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The Design and Flight Trials of a Multi-Purpose Autonomous Flight Vehicle System

L.A. Thompson
RMIT Aerospace Wackett Centre
P.O. Box 2476V
Melbourne, Vic. 3001
AUSTRALIA

C. Bil
Delft University of Technology
P.O. Box 5058
2600GB Delft
The NETHERLANDS

Abstract

The advent of reliable and low cost GPS equipment allows the development of autonomous flight vehicles for survey and surveillance missions at less cost than manned flights. This paper introduces the Multi-purpose Autonomous Flight Vehicle (MAFV) "Jabiru", a proposal to develop a technology demonstrator in the framework of student research projects. The MAFV-concept provides a flexible aerial platform for an operator-supplied sensor pack that can execute a pre-programmed flight profile. The design is based on a vehicle of modular architecture that can be used efficiently and effectively for a wide range of missions and sensor systems (multi-purpose). It can easily be disassembled for stowage and transportation. Runway takeoff, catapult or air launch can be selected as appropriate. The landing procedure is based on capture by an arresting net recovery system and runway landing. The paper introduces the MAFV-system concept and presents a baseline design configuration. Some aspects of development and operational cost will be discussed with some comments on future plans for radio-controlled flight trials with a half-scale model.

1. Introduction

The use of unmanned aircraft for civilian purposes has been limited to that of remotely controlled flight vehicle operations within line-of-site. The introduction of a global satellite navigation system provides accurate positioning and navigation anywhere on the globe. The Global Positioning System (GPS) has created new opportunities for the development and application of autonomous flight vehicles. It is now technically and economically feasible to replace manned aircraft and systems currently used in the roles of coastal surveillance, oil discharge policing, aerial geological surveying, weather soundings and severe weather reconnaissance with autonomous flight vehicles equipped with the appropriate sensors. The cost of severe weather reconnaissance with an Orion or Hercules aircraft is over $ 10,000 per flight hour. The cost of geological aerial surveying with manned aircraft is $ 2,500 per flight hour. The extremely high cost of undertaking these roles with manned aircraft suggests potentially lower cost methods should be investigated. A study of sensor systems required for each of these roles and mission profiles suggests that a single Multi-purpose Autonomous Flight Vehicle (MAFV) system is both technically and economically feasible. In order to accommodate the diversity of payload requirements and varying mission duration the proposed flight vehicle is to be of modular architecture, with a common cylindrical fuselage core module and standardised structural/electronic interfaces. Fuel, powerplant, payload and navigation/guidance modules will be interchangeable to enable the MAFV to be optimised for the desired mission.

The MAFV system concept requires that all configurations would use a common launch and recovery system and data receiving station. Specialist companies and government agencies can lease a MAFV configured for their specific needs from a regional operator. The estimated cost for severe weather reconnaissance using the MAFV system is approximately $ 150 per hour, similarly a geological survey would cost approximately $ 100 per hour. Some specialist users may prefer to supply their own payload based on a standard structural/electronics interface this would further reduce the costs of the basic MAFV system. Modular launch vehicles with customer developed payloads have already proved extremely cost effective in the space industry.

2. The Autonomous Flight Vehicle *Jabiru*

The *Jabiru*-project entails the design and manufacturing of a MAFV technology demonstrator in the framework of student projects[(1),(2)]. It includes several interesting aspects:

- The development of a MAFV involves different technical disciplines with many interesting and challenging subjects for student research projects. The design synthesis and the necessary team work can be inspiring and motivating.
- The size and complexity of the vehicle makes it feasible to manufacture the aircraft "in-house". Students can participate in and contribute to the development of actual flying hardware, a rare opportunity in an aeronautical teaching environment.

- From discussions with potential MAFV operators it can be concluded that the MAFV-concept will fulfil a practical requirement.

The technology demonstrator itself can be used for further research, eg. LRN aerodynamics, development and testing of avionics/sensors and solar power propulsion. The MAFV is not dependent on "in-house" sensor systems. Other universities and private companies can develop sensor and communications packages in their respective specialist areas for lease, sale and use by MAFV operators. Potential MAFV operators provide useful information on typical sensor units and mission profiles, which can be categorised according to operational altitude and range/endurance requirements:

- Low altitude (< 10000 ft): Close-to-ground operations are typically used for survey and surveillance missions, such as search for mineral deposits[3], agricultural survey, cartography, coastal and maritime surveillance (drug interdiction) and environmental control (oil spills, bushfires, deforestation, volcanic activities, etc.).

- Medium altitude (15000 ft): Meteorological survey and severe weather reconnaissance[4],[5].

- High altitude (> 50000 ft): High altitude missions will generally be used for environmental atmospheric studies[6].

The basic principle of the MAFV *Jabiru* system is depicted in Figure 1:

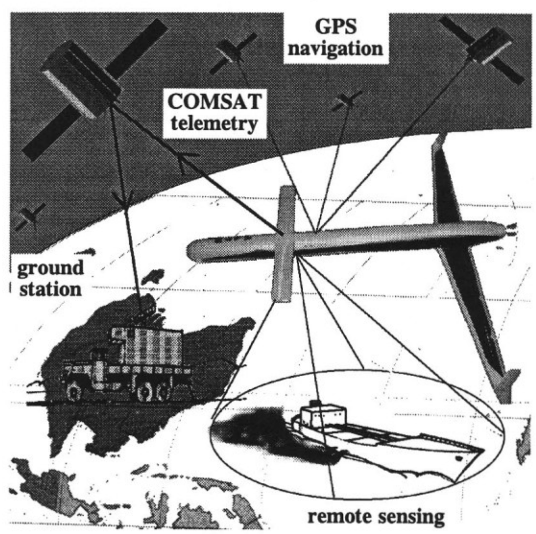


Figure 1: MAFV Jabiru principal system components.

Using differential GPS for navigation and autopilot, the vehicle can determine its actual position with about 8 meter accuracy in real time. From comparison with preprogrammed way-points coordinates, the flight management system manoeuvres the vehicle along its correct trajectory. Once on station, the sensors take their readings and data is stored for delayed transmission to a ground station via a satellite data link. After the mission is completed, the vehicle automatically returns to a predetermined waypoint where control is taken over either manually (radio control) or by an autoland system to guide the vehicle into an arresting net. An illustration of the flexibility of the MAFV concept is the possibility to use dropsondes for bad weather reconnaissance. A dropsonde is a small, self-contained sensor unit which takes readings on its way down and transmits the data back to the MAFV which circles in a holding pattern at an altitude well above the bad weather zone.

The average payload weight was determined from a study of existing commercially available sensor units and systems and operator/customer requirements for manned systems currently employed in the specified role. Table 1 gives some data on typical sensor systems for the MAFV:

Table 1: MAFV payload sizing.

mission	sensor unit/system	weight (lbs)	power (Watt)	size
cartography	**digital camera system**	**< 15**	**24**	**ø6" x 20"**
environmental control	**digital camera system and fixed attitude FLIR**	**42**	**322**	**ø10" x 20"**
maritime surveillance	**fully gimballed FLIR and CCD system (eg. Rockwell SPIRI²T)**	**< 50**	**170**	**ø12.5"**
severe weather reconnaissance	**dropsondes (45 x 1 lb)**	**45**	**NA**	**ø12.5" x 20" long**
geological survey	**Caesium Vapour Magnetometer (2 units required**	**2 x 5.5 lbs**	**11**	**ø4" x 10" each**
meteorological survey	**pressure, OAT, humidity sensor and/or dropsondes**	**3 - 45**	**NA**	**depends on number of dropsondes carried**
high altitude environmental studies	**pressure, OAT,UV, radiation, CO_2,etc.**	**30 - 45**	**120**	**NA**

The MAFV having no crew limitations, is in principle restricted only by onboard fuel reserves. Significant operating cost and flight vehicle utilisation advantages can be gained by maximising endurance. The following performance requirements were defined for the MAFV with an average payload weight of 45 lbs:

Table 2: MAFV mission requirements.

altitude (ft)	speed (kts)	payload (lbs)	endurance (hrs)
7500	80	45	120
15000	100	45	72
60000	220	45	3

Note that endurance is based on all fuel used for cruise. By exchange of fuel and payload alternative missions can be defined. The MAFV with its estimated weight of about 250 lbs is larger and certainly a more flexible concept than eg. Aerosonde with an AUW of 25 lbs. Other autonomous flight vehicles currently under development, such as Perseus and Condor, are probably too large for the majority of applications. The MAFV fills a niche where it can potentially be very successful.

3. General Configuration Description

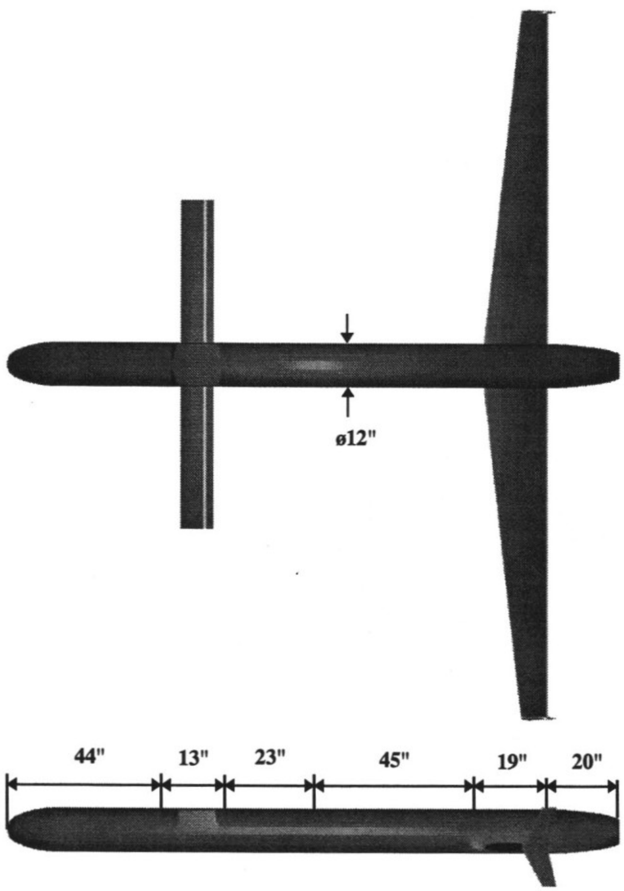
Figure 2 is a 3-view drawing of the proposed configuration with major dimensions indicated:

The arrangement is aerodynamically clean for efficient long duration flights. It contains a minimum number of components which further reduces complexity, weight and drag.

3.1 Airframe.

The vertical fins mounted on the wing tips provide directional stability and reduce wing-induced drag. Ailerons are fitted on the inboard wing with differential movement. By deflecting them both upward, the ailerons can serve as speed brakes/spoilers. By deflecting them down they operate as a plain flap system. An all-moving canard provides primary pitch control. The fuselage has a cylindrical shape and is constructed from interconnecting modules: payload module, canard intersection, electronics compartment, fuel tank, the wing intersection and the engine compartment. This modular arrangement has several advantages:

- Modules can be easily replaced or interchanged, in case of malfunction or to adapt the vehicle to a special mission, eg. an extra large fuel tank for longer range/endurance.
- Modules are easily accessible from each end so additional access hatches are not required.
- The fuselage and other components can be disassembled for transportation or stowage.



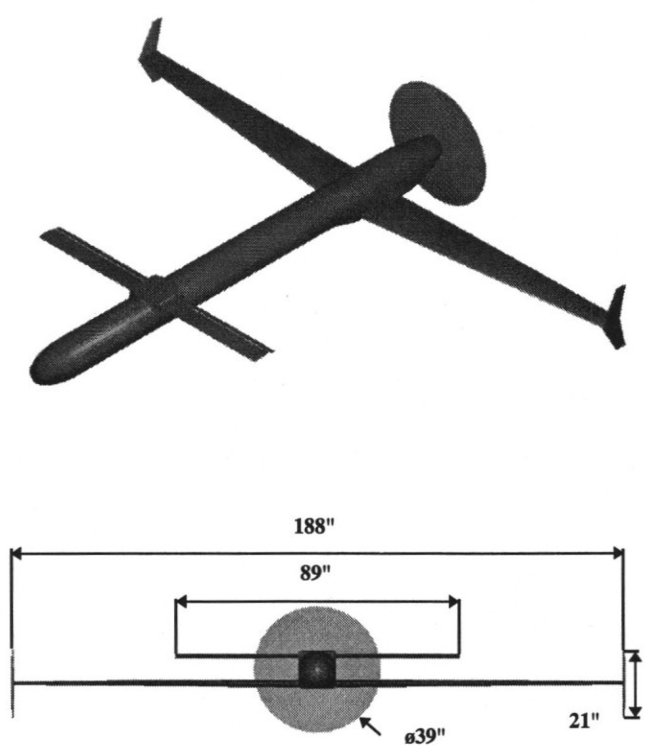


Figure 2: MAFV Jabiru general configuration layout.

Figure 3 illustrates the modular architecture of the aircraft:

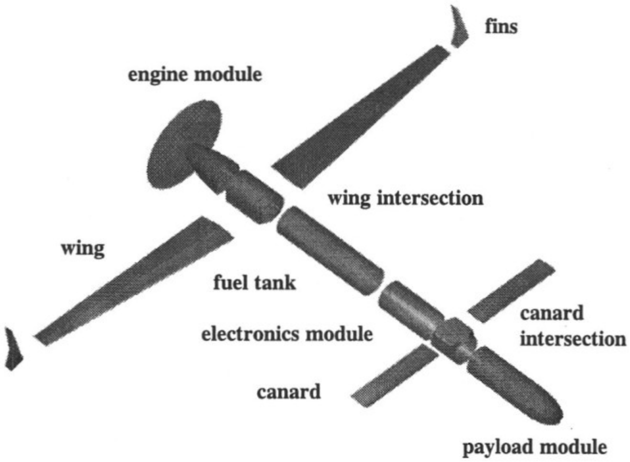


Figure 3: The MAFV Jabiru general architecture.

The payload is contained in a nose cone where the sensors have forward-looking 360 degrees of vision with minimal interference from airflow and engine vibration. The payload module with instruments and sensors can easily be fitted to the flight vehicle by a standard connecting interface, which provides mechanical and electrical link. Payload modules can be `off-the-shelf' or an operator can supply a specific-purpose payload module. Because it is not a primary load-carrying structure, the payload module can be of any reasonable shape and size at relatively low weight.

3.2 Propulsion.

For low to medium altitudes, the propulsion unit will be a (turbocharged) piston engine with pusher-propeller. To achieve the projected endurance for the MAFV a reliable powerplant is required with a very low fuel consumption. The selected engine is a four stroke Honda GX110[7] designed for powering small portable generators (Figure 4):

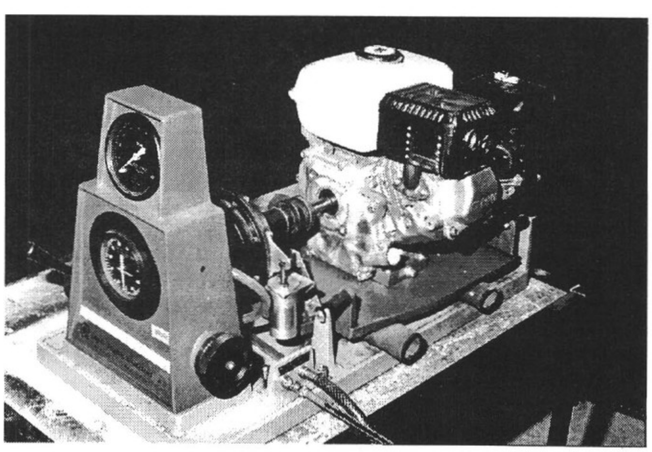


Figure 4: The Honda GX110 engine on the teststand.

This unit is a proven "off-the-shelf" engine with a specific fuel consumption of 0.48 lb/hp/hr, rated at 3.5 hp continuously at 3500 rpm. The bare engine weight without accessories is approximately 17 lbs (26 lbs in industrial form). The large numbers of this engine produced have resulted in a low cost engine core (about $ 200) with scope for further development. Figure 5 gives the (unsupercharged) engine performance at sea level:

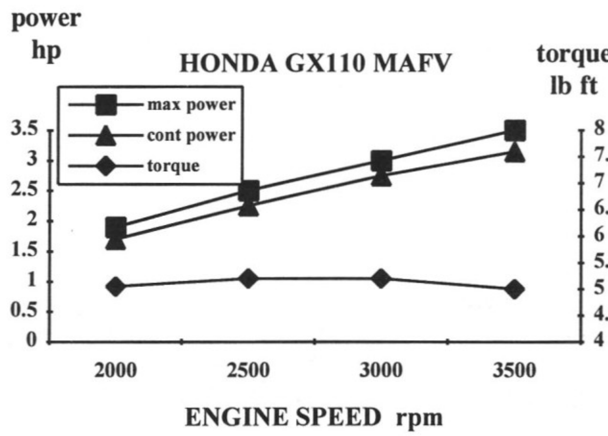


Figure 5: Honda GX110 engine performance[7].

The reduction in both the engine power and the heat transfer coefficient with altitude constitutes a matter of definite concern in this application. With a non-supercharged engine the reduction in power may be considered effectively as increasingly operating the engine at reduced load. At sea level conditions this will generally lead to a rapid drop in the mechanical efficiency of the engine as the load decreases. This is due to the fact that, although there is a reduction in the mechanical loading of the engine components, which implies a reduction in the friction in the engine bearings, the reduction in thermal regime accompanying the decreasing load means lower temperature of the lubricant in the moving components of the engine. This increases the viscous forces and leads to higher friction losses. Hence due to these opposing effects the friction losses remain practically unchanged while the power delivered by engine drops, so effectively friction consumes an increasingly significant part of the engine's useable power. However, due to the low ambient temperature at altitude the thermal regime of an air-cooled engine increases resulting in less viscous lubricant and a decrease in friction losses. This means that increasing altitude will result in a reduction of friction through the twin effects of decreasing mechanical loading of the engine components and the increasing thermal regime. This will have the tendency to slow down decline of mechanical efficiency with altitude.

For this application the engine will be fitted with a turbocharger with variable wastegate that can be activated if excess power is required. The manifold pressure of the wastegate will be used to control the amount of exhaust gas which will be allowed to flow through the compressor-drive turbine. For low altitude missions the turbocharger is used for takeoff and climb and will be bypassed during cruise. For medium altitude missions the turbocharger will be operating continuously. This powerplant configuration provides a single engine unit with low weight and variable power output. The effect of turbocharging on engine performance with varying altitude is shown in Figure 6:

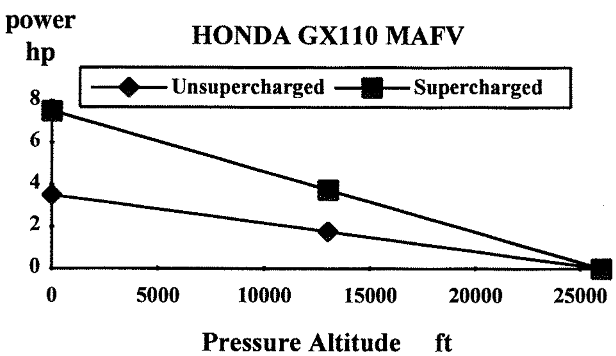


Figure 6: Effect of supercharging on engine power output for different altitudes.

Dynamometer tests at RMIT have confirmed the engine's stated performance. This has enabled the design team to concentrate on weight reduction, installation of engine and turbocharger, and other refinements. A full test program is underway with sustained operation trials at both sea level and at 5000 ft above sea level. Tests with a turbocharged variant are planned for October 1994.

With adjustment of spark timing and at a given fuel/air ratio the specific fuel consumption remains constant with increase in altitude up to 15,000 ft. However it is important to maintain control of inlet manifold conditions with variation in altitude. With carburettor type fuel systems the lowering of inlet manifold temperature with altitude increase can lead to a drop in thermal efficiency. This is due to wet fuel droplets failing to atomise in the inlet and requiring thermal energy on combustion to complete vaporisation of a poor mixture. To avoid this problem a fuel injection system is under development. Initial trials with the system have yielded promising results. As a further development the monitoring of inlet manifold temperature is to be included into the control algorithm for the fuel injection system.

3.3 Structure.

Although the aircraft should be of low weight in order to efficiently fulfil the mission requirements, every reasonable measure has to be considered in terms of system redundancy, reliability and structural integrity to assure a good change of safe return of the vehicle (and its payload!). Expendability should not be a predominant design factor.

The fuselage consists of a thin cylindrical shell with longerons. Each section terminates in a machined cylindrical former with one end having a locating ring and the other having a recess for the ring. Sections are easily joined by fasteners. Standard connectors are used for power supply and to interconnect electronic systems.

The proposed wing structure consists of two spar beams with a high-density foam core and a composite skin. Detailed load calculations, based on FAR-23 regulations, were done for the following conditions[8]:

- Gust and manoeuvre loads.
- Catapult launch.
- Net recovery.
- Landing on winglet-mounted undercarriage.

The loads on the wing indicate that the anticipated loads can be designed for within the given weight budget.

3.4 Aerodynamics.

It is obvious that the low Reynolds numbers degrade the aerodynamic performance of the vehicle. However, careful design and manufacturing can result in an aerodynamically smooth surface which can yield a considerable amount of laminar flow. Extensive research has been carried out on the configuration using the ADAS/NLRAERO potential flow code with corrections applied for viscous drag[9]. The wing incidence was determined for a required lift coefficient at zero angle of attack. The aerodynamic coefficients C_L, C_D and C_m where computed for various combinations of angle of attack, canard incidence and cg-location. The results depicted in Figure 7 shows that a lift/drag ratio of about 20 can be achieved in trimmed flight at 7000 ft (dependent on cg-location):

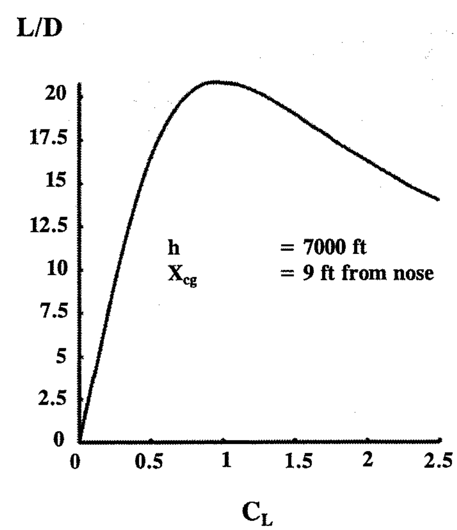


Figure 7: Lift/drag ratio versus lift coefficient for the Jabiru in trimmed flight[9].

Note that no attempt was made to optimise airfoil sections, the canard/flap system and wing twist. This however will be the subject of further study. The aerodynamic data set was used to estimate the endurance for different payload and fuel combinations at a fixed takeoff weight. The flight profile included climb, cruise and decent segments. The endurance predicted is in close agreement with the requirements.

3.5 Takeoff and landing.

The MAFV can takeoff from a runway on a special trolley that falls away after lift-off. Alternatively, the MAFV can be launched by a catapult with compressed air, particularly useful in remote areas or for ship-based operations. Air launch is an option, eg. to extend flight time and save fuel for the high altitude missions. At a takeoff safety speed is about 50 kts. For a runway launch, the takeoff distance would be about 475 ft. At a takeoff weight of 270 lbs the takeoff safety speed is 55 kts which results in a takeoff distance of about 660 ft. With a catapult launch the vehicle is accelerated over a relatively short distance. Using the same takeoff speeds as before, the required acceleration is about 5 g over a 20 ft ramp.

For operations in remote areas or for ship-based operations the landing procedure is based on capture by an arresting net recovery system. The landing procedure can be automated using small beacons for homing and glide path alignment. The approach speed will be about 40 kts. For landing on a sufficiently smooth runway an undercarriage disposition is proposed consisting of a tricycle configuration with fixed wheels mounted on the winglets and a nose wheel retracting in the canard intersection compartment, as shown in Figure 8:

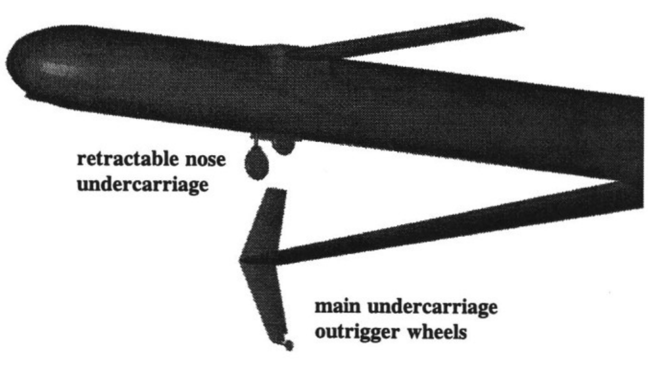


Figure 8: MAFV Jabiru undercarriage arrangements for runway landings.

Although the outrigger wheels will have some shock absorbtion capability, both vertical and sideways, the wing structure stiffness will be designed such that it can absorbe most of the energy. To obtain sufficient ground clearance the engine is shutdown before touchdown and the propeller is locked in horizontal position.

3.6 Navigation.

The establishment of the NAVSTAR system in 1981 has made possible the navigation across the surface of the globe to an accuracy within a 1 metre cube. NAVSTAR is more popularly known as the Global Positioning System (GPS). GPS is a constellation of 21 active (and 3 spare) pseudo-range navigation satellites in a high altitude quasi-synchronous orbit. These satellites continuously transmit unique pseudo-noise-coded signals with data on their ephemerides and clock errors. Corrections to this data are regularly carried out by ground stations.

GPS is actually two distinct navigation services within the one system. These are the Standard Positioning Service (SPS) for civilian use and the Precise Positioning Service (PPS) for military applications. PPS uses two transmitting frequencies of 1575,42 MHz (L1) and 1227,6 MHz (L2). In the military system PPS uses both L1 and L2 frequencies to enhance overall system accuracy. The second frequency enables correction for ionosphere distortions (errors).

The two services differ significantly in accuracy in normal operation. The SPS for civil applications is deliberately degraded by the Selective Availability (SA) of the satellites to users. That is the military will shut down to SPS users selected satellites. With SA in operation the SPS has an accuracy of 60 metres Spherical Error Propabililty (SEP). Velocity computations typically will have an accuracy to within 0.3 m/s for flight speeds less than 75 m/s. In contrast the military PPS has an accuracy of 16 metres SEP and a velocity error of approximately 0.1 m/s.

An alternative to SPS and PPS is Differential GPS (or DGPS). DGPS utilises a ground based GPS transmitter that provides signals from an exact location, this enables a significant improvement in the accuracy of both services. Typically an accuracy of 8 metres SEP and a velocity error of 0.1 m/s for both SPS and PPS services.

For most missions the MAFV will use SPS with inertial navigation backup. The autonomous flight vehicle (or user) measures pseudo ranges and pseudo range rates from a minimum of four satellites and calculates its own 3D position and velocity. The user is passive only and requires no transmission to the satellite. The flight vehicle also receives time of day from each satellite and can correct the flight vehicles internal clock.

In principle the user-defined flight plan consists of waypoint coordinates with information regarding speed, altitude, rate of climb, etc. An interactive window-based flight planner is being developed that allows the user to define waypoints on a digitised map (Figure 9):

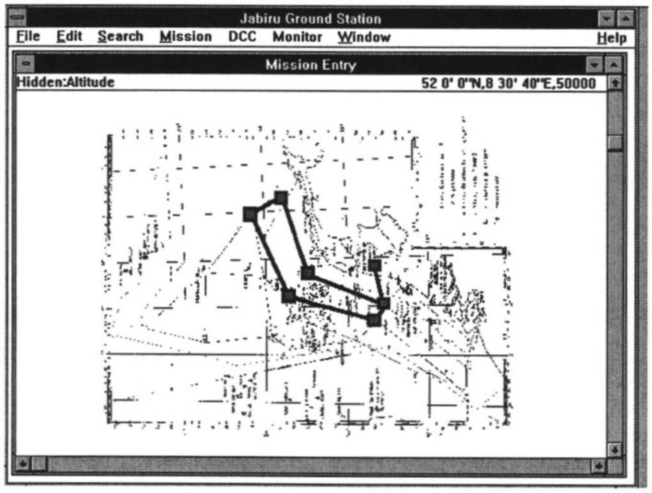


Figure 9: The MAFV Jabiru Flight Planner.

The flight plan is subsequently downloaded into the on-board computer. The flight plan can be modified inflight through satellite communication (see section 3.7). Figure 10 illustrates the schematics of the flight management unit and its connecting systems:

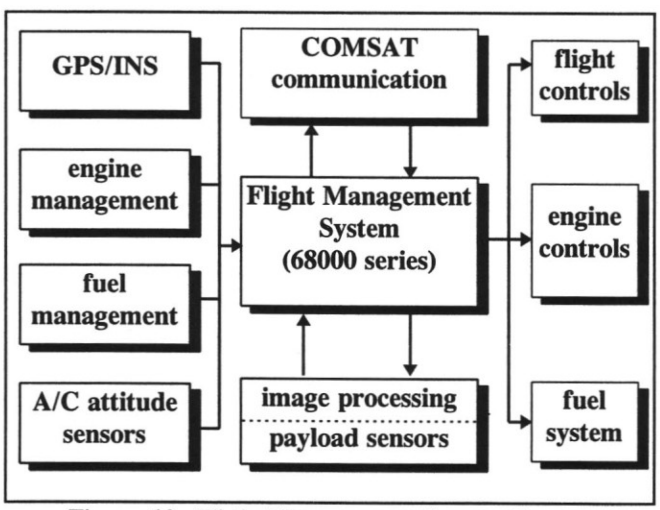


Figure 10: Flight Management System diagram.

The specific navigation requirements for the MAFV are mission dependent. However it is worth to examine an example mission to establish some minimum navigation requirement.

For example, for the oil spill policing and maritime reconnaissance mission, existing manned operations from fixed wing aircraft are executed at a pressure altitude of 5000 ft above sea level and at an airspeed of 100 to 130 kts. The FLIR and visual digital camera system (eg. Kodak DCS 200[10]) will typically be fitted with an autofocus 300-55 mm zoom lens with a field of view of 2.5 to 55 degrees, which represents an area of about 1500 x 600 m. With **SPS-nav.** at a SEP of about 60 m, an overlap of 10% will be required. The images are stored, compressed and transmitted to a ground station as a full image or in 'thumbnail' format (see section 3.7), for analysis. If a suspicious activity is detected, a manned aircraft can be despatched for further investigation and to take evidence.

Except for the high altitude mission, the majority of MAFV operational altitudes will be well separated from that of commercial jet traffic. Discussions with civil aviation authorities have established that trial operations with the MAFV can be carried out on a permit to fly basis, until formal international codes for civil operation of autonomous flight vehicles are in place. All MAFV electronic systems are being developed in accordance with RTCA-DO-178A guidelines[11].

3.7 Communications.

The operational requirements of the MAFV demand long patrols into remote areas making continuous communication impractical. To enable transmission of data to base and to facilitate inflight reprogramming of the flight plan occasional communication via satellite is employed.

The MAFV *Jabiru* utilises existing communications satellites system for the relay of both transmission and reception of data. The time proven IMARSAT-C communications network is an ideal vehicle for the relay of compressed data images. Future enhancements are anticipated as other satellite communication systems are introduced, such as Motorola's Iridium. Due to the autonomous operation continuous communication is not required nor is it proposed in the MAFV-concept.

The data to be transmitted consists of, for example, DCS-images, GPS location at where the image was taken, time and any other flight system data requested. Full images (1524 x 1012 pixels) are stored in the MAFV onboard data storage memory. These images can be compressed and transmitted via IMARSAT or a reduced data 'thumbnail' of the image can be transmitted instead. A typical 'thumbnail' image is about 125 Kb (192 x 128 pixles) whereas a full JPEG (Joint Photographic Experts Group) image is about 1.5 Mb. This allows a considerable reduction in the time required for data transmission. The advantage of this is such that the base station can scan incoming thumbnail images and instruct the MAFV to transmit or delete selected images.

The time required to transmit the data is dependent on the baudrate, the number of files and the file size. A full color DCS-image of 4.5 Mb can be compressed to a file with a typical size of 150 Kb to 300 Kb. Transmission of 2.5 to 5 min per image can be anticipated with the currently available equipment.

With the ongoing research work on image recognition it is anticipated that a first screening of information will eventually be possible by the onboard MAFV mission control system autonomously. In the interim data will be stored and transmitted at a preprogrammed interval.

4. Operational Cost Estimation

To assess the commercial and economic viability of the MAFV-system it is essential to have an estimate for the operational cost per flight hour. This is quit a difficult task as it requires input information that can at this point only be estimated. Therefore, the following information must be considered as indicative only.

The calculations are based on an expected life time of about 5 years (the Jindivik target aircraft has a life cycle of 20 years or about 20,000 hrs). The estimated acquisition cost of a MAFV to a customer, assuming a production series of 200 units, is (in US $):

Table 3: MAFV Jabiru estimated acquisition cost.

Item	Acquisition Cost
Guidance	**70,000**
Engine	**3,500**
Airframe	**16,500**
Payload	**60,000**
Total	**150,000**

Assuming the MAFV operates for 25% of the year, i.c. 10,950 hrs in 5 years, the depreciation cost is $ 13 per flight hour. Fuel cost at a fuel consumption of about 1.5 litre/hour is about $ 1.00/hour. Maintenance cost is approximately 6 hours per mission at a labour rate of $ 36/hr = $ 216 per mission or 216/72 = $ 3.00 per flight hour (based on a 3 day mission). Engine overhaul is every 150 hours or every 2 missions and costs $ 750 per overhaul hour which is $ 5.00 per flight hour. Data monitoring requires 2 people for 30 min each every 2 hours to take care of check in by the MAFV. This is $ 73 per every 2 hours of flight therefore data cost = $ 36.50/flight hour. In total, the direct operating costs are:

Table 4: MAFV Jabiru estimated direct operating cost.

Item	Direct Operating Cost/ Flight Hour
Depreciation	**13.00**
Fuel	**1.00**
Maintenance	**3.00**
Engine overhaul	**5.00**
Data monitoring	**36.50**
Total	**58.50**

The cost of a ground station is about $ 350,000 with an expected life of about 15 years. Cost per annum for one aircraft (operating at 25% of the year) is about $ 11 per flight hour. Launch system cost is $ 85,000 and $ 50,000 for the recovery system, total $ 135,000. Depreciation is about $ 12.50 per flight hour written off over 5 years. Maintenance on launch and recovery systems is about 5 hours per flight 5 x $ 36 = $ 180 per flight = $ 180/72 = $ 2.50 per flight hour. Maintenance on sensors is difficult to estimate but assume 10 hours per flight = 10 x $ 36 = $ 360 per flight = $ 360/72 = $ 5.00 per flight hour. The total operational cost summary becomes:

Table 5: MAFV Jabiru total operating cost.

Item	Operating Cost /Flight Hour
Flight vehicle direct operating cost	**58.50**
Sensor system maintenance cost	**5.00**
Launch and recovery system maintenance	**2.50**
Depreciation ground station	**11.00**
Depreciation launch and recovery system	**12.50**
Total	**89.50**

This clearly shows that the operational cost of the MAFV is significantly lower than that of traditional manned surveillance missions. This of course is primarily due to the exceptional endurance capability of the MAFV and its high level of utilisation.

5. Conclusions and future developments.

The technology is currently available to consider autonomous flight vehicles to complement or replace manned aircraft for survey and surveillance missions. The Multipurpose Autonomous Flight Vehicle (MAFV) *Jabiru* has been introduced as an interesting subject for a university research project to design and build a technology demonstrator. The operational cost for a typical MAFV mission is about $ 100. These potential cost savings have prompted expressions of interest from potential operators, such as geological and meteorological agencies.

The design objective is to develop a vehicle of a modular architecture that can accommodate a wide variation in mission requirements and payloads. Initial sizing has been carried out based on an average payload weight of 45 lbs, which indicate that the proposed MAFV can be on station for about 120 to 72 hrs for missions at low to medium altitudes respectively. For high altitude missions the vehicle has to be equipped with a gas turbine jet engine with an endurance of about 3 hours.

A half-scale model is currently being built and will be used to carry out flight trials to assess the vehicle's stability and control characteristics (Figure 11):

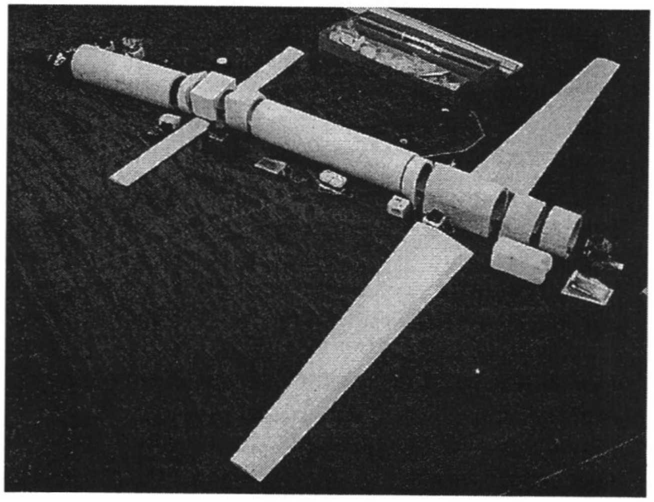


Figure 11: MAFV Jabiru experimental vehicle.

First flight is expected to be in June 1994. Subsequently a full-scale 'proof of concept' will be build for systems integration and testing. The estimated time for the development of the technology demonstrator is 2 years.

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