SETTING UP A SMALL UAV
A BRIEF LOOK AT AUTONOMOUS FLIGHT

One of the most interesting developments in R/C modelling in recent years has been the to trend towards stability augmentation and on to the next step, full autonomous flight. With the successful crossings of the Atlantic, first by Aerosonde and later by Maynard Hill and his team, it has been demonstrated quite forcefully that the technology for long range, autonomous flights by model aircraft is now well and truly within the reach of the advanced modeller.

SECURITY AND SAFETY CONSIDERATIONS

Setting up a small UAV is quite simple and relatively inexpensive using some of the currently available off the shelf modules. For example the autonomous control system used in the 4 metre span Silvertone Flamingo shown below cost approximately US$5,000.00. Another popular and very effective small autopilot is the Micropilot 2128.

One of the major difficulties facing the budding UAV operator is convincing the suppliers of equipment and relevant governing authorities of two things:

(1) That you are not a terrorist intending to use this equipment for nefarious purposes.

(2) That you are a responsible operator who will not fly your autonomous aircraft in a manner dangerous.

With regard to point One, here at Silvertone, in the 56 years that we have been in business, we have had several instances of customers using our equipment for illegal purposes. These incidents involved us in some messy entanglements with police and other agencies. So please bear with us if some of the questions we ask when first embarking on new UAV business arrangements seem a little pointed.

One of these incidents arose out of a series of anonymous letters being sent to the NSW Police Anti-Terrorist squad. These letters claimed that one of our customers was going to use some of our equipment to bomb the Sydney Olympics in the year 2000. It was all nonsense of course, but the authorities must take these threats seriously.

The dangers of this type equipment being misused are quite real. But then, that is true of all technology. Mobile phones are used to detonate explosives at precise times and locations in public places. Airliners are used to knock down buildings. Alongside an Airliner, a 10kg aircraft is insignificant. However for some reason, government authorities are particularly fearful of technology capable of delivering a payload, however small, to a point anywhere on Earth. Therefore please respect our need for caution and concern when embarking on new business ventures.

As a result of this official concern regarding UAVs most Western Governments have placed UAVs fitted with an autopilot on the restricted export list. Consequently an export license must be applied for and obtained and an end user certificate is to be supplied to the relevant Government authorities. They have also restricted the radius of operation of small UAVs to 300km. If this radius is exceeded, then an inbuilt command will send the UAV back home automatically. This command is built into all small commercial Autopilots.

This same restriction applies to the sale of Autopilot modules but here the issue is even more complex. For example for a private individual to purchase a Canadian made Micropilot of which both the hardware and software are export controlled, it is necessary for Micropilot to obtain an end user certificate from the customer

and then apply to the Canadian Government for an export permit. It generally takes 2 to 4 weeks from the application date to receive an export permit. If Silvertone has purchased the Micropilot Autopilot to fit to a customers Flamingo, once we have integrated that autopilot the Flamingo airframe it is considered a product of Australia and is under Australian export controls. This then requires Silvertone to apply to the Australian Government as well as the Canadian Government for the export permits, thus increasing the delay in an already lengthy process.

All of the above takes time and costs money and it for these reasons Silvertone offers the Flamingo less navigation avionics as the preferred option. Silvertone Flamingos supplied to the standard outlined in our Export Price List (Ready to fly but with no navigation avionics supplied or fitted) are an unrestricted export and do not require an export license and end user certificate thus reducing costs and minimising delivery times.

With regard to point No 2 above, many model Aircraft Governing bodies virtually ban autonomous flight on model flying fields under their jurisdiction by placing these types of aircraft outside of their insurance specifications. Such is the case here in Australia. The MAAA has ruled that models must be flown manually in full sight of the operator to meet their insurance requirements.

Obviously then becoming a UAV operator is a task not to be undertaken lightly. It is also obvious that we share the concerns of all authorities and we will involve them, and co-operate with them, to the best of our abilities if we become suspicious of any customer's intentions. In the case of the Olympic incident we immediately dismantled the aircraft in question and hid key components in various locations until after the Olympics. This was at the request of the Police and as a precaution that the aircraft was not stolen and used without our knowledge.

UAVs are a serious business and it is most important that everybody understands quite clearly from the outset, what is involved and where we all stand in regards to security and safety.

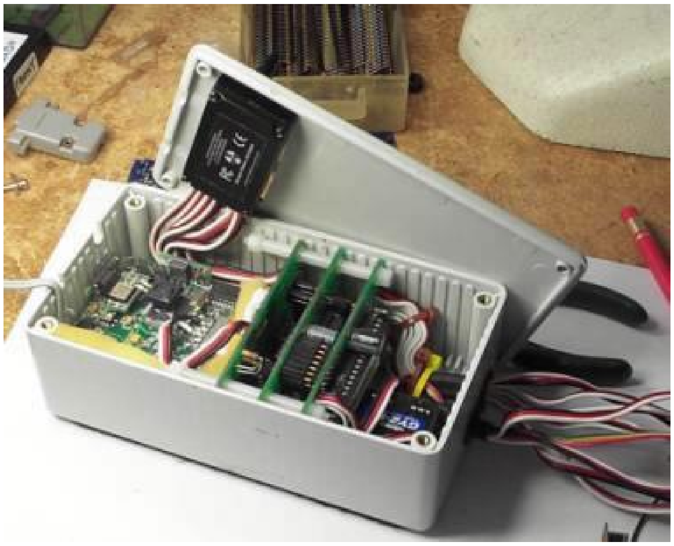
With that little bit of unpleasantness behind us, let us now move on to the business at hand. Namely how does one make these little marvels of technology work?

SILVERTONE FLAMINGO

A typical example of a small UAV is the Silvertone Flamingo shown below. The following paper is intended to provide some background information on the setting up of such an aircraft.

Silvertone Flamingo UAV on a private airfield in Queensland (Australia) 2008.

The Flamingo under discussion is fitted with an Ezi-Nav Microprocessor controlled autopilot that is manufactured by Dave Jones of AUAV in Florida USA. The Ezi-Nav is comprised of a series of software modules, which together with solid-state sensors combine to make up the autonomous flight control system. The autopilot software features a GPS steering module, the altitude hold module, a solid-state attitude hold module (IMU), plus various navigation and housekeeping modules. There is also provision for a data uplink/downlink.



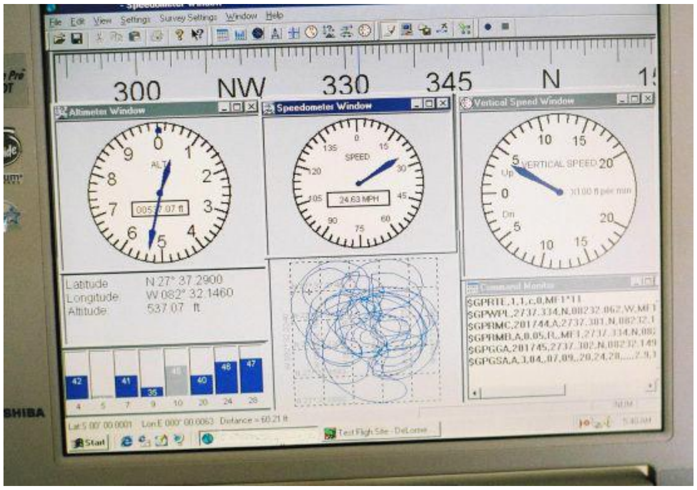
Ezi-Nav Autopilot showing interior modified by Silvertone to include IMU and a 2.4GHz RX

Completed Ezi-Nav modified to include RX.

One of the big problems facing civilian UAV operators is that of frequency allocations suitable for use in UAVs. The most serious of these being that of video transmitter output power legally allowed on the commonly used 2.4GHz ISM band. Whilst the UAV is free to roam across vast tracts of terrain getting back a real time video image using transmitters abiding by the Australia legal limit for Analogue video transmissions of 10mw effectively clamps the operational range to only hundreds of metres. That is if you want to see what is happening in real time. If the application can tolerate stored video to be reviewed at a later date then that really is a very nice way to do it for the video images are of a much higher quality and well worth waiting for. (See photo below.) Interestingly enough there is an avenue open and that is Digital Spread Spectrum (DSS) video transmitters that are allowed up to 4W legally. The problem is finding a commercial unit at a reasonable price. There is an excellent digital unit available but the price is in the order of US$25,000. This unit will work over ranges in excess of 50km.

In the Flamingo serving at various times as the downlink, is a real-time video system fitted with a video overlay. The overlay displays groundspeed, altitude, compass- heading, GMT time and GPS location. The autopilot is designed to plug into a standard R/C airborne system between the receiver and servos. The overlay is switched in or out between the camera and the video transmitter. See the block diagram below.

The Ezi-Nav can also provide a complete and more traditional data downlink providing the Ground Control Station with such data as speed, altitude, battery voltage, engine RPM and a host of other data as well as mapping information. The data link also allows for uploading a new series of waypoints and altitude information providing the ability to re-program the aircraft in flight. This however requires the aircraft to be fitted with a bi-directional modem with the consequent increase in cost, weight and complexity. For most simple UAV operations the video overlay provides sufficient data without the additional weight and complexity of the modems. If a data link is required a simple two way modem set-up good for 20km range is available at around US$800.00. As with all radio

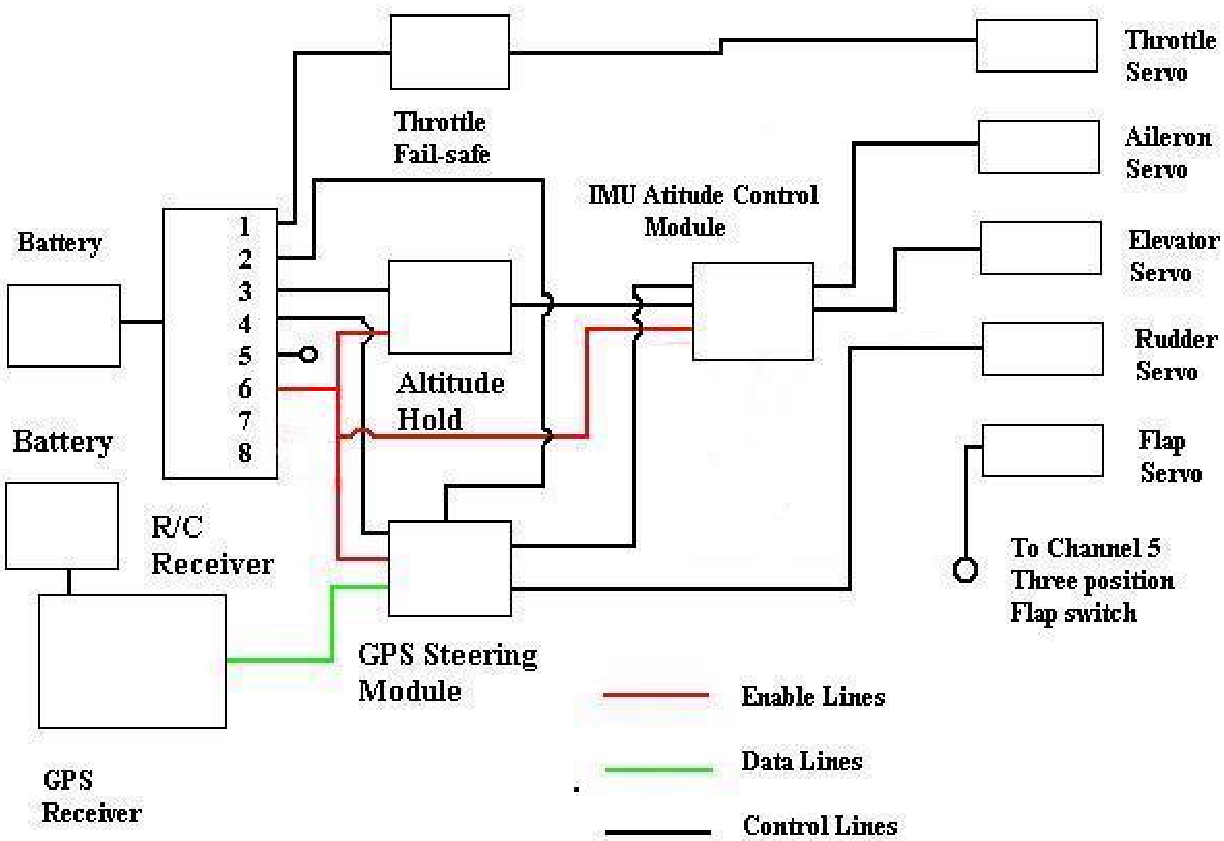


Ezi-Nav Ground Control Station showing instrument displays and mapping data.

Xtend Modem used in the Flamingo for the 900MHz data link

links the antennas are the key to success so obtain the best antennas your budget can withstand.

Since these modules function as control rather than augmentation (assist) units, they are either in complete control or by-passed. None of the modules are designed to provide "mixing" of manual and automatic control.



Block diagram of the Flamingo Autopilot showing the essential control elements.

The Ezi-Nav as indeed most autopilots, has an enable channel input so that the operator can bypass the automatic operation and operate the servo directly by normal, manual radio control. This enable channel can be plugged into any spare channel in the system preferably a switched channel (normally ch 6). Therefore with the flick of a single switch the aircraft moves from manual to automatic flight.

The Altitude hold module is pre-set in the flight planning stage. The waypoint data contains an altitude parameter which will instruct the aircraft to climb or descend while on route to the next waypoint. In order to achieve this it may be necessary to insert a loiter command to allow the aircraft time to arrive at the defined altitude.

To get the modules to automatically take control when the R/C radio loses command signal, you need to use an R/C system such as PCM that comes with a built-in fail-safe and servo hold (preset) feature. The enable channel is programmed for fail-safe enable.

Using the GPS enabled system with a wing levelling unit (optical or IMU) and an altitude hold makes it possible for an aircraft to be sent off on a fully automatically controlled mission to any point within range of the aircraft. Manual control via the transmitter is only required for take-off and landing. The transmitter may be switched off for the rest of the flight. Most Autopilots are restricted to 300km radious of operation due to Government regulations.

The microprocessor based GPS steering module receives output data from a dedicated GPS receiver and converts it to an R/C servo position command. Your GPS receiver provides the raw GPS data to the autopilot and the autopilot performs the navigation calculations and manages waypoints and routes. Simply connect the dedicated GPS to the autopilot and it will translate the track/bearing error into a servo position command. This module also corrects for cross-track error so it will stay on course for long distance navigation.

VIDEO DOWNLINK

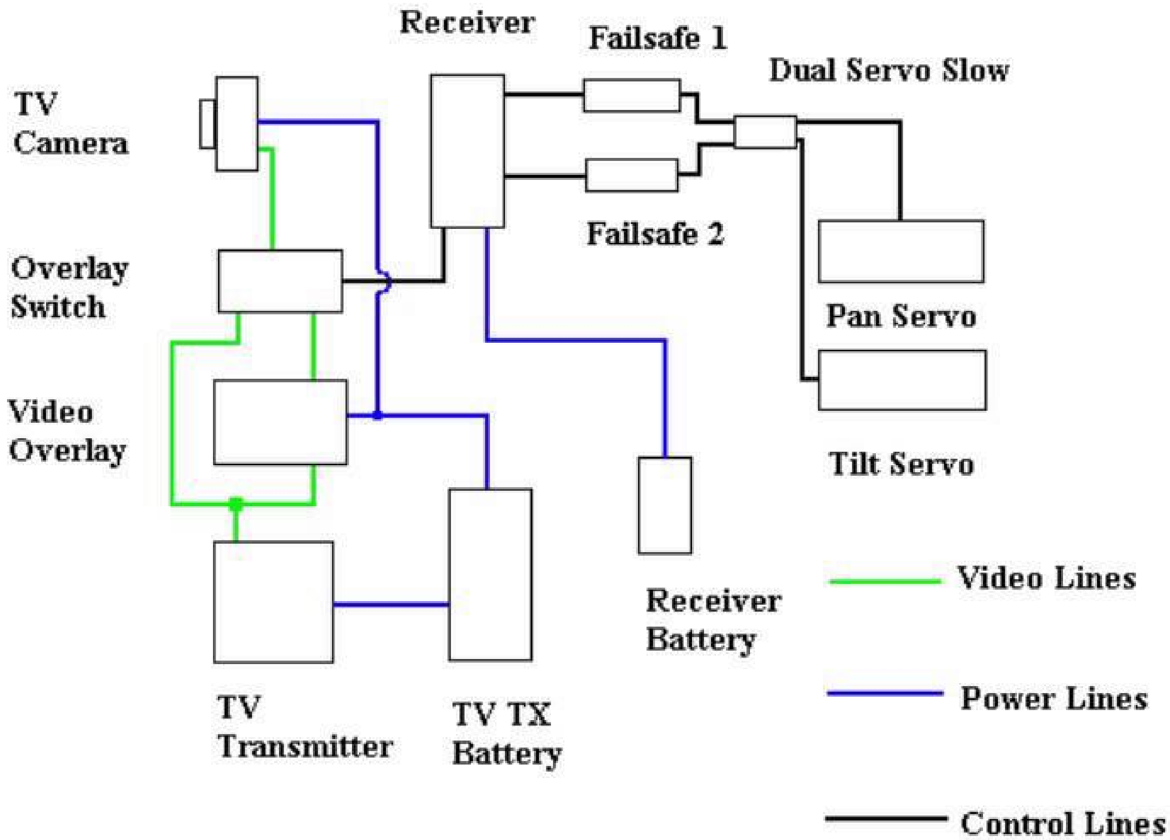
The type of system outlined above is ideal for extended range missions, such as aerial photography, fire detection, agricultural survey etc. In keeping with the requirements for these missions, the Flamingo is fitted with a real time video downlink. The block diagram below shows the basic layout of the various components.

The heart of the surveillance system is the video camera and we recommend the use of the best that can be justified under the project budget. The frame grab shown below was taken with a 625 line camera and is of quite poor quality compared to the stored video shown in the adjacent photo. Vegetation suffers very badly with low-resolution cameras as the photos below shows this quite clearly.

By far the best quality video is obtained with a digital video camera on-board and using a low-resolution real time mini camera as an aiming guide. There is always the risk of course of the loss of a very expensive camera but that has to be balanced out by the results obtained. The photos below vividly illustrate the difference in the results obtained.

Referring now to the video block diagram the system begins with the TV camera. The video output is fed into a relay-switching module, which either routes the video directly to the TV transmitter or through a video overlay unit. This relay is controlled from a separate video control transmitter, along with the signals to control the pan and tilt servos for the camera. The cameraman who is seated in front of the video monitor operates this transmitter. The camera is able to pan through 170 degrees in the horizontal and 100 degrees in the vertical.

To prevent excessive panning speeds, a dual servo slow unit is fitted between the fail-safes and the pan and tilt servos. This unit holds panning speeds to an acceptable level. Fast panning speeds give a very jerky look to the finished video and can make the viewer quite nauseous after prolonged viewing.



Block diagram of the real-time video downlink installed in the Weightlifter.

The fail-safes are fitted to serve as set-locks. If the transmitter is switched of in flight the camera will move to the pre-set position and sit absolutely still in order to further enhance the quality of the finished video. All of these refinements are fitted to give maximum flexibility combined with a rock solid finished video. Excessive movement in the finished video is annoying and detracts from the quality of the finished product.

Finally to close off here is a word on the video receiver antenna. Here only the best will do. As the airborne video transmitter is by law a low power unit a very good antenna is required on the video receiver. We are currently using a 17db yagi hand-held and pointed at the aircraft by an assistant. At the 2007 Challenge we used a dish and this gave much better range. Both the Yagi and dish antennas are very directional and must be pointed directly at the aircraft. This is a tedious and somewhat boring task for any assistant and their minds often tend to wander. As a result there are blocks of scrambled video in the middle of the clip where the antenna drifts off target. A better arrangement would be an auto tracking antenna or possibly an omni directional antenna such as a high gain collinear antenna.

We hope this paper has help clarify some of the mysteries of autonomous flight.

Stay responsible and keep yourself and others safe.

Happy flying.

AUAV Ground Station Van. Note the video dish mounted GCS trailer. A very nicely set-up GCS

Another view from the CCMAC field (380 line camera)

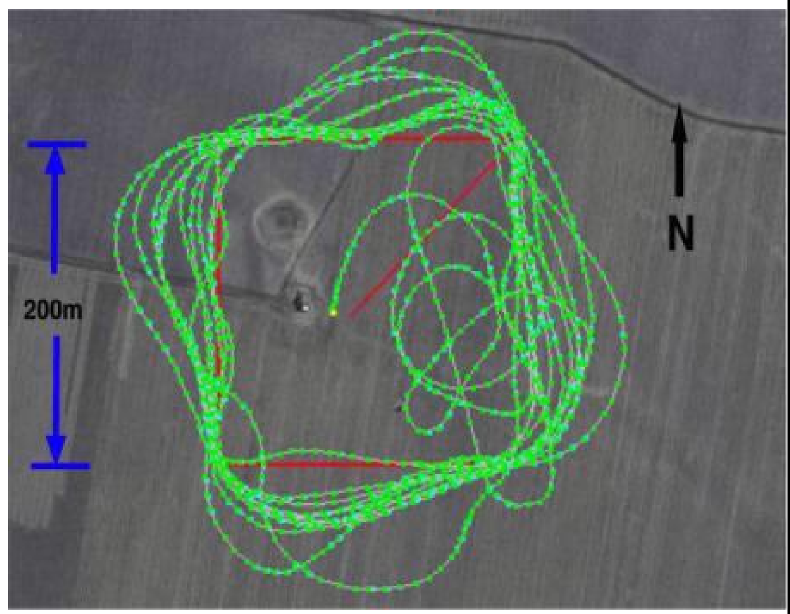
Photo showing video overlay data. From top clockwise Compass Heading, Altitude (Ft/ASL) GPS location, Time, Speed in MPH. Frame grab from a 625 line mini camera.

Frame grab taken from an on-board digital video camera. Note the tremendous improvement in picture quality. This clearly shows a lost aircraft floating in the pond. This aircraft was found accidentally while on a routine survey mission. Photo courtesy of Dave Jones, AUAV.

Flamingo ready for Outback Challenge 2007. Note camera blister under the fuselage and the pitot head in the nose.

Dave Jones(AUAV) working on the Flamingo prior to the Outback Challenge 2007. Note the ease of access to the avionics using the pannier style nose configuration and a sensible stand.

Antenna array used in the Outback Challenge 2007. This array included antennas for the video, control and duplex data transmitters.



Tracking plot painted over a Google Earth display using the Ezi-Nav autopilot. Note scale on the left hand edge of the screen.

FLYING FIELD SAFETY. IT IS PRICELESS.