UTA Autonomous Vehicle Laboratory Enters the 2004 AUVSI Student UAV Competition

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THE UNIVERSITY OF TEXAS AT ARLINGTON
AUTONOMOUS VEHICLE LABORATORY

MULTIMISSION AUTONOMOUS AERIAL VEHICLE

Bud A Pitman, Bancy Punoose, J.R. Sawyer

1. ABSTRACT:

This paper describes the development, design philosophy, and implementation of a fixed-wing AAV to perform autonomous reconnaissance of a pre-determined set of locations and the development of an airframe that will be multi-mission capable for future research and competitions. The Undergraduate Design Team is comprised of Aerospace Engineering, Computer Science and Engineering, and Mechanical Engineering students.

The complete mission objectives are for an unmanned, radio controllable aircraft to be launched, under autonomous control, navigate a specified course, use onboard sensors to locate and assess a series of man-made objects, and land under autonomous control. The mission time, endurance capability (specific fuel/energy consumption), total aircraft cost, and other factors, will be scored.

In this paper, architectures for system design, integration, and operation of an experimental fixed –wing AAV are explored. The scope of this project demanded a multi- disciplinary team of engineers with a creative and objective mindset.

2. INTRODUCTION:

The development and use of Autonomous Aerial Vehicles (AAV) gives us the ability to gather information and/or data without risk to human life and without the need for constant positive control by a human operator. The AAV provides a functionality limited only by the capabilities of the specific airframe, control system, payload, and our imagination.

The AUVSI 2nd Annual Student UAV Competition presents a set of goals that are, at first inspection, fairly straightforward. The solution to this set of tasks however, is not a trivial exercise.

The Aerospace Engineering students have produced a full airframe design and constructed a prototype for testing. This prototype was designed to be multi-mission capable and very efficient. The Computer Science and Engineering students have provided a completely commercial-off-the–shelf (COTS) hardware solution for the avionics, reconnaissance, and data management systems.

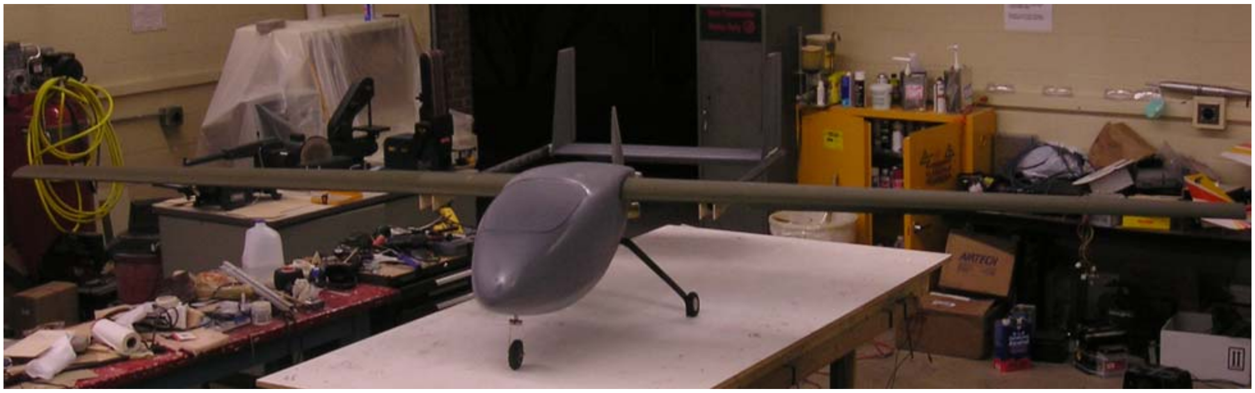


Figure 1: UTA Team AVL- 001

3. AIR VEHICLE DESCRIPTION:

a. Design:

The design was completed using Computer Aided Design (CAD) tools, traditional methods of calculation, and modeling to produce an airframe that will have reliable and easily predictable flight characteristics. Construction of the airframe mandated the use of composite materials and techniques to minimize airframe weight.

The design focused on implementing well-defined characteristics of a conventional airplane to enable multi-mission multi role capabilities. Wing, tail, and fuselage will be placed in the positions found on a conventional airplane, i.e., no flying wing or canard configurations were used.

Initial design parameters provided by the CSE team are as follows

1. Mission Duration: 40 minutes
2. Take-Off and Landing: 100 ft. with no obstacle.
3. Design vehicle Take-Off weight: 35 lbs. max
4. This is no minimum or maximum speed.
5. Flight Altitude: Minimum 50 ft. AGL Maximum 400 ft. AGL

Table 1: Characteristics of UTA AVL and Similar Aircraft

	UTA AVL	Predator	Pioneer
Cruise Speed (mph)	35	104	65
Max Speed (mph)	90	140	115
Cruise Altitude (ft)	300	11000	26000
Max Ceiling (ft)	11000	15000	40000
Max T-O Weight (lbs)	35	2100	450
Empty Weight (lbs)	23	700	75
Range (mi)	5	500	114
T-O Distance (ft)	100	5000	2000
Landing Distance (ft)	100	5000	2000
Wing Loading (lbs/ft^2)	2	18	12

b. Manufacturing the Aircraft:

One of the most important considerations in the design of an aircraft is not only to meet the requirements, but also to manufacture it cost-effectively. To control aircraft cost, the main components are manufactured in AVL, and other components are purchased.

Main components manufactured in-house

1. Wing
2. Fuselage
3. Vertical and Horizontal Tail Surfaces

Main components supplied by vendors

1. Tail Booms
2. Landing Gear
3. Engine

c. Airfoil Design:

The design of the main wing mandated a low speed airfoil, low base drag coefficient, low wing weight, and low induced drag. The Anderson SPICA was selected for the largest maximum lift coefficient and lowest induced drag coefficient.

d. Manufacturing the Wing:

Templates of the root and the tip of the wing were machined from steel plate. The foam was cut to the correct length using hot wire, and then we insert the template at each end of the foam. Using hot wire, we traced the template from leading edge to trailing edge. This method produced fairly precise wing cuts and the steel templates are durable and reusable.

Table 2: Wing Characteristics

Wing Area (ft^2)	16.23
Aspect Ratio	10.4
Leading Edge Sweep (°)	2
Taper Ratio	0.69
Span (ft.)	13
Root cord (ft.)	1.5
Tip Cord (ft.)	1
MAC (ft.)	1.264

Figure 2: Carbon Tube Installation

Figure 3: Hot Wire Cut Foam

In order to have detachable wings for easy transport, it was necessary to bisect the full wing (see figure 3) and join the two wings to the fuselage. To accomplish this, we needed to cut two holes on the roots of each wing half and insert wing socks in order for the wing tube to be slide in and out easily. (See figure 2). The wings were joined to the fuselage by passing two longer carbon wing tubes with slightly smaller diameters through the fuselage and into the carbon sleeves in both wings. This provides us with a very strong wing that can be detached for storage and transport.

e. Manufacturing the Fuselage:

The manufacture of the fuselage may have been the most difficult construction task in comparison to the rest of the aircraft. The fuselage is made of paper honeycomb material sandwiched between two layers of fiberglass. The use of these materials ensured an exceeding strong, durable, and light fuselage.

To manufacture multiple units, we decided to make a mold in the shape of the fuselage so every fuselage that we produce would have exactly the same outer dimensions and smooth finish. To make a mold, a plug in the exact shape of the fuselage was needed. There were two ways we considered making the plug. At first, we explored the option of buying machineable media and using a computerized numerical controlled (CNC) milling machine to mill out the fuselage shape and covering it with wax-release. Unfortunately, when we did a cost analysis we found that it would cost us over $ 500: $300 for the material and $200 for shipping. Due to budget constraints, we decided to do it in house using the method described below.

f. Making the Mold:

Using the dimensions from the CAD-drawings, we printed out 20 cross-sectional shapes on to paper, glued them on to fiberboard, and cut the shape out of the fiberboard.

Figure 4: CAD Fuse Cross-Section

Figure 5: Block Foam Template

We then cut square blocks of blue foam slightly larger than the sectional templates. The foam and the templates were then glued together. The foam was cut to the shape of the template using hot wire.

Figure 6: Fuselage Foam Plug

Figure 7: Positive of Fuselage

Next, all the foam sections were reassembled into the shape of the fuselage and covered with gypsum cement. The fuselage plug was then sanded smooth. Next the mold was divided into two halves with fiberboard to facilitate forming the actual fuselage mold.

We prepared the plug by applying two coats of poly vinyl and two coats of wax release agent. Then we applied epoxy resin to the surface followed by three layers of 4 oz. fiberglass.

Figure 8: Mold Divider

Figure 9: Release Agent Application

When the fiberglass was tack-free, the plug was covered with epoxy tooling foam followed by a layer of epoxy resin and fiberglass. The mold was separated from the plug and the interior surface was lightly sanded to get a smooth finish.

Figure 10: Final Sealing of Mold

Figure 11: Final Fuselage Mold

g. Making the Fuselage from the Mold:

Release agent was applied on the inside surface of the final mold. Then, two layers of fiberglass, epoxy, and honeycomb material were placed in each half of the mold. The mold was immediately vacuum-bagged to conform the paper honeycomb to the sides of the mold.

When the honeycomb material and the outer fiberglass were cured, plywood was installed for wing mounts. Two layers of fiberglass were placed on top of the honeycomb material. Vacuum bags were again utilized on the exterior and interior of the mold to conform the inner composite layers to the existing paper honeycomb. The fuselage halves were then joined with epoxy and fiberglass. Finally, the fuselage was painted for a smooth, uniform appearance.

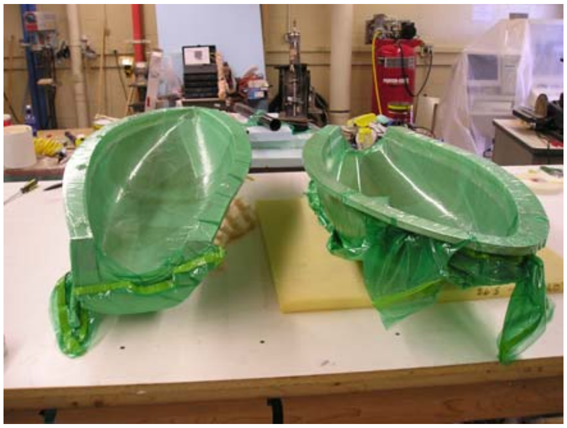


Figure 12: Vacuum Bagged Molds

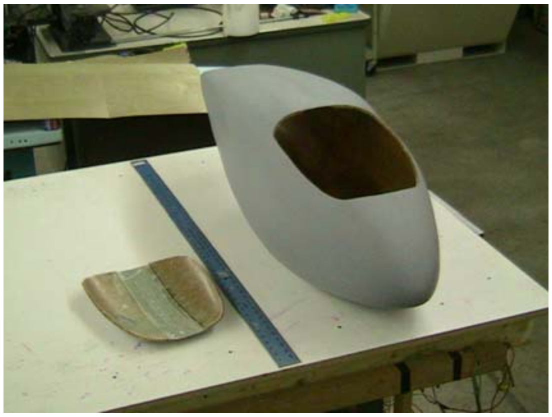


Figure 13: Fuselage Exterior

h. Manufacturing the Vertical and Horizontal Tail Surfaces:

Like the wings, the tail surfaces were also cut from foam. Shaped balsa wood was added to the trailing edge of the surface for strength. The tail surfaces were then covered with two layers of fiberglass cloth and epoxy. After curing, the control surfaces (rudders and elevators) were cut from the existing surfaces. The vertical surfaces were attached to the horizontal surfaces using epoxy resin and carbon fiber rods. The entire tail surface assembly was attached to the fuselage and wings using twin tail booms. The booms are four foot long carbon fiber tubes with 1 ½ inch diameter.

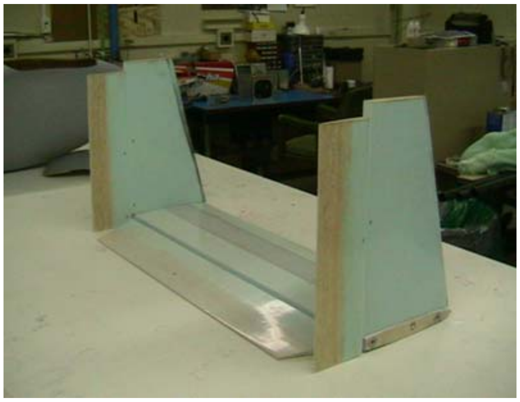


Figure 14: Control Surfaces

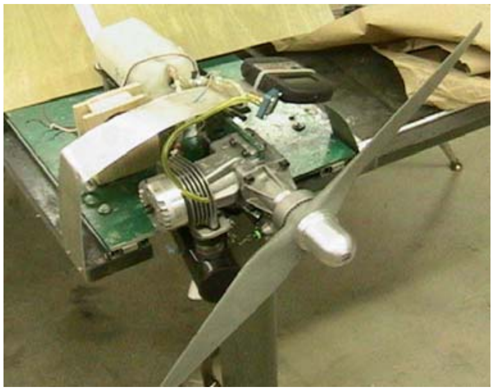


Figure 15: Diesel Test Stand

i. Engine:

In order to meet the requirements of reliability, power and efficiency, an engine with at least 4 HP was needed. Weight reduction of the engine and ability to get enough horsepower mandated a clever solution. The engine chosen was a Supertigre G-3000 with a diesel conversion kit. The converted diesel engine produces 20 pounds of thrust with the engine weighing in at only three pounds.

j. Testing:

Testing the aircraft is a continuous evolution as new features are brought online. The testing of the aircraft's main control surfaces and sensors will be conducted in parts: bench, piloted, semi-autonomous, and autonomous flight. The bench testing ensures that each control actuated properly, had the correct degree of motion, and torque to accomplish the task in flight. The above ground level (AGL) sensor, global positioning system (GPS), and inertial navigation system (INS) were also calibrated and tested on the bench to ensure nominal behavior.

In order to ensure safety and facilitate repetitive calibration, flight test cards were developed. The flight test cards document the post-installation check lists, preflight check lists, and post-flight check lists to ensure safe operation of the AAV. Static and flight test cards are sequentially numbered and each test must be signed off by a representative member of the Airframe team and CSE team.

4. GROUND CONTROL STATION (GCS) DESCRIPTION:

a. Overview:

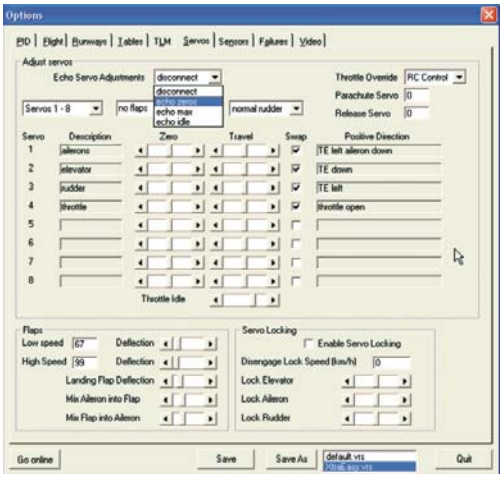
The GCS consists of three entities; The Avionics GCS, Data Collection Station and Pilot Operated Remote Control Transmitter. The division of Avionics GCS and Data Collection Station was done to avoid any conflict with the mission objectives, safe positive control, and autonomous operation of the AAV. The AAV will be operating in a totally autonomous mode from takeoff to landing. In flight, the AAV will communicate, via radio frequency transmitters/receivers, with two discrete computer systems using 900 MHz band radio modems and 2.4 GHz band Wireless Network Cards. There will also be the 72 MHz band Pilot Operated Remote Control Transmitter.

b. Avionics Ground Control Station:

Communication with the autonomous avionic suite will be performed in two ways. If the AAV is on the ground and in a safe configuration, communication and data will be handled with a hardwire RS232 connection between the Micropilot MP2028g Autonomous Control System (Described in the Section 5: Payload Description) and GCS notebook computer. If the AAV is in flight, communication between MP2028g and notebook computer is handled over an identical RS232 connection with the addition of 900 MHz, 9600 baud, radio modems.

c. Using MP2028g HORIZONmp Software:

The MP2028g includes the HORIZONmp for mission creation, parameter adjustment, flight monitoring and mission simulation. The HORIZONmp software offers a GUI interface for communicating with the MP2028g. It acts as a setup tool for configuration of the MP2028g. Its main function is to allow the user to observe and interact with their UAV while it is in flight or on the ground via the RS232 cable provided by MicroPilot. In flight communication is done via 900 MHz radio modems.

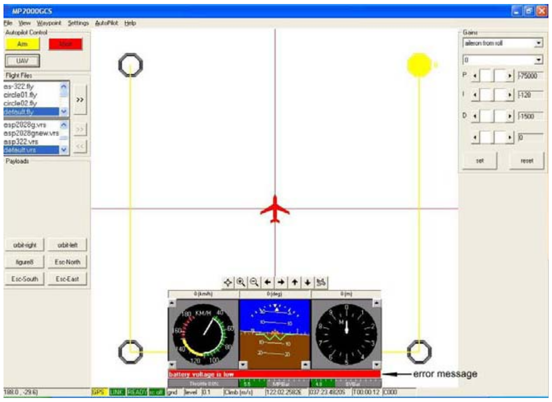


Echo Servo Adjustments: disconnect
Throttle Override: RC Control
Parachute Servo: 0
Release Servo: 0
Servos 1 - 8
no flaps
normal rudder

Servo	Description	Swap	Positive Direction
1	ailerons	☑	TE left aileron down
2	elevator	☑	TE down
3	rudder	☑	TE left
4	throttle	☑	throttle open
5		☐	
6		☐	
7		☐	
8		☐	

Low speed: 67
High Speed: 99
☐ Enable Servo Locking
Disengage Lock Speed (km/h): 0
default.vrs

Figure 16: PID Adjustment Example



es-322.fly
circle01.fly
circle02.fly
default.fly
esp2028g.vrs
esp2028gnew.vrs
esp322.vrs
default.vrs

aileron from roll
P: -75000
I: -128
D: -1500
0

battery voltage is low

188.0 , -29.6 | gnd | level | 0.1 | Climb (m/s) | 122 02.2582E | 037 23.4820S | T00:00:12 | C000

Figure 17: Active GCS Example

d. Data Collection Station:

An additional notebook computer is used for autonomous data download of gathered data from the AAV. The notebook computer is connected to the AAV using a 2.4 GHz WI-FI wireless network system. The single board PC on board the AAV automatically will send raw and processed images to the Data Collection Notebook via an omni directional antenna on the AAV and a hand-held directional antenna on the ground. The data may then be processed further, printed, or transferred at will.

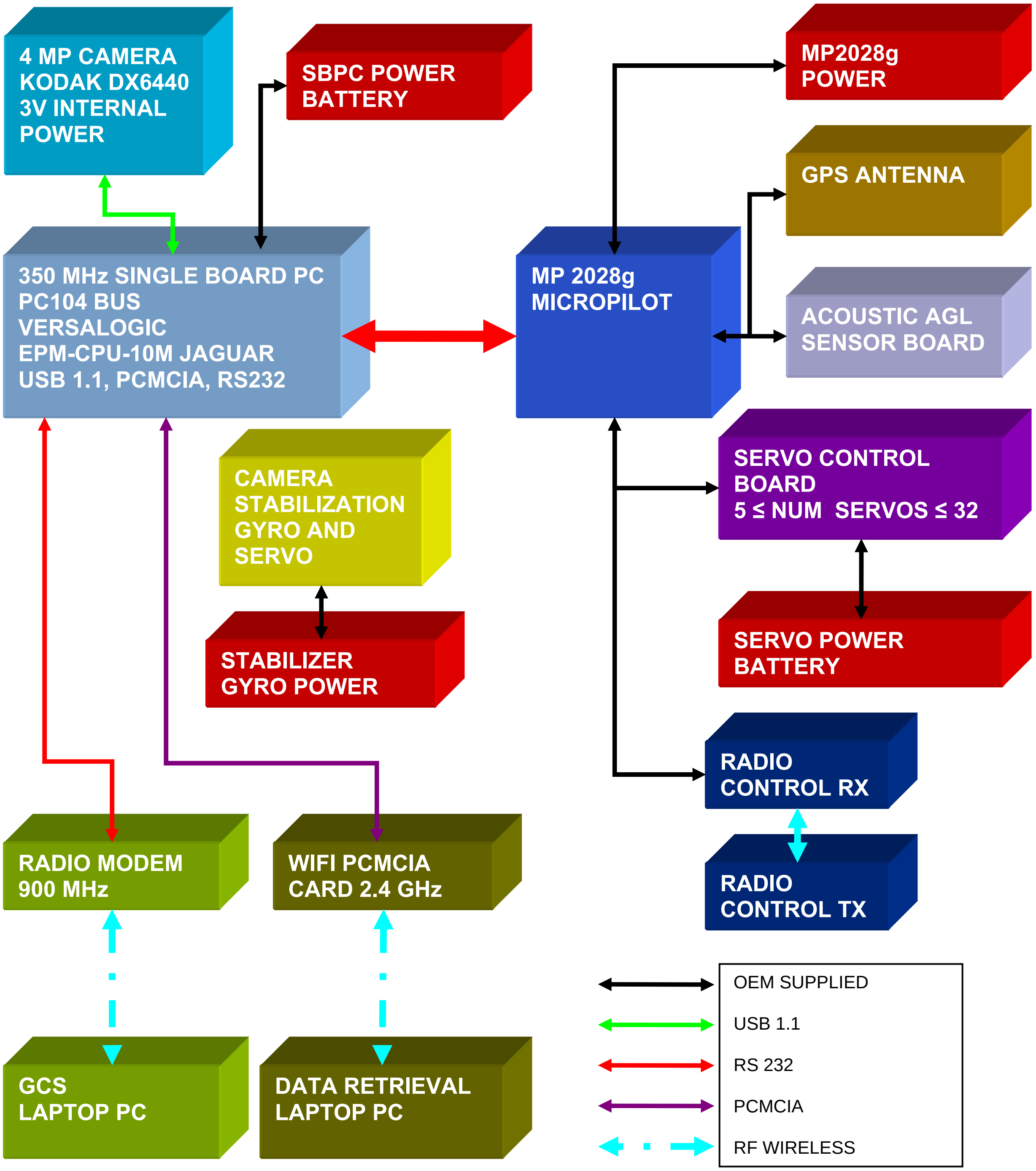


Figure 18: Autonomous Aerial Recon Vehicle: Payload Overview

5. PAYLOAD DESCRIPTION:

Due to generous contributions from MicroPilot of Canada with their autopilot avionics and VersaLogic of California with their Single Board Computer (SBPC), it was possible to construct a fairly high-level software systems architecture running Java on the Linux Operating System. The software system on the SBPC is a central part of the mission package onboard the AAV.

The architecture was chosen because of it modularity. The entire mission specific package lies between one RS232 data line. This line is the connection between the MicroPilot MP2028g and the 900 MHz telemetry radio modem. The entire AUVSI payload may be disconnected from this single data path and replaced with a completely different payload.

The SBPC on the AAV serves as an information conduit and information storage device via this RS232 data path. It monitors the MicroPilot's raw data being sent to the ground station and intercepts the GPS location and attitude of the aircraft. The C maintains a list of targets and their GPS locations along with the most current GPS location of the aircraft and the attitude of the aircraft.

When the SBPC detects that the AAV is over a target, it will send a command to the camera to take a picture of the target. It will then download the image into the SBPC memory from the camera. In addition, the onboard computer will write a file with the attitude of the aircraft at the time the picture was taken. The SBPC will then download the image and attitude file to the ground station via WI-FI network card.

When a different mission is designated for this AAV the payload may be configured at will. The modularity and reusability of the AAV was a major design philosophy. The modularity of the payload lends itself directly to safety and reliability. If the mission package should fail, the AAV will not become unsafe. The programming of the MP2028g will remain intact as will the ability to take RC manual control.

a. Payload Hardware Composition:

1. **VersaLogic EPM-CPU-10M Jaguar 350 MHz Single Board PC With PC104 Bus**
2. **Kodak DX6440 4 Mega Pixel Camera**
3. **Camera Stabilization Gyroscope And Servo**
4. **MP 2028g MicroPilot Autonomous Control System**
5. **MicroPilot Acoustic Altimeter**
6. **MaxStream 9XStream 900 MHz Radio Modem**
7. **ORiNOCO 11B/G PC Card IEEE 802.11 B/G**

b. VersaLogic Jaguar 350 MHz Single Board PC (SBPC) Description:

The Jaguar Pentium III Single Board Personal Computer (SBPC) was chosen due to its known reliability. The PC 104 bus enables expansion limited only by weight and power requirements.

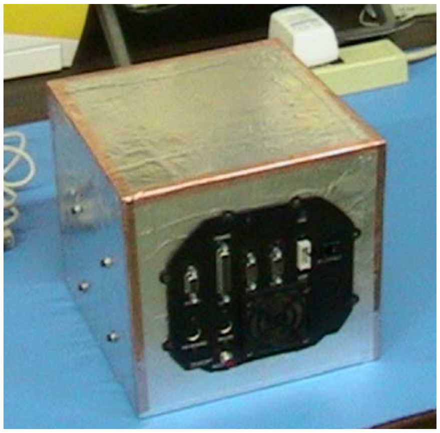


Figure 18: RF Shielded Enclosure

Figure 19: PC Installation

The enclosure for the PC and camera is made of .25” fiberglass covered honeycomb composite. The exterior of the PC/Camera enclosure is laminated in aluminum and copper tape with conductive adhesive. The enclosure is designed to reflect all RF interference away from all other components on the AAV thus avoiding any possibility of interference with the Avionics as well as the GPS receiver. The SBPC is the single largest source of RF interference and no interference can be allowed. RF energy will be reflected forward and down from the AAV.

The Jaguar was designed for projects requiring fast processing, compact size, flexible memory options, high reliability, and long-term availability. It also features high speed rendering, with standard CRT interface, DiskOnChip support, 128 KB level 2 cache, watchdog timer, and Vcc sensing reset circuit. Standard I/O ports include floppy, keyboard, PS/2 mouse, PCI-based IDE, LPT, and two COM ports (one RS-232/422/485 selectable).

The high reliability design and construction of SBPC features Transient Voltage Suppressors (TVS) on user I/O ports for enhanced ESD protection, latching I/O connectors, low-EMI clock generation, and self-resetting fuse on the 5V supply to the keyboard, mouse, and USB ports.

The Jaguar delivers full Socket 370 compatibility with PC/104-Plus interconnection ability. Each board is subjected to environmental stress screening and complete functional testing.

c. Kodak DX6440 4 Mega Pixel Camera and Optics:

The camera and control system was chosen for image quality, ease of operation, redundant data storage, and Java Picture Taking Protocol compatibility. The camera is mounted on a free pitch axis mount that is controlled by a heading hold gyroscope and servo normally used for RC model helicopters. The gyro ensures, while the wings are level, any pitch of the AAV will not affect the cameras orientation perpendicular to the ground. A GPS overlay for every photo can be available for ease in identification and location of each pixel in the image.

The use of a wide-angle lens attachment is available also for low-altitude mission requirements. The image processing and GPS overlay can be calculated for the wide angle lens as well.

d. MP2028g Autonomous Control System and Avionics:

The MP2028^{g} weighs only 28 grams with dimensions of 10 cm by 4 cm. The MP2028^{g} includes the HORIZON^{mp} ground control software. This unit was provided to the team by MicroPilot. Extensive data logging and manual overrides are also supported, as is a highly functional command buffer. All feedback loop gains and flight parameters are user-programmable and feedback loops are adjustable in-flight. The MP2028g also includes the HORIZONmp for mission creation, parameter adjustment, flight monitoring and mission simulation.

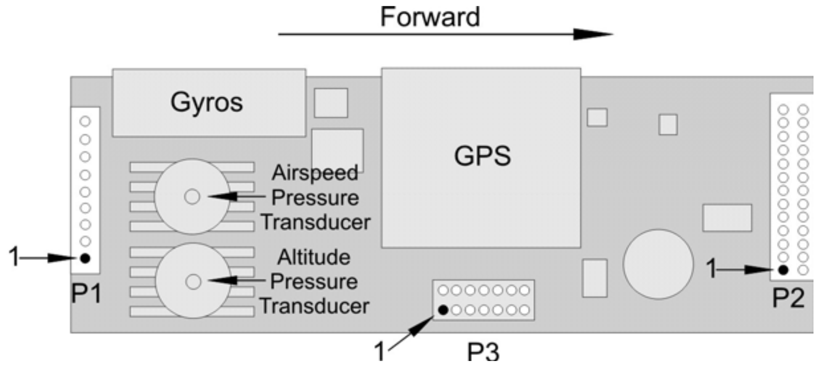


Figure 21: MP2028g Layout

e. Acoustic Altimeter:

The AGL board is an ultrasonic altimeter that provides high-resolution altitude information up to an altitude of 16 feet and is required for autonomous takeoff and landing. By default, the MP2028g expects an AGL board. The ultrasonic transducer is mounted facing down on the bottom of the fuselage. The cable between the transducer and the board is shielded coax.

f. Camera Stabilization Gyroscope:

Due to the effects of wind during flight; it was necessary to actively stabilize the camera on the aircraft in order to produce quality aerial photographs. The gyroscope is a standard helicopter stability gyroscope made by CSM model CSM200 controlling a servo model JR4735.

g. 9XStream is MaxStream Radio Modems:

The 9XStream is MaxStream's longest range, low power wireless OEM module. MaxStream radios were chosen for their known reliability and long range. During testing the modems communicated reliably at ranges of 5 miles. Receiver sensitivity is a measure of the weakest signal a radio is able to detect and demodulate. Superior receiver sensitivity can overcome many of the challenges inherent to RF communication systems such as signal attenuation (degradation). Simply put, MaxStream allows integrators to cover more ground with fewer radios.

Every -6 dB of receiver sensitivity gained doubles the range (outdoor RF line-of-sight environments. -10 dB doubles the range in indoor/urban environments. MaxStream wireless modems achieve up to 8 times the range of competing modems.

h. Silver ORiNOCO 802.11b/g PC Card Wi-Fi Networking System:

The ORiNOCO 802.11b/g ComboCard is a high-performance wireless LAN adapter card that complies with the 802.11b and 802.11g wireless standards. This card was selected for its reliability and the availability of an external antenna connection. This connection provides access to an omni-directional antenna providing broad coverage and 5.5 dBi gain.

The card is interoperable with IEEE 802.11a, 802.11b and 802.11g equipment from any manufacturer.

i. Radio Control Receiver:

The remote control transmitter and receiver is a JR XP8103H transmitter and NER-649S PCM receiver. These were chosen for their reliability, familiarity of the designated pilots of the AAV, and quality. The computer system used in the XP8103 is the easiest to understand, easiest to operate multi-function 8-channel computer radio. The large LCD display provides easy-to-read graphics and the control sticks offer adjustable spring tension and length. The transmitter provides automatic fail-safe and information update in PCM mode when fail-safe is used and Direct Servo Control (DSC) permits operation of all the controls and servos while also making transferable all data between transmitters without generating a radio signal.

6. DATA LINK DESCRIPTION:

The AAV’s data link is comprised of two key components: EIA-232 Serial connection via the MaxStream Radio Modems and a TCP/IP network connection via the ORiNOCO Silver 802.11b/g PC Card. The MaxStream modems operate at 900 MHz and afford a theoretical range of five kilometers. The ORiNOCO PC Card operating at 2.4 GHz and utilizing the 802.11B protocols has a one kilometer range. This range is extended to 3 kilometers with the use of an omni directional antenna on board the AAV and a directional antenna at the GCS.

The serial connection is dedicated to the raw data stream of the MicroPilot MP2028^{g} autopilot subsystem. The raw data stream contains aircraft GPS location, INS information, and all current MicroPilot information. The information is fed to the HORIZON software on the ground via the radio modems, to monitor AAV operation.

The network connection is dedicated to download of images from the onboard Kodak camera. In addition, attitude files corresponding to each image taken accompany each picture. This link, in the future, may support more unique telemetry as the system evolves.

The bands in operation and discrete data paths for critical and non-critical information lead to system reliability and safety. One system cannot interfere with another and lead to a failure.

7. METHOD OF AUTONOMY:

The autonomous flight is governed by the MicroPilot MP2028^{g} autopilot subsystem. The MicroPilot uses onboard sensor data from GPS, INS, sonic and pressure altimeter, and airspeed sensor to model the aircrafts attitude in flight. Using the sensor data and coupled with Proportional, Integral, Derivative (PID) control loops, the MicroPilot controls the actuation of the control surfaces. The PID loops control the update of signals to the servos controlling the surfaces.

On a macro level, the MicroPilot embedded flight software implements the following flight rules: airspeed hold, altitude hold, turn coordination, GPS navigation as well as autonomous launch and recovery. The aircraft follows a sequential flight plan that includes aircraft-specific parameters and capabilities so the flight software neither underestimates nor overestimates the capabilities of the aircraft being controlled.

8. SAFETY CONSIDERATIONS:

This project was begun in earnest in February of 2004 and safety was of paramount concern from the beginning of the project and through its completion. A project involving compression of time and rapid development could lead to errors in judgment and missed opportunities. This was addressed at the beginning of the project and throughout the daily operation of the equipment in Autonomous Vehicle Laboratory. The students involved were professional and, as the project progressed, safety concerns regarding reliability of the system were continuously updated. The Mechanical and Aerospace Engineering (MAE) team designed a very robust and reliable AAV. The Computer Science and Engineering (CSE) team concentrated on the mission package, thus ensuring modularity and fault tolerance.

The airframe has been engineered as a very strong and light airframe. The materials and construction method used were chosen for known confidence in quality and known capabilities. The airframe has been designed to perform with high stability and docile characteristics.

The hardware in the mission payload and avionics involve many types of hardware, power requirements, and radio frequency generators and tolerances. The payload and avionics will be shielded and tested at all points in implementation to prevent interference and failure. Vibration tolerances were also accounted for by isolation of safety critical and mission-critical items. A full AAV system checklist was written and followed for every change in the AAV configuration. This checklist will be run after any change in either airframe or electronic implementation.

All payload devices were designed and/or implemented with their own discrete power supplies and thus will not be co-dependent upon the power supplies of other devices. This avoids any potential power problems, interference problems, and protects the operation of the MicroPilot. The operation of the MicroPilot is important. The operation of the Radio Control system however, was deemed the most important.

The Radio Control system is the foundation for fault recovery and AAV recovery if the MicroPilot should fail. The MicroPilot is second in the hierarchy of criticality. The MicroPilot will be tested extensively for highly reliable operation of the AAV and navigation accuracy. The Mission Payload was specifically designed and implemented to ensure no interference with items higher in the chain of critical hardware.

9. APPENDICES:

Appendix I:

UAV Result Characteristics Comparison

	UAV PROPOSED	UAV FINAL
Cruise Mach No.	0.065 (35 mph)	0.0712 (54 mph)
Maximum Mach No.	0.12 (90 mph)	.12 (90 mph)
Cruise Altitude (ft)	100	200
Max. T-O Weight (lbs)	25	35
Empty Weight (lbs)	15	23
Range (ft)	2300	2500
T-O Distance (ft)	100	132
Landing Distance (ft)	100	525
Payload (lbs)	10	10

Appendix II:

Design Parameters

	SPECIFICATION	UNITS
Aspect Ratio	10.4	
Wing Area	16.25	ft^2
Wing Span	13	ft
W/S	2	lb/ft^2
C_L max	1.2	
Fuselage Length	6.8	ft
Fuselage Diameter	1.5	ft
Weight Take-Off	35	lbs
Weight Landing	33	lbs
Total Viscous Drag	5	lbs
C_D Coefficient	0.026	
Engine Thrust	19	lbs
T/W	0.55	

Appendix III:
Jaguar Single Board PC Specifications

Model Number: EPM-CPU-10m - Intel Celeron 350 MHz (equiv) extended temp.
Accessories: Dual USB transition cable. Type I/II Compact Flash adapter. 96 MB DiskOnChip Flash module. 128 MB SDRAM module
[Specifications are typical at 25°C with 5.0V supply unless otherwise noted]
Chipset: Intel 440BX
System Reset: Vcc sensing, resets below 4.70V typical. Watchdog timeout
Compatibility: PC/104, except board width; PC/104-Plus – Full compliance.
Board Size: 3.95” x 3.775”
Operating Temperature: – 40° C to +75° C free air, no airflow.
Bus Speed: CPU External: 66/100 MHz: PCI: PC/104: 8 MHz
Humidity: Less than 95%, non-condensing
Power Requirements: 5V ±5% @ 3.52A typical. 17.60 W
DRAM Interface: One 144-pin SODIMM, 256 MB of 3.3V SDRAM
Flash Interface: One 32-pin JEDEC DIP socket. M-Systems DiskOnChip
Video Interface: ATI Rage Mobility chip AGP interface and 4 MB integrated RAM. CRT, LVDS and DVO (TTL) outputs. Resolutions up to 1280x1024 with 16.7 million displayable colors. Supports MPEG-2, 3-D, edge anti-aliasing, specular shading and texture mapping.
COM 1 Interface: RS-232, 16C550 compatible, 115K baud max.
COM 2 Interface: RS-232/422/485, 16C550 compatible, 460K baud max.
LPT Interface: Bidirectional/EPP/ECP compatible.
USB Interface: Two user ports (1.1 protocols).
PCMCIA Interface: Vadem VG-468 Chipset (register compatible with Intel 82365SL) PC/104; Type I, II, and III compatible
Operating Systems: Linux
BIOS: General Software Embedded BIOS with OEM Enhancements.

Appendix IV:
Kodak EasyShare DX6440 Zoom Digital Camera Specifications

Color: 24-bit
Dimensions: W: 109 mm D: 38 mm H: 64.5 mm Wt: 220 g w/battery and card
File Format: Still JPEG/EXIF v2.2
Range Wide: 1.6-16.7 ft (0.5-5.1 m) f/2.4
Image sensor: 1/2.5 in. interline transfer CCD, 4:3 aspect ratio, 2408 x 1758 pixels
Aperture Wide: f/2.2 - f/5.6; Tele: f/4.8 - f/13
Focal Length: 33 - 132 mm
Focus Distance Standard Wide: 19.7 in. (50 cm) to infinity
Operating Temperature: 32 to 104° F (0 to 40° C)
Picture/Video Storage: 16 MB internal; SD Card 128 MB; Image Storage Auto
Pixel Resolution: Best 2304 x 1728 (4.0 M) pixels
Landscape: Wide: 1/2200-1/60 sec
Night: 1/2200 to 1/2 sec.

Appendix V:
9XStream is MaxStream Radio Modems Specifications

Connection: Plug-and-communicate (default mode - no configuration required).
True peer-to-peer network (no need to configure a "Master" radio). Transparent mode supports existing software applications and legacy systems.
Data Handling: Addressing capabilities provide point-to-point and point-to-multipoint networks. Uses Standard AT commands and/or fast binary commands for changing parameters. Retry and acknowledgements of packets provides guaranteed delivery of critical packets in difficult environments. 9th bit parity support (None, Even, Odd, Mark, Space)
Protocol Support: Native RS485/422 (multi-drop bus) protocol support.
Modes: Multiple low power modes including shutdown pin, cyclic sleep and serial port sleep for current consumption as low as 26 µA.
Baud Rates: Host interface baud rates from 1200 to 57600 bps.
Monitoring: Signal strength register for link quality monitoring and debugging.

Appendix VI:
Silver ORiNOCO 802.11b/g PC Card Wi-Fi Networking System Specifications

Bus: CardBus Type-II slot. Connector for external range extender antenna.
Certifications & Standards: - IEEE 802.11B IEEE 802.11G IEEE 802.1x
Physical characteristics: Dimensions: 4.79 x 2.12 x 0.19
Environmental Conditions:
  Temperature: 0 to 55 C, (operating)
  Humidity: 90% non-condensing, (operating) 95% non-condensing (Storage)
Power description: Input Voltage: 3.3V DC 0.2V DC
Ports: 1 x, radio-Ethernet
Protocols Supported: Csma/CA
Frequency band/bandwidth: 2400 to 2484MHZ
Transmission speed: 6 to 54MBPS (IEEE 802.11G) 1 to 11MBPS (IEEE 802.11B)
Transmit power: 60 MW (maximum) (IEEE 802.11G) 85 MW (IEEE 802.11B)
Modulation: - 802.11G orthogonal Frequency division modulation (64, QAM, 16 QAM, QPSK, BPSK) 802.11B Direct sequence spread spectrum (CCK, DQPSK, DBPSK)

Appendix VII:
AAV Budget and Cost:

ITEM	RETAIL	ACTUAL	EXPLANATION
VersaLogic EPM-CPU-10	$1,225.00	$0.00	Donation
MicroPilot MP2028g	$5,000.00	$0.00	Donation
MicroPilot - AGL Board	$500.00	$0.00	Donation
9XStream - Radio Modems	$180.00	$0.00	Donation
Kodak DX6440 Camera	$284.00	$284.00	Actual Cost
Camera Gyro and Servo	$96.00	$96.00	Actual Cost
Silver ORiNOCO PC Card	$45.00	$0.00	Donation
Radio Control RX and TX	$1,119.00	$0.00	Donation
A/C Components and Material	$1,200.00	$1,200.00	Approx. as of 15May2004
Electronics and Material	$360.00	$360.00	Approx. as of 15May2004
Support and Power Equipment	$847.00	$847.00	Approx. as of 15May2004
TOTALS	$10,856.00	$2,787.00	Approx. as of 15May2004

REFERENCES:

Versalogic EPM-CPU-10M Jaguar Manual
http://www.versalogic.com/Products/Manuals/MEPMCPU10.pdf

Kodak DX6440 Manual
http://www.kodak.com/global/en/service/products/ekn027036.jhtml

MP 2028g MicroPilot Manual
http://www.micropilot.com/resources/manuals/Manual-MP2028.pdf

MaxStream 9XStream Manual
http://www.maxstream.net/products/xstream/module/manual_XStream-OEM-RF-Module_v4.29.pdf

ORiNOCO 11B/G PC Card Manual
http://www.proxim.com/learn/library/datasheets/11bgpccard.pdf