ECE 477 Final Report – Spring 2009
Team 12 – FlySpy

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CRITERION	SCORE	MPY	PTS
Technical content	0 1 2 3 4 5 6 7 8 9 10	3	
Design documentation	0 1 2 3 4 5 6 7 8 9 10	3	
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Abstract

FlySpy is a hobby aircraft modified to fly and take pictures under its own control. It uses GPS for navigation, flying along a path of waypoints defined on a microSD card and triggering the onboard camera at defined points. Autonomous flight control is achieved using inertial sensors (accelerometers and gyros) as feedback, while a switch on the remote control allows manually-controlled flight for takeoff and landing.

1.0 Project Overview and Block Diagram

The FlySpy, as built by our team, is a modification of the Easy Glider Pro hobby aircraft from Multiplex Modelsport. The control system is primarily constructed on a printed circuit board (PCB) mounted within the plane's "cockpit". The pitch and roll of the plane are calculated using a three-axis accelerometer and a two-axis gyro, which are used in the autopilot feedback loop to stabilize the aircraft. Flight surface servos and the propeller throttle are controlled using PWM, either from the microcontroller or from the RC receiver. A consumer digital camera and ultrasonic rangefinder are mounted on the bottom of the fuselage. The camera's on/off switch and shutter are wired to pins on the microcontroller, allowing the controller to take photographs automatically. The rangefinder is to support fully autonomous landing, although this is not implemented. The guidance system uses an FV-M8 GPS module to get a position, heading, and velocity measurement 5 times a second. GPS waypoints are read in from files on a FAT-formatted microSD card, and flight data is written back out.

Essentially, FlySpy is an aerial reconnaissance platform. It allows a user to take pictures of ground locations given only their GPS coordinates, making it easy to survey areas that the user cannot travel to himself.

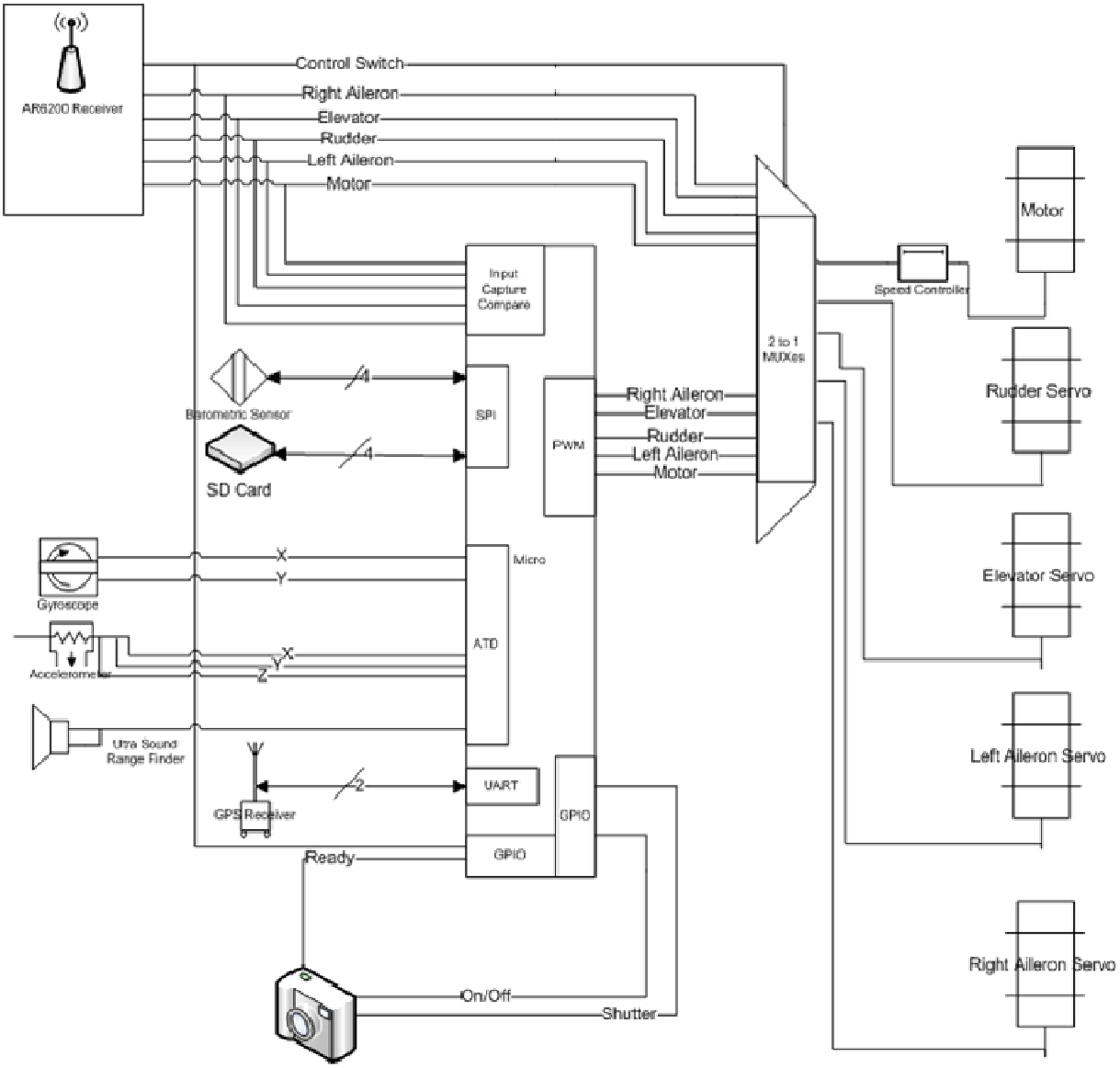


Fig 1.1: Block Diagram

Fig 1.2: The FlySpy

2.0 Team Success Criteria and Fulfillment

1. Ability to control airplane's control surfaces and throttle
   Status: Completed.

2. Ability to read/write flight information to non-volatile memory
   Status: Completed. Reading from and writing to files on a FAT filesystem on the microSD card is supported and used extensively in our project.

3. Ability to take pictures with onboard camera
   Status: Completed. The camera is completely mounted on the plane, which bears the load and stays in the air.

4. Ability to autonomously navigate to GPS coordinates
   Status: Incomplete. We have not had sufficient time to tune the control algorithms to get the plane airborne under its own control.

5. Ability to calculate orientation of the vehicle
   Status: Completed.

3.0 Constraint Analysis and Component Selection

3.1 Design Constraint Analysis

In designing the full layout for FlySpy, we observe various constraints that limit our project to an extent. The most critical is that our microcontroller must have enough pulse width modulation channels to support the output to all the controls of the airplane. In addition to the number of PWM channels, we also need to make sure that the channels have a high enough resolution to smoothly control the plane's surfaces. In order to calculate the orientation of the aircraft, we have to have a lot of ATD channels that will convert data from accelerometers and gyroscopes in multiple axes. Another big issue is the size and weight of the included components. The Easy Glider Pro has a decent amount of space in the cockpit but a lot of this space is filled by the RC components. This means that items that we want secured in the cockpit will have to be small, but pieces that are not critical to be close to the microcontroller will have the option of being mounted to the outside shell of the airplane. We must also be mindful of the weight of the components that we use because too much weight will not allow the plane to fly.

3.2 Computation Requirements

A good amount of calculation will be needed to both calculate the current orientation of the aircraft based off accelerometer and gyroscope inputs and calculate the needed orientation of the aircraft from the GPS destination and current location. In calculating the current orientation off of the accelerometer and gyro data, we find ourselves needing quite a few floating point operations. We approximate 100 floating point operations for every update at a 50 Hz interval [6]. Assuming that we go with a very low-end microcontroller without native floating point hardware (such as Microchip's PIC line), we conservatively estimate that each floating point operation will take 100 clock cycles. This means that we need a processor of at least 500 kHz to sustain the updates. Based on these estimates, we concluded that an integer-only processor of with a clock of 1MHz or more would be sufficient to maintain the orientation calculations.

Once we have successfully done the navigation and orientation calculations, we then will set the control surfaces so that the current orientation will approach the desired orientation. We will also have to write the current data to the SD Card for flight logging. These should not require much CPU power compared to the orientation calculations.

We do not expect to need much RAM on the chip, as there are no large data structures being manipulated in-memory. Program memory is not expected to be particularly constraining.

3.3 General Purpose Digital I/O Requirements

In the design for FlySpy, the camera will be the only device that will use the general-purpose I/O ports. We assume that the camera will need to make use of only a few of these. We will need to output control of the camera's on/off switch and shutter pushbutton, and we will need to relay back to our microcontroller a line which signifies the on/off status and the picture ready status of the camera. We will also need an input pin to the microcontroller that will signify if the plane is being controlled from the manual pilot or by its own signals.

3.4 Interfaces and On-Chip Peripheral Requirements

On-chip peripherals are plenty in our design. We will make use of 5 channels of Pulse Width Modulation. We are requiring that these channels have 16-bit resolution because the control surface's servos can only tolerate a small range of pulse width and with 8-bit resolution we will not be able to make very accurate deflections. In order to record the flight path of the manual pilot when in manual mode, we will need to intercept the PWM signals coming from the receiver. To do this, we will need 5 input capture timer channels to record the pulse widths and write them to memory. The GPS receiver module will communicate through SCI interface as well as another SCI interface for debugging purposes. SPI interfaces will be needed to read and write to and from the SD Card and also to communicate with the barometer to receive altitude. To interface with all of the sensors that will need to calculate the orientation of the aircraft, we estimate making use of 6 channels of 10-bit ATD. This includes 3 axes from the accelerometer chip, 2 axes from the gyroscope chip, and a range finder.

3.5 Off-Chip Peripheral Requirements

In FlySpy, a lot of off chip devices are required to provide important information to the microcontroller so that it may compute and execute a flight path. For to acquire this information, we will need a GPS Receiver, three axis accelerometer, two axis gyroscope, barometer, and a rangefinder. A GPS receiver is needed to provide position and heading information. The receiver must have a minimum accuracy of about 5-6 meters so that we capture a picture of the

GPS coordinate within our picture. The barometer will be used as an altimeter, providing accurate measurements of pressure enough to stay within a +-1m range of flight altitude. The gyroscope will be used to sense angular rotation of the aircraft's pitch and roll. The accelerometer will be used to correct the error of the gyroscope's accumulation of rotation data overtime. The rangefinder will be used to sensor when the aircraft is close to the ground enabling it to land correctly.

Aside from the components that we will need for the autopilot, we will also need the general components to the RC aircraft. This includes the airframe, servos, receiver/transmitter pair, motor, and speed controller.

3.6 Power Constraints

Battery power in FlySpy is critical so that we may have enough power to control the RC components and our autopilot devices. Once all of these devices are added to the plane, it will weigh more and need more power than the plane as it is out of the box. The motor, being the component with the most power consumption, will need enough power to handle this weight over the duration of time that we need to travel a reasonable flight path. The battery itself will add weight to the plan and usually the more powerful it is, the more it will weigh.

In choosing a battery we must be mindful of its weight, flight time, and size. Size is also critical because it will be placed in the cockpit; any space consumed by the battery is less space for the autopilot. The battery must be able to source more than +5 V and 2.75 A. The servos, motor and receiver will run off of a +5 V rail; the motor is expected to draw about 2 A and the servos 150 mA each. The other components will run off a +3.3 V rail stepped down from the +5 V rail and are roughly estimated to draw 150 mA.

3.7 Packaging Constraints

The packaging on FlySpy is a major concern. The aircraft that we have selected was made just to withhold the RC components for a manual pilot. It is also molded on the inside so that pieces may have compartments to fit into without sliding. Knowing this, we have major constraints on space for items that will be placed on the interior of the aircraft. We estimate

dimensions close to 1.5 in. X 1 in. X 5 in. The pieces that will be placed internally also have to be placed in a way that they do not disturb the servos or servo rods that sit in the cockpit.

For the components, that can be far away from the microcontroller may be placed on the exterior of the aircraft. This will be beneficial to use with use of the GPS receiver and the camera. The GPS receiver may be placed on top of the fuselage and close to the rudder. This unit can be used to counter balance the components that we insert internally, therefore helping to retain a good aerodynamic center. The camera itself will need to be mounted to the bottom of the aircraft. It must be placed at the aerodynamic center because we do not want to add more weight to counter react it and adding to the total weight.

3.8 Cost Constraints

Currently, there aren't any solutions that give you a airplane with built in autonomous abilities. On the other hand, they do commercially sell autopilot units that you may insert into your own plane. MicroPilot markets themselves as the world leaders in miniature UAV autopilots so we will compare our design with their unit alone. Their low end autopilot controller that they market as "Disposable control..." is $2000 dollars per unit. We are aiming for a total cost (plane, controller, computing hardware) of under $1000.

3.9 Component Selection Rationale

The microcontroller was one of the more difficult parts to select due to the bewildering number of choices available from various manufacturers. The core requirements were as follows:

Type	**#**	**Comments**
PWM Outputs	5	One for each aircraft control signal (two ailerons, elevator, rudder, throttle). While a controller with only 4 signals available would be doable by running both ailerons off the same PWM signal, this choice would slightly limit the flexibility of the aircraft's control; for example, the ailerons could not be used as flaps for takeoff and landing. This is not critical to fulfilling any PSSCs, but a full 5 channels is a "nice to have" feature.
Input Compare	5	For reading the PWM control signals from the R/C receiver

A/D	8+	The microcontroller will interface with a 3-axis accelerometer, a 2-axis gyro, and possibly some other analog devices, such as a compass, barometer, or rangefinder.
SPI	1	Communicate with the SD card.
Digital I/O	3+	"Spare change" pins to control the camera.
SCI ports	2	One to communicate with the GPS module, and one for general debugging/PC interfacing.
Debug interface	1	JTAG, ICD-2, or otherwise

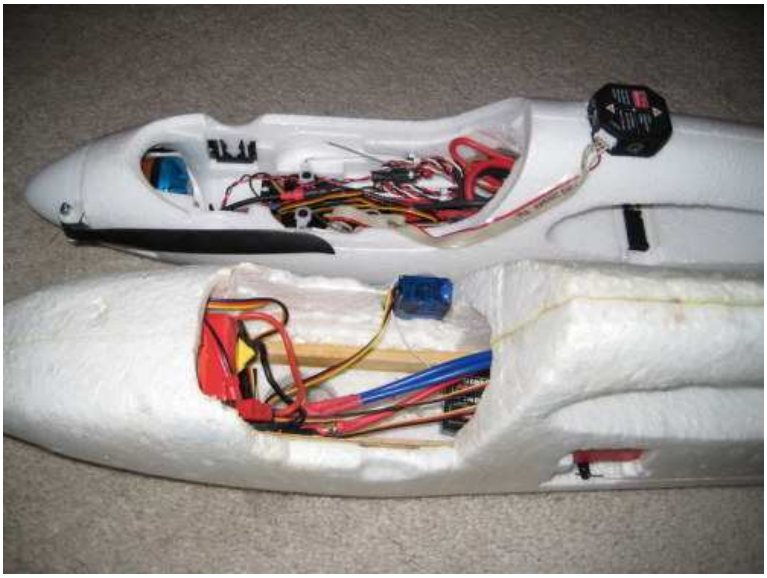
In addition, voltage was a serious consideration, as it determines which peripherals can be interfaced directly to the microcontroller and which ones require conversion logic. Direct interfacing was preferred. The SD card operates at 3.3v and uses signal levels in that range. Similarly, the GPS unit can use 3.3v signaling. Bench testing of our airplane kit's hardware shows that the servos and speed controller should work fine with a 3.3v. This made a 3.3v device a viable option, conveniently reducing power consumption for the microcontroller itself. The R/C receiver gives 5v PWM signals, which could require some signal conditioning.

PIC24FJ128GA106 [1]	MC9S12HZ128CA [2]
- 5 16-bit PWM channels (via Output Compare)	- 4 16-bit PWM channels
- 9 Input Compare channels	- 8 Input Compare channels
- Internal Oscillator	- Internal Oscillator
- 16 A/D channels at 10bits	- 16 A/D channels at 10bits
- ICD debugging interface	- BDM debugging interface
- Current draw: up to 24mA	- Current draw: 65 mA with everything enabled
- 2.2v to 3.6v operating voltage means that it can be run at 3.3v and thus interfaced directly to all of the peripherals.	- Operates at 5v. This certainly means that signal conditioning would be required on the SPI interface, and probably the SCI interface to

	the GPS unit. A 3.3v rail is still necessary to power the various peripherals, but the analog inputs can measure 0-3.3v perfectly fine, with the consequence that the resolution will be worse.
- Can tolerate up to 6V on digital inputs. This will allow the receiver's PWM signals to be fed directly to the input pins on the microcontroller.	- Can tolerate 5v digital inputs due to its operating voltage.
- Unit cost is around $5.	- Unit cost is around $10.
- William is already familiar with the Microchip development environment.	- Group has decent familiarity with 9S12 processors and peripherals from 362.

Due primarily to the voltage level issue and unit pricing, we decided to buy the PIC.

For the airplane, we stayed within the Multiplex brand of aircrafts. This is because of the ELAPOR material that their products used which is popular for its durability and easy reconstruction after crashes. When we narrowed our search down to two of their airframes, we were torn between the Easy Star and the Easy Glider Pro. When comparing the two we were concern about three main differences. The Easy Star has a propeller that sits up in the middle of the plane which was appealing because if we crashed the plane, the engine or propeller wouldn't be the first to hit. The Easy Glider has its propeller and motor in the front but has a bigger motor to withstand more weight. The size of the cockpit was another aspect we looked at closely as depicted below:



Easy Star in front and Easy Glider Pro in back [5]

The Easy Star has a lot more cockpit space available to us so we may put our components in without worrying much about them brushing against the servos and receiver. The Easy Glider Pro has significantly less space available to us. The main determining factors were the wing spans and ailerons. The wingspan of the Easy Glider Pro is much lengthier than the Easy Star. The larger the wingspan, the more stable our flight will be without our microcontroller having to give much correction. Also the Easy Star does not have ailerons, which is a major downfall. Ailerons give us the capability to make direct and sharp turns but without them you may only turn with your rudder. The rudder turn is not ideal and is a sluggish and slow rotation around the yaw axis. For these reasons we choose the Easy Glider Pro.

Easy Glider Pro [3]	**Easy Star** [4]
Wing Length: 72 in. **Wing Area:** 645 Sq in. **Wing Loading:** 6.25 oz/sq ft. (glider) **Fuselage Length:** 44 in.	**Wing Length:** 54 in. **Wing Area:** 372 sq. in. **Wing Loading:** 10.76 oz./sq. ft. **Fuselage Length:** 34 in.

Weight (English): 34 oz (Electric) **Weight (Metric):** 29 oz. (Glider)	**Weight (English):** 24 oz.

4.0 Patent Liability Analysis

The possible infringement could be occurred in the algorithm of controlling the airplane's position and orientation using appropriate sensors and GPS system, controlling camera to take appropriate photo at the projected GPS coordinates, and switching the control authority between FlySpy system and remote controller. As the demand on the UAV technology has been high due to military purpose, a number of related patents were researched and the following 3 patents were the most concerned ones in the each category.

4.1 Results of Patent and Product Search

4.1.1 Programmable autopilot system for autonomous flight of unmanned aerial vehicles U.S. Patent No. 7302316 [7]

Filing Date: November 27, 2007

Abstract: A system and method for providing autonomous control of unmanned aerial vehicles (UAVs) is disclosed. The system includes a ground station in communication with an unmanned aerial vehicle. The method for providing autonomous control of a UAV includes methods for processing communications between the ground station and UAV. The method also includes process for estimating the attitude of the UAV and autonomously maintaining its altitude within a desired threshold, process for autonomously orbiting about a specified point in space, and process for an autonomous takeoff and landing of the UAV.

Claims for Possible Infringement:

Claim1. An autopilot control system for an unmanned aerial vehicle, comprising: a ground station; and an on-plane control system, comprising: a processor; memory in electronic communication with the processor; three accelerometers in electronic communication with the processor; three rate gyroscopes in electronic communication with the processor; an absolute pressure sensor in electronic communication with the processor; a differential pressure sensor in electronic communication with the processor; a global positioning system in electronic communication with the processor; a transceiver in electronic communication with the processor to receive and transmit wireless signals; and a power source that supplies power to both the on-plane control system and to an actuator used to propel the unmanned aerial vehicle.[7]

Claim4. The autopilot control system as defined in claim 3, wherein the on-plane control system further comprises a bypass circuit that allows the unmanned aerial vehicle to be controlled by the RC controller instead of the on-plane control system.[7]

4.1.2 Precision Approach Control U.S. Patent Application No. 2008/0071431 [8]

Filing Date: March 20, 2008

Abstract: An aircraft control system for operations close to the ground includes a camera having a rangefinder for measuring the azimuth, elevation and slant range from a fixed point on the aircraft relative to a selected target point on a surface below the aircraft, a navigation system for measuring the latitude and longitude of the aircraft on the surface, a computer for computing the position of the fixed point on the aircraft relative to the target point from the respective measurements of the camera and the navigation system, and a controller for controlling the movement of the aircraft.

Claims for Possible Infringement:

Claim1. An aircraft command and control system, comprising: a camera, including a rangefinder, disposed aboard the aircraft for measuring an azimuth angle, an elevation angle and a slant range from a fixed point on the aircraft relative to a selected target point on a surface located below the aircraft; a navigation system disposed aboard the aircraft for measuring a latitude and a longitude of a point on the surface that is disposed perpendicularly below the fixed point on the aircraft; a computer for computing the position of the fixed point on the aircraft relative to the target point on the surface from the respective measurements of the camera and the navigation system; and, a controller for controlling the movement of the aircraft such that the fixed point on the aircraft is positioned at a selected azimuth angle, elevation angle and slant range above the selected target point on the surface.[8]

Claim 4: “The system of claim 1, wherein the navigation system comprises a Global Positioning Satellite (GPS) system, an Inertial Navigation System (INS), or both a GPS and an INS.” [8]

Claim 5: “The system of claim 1, wherein the aircraft comprises a helicopter or an aerial vehicle.”[8]

4.1.3 Anti-hijacking system operable in emergencies to deactivate on-board flight controls and remotely pilot aircraft utilizing autopilot U.S. Patent Application No. 2004/0079837 [9]

Filing Date: April 29, 2004

Abstract: In an anti-hijacking system for autopilot equipped aircraft, a transceiver communicates with at least one remote guidance facility. A panic button is activated by flight crew in case of hijacking. A manager is coupled to the transceiver and the panic button, as well as existing avionics including the aircraft's master computer and autopilot. The manager recognizes predetermined override inputs, such as activation of the panic button or receipt of override signals from the remote guidance facility. Responsive to the override input, the manager deactivates on-board control of selected aircraft flight systems and the autopilot system, and directs the autopilot to fly the aircraft to a safe landing.

Claims for Possible Infringement:

Claim1. A method for preventing hijacking of an aircraft, comprising operations of: providing a hijacking intervention module aboard an aircraft having an autopilot system; the module sensing a predetermined override input; responsive to the sensing of the predetermined override input, the module performing operations comprising: deactivating on-board control of predetermined aircraft flight systems; deactivating on-board control of the autopilot system; directing the autopilot system to fly the aircraft to a landing. [9]

Claim2. The method of claim 1, the operations responsive to the sensing of the predetermined override input further comprising: receiving manual commands from at least one remote guidance facility, the manual commands comprising instructions to manually manipulate specified aircraft flight systems. [9]

4.2 Analysis of Patent Liability

4.2.1 Analysis of Liability involving Programmable autopilot system for autonomous flight of unmanned aerial vehicles

In Claim1, it states that components such as gyroscope, accelerometer, memory, pressure sensor, GPS receiver, and bypass module are all connected to the processor. The components used and how components are mapped is very similar to our design because the sensors are needed for specific measurement of in-flight information. Although our system utilizes single gyroscope,

accelerometer, and pressure sensor, the patent states that three of gyroscopes and accelerometer, two of pressure sensors are used for the calculation of plane's altitude and orientation. This would be a great reason that our system is different from theirs since we are utilizing less number of components for the system with the same objective which is to control airplane as unmanned. The calculation algorithm will be different as we have different number of sensors and the main loop depicted in patent is also different

4.2.2 Analysis of Liability involving Precision Approach Control

In Claim1, the patent states that it utilizes the GPS navigation system to approach to the projected spot of photograph. Although both system use GPS navigation system, the difference between the patent and FlySpy is the algorithm to determine when to take the photo. FlySpy solely depends on the GPS information and pressure sensor while the patent uses the laser rangefinder for more accurate measurement. The laser rangefinder works with azimuth lens on camera to find the best angle and distance for photo shot. FlySpy's photo taking system does not include laser range finder or azimuth lens and therefore it does not cause an infringement.

4.2.3 Analysis of Liability involving Anti-hijacking system operable in emergencies to deactivate on-board flight controls and remotely pilot aircraft utilizing autopilot

In Claim1, the patent explains the switching the control of the airplane by an emergency push button and this is very similar to the bypass module of FlySpy. As supposed that the pilot is the autonomous flight control system and hijacking is the malfunction of the autopilot, FlySpy should switch its control authority to the remote controller. However, FlySpy's module does not support the control from multiple stations and the patent's statement restricts the purpose of invention to the passenger planes.

4.3 Action Recommended

To avoid the infringement on [7], FlySpy has to develop the algorithm that can achieve the goals without following the sensor selections in the patent. If FlySpy can accomplish the goal successfully with less number of components and the equal accuracy, the technology can be patented as well. To avoid the infringement on [8], FlySpy has to use the camera strictly and approach to the destination for photo taking by GPS guidance only as it is planned. Although the

similarity of the design is found in the patent and FlySpy's control bypassing module, the targeting air plane is different and the patent [9] states the exclusive use in the hijacking circumstance of passenger planes and the interaction between pilots and ground facility is very important part in the decision process as claimed in 1 and 2 of [9]. Therefore, there will be no infringement on [9].

4.4 Summary

As the demand on unmanned aerial vehicle was high, there were a number of patents on UAV inventions. Through this reports, the closest three patents showed some similarities and differences. Even if three patents work the same functions in UAV, the design plan showed enough design dissimilarity to avoid from the infringement on existing patents.

5.0 Reliability and Safety Analysis

Due to the range and potential for loss of control, safety is an issue not only for the user but also for others who may be within flight range. Software error is the primary concern; because of the complexity of the software design, software error is a far likelier culprit in erratic behavior or loss of control than hardware failure.

This analysis disregards the standard components on board the RC airplane: servos, motor, receiver, battery, step-down converter (providing +5 V to power the servos, motor and receiver off of the battery) and only takes into account the components added in this design project.

5.1 Reliability Analysis

The most complex component in the design is the PIC24FJ256GA110 microcontroller. Most of the other components, except for the GPS receiver, are fairly simple in comparison. During testing, we did not observe any components that ran hot with a reasonable load. Because of the relative irrelevance of these considerations, "mission-critical" components were chosen in additional to the microcontroller. The PI3V512 multiplexor was chosen because it controls switching between manual and autonomous modes. The LTC1174 buck converter was chosen because all components except the motor, servos and receiver are powered on the +3.3V rail.

Microcontroller

The microcontroller model from section 5.1 in the handbook was used [10]. With this model, $\lambda_P = (C_1\pi_T + C_2\pi_E)\pi_Q\pi_L$ failures per 10^6 hours.

Parameter name	**Description**	**Value**	***Comments*** *regarding choice of parameter value, especially if you had to make assumptions.*
C_1	Die complexity	.28	16 bit
π_T	Temperature coeff.	.29	TJ = -40 to +125 C from page 260 of datasheet [11]; estimate +50 C
C_2	Package Failure Rate	.053	SMT, ~128 pins

π_E	Environment Factor	4.0	Assume ground mobile since the plane operates fairly close to the ground (no typical stresses of airborne environments)
π_Q	Quality Factor	10	Commercial product
π_L	Learning Factor	1.0	>= 2.0 years in production
Entire design:	*Failures per million hours*		2.932
	Mean time to failure (MTTF) in years		38.908

Multiplexor

The digital MOS model from section 5.1 in the handbook was used [10]. With this model, $\lambda_P = (C_1\pi_T + C_2\pi_E)\pi_Q\pi_L$ failures per 10^6 hours.

Parameter name	**Description**	**Value**	***Comments*** *regarding choice of parameter value, especially if you had to make assumptions.*
C_1	Die complexity	.010	~100 transistors (each 2:1 mux = 3 NAND gates = 12 transistors, x 5 = 60 each way because bidirectional)
π_T	Temperature coeff.	5.6	TJ = +150 C from page 2 of datasheet [12]
C_2	Package Failure Rate	.0087	SMT, ~24 pins
π_E	Environment Factor	4.0	Assume ground mobile since the plane operates fairly close to the ground (no typical stresses of airborne environments)
π_Q	Quality Factor	10	Commercial product
π_L	Learning Factor	1.0	>= 2.0 years in production
Entire design:	*Failures per million hours*		.908
	Mean time to failure (MTTF) in years		125.72

Buck Converter

The linear MOS model from section 5.1 in the handbook was used [10]. With this model, $\lambda_P = (C_1\pi_T + C_2\pi_E)\pi_Q\pi_L$ failures per 10^6 hours.

Parameter	**Description**	**Value**	***Comments*** *regarding*

name			*choice of parameter value, especially if you had to make assumptions.*
C1	Die complexity	.010	<100 transistors
π_T	Temperature coeff.	58	$T_j=T_a+(P_D*110^oC/W)$ from page four of datasheet [13]
C_2	Package Failure Rate	.0026	SMT, ~8 pins
π_E	Environment Factor	4.0	Assume ground mobile since the plane operates fairly close to the ground (no typical stresses of airborne environments)
π_Q	Quality Factor	10	Commercial product
π_L	Learning Factor	1.0	>= 2.0 years in production
Entire design:	*Failures per million hours*		5.904
	Mean time to failure (MTTF) in years		19.33

These conclusions appear reasonable. The calculations suggest that the components are reliable, as would be expected. Based on this analysis, one way to improve the reliability would be to select a microcontroller with fewer pins.

5.2 Failure Mode, Effects, and Criticality Analysis (FMECA)

Three criticality levels were defined (based on in-flight operation rather than benchtop testing):

In the **High** criticality level, the plane either crashes or cannot be returned to manual control. In the latter case, the plane will simply fly autonomously until the battery runs down or it crashes. Not only is a crash condition potentially injurious to the project, but in addition, it could present a danger to the user and any individuals within flight range. The plane is made of foam, but it is equipped with a front-mounted plastic propeller. Because of the danger to the user and the potential for destruction of the product, a hardware failure rate λ of 10^{-9} seems advisable.

In the **Medium** criticality level, the plane loses its autonomous control functionality; however it can still be flown manually. The plane must be returned to manual control. *This category assumes that flight stability can be reachieved in the wake of autonomous control failure; if it cannot, any event in this category would need to be upgraded to High criticality level.* The selection of an appropriate failure rate is somewhat arbitrary; however, a failure rate of λ = 10 per million hours would result in an MTTF of about 11.4 years, longer than the expected use of the product.

In the **Low** criticality level, the project experiences some loss of non-critical functionality. For example, the plane could not take photos. A failure rate of $\lambda = 35$ per million hours is fairly generous for low criticality failures and would result in an MTTF of about 3.3 years. Most point and shoot cameras probably have a lifetime of about 3-5 years.

As an aside, intelligent engineering would have dictated using a multiplexer with a +5 V supply; the current multiplexer is powered on the +3.3 V rail. If the +3.3 V power supply circuit fails, the plane will necessarily crash because no PWM signals can be switched. However, had the mux been powered on the +5 V rail along with the servos, motor and receiver, manual control could have been maintained.

5.3 Summary

In summary, software error is the biggest threat to the safety and reliability of the project. Physical reliability of the hardware is a secondary focus. Aside from the microcontroller and GPS module, few components would be considered complex and none of the components run very hot under testing with a reasonable load. The plane is comparatively safe to a user testing it in lab. However, in-flight operation introduces a risk of injury to the users and others in the vicinity as well as damage to the body of the plane. The best safety precaution is probably to keep the potential flight area as clear of people as possible and to stay alert.

6.0 Ethical and Environmental Impact Analysis

Ethically, the FlySpy presents some hazards to the user, as it is an airborne vehicle with a fast-spinning prop; the risks are exacerbated by its autonomy. FlySpy also has obvious civil privacy implications. There may also be military uses for FlySpy; however, since it is unarmed, we do not think the ethical implications are overly pressing.

The drone has environmental concerns similar to most electronic consumer devices. However, as FlySpy is modified from a commercially available hobby model aircraft, FlySpy's airframe provides a disposal concern beyond that already posed by the onboard electronics. Due to the risk of loss, the risk of improper disposal is somewhat greater than that of, say, an iPod.

6.1 Ethical Impact Analysis

6.1.1 Consumer Safety Hazards

FlySpy is A) airborne, B) autonomous, and C) propeller-powered. As such, it poses a significant risk of physical harm to a careless user.

Being airborne and highly mobile, FlySpy could collide with an object and potentially cause damage. Possible objects include: cars, windows, pets, and humans. The momentum of the plane and the sharp, fast-spinning, hard plastic propeller can both contribute to damage or injury.

The propeller deserves special consideration. It can seriously injure a human who sticks a finger into its arc while it is spinning. On top of being sharp, fast, and painful on impact, it is also difficult to see while in operation. Prop-related injuries are a major hazard of all aircraft that involve spinning blades; some of the potential mitigations of the risk are as follows:

1. Brightly color the blade tips to make the arc's edge more visible (Team 8: OCHO is doing exactly this). Also, color the nose cone so that it is easier to notice when it is spinning.
2. Warnings in the user manual to keep one's fingers out of the blade arc as much as possible and to keep the propeller assembly detached from the motor until ready to fly.

3. Brightly colored warning sticker near the nose with a picture warning of the risk.
4. After boot up, the speed controller itself requires the throttle input to be set to 0 before it will "arm" and start spinning the motor in response to nonzero throttle inputs.
5. We specifically selected a model plane with a prop mounted on the nose, as opposed to in the rear of the plane. This makes it easier to hand-launch the plane without passing one's hand through the propeller arc.

6.1.2 Loss of Plane Control

FlySpy has a couple classes of "loss of plane control" conditions that could pose risks. Under manual control, it can easily be crashed by an inexperienced pilot; as such, the user manual should note that this plane is not trivial to operate and that the user should take lessons from a local hobby group before trying to fly the plane solo.

Under autonomous control, the plane could fly off "into the wild blue yonder", out of range of the radio receiver. This could result in a crash when the batteries run out, or in total loss of the plane. We designed the autopilot override such that the plane will maintain steady flight when out of radio range, and be reliably and quickly switchable to manual control when in radio range.

6.1.3 Privacy Risks

FlySpy, being an aerial photography/reconnaissance device, poses obvious privacy risks. Users could easily misuse it to spy on their neighbors. While we are not aware of the legality of aerial photography, using FlySpy to spy on others against their will is certainly unethical. Unfortunately, we can think of no reliable way of preventing such use. We can only add dire warnings in the user manual about legal consequences.

FlySpy could also be used by police forces to spy on private citizens, which raises civil rights issues, particularly in nations with poor human rights records. Again, we have no direct means of preventing abuse; the best we could do is to refuse to sell to customers in countries that have records of civil rights abuse, but we have little ability to prevent resale or proxy purchasing. We would probably have to rely on United States export regulations.

6.1.4 FAA Regulations

The Federal Aviation Administration has rules that affect model aircraft, including FlySpy. In particular, a pilot must have an (inexpensive) FAA permit in order to legally fly the aircraft; this would be noted in the user manual.

Also, the FAA restricts flight in certain areas, such as airport approach and takeoff corridors and security-related no-fly zones. We cannot directly prevent the user from flying the plane into such zones under manual control (at least, not without compromising the reliability of the manual/autonomous switching system), but we could conceivably load GPS coordinates of no-fly zones into the firmware to prevent the user overflying them in autonomous mode. This could be difficult to keep up-to-date, however. As such, the only option may be to simply note the existence of such zones in the manual and to remind the user to check with local aviation authorities, including a disclaimer that we are not responsible for user misuse.

6.2 Environmental Impact Analysis

6.2.1 Material Disposal

FlySpy has three major classes of material posing environmental concerns: the airframe, the control circuitry, and the LiPo battery. Since the plane is meant to be used outdoors and has a nontrivial chance of getting lost outdoors (the “wild blue yonder” failure mode), the risk of its materials ending up out in the woods somewhere is higher than that of most other consumer devices.

The airframe is constructed of a material called “Elapor”. Elapor is extremely lightweight, yet very robust. However, being essentially Styrofoam, it is not really recyclable, and so will end up in a landfill [14]. This waste is somewhat mitigated by the fact that FlySpy is not a throw-away product, so each unit is expected to be used for years. Also, the choice of material both reduces the likelihood of damage, as Elapor is much less brittle than balsa wood, and makes damage to the airframe easy to repair using tape and glue, reducing the number of units that will get thrown away due to damage. In the event that the plane gets lost, the Elapor will be a pollutant, and will take a very long time to decompose. To possibly mitigate this environmental hazard, we could switch to something like a balsa wood airframe, but that would make FlySpy more prone to damage, or to a hard plastic airframe, which would be heavier.

Like those of virtually all electronic devices, FlySpy's circuit boards and electronic components are an environmental concern. Most of the parts could be manufactured in an RoHS-compliant way; many of our components are already RoHS-compliant. However, lead-free parts, particularly lead-free solder, are known to affect reliability, so it may not be worth the tradeoff [15]. The components themselves are all standard electronic parts; there is nothing particularly unusual about any of the electronics, so any standard electronics recycler could process them. As with the airframe, there is a decent risk that the electronic parts could end up in the environment due to plane loss.

The lithium polymer (LiPo) battery used in FlySpy could be a major environmental problem, particularly if it is damaged and/or lost during a crash. The user should be encouraged to safely dispose of the battery at a battery drop; perhaps the user could get a new battery at a discount if he trades in the old one in the process.

In short, the environmental concerns of FlySpy are fairly large, and primarily relate to safe disposal.

6.2.2 Wildlife Interaction

Bird strikes are a fairly common problem in aviation, so FlySpy could have the same issue. As a bird is yet another “object” with which the propeller does not get along well, serious injury to wild fowl could result from a collision. There is little that we can do to mitigate this risk in our design and documentation; fortunately, such collisions are relatively rare to start with.

6.3 Summary

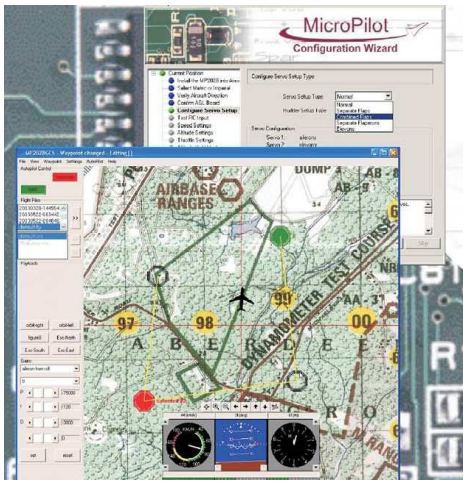
FlySpy has nontrivial safety hazards, but they are not so great as to be dangerous to your average careful user. It is, however, certainly not a product for children. There are some ethical issues relating to how FlySpy is used, but they are not overwhelming. The environmental impact is potentially very serious; however, there is not a lot we can do beyond incentivizing proper disposal.

7.0 Packaging Design Considerations

Flyspy's packaging is going to be the plane called Easy Glider Pro and minimal modification to the plane is going to be done to avoid the drastic change in aerodynamic structure of the plane. The weight of the circuit board will be light and therefore it would not change the balance of the system very much but the weight of the camera can ruin the balance of the air plane therefore it should be placed at very appropriate spot.

Since we expected that the additional weight would require more power of motor, we ordered a motor with extra capacity.

Figure 1. Micro Pilot's Software



7.1 Commercial Product Packaging

After searching online, two competitors to our system were found. One is Micro Pilot MP-2028 from Micropilot and another is Kestrel Autopilot from Procerus Technology.They provide the circuit that can be installed to RC-scale air plane to guide the plane to fly through pre-programmed GPS coordinates. Their packaging is amazing in terms of their size and weight of the circuit. Those products which are similar to our system had every component on the board but our system will use cables to connect to many components and locate them on the better place. They consist of similar components and the object of the system is the same therefore they are appropriate examples to compare our system.

Figure 2. Micro Pilot's Circuit

7.1.1 Micro Pilot MP-2028

Micro Pilot provides a handy solution to turn any RC-scale plane into unmanned aerial vehicle with single circuit installation. The circuit only weighs 28 grams including 3-axis gyros, accelerometers, GPS, pressure, altimeter, pressure and airspeed sensors [16]. It also provides explanatory manuals and videos for installation and flight operation. The circuit size is 4" x 1.5" x 0.6"

which is very small so that it can fit in our plane without any problem. Micropilot's circuit seems much optimized since they could put all sensors on the board and still the size is very small. It also provides flight management software and it costs about $2,000.

7.1.2 Procerus Kestrel Autopilot

The size of Kestrel Autopilot developed by Procerus Technology is 2" x 1.37" x 0.47" and the weight of Auto pilot is only 16.7 grams [17]. Autopilot has a dual-layer PCB and has most sensors on the board without GPS receiver. Even though they did not include GPS receiver, its cost is about $5,000. However, it is smaller than Micro Pilot and it has wi-fi connectivity to the ground station. It has a very compact size and it was developed with military purpose. Since we are now going to use the dual-layer PCB, our design would be more similar to the Micro Pilot than Autopilot.

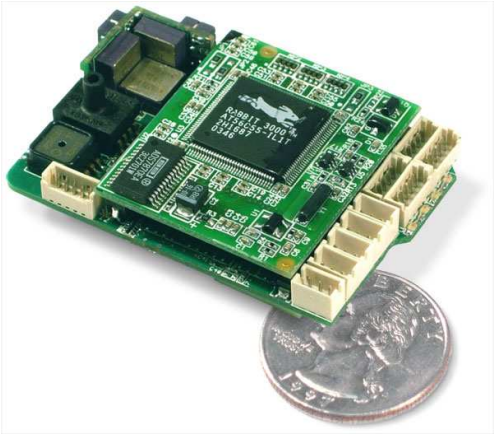


Figure 3. Autopilot's Circuit

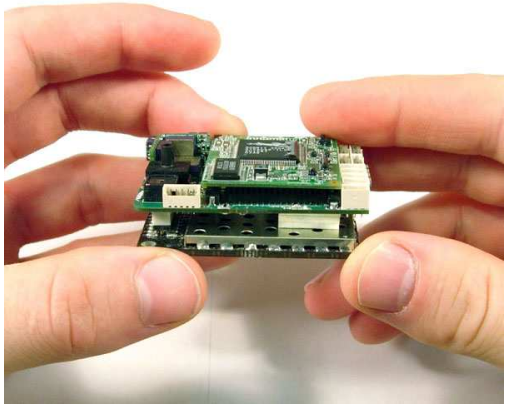


Figure 4. Autopilot's Circuit #2

7.2 Project Packaging Specifications

The components that are going to be added to the plane to realize the unmanned system into our RC air plane are a single microcontroller, gyro sensor, pressure sensor, ultrasonic range finder, accelerometer, camera and micro SD card. Every component except range finder and camera will be placed under the airplane since the range finder has to measure the distance between the plane and the ground and the camera has to take photos of the ground.

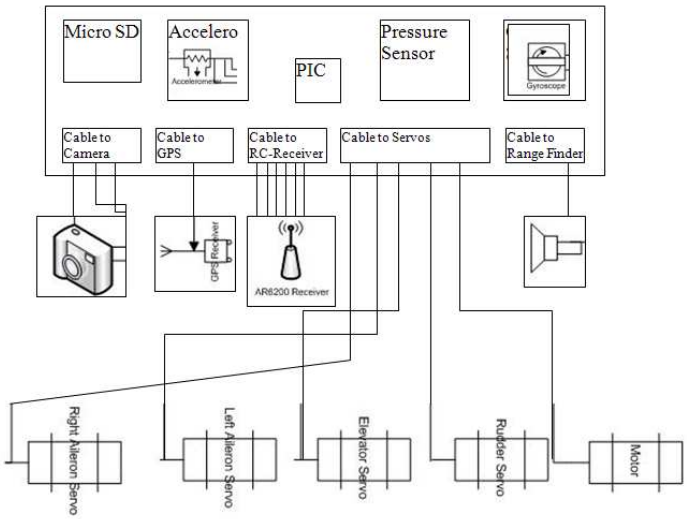
The circuit board which is going to be placed in fuselage will be smaller than 1.5" x 5" x 1". As depicted in Figure B-1 and B-1 in Appendix B, the available area in the fuselage is enough for every component's arrangement and we do not have any concern on the available space.

Our biggest concern on the packaging is to prevent breaking the aerodynamic structure of the plane especially via the weight of camera. Camera will weigh between 100 and 150 grams while PCB circuit will weigh less than 50 grams. We already expected at least 300 grams of additional components and therefore, ordered more powerful motor that can sustain the flight. However, we have not decided where to put the camera exactly since we do not have all components that we ordered yet. This will be determined after designed PCB is obtained.

7.3 PCB Footprint Layout

In Figure 7.3.1, the drawing has the real size of every component on the board. The microcontroller will be surface-mounted. We do not have many components on the board since we connect to the microcontroller via cables. We do have enough free space to avoid the acute angle on the board and the board itself will fit in the fuselage of the plane without any problem. Our board size will be maximum 4" x 1.5" and will be finalized after all components arrive. The size of connectors is drawn with some exaggeration and it will not be bigger than the size in the rough sketch of PCB Footprint in Figure 7.3.1.

Figure 7.3.1



7.4 Summary

Our major concern on packaging is to minimize the modification to the original plane's structure. As long as the plane flies without any in-flight risk due to the imbalance of the body, our packaging is successful. Size of our circuit board is a little bigger than our competitors but our

system’s packaging fits in our plane and we think that the success of whole project is based on the algorithm of flying orientation control. The position of camera will be determined not to ruin the balance of the plane and therefore, our packaging is going to be successful.

8.0 Schematic Design Considerations

The FlySpy will use inertial devices (accelerometers and gyros) and a barometer to maintain stable flight and GPS to do overall navigation; photographs will be taken using a modified commercial digital camera. The FlySpy is also equipped with a rangefinder to support autonomous landing if time permits.

8.1 Theory of Operation

8.1.1 Power Supply

In order to simplify the electrical design, we selected parts with an eye towards minimizing the number of different DC power rails required. The SD card, accelerometer, gyro, GPS module, and barometer all operate at 3.3V. Thus, we selected a microcontroller and rangefinder that also support 3.3V operation, and verified in benchtop testing that our servos and speed controllers could accept a 3.3V PWM signal.

As such, there will be two main power rails in the circuit, at 3.3V and 5V. The motor speed controller for the propeller connects directly to the 7.4V main battery and provides the 5V rail, which will be used to power the R/C receiver and the servos attached to the flight control surfaces.

The 3.3V rail will be provided by a high-efficiency buck converter from the 5V rail. A high estimate for the current draw on the 3.3V rail is 100mA, which seems doable using a buck converter such as the LTC1174. If a buck converter turns out to be infeasible, a low-dropout voltage regulator will suffice; the efficiency hit is tolerable, as most of the current in the system will be drawn by the motor and servos.

8.1.2 Analog Devices

The gyro, accelerometer, and rangefinder are all analog devices that output simple voltages between 0 and 3.3V proportional to the angular rate, acceleration, and range detected, respectively.

The gyro represents “no rotation” as a “zero point” voltage midway through its output range, and reports both the direction and magnitude of rotation rate as voltage offsets from that zero point. The overall rotation is calculated using integration in software. We have not yet tested our gyro for this behavior. Based on experience in FIRST robotics, in most gyro chips the zero point is slightly temperature-dependent or varies among individual units. This is called “gyro bias”, and can be compensated for by sampling the gyro for a second or two after bootup, averaging its

output, and assuming that is the zero point. Obviously the device must be as stationary as possible during this bias calculation.

The accelerometer's voltage output is very similar to that of the gyro, except that it reports positive and negative acceleration instead of angular rate. It responds to gravity, which could be useful in determining which way is "down". We have not yet tested for temperature-variant behavior or other irregularities, but expect that the device will require some tuning.

The rangefinder's output voltage is proportional to the range detected. Every 50ms, the device sends out an ultrasonic pulse and listens for the response. Based on the response time, it drives an analog voltage to correspond to the range. [20]

The components selected were the IDG300 gyroscope, ADXL330 accelerometer, and the Maxbotix LV-EZ1.

8.1.3 SPI Devices

Both the SD card and barometer use SPI to communicate with the microcontroller. The barometer reports a simple pressure value, and the SD card has a standard block-level SPI interface.

8.1.4 GPS Module

The GPS module communicates using RS-232 serial signals. It reports a latitude and longitude over the serial link in the form of NMEA sentences, a standardized ASCII-based interchange format.

8.1.5 Camera

The camera is an off-the-shelf commercial digital camera. We have disassembled it and will use digital outputs, possibly with additional signal conditioning, to control its shutter and focus.

8.2 Hardware Design Narrative

8.2.1 Input Capture

The input capture system will be used to time the pulse width of the 5 PWM control signals coming from the RC receiver. This allows the on-board software to record the human pilot's commands, which will be useful during flight testing with the autopilot disabled. The relevant pins on the microcontroller will be connected directly to the PWM signal pins on the receiver. No voltage level translation is necessary; the digital-only pins on the controller can tolerate up to 6V [18]. The pins used are RPI38, RPI39, RPI40, RPI41, and RP21.

8.2.2 Output Compare

The output compare module will be used to generate the PWM control signals that are the final output of the flight control software. There is a flexible PWM output mode supported on-chip [18]. The pins used are RP20, RP22, RP23, RP24, and RP25, and they will be connected directly to the control signal multiplexer.

8.2.3 Analog to Digital Converter

The A/D system will be used to read the accelerometers, gyros, and rangefinders. All those devices will connect directly to the microcontroller through ANxx pins as seen on our schematic.

8.2.4 UART Module

We will be using two UART interfaces. One will communicate with the GPS module at 9600 baud, 8 bits, 1 stop bit, no parity and will use pins RPI37, RP11, RP12, and RP3. The other interface (on RPI44, RP15, RP16, and RP30) will be exposed via a 9-pin serial header for debugging via a computer.

8.2.5 SPI Interface

The barometer and SD card will both be connected directly to the microcontroller via SPI interfaces. The barometer will be on RP31, RPI32, RP14, and RP29, and the SD card via RPI43, RP5, RP10, and RP17.

8.2.6 ICD-2 Interface

We will be using the Microchip ICD-2 module to program and debug our microcontroller. This requires some pin allocations in order to interface with the module [19]. We are exposing the PGEC1, PGED1, and MCLR pins via an RJ-12 jack that the ICD-2 will plug into. The ICD-2 can also provide V_{SS} and V_{DD} for the microcontroller to operate on; however, we are currently unsure how this should be integrated with the plane's on-board power, if at all.

8.3 Summary

The hardware choices are currently almost complete. We still have some details to nail down, but at this point, the major issues should be software ones.

9.0 PCB Layout Design Considerations

The dimensions in the cavity of the fuselage permitted PCB dimensions of 1.5” wide x 5” long. A double-sided board is currently planned; however, after cost analysis, a ground plane and/or a power plane might be integrated into the design.

9.1.1 PCB Layout Design Considerations - Overall

9.1.2 Headers

Headers for important signals on surface mount pins are necessary to provide probe points. The surface mount components used are the PIC 24FJ256GA110 microcontroller, the MAX3222e RS232 translator, the PI3V512 5-port 2:1 mux, and the LEA-4P GPS receiver. The critical signals generated by or input to these devices that might be probed in debugging and bench testing are thus included on the headers. Headers are also provided for off-board connections such as the rangefinder, receiver, motor, servos and +5V supply input to the +3.3V regulator.

9.1.3 Signal Routing

Signal routing will primarily be on the second layer, due to the density of components on the top layer. Although the breakout boards for the gyro, accelerometer and barometer are comparatively large (for instance, the gyro breakout board measures 0.7” x 0.7”) [23], it is possible to route signals in the space under the breakout boards. This is because the breakout boards, connected by standard 0.100 headers, are to be mounted on top of the PCB with stand-offs.

Analog signals should be routed away from digital signals as possible to avoid interference.

9.1.4 Component Placement

Bypass capacitors were placed for the micro, MAX3222e, mux, and GPS receiver. These bypass capacitors were chosen to be 0.01μF as a typical value to avoid the inductive effects of larger capacitors [24] and to reduce high-frequency emissions of the digital circuitry [24]. They were placed physically near the components.

An attempt will be made in the course of the board layout to physically separate the digital, analog and RF circuitry (please refer to Appendix A for an approximate layout of the most significant components). The clock circuitry of the microcontroller is anticipated to be the main source of noise and to produce wide-band noise [21]. Therefore, the microcontroller will be

placed near the middle of the board, with analog circuitry (gyro, accelerometer), and RF (GPS) on the far front and back of the board. The microcontroller will be closer to the gyro and accelometer to reduce the length of traces needed to connect these analog components to the A/D pins of the microcontroller and reduce analog noise.

The headers will probably be placed near respective signal traces to minimize the extra routing.

9.1.5 Trace Sizing

Because the +5 V supply, supplied by the speed controller through its PWM cable, will be brought out from the speed controller to headers on the board to power the servos, the +5 V power trace under the headers must be capable of carrying about 600 mA. A 60 mil trace is more than sufficient, based on PCB trace width calculations.

The estimated current draw on the +3.3V rail, however, is a comparatively low 150 mA, requiring only thin traces. Traces of 60 mils should be sufficient to supply power from the step-down converter to all components on the +3.3V rail.

The signal traces are to have a minimal size of around 12 mils because of the tight dimensional constraints on the PCB in the space-critical application.

9.1.6 EMI Reduction

It is optimistically anticipated that RF interference from internal sources should not be a significant issue in the system. Early in the component selection process, a spread spectrum transmitter/receiver pair was selected to minimize interference from the microcontroller. The transmission band of the spread spectrum transmitter is in the 2-2.4 GHz range, higher frequency than the GPS signals at 1.575 GHz and 1.228 GHz. Although the GPS and micro could still interfere if the transmitter is a multiple of the frequency, the interference is minimized by the use of the spread spectrum transmitter. Therefore, because of the limited analog circuitry on the board, digital circuitry, primarily the clock circuitry of the microcontroller, is the primary noise concern. The use of a ground plane to protect against this noise is being investigated.

Analog noise can be reduced by using the shortest traces possible between the gyro and accelerometer and the microcontroller A/D pins.

The use of several small bypass capacitors, 0.1 μF, will reduce high-frequency emissions.

9.1.7 Manufacturing Concerns

This is a standard PCB with no especially difficult or minimal manufacturing specifications.

9.2 PCB Layout Design Considerations – Microcontroller

9.2.1 Oscillator Circuit Layout

At the present time, the team does not understand how to integrate an external oscillator into the system and has not decided on a clocking speed.

9.2.2 Decoupling

All of the power pins (V_{DD}/V_{SS}) on the microcontroller have 0.1μF bypass capacitors, which will be located as close to the relevant pins as possible, probably on the underside of the PCB.

The Motorola PCB application note [21] suggests using an RC filter circuit to reduce noise on the analog-to-digital converter reference pins. The note does not specify the precise topology of the filter required, but it does suggest routing the reference voltages directly from the +3.3V power supply, which is planned.

9.3 PCB Layout Design Considerations - Power Supply

The system runs on two power supply rails: +5V and +3.3V, derived from a +7.4V Li-Po 2500mAh battery.

The +5V rail is provided by the speed controller through its PWM cable. The physical presence of the +5V rail on the PCB is fairly limited; it connects to the +5V pins of all the PWM connector headers, which are clustered close together, and it provides the input to a high-efficiency DC/DC step-down converter.

The +3.3V rail is generated by the LTC1174 DC/DC step-down converter [22] and provides power to all of the devices in the system besides the servos and receiver. It is designed in line with the application note in the LTC1174 data sheet [22], according to the High Efficiency 3.3V Regulator circuit on page 13. The Schottky catch diode will be located close to its GND and SW connections, the Cin capacitors will be closely connected to the Vin and GND pins, and the decoupling capacitor will be placed close to the Vin pin. Shutdown and IPGM are pulled up. An appropriate bulk capacitor will be placed immediately at the terminals of the supply.

There will be two major sections of the PCB; the analog gyro and accelerometer are clustered at one end of the board, and the rest is devoted to digital devices. To reduce noise, independent traces will be run directly to the power and ground terminals of the analog devices

from the +3.3V supply. The same design will be used for the barometer, which, while providing digital output, is an analog sensor and thus likely sensitive to supply voltage fluctuations.

9.4 Summary

The primary design constraints are space and noise immunity. Given the space-critical application and tight constraints on the PCB size, surface mount components were chosen for those devices not on breakout boards or brought out to headers from off-board. Minimal trace widths will be used, and most routing is expected to be on the second layer of the board. The space under the breakout boards will be utilized for routing as well. Noise immunity will be designed through separation of the analog, digital and RF circuitry and may be increased with the inclusion of a ground plane in the design.

10.0 Software Design Considerations

Since we need to interface with a wide variety of devices, we will have to program to accommodate for different data rates from these different devices. This makes our device time critical, meaning that some things will need to have precise timing in order for us to make correct calculations in guiding the aircraft. Examples of this would be the gyros which depend on the change in voltage over time to correctly calculate the change in pitch and roll.

Our software will be written for the Microchip PIC24FJ256GA110 [26]. This is capable of having a maximum clock speed of 32 MHz with its own internal oscillator. The software concerns with our design are how complex of instructions will be able to complete within a certain amount of time. If they are too costly, we will be forced to scale down to lesser accurate algorithms.

10.1 Software Design Considerations

In designing our software, our most prominent concern is how complex our calculations can be within the certain time constraints of the individual components. When using the term complex, we are referring to the use of trigonometric functions which are highly costly with the math library provided to us by the microcontroller manufacturer. If the precise algorithms are too costly with instruction cycles, we will be forced to use less accurate algorithms which will affect our performance. The table below shows the amount of cycles it takes to do each mathematical instruction.

Figure 10.1.1 – Instruction Cost Breakdown [27]

Function Group	Function	Performance (cycles) 1,2,3,4
Basic Floating Point	addition	122
	subtraction	124
	multiplication	109
	division	361
	remainder	385
Trigonometric and Hyperbolic	acos	478
	asin	363
	atan	696
	atan2	3206
	cos	3249
	sin	2238

	tan	2460
	cosh	1049
	sinh	525
	tanh	338
Logarithmic and Exponential	exp	530
	frexp	39
	ldexp	44
	log	2889
	log10	3007
Power Function	pow	2134
	sqrt	493
Rounding Functions	ceil	94
	floor	51
Absolute Value Function	fabs	6
Modular Arithmetic Functions	modf	151
	fmod	129

1. Results are based on using the dsPIC30F MPLAB C30 Compiler (SW006012) version 1.20.

2. Maximum "Memory Usage" when all functions in the library are loaded. Most applications will use less.

3. All performance statistics represented here are for 32-bit IEEE754 floating-point input and output data types.

4. Performance (in instruction cycles) listed here represent an average number of instruction cycles required to perform the floating-point operation.

There are two specific areas in FlySpy that we foresee having complex, expensive code. The accelerometer that we are reading on the ATD channels, will give us the reading of acceleration over the x, y, and z axis. Given just these individual components, we will have to constantly calculate the magnitude of the axis to see if we are just reading gravitation pull. This causes for costly the costly square root function, which is not really a big concern. On the other hand, when calculating the actual pitch and roll values at that instantaneous moment with the accelerometer, we will need to use the square root and the atan function. As seen in the table, the atan function will function cost about 696 performance cycles. If clocking at 32 MHz, we have 640,000 cycles available between samples. An alternative to actually using the atan function would be to compose a look up table that references the actual values of the adc channel to an angle value. Although this may take a lot of memory, it may prove to be quite helpful in terms of

timing if the atan function cannot execute within the about of time that we propose to refresh the accelerometer data.

The major algorithm that we are taking into consideration is the algorithms that we use to calculate distance and correct heading from the GPS data. Given that the gps data is basically represented in degrees, if we want to be precise with our calculations, it will take several occurrences of trigonometric functions to derive a bearing and distances from two points that are very precise. We have seen that there are scaled down versions of these algorithms but they do show that they affect accuracy largely over a certain amount of distance. [28].

Given the fact that we are using various devices, we find ourselves having to model our software design in a fashion to accommodate for accurate, up to date data from each of these components while they require different timing subroutines. The GPS module that we are using, the FV-M8 [4], works at 5 Hz. On the other hand, the IDG300 two-axis gyro [5] will require us to sample its data faster, around 50 Hz, in order to retrieve accurate data. We view these items as the two pacesetting products in our design. Therefore we will have to use timer interrupts to update GPS data and also a faster timer interrupt to sum the change in rotation for the gyro data.

The basic operational logic of the autopilot unit is as flowcharted in Appendix A. Although shown in a direct format, some procedures will be done iteratively more than other portions. All procedures of basic operation past initialization will be interrupt driven to assert that we have clean and up to date data.

The variables that hold the current GPS and orientation information will be stored as global variable, therefore accessible to all functions. This brings coherence into play but we will use timing to assert that there is not simultaneous use instead of using locks. Since there will not be that much program code or memory storage in comparison to the 256Kb series of microcontrollers that we are using, we will be fine using the default mapping of program memory for the stack, heap, and program memory. This is displayed in detail in Appendix C.

The PIC24FJ256GA110 is an 100-pin device and we will use the following ports for interfacing to different devices as listed:

Device Ports	Interface Type
Accelerometer Axes	ATD AN5-3
Range Finder	ATD AN2

Gyro Axes	ATD AN1-0
Barometer	SPI0
SD Card	SPI2
GPS Module	SPI3
ICD	I2C
Serial Port	UART

10.2 Software Design Narrative

File Name	Description
Main.c (written in pseudo-code)	Used to initialize all micro-controller ports and modules, thereafter it start the timer on all interrupts and remain in an empty infinite loop throughout the rest of the operation
ADC.c/ADC.h (written and tested)	This module consists of functions to operate all analog to digital functions. This reduces t has control of all the channels, has multiple functions and can read all channels base on the channel number
Timer.c (written and not tested)	Initializes all time interrupts for all general operation. Has multiple clocks for different timers (Ex: 5 Hz for GPS, 50Hz for orientation calculations.)
GPS.c (written in pseudo-code)	This module consists of functions to retrieve GPS data from the GPS receiver. Also functions to calculate difference in baring and distance
Camera.c (written in pseudo-code)	Module consists of simple functions that control the operations of a camera. Simply turning the camera on, flash, a picture signal and placing the camera back to the off state
Filesystem.c (written in pseudo-code)	Module consists formatting for i/o into the auto pilot programs. Uses microchips filesystem library to read and write from the non-volatile memory
Control.c	Has functions which set the PMW control signals to the aircraft control

(written in pseudo-code)	surfaces.
Sensors.c (written in pseudo-code)	Module consists of algorithm that will be used to fuse the accelerometer and gyro data to successful obtain the planes orientation. Also, it will retrieve and use data from the barometer and range finder, setting the global variables for other modules to make uses.
Config.c (written and not tested)	Module simply sets the peripheral pin select and tri-state i/o of 100 pin microchip
Transmitter.c (written in pseudo-code)	Module uses input capture to clock manual users control signals from the receiver unit

10.3 Summary

In designing the software for FlySpy, timing is the most critical issue. Besides the testing that we can do in to see if any algorithm has given us the correct response, we still will have to alter our workflow to accommodate the response rate needed for a stabile flight. We believe that we have come up with a solution that will yet and still pass the test of updating in a timely fashion with the required peripherals.

11.0 Version 2 Changes

- Put parts directly onto the PCB instead of on breakout boards (examples: SD card, all of our sensors). This would make our design more manufacturable and allow us to compact the PCB more.
- Find PCB space to include the ICD 2 (debug) header and RS-232 serial port instead of using external adapter boards.
- Instead of using the accelerometer, which is affected by the plane's motion, to estimate the direction of "down", we could use a non-inertial device, such as a magnetometer, to correct for errors in the inertial system's orientation estimates.
- Power the multiplexer directly off the 5V power rail, which eliminates its dependence on the proper operation of the 3.3V buck converter.
- Incorporate two-way wireless communication.

12.0 Summary and Conclusions

As far as electrical engineering work goes, the FlySpy project has been a success. There were no hardware problems, and there are no known logic bugs in the software. As of the writing of this report, the software only lacks proper parameter tuning, and if that can be completed, all five PSSCs will be completed by the end of the semester.

The project has been very educational, providing an opportunity to work with all manner of interesting hardware (inertial sensors, GPS, microcontrollers) in a real-world application setting. The team gained significant real-world design and engineering skills, particularly with respect to navigating the jungle of parts available and in doing research to get a problem solved expediently. The team also learned to work independently; the TAs, while nearly always helpful, did not have all the answers, and the team had to learn to deal with this.

FlySpy was certainly the “something cool” that we went into engineering to create. Although we didn’t quite complete it, we have made great strides in our understanding of the engineering process in the real world as a result of working on it.

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Appendix A: Individual Contributions

A.1 Contributions of Heather Barrett:

Hardware Design

I was heavily involved in the hardware design. I did about 95% of the work on the first schematic revision, assisted by Jeremy and William's research into the microcontroller peripheral pin select feature along with the function of the PWM channels, A/D channels, and SPI and SCI interfaces. I was also heavily involved with the component selection and acquisition. I was heavily involved in the PCB footprint creation, planning, component placement, wiring, and component verification of the PCB.

Documentation

I put together the senior design report by myself, worked with William on the final report and worked with Daeho on the user manual.

Construction

I did some of the soldering on the PCB and soldered some connectors.

Miscellaneous

I helped with top level planning in the early stages of the project.

A.2 Contributions of William Ehlhardt:

With respect to the design project itself, I primarily worked on the hardware design. I did a lot of the work in nailing down the overall structure of the hardware, designing the flow of signals from system to system. I worked out which microchip peripherals we were using and how they connected to the sensors and other hardware. I selected the microcontroller based on our peripheral usage, as well as other part selection; I was the one who decided to change GPS modules instead of trying to get the GPS antenna signal routed. I did the mapping of functions to pins on the microcontroller and the subsequent pin function changes required to make routing easier.

I did the bulk of the work on the PCB layout and the subsequent schematic redesigns made to facilitate routing. The PCB was my single most significant functional contribution to the project and took me the better part of two weeks.

Once the PCB came back, I helped with the hardware assembly, although I had others do some of the harder soldering work. I assembled the 3.3V power supply and babysat it through several hours of burn-in under load. I validated the signal conditioning for the gear switch (autopilot/manual) control, catching a capacitor value mistake in the process. I then validated the whole autopilot/manual multiplexing system and confirmed its correct operation.

While Jeremy did the bulk of the software development, I helped significantly on it. I wrote the SPI-based driver for the barometer myself. I also did the tedious work of creating the peripheral pin select code that assigns the microcontroller peripherals to physical pins (although I later discovered that there was an automation tool to do all that easily). I managed to track down several minor and a few major bugs that were tripping Jeremy up.

Heather and I did the compilation of the homeworks into the final report submission materials, along with a lot of the editing thereof.

A.3 Contributions of Daeho Hong:

My major part in this project was to implement SD card interface and flight logging functions. First I spent a few weeks to research on how SD card works and FAT file system works because I expected that I have to write the entire file header and generate control signals for the SD card. I also researched on the SD card circuitry which was simple and it did not take a lot of time. SD card breakout board was purchased and it helped a lot.

After our microcontroller was selected, I found out that there were file I/O library for PIC microcontroller on microchip.com which is the vendor of our microcontroller. It offered the most of the SD card interface and file I/O functions and some optional functions could be enabled by our needs. I enabled fprintf function which was initially disabled to save resources of the microchip. I wrote flight logging functions to write the log in XML script so that it can be displayed with a certain scheme but it was not suitable for our situation so Jeremy changed to just text log.

After the flight logging is done, I wanted to help Jeremy figuring out the flight controls but Jeremy was too ahead of me to catch up his pace and I decided to work on other

miscellaneous part that can help our team. Therefore, I spent time on preparing the user-manual and poster. For user manual, the installation process, user guide, and trouble-shooting were written. It was very straight forward and I felt that the manual control mode and flight logging functions were the most important part that can help the user to solve the problem when they encounter any unfavorable circumstance.

For the poster, I took the image of our plane and edited it with Photoshop so that it can get along with the aerial photograph of Purdue Memorial Mall. I paid more attention on the graphic to make it interesting for the audience and revised it to make sure that it contains necessary information. The size of the poster was limited and it was difficult to put everything in the poster.

A.4 Contributions of Jeremy Tillman:

As the team leader for FlySpy, I was in charge of researching existing methods of controlling a RC Airplane autonomously. Since no one on the team, including myself, had no previous experience of flying RC Airplanes, I successfully sought out advice and experienced pilots to support the group with piloting and controls skills. Once enough contacts and information were acquired, I focused more on the components that the airplane would operate off of and its general logic of operation. In doing so, I selected the components that would be included in our design, as well as the aircraft that we would modify. I researched Inertial Measurement Units and what devices would be needed in building our own to given us adequate information about our airplane's orientation and position.

I acquired an unused camera from a personal friend. Thereafter, I disassembled it to gain access to pins that would enable the microcontroller to power on and off, as well as take picture with. I was very much involved in the hardware block diagram and loosely involved with the actual schematic, only lending a hand where previous knowledge of interfacing or deep skills were not needed. Once the plane was purchase, I assembled it to its stock entirety. I also setup flight dates with our experienced pilot to flight test the plane, noting the power of the engine and flight traits of the airframe.

Once the devices were purchased for the PCB, I learned to solder small port appropriately, as our microcontroller had a small pitch and a large amount of pins. I used a soldered a practice microcontroller to the breakout board and started developing a small amount

of code before the actual board had arrived. I also soldered the microcontroller and multiple breakout devices to the PCB. Thereafter, I made cables that interfaced with the PC and off board peripherals.

I was in charge of the entire autopilot program aside from bare level microcontroller-device interfacing. I asserted that the plane was retrieving correct information from the off chip devices and use them to determine the control of the planes surfaces as well as throttle. Once a reasonable amount of the program was written, I found material and methods to package the PCB board into the cockpit as well as mount the camera and range finder to the bottom. When the packaging was complete, I setup times with experienced pilots to test the autopilot algorithm.

Appendix B: Packaging

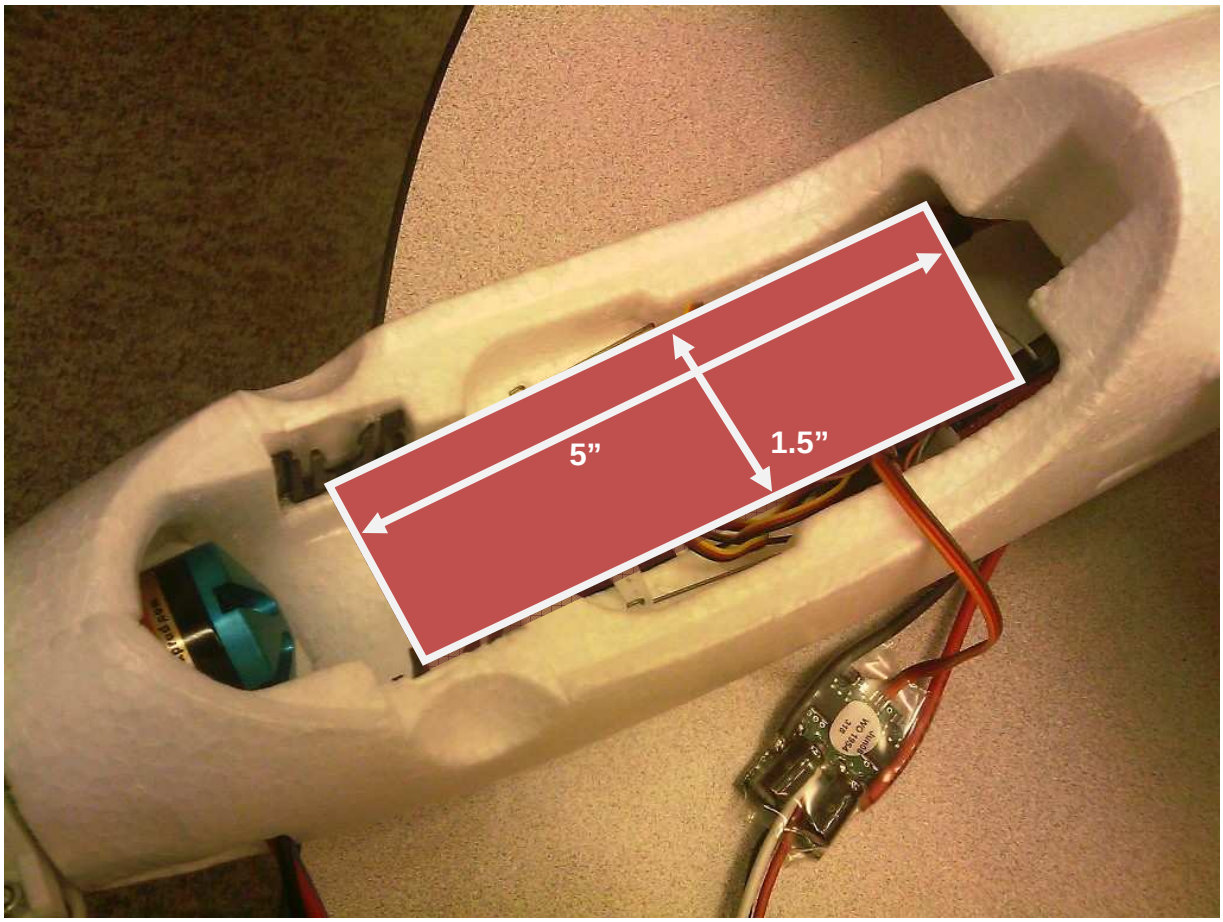


Figure B-1: Approximate placement of PCB within fuselage (top view)

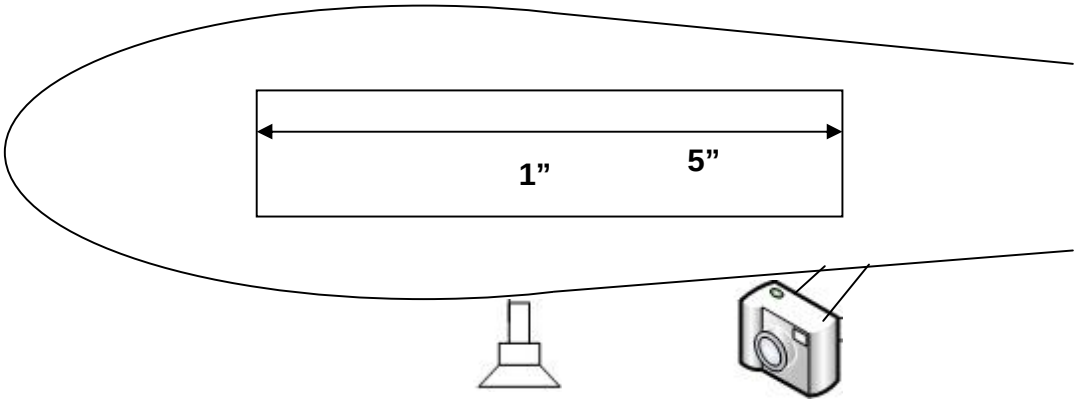
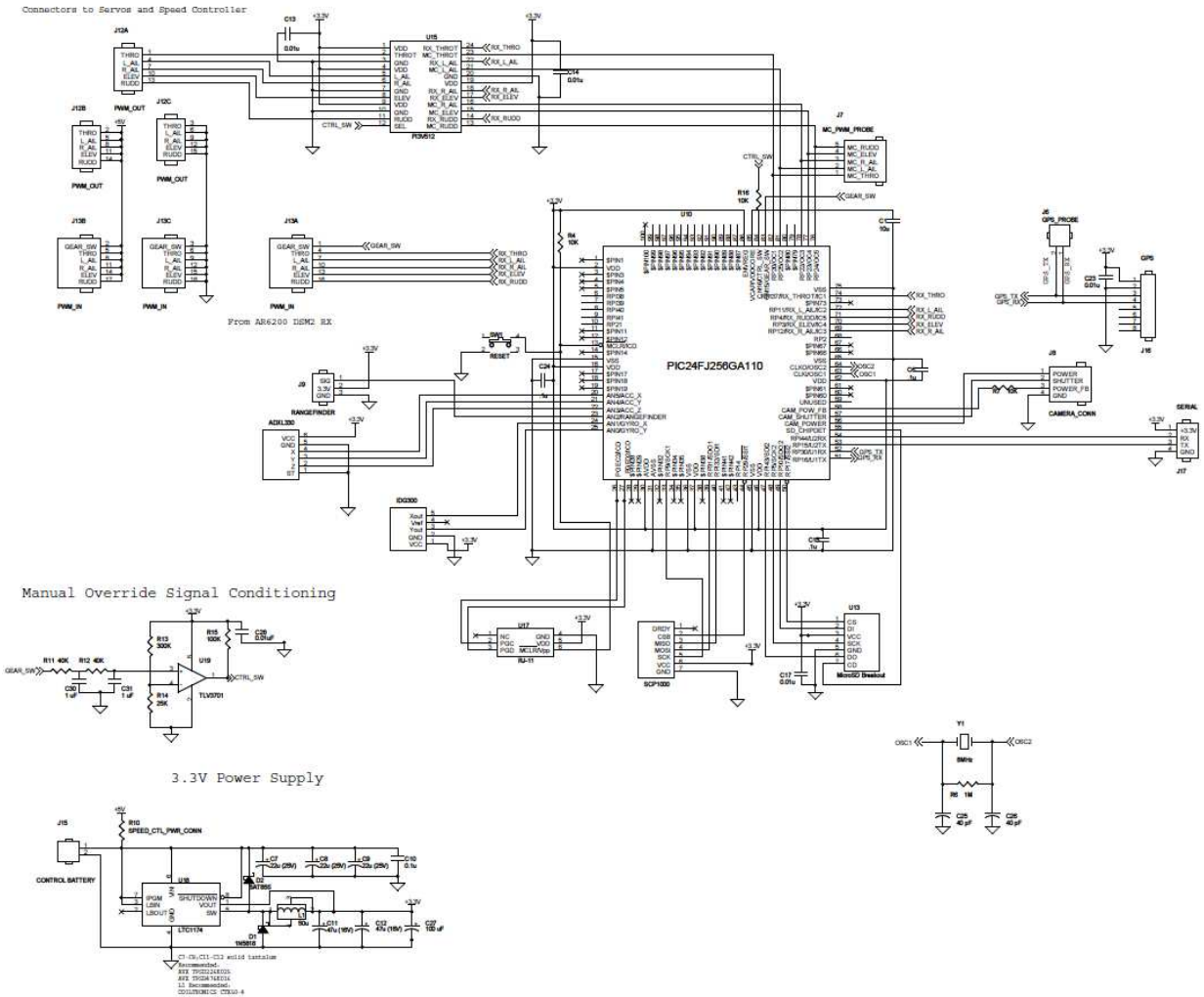


Figure B-2: Overall packaging sketch

Appendix C: Schematic



Appendix D: PCB Layout Top and Bottom Copper

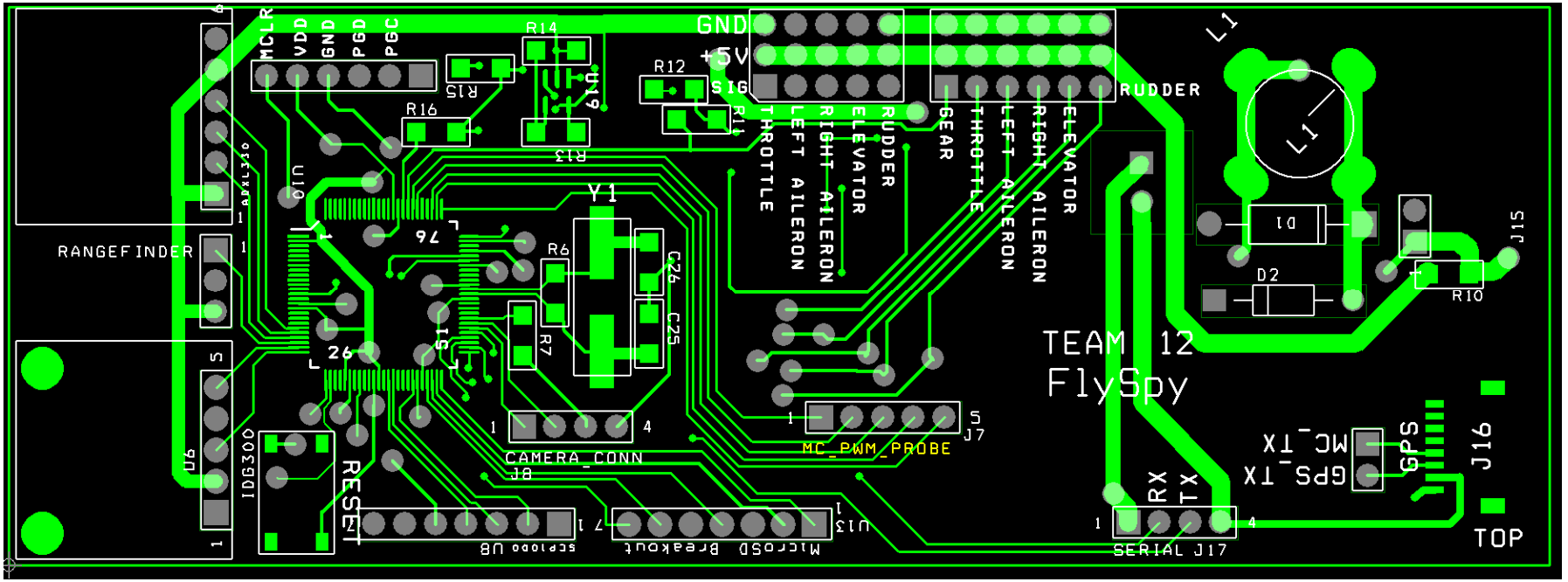


Fig D-1: PCB Top Layer

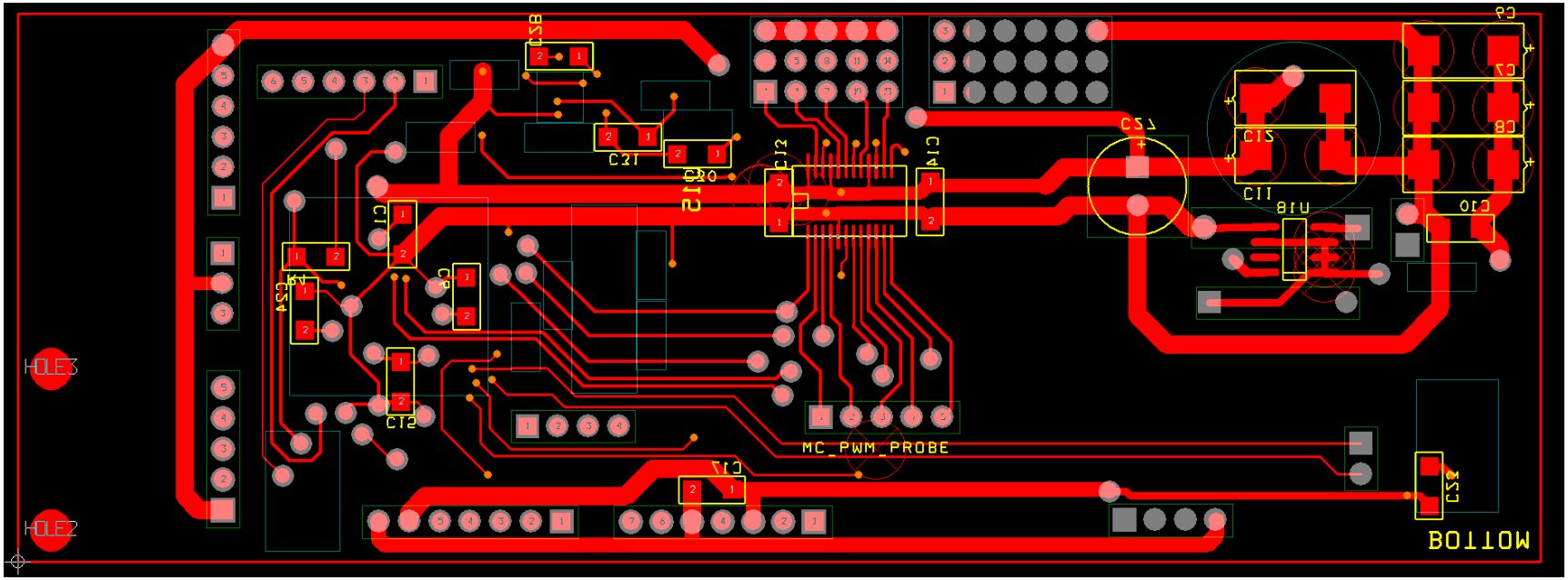


Fig D-2: PCB Bottom Layer

Appendix E: Parts List Spreadsheet

Vendor	*Manufacturer*	*Part No.*	*Description*	*Unit Cost*	**Qty**	*Total Cost*
MicroChip	MicroChip	PIC24FJ128GA106	16-bit Microcontroller	$4.90	1	$4.90
Advantage Hobby	Multiplex	MPU214226	Easy Glider Pro Kit	$109.99	1	$109.99
Advantage Hobby	Multiplex	MPUM998226	Easy Glider Pro Servo Pack	$77.89	1	$77.99
Advantage Hobby	Multiplex	MPUM993226	Easy Glider Pro Power Pack	$145.89	1	$145.89
Advantage Hobby	Multiplex	SPM6600	DX6i 6 Channel Spread Spectrum Rx/Tx	$199.99	1	$199.99
Advantage Hobby	Multiplex	FPWEVOLITE25002S	Li-Po 7.4V 2500mAh Battery	$49.99	1	$49.99
SparkFun	InvenSense	SEN-00698	Dual Axis Gyro	$74.95	1	$74.95
SparkFun	VIT Tech.	SCP1000	Mems Barometric Pressure Sensor	$54.95	1	$54.95
SparkFun	Analog Devices	ADXL330	Triple Axis Accelerometer	$34.95	1	$34.95
SparkFun	Maxbotix	LV-EZ1	Ultrasonic Range Finder	$24.95	1	$24.95
Ublox	Ublox	LEA-4P	Programmable GPS Module	$99.99	1	$99.99
Jeremy Tillman	Nikon	Coolpix s7	Camera	$0	1	$0
Jeremy Tillman	Secure Digital	1GBSD	SD Card	$0	1	$0
				TOTAL		**$878.54**

Appendix F: Software Listing

```
/*********************************************************************
 * FlySpy v0.c
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 ********************************************************************/

#include "FlySpy.h"


_CONFIG1( JTAGEN_OFF & GCP_OFF & GWRP_OFF & COE_OFF & FWDTEN_OFF & ICS_PGx2)
_CONFIG2( FCKSM_CSDCMD & OSCIOFNC_OFF & POSCMOD_NONE & FNOSC_FRCPLL)

extern GPSINFO CurrentGPS;
extern WAYPOINT wayPoints[MAXWAYPOINTS];
extern TAKEOFFLANDING StartEndPoint;
extern SENSORDATA sensorInfo;
extern int wayPointCount;
extern int SecondFlag;
extern int TimerFlag;
extern int TimerCount;


int main(void)
{

         float man_l_ail, man_r_ail, man_throttle, man_elev, man_rudder;

         unlockIO();
         CLKDIV = 0x3000; // Changes Oscillator Postscalar to 1:1
         ioMap();          //Set micro pin directions and peripherals pin selects
         lockIO();         //Locks port pin directions
         initgps();        //Initializes communication to the GPS through UART and
configures its message types
         initCamera();              //Initializes Camera Outputs
         gpserial_init();  //Initializes the communication to the RS-232

         #ifdef GPS_PASSTHROUGH
         #warning Compiling for GPS passthrough mode.
                  printf("GPS Passthrough mode go!\r\n");
                  gps_passthrough();
         #endif
         initio();         //Initializes SD Communication and Reads in Flight
Information
         initSensors();    //Initializes the Sensor structure and zeros sensor
algorithms
         initSurfaces();
         initADC();        //Initializes the Analog to digital module
         barometer_init(); //Intitializes and starts communication with the SPC-1000

         initTimer();      //Initializes and starts all Timer
         initpwm();        //Initializes Input Capture of the Receiver PWM and Output
Compare of PWM to Airplane Control Surfaces

         printf("Please Wait to Aquire GPS Signal\r\n");
         do
         {
                  retrieveGpsData();
         }while(!CurrentGPS.Signal);
```

```
		printf("GPS Signal Aquired!\r\n");

		#ifdef MANUAL_ONLY_MODE
			printf("Manual only mode\r\n");
			FSFILE *fptr;
			int length =  0;
			char logBuffer[2000];
			int lastState = 1;
			int val;
			int count = 0;
			int length_check;

			__delay32(32000000);
			fptr = FSfopen("LOG.TXT", "w");
			if ( fptr == NULL )
			{
				printf("Error in Creating LOG.TXT: %d\r\n", FSerror());
				while(1);
			}
			FSfprintf(fptr, "Time, Latitude, Longitude, Speed, Heading, Pitch,
Roll, Altitude, Clearing, Throttle, L-Aileron, R-Aileron, Elevator, Rudder, Gyro Pitch
Volt, Gyro Roll Volt, AccelG X, AccelG Y, AccelG Z, Variance\r\n");
			FSfclose(fptr);

			while(1)
			{
				val = CTRL_SW;

				if ( lastState != val )
				{
					if ( val == 0)
					{
						fptr = FSfopen("LOG.TXT", "a");
						if (fptr == NULL)
						{
							printf("Error in FSfopen of
LOG.TXT: %d\r\n", FSerror());
							while(1);
						}
					}
					else
					{
						if ( length > 0)
						{

							length_check =
FSfwrite(logBuffer,1,length, fptr);
							if(length  !=length_check)
							{
								FSfclose(fptr);
								printf("Error in
FSfwrite: %d\r\n", FSerror());
								while(1);
							}
							length = 0;
							FSfclose(fptr);
						}

					}
					lastState = val;
				}

				retrieveGpsData();
```

```
                        if (TimerFlag == 1)
                        {
                                if (lastState == 0 )
                                {
                                        read_PWM_IN(&man_l_ail, &man_r_ail,
&man_throttle, &man_elev, &man_rudder);
                                        sensorInfo.inuse = 1;
                                        length +=
sprintf(&logBuffer[length],"%2d:%2d:%2d.%3d.%1d, %8.6f, %9.6f, %5.2f, %6.3f, %4.3f,
%4.3f, %4.3f, %4.3f, %4.3f, %4.3f, %4.3f, %4.3f, %4.3f, %4.3f, %4.3f, %4.3f, %4.3f,
%4.3f, %4.3f\r\n", CurrentGPS.Hour, CurrentGPS.Minute, CurrentGPS.Second,
CurrentGPS.Mils, TimerCount, CurrentGPS.Latitude, CurrentGPS.Longitude,
CurrentGPS.Heading, CurrentGPS.Speed, sensorInfo.Pitch, sensorInfo.Roll,
sensorInfo.Altitude, sensorInfo.Clearing, (double) man_throttle, (double) man_l_ail,
(double) man_r_ail, (double) man_elev,(double) man_rudder,
sensorInfo.GyroPitchVoltage, sensorInfo.GyroRollVoltage, sensorInfo.Accelerometer_X,
sensorInfo.Accelerometer_Y, sensorInfo.Accelerometer_Z, sensorInfo.MagnitudeVariance);
                                        sensorInfo.inuse = 0;
                                }
                                count++;
                                if ( count > 9 )
                                {
                                        if ( length > 0)
                                        {

                                                length_check =
FSfwrite(logBuffer,1,length, fptr);
                                                if(length  !=length_check)
                                                {
                                                        FSfclose(fptr);
                                                        printf("Error in
FSfwrite: %d\r\n", FSerror());
                                                        while(1);
                                                }
                                                length = 0;
                                        }
                                        count = 0;
                                }
                                TimerFlag = 0;
                        }

                }
        #else
                double targetBearing;
                double targetDistance;
                double bearingDifference;
                double Pitch;
                double Roll;
                int wp_index; // Indexs the current waypoint that we are
approaching in the wayPoints array
                int lcv;
                float auto_l_ail, auto_r_ail, auto_throttle, auto_elev,
auto_rudder;

                enableControlSurfaces();
                wp_index = 0;
                logStart();

                if ( StartEndPoint.TakeOff )
                {
                        SecondFlag = 0 ;
                        lcv = 0;
                        while( lcv < StartEndPoint.Delay )
```

```
                                {
                                        __delay32(SYSCLK/2);
                                        lcv++;
                                }
                                setSurface(.5,THROTTLE);
                                setPitch(20);
                                setRoll(0);
                                while(StartEndPoint.TakeOff_Altitude - sensorInfo.Altitude
> 20);
                        }
                        setSurface(.5, THROTTLE);
                        while (wp_index < wayPointCount)
                        {
                                retrieveGpsData(); //Retrieves Current GPS Data
                                calculatePath(CurrentGPS.Latitude, CurrentGPS.Longitude,
wayPoints[wp_index].Latitude, wayPoints[wp_index].Longitude, &targetDistance,
&targetBearing);
                                if (targetDistance < .020) //if Distance is less than 20
meters
                                {
                                        if ( wayPoints[wp_index].Picture == 1)
                                        {
                                                setPitch(0);
                                                setRoll(0);
                                                logPicturePoint(&CurrentGPS);
                                                takePicture();
                                        }
                                        wp_index++;
                                }
                                else
                                {
                                        bearingDifference = fmodf(targetBearing -
CurrentGPS.Heading +  540, 360) - 180;
                                        Roll = bearingDifference * MAX_ROLL / 180;
                        //              sensorInfo.inuse = 1;
                                //      if ( sensorInfo.Altitude * 100 - 25 >
wayPoints[wp_index].Altitude )
                                //      {
                                //              Pitch = -MAX_PITCH;
                                //      }
                                //      else if ( sensorInfo.Altitude * 100  <
wayPoints[wp_index].Altitude - 25 )
                                //      {
                                //              Pitch = MAX_PITCH;
                                        //}
                                        //sensorInfo.inuse = 0;
                                        //Equate how much turn should be given at the
time
                                        //Call setOrientation to guide the plane in that
direction
                                        //setRoll(Roll);
                                        //setPitch(Pitch);
                                        setRoll(ROLL_ZERO);
                                        setPitch(PITCH_ZERO);
                                }
                                if(SecondFlag == 1)
                                {
                                        read_PWM_IN(&man_l_ail, &man_r_ail,
&man_throttle, &man_elev, &man_rudder);
                                        read_PWM_OUT(&auto_l_ail, &auto_r_ail,
&auto_throttle, &auto_elev, &auto_rudder);
                                        sensorInfo.inuse = 1;
```

```
                                        logCoord(&wayPoints[wp_index],&CurrentGPS,
targetDistance, targetBearing, sensorInfo.Altitude, sensorInfo.Pitch, sensorInfo.Roll,
sensorInfo.Clearing, auto_throttle, auto_elev, auto_rudder, auto_l_ail, auto_r_ail,
man_throttle, man_elev, man_rudder, man_l_ail, man_r_ail);
                                        //Log information to SD Card
                                        sensorInfo.inuse = 0;
                                        SecondFlag = 0;
                                }

                        }
                        if ( StartEndPoint.Landing )
                        {
                                //Go to landing
                        }

                        setPitch(PITCH_ZERO);
                        setRoll(ROLL_ZERO);
                        setSurface(0,THROTTLE);

        #endif
    while(1);
        return 0;
}

/*****************************************************************************
 * ADC.c
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *****************************************************************************/

#include "FlySpy.h"


void initADC()
{
        AD1PCFGH = 0x0000; //All Ports to analog inputs
        AD1PCFGL = 0x0000;

        AD1CON1 = 0x00E0; // SSRC<3:0> = 111 implies internal
                                                        // counter ends sampling and
starts
                                                        // converting.

        // in this example AN12 is the input
        AD1CSSL = 0;
        AD1CON3 = 0x1F02; // Sample time = 31Tad,
        // Tad = 2 Tcy
        AD1CON2 = 0;

        AD1CON1bits.ADON = 1; //turning ADC ON
        return;
}

void setADCPort(int portNumber)
{

        AD1CHS = portNumber; // Setting the ADC input as the appropriate pin;

}

int retrieveADCVal()
{
```

```
        int retVal;
        AD1CON1bits.DONE = 0; //Assert that the DONE bit has been cleared from
previous ADC Read
        AD1CON1bits.SAMP = 1; // Starting to sample and then will automatically go
into convert
        while(!AD1CON1bits.DONE); // Wait for conversion to finish
        retVal = ADC1BUF0;
        return(retVal);
}


int sampleADCPort(int portNumber)
{
        int retVal;

        setADCPort(portNumber);     //Set the analog port to sample
        retVal = retrieveADCVal();  //Retrieve port value

        return (retVal);
}


/************************************************************************
 * ADC.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 ************************************************************************/

void initADC();
void setADCPort(int);
int retrieveADCVal();
int sampleADCPort(int);


/************************************************************************
 * barometer.c
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 ************************************************************************/

#include "FlySpy.h"

extern SENSORDATA sensorInfo;

#define MYSPISTAT  SPI1STATbits
#define MYSPICON1  SPI1CON1bits
#define MYSPICON2  SPI1CON2
#define MYSPIBUF   SPI1BUF

signed int temp = 0;
long pressure = 0;
float Altitude = 0;

static unsigned char spi_comm(unsigned char send)
{
        unsigned char reply = 0;
        MYSPISTAT.SPIROV = 0;                       // clear Mr. Overflow Bit
        MYSPIBUF = send;                            // Initiate the transfer
        while (MYSPISTAT.SPITBF) ;  // And wait for its completion
        while (!MYSPISTAT.SPIRBF) ; // Wait for a byte
        reply = (MYSPIBUF & 0xFF);
```

```
        //printf("0x%02x ", (int) reply);
        return reply;               // And feed it back
}

static void writereg8(unsigned char addr, unsigned char value)
{
        // Convert the address into the "write to this address"
        // command to be sent over the SPI bus
        addr = (addr << 2) | 0b00000010;

        BAROMETER_CS = 0;  // Select the barometer
        spi_comm(addr);    // Throw the data onto (under?) the bus
        spi_comm(value);
        BAROMETER_CS = 1;  // Deselect the barometer
}

/* I don't think there are any 16-bit writable registers.
        -William */
#if 0
static void writereg16(unsigned char addr, unsigned int value)
{
        // Convert the address into the "write to this address"
        // command to be sent over the SPI bus
        addr = (addr << 2) | 0b00000010;

        BAROMETER_CS = 0;  // Select the barometer
        spi_comm(addr);    // Throw the data onto (under?) the bus
        spi_comm((value >> 8) & 0xFF);       // Send the high byte first,
        spi_comm(value & 0xFF);              // and then the low byte
        BAROMETER_CS = 1;  // Deselect the barometer
}
#endif

static unsigned char readreg8(unsigned char addr)
{
        unsigned char ret = 0;
        // Convert the address into the "read from this address"
        // command to be sent over the SPI bus
        addr = (addr << 2) & 0b11111100;

        BAROMETER_CS = 0;           // Select the barometer
        spi_comm(addr);                     // Send a "read" command
        ret = spi_comm(0x00);       // Read back the response
        BAROMETER_CS = 1;           // Deselect the barometer

        return ret;
}

static unsigned int readreg16(unsigned char addr)
{
        unsigned int high = 0, low = 0;
        // Convert the address into the "read from this address"
        // command to be sent over the SPI bus
        addr = (addr << 2) & 0b11111100;

        BAROMETER_CS = 0;           // Select the barometer
        spi_comm(addr);                     // Send a "read" command
        high = spi_comm(0x00);      // Read back the high byte
        low  = spi_comm(0x00);      // Read back the low byte
        BAROMETER_CS = 1;           // Deselect the barometer

        return (high << 8) | low;
}
```

```
void barometer_init(void)
{
         /**** Set up the SPI interface ****/
         BAROMETER_CS = 1;  // deselect the barometer
         MYSPISTAT.SPIEN = 0;        // turn off the module

         MYSPICON1.DISSCK   = 0;     // enable PIC-sourced clock
         MYSPICON1.DISSDO   = 0;     // SDO pin controlled by module
         MYSPICON1.MODE16   = 0;     // Byte-width communications
         MYSPICON1.SMP              = 0;     // Sample phase (TODO: check this?)
         MYSPICON1.CKE              = 1;     // Latch out new data on the FALLING
                                                          // clock edge; the
barometer latches
                                                          // it in on the
RISING edge.
         MYSPICON1.SSEN     = 0;     // Don't use SS1 pin
         MYSPICON1.CKP              = 0;     // Clock idles on LOW
         MYSPICON1.MSTEN    = 1;     // Master mode

         /* Set the clock output to 125kHz */
#if   (SYSCLK == 8000000)
         MYSPICON1.PPRE     = 1;     // 1:16 primary prescale
#elif (SYSCLK == 32000000)
         MYSPICON1.PPRE     = 0;     // 1:64 primary prescale
#else
#error Unsupported clock frequency!
#endif
         MYSPICON1.SPRE     = (8 - 2);         // 1:2 secondary prescale

         MYSPICON2 = 0;                        // Don't use any framed mode stuff

         // TODO: config to monitor transmit/receive status?

         MYSPISTAT.SPIEN = 1;        // flip that bad boy back on

         while (barometer_startup_running())
         {
                  __delay32(8000000);
                   printf("BaroBoot\r\n");
         }
         /*       Order the barometer to commence acquisition in high-speed
                  continuous mode */
         writereg8(0x03, 0x09);
}

baro_status_t barometer_status(void)
{
         unsigned char status = 0;
         baro_status_t res = {0,0,0};

         // Read in the device status
         status = readreg8(0x07);
         //printf("0x%02x ", (int) status);

         // Mash together the output structure
         res.dataready              = !!(status & 0b00100000);
         res.error                  = !!(status & 0b00010000);
         res.startup_running        = !!(status & 0b00000001);

         return res;
}
```

```
char barometer_dataready(void)
{
	baro_status_t res = barometer_status();
	return res.dataready;
}

char barometer_error(void)
{
	baro_status_t res = barometer_status();
	return res.error;
}

char barometer_startup_running(void)
{
	baro_status_t res = barometer_status();
	return res.startup_running;
}

void barometer_read(signed int *temp, long *pressure)
{
	signed int _temp = 0;
	long presh = 0, presl = 0;
	long _pressure = 0;

	// Pull in the readings from the barometer
	_temp = readreg16(0x21);
	presh = readreg8(0x1F) & 0b111;
	presl = readreg16(0x20);
	_pressure = (presh << 16) | presl;

	// Convert units
	*temp = _temp / 2;
	*pressure = (_pressure >>2);
}

void barometer_test()
{
	unsigned char addr = 0x07;
	unsigned char cmd = (addr << 2) & 0b11111100;

	BAROMETER_CS = 0;  // Select the barometer
	spi_comm(cmd);              // Call
	printf("%02x\r\n", (int) spi_comm(0x00)); // and response
	BAROMETER_CS = 1;  // Deselect the barometer

	if (MYSPISTAT.SPIRBF)
	{
		printf("%02x\r\n", MYSPIBUF);
	}
	if (MYSPISTAT.SPIROV)
	{
		printf("LOLOVERFLOW\r\n");
	}
}

void updateAltitude()
{
		baro_status_t stat = barometer_status();
		if (stat.dataready && (!stat.startup_running))
		{
			barometer_read(&temp, &pressure);
			Altitude = 44.33 - 4.9465* pow(pressure, .190263);
			if (!sensorInfo.inuse)
```

```
                                        sensorInfo.Altitude = Altitude;
                }
}


/*****************************************************************************
 * barometer.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *****************************************************************************/

#ifndef __BAROMETER_H
#define __BAROMETER_H

/***** API OVERVIEW *****/
/*       This file is a driver for the SCP1000 barometer over SPI#1.
         To use the barometer,
         1. Call barometer_init() to set it up to acquire data.
         2. Don't read data until barometer_status reports that startup
                  is complete.
         3. Poll barometer_status() every 10-20ms [1] to see if there
                  is data ready to be bussed in.
         4. If so, call barometer_read() to get that data.

         [1]  In high-speed acquisition mode, you have a 25ms window
                  between the barometer having data ready and the time that
                  it starts to acquire a new value and trashes its data
                  buffer. barometer_status() reports when new data is ready.
*/


void barometer_init(void);

typedef struct _baro_status_t
{
         // Is there data ready to be read in?
         unsigned dataready:1;
         /*  Indicates whether the last "data ready" timed out before
                  the micro serviced it.
                  Should this be the case, the next value to be returned
                  by barometer_read will be garbage; however, the read
                  will clear the error */
         unsigned error:1;
         // Startup procedure running?
         unsigned startup_running:1;
}
baro_status_t;
baro_status_t barometer_status(void);

char barometer_dataready(void);
char barometer_error(void);
char barometer_startup_running(void);

/*       Returns the barometer's measured temperature in TENTHS of degC,
                  and the pressure in TENTHS of Pascals.
         Notice that there is a chance this could return garbage;
                  see the "error" bit documentation above.
         It would also be a poor plan to call this if the dataready
                  status bit is not set.
         */
void barometer_read(signed int *temp, long *pressure);
```

```
void barometer_test();

void updateAltitude();
#endif



/*****************************************************************************
 * camera.c
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *****************************************************************************/

#include "FlySpy.h"

void initCamera()
{
         /* Pull both control outputs HIGH on bootup */
         CAM_SHUTTER = 1;
         CAM_POWER= 1;
}

int changePowerMode(int mode)
{
         // If the camera is not in the desired power state...
         if(CAM_POW_FB != mode)
         {
                  // "Close" the power switch by pulling LOW
                  CAM_POWER = 0;
                  // Keep it closed until the power state changes to the
                  // desired state, as reported by the feedback
                  if (CAM_POW_FB != mode)
                  {
                           __delay32(1000000); //Only wait for a specific amount of
time so plane can control itself again
                  }
         }
         // We have reached the desired mode, so flip that pin back
         // on up to "high"
         CAM_POWER = 1;
         __delay32(1000000);
         if (CAM_POW_FB != mode)
                  return 0;
         return 1;
}

int powerOnCamera()
{
         return (changePowerMode(1));
}

int powerOffCamera()
{
         return ( changePowerMode(0) );
}

int takePicture()
{
         int status;
         status = powerOnCamera();
         if ( status == 1)
         {
```

```
                    // "Close" the shutter switch by pulling it LOW
                    CAM_SHUTTER = 0;
                    __delay32(1000000);//Wait for delayed amount of time for camera to
finish shot

                    // Pull the shutter switch back HIGH
                    CAM_SHUTTER = 1;

                    __delay32(128000000);
                    status = powerOffCamera();
          }
          return ( status );
}


/*****************************************************************************
 * camera.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *****************************************************************************/

void initCamera(void);
int takePicture(void);


/*****************************************************************************
 * Compiler.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *****************************************************************************/

/*****************************************************************
 *
 *                  Compiler and hardware specific definitions
 *
 *****************************************************************
 * FileName:        Compiler.h
 * Dependencies:    None
 * Processor:       PIC18, PIC24F, PIC24H, dsPIC30F, dsPIC33F, PIC32
 * Compiler:        Microchip C32 v1.00 or higher
 *                                      Microchip C30 v3.01 or higher
 *                                      Microchip C18 v3.13 or higher
 *                                      HI-TECH PICC-18 STD 9.50PL3 or higher
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 *
 *
 * Author               Date         Comment
 *~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 * Howard Schlunder                  10/03/2006         Original, copied from old
Compiler.h
 * Howard Schlunder                  11/07/2007         Reorganized and simplified
 ********************************************************************/
#ifndef __COMPILER_H
#define __COMPILER_H

// Include proper device header file
#if defined(__18CXX) || defined(HI_TECH_C)
          // All PIC18 processors
          #if defined(HI_TECH_C)      // HI TECH PICC-18 compiler
                    #define __18CXX
                    #include <htc.h>
          #else                                          // Microchip C18 compiler
              #include <p18cxxx.h>
          #endif
#elif defined(__PIC24F__)   // Microchip C30 compiler
          // PIC24F processor
          #include <p24Fxxxx.h>
#elif defined(__PIC24H__)   // Microchip C30 compiler
          // PIC24H processor
          #include <p24Hxxxx.h>
#elif defined(__dsPIC33F__) // Microchip C30 compiler
          // dsPIC33F processor
          #include <p33Fxxxx.h>
#elif defined(__dsPIC30F__) // Microchip C30 compiler
          // dsPIC30F processor
          #include <p30fxxxx.h>
#elif defined(__PIC32MX__)  // Microchip C32 compiler
          #if !defined(__C32__)
                    #define __C32__
          #endif
          #include <p32xxxx.h>
          #include <plib.h>
#else
          #error Unknown processor or compiler.  See Compiler.h
#endif

#include <stdio.h>
#include <stdlib.h>
#include <string.h>


// Base RAM and ROM pointer types for given architecture
#if defined(__C32__)
```

```
          #define PTR_BASE            DWORD
          #define ROM_PTR_BASE        DWORD
#elif defined(__C30__)
          #define PTR_BASE            WORD
          #define ROM_PTR_BASE        WORD
#elif defined(__18CXX)
          #define PTR_BASE            WORD
          #define ROM_PTR_BASE        unsigned short long
#endif


// Definitions that apply to all compilers, except C18
#if !defined(__18CXX) || defined(HI_TECH_C)
          #define memcmppgm2ram(a,b,c)          memcmp(a,b,c)
          #define strcmppgm2ram(a,b)            strcmp(a,b)
          #define memcpypgm2ram(a,b,c)          memcpy(a,b,c)
          #define strcpypgm2ram(a,b)            strcpy(a,b)
          #define strncpypgm2ram(a,b,c)         strncpy(a,b,c)
          #define strstrrampgm(a,b)             strstr(a,b)
          #define  strlenpgm(a)                          strlen(a)
          #define strchrpgm(a,b)                        strchr(a,b)
          #define strcatpgm2ram(a,b)            strcat(a,b)
#endif


// Definitions that apply to all 8-bit products
// (PIC18)
#if defined(__18CXX)
          #define  __attribute__(a)

    #define FAR                          far

          // Microchip C18 specific defines
          #if !defined(HI_TECH_C)
              #define ROM                       rom
                   #define strcpypgm2ram(a, b)          strcpypgm2ram(a,(far rom
char*)b)
          #endif

          // HI TECH PICC-18 STD specific defines
          #if defined(HI_TECH_C)
              #define ROM                       const
                   #define rom
              #define Nop()                     asm("NOP");
                   #define ClrWdt()                                 asm("CLRWDT");
              #define Reset()
          asm("RESET");
          #endif

// Definitions that apply to all 16-bit and 32-bit products
// (PIC24F, PIC24H, dsPIC30F, dsPIC33F, and PIC32)
#else
          #define  ROM                                                      const

          // 16-bit specific defines (PIC24F, PIC24H, dsPIC30F, dsPIC33F)
          #if defined(__C30__)
                   #define Reset()                                  asm("reset")
        #define FAR                __attribute__((far))
          #endif

          // 32-bit specific defines (PIC32)
          #if defined(__C32__)
                   #define persistent
```

```
                #define far
        #define FAR
                #define Reset()                                 SoftReset()
                #define ClrWdt()                        (WDTCONSET =
_WDTCON_WDTCLR_MASK)
                #define Nop()                                   asm("nop")
         #endif
#endif



#endif


/******************************************************************************
 * FlySpy.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *****************************************************************************/

#ifndef __FLYSPY_H
#define __FLYSPY_H

#include <libpic30.h>
#include <math.h>
#include <stdio.h>
#include <limits.h>
#include "p24fj256ga110.h"
#include "ADC.h"
#include "gps.h"
#include "barometer.h"
#include "gpserial.h"
#include "Timer.h"
#include "iomapping.h"
#include "sensors.h"
#include "camera.h"
#include "pwm.h"
#include "io.h"
#include "surfaces.h"
#include "MDD FILE SYSTEM\FSIO.h"

//#define GPS_PASSTHROUGH
//#define MANUAL_ONLY_MODE

#ifndef __PIC24FJ256GA110__
#error "FlySpy does not (yet) build for this target. Are you trying to run it on
Explorer 16? Don't!"
#endif

// Main system clock frequency
// (Used in gpserial, but makes more sense here)
#define SYSCLK     32000000
#define VREF       3.3
#define PI 3.141592653589793

#define MAX_PITCH 20
#define MAX_ROLL 30

#define ACCEL_X    5
#define ACCEL_Y    4
#define ACCEL_Z    3
```

```
#define RANGE_FINDER 2

#define GYRO_X     1
#define  GYRO_Y    0

#define MAX_PITCH_DEGREES 20
#define MAX_ROLL_DEGREES 20

#define ROLL_ZERO 0
#define PITCH_ZERO 12

enum SURFACETYPE {
         THROTTLE,
         LEFTAILERON,
         RIGHTAILERON,
         ELEVATOR,
         RUDDER
};

#endif // #ifndef __FLYSPY_H



/********************************************************************
 *
 *                  Generic Type Definitions
 *
 ********************************************************************
 * FileName:        GenericTypeDefs.h
 * Dependencies:   None
 * Processor:       PIC18, PIC24, dsPIC, PIC32
 * Compiler:        Microchip C18, C30, C32
 * Company:         Microchip Technology, Inc.
 *
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 *
 ********************************************************************
 * File Description:
 *
 * Change History:
 *  Rev   Date         Description
 *  1.1   09/11/06     Add base signed types
 *  1.2   02/28/07    Add QWORD, LONGLONG, QWORD_VAL
 *  1.3   02/06/08     Add def's for PIC32
```

```
 *  1.4   08/08/08     Remove LSB/MSB Macros, adopted by Peripheral lib
 *  1.5   08/14/08     Simplify file header
 ************************************************************************/

#ifndef __GENERIC_TYPE_DEFS_H_
#define __GENERIC_TYPE_DEFS_H_

typedef enum _BOOL { FALSE = 0, TRUE } BOOL;   // Undefined size

#ifndef NULL
#define NULL    0//((void *)0)
#endif

#define  PUBLIC                                  // Function attributes
#define PROTECTED
#define PRIVATE   static

typedef unsigned char                BYTE;                                  // 8-bit
unsigned
typedef unsigned short int  WORD;                                  // 16-bit unsigned
typedef unsigned long                DWORD;                                 // 32-bit
unsigned
typedef unsigned long long  QWORD;                                 // 64-bit unsigned
typedef signed char                                 CHAR;                                  //
8-bit signed
typedef signed short int    SHORT;                                 // 16-bit signed
typedef signed long                                 LONG;                                  //
32-bit signed
typedef signed long long    LONGLONG;                    // 64-bit signed

/* Alternate definitions */
typedef void                VOID;

typedef char                CHAR8;
typedef unsigned char       UCHAR8;

/* Processor & Compiler independent, size specific definitions */
// To Do:  We need to verify the sizes on each compiler.  These
//         may be compiler specific, we should either move them
//         to "compiler.h" or #ifdef them for compiler type.
typedef signed int          INT;
typedef signed char         INT8;
typedef signed short int    INT16;
typedef signed long int     INT32;
typedef signed long long    INT64;

typedef unsigned int        UINT;
typedef unsigned char       UINT8;
typedef unsigned short int  UINT16;
typedef unsigned long int   UINT32;  // other name for 32-bit integer
typedef unsigned long long  UINT64;

typedef union _BYTE_VAL
{
    BYTE Val;
    struct
    {
        unsigned char b0:1;
        unsigned char b1:1;
        unsigned char b2:1;
        unsigned char b3:1;
        unsigned char b4:1;
        unsigned char b5:1;
```

```
        unsigned char b6:1;
        unsigned char b7:1;
    } bits;
} BYTE_VAL, BYTE_BITS;

typedef union _WORD_VAL
{
    WORD Val;
    BYTE v[2];
    struct
    {
        BYTE LB;
        BYTE HB;
    } byte;
    struct
    {
        unsigned char b0:1;
        unsigned char b1:1;
        unsigned char b2:1;
        unsigned char b3:1;
        unsigned char b4:1;
        unsigned char b5:1;
        unsigned char b6:1;
        unsigned char b7:1;
        unsigned char b8:1;
        unsigned char b9:1;
        unsigned char b10:1;
        unsigned char b11:1;
        unsigned char b12:1;
        unsigned char b13:1;
        unsigned char b14:1;
        unsigned char b15:1;
    } bits;
} WORD_VAL, WORD_BITS;

typedef union _DWORD_VAL
{
    DWORD Val;
         WORD w[2];
    BYTE v[4];
    struct
    {
        WORD LW;
        WORD HW;
    } word;
    struct
    {
        BYTE LB;
        BYTE HB;
        BYTE UB;
        BYTE MB;
    } byte;
    struct
    {
        WORD_VAL low;
        WORD_VAL high;
    }wordUnion;
    struct
    {
        unsigned char b0:1;
        unsigned char b1:1;
        unsigned char b2:1;
        unsigned char b3:1;
```

```
        unsigned char b4:1;
        unsigned char b5:1;
        unsigned char b6:1;
        unsigned char b7:1;
        unsigned char b8:1;
        unsigned char b9:1;
        unsigned char b10:1;
        unsigned char b11:1;
        unsigned char b12:1;
        unsigned char b13:1;
        unsigned char b14:1;
        unsigned char b15:1;
        unsigned char b16:1;
        unsigned char b17:1;
        unsigned char b18:1;
        unsigned char b19:1;
        unsigned char b20:1;
        unsigned char b21:1;
        unsigned char b22:1;
        unsigned char b23:1;
        unsigned char b24:1;
        unsigned char b25:1;
        unsigned char b26:1;
        unsigned char b27:1;
        unsigned char b28:1;
        unsigned char b29:1;
        unsigned char b30:1;
        unsigned char b31:1;
    } bits;
} DWORD_VAL;

typedef union _QWORD_VAL
{
    QWORD Val;
         DWORD d[2];
         WORD w[4];
    BYTE v[8];
    struct
    {
        DWORD LD;
        DWORD HD;
    } dword;
    struct
    {
        WORD LW;
        WORD HW;
        WORD UW;
        WORD MW;
    } word;
    struct
    {
        unsigned char b0:1;
        unsigned char b1:1;
        unsigned char b2:1;
        unsigned char b3:1;
        unsigned char b4:1;
        unsigned char b5:1;
        unsigned char b6:1;
        unsigned char b7:1;
        unsigned char b8:1;
        unsigned char b9:1;
        unsigned char b10:1;
        unsigned char b11:1;
```

```
        unsigned char b12:1;
        unsigned char b13:1;
        unsigned char b14:1;
        unsigned char b15:1;
        unsigned char b16:1;
        unsigned char b17:1;
        unsigned char b18:1;
        unsigned char b19:1;
        unsigned char b20:1;
        unsigned char b21:1;
        unsigned char b22:1;
        unsigned char b23:1;
        unsigned char b24:1;
        unsigned char b25:1;
        unsigned char b26:1;
        unsigned char b27:1;
        unsigned char b28:1;
        unsigned char b29:1;
        unsigned char b30:1;
        unsigned char b31:1;
        unsigned char b32:1;
        unsigned char b33:1;
        unsigned char b34:1;
        unsigned char b35:1;
        unsigned char b36:1;
        unsigned char b37:1;
        unsigned char b38:1;
        unsigned char b39:1;
        unsigned char b40:1;
        unsigned char b41:1;
        unsigned char b42:1;
        unsigned char b43:1;
        unsigned char b44:1;
        unsigned char b45:1;
        unsigned char b46:1;
        unsigned char b47:1;
        unsigned char b48:1;
        unsigned char b49:1;
        unsigned char b50:1;
        unsigned char b51:1;
        unsigned char b52:1;
        unsigned char b53:1;
        unsigned char b54:1;
        unsigned char b55:1;
        unsigned char b56:1;
        unsigned char b57:1;
        unsigned char b58:1;
        unsigned char b59:1;
        unsigned char b60:1;
        unsigned char b61:1;
        unsigned char b62:1;
        unsigned char b63:1;
    } bits;
} QWORD_VAL;

#endif //__GENERIC_TYPE_DEFS_H_


/************************************************************************
 * gps.c
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
```

```
 ************************************************************************/

#include "FlySpy.h"

#define BAUDRATEREG1 SYSCLK/32/BAUDRATE1-1

#if BAUDRATEREG1 > 255
#error Cannot set up UART1 for the SYSCLK and BAUDRATE.\
 Correct values in main.h and uart2.h files.
#endif

#define BAUDRATE_MISTAKE 1000*(BAUDRATE1-SYSCLK/32/(BAUDRATEREG1+1))/BAUDRATE1
#if (BAUDRATE_MISTAKE > 2)||(BAUDRATE_MISTAKE < -2)
#error UART1 baudrate mistake is too big  for the SYSCLK\
 and BAUDRATE1. Correct values in uart2.c file.
#endif

enum MESSAGETYPE {
   UNDEFINED,
   GPGGA,
   GPVTG,
};

GPSINFO CurrentGPS;

char gpsEnableWAAS[] = "$PMTK301,2*2E\r\n"; //API to enable WAAS
char gpsEnableDGPS[] = "$PMTK301,1*2D\r\n"; //API to enable RTCM
char gpsEnableSbas[] = "$PMTK313,1*2E\r\n"; //API to enable Sbas
char gpsOutputSetup[] = "$PMTK314,0,0,1,1,0,0,0,0,0,0,0,0,0,0,0,0,0*28\r\n"; //Setting
Output frequency to GPGGA and GPVTG

//GPS Buffer for Receiving new sentence
char gpsReceiveBuffer[100]; //String that GPS Transmission is read into
int gpsReceiveTail = 0; //Amount of characters that have been read in through a
transmission
int gpsSentenceStarted = 0; //Lets the module know if the stream was proceeded by the
'$' sentence starter

//GPS Data Circular Buffer
char gpsBuffer[GPSBUFFERSIZE][100]; //Buffer in which Transmission string is placed
onces a full transmission has completed
int gpsBufferLengths[GPSBUFFERSIZE];
int gpsBufferHead = 0;
int gpsBufferTail = 0;



#ifndef GPS_PASSTHROUGH

void initgps()
{
         U1BRG = BAUDRATEREG1;
         IPC3bits.U1TXIP = 0x01;
         IPC2bits.U1RXIP = 0x05;

         U1STA = 0x0000;
         U1MODE = 0x8000;

         U1STAbits.UTXEN = 1;

         IEC0bits.U1RXIE = 1;

         gpsSendMessage(gpsOutputSetup,47);
```

```
	gpsSendMessage(gpsEnableSbas,15);
	gpsSendMessage(gpsEnableWAAS,15);


}

void __attribute__ ((interrupt, no_auto_psv)) _U1RXInterrupt(void)
{
	int length;
	gpsReceiveBuffer[gpsReceiveTail] = U1RXREG;
	if ( gpsReceiveBuffer[gpsReceiveTail] == '\n' && gpsSentenceStarted == 1 &&
gpsReceiveTail!= 0 && gpsReceiveBuffer[gpsReceiveTail-1] == '\r')
	{
		//If GPS Buffer not full, add it into the buffer
		if((gpsBufferTail + 1 % GPSBUFFERSIZE) != gpsBufferHead &&
validateCheckSum() == 1)
		{
			gpsBufferLengths[gpsBufferTail] = gpsReceiveTail + 1;
			gpsReceiveBuffer[gpsReceiveTail + 1] = '\0';
			for(length = 0; length < gpsBufferLengths[gpsBufferTail];
length++)
			{
				gpsBuffer[gpsBufferTail][length] =
gpsReceiveBuffer[length];
			}

			gpsBufferTail = (gpsBufferTail + 1) %GPSBUFFERSIZE;

		}
		gpsSentenceStarted = 0;
		gpsReceiveTail = 0;
	}
	else if(gpsReceiveBuffer[gpsReceiveTail] == '$')
	{
		gpsSentenceStarted = 1;
		gpsReceiveTail=0;
	}
	else
	{
		//printf("GPS SENT: %c\r\n", gpsReceiveBuffer[gpsReceiveTail]);

		gpsReceiveTail++;
	}
	IFS0bits.U1RXIF = 0;
}

#else
// Passthrough mode; hooks GPS straight through to serial port

void initgps(void)
{
	U1BRG = BAUDRATEREG1;
	IPC3bits.U1TXIP = 0x01;
	IPC2bits.U1RXIP = 0x01;

	U1STA = 0x0000;
	U1MODE = 0x8000;

	U1STAbits.UTXEN = 1;

	gpsSendMessage(gpsOutputSetup,47);
	gpsSendMessage(gpsEnableSbas,15);
	gpsSendMessage(gpsEnableWAAS,15);
```

```
}

#define BUFLEN 256
char buffer[BUFLEN];
int to_write = 0;
int to_read = 0;

static char dequeue(void)
{
         char ret = buffer[to_read];
         to_read = (to_read + 1)%BUFLEN;
         return ret;
}

static void enqueue(char val)
{
         buffer[to_write] = val;
         to_write = (to_write + 1)%BUFLEN;
}

static char drdy(void)
{
         return (to_read != to_write);
}

void gps_passthrough(void)
{
         printf("gogogo\r\n");
         initgps();
         U1STAbits.OERR = 0;
         while (1)
         {
                  //int byte = getchar();     // pull character from gpserial
                  int byte = -1;
                  if (0)
                  //if (byte != -1)
                  {
                           //printf("ECHO:%x\r\n", (int) byte);
                           while(U1STAbits.UTXBF);     // Wait for UART to be
transmit-ready
                           U1TXREG = byte;                       // send it on out
                  }
                  if (U1STAbits.URXDA) enqueue(U1RXREG);
                  if (drdy() && !U2STAbits.UTXBF)      U2TXREG = dequeue();
         }
}
#endif


void gpsSendMessage(char *Message, int Length)
{
         int i;
         for (i = 0; i < Length; i++)
         {
                  while(U1STAbits.UTXBF);
                  U1TXREG = Message[i];
         }
}

//This function returns if the checksum value in the buffertail is valid
int validateCheckSum()
{
```

```
	int lcv;
	int CheckSum = gpsReceiveBuffer[0];

	if( gpsReceiveTail < 6 ) //Assert Sentence is at least proper length for a
check
		return 0;

	for(lcv = 1; lcv < gpsReceiveTail - 4; lcv++)
	{
		CheckSum ^= gpsReceiveBuffer[lcv];
	}

	if ( ((CheckSum & 0xF) == gpsReceiveBuffer[gpsReceiveTail - 2]-48) &&
(((CheckSum & 0xF0) >> 4)== gpsReceiveBuffer[gpsReceiveTail - 3]-48))
		return 1;
	return 0;
}

//Reads all values in the gps buffer and updates the gps structure
void retrieveGpsData(void)
{
	int lcv;
	int messageType;
	int commaPosition;

	while(gpsBufferHead != gpsBufferTail)
	{
		messageType = gpsMessageType();
		if( messageType == GPGGA )
		{
			CurrentGPS.Hour = (gpsBuffer[gpsBufferHead][6] - 48) * 10
+ gpsBuffer[gpsBufferHead][7] - 48;
			CurrentGPS.Minute = (gpsBuffer[gpsBufferHead][8] - 48) *
10 + gpsBuffer[gpsBufferHead][9] - 48;
			CurrentGPS.Second = (gpsBuffer[gpsBufferHead][10] - 48) *
10 + gpsBuffer[gpsBufferHead][11] - 48;
			CurrentGPS.Mils = (gpsBuffer[gpsBufferHead][13] - 48) *
100 + (gpsBuffer[gpsBufferHead][14] - 48) * 10 + (gpsBuffer[gpsBufferHead][15] - 48);
			CurrentGPS.Latitude = (gpsBuffer[gpsBufferHead][17] - 48)
* 10 + (gpsBuffer[gpsBufferHead][18] - 48)+ ((gpsBuffer[gpsBufferHead][19] - 48) * 10
+ (gpsBuffer[gpsBufferHead][20] - 48) + (gpsBuffer[gpsBufferHead][22] - 48) * .1 +
(gpsBuffer[gpsBufferHead][23] - 48) * .01 + (gpsBuffer[gpsBufferHead][24] - 48) * .001
+ (gpsBuffer[gpsBufferHead][25] - 48) * .0001) / 60;
			if (gpsBuffer[gpsBufferHead][27] == 'S')
				CurrentGPS.Latitude *= -1;
			CurrentGPS.Longitude =  (gpsBuffer[gpsBufferHead][29] -
48) * 100 + (gpsBuffer[gpsBufferHead][30] - 48) * 10 + (gpsBuffer[gpsBufferHead][31] -
48) + ((gpsBuffer[gpsBufferHead][32] - 48) * 10 + (gpsBuffer[gpsBufferHead][33] - 48)
+ (gpsBuffer[gpsBufferHead][35] - 48) * .1 + (gpsBuffer[gpsBufferHead][36] - 48) * .01
+ (gpsBuffer[gpsBufferHead][37] - 48) * .001 + (gpsBuffer[gpsBufferHead][38] - 48) *
.0001) / 60;
			if (gpsBuffer[gpsBufferHead][40] == 'W')
				CurrentGPS.Longitude *= -1;
			CurrentGPS.Signal = gpsBuffer[gpsBufferHead][42] - 48;
			lcv = 42;
			commaPosition = 0;
			while(commaPosition < 1)
			{
				if ( gpsBuffer[gpsBufferHead][lcv] == ',')
					commaPosition++;
				lcv++;
			}
			CurrentGPS.SVs = 0;
```

```
                        while(1)
                        {
                                if ( gpsBuffer[gpsBufferHead][lcv] == ',')
                                        break;
                                CurrentGPS.SVs = CurrentGPS.SVs * 10 +
(gpsBuffer[gpsBufferHead][lcv] - 48);
                                lcv++;
                        }
                        lcv++;
                        commaPosition = 0;
                        while(commaPosition < 1)
                        {
                                if (gpsBuffer[gpsBufferHead][lcv] ==  ',')
                                        commaPosition++;
                                lcv++;
                        }
                        CurrentGPS.Altitude = 0;
                        while ( gpsBuffer[gpsBufferHead][lcv] != '.')
                        {
                                CurrentGPS.Altitude = CurrentGPS.Altitude * 10 +
(gpsBuffer[gpsBufferHead][lcv] - 48);
                                lcv++;
                        }
                        commaPosition = lcv++;
                        while (gpsBuffer[gpsBufferHead][lcv] != ',')
                        {
                                CurrentGPS.Altitude = CurrentGPS.Altitude +
(gpsBuffer[gpsBufferHead][lcv] - 48)/(10 * lcv-commaPosition);
                                lcv++;
                        }
                }
                else if ( messageType == GPVTG )
                {
                        CurrentGPS.Heading = 0;
                        lcv = 6;
                        while(1)
                        {
                                if(gpsBuffer[gpsBufferHead][lcv] == '.')
                                        break;
                                CurrentGPS.Heading = CurrentGPS.Heading * 10 +
(gpsBuffer[gpsBufferHead][lcv] - 48);
                                lcv++;
                        }
                        commaPosition = lcv++;
                        while(1)
                        {
                                if(gpsBuffer[gpsBufferHead][lcv] == ',')
                                        break;
                                CurrentGPS.Heading = CurrentGPS.Heading +
(gpsBuffer[gpsBufferHead][lcv] -48)/(float)( 10 * (lcv - commaPosition));
                                lcv++;
                        }
                        commaPosition = 0;
                        lcv++;
                        while (commaPosition < 5)  // Read 5 more commas
                        {
                                if(gpsBuffer[gpsBufferHead][lcv] == ',')
                                        commaPosition++;
                                lcv++;
                        }
                        CurrentGPS.Speed = 0;
                        while(1)
                        {
```

```
                                        if(gpsBuffer[gpsBufferHead][lcv] == '.')
                                                break;
                                        CurrentGPS.Speed = CurrentGPS.Speed * 10 +
(gpsBuffer[gpsBufferHead][lcv] - 48);
                                        lcv++;
                                }
                                commaPosition = lcv++;
                                while(1)
                                {
                                        if(gpsBuffer[gpsBufferHead][lcv] == ',')
                                                break;
                                        CurrentGPS.Speed = CurrentGPS.Speed +
(gpsBuffer[gpsBufferHead][lcv] -48)/(float)( 10 * (lcv - commaPosition));
                                        lcv++;
                                }
                        }
                        gpsBufferHead = ( gpsBufferHead + 1 ) % GPSBUFFERSIZE;
                }
}

//Finds the type of gps sentence from the head of the gps buffer
// 0 - Unused Type
// 1 - GPPGGA
// 2 - GPVTG
int gpsMessageType(void)
{
        if (gpsBuffer[gpsBufferHead][0] == 'G' && gpsBuffer[gpsBufferHead][1] == 'P')
        {
                if (gpsBuffer[gpsBufferHead][2] == 'G' &&
gpsBuffer[gpsBufferHead][3] == 'G' && gpsBuffer[gpsBufferHead][4] == 'A')
                        return GPGGA;
                else if (gpsBuffer[gpsBufferHead][2] == 'V' &&
gpsBuffer[gpsBufferHead][3] == 'T' && gpsBuffer[gpsBufferHead][4] == 'G')
                        return GPVTG;
        }
        return UNDEFINED;
}

// Calculates the distance and bearing from staring coordinates to ending coordinates
// Coordinates must be sent in radians
void calculatePath(double startingLatitude, double startingLongitude, double
endingLatitude, double endingLongitude,
                                                double* distance, double* bearing)
{
        double deltaLatitude = endingLatitude - startingLatitude;
        double deltaLongitude = endingLongitude - startingLongitude;

        double sinHalfDeltaLatitude = sin(deltaLatitude /2 );
        double sinHalfDeltaLongitude = sin(deltaLongitude / 2);

        double sinStartingLatitude = sin(startingLatitude);
        double sinEndingLatitude = sin(endingLatitude);

        double cosStartingLatitude = cos(startingLatitude);
        double cosEndingLatitude = cos(endingLatitude);
        double cosDeltaLongitude = cos(deltaLongitude);

        double haversineA = sinHalfDeltaLatitude * sinHalfDeltaLatitude +
cosStartingLatitude * cosEndingLatitude * sinHalfDeltaLongitude *
sinHalfDeltaLongitude;
        *distance = EARTH_RADIUS * 2 * atan2( sqrt(haversineA), sqrt(1-haversineA));
```

```
         *bearing = fmod(atan2(sin(deltaLongitude) *
cosEndingLatitude,cosStartingLatitude*sinEndingLatitude - sinStartingLatitude *
cosEndingLatitude*cosDeltaLongitude)*180/PI + 360,360);
}



/*********************************************************************
 * gpserial.c
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *********************************************************************/



#include "FlySpy.h"

/*********************************************************************
 * U2BRG register value and baudrate mistake calculation
 * Taken from Microchip's Explorer 16 sample code
 *********************************************************************/
#define BAUDRATEREG2 SYSCLK/32/BAUDRATE2-1

#if BAUDRATEREG2 > 255
#error Cannot set up UART2 for the SYSCLK and BAUDRATE.\
 Correct values in main.h and uart2.h files.
#endif

#define BAUDRATE_MISTAKE 1000*(BAUDRATE2-SYSCLK/32/(BAUDRATEREG2+1))/BAUDRATE2
#if (BAUDRATE_MISTAKE > 2)||(BAUDRATE_MISTAKE < -2)
#error UART2 baudrate mistake is too big  for the SYSCLK\
 and BAUDRATE2. Correct values in uart2.c file.
#endif


void gpserial_init(void)
{
         /* Set up UART 2 for the spec'd baud rate */
         U2BRG = BAUDRATEREG2;
         U2MODE = 0;
         U2STA = 0;
         U2MODEbits.UARTEN = 1;
         U2STAbits.UTXEN = 1;
         // reset RX flag
         IFS1bits.U2RXIF = 0;

         /* Now set it up as STDIO */
         __C30_UART = 2;
}



/*********************************************************************
 * gpserial.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *********************************************************************/

#ifndef __GPSERIAL_H
#define __GPSERIAL_H
```

```
// Baudrate
#define BAUDRATE2           19200

void gpserial_init(void);

#endif



/************************************************************************
 * gps.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 ************************************************************************/



// Baudrate
#define BAUDRATE1           38400
#define GPSBUFFERSIZE       5
#define EARTH_RADIUS 6371

typedef struct gpsinformation
{
         int Hour;
         int Minute;
         int Second;
         int Mils;

         double Latitude;
         double Longitude;

         double Speed;
         double Heading;

         int SVs;
         int Signal;
         double Altitude;

} GPSINFO;


void initgps(void);
void gpsSendMessage(char *, int);
int validateCheckSum(void);
int gpsMessageType(void);
void retrieveGpsData(void);
void calculatePath(double, double, double, double, double*, double*);



/************************************************************************
 * HardwareProfile.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 ************************************************************************/

/************************************************************************
 *
 *                Microchip Memory Disk Drive File System
 *
```

```
 ********************************************************************************
 * FileName:        HardwareProfile.h
 * Dependencies:    None
 * Processor:       PIC18/PIC24/dsPIC30/dsPIC33/PIC32
 * Compiler:        C18/C30/C32
 * Company:         Microchip Technology, Inc.
 *
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 * CONSEQUENTIAL DAMAGES, FOR ANY REASON WHATSOEVER.
 *
********************************************************************************/


#ifndef _HARDWAREPROFILE_H_
#define _HARDWAREPROFILE_H_

// Define your clock speed here

// Sample clock speed for PIC18
#if defined (__18CXX)

    #define GetSystemClock()        40000000                        // System clock
frequency (Hz)
    #define GetPeripheralClock()    GetSystemClock()                // Peripheral
clock freq.
    #define GetInstructionClock()   (GetSystemClock() / 4)          // Instruction
clock freq.

// Sample clock speed for a 16-bit processor
#elif defined (__C30__)

    #define GetSystemClock()        32000000
    #define GetPeripheralClock()    GetSystemClock()
    #define GetInstructionClock()   (GetSystemClock() / 2)

    // Clock values
    #define MILLISECONDS_PER_TICK       10                      // Definition for use
with a tick timer
    #define TIMER_PRESCALER             TIMER_PRESCALER_8       // Definition for use
with a tick timer
    #define TIMER_PERIOD                20000                   // Definition for use
with a tick timer

// Sample clock speed for a 32-bit processor
#elif defined (__PIC32MX__)
```

```
    // Indicates that the PIC32 clock is running at 48 MHz
    //#define RUN_AT_48MHZ
    // Indicates that the PIC32 clock is running at 24 MHz
    //#define RUN_AT_24MHZ
    // Indicates that the PIC32 clock is running at 60 MHz
    #define RUN_AT_60MHZ

    // Various clock values

    #if defined(RUN_AT_48MHZ)
        #define GetSystemClock()            48000000UL              // System clock
frequency (Hz)
        #define GetPeripheralClock()        48000000UL              // Peripheral
clock frequency
        #define GetInstructionClock()       (GetSystemClock())      // Instruction
clock frequency
    #elif defined(RUN_AT_24MHZ)
        #define GetSystemClock()            24000000UL
        #define GetPeripheralClock()        24000000UL
        #define GetInstructionClock()       (GetSystemClock())
    #elif defined(RUN_AT_60MHZ)
        #define GetSystemClock()            (60000000ul)
        #define GetPeripheralClock()        (GetSystemClock())
        #define GetInstructionClock()       (GetSystemClock())
    #else
        #error Choose a speed
    #endif

    // Clock values

    #define MILLISECONDS_PER_TICK       10                  // Definition for use with
a tick timer
    #define TIMER_PRESCALER             TIMER_PRESCALER_8   // Definition for use with
a tick timer
    #define TIMER_PERIOD                37500               // Definition for use with
a tick timer
#endif




// Select your interface type
// This library currently only supports a single physical interface layer at a time


// Description: Macro used to enable the SD-SPI physical layer (SD-SPI.c and .h)
#define USE_SD_INTERFACE_WITH_SPI

// Description: Macro used to enable the CF-PMP physical layer (CF-PMP.c and .h)
//#define USE_CF_INTERFACE_WITH_PMP

// Description: Macro used to enable the CF-Manual physical layer (CF-Bit
transaction.c and .h)
//#define USE_MANUAL_CF_INTERFACE

// Description: Macro used to enable the USB Host physical layer (USB host MSD
library)
//#define USE_USB_INTERFACE


/*****************************************************************/
/****************** Pin and Register Definitions ******************/
```

```
/************************************************************************/

/* SD Card definitions: Change these to fit your application when using
   an SD-card-based physical layer                                      */

#ifdef USE_SD_INTERFACE_WITH_SPI
    #ifdef __18CXX

        // Sample definition for PIC18 (modify to fit your own project)

        // Description: SD-SPI Chip Select Output bit
        #define SD_CS               PORTBbits.RB3
        // Description: SD-SPI Chip Select TRIS bit
        #define SD_CS_TRIS          TRISBbits.TRISB3

        // Description: SD-SPI Card Detect Input bit
        #define SD_CD               PORTBbits.RB4
        // Description: SD-SPI Card Detect TRIS bit
        #define SD_CD_TRIS          TRISBbits.TRISB4

        // Description: SD-SPI Write Protect Check Input bit
        #define SD_WE               PORTAbits.RA4
        // Description: SD-SPI Write Protect Check TRIS bit
        #define SD_WE_TRIS          TRISAbits.TRISA4

        // Registers for the SPI module you want to use

        // Description: The main SPI control register
        #define SPICON1             SSP1CON1
        // Description: The SPI status register
        #define SPISTAT             SSP1STAT
        // Description: The SPI buffer
        #define SPIBUF              SSP1BUF
        // Description: The receive buffer full bit in the SPI status register
        #define SPISTAT_RBF         SSP1STATbits.BF
        // Description: The bitwise define for the SPI control register (i.e.
_____bits)
        #define SPICON1bits         SSP1CON1bits
        // Description: The bitwise define for the SPI status register (i.e.
_____bits)
        #define SPISTATbits         SSP1STATbits

        // Description: The interrupt flag for the SPI module
        #define SPI_INTERRUPT_FLAG  PIR1bits.SSPIF
        // Description: The enable bit for the SPI module
        #define SPIENABLE           SPICON1bits.SSPEN

/*
        // Defines for the FS-USB demo board

        // Tris pins for SCK/SDI/SDO lines
        #define SPICLOCK            TRISBbits.TRISB1
        #define SPIIN               TRISBbits.TRISB0
        #define SPIOUT              TRISCbits.TRISC7

        // Latch pins for SCK/SDI/SDO lines
        #define SPICLOCKLAT         LATBbits.LATB1
        #define SPIINLAT            LATBbits.LATB0
        #define SPIOUTLAT           LATCbits.LATC7

        // Port pins for SCK/SDI/SDO lines
        #define SPICLOCKPORT        PORTBbits.RB1
        #define SPIINPORT           PORTBbits.RB0
```

```
        #define SPIOUTPORT          PORTCbits.RC7
*/

        // Defines for the HPC Explorer board

        // Description: The TRIS bit for the SCK pin
        #define SPICLOCK            TRISCbits.TRISC3
        // Description: The TRIS bit for the SDI pin
        #define SPIIN               TRISCbits.TRISC4
        // Description: The TRIS bit for the SDO pin
        #define SPIOUT              TRISCbits.TRISC5

        // Description: The output latch for the SCK pin
        #define SPICLOCKLAT         LATCbits.LATC3
        // Description: The output latch for the SDI pin
        #define SPIINLAT            LATCbits.LATC4
        // Description: The output latch for the SDO pin
        #define SPIOUTLAT           LATCbits.LATC5

        // Description: The port for the SCK pin
        #define SPICLOCKPORT        PORTCbits.RC3
        // Description: The port for the SDI pin
        #define SPIINPORT           PORTCbits.RC4
        // Description: The port for the SDO pin
        #define SPIOUTPORT          PORTCbits.RC5


        // Will generate an error if the clock speed is too low to interface to the
card
        #if (GetSystemClock() < 400000)
            #error System clock speed must exceed 400 kHz
        #endif

    #elif defined __PIC24F__

        // Description: SD-SPI Chip Select Output bit
        #define SD_CS               PORTFbits.RF5 //PORTBbits.RB1
        // Description: SD-SPI Chip Select TRIS bit
        #define SD_CS_TRIS          TRISFbits.TRISF5 //TRISBbits.TRISB1

        // Description: SD-SPI Card Detect Input bit
        #define SD_CD               PORTFbits.RF6 //PORTFbits.RF0
        // Description: SD-SPI Card Detect TRIS bit
        #define SD_CD_TRIS          TRISFbits.TRISF6 //TRISFbits.TRISF0

        // Description: SD-SPI Write Protect Check Input bit
        //#define SD_WE               PORTFbits.RF1
        // Description: SD-SPI Write Protect Check TRIS bit
        //#define SD_WE_TRIS          TRISFbits.TRISF1

        // Registers for the SPI module you want to use

        // Description: The main SPI control register
        #define SPICON1             SPI2CON1 //SPI1CON1
        // Description: The SPI status register
        #define SPISTAT             SPI2STAT //SPI1STAT
        // Description: The SPI Buffer
        #define SPIBUF              SPI2BUF //SPI1BUF
        // Description: The receive buffer full bit in the SPI status register
        #define SPISTAT_RBF         SPI2STATbits.SPIRBF //SPI1STATbits.SPIRBF
        // Description: The bitwise define for the SPI control register (i.e.
_____bits)
        #define SPICON1bits         SPI2CON1bits //SPI1CON1bits
```

```
        // Description: The bitwise define for the SPI status register (i.e.
_____bits)
        #define SPISTATbits         SPI2STATbits //SPI1STATbits
        // Description: The enable bit for the SPI module
        #define SPIENABLE           SPI2STATbits.SPIEN //SPISTATbits.SPIEN

        // Tris pins for SCK/SDI/SDO lines

        // Description: The TRIS bit for the SCK pin
        #define SPICLOCK            TRISDbits.TRISD15 //TRISFbits.TRISF6
        // Description: The TRIS bit for the SDI pin
        #define SPIIN               TRISDbits.TRISD14 //TRISFbits.TRISF7
        // Description: The TRIS bit for the SDO pin
        #define SPIOUT              TRISFbits.TRISF4 //TRISFbits.TRISF8

        // Will generate an error if the clock speed is too low to interface to the
card
        #if (GetSystemClock() < 100000)
            #error Clock speed must exceed 100 kHz
        #endif

    #elif defined (__PIC32MX__)

        // Description: SD-SPI Chip Select Output bit
        #define SD_CS               PORTBbits.RB1
        // Description: SD-SPI Chip Select TRIS bit
        #define SD_CS_TRIS          TRISBbits.TRISB1

        // Description: SD-SPI Card Detect Input bit
        #define SD_CD               PORTFbits.RF0
        // Description: SD-SPI Card Detect TRIS bit
        #define SD_CD_TRIS          TRISFbits.TRISF0

        // Description: SD-SPI Write Protect Check Input bit
        #define SD_WE               PORTFbits.RF1
        // Description: SD-SPI Write Protect Check TRIS bit
        #define SD_WE_TRIS          TRISFbits.TRISF1

        // Registers for the SPI module you want to use

        // Description: The main SPI control register
        #define SPICON1             SPI1CON
        // Description: The SPI status register
        #define SPISTAT             SPI1STAT
        // Description: The SPI Buffer
        #define SPIBUF              SPI1BUF
        // Description: The receive buffer full bit in the SPI status register
        #define SPISTAT_RBF         SPI1STATbits.SPIRBF
        // Description: The bitwise define for the SPI control register (i.e.
_____bits)
        #define SPICON1bits         SPI1CONbits
        // Description: The bitwise define for the SPI status register (i.e.
_____bits)
        #define SPISTATbits         SPI1STATbits
        // Description: The enable bit for the SPI module
        #define SPIENABLE           SPICON1bits.ON
        // Description: The definition for the SPI baud rate generator register
(PIC32)
        #define SPIBRG                              SPI1BRG

        // Tris pins for SCK/SDI/SDO lines

        // Description: The TRIS bit for the SCK pin
```

```
        #define SPICLOCK            TRISFbits.TRISF6
        // Description: The TRIS bit for the SDI pin
        #define SPIIN               TRISFbits.TRISF7
        // Description: The TRIS bit for the SDO pin
        #define SPIOUT              TRISFbits.TRISF8

        // Will generate an error if the clock speed is too low to interface to the
card
        #if (GetSystemClock() < 100000)
            #error Clock speed must exceed 100 kHz
        #endif

    #endif

#endif


#ifdef USE_CF_INTERFACE_WITH_PMP

    /* CompactFlash-PMP card definitions: change these to fit your application when
    using the PMP module to interface with CF cards                              */

    #ifdef __18CXX
        #error The PIC18 architecture does not currently support PMP interface to CF
cards
    #elif defined __dsPIC30F__

        // Sample dsPIC30 defines

        // Description: The output latch for the CF Reset signal
        #define CF_PMP_RST              _RD0
        // Description: The TRIS bit for the CF Reset signal
        #define CF_PMP_RESETDIR         _TRISD0
        // Description: The input port for the CF Ready signal
        #define CF_PMP_RDY              _RD12
        // Description: The TRIS bit for the CF Ready signal
        #define CF_PMP_READYDIR         _TRISD12
        // Description: The input port for the CF card detect signal
        #define CF_PMP_CD1              _RC4
        // Description: The TRIS bit for the CF card detect signal
        #define CF_PMP_CD1DIR           _TRISC4

    #elif defined __dsPIC33F__

        // Sample dsPIC33 defines

        // Description: The output latch for the CF Reset signal
        #define CF_PMP_RST              _RD0
        // Description: The TRIS bit for the CF Reset signal
        #define CF_PMP_RESETDIR         _TRISD0
        // Description: The input port for the CF Ready signal
        #define CF_PMP_RDY              _RD12
        // Description: The TRIS bit for the CF Ready signal
        #define CF_PMP_READYDIR         _TRISD12
        // Description: The input port for the CF card detect signal
        #define CF_PMP_CD1              _RC4
        // Description: The TRIS bit for the CF card detect signal
        #define CF_PMP_CD1DIR           _TRISC4

    #elif defined __PIC24F__

        // Default case for PIC24F
```

```
        // Description: The output latch for the CF Reset signal
        #define CF_PMP_RST               PORTDbits.RD0
        // Description: The TRIS bit for the CF Reset signal
        #define CF_PMP_RESETDIR          TRISDbits.TRISD0
        // Description: The input port for the CF Ready signal
        #define CF_PMP_RDY               PORTDbits.RD12
        // Description: The TRIS bit for the CF Ready signal
        #define CF_PMP_READYDIR          TRISDbits.TRISD12
        // Description: The input port for the CF card detect signal
        #define CF_PMP_CD1               PORTCbits.RC4
        // Description: The TRIS bit for the CF card detect signal
        #define CF_PMP_CD1DIR            TRISCbits.TRISC4

    #endif

    // Description: Defines the PMP data bus direction register
    #define MDD_CFPMP_DATADIR       TRISE
#endif


#ifdef USE_MANUAL_CF_INTERFACE
    // Use these definitions with CF-Bit transaction.c and .h
    // This will manually perform parallel port transactions

    #ifdef __18CXX

        // Address lines

        // Description: The CF address bus output latch register (for PIC18)
        #define ADDBL                   LATA
        // Description: The CF address bus TRIS register (for PIC18)
        #define ADDDIR                  TRISA

        // Data bus

        // Description: The Manual CF data bus port register
        #define MDD_CFBT_DATABIN        PORTD
        // Description: The Manual CF data bus output latch register
        #define MDD_CFBT_DATABOUT       LATD
        // Description: The Manual CF data bus TRIS register
        #define MDD_CFBT_DATADIR        TRISD

        // control bus lines

        // Description: The CF card chip select output latch bit
        #define CF_CE                   LATEbits.LATE1
        // Description: The CF card chip select TRIS bit
        #define CF_CEDIR                TRISEbits.TRISE1
        // Description: The CF card output enable strobe latch bit
        #define CF_OE                   LATAbits.LATA5
        // Description: The CF card output enable strobe TRIS bit
        #define CF_OEDIR                TRISAbits.TRISA5
        // Description: The CF card write enable strobe latch bit
        #define CF_WE                   LATAbits.LATA4
        // Description: The CF card write enable strobe TRIS bit
        #define CF_WEDIR                TRISAbits.TRISA4
        // Description: The CF card reset signal latch bit
        #define CF_BT_RST               LATEbits.LATE0
        // Description: The CF card reset signal TRIS bit
        #define CF_BT_RESETDIR          TRISEbits.TRISE0
        // Description: The CF card ready signal port bit
        #define CF_BT_RDY               PORTEbits.RE2
        // Description: The CF card ready signal TRIS bit
```

```
        #define CF_BT_READYDIR          TRISEbits.TRISE2
        // Description: The CF card detect signal port bit
        #define CF_BT_CD1               PORTCbits.RC2
        // Description: The CF card detect signal TRIS bit
        #define CF_BT_CD1DIR            TRISCbits.TRISC2

    #elif defined __dsPIC30F__

        // Address lines

         // Description: The CF address bus bit 0 output latch definition (for
PIC24/30/33/32)
        #define ADDR0                   _LATB15
        // Description: The CF address bus bit 1 output latch definition (for
PIC24/30/33/32)
        #define    ADDR1                   _LATB14
        // Description: The CF address bus bit 2 output latch definition (for
PIC24/30/33/32)
        #define ADDR2                   _LATG9
        // Description: The CF address bus bit 3 output latch definition (for
PIC24/30/33/32)
        #define ADDR3                   _LATG8
        // Description: The CF address bus bit 0 TRIS definition (for PIC24/30/33/32)
        #define ADRTRIS0                _TRISB15
        // Description: The CF address bus bit 1 TRIS definition (for PIC24/30/33/32)
        #define ADRTRIS1                _TRISB14
        // Description: The CF address bus bit 2 TRIS definition (for PIC24/30/33/32)
        #define ADRTRIS2                _TRISG9
        // Description: The CF address bus bit 3 TRIS definition (for PIC24/30/33/32)
        #define ADRTRIS3                _TRISG8

        // Data bus

        // Description: The Manual CF data bus port register
        #define MDD_CFBT_DATABIN        PORTE
        // Description: The Manual CF data bus output latch register
        #define MDD_CFBT_DATABOUT       PORTE
        // Description: The Manual CF data bus TRIS register
        #define MDD_CFBT_DATADIR        TRISE

        // control bus lines

        // Description: The CF card chip select output latch bit
        #define CF_CE                   _RD11
        // Description: The CF card chip select TRIS bit
        #define CF_CEDIR                _TRISD11
        // Description: The CF card output enable strobe latch bit
        #define CF_OE                   _RD5
        // Description: The CF card output enable strobe TRIS bit
        #define CF_OEDIR                _TRISD5
        // Description: The CF card write enable strobe latch bit
        #define CF_WE                   _RD4
        // Description: The CF card write enable strobe TRIS bit
        #define CF_WEDIR                _TRISD4
        // Description: The CF card reset signal latch bit
        #define CF_BT_RST               _RD0
        // Description: The CF card reset signal TRIS bit
        #define CF_BT_RESETDIR          _TRISD0
        // Description: The CF card ready signal port bit
        #define CF_BT_RDY               _RD12
        // Description: The CF card ready signal TRIS bit
        #define CF_BT_READYDIR          _TRISD12
        // Description: The CF card detect signal port bit
```

```
        #define CF_BT_CD1               _RC4
        // Description: The CF card detect signal TRIS bit
        #define CF_BT_CD1DIR            _TRISC4

    #elif defined __dsPIC33F__

        // Address lines

        // Description: The CF address bus bit 0 output latch definition (for
PIC24/30/33/32)
        #define ADDR0                   _LATB15
        // Description: The CF address bus bit 1 output latch definition (for
PIC24/30/33/32)
        #define    ADDR1                  _LATB14
        // Description: The CF address bus bit 2 output latch definition (for
PIC24/30/33/32)
        #define ADDR2                   _LATG9
        // Description: The CF address bus bit 3 output latch definition (for
PIC24/30/33/32)
        #define ADDR3                   _LATG8
        // Description: The CF address bus bit 0 TRIS definition (for PIC24/30/33/32)
        #define ADRTRIS0                _TRISB15
        // Description: The CF address bus bit 1 TRIS definition (for PIC24/30/33/32)
        #define ADRTRIS1                _TRISB14
        // Description: The CF address bus bit 2 TRIS definition (for PIC24/30/33/32)
        #define ADRTRIS2                _TRISG9
        // Description: The CF address bus bit 3 TRIS definition (for PIC24/30/33/32)
        #define ADRTRIS3                _TRISG8

        // Data bus

        // Description: The Manual CF data bus port register
        #define MDD_CFBT_DATABIN        PORTE
        // Description: The Manual CF data bus output latch register
        #define MDD_CFBT_DATABOUT       PORTE
        // Description: The Manual CF data bus TRIS register
        #define MDD_CFBT_DATADIR        TRISE

        // control bus lines

        // Description: The CF card chip select output latch bit
        #define CF_CE                   _RD11
        // Description: The CF card chip select TRIS bit
        #define CF_CEDIR                _TRISD11
        // Description: The CF card output enable strobe latch bit
        #define CF_OE                   _RD5
        // Description: The CF card output enable strobe TRIS bit
        #define CF_OEDIR                _TRISD5
        // Description: The CF card write enable strobe latch bit
        #define CF_WE                   _RD4
        // Description: The CF card write enable strobe TRIS bit
        #define CF_WEDIR                _TRISD4
        // Description: The CF card reset signal latch bit
        #define CF_BT_RST               _RD0
        // Description: The CF card reset signal TRIS bit
        #define CF_BT_RESETDIR          _TRISD0
        // Description: The CF card ready signal port bit
        #define CF_BT_RDY               _RD12
        // Description: The CF card ready signal TRIS bit
        #define CF_BT_READYDIR          _TRISD12
        // Description: The CF card detect signal port bit
        #define CF_BT_CD1               _RC4
        // Description: The CF card detect signal TRIS bit
```

```
        #define CF_BT_CD1DIR            _TRISC4

    #elif defined __PIC24F__

        // Address lines

        // Description: The CF address bus bit 0 output latch definition (for
PIC24/30/33/32)
        #define ADDR0                   LATBbits.LATB15
        // Description: The CF address bus bit 1 output latch definition (for
PIC24/30/33/32)
        #define    ADDR1                   LATBbits.LATB14
        // Description: The CF address bus bit 2 output latch definition (for
PIC24/30/33/32)
        #define ADDR2                   LATGbits.LATG9
        // Description: The CF address bus bit 3 output latch definition (for
PIC24/30/33/32)
        #define ADDR3                   LATGbits.LATG8
        // Description: The CF address bus bit 0 TRIS definition (for PIC24/30/33/32)
        #define ADRTRIS0                TRISBbits.TRISB15
        // Description: The CF address bus bit 1 TRIS definition (for PIC24/30/33/32)
        #define ADRTRIS1                TRISBbits.TRISB14
        // Description: The CF address bus bit 2 TRIS definition (for PIC24/30/33/32)
        #define ADRTRIS2                TRISGbits.TRISG9
        // Description: The CF address bus bit 3 TRIS definition (for PIC24/30/33/32)
        #define ADRTRIS3                TRISGbits.TRISG8

        // Data bus

        // Description: The Manual CF data bus port register
        #define MDD_CFBT_DATABIN        PORTE
        // Description: The Manual CF data bus output latch register
        #define MDD_CFBT_DATABOUT       PORTE
        // Description: The Manual CF data bus TRIS register
        #define MDD_CFBT_DATADIR        TRISE

        // control bus lines

        // Description: The CF card chip select output latch bit
        #define CF_CE                   PORTDbits.RD11
        // Description: The CF card chip select TRIS bit
        #define CF_CEDIR                TRISDbits.TRISD11
        // Description: The CF card output enable strobe latch bit
        #define CF_OE                   PORTDbits.RD5
        // Description: The CF card output enable strobe TRIS bit
        #define CF_OEDIR                TRISDbits.TRISD5
        // Description: The CF card write enable strobe latch bit
        #define CF_WE                   PORTDbits.RD4
        // Description: The CF card write enable strobe TRIS bit
        #define CF_WEDIR                TRISDbits.TRISD4
        // Description: The CF card reset signal latch bit
        #define CF_BT_RST               PORTDbits.RD0
        // Description: The CF card reset signal TRIS bit
        #define CF_BT_RESETDIR          TRISDbits.TRISD0
        // Description: The CF card ready signal port bit
        #define CF_BT_RDY               PORTDbits.RD12
        // Description: The CF card ready signal TRIS bit
        #define CF_BT_READYDIR          TRISDbits.TRISD12
        // Description: The CF card detect signal port bit
        #define CF_BT_CD1               PORTCbits.RC4
        // Description: The CF card detect signal TRIS bit
        #define CF_BT_CD1DIR            TRISCbits.TRISC4
    #endif
```

```
#endif

#include "uart2.h"

#endif


/*********************************************************************
 * io.c
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 ********************************************************************/

#include "FlySpy.h"

char IOBuffer[100];

WAYPOINT wayPoints[MAXWAYPOINTS];
TAKEOFFLANDING StartEndPoint;
int wayPointCount = 0;

void initio(void)
{
         FSFILE *fptr;

         FSInit();          //Initializes the FILE SYSTEM communication with the SD
Card
         int index;
         while (!FSInit()); // Waiting for SD card to finish initialization

         if ( FSchdir("\\") ) //Navigates to the root directory of the SD Card
         {
                  printf("Error: Could not move to root directory.\r\n");
                  while(1);
         }

         if (FSchdir(PROGRAMFOLDER)) //Tries to change directory to that specified for
this application
         {
                           printf("Error: Could not find the FLYSPY directory.\r\n");
                           while(1);
         }

         printf("Found the FLYSPY directory.\r\n");

         //Read in flight information
         fptr = FSfopen(INPUTFILE,"r");
         if( fptr == NULL )
         {
                  printf("Error: The input file was not found.\r\n");
                  while(1);
         }

         printf("Found the input file: %s\r\n", INPUTFILE);
         wayPointCount = 0;
         index = 0;
         StartEndPoint.TakeOff = 0;
         StartEndPoint.Landing = 0;

         while(!FSfeof(fptr))
         {
                  index = 0;
```

```
                    do
                    {
                      FSfread(&IOBuffer[index], 1, 1, fptr); //Reading one character
into the buffer
                      index++;
                    }while(!FSfeof(fptr) && IOBuffer[index-1] != '\n'); //Reading until
I have reached the end of the file or the end of the line
                    if(index < 2) //Making sure I have atleast read in the instruction
type
                              continue;
                    IOBuffer[index] = '\0'; //Putting Null Terminator at the end of the
string
                    if (IOBuffer[0] == 'T' && IOBuffer[1] == 'O') //Represents a
TakeOff instruction
                    {
                              sscanf(IOBuffer, "TO %lf %d\n",
&StartEndPoint.TakeOff_Altitude, &StartEndPoint.Delay);
                              StartEndPoint.TakeOff = 1;
                    }
                    else if(IOBuffer[0] == 'W' && IOBuffer[1] == 'P') //Represents a
waypoint instruction
                    {
                              sscanf(IOBuffer, "WP %lf %lf %f %d\n",
                                        &wayPoints[wayPointCount].Latitude,
                                        &wayPoints[wayPointCount].Longitude,
                                        &wayPoints[wayPointCount].Altitude,
                                        &wayPoints[wayPointCount].Picture);
                              wayPointCount++;
                    }
                    else if (IOBuffer[0] == 'L' && IOBuffer[1] == 'M') //Represents a
Landing Mark Instruction
                    {
                              sscanf(IOBuffer, "LM %lf %lf %lf\n",
&StartEndPoint.Landing_Latitude, &StartEndPoint.Landing_Longitude,
&StartEndPoint.Landing_Altitude);
                              StartEndPoint.Landing = 1;
                    }
          }
          FSfclose(fptr);
}


/*********************************************************************
Author: Daeho Hong
          Function: int logStart()
          Summary:
                    Writing the very first part of the log which is xml initialization

*********************************************************************/
int logStart()
{
// Create a file
          FSFILE *pointer;
     pointer = FSfopen (OUTPUTFILE, "w");
     if (pointer == NULL)
          {
       return FALSE;
          }
     FSfprintf(pointer,"<?xml version=\"1.0\" encoding=\"UTF-8\"?>\n");
     FSfprintf(pointer,"<?xml-stylesheet type=\"text/xsl\" href=\"xsl3.xsl\"?>\n");
     FSfprintf(pointer,"<FLYSPY>\n");
     if (FSfclose(pointer) == FALSE)
          {
```

```
                return FALSE;
        }
return TRUE;
}
/*********************************************************************
Author: Daeho Hong
        Function: int logEnd()
        Summary:
                Writing the very last part of the log which is xml closer

*********************************************************************/
int logEnd()
{
// Create a file
        FSFILE *pointer;
    pointer = FSfopen (OUTPUTFILE, "a");
    if (pointer == NULL)
        {
      return FALSE;
        }
    FSfprintf(pointer,"<FLYSPY>\n");
    if (FSfclose(pointer) == FALSE)
    {
          return FALSE;
        }
return TRUE;
}

void logPicturePoint(GPSINFO *Gps)
{
        int length;
        FSFILE *pointer;
    //Assert that we are not in manual flight and we aren't moving
        if (Gps->Speed < 88 && CTRL_SW == 0)
                return;

    pointer = FSfopen (OUTPUTFILE, "a");

        length = sprintf(IOBuffer,"\t<Picture Time=\"%d:%d:%d.%d\">\n",Gps->Hour,
Gps->Minute, Gps->Second, Gps->Mils);
        FSfwrite(IOBuffer, 1, length, pointer);
        length = sprintf(IOBuffer,"\t\t\t<Latitude>%f</Latitude>\n", Gps->Latitude);
        FSfwrite(IOBuffer, 1, length, pointer);
        length = sprintf(IOBuffer,"\t\t\t<Longitude>%f</Longitude>\n", Gps-
>Longitude);
        FSfwrite(IOBuffer, 1, length, pointer);
        FSfprintf(pointer, "\t</Picture>\n");
        FSfclose(pointer);
}
/*********************************************************************
Author: Daeho Hong
        Function: int logCoord(int,...,int)
        Summary:
                Writing a signle coordinate

*********************************************************************/
int logCoord(WAYPOINT* wp, GPSINFO* Gps, double distance, double bearing, double
altitude, double pitch, double roll, float clearing, float throt_auto, float ele_auto,
float rudder_auto, double left_auto, double right_auto,double throt_man, double
ele_man, double rudder_man, double left_man, double right_man)
{
        int length;
        FSFILE *pointer;
```

```
    //Assert that we are not in manual flight and we aren't moving
         if (Gps->Speed < 88 && CTRL_SW == 0)
                  return 0;
// Create a file
    pointer = FSfopen (OUTPUTFILE, "a");

    if (pointer == NULL)
         {
      return FALSE;
         }
         length = sprintf(IOBuffer, "\t<Coordinate Time=\"%d:%d:%d.%d\">\n", Gps-
>Hour, Gps->Minute, Gps->Second, Gps->Mils);
         //FSfprintf(pointer,"\t<Coordinate Time=""%d:%d:%d.%d"">\n", Gps->Hour, Gps-
>Minute, Gps->Second, Gps->Mils);
         FSfwrite(IOBuffer, 1, length, pointer);
         FSfprintf(pointer,"\t\t<Destination>\n");
         length = sprintf(IOBuffer,"\t\t\t<Latitude>%f</Latitude>\n", wp->Latitude);
         FSfwrite(IOBuffer, 1, length, pointer);
         length = sprintf(IOBuffer,"\t\t\t<Longitude>%f</Longitude>\n", wp-
>Longitude);
         FSfwrite(IOBuffer, 1, length, pointer);
         FSfprintf(pointer,"\t\t</Destination>\n");
         FSfprintf(pointer,"\t\t<POSITION>\n");
         length = sprintf(IOBuffer,"\t\t\t<Latitude>%f</Latitude>\n", Gps->Latitude);
         FSfwrite(IOBuffer, 1, length, pointer);
         length = sprintf(IOBuffer,"\t\t\t<Longitude>%f</Longitude>\n", Gps-
>Longitude);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<Longitude>%f</Longitude>\n", Gps->Longitude);
         length = sprintf(IOBuffer,"\t\t\t<Speed>%f</Speed>\n", Gps->Speed);
         FSfwrite(IOBuffer, 1, length, pointer);
         length = sprintf(IOBuffer,"\t\t\t<Heading>%f</Heading>\n", Gps->Heading);
         FSfwrite(IOBuffer, 1, length, pointer);
         length = sprintf(IOBuffer,"\t\t\t<Distance>%f</Distance>\n", distance);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<Latitude>%f</Latitude>\n", Gps->Latitude);
         length = sprintf(IOBuffer,"\t\t\t<Altitude>%f</Altitude>\n", altitude);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<Altitude>%f</Altitude>\n", altitude);
         length = sprintf(IOBuffer,"\t\t\t<Distance>%f</Distance>\n", distance);
         FSfwrite(IOBuffer, 1, length, pointer);
         length = sprintf(IOBuffer,"\t\t\t<Bearing>%f</Bearing>\n", bearing);
         FSfwrite(IOBuffer, 1, length, pointer);
         FSfprintf(pointer,"\t\t</POSITION>\n");
         FSfprintf(pointer,"\t\t<Orientation>\n");
         length = sprintf(IOBuffer,"\t\t\t<Pitch>%e</Pitch>\n", pitch);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<Pitch>%e</Pitch>\n", pitch);
         length = sprintf(IOBuffer,"\t\t\t<Roll>%e</Roll>\n", roll);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<Roll>%e</Roll>\n", roll);
         length = sprintf(IOBuffer,"\t\t\t<Clearing>%f</Clearing>\n",
(double)clearing);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<Clearing>%f</Clearing>\n", clearing);
         FSfprintf(pointer,"\t\t</Orientation>\n");
         FSfprintf(pointer,"\t\t<SurfaceByAuto>\n");
         length = sprintf(IOBuffer,"\t\t\t<Throttle>%f</Throttle>\n",
(double)throt_auto);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<Throttle>%f</Throttle>\n", throt_auto);
         length = sprintf(IOBuffer,"\t\t\t<Elevator>%f</Elevator>\n",
(double)ele_auto);
```

```
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<Elevator>%f</Elevator>\n", ele_auto);
         length = sprintf(IOBuffer,"\t\t\t<Rudder>%f</Rudder>\n",
(double)rudder_auto);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<Rudder>%f</Rudder>\n", rudder_auto);
         length = sprintf(IOBuffer,"\t\t\t<LeftAileron>%f</LeftAileron>\n",
(double)left_auto);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<LeftAileron>%f</LeftAileron>\n", left_auto);
         length = sprintf(IOBuffer,"\t\t\t<RightAileron>%f</RightAileron>\n",
right_auto);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<RightAileron>%f</RightAileron>\n", right_auto);
         FSfprintf(pointer,"\t\t</SurfaceByAuto>\n");
         FSfprintf(pointer,"\t\t<SurfaceByManual>\n");
         length = sprintf(IOBuffer,"\t\t\t<Throttle>%f</Throttle>\n", throt_man);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<Throttle>%f</Throttle>\n", throt_man);
         length = sprintf(IOBuffer,"\t\t\t<Elevator>%f</Elevator>\n", ele_man);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<Elevator>%f</Elevator>\n", ele_man);
         length = sprintf(IOBuffer,"\t\t\t<Rudder>%f</Rudder>\n", rudder_man);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<Rudder>%f</Rudder>\n", rudder_man);
         length = sprintf(IOBuffer,"\t\t\t<LeftAileron>%f</LeftAileron>\n", left_man);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<LeftAileron>%f</LeftAileron>\n", left_man);
         length = sprintf(IOBuffer,"\t\t\t<RightAileron>%f</RightAileron>\n",
right_man);
         FSfwrite(IOBuffer, 1, length, pointer);
         //FSfprintf(pointer,"\t\t\t<RightAileron>%f</RightAileron>\n", right_man);
         FSfprintf(pointer,"\t\t</SurfaceByManual>\n");
         FSfprintf(pointer,"\t</Coordinate>\n");
    if (FSfclose(pointer) == FALSE)
    {
           return FALSE;
         }
return TRUE;
}



/*************************************************************************
 * io.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *************************************************************************/

#define PROGRAMFOLDER       "FLYSPY"
#define INPUTFILE           "WAYPTS.TXT"
#define OUTPUTFILE          "FLYINFO.XML"
#define MAXWAYPOINTS        20

typedef struct userwaypoint
{
         double Latitude;
         double Longitude;
         float Altitude;
         int Picture;
}WAYPOINT;
```

```
typedef struct
{
         int TakeOff;
         int Delay;
         int Landing;
         double TakeOff_Altitude;
         double Landing_Altitude;
         double Landing_Latitude;
         double Landing_Longitude;
}TAKEOFFLANDING;

void initio(void);

/*********************************************************************
Author: Daeho Hong
         Function: int logEnd()
         Summary:
                  Writing the very last part of the log which is xml closer

*********************************************************************/
int logEnd();

/*********************************************************************
Author: Daeho Hong
         Function: int logStart()
         Summary:
                  Writing the very first part of the log which is xml initialization

*********************************************************************/
int logStart();
void logPicturePoint(GPSINFO *Gps);
/*********************************************************************
Author: Daeho Hong
         Function: int logCoord(int,...,int)
         Summary:
                  Writing a signle coordinate

*********************************************************************/
int logCoord(WAYPOINT* wp, GPSINFO* Gps, double distance, double bearing, double
altitude, double pitch, double roll, float clearing, float throt_auto, float ele_auto,
float rudder_auto, double left_auto, double right_auto,double throt_man, double
ele_man, double rudder_man, double left_man, double right_man);


/*********************************************************************
 * iomapping.c
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *********************************************************************/

/*********************************************************************
 *
 * I/O Mapping for Peripheral Pin Select devices
 *
 * Adapted from the Microchip Explorer 16 sample code
 *
 * Author               Date        Comment
 *~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 * William Ehlhardt                  3/23/09           Set up for FlySpy project
 *********************************************************************/

#include "FlySpy.h"
```

```
#ifdef __PIC24FJ256GA110__

void ioMap()
{
	/* Analog device pins: Set them all to analog mode! */
	AD1PCFGbits.PCFG0 = 0;
	AD1PCFGbits.PCFG1 = 0;
	AD1PCFGbits.PCFG2 = 0;
	AD1PCFGbits.PCFG3 = 0;
	AD1PCFGbits.PCFG4 = 0;
	AD1PCFGbits.PCFG5 = 0;

	/* TODO: Do the ICD pins need some magic setup here?
		 They overlap some analog channels.
		 Also, do I need to specifically disallow ICD2 action
			 on the AN0/AN1 channels?
		 Presumably not, but it's worth a check -William */

	/* Autopilot/manual */
	_TRISD7 = 1;                                            // CTRL_SW input
	_TRISD6 = 1;                                            // GEAR_SW input

	/* Camera I/O */
	_TRISA2 = 1;                                            // CAM_POW_FB input
		 (RA2)
	_TRISG2 = 0;                                            // CAM_SHUTTER output
	(RG2)
	_TRISG3 = 0;                                            // CAM_POWER output
		 (RG3)

	/* SPI #1: Barometer */
	RPOR4bits.RP9R = SCK1OUT_IO;         // SCK1 output     (RP9)
	_TRISB9 = 0;                                            //        AKA RB9
	AD1PCFGbits.PCFG9 = 1;                          //        AKA AN9
	RPOR15bits.RP31R = SDO1_IO;          // SDO1 output     (RP31)
	_TRISF13 = 0;                                           //        AKA RF13
	RPINR20bits.SDI1R = 32;                         // SDI1 input      (RPI32)
	_TRISF12 = 1;                                           //        AKA RF12
	// I'll manage the EN bit manually, as the barometer
	//  uses variable-length frames.
	//       RPOR14bits.RP29R = SS1OUT_IO;        // SSI1 output     (RP29)
	_TRISB15 = 0;                                           //        AKA RB15
	AD1PCFGbits.PCFG15 = 1;                         //        AKA AN15

	/* SPI #2: MicroSD */
	// TODO: enable the pullup on this pin?
	_TRISF6 = 1;                                            // SD chip detector
input    (RF6)
	RPINR22bits.SDI2R = 43;                         // SDI2 input      (RPI43)
	_TRISD14 = 1;                                           //        AKA RD14
	RPOR2bits.RP5R = SCK2OUT_IO;         // SCK2 output     (RP5)
	_TRISD15 = 0;                                           //        AKA RD15
	RPOR5bits.RP10R = SDO2_IO;           // SDO2 output     (RP10)
	_TRISF4 = 0;                                            //        AKA RF4
	RPOR8bits.RP17R = SS2OUT_IO;         // SSI2 output     (RP17)
	_TRISF5 = 0;                                            //        AKA RF5

	/* UART #1: GPS */
	RPOR8bits.RP16R = U1TX_IO;           // U1TX output     (RP16)
	_TRISF3 = 0;                                    //        AKA RF3
	RPINR18bits.U1RXR = 30;                         // U1RX input      (RP30)
	_TRISF2 = 1;                                    //        AKA RF2
```

```
        /* UART #2: General serial */
        RPOR7bits.RP15R = U2TX_IO;          // U2TX output     (RP15)
        _TRISF8 = 0;                                //       AKA RF8
        RPINR19bits.U2RXR = 44;                     // U2RX input      (RPI44)
        _TRISF7 = 1;                                //       AKA RF7

        /* Input compare (PWM in) */
        RPINR7bits.IC1R = 37;                       // IC1 (THROT)     (RPI37)
        _TRISC14 = 1;                               //       AKA RC14
        RPINR7bits.IC2R = 11;                       // IC2 (L_AIL)     (RP11)
        _TRISD0 = 1;                                //       AKA RD0
        RPINR8bits.IC3R = 12;                       // IC3 (R_AIL)     (RP12)
        _TRISD11 = 1;                               //       AKA RD11
        RPINR8bits.IC4R =  3;                       // IC4 (ELEVATOR) (RP3)
        _TRISD10 = 1;                               //       AKA RD10
        RPINR9bits.IC5R =  4;                       // IC5 (RUDDER)    (RP4)
        _TRISD9 = 1;                                //       AKA RD9

        /* Output compare (PWM out) */
        RPOR10bits.RP20R = OC1_IO;
        _TRISD5 = 0;                                //       AKA RD5
        RPOR12bits.RP25R = OC2_IO;
        _TRISD4 = 0;                                //       AKA RD4
        RPOR11bits.RP22R = OC3_IO;
        _TRISD3 = 0;                                //       AKA RD3
        RPOR11bits.RP23R = OC4_IO;
        _TRISD2 = 0;                                //       AKA RD2
        RPOR12bits.RP24R = OC5_IO;
        _TRISD1 = 0;                                //       AKA RD1
}

/*****************************************************************************
 * Function: lockIO
 *
 * Preconditions: None.
 *
 * Overview: This executes the necessary process to set the IOLOCK bit to lock
 * I/O mapping from being modified.
 *
 * Input: None.
 *
 * Output: None.
 *
 *****************************************************************************/
void lockIO(){

asm volatile ("mov #OSCCON,w1 \n"
                                    "mov #0x46, w2 \n"
                                    "mov #0x57, w3 \n"
                                    "mov.b w2,[w1] \n"
                                    "mov.b w3,[w1] \n"
                                    "bset OSCCON, #6");


}

/*****************************************************************************
 * Function: unlockIO
 *
 * Preconditions: None.
 *
 * Overview: This executes the necessary process to clear the IOLOCK bit to
```

```
 * allow I/O mapping to be modified.
 *
 * Input: None.
 *
 * Output: None.
 *
 ***************************************************************************/
void unlockIO(){

asm volatile ("mov #OSCCON,w1 \n"
                                    "mov #0x46, w2 \n"
                                    "mov #0x57, w3 \n"
                                    "mov.b w2,[w1] \n"
                                    "mov.b w3,[w1] \n"
                                    "bclr OSCCON, #6");

}
#else
#error "This code is only for a PIC24FJ256GA110!"
#endif


/*****************************************************************************
 * iomapping.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *****************************************************************************/

/*****************************************************************************
 *
 * I/O Mapping for Peripheral Pin Select devices
 *
 * Adapted from the Microchip Explorer 16 sample code
 *
 * Author               Date        Comment
 *~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
 * William Ehlhardt                  3/23/09           Set up for FlySpy project
 *****************************************************************************/

#ifndef IOMAPPING_H
#define IOMAPPING_H

/* TODO: #define TRIS/LAT/whatever stuff here. I believe we need it for
    properly initializing the pins for output, in particular.
         See Fig 12-4 in the I/O Ports reference */

#define CAM_POW_FB          _RA2
#define CAM_SHUTTER         _LATG2
#define CAM_POWER  _LATG3

#define CTRL_SW             _RD7
#define GEAR_SW             _RD6

// Barometer Chip Select
#define BAROMETER_CS        _LATB15

//PPS Outputs (from datasheet)
#define NULL_IO             0
#define C1OUT_IO   1
#define C2OUT_IO   2
#define U1TX_IO             3
#define U1RTS_IO   4
```

```
#define U2TX_IO             5
#define U2RTS_IO   6
#define SDO1_IO             7
#define SCK1OUT_IO 8
#define SS1OUT_IO  9
#define SDO2_IO             10
#define SCK2OUT_IO 11
#define SS2OUT_IO  12
#define OC1_IO              18
#define OC2_IO              19
#define OC3_IO              20
#define OC4_IO              21
#define OC5_IO              22

extern void ioMap();
extern void unlockIO();
extern void lockIO();

#endif


/************************************************************************
 * pwm.c
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 ************************************************************************/

#include "FlySpy.h"
#include "util.h"

static volatile  float MANUAL_LAILERON_WIDTH = 0;
static volatile  int LAILERON_LAST_RISING = -1;

static volatile  float MANUAL_RAILERON_WIDTH = 0;
static volatile  int RAILERON_LAST_RISING = -1;

static volatile  float MANUAL_THROTTLE_WIDTH = 0;
static volatile  int THROTTLE_LAST_RISING = -1;

static volatile  float MANUAL_ELEVATOR_WIDTH = 0;
static volatile  int ELEVATOR_LAST_RISING = -1;

static volatile  float MANUAL_RUDDER_WIDTH = 0;
static volatile  int RUDDER_LAST_RISING = -1;

void initpwm()
{
         initOutputCompare();
         initInputCapture();
}

void initOutputCompare()
{
         //Clearing all Control bits
         OC1CON1 = 0;
         OC1CON2 = 0;

         OC1R = msToClk(MIN_THROTTLE);  //Setting 1.0ms Pulse Width - Mininum for
Throttle
         OC1RS = PERIODCLK; //Period of 20ms

         OC1CON2bits.SYNCSEL = 0x0B; // Synchronized by Timer1(50Hz)
```

```
          OC1CON1bits.OCTSEL = 0x04; // Select Timer1 as the clock source
          OC1CON1bits.OCM = 6; //Setting PWM Output in Edge Aligned Mode

          //Clearing all Control bits
          OC2CON1 = 0;
          OC2CON2 = 0;

          OC2R = msToClk(ZERO_LAILERON);  //Setting 1.5ms Pulse Width - Midpoint
          OC2RS = PERIODCLK; //Period of 20ms

          OC2CON2bits.SYNCSEL = 0x0B; // Synchronized by Timer1(50Hz)
          OC2CON1bits.OCTSEL = 0x04; // Select Timer1 as the clock source
          OC2CON1bits.OCM = 6; //Setting PWM Output in Edge Aligned Mode

          //Clearing all Control bits
          OC3CON1 = 0;
          OC3CON2 = 0;

          OC3R = msToClk(ZERO_RAILERON);  //Setting 1.5ms Pulse Width - Midpoint
          OC3RS = PERIODCLK; //Period of 20ms

          OC3CON2bits.SYNCSEL = 0x0B; // Synchronized by Timer1(50Hz)
          OC3CON1bits.OCTSEL = 0x04; // Select Timer1 as the clock source
          OC3CON1bits.OCM = 6; //Setting PWM Output in Edge Aligned Mode

          //Clearing all Control bits
          OC4CON1 = 0;
          OC4CON2 = 0;

          OC4R = msToClk(ZERO_ELEVATOR);  //Setting 1.5ms Pulse Width - Midpoint
          OC4RS = PERIODCLK; //Period of 20ms

          OC4CON2bits.SYNCSEL = 0x0B; // Synchronized by Timer1(50Hz)
          OC4CON1bits.OCTSEL = 0x04; // Select Timer1 as the clock source
          OC4CON1bits.OCM = 6; //Setting PWM Output in Edge Aligned Mode

          //Clearing all Control bits
          OC5CON1 = 0;
          OC5CON2 = 0;

          OC5R = msToClk(ZERO_RUDDER);  //Setting 1.5ms Pulse Width - Midpoint
          OC5RS = PERIODCLK; //Period of 20ms
          OC5CON2bits.SYNCSEL = 0x0B; // Synchronized by Timer1(50Hz)
          OC5CON1bits.OCTSEL = 0x04; // Select Timer1 as the clock source
          OC5CON1bits.OCM = 6; //Setting PWM Output in Edge Aligned Mode
}

void initInputCapture()
{
          IPC0bits.IC1IP = 0x05;
     IFS0bits.IC1IF = 0;     //Clear the interrupt status flag
          IEC0bits.IC1IE = 1; //Enable Interrupts

          IC1CON1 = 0;
          IC1CON2 = 0;

          IC1CON1bits.ICTSEL = 0x0; //Input Capture Timer is Timer 1
          IC1CON2bits.SYNCSEL = 0x0D; //Synchronized by Timer1
          IC1CON1bits.ICM = 0x01; //Edge Detect Capture mode

          IPC1bits.IC2IP = 0x05;
     IFS0bits.IC2IF = 0;     //Clear the interrupt status flag
          IEC0bits.IC2IE = 1; //Enable Interrupts
```

```
          IC2CON1 = 0;
          IC2CON2 = 0;

          IC2CON1bits.ICTSEL = 0x0; //Input Capture Timer is Timer 1
          IC2CON2bits.SYNCSEL = 0x0D; //Synchronized by Timer1
          IC2CON1bits.ICM = 0x01; //Edge Detect Capture mode

          IPC9bits.IC3IP = 0x05;
    IFS2bits.IC3IF = 0;     //Clear the interrupt status flag
          IEC2bits.IC3IE = 1; //Enable Interrupts

          IC3CON1 = 0;
          IC3CON2 = 0;

          IC3CON1bits.ICTSEL = 0x0; //Input Capture Timer is Timer 1
          IC3CON2bits.SYNCSEL = 0x0D; //Synchronized by Timer1
          IC3CON1bits.ICM = 0x01; //Edge Detect Capture mode

          IPC9bits.IC4IP = 0x05;
    IFS2bits.IC4IF = 0;     //Clear the interrupt status flag
          IEC2bits.IC4IE = 1; //Enable Interrupts

          IC4CON1 = 0;
          IC4CON2 = 0;

          IC4CON1bits.ICTSEL = 0x0; //Input Capture Timer is Timer 1
          IC4CON2bits.SYNCSEL = 0x0D; //Synchronized by Timer1
          IC4CON1bits.ICM = 0x01; //Edge Detect Capture mode

          IPC9bits.IC5IP = 0x05;
    IFS2bits.IC5IF = 0;     //Clear the interrupt status flag
          IEC2bits.IC5IE = 1; //Enable Interrupts

          IC5CON1 = 0;
          IC5CON2 = 0;

          IC5CON1bits.ICTSEL = 0x0; //Input Capture Timer is Timer 1
          IC5CON2bits.SYNCSEL = 0x0D; //Synchronized by Timer1
          IC5CON1bits.ICM = 0x01; //Edge Detect Capture mode
}

float calculatePulseWidth(int StartTime, int StopTime)
{
          int diff;

          if( StopTime < StartTime) diff = (PERIODCLK - StartTime + StopTime);
          else diff = StopTime - StartTime;

          return (diff * PERIODMS / PERIODCLK);
}

void __attribute__ ((__interrupt__,  auto_psv)) _IC1Interrupt(void)
{
          int val;
          float curr_width;

          do
          {
                    val = IC1BUF;
          }while (IC1CON1bits.ICBNE);

          if (THROTTLE_LAST_RISING == -1)
```

```
   {
                    THROTTLE_LAST_RISING = val;
          }
          else
          {
                    curr_width = calculatePulseWidth(THROTTLE_LAST_RISING, val);
                    if (curr_width < 3 && curr_width > .5)
          {
                              MANUAL_THROTTLE_WIDTH = curr_width;
                              THROTTLE_LAST_RISING = -1;
          }
                    else
                    {
                              THROTTLE_LAST_RISING = val; //Determined that I may get a
falling edge first so if value is over max pulse width, start timing over.
                    }
          }
          IFS0bits.IC1IF = 0; //Clears and enables interrupts
}

void __attribute__ ((__interrupt__,  auto_psv)) _IC2Interrupt(void)
{
          int val;
          float curr_width;

          do
          {
                    val = IC2BUF;
          }while (IC2CON1bits.ICBNE);

          if (LAILERON_LAST_RISING == -1)
   {
                    LAILERON_LAST_RISING = val;
          }
          else
          {
                    curr_width = calculatePulseWidth(LAILERON_LAST_RISING, val);
                    if (curr_width < 3 && curr_width > .5)
          {
                              MANUAL_LAILERON_WIDTH = curr_width;
                              LAILERON_LAST_RISING = -1;
          }
                    else
                    {
                              LAILERON_LAST_RISING = val; //Determined that I may get a
falling edge first so if value is over max pulse width, start timing over.
                    }
          }
          IFS0bits.IC2IF = 0; //Clears and enables interrupts
}

void __attribute__ ((__interrupt__,  auto_psv)) _IC3Interrupt(void)
{
          int val;
          float curr_width;

          do
          {
                    val = IC3BUF;
          }while (IC3CON1bits.ICBNE);

          if (RAILERON_LAST_RISING == -1)
    {
```

```
                RAILERON_LAST_RISING = val;
        }
        else
        {
                curr_width = calculatePulseWidth(RAILERON_LAST_RISING, val);
                if (curr_width < 3 && curr_width > .5)
        {
                        MANUAL_RAILERON_WIDTH = curr_width;
                        RAILERON_LAST_RISING = -1;
        }
                else
                {
                        RAILERON_LAST_RISING = val; //Determined that I may get a
falling edge first so if value is over max pulse width, start timing over.
                }
        }
        IFS2bits.IC3IF = 0; //Clears and enables interrupts
}

void __attribute__ ((__interrupt__,  auto_psv)) _IC4Interrupt(void)
{
        int val;
        float curr_width;

        do
        {
                val = IC4BUF;
        }while (IC4CON1bits.ICBNE);

        if (ELEVATOR_LAST_RISING == -1)
    {
                ELEVATOR_LAST_RISING = val;
        }
        else
        {
                curr_width = calculatePulseWidth(ELEVATOR_LAST_RISING, val);
                if (curr_width < 3 && curr_width > .5)
        {
                        MANUAL_ELEVATOR_WIDTH = curr_width;
                        ELEVATOR_LAST_RISING = -1;
        }
                else
                {
                        ELEVATOR_LAST_RISING = val; //Determined that I may get a
falling edge first so if value is over max pulse width, start timing over.
                }
        }
        IFS2bits.IC4IF = 0; //Clears and enables interrupts
}

void __attribute__ ((__interrupt__,  auto_psv)) _IC5Interrupt(void)
{
        int val;
        float curr_width;


        do
        {
                val = IC5BUF;
        }while (IC5CON1bits.ICBNE);

        if (RUDDER_LAST_RISING == -1)
   {
```

```
                RUDDER_LAST_RISING = val;
        }
        else
        {
                curr_width = calculatePulseWidth(RUDDER_LAST_RISING, val);
                if (curr_width < 3 && curr_width > .5)
        {
                        MANUAL_RUDDER_WIDTH = curr_width;
                        RUDDER_LAST_RISING = -1;
        }
                else
                {
                        RUDDER_LAST_RISING = val; //Determined that I may get a
falling edge first so if value is over max pulse width, start timing over.
                }
        }
        IFS2bits.IC5IF = 0; //Clears and enables interrupts
}
float clkToMs(int ClockTicks)
{
        return ClockTicks * PERIODMS / PERIODCLK;
}

int msToClk(float MilSecs )
{
        return ((int)(MilSecs * PERIODCLK / PERIODMS));
}

void
read_PWM_IN(float *l_ail, float *r_ail, float *throttle, float *elev, float *rudder)
{
        /* Throttle */
        IEC0bits.IC1IE = 0;                                                     // flip off
the interrupt
        *throttle = MANUAL_THROTTLE_WIDTH;    // safely read data
        IEC0bits.IC1IE = 1;                                                     //
interrupt back on

        /* Left Aileron */
        IEC0bits.IC2IE = 0;                                                     // flip off
the interrupt
        *l_ail = MANUAL_LAILERON_WIDTH;                 // safely read data
        IEC0bits.IC2IE = 1;                                                     //
interrupt back on

        /* Right Aileron */
        IEC2bits.IC3IE = 0;                                                     // flip off
the interrupt
        *r_ail = MANUAL_RAILERON_WIDTH;                 // safely read data
        IEC2bits.IC3IE = 1;                                                     //
interrupt back on

        /* Elevator */
        IEC2bits.IC4IE = 0;                                                     // flip off
the interrupt
        *elev = MANUAL_ELEVATOR_WIDTH;                  // safely read data
        IEC2bits.IC4IE = 1;                                                     //
interrupt back on

        /* Rudder */
        IEC2bits.IC5IE = 0;                                                     // flip off
the interrupt
        *rudder = MANUAL_RUDDER_WIDTH;                  // safely read data
```

```
        IEC2bits.IC5IE = 1;                                             //
interrupt back on
}

void read_PWM_OUT(float *l_ail, float *r_ail, float *throttle, float *elev, float
*rudder)
{
        *l_ail = LAILERONREG * PERIODMS / PERIODCLK;
        *r_ail = RAILERONREG * PERIODMS / PERIODCLK;
        *throttle = THROTTLEREG * PERIODMS / PERIODCLK;
        *elev = ELEVATORREG * PERIODMS / PERIODCLK;
        *rudder = RUDDERREG * PERIODMS / PERIODCLK;
}



/************************************************************************
 * pwm.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 ************************************************************************/

#define PERIODCLK 5000 // 20ms count for the TIMER1 Clock sources which is Fosc/(2*64)
= 32Mhz/(2*64)
#define PERIODMS 20.0 //  The PWM period in milliseconds

#define THROTTLEREG OC1R
#define LAILERONREG         OC2R
#define RAILERONREG         OC3R
#define ELEVATORREG         OC4R
#define RUDDERREG  OC5R

void initpwm(void);
void initOutputCompare(void);
void initInputCapture(void);
float clkToMs(int);
int msToClk(float);
void read_PWM_IN(float *l_ail, float *r_ail,
                                    float *throttle, float *elev, float *rudder);
void read_PWM_OUT(float *l_ail, float *r_ail,
                                    float *throttle, float *elev, float *rudder);



/************************************************************************
 * SD-SPI.c
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 ************************************************************************/

/********************************************************************
 *
 *               Microchip Memory Disk Drive File System
 *
 ********************************************************************
 * FileName:        SD-SPI.c
 * Dependencies:    SD-SPI.h
 *                  string.h
 *                  FSIO.h
 *                  FSDefs.h
```

```
 * Processor:       PIC18/PIC24/dsPIC30/dsPIC33/PIC32
 * Compiler:        C18/C30/C32
 * Company:         Microchip Technology, Inc.
 * Version:         1.2.0
 *
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 *
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 * CONSEQUENTIAL DAMAGES, FOR ANY REASON WHATSOEVER.
 *
********************************************************************************/

#include "FSIO.h"  //"MDD File System\FSIO.h"
#include "FSDefs.h" //"MDD File System\FSDefs.h"
#include "SD-SPI.h"  //"MDD File System\SD-SPI.h"
#include "string.h"
#include "FSConfig.h"
#include "HardwareProfile.h"

/********************************************************************************
 * Global Variables
 ********************************************************************************/

// Description:  Used for the mass-storage library to determine capacity
DWORD MDD_SDSPI_finalLBA;


#ifdef __18CXX
    // Summary: Table of SD card commands and parameters
    // Description: The sdmmc_cmdtable contains an array of SD card commands, the
corresponding CRC code, the
    //              response type that the card will return, and a parameter
indicating whether to expect
    //              additional data from the card.
    const rom typMMC_CMD sdmmc_cmdtable[] =
#else
    const typMMC_CMD sdmmc_cmdtable[] =
#endif
{
    // cmd                      crc     response
    {cmdGO_IDLE_STATE,          0x95,   R1,     NODATA},
    {cmdSEND_OP_COND,           0xF9,   R1,     NODATA},
    {cmdSEND_CSD,               0xAF,   R1,     MOREDATA},
    {cmdSEND_CID,               0x1B,   R1,     MOREDATA},
    {cmdSTOP_TRANSMISSION,      0xC3,   R1,     NODATA},
    {cmdSEND_STATUS,            0xAF,   R2,     NODATA},
    {cmdSET_BLOCKLEN,           0xFF,   R1,     NODATA},
    {cmdREAD_SINGLE_BLOCK,      0xFF,   R1,     MOREDATA},
```

```
    {cmdREAD_MULTI_BLOCK,       0xFF,   R1,     MOREDATA},
    {cmdWRITE_SINGLE_BLOCK,     0xFF,   R1,     MOREDATA},
    {cmdWRITE_MULTI_BLOCK,      0xFF,   R1,     MOREDATA},
    {cmdTAG_SECTOR_START,       0xFF,   R1,     NODATA},
    {cmdTAG_SECTOR_END,         0xFF,   R1,     NODATA},
    {cmdERASE,                  0xDF,   R1b,    NODATA},
    {cmdAPP_CMD,                0x73,   R1,     NODATA},
    {cmdREAD_OCR,               0x25,   R3,     NODATA},
    {cmdCRC_ON_OFF,             0x25,   R1,     NODATA}
};



/*****************************************************************************
 * Prototypes
 *****************************************************************************/

extern void Delayms(BYTE milliseconds);
BYTE MDD_SDSPI_ReadMedia(void);
BYTE MDD_SDSPI_MediaInitialize(void);
MMC_RESPONSE SendMMCCmd(BYTE cmd, DWORD address);

#if defined __C30__ || defined __C32__
    void OpenSPIM ( unsigned int sync_mode);
    void CloseSPIM( void );
    unsigned char WriteSPIM( unsigned char data_out );
#elif defined __18CXX
    void OpenSPIM ( unsigned char sync_mode);
    void CloseSPIM( void );
    unsigned char WriteSPIM( unsigned char data_out );

    unsigned char WriteSPIManual(unsigned char data_out);
    BYTE ReadMediaManual (void);
    MMC_RESPONSE SendMMCCmdManual(BYTE cmd, DWORD address);
#endif

#ifdef __PIC32MX__

/*****************************************************
  Function:
    static inline __attribute__((always_inline)) unsigned char SPICacutateBRG
(unsigned int pb_clk, unsigned int spi_clk)
  Summary:
    Calculate the PIC32 SPI BRG value
  Conditions:
    None
  Input:
    pb_clk -  The value of the PIC32 peripheral clock
    spi_clk - The desired baud rate
  Return:
    The corresponding BRG register value.
  Side Effects:
    None.
  Description:
    The SPICalutateBRG function is used to determine an appropriate BRG register value
for the PIC32 SPI module.
  Remarks:
    None
  *****************************************************/

static inline __attribute__((always_inline)) unsigned char SPICalutateBRG(unsigned int
pb_clk, unsigned int spi_clk)
```

```
{
    unsigned int brg;

    brg = pb_clk / (2 * spi_clk);

    if(pb_clk % (2 * spi_clk))
        brg++;

    if(brg > 0x100)
        brg = 0x100;

    if(brg)
        brg--;

    return (unsigned char) brg;
}
#endif


/*****************************************************
  Function:
    BYTE MDD_SDSPI_MediaDetect
  Summary:
    Determines whether an SD card is present
  Conditions:
    The MDD_MediaDetect function pointer must be configured
    to point to this function in FSconfig.h
  Input:
    None
  Return Values:
    TRUE -  Card detected
    FALSE - No card detected
  Side Effects:
    None.
  Description:
    The MDD_SDSPI_MediaDetect function will determine if an
    SD card is connected to the microcontroller by polling
    the SD card detect pin.
  Remarks:
    None
  *****************************************************/

BYTE MDD_SDSPI_MediaDetect (void)
{
    return(!SD_CD);
}//end MediaDetect


/*****************************************************
  Function:
    WORD MDD_SDSPI_ReadSectorSize (void)
  Summary:
    Determines the current sector size on the SD card
  Conditions:
    MDD_MediaInitialize() is complete
  Input:
    None
  Return:
    The size of the sectors for the physical media
  Side Effects:
    None.
  Description:
    The MDD_SDSPI_ReadSectorSize function is used by the
```

```
    USB mass storage class to return the card's sector
    size to the PC on request.
  Remarks:
    None
  *****************************************************/

WORD MDD_SDSPI_ReadSectorSize(void)
{
    return MEDIA_SECTOR_SIZE;
}


/*****************************************************
  Function:
    DWORD MDD_SDSPI_ReadCapacity (void)
  Summary:
    Determines the current capacity of the SD card
  Conditions:
    MDD_MediaInitialize() is complete
  Input:
    None
  Return:
    The capacity of the device
  Side Effects:
    None.
  Description:
    The MDD_SDSPI_ReadCapacity function is used by the
    USB mass storage class to return the total number
    of sectors on the card.
  Remarks:
    None
  *****************************************************/
DWORD MDD_SDSPI_ReadCapacity(void)
{
    return (MDD_SDSPI_finalLBA);
}


/*****************************************************
  Function:
    WORD MDD_SDSPI_InitIO (void)
  Summary:
    Initializes the I/O lines connected to the card
  Conditions:
    MDD_MediaInitialize() is complete.  The MDD_InitIO
    function pointer is pointing to this function.
  Input:
    None
  Return:
    None
  Side Effects:
    None.
  Description:
    The MDD_SDSPI_InitIO function initializes the I/O
    pins connected to the SD card.
  Remarks:
    None
  *****************************************************/

void MDD_SDSPI_InitIO (void)
{
    // Turn off the card
    SD_CD_TRIS = INPUT;            //Card Detect - input
```

```
    SD_CS = 1;                      //Initialize Chip Select line
    SD_CS_TRIS = OUTPUT;             //Card Select - output
    //SD_WE_TRIS = INPUT;             //Write Protect - input
}


/*****************************************************
  Function:
    WORD MDD_SDSPI_ShutdownMedia (void)
  Summary:
    Disables the SD card
  Conditions:
    The MDD_ShutdownMedia function pointer is pointing
    towards this function.
  Input:
    None
  Return:
    None
  Side Effects:
    None.
  Description:
    This function will disable the SPI port and deselect
    the SD card.
  Remarks:
    None
  *****************************************************/

void MDD_SDSPI_ShutdownMedia(void)
{
    // close the spi bus
    CloseSPIM();

    // deselect the device
    SD_CS = 1;
}


/*****************************************************************************
  Function:
    MMC_RESPONSE SendMMCCmd (BYTE cmd, DWORD address)
  Summary:
    Sends a command packet to the SD card.
  Conditions:
    None.
  Input:
    None.
  Return Values:
    MMC_RESPONSE    - The response from the card
                    - Bit 0 - Idle state
                    - Bit 1 - Erase Reset
                    - Bit 2 - Illegal Command
                    - Bit 3 - Command CRC Error
                    - Bit 4 - Erase Sequence Error
                    - Bit 5 - Address Error
                    - Bit 6 - Parameter Error
                    - Bit 7 - Unused. Always 0.
  Side Effects:
    None.
  Description:
    SendMMCCmd prepares a command packet and sends it out over the SPI interface.
    Response data of type 'R1' (as indicated by the SD/MMC product manual is returned.
  Remarks:
```

```
    None.

*****************************************************************************
*/

MMC_RESPONSE SendMMCCmd(BYTE cmd, DWORD address)
{
    WORD timeout = 0x8;
    BYTE index;
    MMC_RESPONSE    response;
    CMD_PACKET  CmdPacket;

    SD_CS = 0;                          //Card Select

    // Copy over data
    CmdPacket.cmd        = sdmmc_cmdtable[cmd].CmdCode;
    CmdPacket.address    = address;
    CmdPacket.crc        = sdmmc_cmdtable[cmd].CRC;       // Calc CRC here

    CmdPacket.TRANSMIT_BIT = 1;             //Set Tranmission bit

    WriteSPIM(CmdPacket.cmd);                //Send Command
    WriteSPIM(CmdPacket.addr3);              //Most Significant Byte
    WriteSPIM(CmdPacket.addr2);
    WriteSPIM(CmdPacket.addr1);
    WriteSPIM(CmdPacket.addr0);              //Least Significant Byte
    WriteSPIM(CmdPacket.crc);                //Send CRC

    // see if we are going to get a response
    if(sdmmc_cmdtable[cmd].responsetype == R1 || sdmmc_cmdtable[cmd].responsetype ==
R1b)
    {
        do
        {
            response.r1._byte = MDD_SDSPI_ReadMedia();
            timeout--;
        }while(response.r1._byte == MMC_FLOATING_BUS && timeout != 0);
    }
    else if(sdmmc_cmdtable[cmd].responsetype == R2)
    {
        MDD_SDSPI_ReadMedia();

        response.r2._byte1 = MDD_SDSPI_ReadMedia();
        response.r2._byte0 = MDD_SDSPI_ReadMedia();
    }

    if(sdmmc_cmdtable[cmd].responsetype == R1b)
    {
        response.r1._byte = 0x00;

        for(index =0; index < 0xFF && response.r1._byte == 0x00; index++)
        {
            timeout = 0xFFFF;

            do
            {
                response.r1._byte = MDD_SDSPI_ReadMedia();
                timeout--;
            }while(response.r1._byte == 0x00 && timeout != 0);
        }
    }

    mSend8ClkCycles();                      //Required clocking (see spec)
```

```
    // see if we are expecting data or not
    if(!(sdmmc_cmdtable[cmd].moredataexpected))
        SD_CS = 1;

    return(response);
}

#ifdef __18CXX
#if (GetSystemClock() >= 25600000)

/*****************************************************************************
  Function:
    MMC_RESPONSE SendMMCCmdManual (BYTE cmd, DWORD address)
  Summary:
    Sends a command packet to the SD card with bit-bang SPI.
  Conditions:
    None.
  Input:
    None.
  Return Values:
    MMC_RESPONSE    - The response from the card
                    - Bit 0 - Idle state
                    - Bit 1 - Erase Reset
                    - Bit 2 - Illegal Command
                    - Bit 3 - Command CRC Error
                    - Bit 4 - Erase Sequence Error
                    - Bit 5 - Address Error
                    - Bit 6 - Parameter Error
                    - Bit 7 - Unused. Always 0.
  Side Effects:
    None.
  Description:
    SendMMCCmd prepares a command packet and sends it out over the SPI interface.
    Response data of type 'R1' (as indicated by the SD/MMC product manual is returned.
    This function is intended to be used when the clock speed of a PIC18 device is
    so high that the maximum SPI divider can't reduce the clock below the maximum
    SD card initialization sequence speed.
  Remarks:
    None.

*****************************************************************************
*/

MMC_RESPONSE SendMMCCmdManual(BYTE cmd, DWORD address)
{
    WORD timeout = 0x8;
    BYTE index;
    MMC_RESPONSE    response;
    CMD_PACKET  CmdPacket;

    SD_CS = 0;                          //Card Select

    // Copy over data
    CmdPacket.cmd        = sdmmc_cmdtable[cmd].CmdCode;
    CmdPacket.address    = address;
    CmdPacket.crc        = sdmmc_cmdtable[cmd].CRC;       // Calc CRC here

    CmdPacket.TRANSMIT_BIT = 1;             //Set Tranmission bit

    WriteSPIManual(CmdPacket.cmd);                //Send Command
    WriteSPIManual(CmdPacket.addr3);              //Most Significant Byte
    WriteSPIManual(CmdPacket.addr2);
```

```
    WriteSPIManual(CmdPacket.addr1);
    WriteSPIManual(CmdPacket.addr0);              //Least Significant Byte
    WriteSPIManual(CmdPacket.crc);                //Send CRC

    // see if we are going to get a response
    if(sdmmc_cmdtable[cmd].responsetype == R1 || sdmmc_cmdtable[cmd].responsetype ==
R1b)
    {
        do
        {
            response.r1._byte = ReadMediaManual();
            timeout--;
        }while(response.r1._byte == MMC_FLOATING_BUS && timeout != 0);
    }
    else if(sdmmc_cmdtable[cmd].responsetype == R2)
    {
        ReadMediaManual();

        response.r2._byte1 = ReadMediaManual();
        response.r2._byte0 = ReadMediaManual();
    }

    if(sdmmc_cmdtable[cmd].responsetype == R1b)
    {
        response.r1._byte = 0x00;

        for(index =0; index < 0xFF && response.r1._byte == 0x00; index++)
        {
            timeout = 0xFFFF;

            do
            {
                response.r1._byte = ReadMediaManual();
                timeout--;
            }while(response.r1._byte == 0x00 && timeout != 0);
        }
    }

    WriteSPIManual(0xFF);                      //Required clocking (see spec)

    // see if we are expecting data or not
    if(!(sdmmc_cmdtable[cmd].moredataexpected))
        SD_CS = 1;

    return(response);
}
#endif
#endif



/*****************************************************************************
  Function:
    BYTE MDD_SDSPI_SectorRead (DWORD sector_addr, BYTE * buffer)
  Summary:
    Reads a sector of data from an SD card.
  Conditions:
    The MDD_SectorRead function pointer must be pointing towards this function.
  Input:
    sector_addr - The address of the sector on the card.
    byffer -      The buffer where the retrieved data will be stored.  If
                  buffer is NULL, do not store the data anywhere.
  Return Values:
```

```
    TRUE -  The sector was read successfully
    FALE - The sector could not be read
  Side Effects:
    None
  Description:
    The MDD_SDSPI_SectorRead function reads 512 bytes of data from the SD card
    starting at the sector address and stores them in the location pointed to
    by 'buffer.'
  Remarks:
    The card expects the address field in the command packet to be a byte address.
    The sector_addr value is converted to a byte address by shifting it left nine
    times (multiplying by 512).

*****************************************************************************
*/

BYTE MDD_SDSPI_SectorRead(DWORD sector_addr, BYTE* buffer)
{
    WORD index;
    WORD delay;
    MMC_RESPONSE    response;
    BYTE data_token;
    BYTE status = TRUE;
    DWORD   new_addr;

#ifdef USB_USE_MSD
    DWORD firstSector;
    DWORD numSectors;
#endif

    // send the cmd
    new_addr = sector_addr << 9;
    response = SendMMCCmd(READ_SINGLE_BLOCK,new_addr);

    // Make sure the command was accepted
    if(response.r1._byte != 0x00)
    {
        response = SendMMCCmd (READ_SINGLE_BLOCK,new_addr);
        if(response.r1._byte != 0x00)
        {
            return FALSE;
        }
    }

    index = 0x2FF;

    // Timing delay- at least 8 clock cycles
    delay = 0x40;
    while (delay)
        delay--;

    //Now, must wait for the start token of data block
    do
    {
        data_token = MDD_SDSPI_ReadMedia();
        index--;

        delay = 0x40;
        while (delay)
            delay--;

    }while((data_token == MMC_FLOATING_BUS) && (index != 0));
```

```
    // Hopefully that zero is the datatoken
    if((index == 0) || (data_token != DATA_START_TOKEN))
    {
        status = FALSE;
    }
    else
    {
#ifdef USB_USE_MSD
        if ((sector_addr == 0) && (buffer == NULL))
            MDD_SDSPI_finalLBA = 0x00000000;
#endif

        for(index = 0; index < MEDIA_SECTOR_SIZE; index++)      //Reads in 512-byte of
data
        {
            if(buffer != NULL)
            {
#ifdef __18CXX
                data_token = SPIBUF;
                SPI_INTERRUPT_FLAG = 0;
                SPIBUF = 0xFF;
                while(!SPI_INTERRUPT_FLAG);
                buffer[index] = SPIBUF;
#else
                SPIBUF = 0xFF;
                while (!SPISTAT_RBF);
                buffer[index] = SPIBUF;
#endif
            }
            else
            {
#ifdef USB_USE_MSD
                if (sector_addr == 0)
                {
                    if ((index == 0x1C6) || (index == 0x1D6) || (index == 0x1E6) ||
(index == 0x1F6))
                    {
                        firstSector = MDD_SDSPI_ReadMedia();
                        firstSector |= (DWORD)MDD_SDSPI_ReadMedia() << 8;
                        firstSector |= (DWORD)MDD_SDSPI_ReadMedia() << 16;
                        firstSector |= (DWORD)MDD_SDSPI_ReadMedia() << 24;
                        numSectors = MDD_SDSPI_ReadMedia();
                        numSectors |= (DWORD)MDD_SDSPI_ReadMedia() << 8;
                        numSectors |= (DWORD)MDD_SDSPI_ReadMedia() << 16;
                        numSectors |= (DWORD)MDD_SDSPI_ReadMedia() << 24;
                        index += 8;
                            if ((firstSector + numSectors) > MDD_SDSPI_finalLBA)
                        {
                            MDD_SDSPI_finalLBA = firstSector + numSectors - 1;
                        }
                    }
                    else
                    {
                        MDD_SDSPI_ReadMedia();
                    }
                }
                else
                    MDD_SDSPI_ReadMedia();
#else
                MDD_SDSPI_ReadMedia();
#endif
            }
        }
```

```
        // Now ensure CRC
        mReadCRC();               //Read 2 bytes of CRC
        //status = mmcCardCRCError;
    }

    mSend8ClkCycles();            //Required clocking (see spec)

    SD_CS = 1;

    return(status);
}//end SectorRead


/*****************************************************************************
  Function:
    BYTE MDD_SDSPI_SectorWrite (DWORD sector_addr, BYTE * buffer, BYTE
allowWriteToZero)
  Summary:
    Writes a sector of data to an SD card.
  Conditions:
    The MDD_SectorWrite function pointer must be pointing to this function.
  Input:
    sector_addr -      The address of the sector on the card.
    buffer -           The buffer with the data to write.
    allowWriteToZero -
                     - TRUE -  Writes to the 0 sector (MBR) are allowed
                     - FALSE - Any write to the 0 sector will fail.
  Return Values:
    TRUE -  The sector was written successfully.
    FALSE - The sector could not be written.
  Side Effects:
    None.
  Description:
    The MDD_SDSPI_SectorWrite function writes 512 bytes of data from the location
    pointed to by 'buffer' to the specified sector of the SD card.
  Remarks:
    The card expects the address field in the command packet to be a byte address.
    The sector_addr value is ocnverted to a byte address by shifting it left nine
    times (multiplying by 512).

*****************************************************************************
*/

BYTE MDD_SDSPI_SectorWrite(DWORD sector_addr, BYTE* buffer, BYTE allowWriteToZero)
{
    WORD            index;
    BYTE            data_response;
#ifdef __18CXX
    BYTE            clear;
#endif
    MMC_RESPONSE    response;
    BYTE            status = TRUE;

    if (sector_addr == 0 && allowWriteToZero == FALSE)
        status = FALSE;
    else
    {
        // send the cmd
        response = SendMMCCmd(WRITE_SINGLE_BLOCK,(sector_addr << 9));

        // see if it was accepted
        if(response.r1._byte != 0x00)
            status = FALSE;
```

```
        else
        {
            WriteSPIM(DATA_START_TOKEN);                //Send data start token

            for(index = 0; index < MEDIA_SECTOR_SIZE; index++)      //Send 512 bytes
of data
            {
#ifdef __18CXX
                clear = SPIBUF;
                SPI_INTERRUPT_FLAG = 0;
                SPIBUF = buffer[index];         // write byte to SSP1BUF register
                while( !SPI_INTERRUPT_FLAG );   // wait until bus cycle complete
                data_response = SPIBUF;         // Clear the SPIBUF
#else
                SPIBUF = buffer[index];
                while (!SPISTAT_RBF);
                data_response = SPIBUF;
#endif
            }

            // calc crc
            mSendCRC();                                 //Send 2 bytes of CRC

            data_response = MDD_SDSPI_ReadMedia();              //Read response

            if((data_response & 0x0F) != DATA_ACCEPTED)
            {
                status = FALSE;
            }
            else
            {
                index = 0;            //using i as a timeout counter

                do                  //Wait for write completion
                {
#ifdef __18CXX
                    clear = SPIBUF;
                    SPI_INTERRUPT_FLAG = 0;
                    SPIBUF = 0xFF;
                    while(!SPI_INTERRUPT_FLAG);
                    data_response = SPIBUF;
#else
                    SPIBUF = 0xFF;
                    while(!SPISTAT_RBF);
                    data_response = SPIBUF;
#endif
                    index++;
                }while((data_response == 0x00) && (index != 0));

                if(index == 0)                                  //if timeout first
                    status = FALSE;
            }

            mSend8ClkCycles();
        }

        SD_CS = 1;

    } // Not writing to 0 sector

    return(status);
} //end SectorWrite
```

```
/*****************************************************************************
  Function:
    BYTE MDD_SDSPI_WriteProtectState
  Summary:
    Indicates whether the card is write-protected.
  Conditions:
    The MDD_WriteProtectState function pointer must be pointing to this function.
  Input:
    None.
  Return Values:
    TRUE -  The card is write-protected
    FALSE - The card is not write-protected
  Side Effects:
    None.
  Description:
    The MDD_SDSPI_WriteProtectState function will determine if the SD card is
    write protected by checking the electrical signal that corresponds to the
    physical write-protect switch.
  Remarks:
    None

*****************************************************************************
*/

BYTE MDD_SDSPI_WriteProtectState(void)
{
    return(0); //Since we don't have a write protect pin so we always return 0 meaning
not write protected(SD_WE);
}


/*****************************************************************************
  Function:
    void Delayms (BYTE milliseconds)
  Summary:
    Delay.
  Conditions:
    None.
  Input:
    BYTE milliseconds - Number of ms to delay
  Return:
    None.
  Side Effects:
    None.
  Description:
    The Delayms function will delay a specified number of milliseconds.  Used for SPI
    timing.
  Remarks:
    Depending on compiler revisions, this function may delay for the exact time
    specified.  This shouldn't create a significant problem.

*****************************************************************************
*/

void Delayms(BYTE milliseconds)
{
    BYTE    ms;
    DWORD   count;

    ms = milliseconds;
    while (ms--)
    {
```

```
        count = MILLISECDELAY;
        while (count--);
    }
    Nop();
    return;
}


/*****************************************************************************
  Function:
    void CloseSPIM (void)
  Summary:
    Disables the SPI module.
  Conditions:
    None.
  Input:
    None.
  Return:
    None.
  Side Effects:
    None.
  Description:
    Disables the SPI module.
  Remarks:
    None.

*****************************************************************************
*/

void CloseSPIM (void)
{
#if defined __C30__ || defined __C32__

    SPISTAT &= 0x7FFF;

#elif defined __C18XX

    SPICON1 &= 0xDF;

#endif
}



/*****************************************************************************
  Function:
    unsigned char WriteSPIM (unsigned char data_out)
  Summary:
    Writes data to the SD card.
  Conditions:
    None.
  Input:
    data_out - The data to write.
  Return:
    0.
  Side Effects:
    None.
  Description:
    The WriteSPIM function will write a byte of data from the microcontroller to the
    SD card.
  Remarks:
    None.
```

```
*****************************************************************************
*/

unsigned char WriteSPIM( unsigned char data_out )
{
#ifdef __PIC32MX__
    BYTE   clear;
    putcSPI1((BYTE)data_out);
    clear = getcSPI1();
    return ( 0 );                // return non-negative#
#elif defined __C18XX
    BYTE clear;
    clear = SPIBUF;
    SPI_INTERRUPT_FLAG = 0;
    SPIBUF = data_out;
    if (SPICON1 & 0x80)
        return -1;
    else
        while (!SPI_INTERRUPT_FLAG);
    return 0;
#else
    BYTE   clear;
    SPIBUF = data_out;           // write byte to SSP1BUF register
    while( !SPISTAT_RBF ); // wait until bus cycle complete
    clear = SPIBUF;
    return ( 0 );                // return non-negative#
#endif
}



/*****************************************************************************
  Function:
    BYTE MDD_SDSPI_ReadMedia (void)
  Summary:
    Reads a byte of data from the SD card.
  Conditions:
    None.
  Input:
    None.
  Return:
    The byte read.
  Side Effects:
    None.
  Description:
    The MDD_SDSPI_ReadMedia function will read one byte from the SPI port.
  Remarks:
    This function replaces ReadSPI, since some implementations of that function
    will initialize SSPBUF/SPIBUF to 0x00 when reading.  The card expects 0xFF.

*****************************************************************************
*/
BYTE MDD_SDSPI_ReadMedia(void)
{

#ifdef __C32__

    putcSPI1((BYTE)0xFF);
    return (BYTE)getcSPI1();

#elif defined __C18XX
```

```
    BYTE clear;
    clear = SPIBUF;
    SPI_INTERRUPT_FLAG = 0;
    SPIBUF = 0xFF;
    while (!SPI_INTERRUPT_FLAG);
    return SPIBUF;

#else
    SPIBUF = 0xFF;                              //Data Out - Logic ones
    while(!SPISTAT_RBF);                      //Wait until cycle complete
    return(SPIBUF);                             //Return with byte read
#endif
}

/*********************************************************************
  Function:
    void OpenSPIM (unsigned int sync_mode)
  Summary:
    Initializes the SPI module
  Conditions:
    None.
  Input:
    sync_mode - Sets synchronization
  Return:
    None.
  Side Effects:
    None.
  Description:
    The OpenSPIM function will enable and configure the SPI module.
  Remarks:
    None.

********************************************************************************
*/

#ifdef __18CXX
void OpenSPIM (unsigned char sync_mode)
#else
void OpenSPIM( unsigned int sync_mode)
#endif
{
    SPISTAT = 0x0000;               // power on state

#ifndef __PIC32MX__
    SPICON1 = 0x0000;                // power on state
    SPICON1 |= sync_mode;          // select serial mode
#endif

#ifdef __18CXX
    SPICON1 |= 0x80;
    SPISTATbits.CKE = 1;
#else
    SPICON1bits.CKP = 1;
    SPICON1bits.CKE = 0;
#endif

    SPICLOCK = 0;
    SPIOUT = 0;                  // define SDO1 as output (master or slave)
    SPIIN = 1;                  // define SDI1 as input (master or slave)
    SPIENABLE = 1;             // enable synchronous serial port
}
```

```
#ifdef __18CXX
#if (GetSystemClock() >= 25600000)

// Description: Delay value for the manual SPI clock
#define MANUAL_SPI_CLOCK_VALUE             1

/*****************************************************************************
  Function:
    unsigned char WriteSPIManual (unsigned char data_out)
  Summary:
    Write a character to the SD card with bit-bang SPI.
  Conditions:
    None.
  Input:
    data_out - Data to send.
  Return:
    0.
  Side Effects:
    None.
  Description:
    Writes a character to the SD card.
  Remarks:
    The WriteSPIManual function is for use on a PIC18 when the clock speed is so
    high that the maximum SPI clock divider cannot reduce the SPI clock speed below
    the maximum SD card initialization speed.

*****************************************************************************************
*/
unsigned char WriteSPIManual(unsigned char data_out)
{
    char i = data_out;
    unsigned char clock;

    ADCON1 = 0xFF;
    SPICLOCKLAT = 0;
    SPIOUTLAT = 1;
    SPICLOCK = OUTPUT;
    SPIOUT = OUTPUT;

    if ((SPIOUTPORT != SPIOUTLAT) || (SPICLOCKPORT != SPICLOCKLAT))
        return (-1);

    // Perform loop operation iteratively to reduce discrepancy
    // Bit 7
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    if (i & 0x80)
        SPIOUTLAT = 1;
    else
        SPIOUTLAT = 0;
    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);

    // Bit 6
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    if (i & 0x40)
        SPIOUTLAT = 1;
```

```
    else
        SPIOUTLAT = 0;

    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);

    // Bit 5
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    if (i & 0x20)
        SPIOUTLAT = 1;
    else
        SPIOUTLAT = 0;
    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);

    // Bit 4
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    if (i & 0x10)
        SPIOUTLAT = 1;
    else
        SPIOUTLAT = 0;
    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);

    // Bit 3
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    if (i & 0x08)
        SPIOUTLAT = 1;
    else
        SPIOUTLAT = 0;
    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);

    // Bit 2
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    if (i & 0x04)
        SPIOUTLAT = 1;
    else
        SPIOUTLAT = 0;
    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);

    // Bit 1
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    if (i & 0x02)
        SPIOUTLAT = 1;
    else
        SPIOUTLAT = 0;
```

```
    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);

    // Bit 0
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    if (i & 0x01)
        SPIOUTLAT = 1;
    else
        SPIOUTLAT = 0;
    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);

    SPICLOCKLAT = 0;

    return 0;
}


/*****************************************************************************
  Function:
    BYTE ReadMediaManual (void)
  Summary:
    Reads a byte of data from the SD card.
  Conditions:
    None.
  Input:
    None.
  Return:
    The byte read.
  Side Effects:
    None.
  Description:
    The MDD_SDSPI_ReadMedia function will read one byte from the SPI port.
  Remarks:
    This function replaces ReadSPI, since some implementations of that function
    will initialize SSPBUF/SPIBUF to 0x00 when reading.  The card expects 0xFF.
    This function is for use on a PIC18 when the clock speed is so high that the
    maximum SPI clock prescaler cannot reduce the SPI clock below the maximum SD card
    initialization speed.

*****************************************************************************
*/
BYTE ReadMediaManual (void)
{
    char i, result = 0x00;
    unsigned char clock;

    SPICLOCKLAT = 0;
    SPIOUTLAT = 1;
    SPICLOCK = OUTPUT;
    SPIOUT = OUTPUT;
    SPIIN = INPUT;

    if ((SPIOUTPORT != SPIOUTLAT) || (SPICLOCKPORT != SPICLOCKLAT))
        return (-1);

    // Perform loop operation iteratively to reduce discrepancy
    // Bit 7
```

```
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    if (SPIINPORT)
        result |= 0x80;

    // Bit 6
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    if (SPIINPORT)
        result |= 0x40;

    // Bit 5
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    if (SPIINPORT)
        result |= 0x20;

    // Bit 4
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    if (SPIINPORT)
        result |= 0x10;

    // Bit 3
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    if (SPIINPORT)
        result |= 0x08;

    // Bit 2
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    if (SPIINPORT)
        result |= 0x04;

    // Bit 1
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
```

```
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    if (SPIINPORT)
        result |= 0x02;

    // Bit 0
    SPICLOCKLAT = 0;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    SPICLOCKLAT = 1;
    clock = MANUAL_SPI_CLOCK_VALUE;
    while (clock--);
    if (SPIINPORT)
        result |= 0x01;

    SPICLOCKLAT = 0;

    return result;
}//end ReadMedia

#endif      // End >25600000
#endif      // End __18CXX


/*****************************************************************************
  Function:
    BYTE MDD_SDSPI_MediaInitialize (void)
  Summary:
    Initializes the SD card.
  Conditions:
    The MDD_MediaInitialize function pointer must be pointing to this function.
  Input:
    None.
  Return Values:
    TRUE -  The card was successfully initialized
    FALSE - Communication could not be established.
  Side Effects:
    None.
  Description:
    This function will send initialization commands to and SD card.
  Remarks:
    None.

*****************************************************************************
*/

BYTE MDD_SDSPI_MediaInitialize(void)
{
    WORD timeout;
    BYTE       status = TRUE;
    MMC_RESPONSE    response;
#if defined __C30__ || defined __C32__
    WORD spiconvalue = 0x0003;
#endif

    SD_CS = 1;              //Initialize Chip Select line

    //Media powers up in the open-drain mode and cannot handle a clock faster
    //than 400kHz. Initialize SPI port to slower than 400kHz
#if defined __C30__ || defined __C32__
#ifdef __PIC32MX__
    SPIBRG = SPICalutateBRG(GetPeripheralClock(), 400000);
```

```
    SPICON1bits.MSTEN = 1;
    OpenSPIM (MASTER_ENABLE_ON);

#else
    // Calculate the prescaler needed for the clock
    timeout = GetSystemClock() / 400000;
    // if timeout is less than 400k and greater than 100k use a 1:1 prescaler
    if (timeout == 0)
    {
        OpenSPIM (MASTER_ENABLE_ON | PRI_PRESCAL_1_1 | SEC_PRESCAL_1_1);
    }
    while (timeout != 0)
    {
        if (timeout > 8)
        {
            spiconvalue--;
            // round up
            if ((timeout % 4) != 0)
                timeout += 4;
            timeout /= 4;
        }
        else
        {
            timeout = 0;
        }
    }

    OpenSPIM (MASTER_ENABLE_ON | spiconvalue | ((~(timeout << 2)) & 0x1C));
#endif


    // let the card power on and initialize
    Delayms(1);

    //Media requires 80 clock cycles to startup [8 clocks/BYTE * 10 us]
    for(timeout=0; timeout<10; timeout++)
        mSend8ClkCycles();

    SD_CS = 0;

    Delayms(1);

    // Send CMD0 to reset the media
    response = SendMMCCmd(GO_IDLE_STATE,0x0);

    if((response.r1._byte == MMC_BAD_RESPONSE) || ((response.r1._byte & 0xF7) !=
0x01))
    {
        status = FALSE;      // we have not got anything back from the card
        SD_CS = 1;                              // deselect the devices

        return status;
    }

    // According to spec cmd1 must be repeated until the card is fully initialized
    timeout = 0xFFF;

    do
    {
        response = SendMMCCmd(SEND_OP_COND,0x0);
        timeout--;
    }while(response.r1._byte != 0x00 && timeout != 0);
```

```
    // see if it failed
    if(timeout == 0)
    {
        status = FALSE;      // we have not got anything back from the card

        SD_CS = 1;                                  // deselect the devices
    }
    else
    {

#else

    // let the card power on and initialize
    Delayms(1);

    #if (GetSystemClock() < 25600000)

        #if (GetSystemClock() < 1600000)
            OpenSPIM (SYNC_MODE_FAST, BUS_MODE, SMP_PHASE);
        #elif (GetSystemClock() < 6400000)
            OpenSPIM (SYNC_MODE_MED, BUS_MODE, SMP_PHASE);
        #else
            OpenSPIM (SYNC_MODE_SLOW, BUS_MODE, SMP_PHASE);
        #endif

        // let the card power on and initialize
        Delayms(1);

        //Media requires 80 clock cycles to startup [8 clocks/BYTE * 10 us]
        for(timeout=0; timeout<10; timeout++)
            mSend8ClkCycles();

        SD_CS = 0;

        Delayms(1);

        // Send CMD0 to reset the media
        response = SendMMCCmd(GO_IDLE_STATE,0x0);

        if((response.r1._byte == MMC_BAD_RESPONSE) || ((response.r1._byte & 0xF7) !=
0x01))
        {
            status = FALSE;      // we have not got anything back from the card
            SD_CS = 1;                                  // deselect the devices

            return status;
        }

        // According to spec cmd1 must be repeated until the card is fully initialized
        timeout = 0xFFF;

        do
        {
            response = SendMMCCmd(SEND_OP_COND,0x0);
            timeout--;
        }while(response.r1._byte != 0x00 && timeout != 0);

    #else

        // Make sure the SPI module doesn't control the bus
        SPICON1 = 0x00;

        //Media requires 80 clock cycles to startup [8 clocks/BYTE * 10 us]
```

```
        for(timeout=0; timeout<10; timeout++)
            WriteSPIManual(0xFF);

        SD_CS = 0;

        Delayms(1);

        // Send CMD0 to reset the media
        response = SendMMCCmdManual (GO_IDLE_STATE, 0x0);

        if ((response.r1._byte == MMC_BAD_RESPONSE) || ((response.r1._byte & 0xF7) !=
0x01))
        {
            status = FALSE;     // we have not got anything back from the card
            SD_CS = 1;                              // deselect the devices

            return status;
        }

        // According to the spec cmd1 must be repeated until the card is fully
initialized
        timeout = 0xFFF;

        do
        {
            response = SendMMCCmdManual (SEND_OP_COND, 0x0);
            timeout--;
        }while(response.r1._byte != 0x00 && timeout != 0);
    #endif

    // see if it failed
    if (timeout == 0)
    {
        status = FALSE;     // we have not got anything back from the card

        SD_CS = 1;                              // deselect the devices

    }
    else
    {
#endif

        Delayms (2);

        #ifdef __PIC32MX__
            #if (GetSystemClock() <= 20000000)
                SPIBRG = SPICalutateBRG(GetPeripheralClock(), 10000);
            #else
                SPIBRG = SPICalutateBRG(GetPeripheralClock(), 20000000); // SPI Speed
is 20MHz
            #endif
            SPICON1 = 0x0000C060;
            SPICON1bits.MSTEN = 1;
        #else
            OpenSPIM(SYNC_MODE_FAST);
        #endif

        // Turn off CRC7 if we can, might be an invalid cmd on some cards (CMD59)
        response = SendMMCCmd(CRC_ON_OFF,0x0);

        // Now set the block length to media sector size. It should be already
        response = SendMMCCmd(SET_BLOCKLEN,MEDIA_SECTOR_SIZE);
```

```
        for(timeout = 0xFF; timeout > 0 && MDD_SDSPI_SectorRead(0x0,NULL) != TRUE;
timeout--)
        {;}

        // see if we had an issue
        if(timeout == 0)
        {
            status = FALSE;
            SD_CS = 1;                              // deselect the devices

        }
    }

    return(status);
}//end MediaInitialize



/*****************************************************************************
 * SD-SPI.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *****************************************************************************/

/*****************************************************************************
 *
 *                Microchip Memory Disk Drive File System
 *
 *****************************************************************************
 * FileName:        SD-SPI.h
 * Dependencies:    GenericTypeDefs.h
 *                  FSconfig.h
 *                  FSDefs.h
 * Processor:       PIC18/PIC24/dsPIC30/dsPIC33/PIC32
 * Compiler:        C18/C30/C32
 * Company:         Microchip Technology, Inc.
 * Version:         1.2.0
 *
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 *
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 * CONSEQUENTIAL DAMAGES, FOR ANY REASON WHATSOEVER.
 *
*****************************************************************************/

#ifndef SDMMC_H
#define SDMMC_H
```

```
#include "GenericTypeDefs.h"
#include "FSconfig.h"
#include "FSDefs.h" //"MDD File System\FSDefs.h"


#ifdef __18CXX
    // Description: This macro is used to initialize a PIC18 SPI module with a 4x
prescale divider
    #define   SYNC_MODE_FAST    0x00
    // Description: This macro is used to initialize a PIC18 SPI module with a 16x
prescale divider
    #define   SYNC_MODE_MED     0x01
    // Description: This macro is used to initialize a PIC18 SPI module with a 64x
prescale divider
    #define   SYNC_MODE_SLOW    0x02
#elif defined __PIC32MX__
    // Description: This macro is used to initialize a PIC32 SPI module
    #define   SYNC_MODE_FAST    0x3E
    // Description: This macro is used to initialize a PIC32 SPI module
    #define   SYNC_MODE_SLOW    0x3C
#else
    // Description: This macro indicates the SPI enable bit for 16-bit PICs
    #define  MASTER_ENABLE_ON       0x0020

    // Description: This macro is used to initialize a 16-bit PIC SPI module
    #define   SYNC_MODE_FAST    0x3E
    // Description: This macro is used to initialize a 16-bit PIC SPI module
    #define   SYNC_MODE_SLOW    0x3C

    // Description: This macro is used to initialize a 16-bit PIC SPI module secondary
prescaler
    #define  SEC_PRESCAL_1_1        0x001c
    // Description: This macro is used to initialize a 16-bit PIC SPI module primary
prescaler
    #define  PRI_PRESCAL_1_1        0x0003
#endif



/****************************************************************/
/*                  Strcutures and defines                      */
/****************************************************************/


// Description: This macro represents an SD card start token
#define DATA_START_TOKEN            0xFE

// Description: This macro represents an SD card data accepted token
#define DATA_ACCEPTED               0x05

// Description: This macro indicates that the SD card expects to transmit or receive
more data
#define MOREDATA    !0

// Description: This macro indicates that the SD card does not expect to transmit or
receive more data
#define NODATA      0

// Description: This macro represents a floating SPI bus condition
#define MMC_FLOATING_BUS    0xFF

// Description: This macro represents a bad SD card response byte
```

```
#define MMC_BAD_RESPONSE    MMC_FLOATING_BUS

// The SDMMC Commands

// Description: This macro defines the command code to reset the SD card
#define     cmdGO_IDLE_STATE        0
// Description: This macro defines the command code to initialize the SD card
#define     cmdSEND_OP_COND         1
// Description: This macro defines the command code to get the Card Specific Data
#define     cmdSEND_CSD             9
// Description: This macro defines the command code to get the Card Information
#define     cmdSEND_CID             10
// Description: This macro defines the command code to stop transmission during a
multi-block read
#define     cmdSTOP_TRANSMISSION    12
// Description: This macro defines the command code to get the card status information
#define     cmdSEND_STATUS          13
// Description: This macro defines the command code to set the block length of the
card
#define     cmdSET_BLOCKLEN         16
// Description: This macro defines the command code to read one block from the card
#define     cmdREAD_SINGLE_BLOCK    17
// Description: This macro defines the command code to read multiple blocks from the
card
#define     cmdREAD_MULTI_BLOCK     18
// Description: This macro defines the command code to write one block to the card
#define     cmdWRITE_SINGLE_BLOCK   24
// Description: This macro defines the command code to write multiple blocks to the
card
#define     cmdWRITE_MULTI_BLOCK    25
// Description: This macro defines the command code to set the address of the start of
an erase operation
#define     cmdTAG_SECTOR_START     32
// Description: This macro defines the command code to set the address of the end of
an erase operation
#define     cmdTAG_SECTOR_END       33
// Description: This macro defines the command code to erase all previously selected
blocks
#define     cmdERASE                38
// Description: This macro defines the command code to begin application specific
command inputs
#define     cmdAPP_CMD              55
// Description: This macro defines the command code to get the OCR register
information from the card
#define     cmdREAD_OCR             58
// Description: This macro defines the command code to disable CRC checking
#define     cmdCRC_ON_OFF           59


// Description: Enumeration of different SD response types
typedef enum
{
    R1,     // R1 type response
    R1b,    // R1b type response
    R2,     // R2 type response
    R3      // R3 type response
}RESP;

// Summary: SD card command data structure
// Description: The typMMC_CMD structure is used to create a command table of
information needed for each relevant SD command
typedef struct
{
```

```
    BYTE      CmdCode;          // The command code
    BYTE      CRC;              // The CRC value for that command
    RESP    responsetype;       // The response type
    BYTE    moredataexpected;   // Set to MOREDATA or NODATA, depending on whether
more data is expected or not
} typMMC_CMD;


// Summary: An SD command packet
// Description: This union represents different ways to access an SD card command
packet
typedef union
{
    // This structure allows array-style access of command bytes
    struct
    {
        #ifdef __18CXX
            BYTE field[6];      // BYTE array
        #else
            BYTE field[7];
        #endif
    };
    // This structure allows byte-wise access of packet command bytes
    struct
    {
        BYTE crc;               // The CRC byte
        #if defined __C30__
            BYTE c30filler;     // Filler space (since bitwise declarations can't
cross a WORD boundary)
        #elif defined __C32__
            BYTE c32filler[3];  // Filler space (since bitwise declarations can't
cross a DWORD boundary)
        #endif

        BYTE addr0;             // Address byte 0
        BYTE addr1;             // Address byte 1
        BYTE addr2;             // Address byte 2
        BYTE addr3;             // Address byte 3
        BYTE cmd;               // Command code byte
    };
    // This structure allows bitwise access to elements of the command bytes
    struct
    {
        BYTE  END_BIT:1;        // Packet end bit
        BYTE  CRC7:7;           // CRC value
        DWORD     address;      // Address
        BYTE  CMD_INDEX:6;      // Command code
        BYTE  TRANSMIT_BIT:1;   // Transmit bit
        BYTE  START_BIT:1;      // Packet start bit
    };
} CMD_PACKET;


// Summary: The format of an R1 type response
// Description: This union represents different ways to access an SD card R1 type
response packet.
typedef union
{
    BYTE _byte;                         // Byte-wise access
    // This structure allows bitwise access of the response
    struct
    {
        unsigned IN_IDLE_STATE:1;       // Card is in idle state
```

```
        unsigned ERASE_RESET:1;         // Erase reset flag
        unsigned ILLEGAL_CMD:1;         // Illegal command flag
        unsigned CRC_ERR:1;             // CRC error flag
        unsigned ERASE_SEQ_ERR:1;       // Erase sequence error flag
        unsigned ADDRESS_ERR:1;         // Address error flag
        unsigned PARAM_ERR:1;           // Parameter flag
        unsigned B7:1;                  // Unused bit 7
    };
} RESPONSE_1;

// Summary: The format of an R2 type response
// Description: This union represents different ways to access an SD card R2 type
response packet
typedef union
{
    WORD _word;
    struct
    {
        BYTE      _byte0;
        BYTE      _byte1;
    };
    struct
    {
        unsigned IN_IDLE_STATE:1;
        unsigned ERASE_RESET:1;
        unsigned ILLEGAL_CMD:1;
        unsigned CRC_ERR:1;
        unsigned ERASE_SEQ_ERR:1;
        unsigned ADDRESS_ERR:1;
        unsigned PARAM_ERR:1;
        unsigned B7:1;
        unsigned CARD_IS_LOCKED:1;
        unsigned WP_ERASE_SKIP_LK_FAIL:1;
        unsigned ERROR:1;
        unsigned CC_ERROR:1;
        unsigned CARD_ECC_FAIL:1;
        unsigned WP_VIOLATION:1;
        unsigned ERASE_PARAM:1;
        unsigned OUTRANGE_CSD_OVERWRITE:1;
    };
} RESPONSE_2;

// Summary: A union of responses from an SD card
// Description: The MMC_RESPONSE union represents any of the possible responses that
an SD card can return after
//              being issued a command.
typedef union
{
    RESPONSE_1  r1;
    RESPONSE_2  r2;
}MMC_RESPONSE;


// Summary: A description of the card specific data register
// Description: This union represents different ways to access information in a packet
with SD card CSD informaiton.  For more
//              information on the CSD register, consult an SD card user's manual.
typedef union
{
    struct
    {
        DWORD _u320;
        DWORD _u321;
```

```
        DWORD _u322;
        DWORD _u323;
    };
    struct
    {
        BYTE _byte[16];
    };
    struct
    {
        unsigned NOT_USED           :1;
        unsigned CRC                :7;
        unsigned ECC                :2;
        unsigned FILE_FORMAT        :2;
        unsigned TMP_WRITE_PROTECT  :1;
        unsigned PERM_WRITE_PROTECT :1;
        unsigned COPY               :1;
        unsigned FILE_FORMAT_GRP    :1;
        unsigned RESERVED_1         :5;
        unsigned WRITE_BL_PARTIAL   :1;
        unsigned WRITE_BL_LEN_L     :2;
        unsigned WRITE_BL_LEN_H     :2;
        unsigned R2W_FACTOR         :3;
        unsigned DEFAULT_ECC        :2;
        unsigned WP_GRP_ENABLE      :1;
        unsigned WP_GRP_SIZE        :5;
        unsigned ERASE_GRP_SIZE_L   :3;
        unsigned ERASE_GRP_SIZE_H   :2;
        unsigned SECTOR_SIZE        :5;
        unsigned C_SIZE_MULT_L      :1;
        unsigned C_SIZE_MULT_H      :2;
        unsigned VDD_W_CURR_MAX     :3;
        unsigned VDD_W_CUR_MIN      :3;
        unsigned VDD_R_CURR_MAX     :3;
        unsigned VDD_R_CURR_MIN     :3;
        unsigned C_SIZE_L           :2;
        unsigned C_SIZE_H           :8;
        unsigned C_SIZE_U           :2;
        unsigned RESERVED_2         :2;
        unsigned DSR_IMP            :1;
        unsigned READ_BLK_MISALIGN  :1;
        unsigned WRITE_BLK_MISALIGN :1;
        unsigned READ_BL_PARTIAL    :1;
        unsigned READ_BL_LEN        :4;
        unsigned CCC_L              :4;
        unsigned CCC_H              :8;
        unsigned TRAN_SPEED         :8;
        unsigned NSAC               :8;
        unsigned TAAC               :8;
        unsigned RESERVED_3         :2;
        unsigned SPEC_VERS          :4;
        unsigned CSD_STRUCTURE      :2;
    };
} CSD;


// Summary: A description of the card information register
// Description: This union represents different ways to access information in a packet
with SD card CID register informaiton.  For more
//              information on the CID register, consult an SD card user's manual.
typedef union
{
    struct
    {
```

```
        DWORD _u320;
        DWORD _u321;
        DWORD _u322;
        DWORD _u323;
    };
    struct
    {
        BYTE _byte[16];
    };
    struct
    {
        unsigned    NOT_USED            :1;
        unsigned    CRC                 :7;
        unsigned    MDT                 :8;
        DWORD       PSN;
        unsigned    PRV                 :8;
        char        PNM[6];
        WORD        OID;
        unsigned    MID                 :8;
    };
} CID;

#ifndef FALSE
    #define FALSE   0
#endif
#ifndef TRUE
    #define TRUE    !FALSE
#endif

#define INPUT   1
#define OUTPUT  0


// Description: A delay prescaler
#define DELAY_PRESCALER   (BYTE)      8

// Description: An approximation of the number of cycles per delay loop of overhead
#define DELAY_OVERHEAD    (BYTE)      5

// Description: An approximate calculation of how many times to loop to delay 1 ms in
the Delayms function
#define MILLISECDELAY   (WORD)
((GetInstructionClock()/DELAY_PRESCALER/(WORD)1000) - DELAY_OVERHEAD)


// Summary: An enumeration of SD commands
// Description: This enumeration corresponds to the position of each command in the
sdmmc_cmdtable array
//              These macros indicate to the SendMMCCmd function which element of the
sdmmc_cmdtable array
//              to retrieve command code information from.
typedef enum
{
    GO_IDLE_STATE,
    SEND_OP_COND,
    SEND_CSD,
    SEND_CID,
    STOP_TRANSMISSION,
    SEND_STATUS,
    SET_BLOCKLEN,
    READ_SINGLE_BLOCK,
    READ_MULTI_BLOCK,
    WRITE_SINGLE_BLOCK,
```

```
    WRITE_MULTI_BLOCK,
    TAG_SECTOR_START,
    TAG_SECTOR_END,
    ERASE,
    APP_CMD,
    READ_OCR,
    CRC_ON_OFF
}sdmmc_cmd;



/*****************************************************************************/
/*                                Macros                                     */
/*****************************************************************************/

// Description: A macro to send clock cycles to dummy-read the CRC
#define mReadCRC()              WriteSPIM(0xFF);WriteSPIM(0xFF);

// Description: A macro to send clock cycles to dummy-write the CRC
#define mSendCRC()              WriteSPIM(0xFF);WriteSPIM(0xFF);

// Description: A macro to send 8 clock cycles for SD timing requirements
#define mSend8ClkCycles()       WriteSPIM(0xFF);

/*****************************************************************************/
/*                                 Prototypes                                */
/*****************************************************************************/

DWORD MDD_SDSPI_ReadCapacity(void);
WORD MDD_SDSPI_ReadSectorSize(void);
void MDD_SDSPI_InitIO(void);

BYTE MDD_SDSPI_MediaDetect(void);
BYTE MDD_SDSPI_MediaInitialize(void);
BYTE MDD_SDSPI_SectorRead(DWORD sector_addr, BYTE* buffer);
BYTE MDD_SDSPI_SectorWrite(DWORD sector_addr, BYTE* buffer, BYTE allowWriteToZero);

BYTE MDD_SDSPI_WriteProtectState(void);
void MDD_SDSPI_ShutdownMedia(void);

#if defined __C30__ || defined __C32__
    extern BYTE ReadByte( BYTE* pBuffer, WORD index );
    extern WORD ReadWord( BYTE* pBuffer, WORD index );
    extern DWORD ReadDWord( BYTE* pBuffer, WORD index );
#endif

#endif


/*****************************************************************************
 * sensors.c
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *****************************************************************************/

#include "FlySpy.h"

#define VarianceLogLength 20
SENSORDATA sensorInfo;


float PitchAngle = 0; //Angle of pitch of the Airplane
```

```
float RollAngle = 0; //Angle of roll of the Airplane - Right Roll is Positive
float Clearing = 0;  //The amount of clearing that we know we have from the bottom of
the aircraft in meters. 6 meters being the max.

float Variance = 0 ;

float magnitudes[VarianceLogLength];

void initSensors()
{
         int lcv;

         for (lcv = 0; lcv < VarianceLogLength; lcv++)
                  magnitudes[lcv] = 0;

         sensorInfo.inuse = 0;
         sensorInfo.Pitch = 0;
         sensorInfo.Roll = 0;
         sensorInfo.Altitude = 0;
         sensorInfo.Clearing = 0;
    sensorInfo.GyroPitchVoltage = 0;
         sensorInfo.GyroRollVoltage = 0;
         sensorInfo.Accelerometer_X = 0;
         sensorInfo.Accelerometer_Y = 0;
         sensorInfo.Accelerometer_Z = 0;
         sensorInfo.MagnitudeVariance = 0;
}

float sampleToG(float measure)
{
         float G = measure / 98.042 - 5.222;
         return G;
}

void updateOrientation()
{
         float Accel_x;
         float Accel_y;
         float Accel_z;
         float magnitude;
         float average;
    float xsample = 0;
         float ysample = 0;
         float zsample = 0;
         float CurrentPitchVolt = 0;
         float CurrentRollVolt = 0;
         double PitchAnglea;
         double RollAnglea;

         int lcv;

         for (lcv = 0; lcv < 10; lcv++)
    {
                  CurrentPitchVolt += sampleADCPort(GYRO_Y) * VREF / 1024;
                  CurrentRollVolt += sampleADCPort(GYRO_X) * VREF / 1024;
         }
         CurrentPitchVolt /= lcv;
         CurrentRollVolt /= lcv;


         PitchAngle += -((CurrentPitchVolt - 1.492412) / .002  / 50);
         RollAngle += ((CurrentRollVolt - 1.5058) / .002 / 50);
```

```
          if (fabs(PitchAngle) > 180)
          {

          }
          for ( lcv = 0; lcv < 10; lcv++ )
          {
                    xsample += sampleADCPort(ACCEL_X);
                    ysample += sampleADCPort(ACCEL_Y);
                    zsample += sampleADCPort(ACCEL_Z);
          }

          Accel_x = sampleToG(xsample/lcv);
          Accel_y = sampleToG(ysample/lcv);
          Accel_z = sampleToG(zsample/lcv);

          magnitude = sqrt(Accel_x * Accel_x + Accel_y * Accel_y + Accel_z * Accel_z);

          average = 0;
          for (lcv = 1; lcv < VarianceLogLength; lcv++)
          {
                    average += magnitudes[lcv];
                    magnitudes[lcv - 1] = magnitudes[lcv];
          }
          magnitudes[lcv] = magnitude;
          average += magnitude;
          average /= VarianceLogLength;

          Variance = 0;
          for (lcv = 0; lcv < VarianceLogLength; lcv++)
          {
                    Variance += (magnitudes[lcv] - average) * (magnitudes[lcv] -
average);
          }
          Variance /=VarianceLogLength;


          if(fabs(1 - magnitude) < .1)
     {
                    PitchAnglea =  atan2(Accel_x,sqrt(Accel_y * Accel_y + Accel_z *
Accel_z)) * 180 / PI;
                    RollAnglea = atan2(Accel_y,sqrt(Accel_z * Accel_z + Accel_x *
Accel_x)) * 180 / PI;
                    if(Accel_z < 0)
                    {
                              if ( Accel_x > 0)PitchAnglea = 180 - PitchAnglea;
                              else PitchAnglea = -180 - PitchAnglea;
                              if ( Accel_y > 0)RollAnglea = 180 - RollAnglea;
                              else RollAnglea = -180 - RollAnglea;
                    }
                    PitchAngle = PitchAngle*.9 + PitchAnglea * .1;
                    RollAngle = RollAngle*.9 + RollAnglea * .1;
          }
          if (!sensorInfo.inuse)
          {
                    sensorInfo.MagnitudeVariance = Variance;
                    sensorInfo.Pitch = PitchAngle;
                    sensorInfo.Roll = RollAngle;
                    sensorInfo.GyroPitchVoltage = CurrentPitchVolt;
                    sensorInfo.GyroRollVoltage = CurrentRollVolt;
                    sensorInfo.Accelerometer_X = Accel_x;
                    sensorInfo.Accelerometer_Y = Accel_y;
                    sensorInfo.Accelerometer_Z = Accel_z;
          }
```

```
	return;
}


void updateClearing()
{
	int lcv;
	int sample;
	for ( lcv = 0; lcv < 10; lcv++ )
	{
		sample += sampleADCPort(RANGE_FINDER);
	}
	Clearing = sample * 3.3 * 3.96875/10240;
	if (!sensorInfo.inuse)
		sensorInfo.Clearing = Clearing;
}



/*****************************************************************************
 * sensors.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *****************************************************************************/

typedef struct
{
	int inuse;

	double Pitch;
	double Roll;
	double Altitude;
	double Clearing;
	double GyroPitchVoltage;
	double GyroRollVoltage;
	double Accelerometer_X;
	double Accelerometer_Y;
	double Accelerometer_Z;
	double MagnitudeVariance;
}SENSORDATA;


void initSensors(void);
void updateOrientation(void);
void updateClearing(void);
float sampleToG(float);



/*****************************************************************************
 * surfaces.c
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *****************************************************************************/

#include "FlySpy.h"

extern float PitchAngle;
extern float RollAngle;
extern float Distance;
```

```
extern float Direction;

AXISPID rollPID;
AXISPID pitchPID;

float PitchRegister = 0;
float RollRegister = 0;

int Control_Enable = 0;

void initSurfaces(void)
{
          PitchRegister = 0;
          RollRegister = 0;

          initializePID(&rollPID, 2,2, 1);
          initializePID(&pitchPID, 2,.5,1);

}
void directSurfaces(void)
{

    float RollPercent;
          float PitchPercent;
          if ( Control_Enable == 1 && CTRL_SW == 1)
          {
                    RollPercent = adjustControl(&rollPID, RollRegister, RollAngle, .02,
100, -100) / 100;
                    setSurface(-RollPercent, LEFTAILERON);
                    setSurface(-RollPercent, RIGHTAILERON);

                    PitchPercent = adjustControl(&pitchPID, PitchRegister, PitchAngle,
.02, 100, -100) / 100;
                    setSurface(-PitchPercent, ELEVATOR);

          }
}

void setPitch(float Pitch)
{
          PitchRegister = Pitch;
}

void setRoll(float Roll)
{
          RollRegister = Roll;
}


void enableControlSurfaces(void)
{
          Control_Enable = 1;
}

void disableControlSurfaces(void)
{
          Control_Enable = 0;
          setSurface(0, THROTTLE);
          setSurface(0, LEFTAILERON);
          setSurface(0, RIGHTAILERON);
          setSurface(0, ELEVATOR);
          setSurface(0, RUDDER);
}
```

```
void setSurface(float Percentage, int Surface)
{
	switch(Surface)
	{
		case THROTTLE:
			THROTTLEREG  = msToClk(Percentage * (MAX_THROTTLE -
MIN_THROTTLE) + MIN_THROTTLE);
			break;
		case LEFTAILERON:
			LAILERONREG = Percentage < 0? msToClk(ZERO_LAILERON +
Percentage * (ZERO_LAILERON - MIN_LAILERON)) : msToClk( ZERO_LAILERON + Percentage *
(MAX_LAILERON - ZERO_LAILERON));
			break;
		case RIGHTAILERON:
			RAILERONREG = Percentage < 0? msToClk(ZERO_RAILERON +
Percentage * (ZERO_RAILERON - MIN_RAILERON)) : msToClk( ZERO_RAILERON + Percentage *
(MAX_RAILERON - ZERO_RAILERON));
			break;
		case ELEVATOR:
			ELEVATORREG = Percentage < 0? msToClk(ZERO_ELEVATOR +
Percentage * (ZERO_ELEVATOR - MIN_ELEVATOR)) : msToClk( ZERO_ELEVATOR + Percentage *
(MAX_ELEVATOR - ZERO_ELEVATOR));
			break;
		case RUDDER:
			RUDDERREG = Percentage < 0? msToClk(ZERO_RUDDER +
Percentage * (ZERO_RUDDER - MIN_RUDDER)) : msToClk( ZERO_RUDDER + Percentage *
(MAX_RUDDER - ZERO_RUDDER));
			break;
	}
	return;
}

void initializePID(AXISPID *pid, float p_const, float i_const, float d_const)
{
	pid-> Prev_Error = 0;
	pid->KP = p_const;
	pid->KI = i_const;
	pid->KD = d_const;
}

float adjustControl(AXISPID *pid, float target, float actual, float delta_t, float
max, float min)
{
	float derivative;
	float error;
	float output;

	error = target - actual;

	pid->Integral += error * delta_t;

	derivative = (error - pid->Prev_Error)/delta_t;

	pid->Prev_Error = error;

	output = pid->KP * error + pid->KI * pid->Integral + pid->KD * derivative;

	if (output > max)
	{
		output = max;
	}
	else if (output < min)
```

```
        {
                output = min;
        }

        return( output );
}


/*****************************************************************************
 * surfaces.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *****************************************************************************/

typedef struct
{
        float Prev_Error;
        float Integral;
        float KP;
        float KI;
        float KD;

}AXISPID;

#define MAX_THROTTLE 1.93 //Percentage of MAX WIDTH as Throttle Maximum
#define MIN_THROTTLE 1.05 //Percentage of MIN WIDTH as Throttle Maximum

#define MAX_ELEVATOR 1.93 //Percentage of MAX WIDTH as Elevator Maximum
#define ZERO_ELEVATOR 1.58 //Pulse Width of the Alieron Zero point
#define MIN_ELEVATOR 1.13 //Percentage of MIN WIDTH as Elevator Maximum

#define MAX_RUDDER 1.93 //Percentage of MAX WIDTH as Rudder Maximum
#define ZERO_RUDDER 1.47 //Pulse Width of the Rudder Zero point
#define MIN_RUDDER 1.13 //Percentage of MIN WIDTH as Rudder Maximum

#define MAX_LAILERON 1.8 //Percentage of MAX WIDTH as Left Alieron Maximum
#define ZERO_LAILERON 1.6 //Pulse Width of the Left Aileron Zero point
#define MIN_LAILERON 1.10 //Percentage of MIN WIDTH as Left Alieron Maximum

#define MAX_RAILERON 1.93 //Percentage of MAX WIDTH as Right Alieron Maximum
#define ZERO_RAILERON 1.65 //Pulse Width of the Right Aileron Zero point
#define MIN_RAILERON 1.22 //Percentage of MIN WIDTH as Right Alieron Maximum

void initSurfaces(void);
void directSurfaces(void);
void setSurface(float, int);
void disableControlSurfaces(void);
void enableControlSurfaces(void);
void setPitch(float);
void setRoll(float);

void initializePID(AXISPID *, float, float, float);
float adjustControl(AXISPID *, float, float, float, float, float);


/*****************************************************************************
 * Timer.c
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 *****************************************************************************/
```

```
#include "FlySpy.h"


int SecondFlag = 0;
int TimerFlag = 0;
int p_TimerCount = 0;
int TimerCount = 0;

/* PRECONDITIONS: Timer1 polls the barometer, so it must be init'd already. */
void initTimer()
{
	T1CON = 0x20; //Stops the Timer1 and reset control reg. Sets Prescaler to
1:64
	TMR1 = 0x00; //Clear contents of the timer register
	PR1 = 0x1388; //Load the Period register with the value 0x0001
	IPC0bits.T1IP = 0x04; //Setup Timer1 interrupt for desired priority level
	// (This example assigns level 1 priority)
	IFS0bits.T1IF = 0; //Clear the Timer1 interrupt status flag
	IEC0bits.T1IE = 1; //Enable Timer1 interrupts

	T1CONbits.TON = 1; //Start Timer1 and clock source set to the internal
instruction cycle

	T2CON = 0x30; //Stops Timer2 and Sets the prescaler to 1:256
	TMR2 = 0x00; //Clears the contents of the timer register
	PR2 = 0xF424; //Loads the Period into the register for a 1 second interrupt
	IPC1bits.T2IP = 0x03;	//Setup a priority level of 3

	IFS0bits.T2IF = 0; // Clear the Timer2 interrupt status flag
	IEC0bits.T2IE = 1; //Enables Timer2 interupts;

	T2CONbits.TON = 1;

	T3CON = 0x20;
	TMR3  = 0x00;
	PR3   = 0x1388;
	IPC2bits.T3IP = 0x5;
	IFS0bits.T3IF = 0;
	IEC0bits.T3IE = 0;
	T3CONbits.TON = 1;
}

void __attribute__((__interrupt__, auto_psv)) _T1Interrupt(void) //50Hz Timer
{

	updateOrientation();
	updateClearing();
	updateAltitude();
	directSurfaces();

	p_TimerCount++;
	if ( p_TimerCount  == 5)
	{
		TimerFlag = 1;
		p_TimerCount = 0;
		TimerCount ++;
		if ( TimerCount > 9)
			TimerCount =0;
	}

	IFS0bits.T1IF = 0; //Reset Timer1 interrupt flag and Return from ISR
}
```

```
void __attribute__((__interrupt__, auto_psv)) _T2Interrupt(void) //Second Timer
{
         SecondFlag = 1;
         IFS0bits.T2IF = 0;
}

void __attribute__((__interrupt__, auto_psv)) _T3Interrupt(void) //50hz  Input Capture
Timer
{
         IFS0bits.T3IF = 0;
}


/************************************************************************
 * Timer.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 ************************************************************************/

void initTimer();


/************************************************************************
 * uart2.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 ************************************************************************/

/*

UART2 Driver Header File for PIC24.

*************************************************************************
 FileName:        uart2.c
 Dependencies:    HardwareProfile.h
 Processor:       PIC24
 Compiler:        MPLAB C30
 Linker:          MPLAB LINK30
 Company:         Microchip Technology Incorporated

Author                Date      Comment
~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~
Anton Alkhimenok   18-Oct-2005
KO                 11-Oct-2006  v1.0

*************************************************************************
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********************************************************************************
*/

//******************************************************************************
// Function Prototypes
//******************************************************************************

char UART2GetChar();
void UART2Init();
char UART2IsPressed();
void UART2PrintString( char *str );
void UART2PutChar( char ch );
void UART2PutDec( unsigned char dec );
void UART2PutHex( int toPrint );

#if defined( __C30__ ) || defined( __PIC32MX__ )
void UART2PutHexWord( unsigned int toPrint );
#endif



/************************************************************************
 * util.c
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 ************************************************************************/

#include "util.h"

long linmap(long x1, long y1, long x2, long y2, long x)
{
         return ((y2 - y1) * (x - x1))/(x2 - x1) + y1;
}

long limit(long min, long max, long x)
{
         if (x < min)       x = min;
         if (x > max)       x = max;
         return x;
}

/************************************************************************
 * util.h
 * Authors: Jeremy Tillman, William Ehlhardt
 * Project: FlySpy
 *          ECE477, Team 12, Spring 2009
 ************************************************************************/

#ifndef _UTIL_H
#define _UTIL_H

/*       Performs linear interpolation of a line defined by two
         points (x1,y1) and (x2,y2) to return the value of y
         corresponding to the given x on the line */
long linmap(long x1, long y1, long x2, long y2, long x);
```

```
/*       Limits x to the range (min, max) */
long limit(long min, long max, long x);

#endif
```

Appendix G: FMECA Worksheet

Failure #	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
A1	No output	Software bug or chip failure	Loss of autonomous control and non-essential features	Observation	Medium	
A2	Some pins are "stuck" at 0 or 1, affecting non-essential peripherals (camera, rangefinder)	Exceeded voltage or current ratings (fried pin), software bug	Cannot power on camera or cannot trigger shutter. Camera will not respond with power on feedback signal if it does not receive particular pulse to power on. No known damage to camera. Rangefinder unaffected.	Observation	Low	
A3	Some pins are "stuck" at 0 or 1, affecting essential peripherals (GPS, analog sensors, etc.)	Exceeded voltage or current ratings (fried pin), software bug	Loss of autonomous control	Observation	Medium	

Control Mode Switching

Failure No.	Failure Mode	Possible Causes	Failure Effects	Method of Detection	Criticality	Remarks
B1	No output	Mux failure	Total loss of control	Observation	High	
B2	“Stuck” in autonomous mode	CTRL_SW shorted high due to comparator failure or filter failure	Loss of manual control	Observation	Medium or high	
B3	“Stuck” in manual mode	CTRL_SW shorted to ground (low) due to filter failure	Loss of autonomous capability	Observation	Medium	