ELECTRICALLY POWERED ICE PROTECTION SYSTEMS FOR MALE UAVS – REQUIREMENTS AND INTEGRATION CHALLENGES

Craig P. Lawson
School of Engineering, Cranfield University, MK43 0AL, UK

Keywords: *ice protection system MALE UAV*

Abstract

The research findings reported in this paper are part of an ongoing programme of research that aims to show how the capability of surveillance class Medium Altitude Long Endurance (MALE) Uninhabited Airborne Vehicles (UAVs) will be enhanced through the incorporation of the most suitable electrically powered Ice Protection System (IPS) into the UAV's design. This will be achieved through study, simulation and physical testing in the Cranfield University (CU) icing tunnel.

This paper presents research on current MALE UAV specifications and capabilities. Research in aircraft icing is identified. Its applicability to MALE UAV icing is discussed and further research specific to MALE UAV icing is proposed. In-use and proposed electrically powered IPS are identified and analysed. Their aircraft integration issues are explored and further practical work is outlined. The importance of aircraft level analysis when incorporating an IPS into a UAV is discussed. The data required to feed into such an analysis is discussed, and the research needed to generate the data is highlighted.

1 Background

Modern military operations come under scrutiny of an intensity greater than that previously seen. Public and political demands stipulate that loss of life be kept to an absolute minimum. Hence, the rapidly increasing use of UAVs in recent military campaigns. Military operations in the Balkans, Afghanistan and Iraq have seen widespread use of surveillance UAVs such as Global Hawk, Predator and Phoenix. Additionally, the potential cost savings in UAV operations compared to manned aircraft are attractive for surveillance operations.

MALE surveillance UAVs have recently suffered losses due to icing. This includes the loss of a US Predator on 18th April 1999 over Bosnia, where a problem with the fuel system combined with icing resulted in the loss of engine power, and consequently the aircraft was lost. This has resulted in the mid-life upgrades of the Predator including the incorporation of chemical IPS. This addition resulted in a more powerful turbocharged engine powering the Predator MQ-1 version B. A programme of research and development enabled the enhanced Predator to be realised with its chemical IPS protecting the wing and tailplane of the aircraft. Icing tunnel tests were carried out by NASA at their Lewis research facility. This was followed by flight testing of the UAV in real icing conditions.

There have also been reports of losses of the rail launched British UAV, Phoenix. The Watchkeeper programme is the UK MoD's solution to fulfil the British Army's requirement for an Intelligence, Target Acquisition and Reconnaissance (ISTAR) capability in the medium term. The delivered hardware will be centred around a MALE UAV which is a derivative of the Hermes 450 UAV, designated WK450. The UAV will include capability enhancements over the Hermes 450, anticipated to include automatic landing and chemically based IPS.

There are several drawbacks associated with using chemical ice protection systems. Firstly, their operation relies on a supply of de-icer fluid. This is inherently limiting as only a finite amount of fluid can be stored on board, thus compromising mission time, a particular drawback for protracted loiter surveillance missions. Secondly, the chemical IPS incorporates a porous medium on the surface to be protected, typically the leading edge of the wings. This detracts from aerodynamic performance.

There is currently renewed drive towards the use of more electric power in aerospace vehicles, where previously pneumatic (in the case of IPS) and hydraulic power is traditionally used. For example, Airbus A380, Boeing 787 and Joint Strike Fighter will all use proportionally more electrical power than previous aircraft. There have been studies conducted into IPS for more electric and all electric aircraft, including at Cranfield University [1].

Two distinct types of electrically powered IPS are of interest, namely; thermal and mechanical [2]. Electro-thermal ice protection sees widespread use in aircraft sensor protection. Additionally, electro-thermal ice protection in the form of heater mats is set to provide wing ice protection on the Boeing 787.

The potential clearly exists for a more capable MALE surveillance UAV by incorporating an electrically powered ice protection system into the aircraft. This can be investigated through research into the application with MALE surveillance UAVs of the various electrically powered IPS that exist in application on manned aircraft and those IPS that have been proposed for potential future applications.

The nature of current threats to national security and military operations places a higher than ever value on intelligence gathering. A more capable MALE surveillance UAV will improve intelligence gathering operations and this is the motivation behind this programme of research.

2 MALE Surveillance UAVs Missions and Configurations

This research is concerned with the capability enhancement of MALE surveillance UAVs by the incorporation of electrically powered IPS. To achieve an optimal solution, it is first necessary to establish a typical configuration for such a vehicle. It is also extremely useful to define the missions that such UAVs will be tasked with carrying out which, itself drives the configuration.

Clearly, military surveillance mission profiles are classified for security reasons and such information will therefore, be unobtainable. However, by looking at the specifications and capabilities of MALE UAVs, the nature of the missions that the vehicles may be tasked with carrying out can be deduced.

Given the state of the art of electrically powered IPS, the target UAV for an electrically powered IPS is likely to be a next generation aircraft. However, a useful starting point is to review current vehicles. To this end research was conducted, finding that over 170 UAVs are currently on the market. These UAVs were then classified so that a subset of the findings containing MALE UAVs could be identified and considered further.

In order to achieve this, criteria defining the MALE class of vehicle that could be used for surveillance operations was set out. The chosen criteria were maximum take-off weight (MTOW), endurance and ceiling. The parameters used for these criteria are shown in Table 1.

MTOM < 150 kg (330 lbs)	3 km < Ceiling < 8 km (10 kft < Ceiling < 26 kft)	Endurance ≥ 4 h

Table 1 – MALE UAV Criteria

Applying these criteria to the 170 UAVs found, yielded 33 current fixed wing UAVs. Clearly, this is not an exhaustive list as numerous other vehicles that fit these criteria are in development and as such specification details remain restricted. These current MALE UAVs are listed in Table 2, including some pertinent specifications for each vehicle.

All the vehicles are powered by either rotary or piston engines. A propeller provides the most efficient solution for MALE vehicle operations. However, that is not to rule out future low observable platform being powered by a jet engine, perhaps sacrificing range and endurance to gain stealth and manoeuvrability. Cruise speeds of the vehicles identified range from 46 to 147 knots. Wing spans from 2.3 to 16.6 meters. Power varies from 22 to 128 hp. The largest MTOW is 1150 kg, with maximum Payload Weight (PW) 250 kg. Clearly, such vehicles could be required to loiter in potential icing conditions for protracted periods while performing surveillance.

This market study has crystallised what is meant by a MALE surveillance UAV. It illustrates the range of capabilities of UAVs in this class of vehicle. How to answer the question: "what, if any, constitutes a useful IPS for such a vehicle?" must now be examined.

3 Aircraft Icing Considering MALE UAVs

This section is focused on setting out how to define what constitutes potential icing encounter conditions for MALE surveillance UAVs. Clearly, this is a necessary step to take in designing a suitable electrically powered IPS for such a vehicle.

A useful starting point is to look at what the airworthiness authorities say about aircraft icing. The review of current MALE UAVs showed a MTOW range of 150 kg to 1150 kg. Mapping this mass range to the EASA Certification Specifications documents, the appropriate documents would be CS-VLA (for very light aircraft) for vehicles up to 750 kg and CS-23 (for normal, utility, aerobatic and commuter aircraft) for the larger MALE UAVs. However, it is CS-25 (for aircraft above 5760 kg) that provides guidance on the severity of icing condition encounter that aircraft should be able to fly safely through. Additionally, much related research has been performed for inhabited aircraft, including aircraft-specific icing severity studies [3]. Although these guidelines can serve as a basis, new research is required as definitions of icing encounter conditions for MALE surveillance UAVs have not been published in the open literature. With the UAVs having smaller sizes and lower cruise speeds than civil transport aircraft, the conditions defined in CS-25 (Appendix C) are not specifically appropriate for MALE UAVs. For example, smaller water droplets will pose an icing threat to MALE surveillance UAVs than is the case with civil transport aircraft.

Additionally, it has been recognised for some time, particularly since the ATR 72 crash near Roselawn, Indiana, USA, on 31st October 1994, that conditions outside those defined in CS-25 Appendix C can pose a threat to aircraft. Freezing rain conditions such as those encountered by the ATR 72 have kick-started research in Super-cooled Large Droplets (SLD) [4][5]. Therefore, this phenomenon must be considered in the research to define icing encounter conditions for a MALE UAV. Research is also being conducted into predicting and forecasting potential icing encounter conditions, including SLD conditions [6][7].

Another important consideration to bear in mind is that, unlike the objectives in defining CS-25 Appendix C, the aim for MALE surveillance UAVs is not to achieve safety for aircraft occupants and those on the ground, but instead to provide a capability enhancement. A trade-off study must consider capability to loiter in icing conditions in terms of severity of conditions and longevity of loiter against the system requirements of weight and power off-takes needed to achieve this level of ice protection. The trade-off study must also be balanced against the likelihood of encountering such conditions on the surveillance missions that the UAV may be tasked with. Again, data is available for the frequency of icing encounter occurrence against altitude for inhabited aircraft [8]. One such example is the data presented in Figure 1, showing instances of icing encounter of fighter aircraft in the USA and Eastern European icing tests. This data forms an interesting basis for the MALE UAV study. However, it is not directly transferable since what constitutes an icing encounter for a MALE UAV will not correspond directly to that of the aircraft used in generating Figure 1.

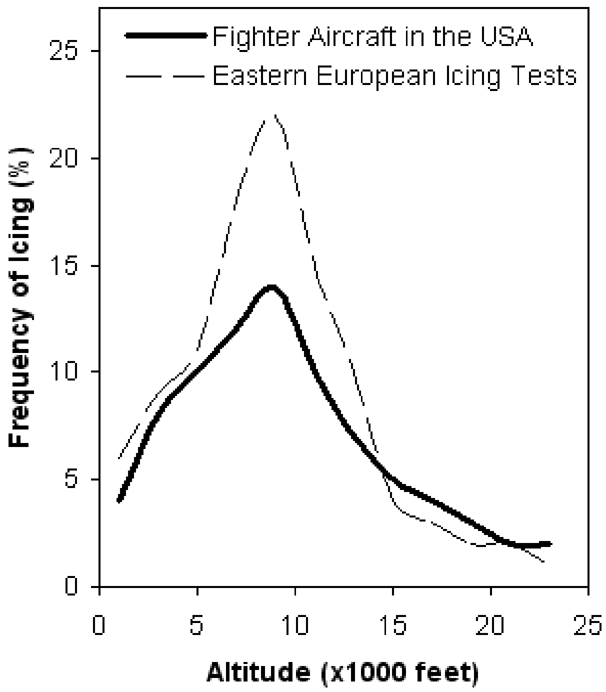

Figure 1 – Variation in Frequency of Icing Encounter with Altitude

The importance of UAV icing is underlined by the US Army's UAV icing flight simulation research programme. This is driven by the fact that their current strategy is to avoid icing encounter for UAVs by not flying when icing conditions are forecast. Despite this, 25% of UAV flights encountered icing in the Kosovo campaign between October 1998 and April 1999 [9]. Also, research is being conducted into the capability of icing detection systems for inhabited aircraft and their applicability to UAVs [10].

The CU programme of research will include simulation and physical testing in the CU icing tunnel using a representative MALE UAV aerofoil section. CU has experience and expertise in this type of simulation work when applied to inhabited aircraft [11] and a world class icing wind tunnel [12].

4 Electrically Powered IPS Technologies

This section is concerned with identifying existing and proposed technologies that could be applied to provide a MALE surveillance UAV electrically powered IPS solution. Two distinct forms of electrical IPS are physically possible. Either the electrical energy can be converted into thermal energy, or into mechanical energy to implement the ice protection. In the case of using mechanical energy, the IPS operates in a de-icing mode thus, removing the ice once it has built up. In the case of using thermal energy the IPS may be operated either as a de-icer or as an anti-icer (preventing ice from building-up).

4.1 Electro-thermal IPS

Electro-thermal IPS see widespread use in a range of manned military and civil aircraft for small surface area applications. The technology is relatively simple, with heater elements melting the ice. However, the power requirements are quite high, hence a tendency to operate cyclically in de-icing mode to reduce power consumption to 1-2 kW/m^2. Nevertheless, small anti-icing strips are usually required between the de-icing areas in order to prevent ice being held on by ice in adjacent areas. These small anti-icing areas require a power of approximately ten times that of the de-icing mats. Recent advances in this technology have seen heater elements become more fatigue resistant and lightweight [13][14]. As a result the Boeing 787 is anticipated to employ such technology to implement wing ice protection.

A recently proposed alternative thermal method that shows great potential to provide energy efficient icing protection is known as thermal shock de-icing. In this method, heater elements are used to rapidly melt the ice immediately next to the aircraft surface thus, breaking adhesion and allowing the entire ice build-up to slide off the airframe under aerodynamic and gravitational forces.

An electro-thermal anti-icing technology which, has been demonstrated in icing tunnels, but has yet to find practical application on any aircraft is microwave based IPS. The microwave system works on the principle that the water droplets are heated before they contact the aircraft's surfaces. This is achieved by producing an area forward of the leading edge which is covered by the microwave system. The droplets' temperatures are raised such that they do not freeze on contact with the aircraft surface. Then, provided they do not freeze as they cool whilst running across the surface of concern, they pose no threat to the aircraft's performance. Thus, the system provides anti-icing protection.

The system only requires enough energy to raise the water temperature, where other thermal systems must provide the much greater energy required for the latent heat of liquidation of ice. Therefore, it has great energy saving potential over current ice protection systems. Such systems are still at the research and development stage, but claims of power requirements are as low as 10 Watts per meter span. The system is also claimed to work as a de-icer as the surface property change that exists on an iced surface 'concentrates' the microwaves in that area, consequently melting the ice next to the airframe surface.

However, there remain significant challenges to be overcome with this type of ice protection system. One such issue is that of ensuring that the water droplets do not freeze when running back over the aerofoil. One solution to this issue may be a hybrid system with thermal mats or an electro-mechanical systems installed downstream to prevent the freezing on runback occurring.

4.2 Electro-mechanical IPS

Two electrically powered mechanical IPS have shown potential to be very energy efficient [15]. Electro-impulsive and electro-expulsive technologies both use electromagnetic forces to break and expel ice. The former flexes the protected structure itself, while the latter consists of a rubber 'boot' installed on the protected surface. This 'boot' has conductors embedded in two parts which can flex apart to fracture ice.

Significantly, electro-expulsive technology has recently been certified for use on the Rayethon Premier I business jet. On this aircraft a hybrid IPS is used where electro-thermal protection is used on the wing leading edge and electro-expulsive technology is used just downstream of this. This system is manufactured and marketed by Cox & Company, Inc. and is based on the electro-expulsive technology developed by NASA [16]. Also, in 2004 Thompson Ramo Woolridge Inc. was reported to have acquired some electro-expulsive ice protection technology for intended application in aircraft, including UAVs. At the time of writing, no further details were available relating to this project.

The fundamental physics suggests that the electro-mechanical and microwave technologies have the potential to be more energy efficient due to the fact that the latent heat of liquidation of ice is not required using these methods of ice protection. However, it is not only energy efficiency that must be considered but also the integration of the IPS into the UAV, the practicality of implementing this and the impact on overall aircraft performance of incorporating the IPS.

5 System Integration Challenges

When designing an optimal solution to provide ice protection for a MALE UAV, not only does IPS performance and energy efficiency need to be considered, but also the integration of the system into the aircraft as a whole must be taken into account.

One of the primary drivers behind investigating electrically powered IPS for MALE UAVs is the less than satisfactory compromises that have to be made with the current chemically based wing IPS. This includes the need for a porous medium at the protected wings' leading edge.

Of course, each form of electrically powered IPS will have its own integration challenges associated with it. However, a common requirement will be the provision of additional secondary power in electrical form. How this is sourced and distributed will depend upon the requirements of the other on-board systems and the type of main powerplant on the vehicle.

The nature of the electrical power requirements will present distinct challenges. For example, electro-thermal IPS may require a relatively large level of power with a fairly smooth power consumption profile during IPS operation. On the other hand, thermal shock, electro-impulsive and electro-expulsive technologies require relatively low power consumption but with significant peak demands.

Alongside these electrical integration challenges, there are also mechanical integration issues to be grappled with. Electro-thermal mats are fairly flexible in how they can be physically integrated. The heater elements could conceivably be embedded in the wing structure. Equally, mats could be surface mounted with the potential to be retro-fitted to any MALE UAV.

In the case of an electro-expulsive system, the elastomer should be surface-mounted. However, with the electro-impulsive system, where the wing structure itself is made to flex by electromagnetic forces, the system must be installed behind the surface to be protected. This therefore, requires a metallic structure to flex and for fatigue issues to be considered. Such a system is unlikely to be suitable for an all-composite wing.

6 Aircraft Level Analysis

Any additional system introduced to an aircraft will have a penalty on aircraft performance associated with it. The additional weight to be carried, along with any drag induced by the system, and extra secondary power to be extracted from the aircraft's main powerplant will contribute towards a detriment in the aircraft's performance. This fact must ultimately be balanced against the operational capability enhancement provided by the system in order to assess whether or not the system is worthwhile including in the aircraft configuration.

In the case of the IPS for MALE UAVs, the all-weather capability enhancement gained must be considered against the aircraft performance penalty incurred due to the system's inclusion. Methods exist at CU to quantify these penalties in the form of a fuel weight penalty for any given system. The fuel weight penalty is the extra fuel required to be carried by the vehicle to fly a mission given the presence of the system under consideration, over and above the amount of fuel that would be required to perform the same mission if the system were not present. This quantity along with a qualitative and quantitative assessment of IPS capability allows alternate IPS to be directly compared.

7 Further Work

Following on from the research reported in this paper, three main bodies of work must be pursued before an optimal electrically powered IPS for a MALE surveillance UAV can be designed. These are briefly described in the following sub-sections.

7.1 MALE UAV Icing

A further body of research is required to characterize MALE UAV icing. With the research presented in sections 2 and 3 on MALE UAV specifications and capabilities, and on aircraft icing, simulation and experimental testing will be carried out specific to MALE surveillance UAVs. CU has experience and expertise in this type of simulation work when applied to inhabited aircraft [11].

The simulation work will be validated and complemented by experimental testing. CU has a world class icing research facility, capable of producing super-cooled water droplets of 10-300 microns in diameter, encompassing those characteristic of icing cloud conditions [12]. These results will enable further research to investigate the most suitable electrically powered IPS to be integrated into the MALE UAV design.

7.2 Technology Demonstrator and IPS Performance Testing

Technology demonstrators will be built with a MALE UAV wing and installed IPS. This will enable experimental investigations to be conducted to establish the de-icing capabilities of candidate electrically powered IPS. The electrical powers required to de-ice the wing in conditions of varying severity will be investigated.

Clearly, the IPS is not expected to protect the aircraft from the most severe of icing conditions. Avoidance will remain a necessary operating strategy. The effectiveness of this strategy should improve in the future once enhanced on-board and remote sensing becomes a viable option. In which case avoidance may be active and in-flight, rather than simply not flying when icing conditions are forecast [17].

7.3 Systems Integration and Aircraft Level Analysis

The design, production and testing of the technology demonstrators will be a thorough exercise in integrating any IPS with an aircraft wing. However, prior to this detailed design of the candidate systems will be performed. This will include mechanical aspects as well as electrical systems design.

This integration task along with the outputs of the IPS performance testing will allow aircraft level performance analysis to be conducted. The results of this analysis will be fuel weight penalties and equivalent range or payload penalties incurred for gaining the all-weather performance by incorporating an IPS.

8 Conclusions

In this paper the potential for the capability enhancement of MALE surveillance UAVs through all-weather performance ability by the incorporation of an electrically powered IPS has been identified. This is driven by reported losses for surveillance UAVs due to icing encounter. The initial response to this has been the introduction of chemically based wing IPS. However, this programme of research is investigating the alternative of using electrically powered IPS.

Current MALE UAVs have been identified in the open literature and their capabilities and specifications have been reported in this paper. Therefore an initial step has been taken in defining a useful IPS for such a vehicle.

The main issues to be considered when designing an optimal IPS for a MALE surveillance UAV have been identified as follows:

1. MALE surveillance UAV icing encounter severity and frequency.
2. IPS performance in terms of protection level and energy efficiency.
3. System integration challenges, both mechanical and electrical.
4. Aircraft performance in terms of the impact of the IPS on this.

Aircraft icing severity and frequency have been reported for inhabited aircraft, and a programme of simulation and experimental testing has been outlined to generate MALE UAV specific icing data.

In-use and proposed electrically powered IPS have been identified and discussed. Issues surrounding their integration into a vehicle have also been touched upon. A programme of further work including technology demonstration is outlined to investigate this integration in more depth.

The importance of aircraft level analysis is discussed. Research in icing, integration and IPS performance is planned, the outputs of which, will provide inputs to an aircraft level analysis. By considering the outputs of this analysis in the form of fuel weight penalties, along with the capability enhancements gained from integrating the IPS, a judgement can be made on how worthwhile the IPS is, or indeed in what respect the system needs to be improved.

References

[1] B. Rouffie, “Ice Protection Systems For An All Electric Aircraft”, Cranfield University MSc Thesis. 2003.

[2] S. K. Thomas, “Aircraft Anti-icing and De-icing Techniques”, AIAA-96-0390. 1996.

[3] R. Jeck, “A Workable, Aircraft-Specific Icing Severity Scheme”, AIAA 98-0094.

[4] R.W, Gent, J.M. Ford, R.J. Moser and D. Miller, “Results form Super-cooled Large Droplet Mass Loss Tests in the ACT Luton Icing Wind Tunnel”, AIAA 2003-389.

[5] S. Cober, G. Isaac, A. Korolev, J. Strapp and D. Marcotte, “Measurements of Aircraft Icing Environments Which Include Supercooled Large Drops”, AIAA 99-0494.

[6] G. Ellrod and J. Nelson, "Detection of Potential Aircraft Icing Regions with GOES Multi-spectral Data", AIAA 97-0412.

[7] C. Wolff, B. Bernstien and F. McDonough, "Nowcasting Aircraft Icing Conditions Using GOES-Derived Satellite Products", *Proc. WWRP Symp. Nowcasting & Very Short Range Forecasting*, Toulouse, France, 5-9 September 2005. 5.33.

[8] A. Amendola, G. Mingione, D. Cailhol and T. Hauf, "EURICE: An European Effort for the Improvement of In-flight Aircraft Icing Safety", AIAA 98-0092.

[9] G. Koenig, C Ryerson and R Kmiec, "UAV Icing Flight Simulation", AIAA 2002-0812.

[10] G. Botura and A. Fahrner, "Icing Detection System – Conception, Development, Testing and Application to UAVs", AIAA 2003-6637.

[11] G. Luxford, D. Hammond and P. Ivey, "Role of Droplet Distortion and Break-up in Large Droplet Aircraft Icing". AIAA-2004-411. 2004.

[12] D. W. Hammond and G. Luxford, "The Cranfield University Icing Tunnel", AIAA 2003-0901. 2003.

[13] J. K. Smith, "Electro-Thermal Ice Protection of a Surveillance Aircraft Radome". AIAA 96-0388. 1996.

[14] P. Perkins, O. Hastings and W. Rieke, "Thin, Lightweight, Electrothermal Ice Protection - New Technology Supplementing Existing Ice Protection". AIAA 96-0391. 1996.

[15] C. P. Lawson, "Aircraft Icing and Ice Protection Systems", Cranfield University Lecture Note AVD 0306. 2004.

[16] K. Al-Khalil, T. Ferguson and D. Phillips, "A Hybrid Anti-icing Ice Protection System". AIAA 97-0302. 1997.

[17] C. Ryerson, "Aircraft Icing Remote Sensing", AIAA 98-0578.

UAV Name	Propulsion	Power (hp)	MTOW (kg)	PW (kg)	Length (m)	Wing-span (m)	Endurance (hrs.)	Ceiling (m)	Range (km)	Cruise Speed (Knots)
Aerostar	Piston	32	200	50	4.4	6.2	10	5400	200	*110
ASN-206	Piston	50	222	50	3.8	6	8	6000	150	105
B-Hunter	Piston	128	952	68	7.5	16	25	6000	300	80
Brevel	Piston	22	150	30	3.4	2.3	4	4000	400	81
Crecerelle	Piston	26	150	35	2.8	3.3	5	3500	160	86
Dragon	Rotary	38	150	30	2.4	3	8	3000	100	*97
E-Hunter	Piston	68	954	114	7.5	15.2	25	6000	300	*106
Eyrie MK 7	Piston	80	225	75	3.8	5	15	4500	50	147
Fox AT3	Piston	30	270	58	4.0	6.3	6	3500	150	*220
Gnat 750	Piston	65	511	64	5.3	10.8	24	7620	2400	46
Hellfox	Piston	40	159	59	3.0	3.4	8	5800	100	*125
Hermes 180	Rotary	38	195	32	4.4	6.0	10	4600	150	*105
Hermes 450S	Rotary	52	450	150	7.0	10.5	20	6000	400	95
Heron	Piston	100	1150	250	8.5	16.6	45	7750	600	125
Horus-SD	Piston	113	1042	204	11.5	14.9	40	7620	3700	70
Hunter	Piston	68	727	114	6.9	8.9	12	4500	600	*110
I-GNAT 912	Piston	80	703	91	6.3	12.9	52	7620	1300	*140
Isis	Rotary	38	193	34	4.5	7.3	24	4500	3200	92
KDH Taifun	Piston	46	160	23	2.1	2.3	4	4000	500	65
Mirach 26	Piston	27	200	50	3.9	4.7	6	3500	200	92
Phoenix	Piston	25	209	52	3.8	5.5	4	3000	100	*86
Pioneer RQ-2B	Rotary	38	203	45	4.3	5.1	6	4500	185	80
Predator MQ-1B	Piston	101	1065	204	8.2	14.8	40	7620	730	70
Prowler II	Piston	63	317	45	4.2	7.3	20	6100	1550	60
Ranger	Piston	43	275	45	4.6	5.7	6	5500	300	97
Searcher MKII	Rotary	73	426	100	5.9	8.6	15	6100	300	108
Seeker II	Piston	50	275	50	4.4	7.0	8	5500	400	65
Shadow 400	Rotary	38	201	45	4.3	5.2	8	4500	185	65
Shadow 600	Rotary	52	265	41	4.8	6.8	14	4800	200	75
Siva	Piston	48	290	49	3.8	6.8	7	4000	300	76
Skyeye R4E UAV	Rotary	98	568	136	4.1	7.3	12	4800	600	*102
Sperwer/Ugglan	Piston	70	300	45	3.5	4.2	6	5200	300	*127
UAV-X1	Piston	42	245	45	4.0	6.0	7	4373	1000	100
* Denotes maximum straight and level speed, not cruise speed. Data from various sources.										

Table 2 – Specifications of Current MALE UAVs