The InView unmanned aircraft for use in scientific, commercial and state applications

Dr Joseph Barnard

Managing Director of Barnard Microsystems Limited

Abstract

The development of the InView Unmanned Aircraft System followed a realisation that no unmanned aircraft we were aware of was, in our opinion, suitable for use in oil, gas and mineral exploration and production work. The ideal aircraft for this application would have two engines, two tail fins, two elevators, dual flight controllers, be able to fly over 500 km, carry a 4 kg payload and weigh less than 20 kg without fuel and payload. Our design focus was on safety, automation and modularity. Work on the development of the InView Unmanned Aircraft System started in December 2009, with the flight of the first prototype taking place on the 9^{th} April, 2010. We are now completing the changes to what will be InView Version IV-07 and have incorporated numerous changes to the original design.

The InView IV-07 has two elevators, two tail fins, two engines and dual flight control units to provide the level of safety we think is essential for civilian unmanned aircraft flying over populated areas.

Author Biography

Dr Joseph Barnard has a Ph.D. degree in Electrophysics from Cornell University in the USA, where he developed on the first GaInAs MESFET. He established Barnard Microsystems Limited in 1986 and is currently directing the development of three types of Unmanned Air Vehicles and associated sensor systems for use in scientific, commercial and state applications:

- the InView Unmanned Aircraft with a 4m wingspan and a 7+ hour flight duration
- a delta wing Unmanned Aircraft with electric, turbine or rocket motor propulsion units
- a hybrid electric and fuel powered, long flight duration, Unmanned Helicopter.

Web site	www.barnardmicrosystems.com
Contact	joseph.barnard@barnardmicrosystems.com

Introduction

We have had an interest that has extended over many years in the use of unmanned aircraft in oil, gas and mineral exploration and production activities. The aircraft specifications and requirements capture were developed over several years, and involved discussions with staff at oil and gas exploration and production companies such as Shell and BP, exploration services companies such as Fugro Airborne Services and Sander Geophysics and mining exploration companies such as Anglo American, BHP Billiton and Falcon Bridge.

Participation in, and contributing presentations at, the Society of Exploration Geophysics Annual Conferences has provided background information on the requirements for unmanned aircraft used in geophysical survey activities. We soon realised that most unmanned aircraft we were aware of would not be suitable for use in oil, gas and mineral exploration and production activities, because:

- they are too heavy, typically over 50 kg, causing extensive crash damage, and / or
- they are too complex (costly experienced operators are required), and / or
- they are too expensive to acquire and operate (big logistical footprint), and / or
- they are not sufficiently safe: most only have a single engine to start with, and / or
- export controls restrict their operation in many oil, gas and mineral rich countries.

We have developed the InView unmanned aircraft for use in scientific (e.g. volcanic ash density measurements), commercial (e.g. oil, gas and mineral exploration) and state (e.g. border patrol) applications. Our design focus was on safety, automation and modularity:

- our aim is to make the InView safer than manned aircraft. Since we are adding to air space congestion, we think that we are obliged to achieve this goal, and we believe the technology will enable this. In our test flights to date, a high proportion of mishaps have been caused by pilot error, particularly in the manual take-off and landing phase of the flight.

- We are developing and introducing automation of the pre-flight checks, the take-off, the flight itself, the landing and the maintenance of the InView unmanned aircraft. Our aim is to introduce adaptive flight control, in which the on-board flight controller compensates for changes in the aircraft, such as the onset of wing icing when the aircraft is flying in the Arctic region, to ensure predictable flight regardless of the status of the air frame. An extension of this work is to monitor the external environment so action can be taken to avoid a collision.

- Modularity has provided us with some key benefits:
    - easy to transport the aircraft in a 4x4 between the laboratory and the test site
    - easy and inexpensive to replace modules with improved versions
    - easy to change payloads to suit the mission

We decided to construct the first prototypes using "LitePly", a lightweight form of plywood. The reason for not going straight for carbon fibre is that we can more easily work with plywood, which is far less expensive than carbon fibre. Our approach is to "test early, and test often". The combination of a modular design and the use of LitePly enables us to rapidly and inexpensively test various, sometimes quite different, design variants. Is LitePly "good enough" for the application? Our current view is that for operation in dry climates in North Africa, LitePly certainly is "good enough".

InView features

The InView twin tail fin IV-06 variant being prepared for a test flight on a late Winter afternoon.

Since it appeared to us that no existing unmanned aircraft satisfied the requirements we defined, we considered this to represent a market opportunity, and developed, flight tested and evolved the InView unmanned aircraft as a technology demonstrator and test bed. The main attributes are as follows:

The long range InView Unmanned Aircraft System at a glance		
▪ scientific, commercial and state missions	**Payload**	4 kg
▪ extensive use of redundancy	**Endurance**	7+ hours
▪ modular for ease of transport	**Max speed**	112 kph
▪ assembled and tested within an hour	**Loiter speed**	24 kph
▪ can operate from a grass field	**Weight**	19.5 kg without fuel
▪ capable of very slow flight	**Wingspan**	4 m
▪ user definable payloads can be carried	**Fuel**	AVGAS 100LL fuel packs
▪ operates in manual, Microprocessor based autopilot and PC autopilot flight modes	**Propulsion**	2x SAITO FG-30 engines Total Power = 3.6 kW

The Design

Our focus in the design and development of the InView was on safety, automation and modularity.

The De Havilland DH 98 Mosquito was a twin-engined aircraft of plywood construction, designed originally as a fast, unarmed light bomber. The amazingly adaptable design was effective for day and night fighting, day and night bombing, anti-shipping attack, and photo reconnaissance.

Above: InView IV-01, our first design, was based on the Telemaster Senior aircraft.

Safety

- use of dual flight control units:
  - manual flight control for flight training and emergency control
  - microprocessor based flight control for safe, but not very versatile, flight control
  - PC based flight control for flexibility and experimentation, but less safe flight control
- automatic take-off to reduce the consequences of human error and ease the logistical demand
- automatic landing to enable emergency landings, reduce the consequences of human error ease the logistical demand
- distributed, on-board sensor network to provide early detection of potential failures, so measures can be taken before a more serious condition develops
- dual rudder and dual elevator as part of a dual redundant safety system
- twin engines are a safety requirement of some staff in mining exploration companies

Modular construction

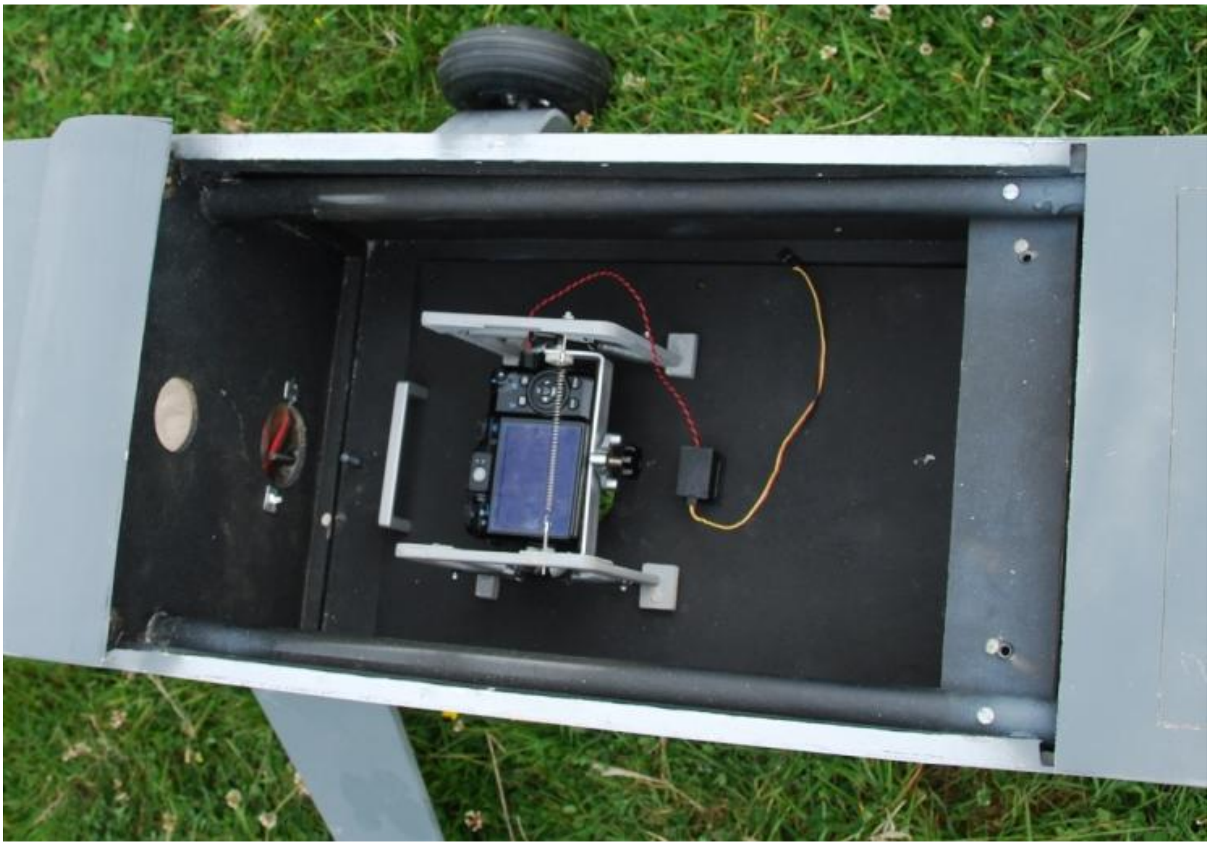
Above: the InView being assembled from the modules that were transported in a small van, which also acts as a mobile Ground Control Station. The advantages of a modular construction are:

- easily interchangeable payloads:
  - main payload in the fuselage, under the wing
  - one payload mounted centrally under each wing
  - one payload mounted at each wing tip
- easy to transport in a small van, and then assemble and test within one hour
- can be stored in a compact manner at a base, or on a ship
- easy to replace modules:
  - due to damage
  - to suit a mission: e.g. long, narrow, wings for a long range mission
  - as part of routine maintenance

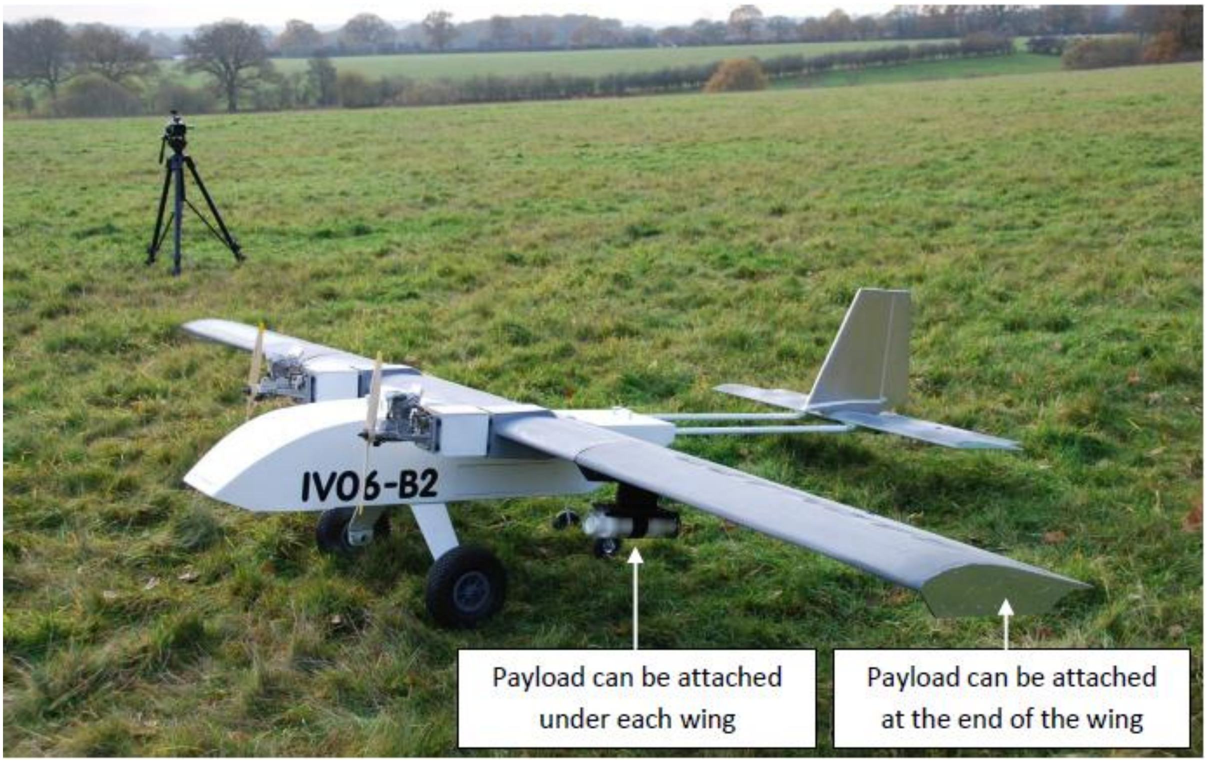
Payload mounting in the fuselage, under each wing and at the end of each wing

The InView has a large payload bay in the fuselage under the central wing section.

Above: Marcel placing a Canon G10 digital camera in a payload tray prior to a test flight.



Above: the payload tray located in the main payload bay of the InView.



Above: the capability to attach a payload to the end of each wing will allow upward looking atmospheric sensing, for example, using a LIDAR to measure the distribution of volcanic ash.

Ability to take off from, and land on, a rough grass field

Above: the InView ready to take off from a rough grass field. It will also land in this field.

- can operate near the area of interest
    - lower cost
    - more hours "on station"
    - no usage of the air space around an airport increases safety
- reduced operational costs
    - no airport charges
    - no Air Traffic Control charges
    - can take-off at any time: efficient flight scheduling
    - can land at any time: no wasting fuel in a holding pattern
- no reliance on any local infrastructure, which might be damaged or non-existent, for example, following a disaster such as a flood, a landslide or an earthquake

Light weight and long range

- less than 20 kg weight without fuel and without a payload
- lower kinetic energy causes less crash damage, for example, to a pipeline
- "like a model plane" view engenders a perception of lower risk and lower insurance costs
- relatively low operating costs, an important factor in commercial applications
- easy to transport, for example, in the back of a small van
- lighter regulatory burden, and associated costs
- large enough to carry 4 kg of user defined payloads in the fuselage and under the wings
- large enough to fly over 700 km

Very slow flight capability

Above: the Fowler flaps on the InView provide a slow flight capability:

- Short Take Off and Landing capability, with large balloon wheels fitted to the aircraft
- Slow flight enables cameras on the InView to take photographs with less motion blur
- Measurements of the Earth's magnetic field can be taken over a longer time to average out noise in the measurements.

Above: the Fowler flaps are located behind the wing mounted engines to provide lift even when the InView is flying very slowly

Large enough to carry professional sensors

Canon EOS 5D Mk II camera body	Canon EF 70 - 200mm f/2.8L zoom lens
▪ 5,616 x 3,744 Pixels = 21 MPixels ▪ computer interface and control via USB 2 ▪ weight = 810 g	▪ viewing angle = 10° x 7° at 200mm ▪ 4 stop image stabilisation ▪ weight = 1,490 g

Typically, we require high resolution aerial photography, in which we use the Canon EOS 5D Mk II body and the Canon EF 70 - 200 mm lens, shown above.

- to read number plates and recognize faces, the InView flies at 400 feet Above Ground Level
- in maritime surveillance operations, the InView flies at around 12,000 feet AGL

.

Flight test results and lessons learnt

We have had seven aircraft variants, some major in scope, some minor, so far. The enhancements have been introduced to:

- correct design flaws
  - change the tail configuration to achieve a suitable centre-of-gravity
  - move the engine mounting forward to achieve a suitable centre of gravity
  - smooth the edges for improved aerodynamic performance and reduced cracking
  - discard the VEE tail configuration as not being suitable
- extend functionality
  - add a front viewing window
  - add a rear viewing window
  - add side viewing windows in the fuselage
  - upgrade each engine from 20cc to 30cc for ability to operate on one engine
- increase versatility
  - add an attachment point under each wing
  - add a modular fuselage payload configuration
  - add an extra tail fin for increased redundancy
- cater for potential customer requirements
  - add stronger undercarriage to enable the InView to operate from rough fields
  - add an attachment point at the edge of each wing for volcanic ash measurements

Above: The InView IV-001 was based on the Telemaster Senior design. The Telemaser Senior, however, had a single engine at the front, but we needed a twin engine configuration. Due to the relocation of the engines, this design was too tail heavy. First Test Flight on 9 April 2010.

The IV-002 had a reduced weight tail section, but was still tail heavy. First flight on 29 April 2010

Above: the "VEE" tail InView IV-03 variant, test flown on 25th May 2010. Although the tail weight was further reduced, the flight characteristics were sluggish and this configuration was dropped. First flight on 25 May 2010.

Above: IV-04, with under-wing mounting points for scientific instruments, such as magnetometers. This variant flew well, and set the baseline for further enhancements. First flight on 4 June 2010.

We added a forward viewing window, side windows and a rear window to IV-05, shown above. The first Test Flight on 20 July 2010.

In IV-06 we added an attachment point at the edge of each wing tip, and modified the undercarriage to have 2 large wheels at the front, and 2 smaller wheels at the back. First Flight on 22 November 2010.

In IV-07, we added a second tail fin, and curvature to the corners of the fuselage for imporved aerodynamics and increased resistance to airframe cracking following repeated take-off and landing on rough grass fields. The first Test Flight took place on 1 February 2011. In a subsequent Test flight, we verified this aircraft can fly, and then land, safely on one engine.

Export controls

We have applied for, and have received, a MoD "Private Venture Security Grading" for the InView of "UNCLASSIFIED" in light of:

- no MoD funding for development (avoids ML10.c. in Schedule 2 Military Goods)
- security features built into the InView and the Ground Control Station
- use of satellite communications in BLOS operation requires another submission

Conclusion

We have completed the definition phase of the InView Unmanned Aircraft System for use in scientific, commercial, and state applications and are now in the testing and modification phase.

Following a strategy of "test early and test often" and thanks to the modular design of the InView, we have rapidly evolved the design to ensure it is suitable for a wide range of scientific, commercial and state applications both now, and in the future.

Interest has been expressed in the use of the InView in geophysical survey work in the Arctic, border patrol work and in oil rig and oil pipeline monitoring.