UNIVERSITY OF PUERTO RICO
MAYAGÜEZ CAMPUS
COLLEGE OF ENGINEERING

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Abstract **– The following paper presents the design developed by the University of Puerto Rico, Mayagüez Campus that has meet with the mission presented by the Association for Unmanned Vehicle Systems International's (AUVSI) rules and will compete in the 2007 AUVSI's Student UAV Competition. The purpose of the aircraft is to be able to navigate through a predetermined course autonomously, meaning with a pilot physically at the controls. Furthermore, the aircraft will fly pass so-called Global Positioning System (GPS) waypoints in order to arrive to a search zone. In such area, by utilizing onboard imagery systems, the aircraft purpose is to find and determine the identity of the targets. The system found on the UPRM-*ALPHA* autonomous aircraft were designed and fabricated with household materials and store bought components. The design, research, and fabrication of the aircraft are divided into four main areas and their corresponding sub-area: aircraft assembly, autopilot, imagery, and the ground control station. Safety systems, such as pilot over-ride, were design and placed on the aircraft in order to reduce risk factor during the flight of the aircraft.**

I. NOMENCLATURE

AGL	Above Ground Level
AMA	American Model Academy
ARF	Almost Ready-to-Fly aircraft
CAD	Computer Aided Design
CG	Center of Gravity
FM	Frequency Modulation
GCS	Ground Control Station
GPS	Global Positioning System
Li-Ion	Lithium Ion Battery
MP	MicroPilot Autopilot System
MSL	Mean Sea Level
Ni-Cd	Nickel – Cadmium Battery
Ni-Mh	Nickel – Metal – Hydride Battery
RM	Radio Modem
Rx	Receiver
Tx	Transmitter
UAV	Unmanned Aerial Vehicle
UPRM	University of Puerto Rico at Mayagüez
USB	Universal Serial Bus

INTRODUCTION

In the last century the aerospace industry has seen a great technological boom. From the Wright Brother's first flight all the way to the Space Shuttle, new

SKYHAWK autonomous aircraft
http://www.me.uprm.edu/Organizations/autonomousaircraft

breakthroughs have constantly paved the way for new technologies to emerge. The Unmanned Aerial Vehicle (UAV) is part of the new era of technological marvels. Since 1902 aircraft have gotten bigger, faster and more dependable. With advancement in technology and efficiency came a greater demand for aircraft usage. Aircraft use has become so widespread that they are now a vital part in our global economy. Recent achievements have allowed aircraft to perform simple tasks without requiring direct human interaction. These advancements allow the use automated airplanes to perform simple or dangerous tasks with a lower cost and without endangering human lives. The term Unmanned Aerial Vehicle stands for any air vehicle capable of sustaining flight without an onboard crew; it could fly autonomously or piloted remotely. Unmanned vehicles have long existed, simple radio controlled airplanes are nothing new. Autonomous vehicles offer a degree of independent flight, able to guide themselves to given waypoints and perform specific tasks without any or little human interaction. Radio control does not offer this independence. The uses for this booming technology are mainly military reconnaissance, civilian surveillance and mobile signal transmission. Recently the uses extend to law enforcement agencies and the planetary exploration of Mars. These aircraft come in all shapes and sizes, from simple hand size micro planes with small video cameras attached, to full size autonomous planes able to fly for long periods of time. The various sizes enable these aircraft to adapt to different roles and capabilities. The future for this technology certainly looks bright. These vehicles can one day be used for more than military tasks. They can be used to gather meteorological information like hurricane hunters. They could be used for search and rescue operations and, since these aircraft don't require human control, they could stay on station searching for a much longer period than regular aircraft. They could also be used to quickly and inexpensively transport goods like medical supplies.

A. Project & Competition Description

The Association for Unmanned Vehicle Systems International (AUVSI) is the world's largest organization devoted exclusively to advancing the unmanned systems. They not only promote the design and construction of any type of autonomous system but look for ways to incorporate this technology into everyday life. With this objective in mind the AUVSI association organized a series of competitions involving autonomous systems and college students. The Student UAV Competition challenges young college undergraduates to design, build and fly a fully autonomous aircraft able to guide itself through a specified route, with as little human interaction as possible, while taking photographs of several targets with its on-board camera system. Once the pictures are taken the team must identify what the targets are and determine their coordinates along with their orientation. Due to the complexity of the mission, the aircraft will require a great deal of sophisticated equipment, ranging from GPS tracking systems to remote camera systems. The SkyHawk team is rising up to this challenge, but it will not be a simple task. The entire aircraft system will be composed of four main sub-systems: the autopilot GPS system, imaging system, ground control station and aircraft design. The autopilot GPS system will be responsible for the guidance and control of the vehicle during flight. The imaging system is in charge of tracking and identifying the targets on the ground with the onboard camera. The ground station system will be in charge of communication between the aircraft and the team as well as receiving the photographic and video transmissions. The aircraft design will deal with the construction and design of the vehicle itself. In the following sections of this document there will be more specific descriptions of each of the UAV's major components and how they work.

A. Problem Description

The problem description is to challenge a new generation of undergraduate university engineers to design and build unmanned aerial vehicles (UAVs) capable of performing realistic autonomous missions in an aviation environment, and to foster ties between young engineers and the organizations developing UAV technologies.

B. Mission and Vision

The SkyHawk Team is determined to design, build and fly a fully autonomous aerial vehicle that will compete in the 2007 AUVSI's Student UAV competition and will be able to fulfill with excellence all the stated mission goals. This is the FIRST time that a team from Puerto Rico will participate in this competition. In the time preceding the competition our team had to design and built a radio controlled (RC) airplane in compliance with the rules of the Academy of Model Aeronautics (AMA) to fly between 100 and 750 ft Mean Sea Level (MSL). We will equip the vehicle with a GPS guidance system and with an advanced imaging system. These will allow the airplane to fly fully autonomously with no direct human control and will allow the team to photograph and identify the targets that will be placed along the competition course. To control the UAV the SkyHawk Team built a ground control station that receives all the programming inputs from the team and receive all the GPS and photographic data. Our team is divided into four sub-groups, each handling a specific aspect of the UAV's creation. Each of the four sub-groups are working simultaneously in their specialty while ensuring that each team member learns about all systems.

C. Team Members

1. **Pablo R. Mejías Santiago,** ***Team Captain, Pilot and GPS Control Design***
2. **Oscar Rivera,** ***Ground Station Member Secretary and Webmaster***
3. **Josué M. Díaz Hernández,** ***Public Relations Officer and Vehicle Design***
4. **Antonio J Cosme,** ***Ground Station Design***
5. **Ramón J. González,** ***Ground Station and GPS Control Design***
6. **Paola Mercado Dohnert,** ***Administrative Officer***
7. **Rauluy Santos Collado,** ***Administrative Officer***
8. **Dr. David Dooner,** ***Faculty Advisor***

D. Alpha UAV

This is the first time that Puerto Rico will participate in this competition. It is from this that Alpha UAV gets its name. First, we chose to use an Almost-Ready-to-Fly (ARF) Decathlon as an experimental aircraft (Flying tests) but we had to change it to another model because its airfoil was semi-symmetrical. Semi-symmetrical airfoil has less lift force than the flat-bottom airfoil. We had to choose another model with this type of airfoil. Our research of aircraft models ended when we chose the ARF Kadet Senior. Kadet Senior has 80.5" of wingspan and provides massive lifting ability. Lift force is the most important factor to this aircraft for better mission performance. Also, we had to change the color of the Senior Kadet to our Institution official colors (White and Green).

Our Red Decathlon (Alpha) as an Experimental Aircraft

This modified Kadet Senior (Alpha UAV) will compete in the 2007 Student UAV Competition

D. Aircraft Specifications

Alpha UAV Specs

Detail	Metric	US
Wingspan	2044.7mm	80.5 inches
Wing Area	76.1dm^2	1180 sq. in.
Length	1644.6mm	64.75 in.
CG	98mm	3 7/8 inches
Gross Weight	6.58 Kg	14.5 lb.
Fuel Tank	709.56mL	24 Fl. oz.

E. Alpha UAV System

CAMERA AND ROTATING SYSTEM

Alpha's rotating mechanism is located in the lowest point of the aircraft to capture better picture quality. Alpha's rotating mechanism was re-designed and substituted by an all-aluminum pan/tilt mount with interval movement to improve better field of view from its location. A 450 TV line High Resolution Camera is mounted in this rotating system with multicoated lens for sunlight protection.

Specifications	NTSC
Pick Up Device	1/4" image sensor
Picture Element	542(H) x 492(V)
Resolution	450 TV line
Video Out	Composite 1.0 VP / 75 OHM
Horizontal Frequency	15.734 KHz
Vertical Frequency	60 Hz
Power Source	DC 12V
Weight	10.5 oz

The camera is mounted in the rotating system and Computer Aided Design (CAD) model.

COMMUNICATIONS

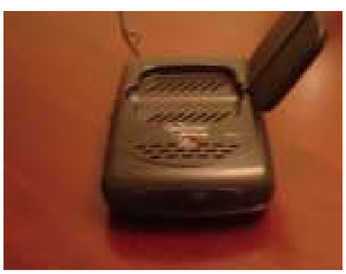
Futaba Radio Control

Communications consists of a Futaba 72 MHz PCM 7-channel Radio Control. Alpha operates in two bands: 43 & 48 on 72 MHz. The Radio is multi-purposes, in case of airplane fail we can use the Transmitter and return it into manual mode.

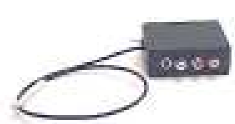
72 MHz PCM 7-Channels Transmitter for manual control

Camera Transmitter

A powerful 1.5 mile camera transmitter provides clear images under any conditions from any altitude. All the specs of the camera help to acquire great images from the targets and objects. This is a universal transmitter and any camera is compatible with this device.



Standard Receiver Hook Up



1.5 Mile Transmitter

The receiver operates on 12 volts DC about 360mA. The ON and OFF power switch is located on the side. The rear RCA jacks are outputs, Yellow-Video, Red-Audio (right side), and White-Audio (left side). Use the supplied Video & Audio cable to hook up the receiver outputs to your TV monitor Video / Audio inputs. The DC power cord plugs into the DC jack next to the Yellow RCA jack. The receiver antenna is adjustable, point towards the transmitter.

The transmitter operates on 12 volts DC about 250mA. The transmitter RCA jacks are inputs, Yellow-Video, Red-Audio (right side), and White-Audio (left side).

Safety

Safety is first. Alpha is equipped with innovative safety devices as a safe circuit that controls all the servos if the signal is lost or low voltage, a battery backer Back-Up system and RC integrated throttle-cut switch.

Battery Back-Up System

RC Integrated Throttle Cut Switch

Fail-Safe circuit board

UAV Power

Alpha UAV is powered by an O.S. 70 (11.5cc) Surpass four-stroke engine. Four stroke engines are more efficient in fuel consumption than the two-stroke engines, a very important factor to fly about 44 minutes.

GROUND CONTROL STATION

Radio Modem

Communications are provided by the 910 MHz Radio Modem (base). This device was included in the MicroPilot Package. We can transmit all the images, flight information, and you can see all the activities on the MicroPilot Horizon® Software including tracking and GPS coordinates.

This is very essential and the most important device to complete the competition and all the communication and the status of the aircraft in the air is received with this device.

The 910 MHz Radio Modem is designed from Micro Hard.

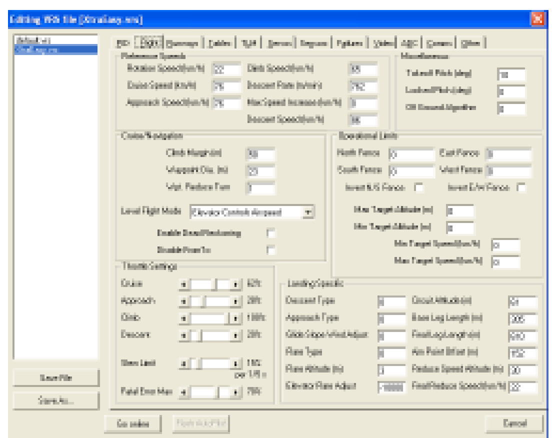
This modem serves as a downlink from the MicroPilot to access the sensor data and monitor the state of the UAV.

This is the Ground Station that included the MicroHard Radio Modem and the 2.4 GHz Camera receiver.

MicroPilot Horizon® Software

To communicate with the Alpha UAV, we use the Horizon software, which is included in the MP2028g Autopilot package. Through Horizon, we can load and create flight programs and configure our sensors and servos to observe and interact with the UAV in flight. Horizon tracks the progress of the UAV in real time allowing the team of access critical mission data such as altitude, attitude, air speed, position and autonomous take-off and landing provided by de AGL ultrasonic sensor.

MicroPilot Horizon® Flight Instruments



Screenshots of the MicroPilot Horizon® AutoPilot Software

Ultrasonic sensor provides autonomous take-off and landing

F. *Preflight checklist*

Pre-flight Checklist

While in lab:
Hardware tests:
Commbox:

- ✓ Sufficient Power (gel cell if needed)
- ✓ Antenna attached
- ✓ USB-Serial Adapter
- ✓ Programmed with compatible code

Laptop:

- ✓ Compatible software installed
- ✓ Sufficient battery life (inverter if needed)
- ✓ Check USB-Serial adapter port mappings and compare with VC settings

On the plane:

- ✓ Autopilot battery voltage > 6.0 V
  - ➢ Modem:
    - ▪ Antenna connected, getting COMM
    - ▪ Good connection between modem and autopilot (cable)
  - GPS
    - ▪ Good connection to autopilot (cable)
    - ▪ Good satellite lock
  - Flight capability check
    - ▪ Tuned PID loops
    - ▪ Trim settings
    - ▪ Autopilot should be temp camped previously

- ✓ Completely charge our transmitter and receiver batteries before your first day of flying.

- ✓ Check every bolt and joint in the Alpha UAV ensure that everything is tight and well bonded.

- ✓ Double check the balance of the airplane. Do this the fuel tank empty.

- ✓ Check the control surfaces. All should move in the correct direction and not bind in any way.

- ✓ If your radio transmitter is equipped with dual rate switches double check that they are on the low rate setting for your first few flights.

- ✓ Check to ensure the controls surfaces are moving the proper amount for both low and high rate settings.

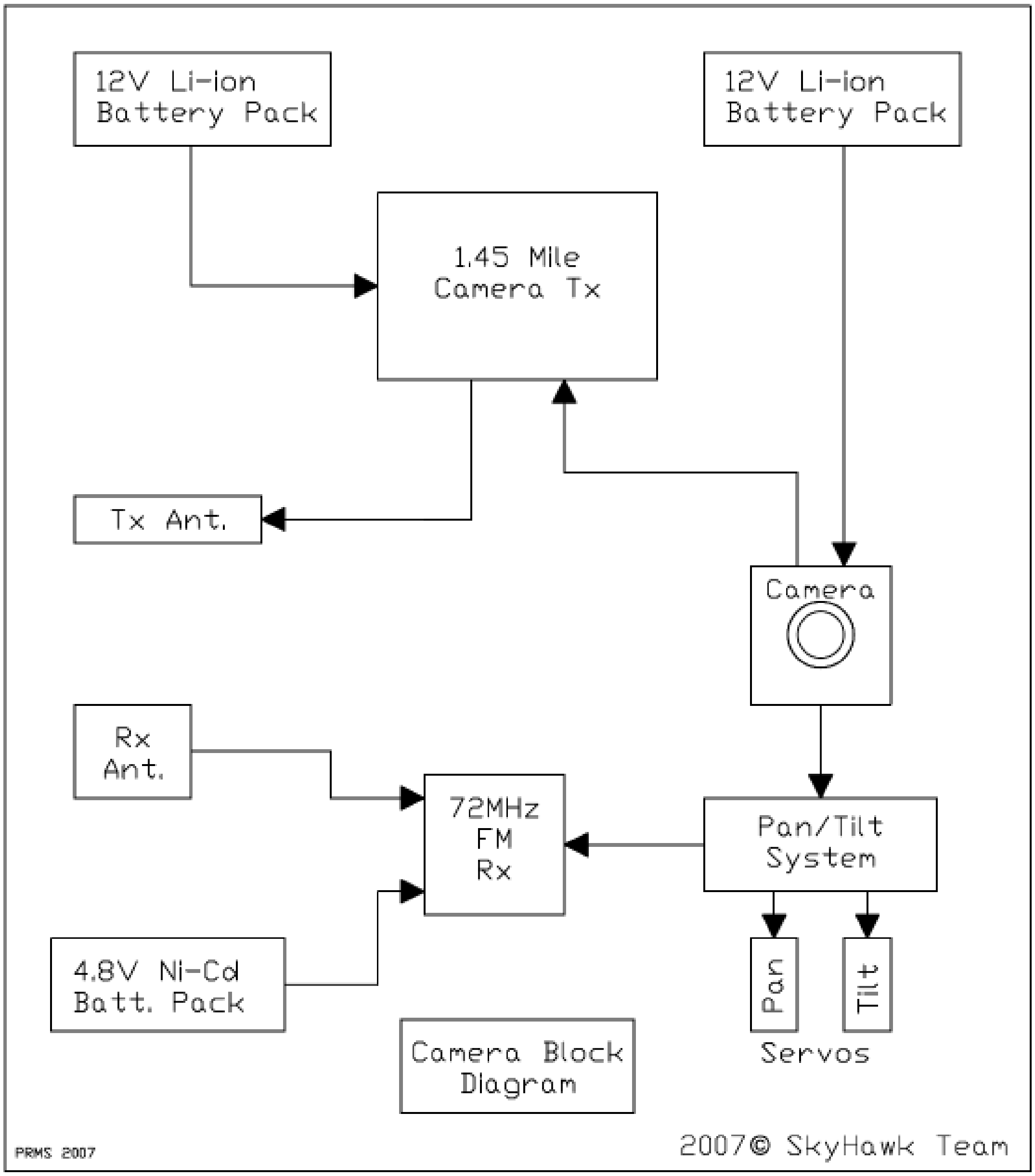
- ✓ Check the receiver antenna. It should be fully extended and not coiled up inside the fuselage.

- ✓ Properly balance the propeller. An out of balance propeller will cause excessive vibration which could lead to engine and/or airframe failure.

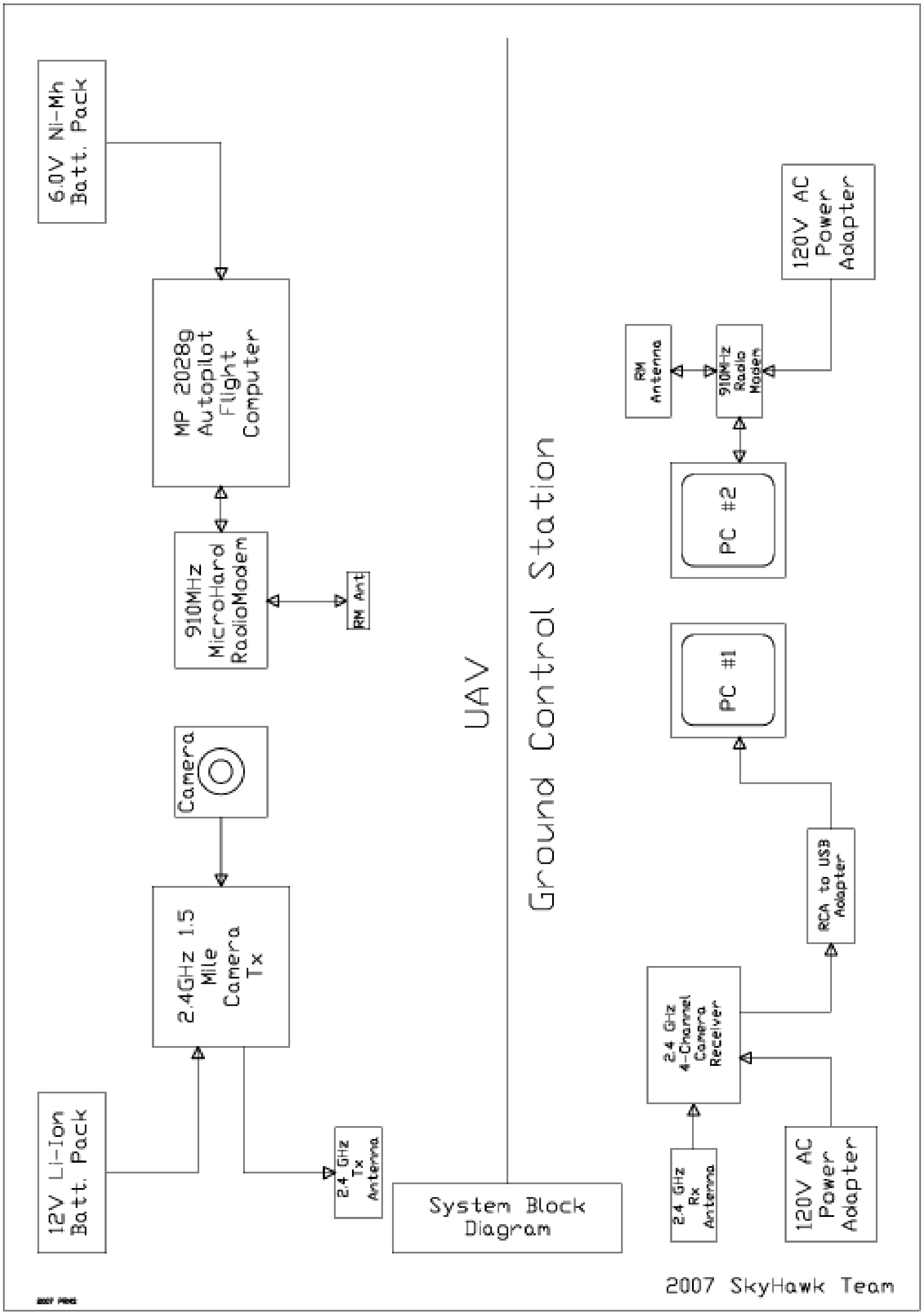
Alpha UAV after Preflight

G. Block Diagrams and System Distribution

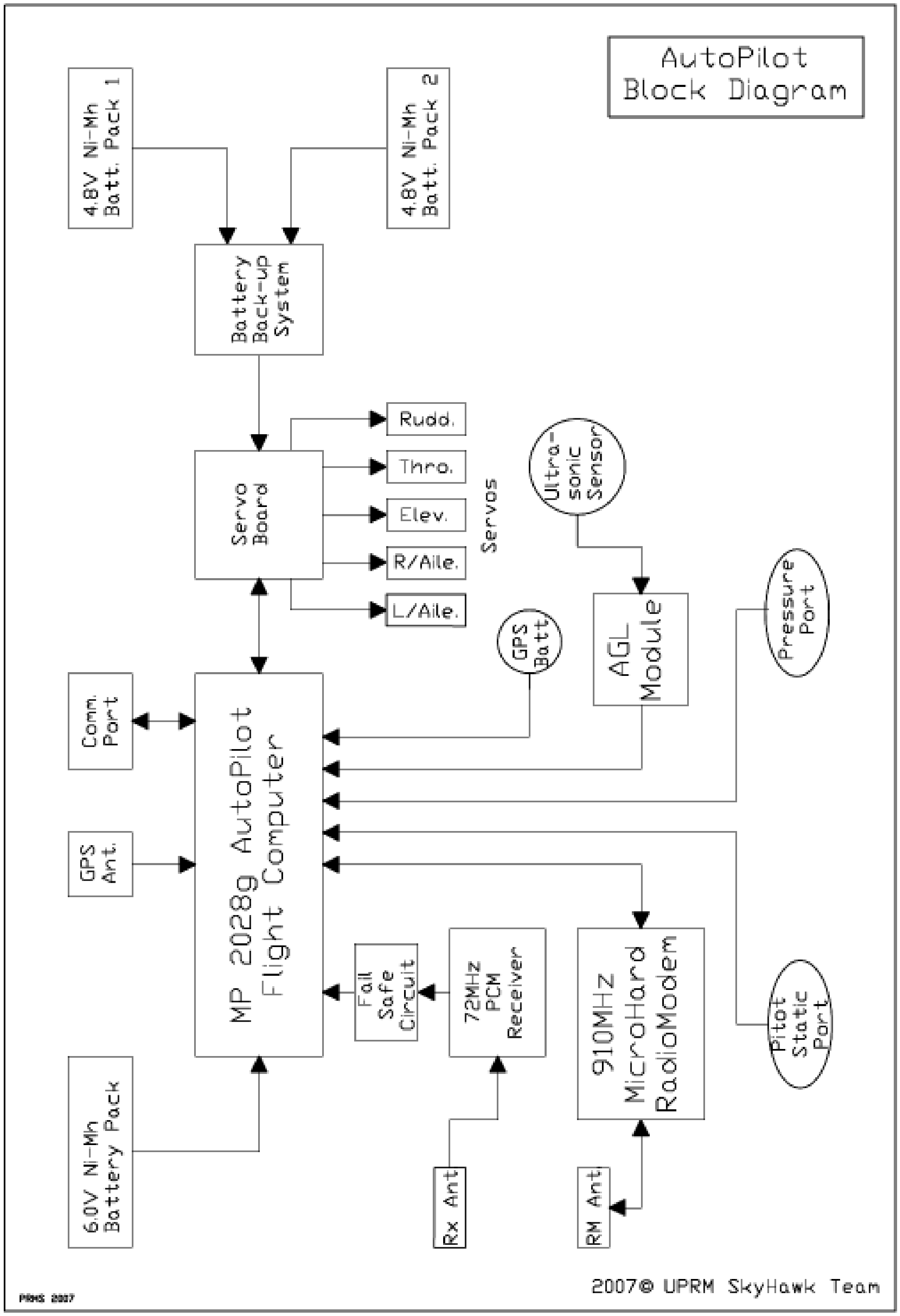
Camera Block Diagram



System Block Diagram



Autopilot Block Diagram



H. References

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