Evaluation of Man-Portable Unmanned Aerial Vehicles

Stefan KERSOP

CSIR:DPSS – Technology for Special Operations

SKersop@csir.co.za, Tel (012) 841-4818, Fax (012) 841-2813

Overview

The SANDF has the requirement for a man-portable UAV system to assist them in over-the-hill reconnaissance missions. We present an evaluation process that was followed to enable acquiring the system that best satisfies their needs.

User Requirement Elicitation

The user requirements for a man-portable UAV system were captured in a detailed URS with inputs obtained from the SANDF. This document contains all the SANDF requirements for a man-portable UAS system needed for aerial over-the-hill type of reconnaissance with the capability to transmit real-time video back to a ground control station. The UAV must also be capable of other functions, such as communication relay.

Key mission capabilities included the following requirements. The system must operate during both day and night. It must be as silent as possible, in order to reduce its own detectability at all times during operation. The system must be operable by no more than two persons, with minimal required skills, and the size and mass must allow it to be two-person portable in back-packable form. The UAV must be able to fly totally autonomously during the entire mission from take-off to recovery. Price was also a key selection factor.

Other performance requirements included range, endurance, observation capabilities, operational environmental conditions and ease of operation. This study was used as benchmark for all further studies and comparisons that were conducted for finding the most suitable system that is currently available.

Evaluation Process

A formal evaluation process was used to filter and evaluate each of the systems identified during the screening market survey. The user requirements in the URS were mapped to the prime requirements for the UAV system. The main factors that were identified were price, functional capabilities, observation capabilities, airframe performance, mass and size, ease of operation, operating environmental conditions and support. Each one of these factors was weighted in the evaluation process, according to the order of importance.

The evaluation process considered both requirements as well as user desires. The requirements were mandatory for the system to be considered for procurement. The user desires included extra capabilities that enhance mission performance, but are not crucial.

Table 1: Evaluation Process Weighting

	Capability	Importance
Required Capabilities		
(Total Weight : 70%)	Price	1
	Autonomous Functions	2
	Observation Functions	3
	Airframe Performance	4
	Mass and Size	5
	Ease of Use	6
	Operating Environment	7
	Support	8
Desired Capabilities		
(Total Weight : 30%)	Autonomous Functions	1
	Observation Functions	2
	Airframe Performance	3
	Mass and Size	4
	Ease of Use	5
	Operating Environment	6
	Support	7

Note : Importance scale ranges from 1 (most important) to 8 (least important)

Market Survey

The aim of the market survey was to identify the systems that might comply with the user requirements. The list of requirements was sent to potential suppliers to determine which systems might potentially comply with the mandatory requirements. The intention was that only suppliers that responded successfully would be invited to take part in a formal evaluation trial.

Initial results from this survey indicated that the following UAS system attributes were common amongst potentially compliant systems:

- Fixed wing aerial platform
- Battery powered, electric propulsion
- Separate Day and Night cameras
- Real time video downlink
- Ground Control Station implemented on laptop with RF interface and external antennas

The results of the market survey were the scores obtained in Table 2. The scoring system was developed such that a system obtains 100% if it complies, at the minimum level, with all the requirements (70% weighting) and user desires (30% weighting). However additional score was awarded for performance above the minimum level for each of the capabilities in Table 1, by up to a factor of 3 for each of the categories, so that the maximum possible score is 300%. A consequence of additional score for excess performance is that scores of greater than 70% for the requirements were achieved by all systems tested, even though only three of these met all the mandatory requirements.

Since only three systems met all of the requirements at the minimum level, and furthermore Sonic declined the invitation to provide an evaluation system, the threshold for invitation to test was relaxed somewhat. The moderated outcome of the market survey was presented to the SANDF, with a proposal to invite the UAV suppliers' systems for evaluation, indicated by underlining in Table 3 (see Figs. 1-12 for images of all UAVs).

Table 2: Scores obtained from market survey

System	Requirements (%)	User Desires (%)	Total (%)
T-Hawk	127	26	153
Kiwit	110	22	132
E-swifteye	144 ✓	50	194 ✓
Maveric	144 ✓	45	189 ✓
Strix	72	38	110
Desert Hawk III	102	38	140
Puma	95	44	139
Raven	103	37	140
Wasp	99	38	137
Casper	84 ✓	28	112 ✓
Aladin	88	30	118

Note : The systems that comply with the mandatory requirements are marked with ✓.

Table 3: UAV systems invited to test (underlined)

Manufacturer / Supplier	UAV System	Country
Cyberflight	<u>E-swifteye</u> <u>Maveric</u> Cybereye	UK
Sonic	Casper	Israel
CSIR	<u>T-Hawk</u>	RSA
AeroVironment	<u>Raven</u> Puma Wasp III	USA
Lockheed Martin	<u>Desert Hawk III</u>	USA
ATE	<u>KIWIT</u>	RSA
EMT	Aladin	Germany
Alpi Aviation	<u>Strix</u>	Italy

Figure 1: E-swifteye

Figure 2: Maveric

Figure 3: Cybereye

Figure 4: Casper

Figure 5: T-Hawk

Figure 6: Raven

Figure 7: Puma

Figure 8: Wasp III

Figure 9: Desert Hawk III

Figure 10: Kiwit

Figure 11: Aladin

Figure 12: Strix

Of the suppliers formally invited to compete in the evaluations in South Africa, the following participated in these evaluations:

- Cyberflight (E-swifteye & Maveric)
- CSIR (T-Hawk)
- ATE (Kiwit)
- Alpi Aviation (Strix)

Evaluation plan

An evaluation plan was developed and approved by the customer, which described in detail the scenarios that were needed for a proper user evaluation of contenders. The desired evaluation outcome was to select the best solution to will suit the SANDF requirements. The evaluation plan outlined each party's roles and responsibilities to make sure that vendors, client representatives and evaluation facilitators knew exactly how the evaluations would take place and what was expected from each party.

The evaluation assessed the operating functions, features and performance of the contenders under representative operating conditions for various missions. These missions fell within four possible scenarios, categorised by the time based use of the information and whether the control centre was static or mobile. These scenarios are summarised in Table 4.

Table 4: Evaluation scenarios

	Information used later (H)	**Information used live (L)**
Control station stationary (S)	SH-ISR[1]	SL-ISR[3]
Control station mobile (M)	MH-ISR[4]	ML-ISR[2]

1. SH-ISR (Stationary control station with information used later)

In this scenario, the operator seeks information that is just out of safe reach and therefore this is often referred to as over-the-hill or behind-the-building aerial reconnaissance. The operator can come close enough to the target to be within the UAV range. The information will be gathered by day or night depending on the target. The information can be transmitted back to the operator live or stored on board. The information is then processed in detail after the flight and used as intelligence for a possible future operation.

2. ML-ISR (Mobile control station with information used in real time)

This scenario caters for missions including aerial reconnaissance for VIP escort, route safety, high risk protection, and for Command and Control (C^2). Due to the own forces moving along a high risk route, it is beneficial to have “eyes in the air” whether it is day or night. This will be able to provide early warning of changing threats and ensure that proactive responses are possible. The UAV will move ahead and around the moving convoy or patrol. The information will be returned in real time to a vehicle in the convoy and will be used to make decisions regarding to possible developing threats.

3. SL-ISR (Stationary control station with information used in real time)

This scenario covers active Command and Control (C^2) through live intelligence of an on-going operation, normally at night. The commander will be able to monitor the progress of an operation as well as any changing threats and then communicate with the team to optimise the probability of success. The information may be able to be relayed directly to the team in the target area.

4. MH-ISR (Mobile control station with information used later)

This is a relatively unlikely scenario, where the control station is mobile but the information is used historically.

The scenarios identified by SANDF required for evaluation were:

- Aerial reconnaissance (SH-ISR)
- Command and Control (C^2) (SL-ISR)
- Convoy protection or route scouting (ML-ISR)

Missions spanning these scenarios were performed in the following different environments:

- Rural – application away from infrastructure, normally in the bush:
  - Small teams application on foot
  - Large team application with vehicle support
- Urban: application with infrastructure or support vehicles.
- Maritime: application from a small seagoing vessel, i.e launches from small boat with recovery on shore or at sea (this can be demonstrated on land for this evaluation).

The application conditions considered were:

- Overt – done in the open, e.g. safety and security
- Covert – done clandestinely, without being detected

For each of the missions performed, the capabilities were evaluated as follows:

- Function (Launch, flight, recovery, etc.)
- Observing (Picture quality and stability, camera control, etc.)
- Performance (endurance, range (mission radius), etc.)
- Form (mass & size)
- User Friendliness (ease of operating the system)
- Environment (weather resilience)
- Support (repairs and spares needed)

Execution of evaluations

Each UAV system was evaluated independently of the others. All the missions were conducted over a period of four days. This included the day and night capability demonstrations. Evaluations were conducted to represent realistic, mission-like conditions of operation.

SANDF users were invited to participate in these evaluations and score each system according to an evaluation score sheet created for them. This ensured that the outcome of each system was directly influenced by the end user. Due to the time restriction of the system evaluations, it was not expected from the SANDF representatives to get proper training on each system. The supplier representatives operated their own systems while giving the operators the chance to get a feel for using the equipment. This was accomplished by letting the operators carry the equipment, helping with the unpacking, and giving their inputs during the flight planning, amongst other activities.

The CSIR T-Hawk system was evaluated first. The aim was to create a baseline with a known system to be used during the evaluations to follow. After each evaluation a score sheet was filled in by each participant followed by a proper debrief capturing all the comments and inputs from all participants. Figs. 13-17 show photos taken during the evaluations.

Figure 13: E-swifteye and Maveric preparation

Figure 14: T-Hawk in flight

Figure 15: Strix preparation

Figure 16: Kiwit preparation

Figure 17: Aerial footage from Kiwit

Field evaluation results

All the scores and debrief inputs of each system were collated and processed to generate a total score comparison, as well as a performance summary for each system.

The T-Hawk system complied with most of the mandatory requirements, except for endurance. The general feedback was that the system is not rugged enough, but suitable to be utilised in most of the scenarios, except for small team deployment as it is not back packable.

The E-swifteye system proved to be suitable for C^2 and convoy protection, but not for tactical or small team reconnaissance as it is too noisy and does not land close enough to the launch point. It complied with most of the mandatory requirements, except for endurance, noise and reliability. The system has an excellent day camera system with pan, tilt and zoom with further capabilities to lock the camera on a stationary target.

The Maveric system is in a different size class to the other systems, being small and with low mass, so being ideal for small team reconnaissance tasks. While it too does not meet the endurance and range requirements, being easy to carry and operate by small teams suggests that it would be suitable for other SANDF operations.

The Kiwit system proved to have a very reliable and stable aerial platform, however the endurance, range and observation payload capabilities did not comply with the requirements. It is easy to utilise and can be used for tactical reconnaissance for distances up to 5 km only. It is locally manufactured and therefore the turn around time on system support would be much quicker and cost effective compared to internationally manufactured systems.

The Strix system was the biggest and costliest of those evaluated. The system is launched by catapult, which adds even more weight to carry in the case of small team reconnaissance applications. The system proved to be unreliable at take-off, especially at higher altitudes like in Pretoria areas. The system is equipped with an excellent day camera payload with pan, tilt, zoom and image stabilisation and might have a place in some of the SANDF operations.

The results for some of the major requirements are compared in Table 5. The full set of results is not shown here, but a selection is provided which includes those with a variation that differentiate between the systems.

From the evaluation outcomes it was determined that the systems did not all perform according to the manufacturers' claims, which they provided as part of the market survey. It is therefore important to see such systems in action before any procurement decision can be made. It is also important to ensure that there is sufficient support for the system within South Africa for its operational life span.

Table 5: Major evaluation outcomes

Major Requirements	**T-Hawk**	**Eswift-Eye**	**Maveric**	**Kiwit**	**Strix**
Score from Market Survey [%]	127	144 ✓	144 ✓	110	72
Compliance count below [✓/13]	10	9	8	7	6
Take off, fly & land autonomously following weigh points on map	✓	✓	✓	✓	✓
Endurance (≥ 60 min) [min]	45	40	30	36	90 ✓
Distance (≥ 10 km) [km]	10 ✓	10 ✓	6	4	10 ✓
Size (wingspan ≤ 2,7m) [m]	2.4 ✓	1.25 ✓	0.75 ✓	2.4 ✓	3
Mass (≤ 5 kg) [kg]	3 ✓	2.2 ✓	1.15 ✓	3.8 ✓	8
Back packable parts (≤ 0,5 m) [m]	1.0	0.4 ✓	✓	1.2	✓
Hand | bungee launched	✓	✓	✓	✓	
Day camera (pan-tilt-zoom) with acceptable image	✓	✓	No zoom	No pan or tilt	✓
Night camera detect fires, people & vehicles	✓	✓			
Land within 75 m radius of launch [m]	✓				✓
Complete 5 flights without maintenance (Ruggedness)			✓	✓	
Low noise (Not audible during night at 300m above ground)	✓		✓	✓	
Price for 2 aircraft, day & night camera, GCS, spares, packaging, chargers, manual (≤ R2M 2011) [1'000'000 R]	0,8 ✓	1,52 ✓	1,71 ✓	0,624✓	2,8

Summary and Conclusions

A user requirement statement (URS) was generated for a man-portable UAV system with inputs as received from the SANDF end user. The operational needs were classified as either mandatory requirements or user desires. An evaluation method was developed to use the requirements and desires in a selection criterion. This was applied in a market survey to identify potentially compliant products. Eleven systems were evaluated using manufacter-provided performance specifications, and three were found fully compliant.

Since only two of the three compliant systems requested for field evaluation in South Africa were offered, the selection criteria were relaxed so that in the end five systems were used for evaluation of suitability to meet the user needs. Systems were provided by Cyberflight (UK) – two systems, Alpi Aviation (Italy), ATE (RSA) and by CSIR TSO.

The evaluation trials consisted of conducting missions spanning three operational scenarios identified by the user. The missions included day and night aerial reconnaissance, command and control and convoy protection. The detailed evaluation plan was provided to each supplier for proper preparation. It is noted that it was at this point that both invited suppliers from USA withdrew from the evaluation.

The evaluations were held near Pretoria. The user was fully involved in the trials giving feedback by means of completing evaluation score sheets after each scenario. All the user feedback was captured and analysed concluding into a final score for each system. Most of the systems complied with most of the requirements, excluding range, endurance and reliability performance which generally were not met. The observation capabilities were similar across all systems, although night-operation capabilities were not supported fully.

The outcome of the evaluations indicated that the systems looked better on paper than the actual performance, and so it was necessary to conduct such evaluations to ensure correct procurement. It also proved that CSIR TSO's man-portable UAV system performs in the same class as the international market for a third of the price and less.

The outcome comparison of the evaluations is presented in Table 6, which indicates the systems that are suitable for which scenarios within the theatre of SANDF operations.

Table 6: Major evaluation outcomes

System	Tactical Recon	Small Team Recon	C^2	Convoy protection	Price RM (2011)	Main Shortcomings
T-Hawk	✓		✓	✓	0,6	Not back-packable, endurance
Maveric		✓	✓	✓	1,71	Range and endurance
Kiwit			✓	✓	0,62	Not back-packable, range and endurance
Eswift-Eye			✓	✓	1,52	Not back-packable, range and endurance, noisy
Strix				✓	2,84	All above and more