from the parafoil indicate that the drop was in the correct spot.

5. Summary and Conclusions

The basic conclusion of these tests is that the powered parafoil appears to be a viable UAV to be used for employment of ISR UGS. They are commercially available, they can travel long ranges, and they can carry a heavy payload. Designing an appropriate UGS dispenser would be much simpler and less expensive than the dispensers needed for HIMARS or the FCS NLOS cannon. Drops can be programmed autonomously to dispense UGS one node at time to populate a field, along a road, or almost any other desired coverage. The powered parafoil can fly multiple passes back and forth, working its way across the field with timed drops along a given pass. High altitude drops that create a spray pattern could also be programmed. Dispersions of dropped UGS are reasonably small, and control of the emplacements appears good.

Future drops should be planned with modified software to implement UGS deployment scenarios.

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