# Team Manitoba Project Description

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**Abstract**

The 2008 entry to the AUVSI Student UAS competition by the University of Manitoba was motivated by the desire to increase the number of options for future teams. By replacing the still image payload with a new video-based payload, live target tracking by a human operator became more achievable. Other incremental improvements were made to the aircraft design and a newer model autopilot was selected for this year. We have implemented a JAUS component and intend to demonstrate it at the competition.

Figure 1: 2008 Entry Photo

# 1 Systems Engineering Approach

## 1.1 Mission and Requirements Analysis

The flight mission posed as part of the Student UAS Competition comprises two general operations: autonomous navigation of explicit waypoints provided by the judges and autonomous search of an area for ground targets. While the first problem is largely solved, the second tends to pose more of a challenge as well as providing more opportunity for innovation.

Postmortem discussions by the University of Manitoba's 2007 team included an expression of interest in helicopters as an air vehicle platform. Helicopters are capable of essentially the same flight operations as a fixed-wing aircraft with the addition of the ability to hover. When performing target surveillance, such an ability would prove to be very useful. However, because of limited team size and limited experience with rotary-wing aircraft, it was decided that a more conservative approach be taken for the 2008 entry.

The second issue taken into consideration was the goal to provide target information reports while still flying. This implies that the operator interfaces to the system must be easy to use to ensure that it is both possible to detect a target during flight and potentially command a change to the flight plan to better observe the target.

Commercial off-the-shelf hardware has, over the years, played a significant role in the implementation of our systems. By purchasing certain hardware which may be too time consuming, expensive, or complex to develop on our own, we are able to focus our efforts on integration and mission-specific components. In addition to commercial hardware, we have a collection of legacy hardware and software from previous years which gives us the opportunity to take advantage of past knowledge and effort to, again, reduce the amount of work necessary for building a new system.

## 1.2 Design Rationale

Although we have an interest in developing a helicopter flight platform at some point in the future, the decision was made for this year to forgo drastic changes to the air vehicle. Because of the inherent complexity in the design and construction of a rotary-wing vehicle and the limited experience of our team with such, we decided to take a staged approach. This year was the first phase of a modification to our traditional platform and has left many possible directions for next year's team.

Rather than begin by changing the air vehicle, we have decided to redesign our payload and associated ground systems. While the intention is for these new components to be used in a helicopter, they will function equally well if future teams decide to continue with a fixed-wing aircraft. The most obvious change for our payload was the move from still image equipment to video equipment. We believe this allows an operator better opportunity to see a target in near-real time and command a change to the flight pattern to obtain better imagery. The ability to obtain multiple frames per second which display a target will allow more accurate estimates of the target's position to be calculated. In addition, a video-based system will be more tolerant of lost frames due to increased quantity compared to still image coverage.

Another desired feature was the use of the autopilot to provide coarse camera stabilization and aiming. Because these features were already implemented in the autopilot and autopilot ground station software, they did not need to be implemented from scratch.

# 2 Descriptions of UAS Component Design

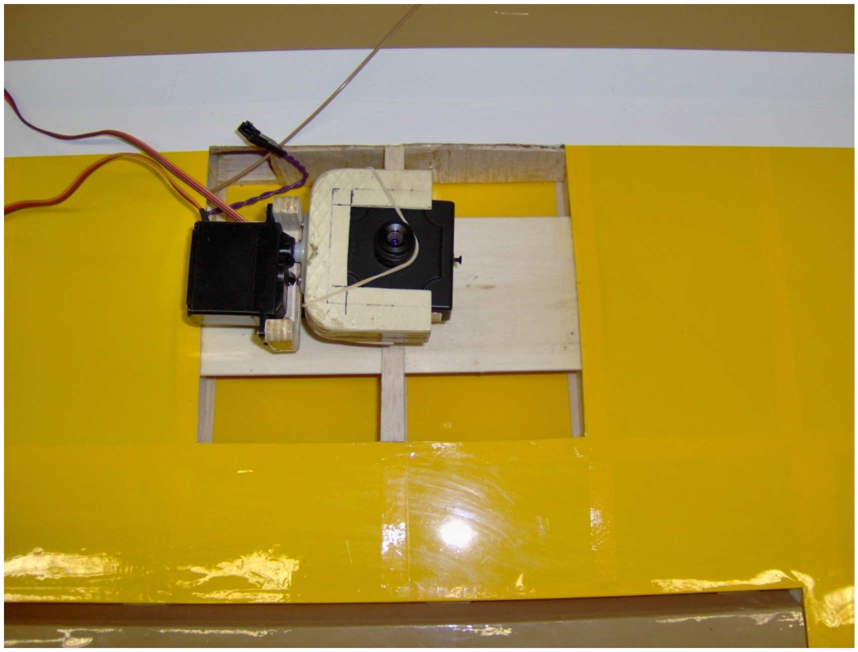
## 2.1 Air Vehicle

Stability was the main factor considered when deciding on the airframe for this year's entry. Rather than trying out new carrier methods for our payload, we decided to use the same modified Sig Kadet Senior airframe from last year. A second plane was built to the same specifications as a precautionary measure to ensure we would have a plane to fly for the competition in the event one failed.

Like last year's plane, the frame was increased from the standard Sig Kadet Senior plans by 5% to provide adequate space for our payload within the fuselage. The horizontal and vertical stabilizers were again changed to airfoils and outboard ailerons were installed in the wings. In the event that one of the planes crash, the main landing gear, made from 7075 aircraft-grade aluminum, can be salvaged from the wreckage and installed on the remaining airframe. Similarly, the OS .70 cubic inch four-stroke engine, wings, and horizontal and vertical stabilizers can be transferred between the planes if need be.

Several modifications were made to this year's airframe with regard to the placement of the cameras. The first camera (shown in Figure 2) provides a telephoto view and was gimbal-mounted in the left wing about a third of the way in from the tip and was counter balanced in the right wing. A second camera (shown in Figure 3) provides a wide-angle view and was hard mounted to the bottom of the fuselage directly in front of the main

Figure 2: Wing-mounted telephoto camera and gimbal mount



landing gear. Both cameras were positioned to avoid losing visual range to blockage by the fuselage and other outboard components of the airframe. In order to accomodate for the sensitivity in the cameras, an alternate engine mount was chosen to dampen the vibrations from the engine.

The only other modification to the fuselage was in the installation of the fuel tank which was installed backwards in order to bring the fuel cutoff mechanism inside the fuselage.

The autopilot host platform was redesigned and rebuilt. By using a smaller, stiffer platform, stability of and access to the autopilot were improved. As usual, the autopilot platform was positioned to sit as close to the plane's centre of gravity as possible.

Three radios were required to handle communications for the autopilot data link and each of the two cameras. Due to the removal of unused computer hardware in the fuselage, there was plenty of space available for installation of those radios inside.

In order to accomodate different power distribution requirements, the regulator board designed for the 2007 entry [1] was reworked to also provide power to the cameras and video transmitters.

Figure 3: Fuselage-mounted wide-angle camera

## 2.2 Autopilot & Mission Planning

In order to have access to newer features, the decision was made to upgrade to Micropilot's MP2128g autopilot. With more processor power and additional memory, it is more capable than the previous models. However, we were able to continue using a familiar scripting language for mission planning and execution.

The autopilot supports features which satisfy requirements of the competition:

**Waypoint Navigation** An operator can graphically, or through a script file, define a series of waypoints for the aircraft to navigate. Altitude or airspeed changes may be commanded as a part of the script file.

**Autonomous Takeoff** The autopilot will perform an autonomous takeoff after being commanded to do so by an operator.

**Autonomous Landing** With an optional ultrasonic altitude sensor attached, the autopilot is capable of performing an autonomous landing on the runway from which it began or at some other runway which has been defined in advance. The ultrasonic sensor is a necessary addition due to lack of confidence in GPS-based altitude calculation.

**Flight Patterns** An operator may define a set of ”flight patterns” which involve coordinates relative to the aircraft position at the initiation of the pattern. One such pattern, for example, will command the plane to circle a certain location. This would be used to allow extended observation of a potential or actual target.

Upon completion of the pattern, the autopilot will resume executing its previous flight plan.

**Error Handling** In a way similar to its flight patterns, the autopilot also supports a set of error handling patterns. An example of where one might use such a pattern is upon loss of data link to the ground station. The standard error pattern defined by the autopilot would be to fly towards to takeoff location in an attempt to reestablish the data link. These error patterns may be replaced by user-defined operations.

## 2.3 Data Link

The MP2128g and associated ground station computer are each connected to a 2.4 GHz radio modem. These transmit an RS-232 signal between the ground station and autopilot. Included in the standard telemetry are position and attitude information, airspeed, ground speed (from GPS), rate of change of altitude, and heading. Camera orientation, projected view area, and servo positions are also included.

The telemetry packets are normally transmitted at 5 Hz, but do not include the entire set of telemetry data in each packet. Some important fields (such as position and attitude) are transmitted in each packet while others are limited to 1 Hz updates.

## 2.4 Ground Control Station

The ground control station software consists of a few different modules. Horizon, the autopilot’s ground interface software, is responsible for interfacing with the autopilot and providing situational awareness to the operator. A map display as well as artificial horizon, altitude and airspeed gauges, are presented to the user. Controls are available for the initiation of user-defined patterns as well as camera target selection. In most cases, the movable camera will be controlled by selecting a ground location to keep in view. The autopilot will attempt to move the camera’s gimbal servos such that the selected location remains visible to the camera.

Horizon allows video captured by a DirectX video device to be displayed in a window. Because this tends to obscure important flight information, during the competition we will likely use a second monitor to display the video stream.

A new feature in Horizon allows users to define map overlays. In past versions of the software, this kind of graphical modification had to be performed by manually editing the map image file. By drawing the overlays in software, modifications can be made more easily.

## 2.5 Payload

### 2.5.1 Cameras

One of our goals for this year's competition is the ability to acquire targets while the vehicle is in the air. In order to achieve this capability, two small-sized capture devices will be used for image acquisition. Each camera has a resolution of 768 x 494 pixels.

As described in section 2.1, a wide-angle camera is mounted in the plane's left wing and a telephoto camera is mounted in the bottom of the fuselage. The wide-angle camera is mounted on a gimbal (described below in section 2.5.2).

Compared to the Canon A620 used for 2007 competition vehicle, the new cameras are capturing images at a lower resolution but allow the operator to view a smooth video feed in real-time. In addition, the compact frame of the cameras reduced the payload size and, thus, more room inside the plane is available for additional electronics in the future.

### 2.5.2 Camera Gimbal

Our first gimbal was a commercial unit designed to work with the camera to which it was attached. However, problems with camera vibration led us to design a custom gimbal mount which helped move the camera closer to the axes of rotation. Additionally, some play in the servos evident in the old design was able to be reduced. The camera gimbal has two servos which provide nearly 180 degree pitch and yaw control.

### 2.5.3 Video Transmitter and Receiver

The video link between the ground control station and the vehicle is established by an RF video transmitter and receiver set. The set used supports 4 channels on 910 MHz, 980 MHz, 1010 MHz and 1040 MHz.The RF output power of the transmitter is 500 mW.

Because the aircraft is constructed primarily of balsa, the video antennas can be kept inside the fuselage without risk of attenuation.

The video receiver includes a lithium polymer battery pack so there would is no need to power it externally. This is beneficial for the construction of a portable UAS control station.

### 2.5.4 Framegrabber

Two framegrabbers are used to capture two separate video feeds from the RF receivers. Their resolution is set to 720 x 480 (NTSC format) at about 30 frames per second. Video from these framegrabbers is presented to an operator for observation and target detection.

### 2.5.5 Autonomous Recognition Options

Although we have not implemented any autonomous target detection algorithms in our system this year, we have left that ability available for future entries.

Sobel edge detection could be used to mark out all interesting edges in the captured images. This would help the operator to identify interesting shapes and features more quickly. However,a high frame rate is necessary to make sure no areas would be lost due to time lag between frames. Therefore only two image frames per second would be processed. This is to make sure the video feed would not be interrupted due to computing time of the image processing algorithms.

Other image processing algorithms such as a feature detection algorithm, SURF, are considered but would not be employed. The reason isthat image processing tasks are often processor-intensive and the framegrabber is capturing images at relatively high frame rates. An efficient algorithm that is simple to compute is preferred and, thus, Sobel edge detection is a better choice. This would help the operator with the task of target aqquisition while being able to view a smooth video feed at the same time.

We also feel that such operator assistance algorithms are preferable to a process which might miss actual targets. If the algorithm does not find a target in the image, a human operator may still see something of interest.

# 3 Joint Architecture for Unmanned Systems (JAUS)

## 3.1 Learning About JAUS

Due to time constraints, our group was not able to develop a complete understanding of the JAUS system. However, it was decided that in order to complete the project, we would focus on learning about the specific messages to be implemented. The team focused on learning about the necessary components and their interfaces (the messages), and so some time was spent in familiarizing ourselves with part 2 of the Reference Architecture [3].

## 3.2 JAUS Message Integration

A basic implementation of the JAUS messaging system was accomplished by creating an interface between the autopilot control software and a UDP network socket. The onboard autopilot hardware and associated software make position, orientation, velocity, and other information available to the operator. This allowed us to write an SDK application that would query the autopilot for relevant information. Upon receiving UDP traffic matching the form of a Query message, the SDK application will query the autopilot for the requested information and return it in a properly-formatted JAUS message.

## 3.3 Challenges to Implementation

A few small obstacles were encountered in the incorporation of JAUS into our system. For example, the ”Position RMS” and ”Attitude RMS” values described in the JAUS specification [2] are not made available by our autopilot. We have attempted to provide similar functionality in our application without such access.

Although the JAUS standard is publicly available, the JAUS compliance test application was not made available to those outside the United States.

JAUS is intended to be a comprehensive system capable of commanding a large number of autonomous units. While the reference architecture documents provide a lot of detail about implementing a JAUS system, it is difficult to know which sections are relevant at which level(s) of the hierarchy. One potential improvement or addition we suggest is the creation of a set of tutorials or standards for what needs to be included in a JAUS system, subsystem, node, or component to aide implementation of that type of component. This sort of documentation would make it easier for those implementing only a portion of a JAUS hierarchy to know where to focus their attention.

# 4 Safety Considerations

Throughout the project, safety of mission operators and observers was a primary concern. Flight tests included the use of checklists to ensure that vital tasks were completed before takeoff was attempted. The autopilot failure events were configured to perform as required by the competition rules and a human safety pilot was always ready to take control of the vehicle in case of emergency.

In addition to flight operations, the actual construction process does present some hazards. Proper ventilation is required when working with certain solvents and dust masks, safety glasses, and disposable gloves were used when appropriate to prevent unsafe contact with materials.

# References

[1] Andrew Bugera, Andrew Oliver, Mo Ran Wang, and Rashed Minhaz. Team Manitoba 2007 AUVSI Student Competition Project Description. In *Association for Unmanned Vehicle Systems International (AUVSI): 5th Annual Student UAS Competition, Lexington Park, MD*, June 2007.

[2] JAUS Working Group. Reference Architecture Specification, Volume II, Part 1. Technical report.

[3] JAUS Working Group. Reference Architecture Specification, Volume II, Part 2. Technical report.