Northwestern Michigan College

2012 AUVSI Journal Entry

UAS

Unmanned Aerial Systems

NMC

Team Bios

Tony Sauerbrey- Certificated Flight Instructor with over 3,000 flight hours as a commercial pilot. Tony is our faculty adviser as Northwestern Michigan College's UAS Program Director. He has over 25 years of model aircraft experience and oversees NMC's new UAS program where training students on UAS operations.

Jeb Bailey- Commercial Pilot with both multi and single engine land ratings. Our Team Captain, Jeb is looking to become a professional UAS pilot.

Brad Kent- Commercial Pilot with both multi and single engine land ratings. Our Team's Logistics Coordinator with over $10,000 in grants and donations for the team. Brad is a business major with aspirations for UAS management.

Carl Rocheleau- Certificated Flight Instructor with over 3,800 flight hours. Carl enjoys spending free time in the hobby of RC aircraft. A professional pilot interested in the UAV field, Carl is an aviation major.

Eric Videan- Commercial Pilot with both multi and single engine land ratings. Eric enjoys taking any RC plane and modifying it to make it capable of aerobatic flight. Eric is our safety pilot along with being a Business Major. He plans to pursue flying UAV's or manned aircraft for a career.

Robert Spaulding- Self-motivated private pilot with multiple classes in the field of UAS. Pursuing a career in the field of UAV industrial and commercial markets, and the creation of uses for the future businesses.

Mason Groot-Instrument rated pilot. Our team's sensor operator. Mason is looking to get into the new and exciting field of UAS, along with pursuing a degree in aviation science and business

Tyler Ramsby- Certified Flight Instructor. Tyler is one of the founding members of the team with years of experience in video production.

Abstract

This paper will describe the challenges faced by the NMC UAS Team in developing a UAS capable of fulfilling the objectives faced during the AUVSI Student Competition. It will detail the process of selection or design of the Airframe, Powerplant, Autopilot and Data Link, Sensors and Video Link, and Mission Execution. This abstract provides an overview, followed by sections describing each system and specific reasons for the choices that were made regarding it.

A unique challenge was posed to the NMC team, as all members are pilots, not engineers. In fact, no member has any formal engineering training whatsoever. Because of this lack of experience in system design, most systems are off the shelf items, configured to operate together in ways that were sometimes never intended. Obviously this posed its own challenges, and has necessitated many revisions; in some cases complete changes in design direction.

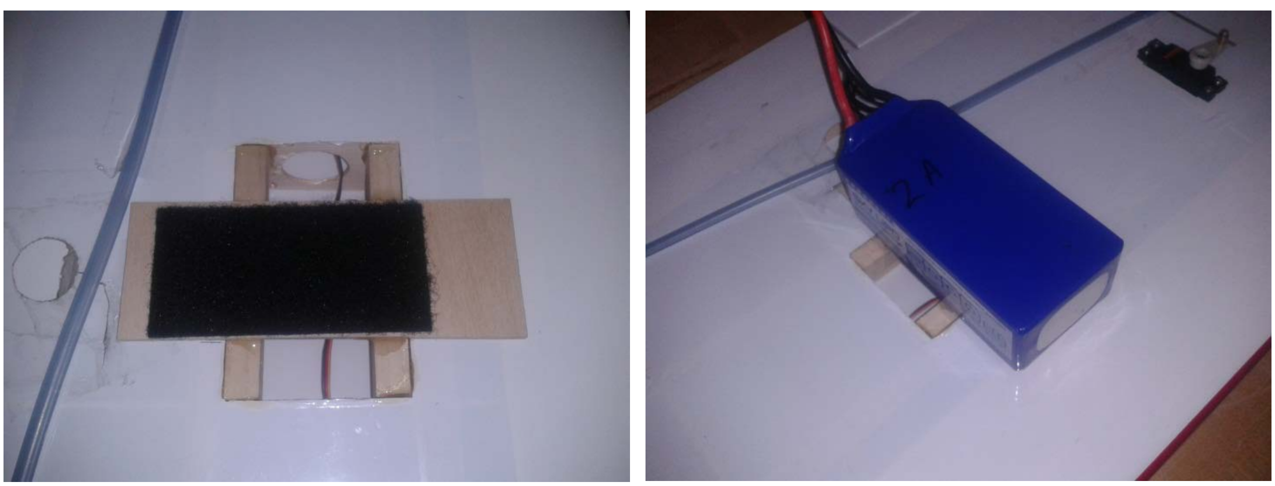
However the team is not without advantages. Each member of the team is a certified pilot, accustomed to learning and being comfortable with all aspects of flight. The familiarity lends itself well to UAS operations, where each member is able to learn every aspect of the operation; no one member is the only person able to troubleshoot a problem, or perform a task. Pilots are also intimately familiar with checklist usage, and division of attention meaning that very little gets skipped or goes unnoticed.

From the beginning our system has utilized a high lift electric trainer aircraft fitted with an autopilot, electro-optical camera, and control, data, and video links. The airframe has remained much the same, with only small modifications. All other systems have gone through at least one major revision.

Airframe

When choosing an airframe for the UAS, several factors were considered. The aircraft needed enough internal space to house the electronics, as well as sufficient lifting capacity to carry the weight of all the systems. It also needed to be stable, and easy to maintain. A Senior Telemaster was settled on, as it fit all the requirements and was readily available as an almost ready to fly kit.

Several modifications were made to the stock airframe, primarily strengthening the landing gear and wing struts, but also constructing frames within the fuselage to mount electronics. Because of the large size of the flight batteries, mounting points were constructed on the underside of each wing, freeing space inside the fuselage for other systems.



One mount under each wing moves the flight batteries outside the fuselage, but keeps weight balanced. Batteries are secured with industrial Velcro, and in dozens of test flights have never shifted position.

Power System

When choosing a power system, the team investigated two broad options: Gas or Electric. Gas had the advantage of a quick turnaround time, as well as constant performance throughout the flight time. Electric power tended to reduce in performance near the end of the flight batteries capacity, but it was determined that the aircraft would rarely if ever be in flight for long enough for this power loss to be an issue. The disadvantage to gas that eliminated it as a possiblility is exhaust. Several Ideas were examined for routing exhaust away from sensors and other electronics, but all were believed to add more weight than the airframe could handle. Electric power requires a long charging period for the flight batteries, but this disadvantage was eliminated with the purchase of three separate sets of batteries.

It was ultimately decided that the aircraft would be powered by an eflite power 60 400 Kv motor and a eighty amp switch mode battery eliminating circuit electronic speed controller also by eflite. This system has provided adequate performance for the aircraft even with the load it will be carrying. The plane will also be carrying two, six cell 22.2 volt 5000 milliamp/hour batteries putting out 150 amps. A few variations of motors, battery sizes, props and accessory power sources to produce the results needed to achieve the optimal run time for performance match. Using a slightly smaller motor it has been concluded that we will get a much higher run time. Since having great climb performance and speed is not vital in this competition the plane is able to use a lower power plant to carry it through the air in a more efficient manor giving it the increased run time, and enough speed and climb performance to accomplish the mission given.

Using a 15/8 propeller lets this plane achieve a few things. The propeller being used is from American Propeller Company (APC) which has a much more aggressive pitch towards the hub and a much flatter pitch towards the tip keeping the propulsion level through the blade as even as possible. The more aggressive pitch towards the hub will generate much more airflow at low rpm than any other standard prop out there.. Turning higher rpm's than using a higher pitched smaller diameter prop will allow the plane to climb much better and also have a shorter takeoff roll. If a larger diameter propeller with a lower pitch was used the plane would climb much better even yet but would be too slow for safe flight under a low power setting in cruise which using the lower power is how the longer run times are achieved. Using the high pitch small diameter prop would make the plane not want to take off or climb very well at all and also would have a tendency to want to fly too fast in cruise and again running too high of rpm shortening the run times.

Using the eighty amp speed controller allows the plane to run very high voltage as well as keeping within a safe operating range for both the motor and the esc. Before incorporation of the auto pilot, calculations showed that our run times on two, six cell 5000 milliamp/hour batteries would allow the plane to run stay airborne for about one hour at approximately fifty percent throttle. After plugging in the autopilot and having a successful first flight the plane only flew for about 37 minutes before running out of power. This is when the decision was made to revisit the drawing board and decide amongst a few different options; different power plant, different airframe, cut weight or add more batteries. The final decision was fairly simple. Build a pod to be fastened to the belly of the fuselage to preserve the space inside the plane as well as make them much easier to access. As far as aerodynamics are concerned, having this pod on the bottom of the airframe will affect how the plane flies, but this effect will be very unnoticeable due to the relatively slow speeds of the aircraft.

At first just doing some static tests, it was decided that a five-cell battery would not produce the power necessary to carry this plane with all of its equipment very effectively. That’s when the six-cell choice was made and has been used ever since the motor had been mounted to the plane. The power system cannot safely operate with a larger voltage battery per operators manual therefore the choice became very easy.

Autopilot

In choosing an autopilot, several primary requirements were established. The autopilot need to be capable of:

- Autonomous Navigation
- In-Flight Retasking
- Camera Control
- Real-Time Data Transmission
- Datalogging
- Custom Programming

The selected autopilot would also need to be inexpensive, simple to operate, and simple to integrate

The original design used the open-source ArduPilotMega autopilot. This was selected for its simplicity, low price, and the team's previous familiarity with the system. However, after extensive testing, it was found to lack some functionality. It also proved difficult to tune to the Telemaster airframe. In the end, it was decided to make the switch to the Micropilot 2128LRC. The Micropilot was a much more expensive choice, but the team was lucky enough to receive one on loan from NMC's Aviation Department. It is also a more complex system, but met all requirements.

Communications

A primary goal was to create a stable and reliable communication method between the aircraft and the ground systems. Two frequencies were ultimately selected.

1. 1.2 ghz for video transmission from the aircraft to the ground system
2. 2.4 ghz for the safety pilot's manual control override and camera pan/tilt controls

Image Downlink

For video transmission, a Lawmate 1W transmitter operating on 1.2 ghz was selected based on price, transmission range, and the unlikelihood of other equipment operating on the 1.2 band.

Video is transmitted from the aircraft in real time, and received by the ground station. The imagery is then manually analyzed by the sensor operator and his assistant. The video is stored on the hard drive of the control station and displayed on the second monitor. This allows us to review the video of the flight after the flight has been terminated, granting the ability to analyze the results in extreme detail.

Initially our camera system was controlled by a standard RC transmitter on the 2.4 ghz frequency. This required a separate RC receiver to be installed on the aircraft, to which was connected the pan/tilt gimbal and zoom control of the camera. Concern was raised over of the use of two transmitters occupying the 2.4 band, but after extensive testing that concern was found to be unfounded. After the switch to the Micropilot, camera control was transferred to the autopilot. This switch enabled additional functionality, as well as removing the need for a second RC receiver.

Telemetry

Telemetry is provided through the Micropilot LRC (Long Range Communication) modem. It operates on the 2.4ghz frequency, reducing the chance of interference through spread spectrum technology.

Aircraft Safety Override

The aircraft can have the flight controls switched by both the systems operator at the computer and the safety pilot on the override transmitter. The safety pilot uses a Spektrum dx8 transmitter bound to the aircraft, going through the Micropilot, to control the aircraft. At anytime the safety-pilot can take control from the autopilot. This is accomplished through the use of a dedicated toggle switch on the transmitter, when placed in the auto-mode the autopilot has control, and when switched into the manual mode the safety pilot will always have control. This guarantees that there will always be positive control of the aircraft.

CRM

Given NMC's focus on mission execution, the team decided to apply many of the same practices used in manned flight. Among these were checklist usage, sterile environment procedures, standardized phraseology, and most importantly crew resource management.

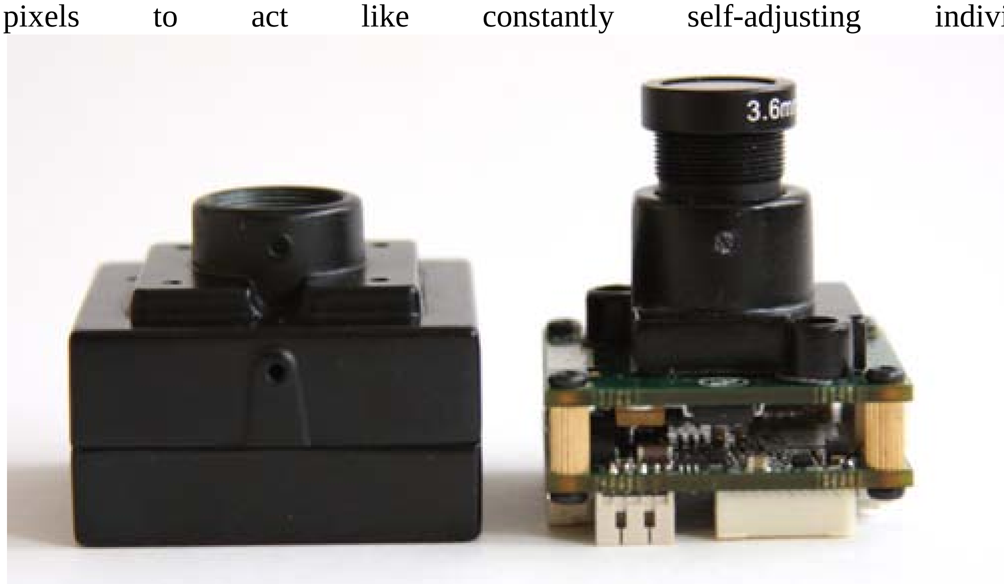
Crew Resource Management (CRM) can be defined as a management system which makes optimum use of all available resources - equipment, procedures and people - to promote safety and enhance the efficiency of flight operations. CRM is concerned not so much with the technical knowledge and skills required to operate equipment but rather with the cognitive and interpersonal skills needed to manage resources within an organized system. CRM aims to foster a climate or culture where the freedom to respectfully question authority is encouraged. However, the primary goal of CRM is enhanced situational awareness, self awareness, leadership, assertiveness, decision making, flexibility, adaptability, event and mission analysis, and communication. It recognizes that a discrepancy between what is happening and what should be happening is often the first indicator that an error is occurring.

NMC decided to approach CRM by assigning each team member to an operational specialty. All team members are to have at least a basic understanding of each operational area's requirements and functionality, so that in times of interaction each team member is aware of the others needs and expectations. Some operational areas were assigned multiple team members for assisting in times of high work load, while other team members were trained in multiple areas of operation so that they could assist where needed in times of higher workload. It was decided that our team captain would oversee the interaction of all operational areas, and give the final command decisions after receiving reports from each operational area. This structure would provide experts in each area that know what to expect from each and every team member as well as what each team member is expecting from them; it would also supply all necessary information to a team leader who can make the crucial decisions needed to make the team succeed. Each team member is encouraged to analyze decisions handed down and bring issues of concern to the attention of other team members immediately.

Communication between team members is to be clear and concise, without the use of non standard terms or slang, at all times. Additionally, during UAS mission operations, communication will be limited to systems operation and mission information only (Sterile UAS Area). This prevents confusion between team members when swift action needs to be taken, also prevents crewmembers from being distracted from their duties by engaging in non-essential conversations and activities during critical parts of the UAS flight operation. Policy was set that checklists were to be used for all UAS operations by team members. This also provides a standard that all team members are familiar with; therefore deviations from this norm can be easily spotted by any crewmember and quickly brought to the teamcaptain's attention.

IMAGERY

When designing NMC's UAS, the original design used the digital pixel system DX201 DPS camera. Unlike traditional cameras, where each pixel cannot adjust to highlights and lowlights in the same scene, Pixim's Digital Pixel System technology empowers hundreds of thousands of pixels to act like constantly self-adjusting individual cameras.



Though the DX201 DPS camera was good for a while, an upgrade was needed. Due to the lack of high quality pictures and the option for zoom. The switch was made to the FoxTechfpv FH-10Z 10X zoom camera.

In switching to the FH-10Z, the camera offered many of the same if not better options than the digital pixel system DX201. It's small dimensions, 56.2 mm(L)×38.5 mm(W)×32 mm(H), giving the perfect fit for the Telemaster airframe. Some of the better options it gave, allowed for a lightweight camera that gave both a high resolution picture and offered 10X optical zoom.

The first camera was mounted to a pan tilt system called the SPT200. Though it worked with the first camera, its features did not work well with FH-10Z camera. The SPT200 didn't provide the range of movement required, and was difficult to mount the FH-10Z camera on.

A custom gimbal was designed with the aid of NMC's advanced manufacturing program, and rapid prototyped on a 3D printer. This new gimbal met all of the requirements for the FH-10Z camera, and also proved to be a lighter option that also provided more ground clearance when mounted to the belly of the fuselage.