A review of propulsion issues for UAVs from a TTCP perspective

Bird, Jeffrey

Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40003716
Laboratory Technical Report (National Research Council Canada. Institute for Aerospace Research. Structures, Materials and Propulsion Laboratory); no. LTR-SMPL-2002-0287, 2003-05-20

National Research Council Canada
Conseil national de recherches Canada

Institute for Aerospace Research
Institut de recherche aérospatiale

Unclassified
Controlled

DECLASSIFIED
DÉCLASSIFIÉ

NRC·CNRC

A Review of Propulsion Issues for UAVs from a TTCP Perspective

LTR-SMPL-2002-0287

J.W. Bird

May 2003

Canada

INSTITUTE FOR AEROSPACE RESEARCH

REPORT
RAPPORT

INSTITUT DE RECHERCHE AÉROSPATIALE

Pages: 14

Tables: -

Figures: 2

STRUCTURES, MATERIALS AND PROPULSION LABORATORY

LABORATOIRE DES STRUCTURES, DES MATÉRIAUX ET DE PROPULSION

Report No.: LTR-SMPL-2002-0287

Date: 20 /05/03

Classification: Unclassified
Distribution: Controlled

DECLASSIFIED
DÉCLASSIFIÉ

For: 46_PJL_03
Pour:

Reference:
Référence:

LTR-SMPL-2002-0287

A Review of Propulsion Issues for UAVs from a TTCP Perspective

Submitted by:
Présenté par: J. Komorowski
Director/Directeur

Author(s): J. W. Bird
Auteur(s):

Approved by:
Approuvé par: D.L. Simpson
Director General/Directeur général

Abstract
Uncrewed air vehicles (UAVs) are seen by many countries as a cost effective contribution to defense capabilities, particularly for long and short-range reconnaissance, communications links and for the attack of high threat targets. While TTCP member nations are collaborating on operational and sensor issues with these vehicles, there is an opportunity to evaluate propulsion requirements for a new generation of vehicles. UAV-unique propulsion system concerns are discussed based on a review on activities and initiatives among the TTCP member nations. Recommendations are made for priorities in collaborative activities for current or evolving technology.

Also to be distributed as TTCP–AER-TP3-TR02-2002
Limited Distribution

Table of Contents

Table of Figures

Background

Uncrewed air vehicles (UAVs) are seen by many countries as a cost effective contribution to defense capabilities, particularly for long and short-range reconnaissance, communications links and for the attack of high threat targets. While TTCP member nations are collaborating on operational and sensor issues with these vehicles, there is an opportunity to evaluate propulsion requirements for a new generation of vehicles. UAVs raise certain unique propulsion system concerns, such as autonomy, fault accommodation, storage and breakout requirements. In addition, the airworthiness and power assurance requirements of low cost, short or limited life engines are unique for military applications. For example, the challenges of low cost and short operational lives may be addressed with novel applications of current or evolving technology.

Technical Panel 3, Propulsion and Power Systems has a mandate within the Technical Cooperation Program to foster improvements in the airworthiness of military airborne propulsion and power systems. With the prevalence of UAVs in current and future operations and plans, TP3 initiated and received approval for a study assignment, identified as SA3E.2.

AER has also provided feedback to TP6, the panel responsible for UAV systems [1]: "How are these aircraft (UAVs) certified and developed? How did we get Predator, which was not the "normal" development and acquisition process for an aircraft? What is a UAV (what makes it unique) and what are the requirements for structures, certification, etc."

Report Objectives

A complete assessment needs to consider many technology and systems activities being conducted in the member nations. A systems approach will be necessary covering conventional and novel power sources for these specialized vehicles, often with high electrical power needs. Therefore, this report aims to:

a) Compile information on propulsion and power systems relevant to current and future UAVs;
b) Identify any technology gaps, cost drivers, performance drivers and certification issues with UAVs; and
c) Assess the need for a TP3-sponsored workshop and recommend a list of key issues and participants for such workshop.

An important objective will be to identify opportunities for information sharing and collaborative work possible under the auspices of TTCP.

Technology Reviews

Propulsion issues must be viewed with an understanding of the UAV as a family of systems, each with one or more missions. A UAV forum [2] provides an on-line clearinghouse for UAV issues. This forum includes an overview of the level of activity: "Today there are some 50 U.S. companies, academic institutions, and government organizations developing over 150 UAV designs. Forty of these companies have some 115 of these designs flying, i.e., at least one working prototype built. Fifteen of these companies have 26 models of UAVs in, or ready for, production."

The UAV forum also includes a useful categorization of the missions or types of UAVs:

1. Tactical - the catch-all for the ubiquitous 50 to 1000 lb deployable air vehicle;
2. Endurance - capable of extended duration flight, typically 24 hrs or greater;
3. Vertical Takeoff & Landing (VTOL) - self explanatory, typically rotary wing;
4. Man Portable - light enough to be back-packed by an individual and launched by hand-throwing or sling-shot mechanism, larger than micro air vehicles;
5. Optionally Piloted Vehicle (OPV) - capable of manned or unmanned flight operations, typically an adaptation of a general aviation aircraft;
6. Micro Air Vehicle (MAV) - defined as having no dimension larger than 15 cm (6 inch);
7. Research - developed for specific investigations, typically with no production intent.

This report examines existing information from the organizations represented by members of TP3 or accessible to them. The information is examined and some propulsion-related observations drawn from the available national material. Finally, a general discussion with conclusions and recommendations is presented.

Australia

A review was prepared of the Global Hawk and BAMS programs [3]. Mission requirements could include about 4000 hours per year for 2-3 vehicles with a surge capacity for 24-hour coverage for 30 days at a range of 1400 nm. For development of existing systems, the question is what service life should be required. Some current development scenarios show the first airframe(s) produced being used as R&D vehicles. Open architectures are proposed for both air vehicles and ground components.

A general review was conducted of the state of the art in UAVs based on a DSTO Workshop, IEEE Systems and Control Conference (Adelaide 2002) and an AIR6000 UAV/UCAV literature review [4]. The UAV enabling technologies were identified as materials and fabrication, energy production and storage, perception and behaviour. Evolving technology suggests that all electric (including solar and fuel cells), adaptable shape air vehicles may be possible for small UAVs. Micro UAVs are likely to have limited application outside of buildings because of wind gusts and weather. Current micro prototypes have battery weights of 60%, motor and propeller of 24% and payload of only 5% and are capable of a 1 km radius and 16-minute endurance. A survey of propulsion systems showed a range of mass specific power (HP/lb):

1. Gas turbines 1 to 6,
2. Fuel cells 1 to 3 (planned),
3. Internal combustion engines 0.5 to 1, and
4. Batteries 0.2 to 0.7.

Suggested improvements to UAVs are offered including better engine reliability through health and usage monitoring, better survivability and mission performance through use of smart sensors. Recommendations are made for a systems approach to the technology through the focusing of existing expertise and collaboration.

A more propulsion-specific review was prepared by the same author [5]. Endurance is identified as a key requirement. Fuel cells are proposed as a promising source of high power, low fuel consumption, and low emissions, in the post 2005 time frame for small and medium UAVs. Improvements to gas turbines are also expected from the US VAATE program in the 2003-2015 time frame. The largest improvements are projected for thrust to weight ratio but SFC and cost are also targeted. For small and micro UAVs, investigations are recommended in electric motor design, performance and reliability and also low Reynolds number propellers. Comprehensive integration of special HUMS, possibly with MEMS components, should offer improvements in propulsion system reliability and autonomy. Reduction of acoustic, RF and IR signatures must also be addressed. EMF interference among tightly packed, sensitive components has been identified as an issue.

The main drivers are considered to be: endurance, reliability, cost (operating and support) and autonomy. Cited Israeli UAV experience of over 85,000 hours of battlefield operation underlines the need for higher reliability. The attributed failure causes were:

1. Flight control 28%,
2. Propulsion 24%,
3. Operator 22%,
4. Communication 11%,
5. Electrical 8%, and
6. Miscellaneous 7%.

Solutions proposed include more redundancy, improved sensors and autonomous systems for operations and recovery, and certificated engines. Another clear limitation to endurance is energy storage for both liquid fuels and batteries.

Another Australian review of UAVs was presented by Graham [6]. Among the broad scope of UAV-applicable missions, nuclear, biological and chemical surveillance and reconnaissance are identified. A review by Eustace [7] includes references to military preferences for suppression of enemy air defenses and additional airborne surveillance by UAVs. Two main UAV propulsion issues are identified: replacing the propulsion system functions conducted by the on-board pilot, and augmenting existing propulsion systems to meet existing or desired UAV missions. Observations are made that suggest near term UAVs will continue to use existing engines with no relaxation in certification standards, and that integration issues will result in performance compromises. Successful small UAVs have benefited from careful systems integration and design of a tailored, small piston engine. Fuel cell programs reviewed are showing promising results and aerospace applications may benefit from major investments by automotive, naval and commercial developers.

These studies raise some interesting issues for propulsion system planners. Identified mission requirements suggest propulsion systems will have to operate for longer missions in degraded or dangerous atmospheres. Since many systems for UAVs may be adapted from existing or evolving technologies, what reliability and service life should be specified? Low weight requirements will force higher performance, which has traditionally meant shorter life. Swappable mission sensor packaging may extend the life of the air vehicle as sensor technology rapidly advances. Are swappable propulsion systems feasible? Electric propulsion limitations are primarily battery capacity and weight. While gas turbines currently available have better power to weight ratios than internal combustion engines, the latter have lower fuel consumption at cruise. It appears that practical endurance requirements may favour systems with high cruise speeds but very efficient loiter modes.

United States

An overall roadmap for UAVs was prepared with information available up to December 2000 [8]. Expenditures of over $3B over the last decade are indicated with expectations of more than $4B in the next decade. Current spending across all services is oriented 62 percent for platform enhancements and 33 percent for sensors. Generic programs (and performers) with direct propulsion applications include:

1. Joint Expendable Turbine Engine (USAF/ADRL and USN/ONR)
2. VAATE Engine Affordability (USAF/AFRL),
3. Advanced Propulsion Materials (USAF/AFRL),
4. More Electric Aircraft (MEA) (USAF/AFRL),
5. High Power Materials and Processes (USAF/AFRL),
6. Reliable Autonomous Control (USAF/AFRL),
7. Autonomy Development Efforts (USN/ONR-35)

The roadmap identifies new capabilities projected for the next 25 years to include:

1. Silent flight as fuel cells replace internal combustion engines,
2. 60% gains in endurance with increasingly efficient turbine engines,
3. Rotorcraft capable of high speed (> 400 knots) and long endurance (>24 hours),
4. Endurance UAVs serving as pseudo-satellites and airborne communication nodes,
5. More responsive targeting of cruise missiles because of more precise terrain mapping from high altitude UAVs,
6. Self-repairing, damage compensating, more survivable UAVs,
7. Aircraft designed with maximum sensor functionality as the foremost criterion (AFRL Sensorcraft), and
8. Significantly speedier information availability to warfighters through on-board, real-time processing, higher data rates and covert transmission.

The most desired capability requirement is identified as increased coverage, which could be met by better endurance or sensing capability or larger numbers of aircraft. Intermediate requirements are for better survivability: low signature, dash capabilities. Lower priorities identified were unobstructed airflow, anti-ice, high altitude operation and power generation.

For greater acceptance and use of UAVs, technology is needed to improve reliability, survivability and autonomy. The reliability shortcomings have been linked to cost reduction decisions for UAVs that omitted system redundancy and used non-man-rated components. Survivability has been traded for lower cost because the consequences of losing a UAV were less with no aircrew. However, there is some concern that the lower survivability has made the UAV a less capable (and thus less desirable) vehicle from a field commander's point of view, even for a dangerous mission.

Technology opportunities for propulsion are clearly linked to the VAATE program, which is following from IHPTET. Improvements in thrust/weight of 150 to 200%, specific fuel consumption of 30% and cost of 50% (relative to the Honeywell F124 1988 baseline) are the goals for the end of the VAATE program in 2015. Cruise SFC trends show the best internal combustion and turbine engines both at about 0.4 lbm/lbf-hr (Figure 1). The SFC floor of 0.2 lbm/lbf-hr is projected as being possible in the 2020 timeframe.

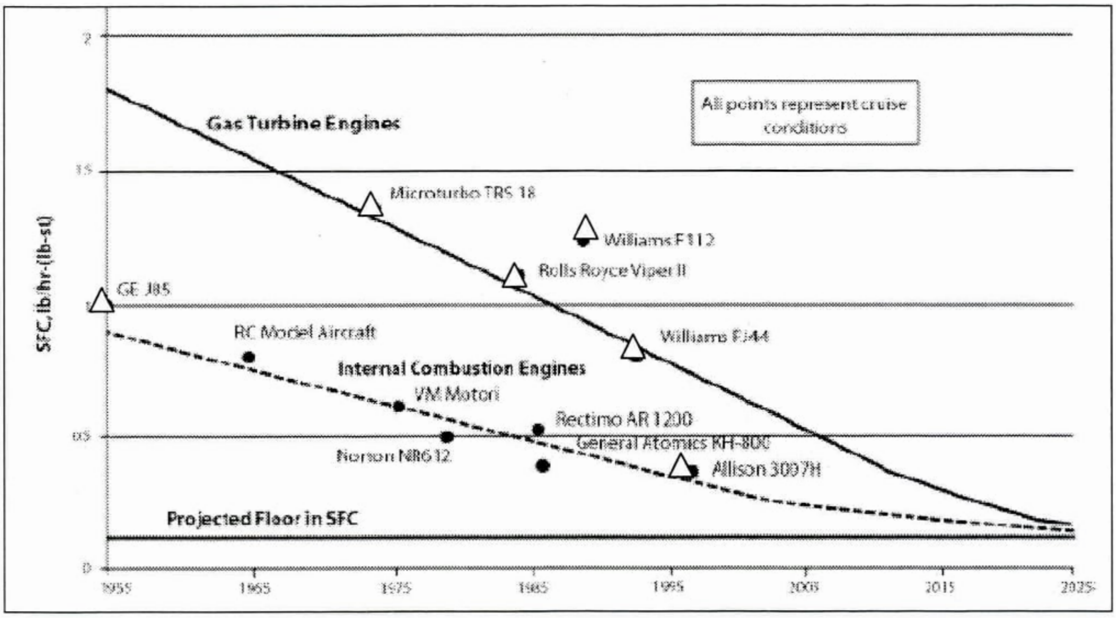

Figure 1: Specific Fuel Consumption Trends (from Reference 8 Figure 4.1.2-2)

Energy source discussions in the roadmap shows batteries and fuel cells still lagging gasoline-based engines on the basis of specific power (hp-hr/lbm), as shown in Figure 2. However, by 2015 it is expected that fuel cells will be up to half the specific power of liquid-fueled turbines. Solar energy is identified as a viable option for high altitude UAVs only.

Another summary of the key features of the roadmap has been carried out by Canadian Defence scientific staff [9]. Key system requirements are identified as accurate navigation and high data transfer rates. A subjective summary of US activity is presented largely from Reference 8. Current systems appear to have been acquired in fleets of 10-100 and include fixed and rotary wing aircraft with speeds to 400 knots. Combat UAVs are favored for missions to suppress enemy defenses, surveillance, and strike. The DARPA UCAV program has goals of acquisition costs of 1/3 of JSF and operation and support costs of ¼ of JSF. It is also observed that significant development remains before large-scale deployment.

Some propulsion system requirements were specifically extracted from Reference 8:

1. UAVs requirements cover specific classes:
    a. 24 hours endurance with 230 knots and ceiling above 40,000 feet
    b. 8-12 hour endurance and 200+ km range, or
    c. 4 hour endurance with 50 km range and operation 12 hours/day with surges to 18 hours per day for three days, or
    d. 1 hour endurance with 10km range and 500 ft ceiling;

2. Common ground stations are sought for multiple aircraft and systems since ground stations are expected to account for 1/3 of the cost of a complete UAV system; and

3. The VTOL Organic Air Vehicle program by DARPA with ducted fan configurations (duct size 6-36 inches) will develop the necessary supporting technologies for power and propulsion, aerodynamics, guidance, navigation and control.

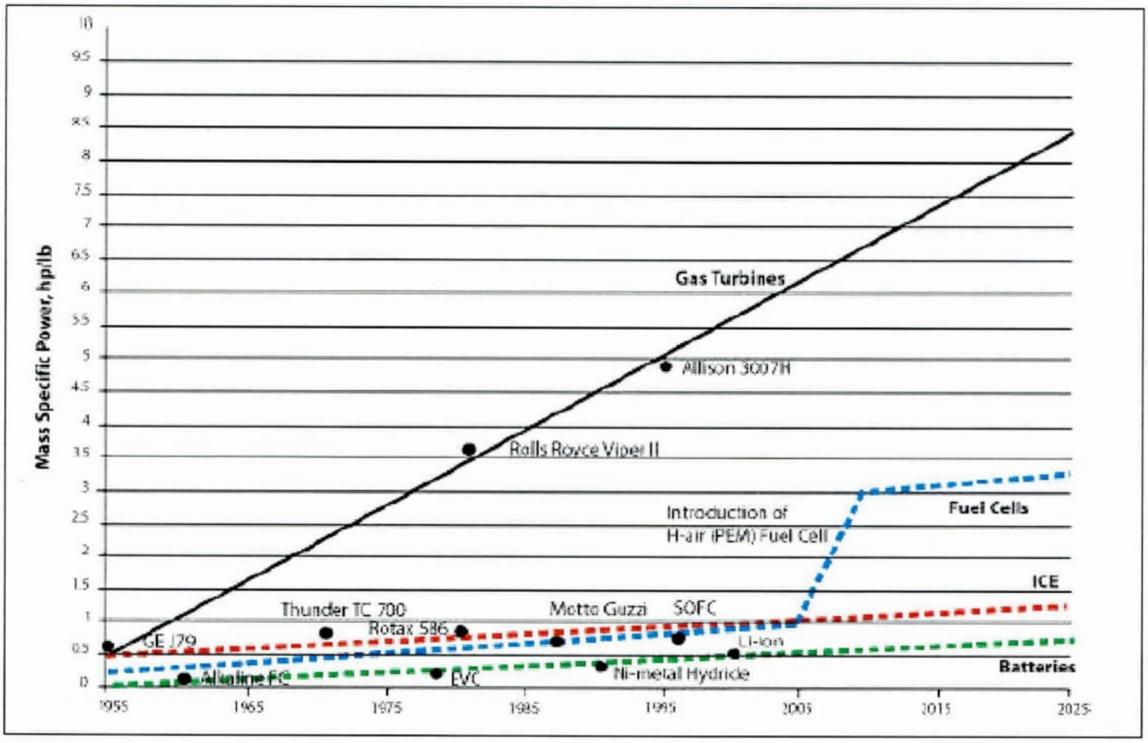

Figure 2: Mass Specific Power Trends (from Reference 8 Figure 4.1.2-3)

Specific UAV propulsion initiatives identified by the roadmap include:

1. Deletion of turbine blade containment rings,
2. Elimination of redundant controls,
3. Reducing hot section life from 2000 to 1000 hours,
4. Use of new fuels with higher energy content but resulting in higher combustion temperatures which will require material and fuel cooling advances,
5. Use of lasers to beam energy to micro-UAVs,
6. Fuel cell power (with the advent of hydrogen-air or proton exchange membrane units) for sentry or penetration UAVs where low noise and emissions are highly desirable,
7. Self-repairing structures and fault tolerant controls to respond to battle damage or failure of other less reliable systems, and
8. Ground stations requiring only airmanship and no piloting skills, deliverable through propulsion system management for autonomy.

A major outcome of this roadmap work is the formation of a Joint UAV Planning Task Force. It is responsible for, among other more general goals, developing and enforcing interface standards, promoting joint experimentation, assisting in the transition of promising UAV-related technologies and recommending priorities for development and procurement policies. A revised roadmap has been prepared based on input from US services to include platform plans, sensor requirements and development, science and technology development and other critical issues. This information among others in this quickly evolving domain will be reviewed in subsequent report.

Chrisinger reviewed the technical challenges for UAV propulsion systems for the USAF in 2002 [10]. Military considerations include: cost, corrosion, FOD and distortion resistance for multiple missions, which may include VTOL/ STOL. The Joint (USAF, USN) Expendable Turbine Engine (JETE) concept is described as a subset of the IHPTET program, with goals of – 40% SFC, +100% specific thrust and –60% cost, to benefit cruise missile programs. New military requirements are described covering persistent, all weather strike capabilities, reduced acquisition costs, dramatically lower operations and support costs, particularly for high risk, high pay-off missions. Technology needs are identified as:

1. Affordable system capable of 500-1000 hours of life (cf. expendable engines with 50 hours and man-rated engines at 2000+ hours),
2. High specific thrust (like expendable engines but man-rated engines stress high thrust to weight ratio)
3. 5+ year storage with the capability of restorage after use (restorage/reusability is a new feature),
4. Low cost per unit - like an expendable but with longer life, and
5. Periodic inspections but no overhauls.

Secondary needs for specific missions include low emissions, particularly noise.

For JETE, new technology could provide 120% longer loiter times and 35% better mission radius; engine production costs currently about $200/lbf could be reduced to $115/lbf. Trade-offs for development costs (driven by sea level and altitude test hours, accelerated mission test hours) are shown for new, derivative and off the shelf engines for 2000, 1000, or 500-hour life. Program components with associated challenges are described as:

1. Splittered rotor (challenge- stall margin),
2. Fuel-lubricated bearings (challenges- temperature limitations, life and reusability), and
3. Monolithic ceramic components (challenges- micro-fractures during manufacturing, compound curvatures).

Based on these reports, some observations are relevant to propulsion assessments by TP3. It is clear that AER activities should be well connected with the DOD UAV Planning Task Force. Propulsion systems will significantly affect key performance requirements like endurance, noise and emissions. Niche technologies for monitoring, low emissions and life prediction may offer significant benefits to unique UAV requirements. The trends in SFC show a continuing need for more efficient propulsion systems. Novel control and monitoring technologies may contribute to meeting these increasingly difficult goals. The trade-offs between reliability, cost and performance are still to be quantified for UAVs.

New Zealand

The electronics warfare group at DTA is successfully flying a semi-disposable mini UAV with an electric propulsion system. The system is based on off the shelf model aircraft components and the group's main interest is in developing autonomous flight control, and navigation capabilities [11].

There has been quite a bit of discussion in the NZ Defence Force about how UAVs might be used. There is support at the senior level but there have not yet been any formal studies of mission requirements or similar issues [11].

Canada

The Canadian air vehicles R&D program is directed from the DRDC Air vehicles Research Section, which covers structures, materials, propulsion and flight mechanics. There are currently no specific UAV activities however, important contributions could be provided by technology activities in fuel cells, batteries, composites, vibration control, high temperature materials and coatings.

UAV system requirements are under investigation by the Canadian Forces Experimentation Centre [12]. Significant focuses are integration in joint services operations and acquisition costs, through simulation, exercises and trials. Integration of endurance, tactical, VTOL and man-portable UAVs are being considered. In addition, a mini-UAV project aimed at urban operations is being planned with DARPA.

A general survey of UAV technology was also carried out by Plumb and Khalid [13]. Opportunities are identified for micro-UAVs for both military and civil applications. Low Reynolds number (Re) experimental facilities are described for small vehicles with Re of about 500.

Some propulsion issues may be identified from these Canadian observations and those of the defence scientific staff [9] discussed in the previous section. On-board power supply capabilities will be key system drivers, in terms of capacity, quality and reliability. Development and support costs for the prime mover and electrical power sources are clearly going to be scrutinized closely. Shaft and turbofan propulsion systems are likely to be required to cover the range of required applications. The high data transfer rates for mission sensors may favour vehicle systems with autonomous features. The significant development requirements identified should offer opportunities for joint activities under TTCP auspices.

UK

The UK MoD has prepared design and airworthiness standards for UAV systems [14]. Power plant scope covers propellers, rotors, engines and associated management systems, fuel management systems, transmission systems, engine casings, and exhaust modules. Power plant specifications are to be based on the appropriate standard for manned aircraft powerplants. However, allowance is to be made for UAV specific requirements like G-loads higher than those used with manned aircraft. Guidance is given to minimize interventions by the 'pilot', for example by providing 'care-free handling' like automatic surge recovery. Induction systems are to include prevention of accretion or ingestion of ice. Consideration is to be given to selective load shedding for operational contingencies.

Health monitoring requirements are included for system safety, mission success, crew confidence and effective maintenance. Detection schemes and associated probabilities are required for all safety-related faults. Guidance is given for the consideration of monitoring using independent sensors, algorithms and processors.

Other

Recent open source information is available which provides some other future system requirements [15]. Network centric plans are to fully integrate evolving UAVs with complete command and control systems across all armed forces. There is an opportunity to use this system specification to identify requirements for the next generation of UAVs. Sweden plans to have a highly capable system for demonstration in 2005 and for delivery in 2010. Saab believes that UAV accident rates need to be improved from today's rate of around 1 per 1000 hours to 1 per 100,000 hours, similar to manned military aircraft. Higher accident probabilities than civil levels of 10^{-6} to 10^{-7} have been justified because military pilots had ejection seats. Common flight critical elements are proposed for all UAVs and certification issues will be important. UCAV requirements are expected to require high levels of autonomy with on-board monitoring and the ability to reconfigure to manage battle damage or system failures. EADS comments stress the need for UCAV costs of 25-30% of fourth generation combat aircraft with operation and support costs less than one quarter of modern fighters. Service life estimates of 20 years and 1000 flying hours may result in storage requirements of up to 5 years, along with associated exercising and monitoring of critical systems. For some air-launched reconnaissance UAVs, current plans to use standoff missile technology are said to be limited by the engines. High combat maneuvering requirements of 6 to 30 g's are suggested for UCAVs.

A European initiative, UAVs: Civilian Applications and Required Regulations Network (UCARE) [16] provides reference documents and a forum for international UAV activity including airworthiness issues. This focus is relevant to dual use UAVs operating in civil airspace but also to second-generation vehicles developed, more generically, for both military and civil operations.

NATO has also offered guidance for UAV operations, design specification, maintenance and training [17]. The safety standard proposed is that UAV operations should be as safe as manned aircraft of equivalent class or category. Concepts are proposed such as fail-safe, independent systems, with adequate redundancy and back up features, managed at the overall systems level. Some significant propulsion systems capabilities are defined:

1. System design is to include failure detection apparatus for pre-flight and in-flight use.
2. All UAV system software is to be verified and validated.
3. The UAV is to remain controllable in the event of a propulsion system failure.
4. All essential elements of the propulsion system shall meet reliability standards as approved by national authorities.
5. Built in test functions are to be able to exercise critical components and systems, provide an indication of their state of health and include a set of diagnostic procedures to aid fault location.
6. Remaining emergency power reserves are to be constantly monitored.
7. In flight diagnostics will be linked to mission abort thresholds and managed actions for in-flight shutdown and return to base.

8. System usage data are to be recorded (hours flown, cycles undertaken and maintenance/inspections carried out) on each critical component.

Discussion of Propulsion Issues

There appears to be political and military will to complement crewed vehicles with UAVs across a wide spectrum of missions, typically the mundane and the dangerous. Current and near term operator interest seems to concentrate on the development of sensor platforms and the integration of conventional platforms into real operations. However, the most significant R&D investments are aimed at platform enhancements, e.g. autonomy, materials and engine demonstrators.

Technologists see UAVs as vehicles for developing and demonstrating novel and revolutionary advances in aerodynamics, electronics and propulsion. Presently there may be few UAV-specific technologies, so mid-term systems will benefit mostly from the integration and application of existing technologies to unique UAV requirements. With UAV users currently focused on developing the sensor platform and integrating relatively low risk systems into real operations, it is the mid to long term requirements for important missions which must first be understood before propulsion opportunities may be sought and actioned. Growing sensor demands are being coupled with weapons loads, which will add to performance and power generation requirements. Longer endurance demands are expected.

The initial attraction of UAVs as small and cheap and therefore expendable has been affected by the addition of expensive, heavy sensor packages to meet real mission requirements. For propulsion and power systems, we should anticipate the need for lower cost and predictable reliability. This trade-off might be optimized with significant savings through the application of reliability-centred design approaches as well as novel approaches to system certification and airworthiness. However, new technologies are going to need to show clear cost/safety benefits to justify inclusion on UAVs. However, smaller vehicles should offer opportunities for economical technology demonstrators. Fault accommodation will be required for degradation and battle damage (impact and ballistic) especially for single engine installations. Stealth with low observables, high altitude (15000 feet) or high maneuverability will be required for survivability. Altitudes near 15000 feet may be favoured for sensor packages. Environmental adaptability (temperature, icing, inlet distortion) will be important for all weather operations as sensor packages become fully capable of meeting 24/7 military needs. Storage requirements for current cruise missile turbine engines often require tests including runs every 180 days so future systems should include design or monitoring features so this period can be automated and extended.

Certification changes which increase the 'acceptable' accident rate or TBF for UAV systems from levels for manned aircraft may be possible by eliminating or adapting blade retention or disc failure requirements. However the cost of sensor packages and the relatively small fleet sizes will likely still require high availability and low loss rates. Trade-offs will need to be quantified for structures, systems and software for different vehicle sizes and mission mixes of the classes of UAVs.

More revolutionary technologies should be examined for next generation UAV systems. Fuel cells would offer low emissions and integrated power for sensors. Full and part power operation, power and torque characteristics and fuel volume and energy efficiency should be assessed for UAV-specific needs. Opportunities for integrated propulsion and power can be pursued with all electric systems incorporating start systems. Novel tribology solutions for fuel lubricated or oil free bearing systems should offer significant advantages for UAV system weight and long term storage.

Recommendations

1. Important issues to be addressed in UAV propulsion investigations should include:

a) Autonomy for system management during degradation, damage accommodation, environmental change,
b) Cost minimization to 1/3 of manned systems costs, for lives of 200 to 1000 hours with known reliability including maintenance methods with periodic inspections which minimize life usage,
c) Long endurance in all weather operations, with substantial electrical loads to be supplied to sensors and communication systems,
d) Certification procedures for systems and software appropriate to UAVs with significant modifications of manned standards and appropriate for dual use.

2. Relevant technologies that may offer niche but significant contributions include:

a) Non-aerospace technology for controls, sensing: capability/reliability/cost trade-offs,
b) Fault tolerance and analytical redundancy including stall and vibration detection and control,
c) Low observables technologies especially noise and IR,
d) Oil-free systems with fuel or air lubrication,
e) All- and more- electric vehicles,
f) Multi-disciplinary design optimization to provide appropriate balances between cost, multi-mission capability, and reliability,
g) Fuel cells as prime movers or large auxiliary power units, and
h) Energy management technologies: high-density fuels, control systems.

3. Propulsion issues will develop from, and contribute to operational plans. Participation in planned UAV meetings and activities of the Joint UAV Planning Task Force is considered essential. Propulsion specialists should take the opportunity to present papers and participate in plenary meetings in:

a) AER TP6 and pan-TTCP workshops
b) Flight International Conferences,
c) AIAA NDIA UAV and Aircraft Survivability (Sharing the Battlespace)
d) AIAA Unmanned Systems, Technologies, and Operations—Aerospace, Land, and Sea Conference and Workshop & Exhibit.

4. Plans should be updated with the new DoD roadmap and the Canadian roadmap.

References

1. TTCP AER, Minutes of the Annual AER Meeting, Version 6, July 2002, Ottawa.
2. Adroit Systems Inc., UAVforum at www.uavforum.com, 22/9/02.
3. Deeble, C. and Newell, B. Global Hawk Update, presentation to DSTO Workshop March 12, 2002.
4. Geddes, R.C. Current UAV Sate of the Art, presentation at DSTO Workshop, March 2002.
5. Geddes, R.C. Future Directions, Propulsion Systems for UAVs, personal communication to P. Frith, 8/05/02.

6. Graham, D. UAVs, Presentation at DSTOV, AMRL Workshop April 2002.
7. Eustace, R. A Brief Introduction to UAV Propulsion, Presentation, May 2002.
8. http://www.acq.osd.mil/usd/uav_roadmap.pdf., April 2001
9. Canadian Defence Liaison Staff (Washington), UAV Newsletter, March 2002.
10. Chrisinger, L. Technical Challenges for Unmanned Aerial Vehicle (UAV) Propulsion Systems, Presentation, Wright- Patterson AFB, date unknown.
11. Conor, P. Personal correspondence, 9/23/02.
12. CFEC. Canadian Forces UAV Activity Summary, 14 March 2003, 3700-5(CFEC).
13. Plumb, N. and M. Khalid. A Qualitative Assessment of the Current State of the Art in UAV Technology, NRC, Institute for Aerospace Research, Aerodynamics Laboratory Technical Report, LTR-AL-2001-0066, July 2001.
14. MoD. Defence Standard 00-970 Part 9, Design and Airworthiness Requirements for UAV Systems, DPA Air/Land Technology Group, Airworthiness Design Requirements and Procedures Branch, February, 2002.
15. Penney, S. Net Wars, Flight International, 16-22 July 2002. pp 58-62.
16. UCARE, UAVs: Civilian Applications and Required Regulations Network (UCARE), www.ucare-network.org
17. NATO. Guidance for UAV Operations, Design Specification, Maintenance and Training of Human Resources. Annex to AC/92-D967. (From Reference 12)