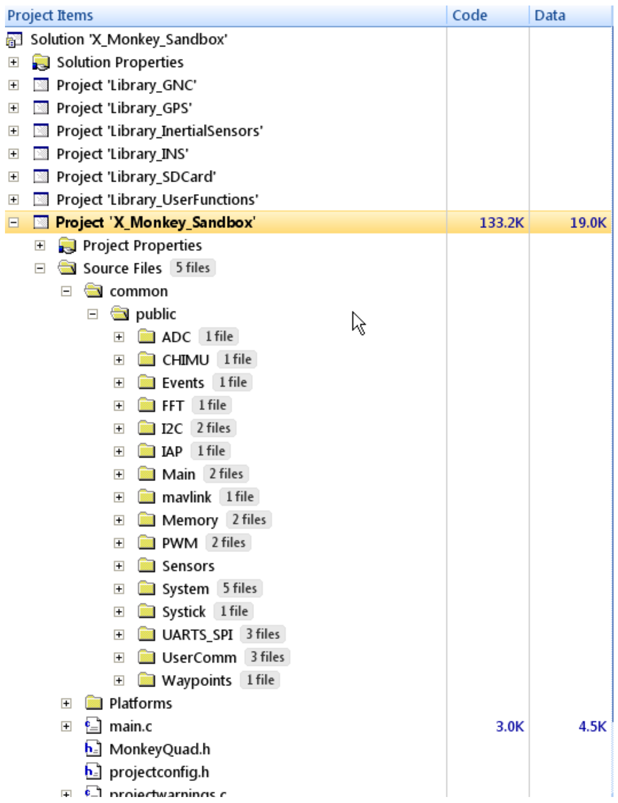
X-Monkey
Software Development Guide



```
Project Items                                          Code      Data
Solution 'X_Monkey_Sandbox'
⊞ Solution Properties
⊞ Project 'Library_GNC'
⊞ Project 'Library_GPS'
⊞ Project 'Library_InertialSensors'
⊞ Project 'Library_INS'
⊞ Project 'Library_SDCard'
⊞ Project 'Library_UserFunctions'
⊟ Project 'X_Monkey_Sandbox'                          133.2K    19.0K
    ⊞ Project Properties
    ⊟ Source Files  5 files
        ⊟ common
            ⊟ public
                ⊞ ADC  1 file
                ⊞ CHIMU  1 file
                ⊞ Events  1 file
                ⊞ FFT  1 file
                ⊞ I2C  2 files
                ⊞ IAP  1 file
                ⊞ Main  2 files
                ⊞ mavlink  1 file
                ⊞ Memory  2 files
                ⊞ PWM  2 files
                ⊞ Sensors
                ⊞ System  5 files
                ⊞ Systick  1 file
                ⊞ UARTS_SPI  3 files
                ⊞ UserComm  3 files
                ⊞ Waypoints  1 file
        ⊞ Platforms
        ⊞ main.c                                        3.0K      4.5K
          MonkeyQuad.h
          projectconfig.h
        ⊞ projectwarnings.c
```

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Release Notes

Title	Monkey		
Subtitle	X-Monkey Software Guide		
Type	Manual		
Document number	UM5100		
Revision Index	**Date**	**Name**	**Status / Comments**
Initial Release	4/2012	MR	Initial release

IMPORTANT DISCLAIMERS

1. Introduction

The Monkey platform provides a high performance basis for mechatronic system control. Originally designed for autonomous vehicle control, the platform can also be used for advanced data logging, industrial control, motion control or other mechatronic applications.

The X-Monkey platform is an enhanced version of prior Monkey circuit assemblies. The X-Monkey includes:

- Powerful base CPU - Cortex M3 (ARM7) LPC 1768 CPU
  - Cortex SWD interface (tested with Rowley Crossworks)
  - Hardware based serial boot loader for easy loading of new software

- High performance U-Blox LEA-6 GPS Module
  - Active on board antenna for increased sensitivity and jamming reduction
  - Autosensing off board GPS antenna switch for external antenna use

- 3 axis gyro (rate sensor)
- 3 axis accelerometer
- 3 axis magnetometer
- RS-485 driver on board for spare port
- Barometric pressure sensor
- Spare analog and digital I/O ports
- Six (6) Isolated and dedicated PWM servo outputs
- Four (4) input capture port connector
- Micro SD Card
- EEPROM for configuration settings
- Flash data log for solid state data logging
- Three status LED's (red, green, blue)
- Interfaces with CHIMU module for attitude estimates and sensor inputs via SPI or UART

Monkey has an excellent GPS module on board (U-Blox series) with both on board and off board antenna capability. The off board antenna capability is important if the unit is used in conditions where the on board antenna will be blocked by enclosures or other jamming.

Monkey has on board inertial measurement sensors, but is intended to work with the CHIMU AHRS as a plug in module to offload attitude determination. The CHIMU includes:

- 3 axis rate sensors to measure angular rate
- 3 axis accelerometers to measure linear acceleration
- 3 axis magnetometer to measure magnetic flux (typically used for compass type heading derivation)

The combination of all these capabilities with the on board ARM processing power allows a full attitude heading reference system (AHRS) with GPS position, velocity and time updates all in one tiny package.

Application areas include, but are not limited to:

- UAVs (AUVs, UAS, etc)
- Robotics
- Education

- Rocket science

1.1 Scope of this Software Development Guide

This guide provides an overview of software development on the X-Monkey platform. It is not a comprehensive guide, but is intended to help familiarize the user with the core structure on Monkey, how you can insert your own code and develop on the platform, and provide descriptions and examples of common functions.

1.2 Limitations

The toolset and project that is provided for Monkey was designed using Rowley Crossworks (www.rowley.co.uk). This compiler / IDE are based on the GCC base. It is a very good tool, and relatively inexpensive, especially for individuals. Rowley frequency updates their toolset with the latest core files for the X-Monkey series of processor, and we adopt the latest after testing.

1.2.1 Precautions and User Responsibility

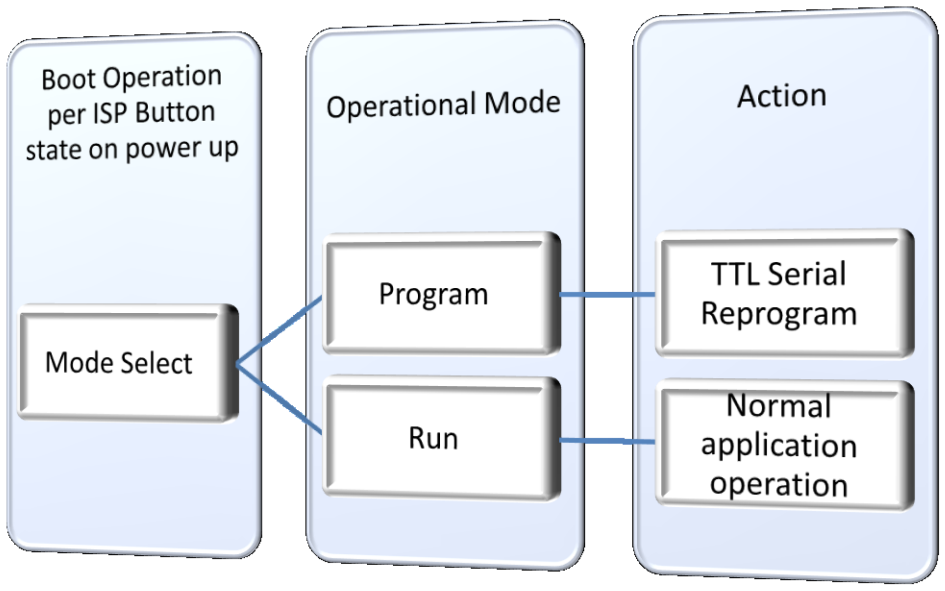
The Monkey is an open electrical device with no case. It has no on board protection from short circuits or accidental electrical damage. No system is fool proof, and all correct use and planning for events in case of failure are the responsibility of the user.

Ryan Mechatronics cannot be held responsible for accidental or intentional damage caused by this unit either directly or indirectly.

1.3 Programming Options

X-Monkey can use either SWD for detailed debugging / programming, or can be loaded with code via a serial boot loader.

The Monkey platform is an excellent prototyping system for users that want or need the power of an ARM Cortex core. User application code can be run on the core. However, the design makes it easy for the on-board ARM processor to be reprogrammed by using on-board firmware upload capability. This allows new Intel HEX formatted code to be uploaded using the serial port. A top level view of the usage modes is shown in the following figure.


Boot Operation per ISP Button state on power up
Operational Mode
Action
Mode Select
Program
Run
TTL Serial Reprogram
Normal application operation

1.3.1 Startup Conditions

The startup condition of the S2 ISP pushbutton on the Monkey dictates what mode the system enters when reset or power is applied.

On Board ARM CPU running user code: For operation in standalone mode, user must have code loaded and running on the processor. In this case, switch **S2** is not depressed.

Reprogramming: In order to reprogram the board, switch **S2** would be depressed before power is applied. When power is applied in this state, the on board boot loader of the ARM is active. Programming steps in this state can be found in Appendix A – Serial Port Reprogramming Example .

2. Setup for Software Development

Presented in this section are the most common setup and method for programming and coding the X-Monkey.

Please note - the Monkey is an open electrical device with no case. It has no on board protection from short circuits or accidental electrical damage. No system is fool proof, and all correct use and planning for events in case of failure are the responsibility of the user.

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2.1 Hardware

Hardware details can be found in the X-Monkey User Manual UM5000, found on our website (www.ryanmechatronics.com). However, shown below is a standard setup for connecting to the unit while debugging.

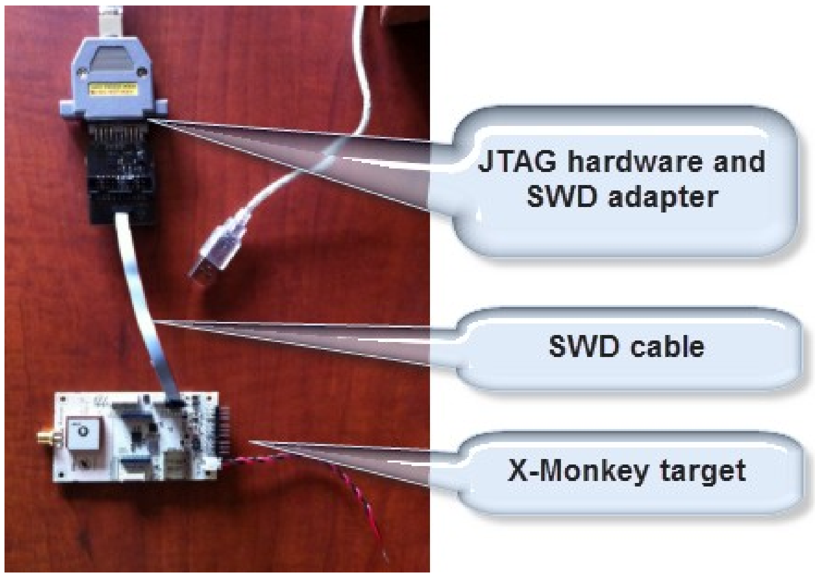


Figure 1. Serial Wire Debug (SWD) X-Monkey setup

2.2 Power

The X-Monkey requires 4.5 to 28V on its input power connector. Typically, we use a 5V bench supply to provide this while debugging. 5 volts is selected so that if there is an accidental short / touch of the power input to the rest of the board there will be limited damage. The X-Monkey CPU pins are (in general) 5V tolerant.

Loss of power to the unit while debugging will stop the debugging of course. It may also require disconnect / connect of the SWD tools to have your PC recognize them again.

2.3 Compiler / Integrated Development Environment (IDE)

Rowley Crossworks for ARM - This is our preferred tool for compiling code. Rowley provides a solid compiler and IDE based on the GCC compiler base, and provides both forum and ticketed support for users. Licenses start at $150 for personal use.

2.4 Debugging Tools

In order to debug using the SWD connector and Rowley Crossworks, you will need a JTAG / SWD interface and an interface cable. Rowley has a list of supported tools on their site. We use these two options (both are required):

ARM-USB-TINY-H - This is a high speed JTAG debugger that works with the Rowley toolset, and costs about $60. Rowley has a JTAG debugger as well, the CrossConnect Lite; it is just a little more costly at $100.

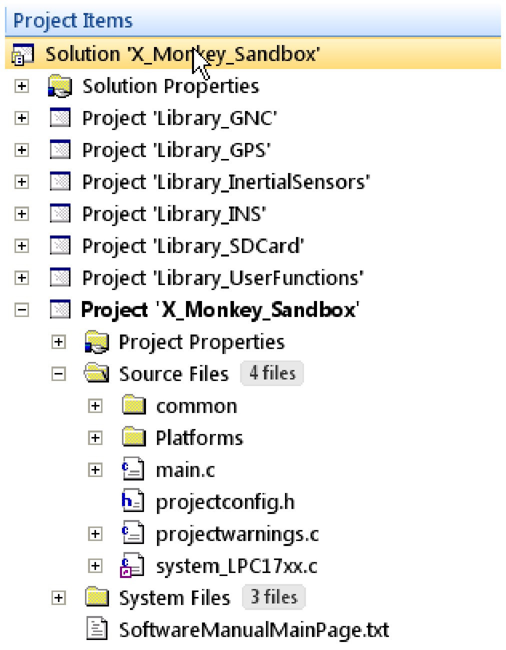
ARM SWD Adapter - This is required for the Serial Wire Debug (SWD) format for ARM Cortex interface. It plugs into the debugger above and comes with the cable that plugs directly into Monkey's SWD header.

3. Software Structure

The project code is structured to allow updates to libraries and common public code independent of user's specific project code.

The user only needs to provide a "**user_main()**" function in their code and link it appropriately. When the X-Monkey is done booting, it will transfer control to this function and still provide access to all functions and libraries on the unit.

The overall project is called a **solution** and it contains a number of items. The solution structure is shown below.



```
Project Items
Solution 'X_Monkey_Sandbox'
  + Solution Properties
  + Project 'Library_GNC'
  + Project 'Library_GPS'
  + Project 'Library_InertialSensors'
  + Project 'Library_INS'
  + Project 'Library_SDCard'
  + Project 'Library_UserFunctions'
  - Project 'X_Monkey_Sandbox'
      + Project Properties
      - Source Files  4 files
          + common
          + Platforms
          + main.c
            projectconfig.h
          + projectwarnings.c
          + system_LPC17xx.c
      + System Files  3 files
        SoftwareManualMainPage.txt
```

Figure 2. Solution Structure

The **solution** contains proprietary **libraries**, **open source code** and **settings** for the project. This section will describe each of the following groups:

- Top level project code components
- Common public code
- Platform code for customization
- Proprietary helper libraries

3.1 Top Level Code Components

The top level code components are highlighted in the figure below.

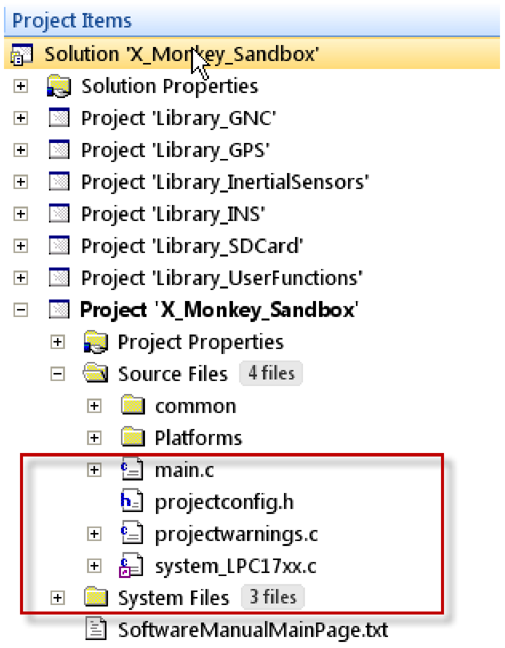


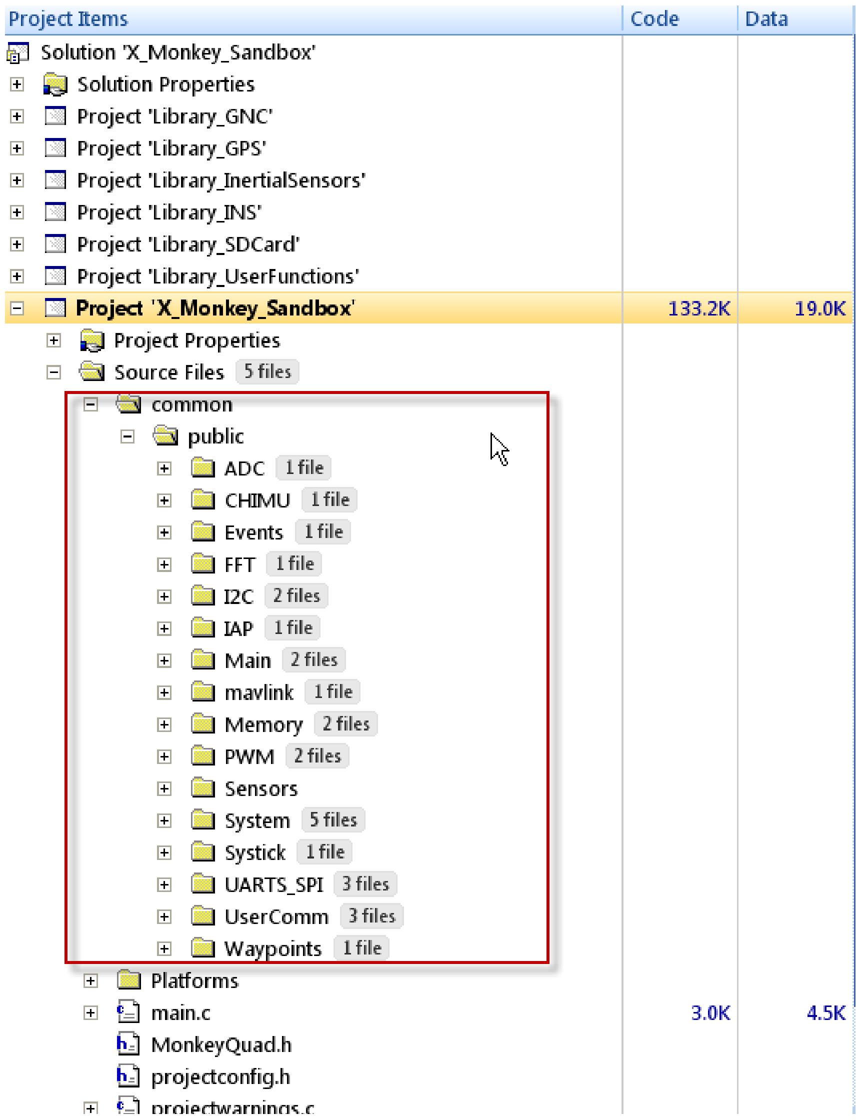
Figure 3. Top level code components

The following quick descriptions apply to these items:

- **main.c** – This is the entry point for the C code.
    - After the system is setup and initialized, main.c calls the function "User_Main()". This is the link to the user code located in the **Platforms->UserMode.c** (or similar) code. This is how your code interfaces into the overall project.
- **projectconfig.h** – this file contains a number of defines that affect the overall project.
    - Items like RS-485 and SD card use can either be enabled or disabled in this file.
- **projectwarnings.c** – contains warnings based on the defines in **projectconfig.h** to try and prevent errors by raising warnings and errors if you choose wrong options.
- **systemfiles** – contains startup code (assembly) specific to this processor.

3.2 Common public source code

The common public source code (expanded) is highlighted in the figure below.



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⊟ **Project 'X_Monkey_Sandbox'**	133.2K	19.0K
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⊟ Source Files 5 files		
⊟ common		
⊟ public		
⊞ ADC 1 file		
⊞ CHIMU 1 file		
⊞ Events 1 file		
⊞ FFT 1 file		
⊞ I2C 2 files		
⊞ IAP 1 file		
⊞ Main 2 files		
⊞ mavlink 1 file		
⊞ Memory 2 files		
⊞ PWM 2 files		
⊞ Sensors		
⊞ System 5 files		
⊞ Systick 1 file		
⊞ UARTS_SPI 3 files		
⊞ UserComm 3 files		
⊞ Waypoints 1 file		
⊞ Platforms		
⊞ main.c	3.0K	4.5K
MonkeyQuad.h		
projectconfig.h		
⊞ projectwarnings.c		

Figure 4. Open Source Code

3.3 Platform code

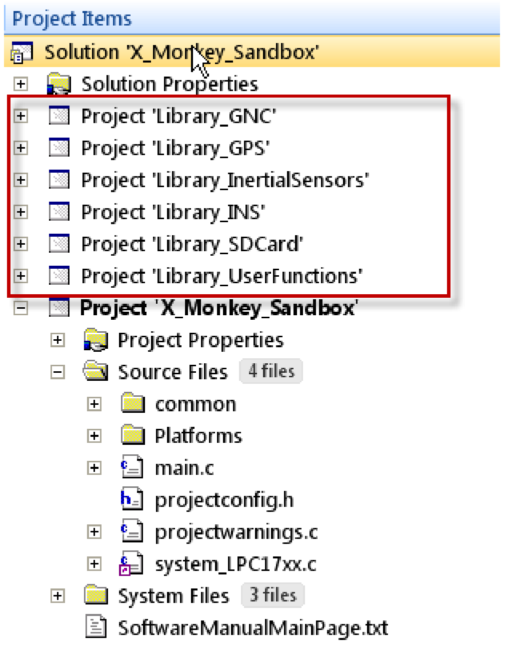
The platform folder contains files that represent specific platforms (i.e. fixed wing UAV, quadcopter, platform stabilization, etc.).

From within Rowley, you can include and exclude different files before compiling. This allows you to selectively choose which platform or function you are compiling for, while maintaining all the libraries and public code.

In this manner, you are able to have different files with **User_Main()** entry points. When main.c passes control to this function, your platform specific code will execute.

3.4 Proprietary helper libraries

The proprietary libraries are highlighted here. However, this is our internal view. Your project will only contain the libraries themselves, which reside in the **Libraries** directory and have a **.a** extension. The included .h files provide access to the compiled code within these libraries.



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Project Items
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    Project Properties
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      Platforms
      main.c
      projectconfig.h
      projectwarnings.c
      system_LPC17xx.c
    System Files  3 files
    SoftwareManualMainPage.txt
```

Figure 5. Libraries

4. Global Variables

One benefit (and sometimes drawback) to the X-Monkey code is the use of global variables, located in **globals.h**. Using these variables makes it very easy for users to access the latest information that is typically populated behind the scenes in interrupt service routines or thru the main state machine.

One major drawback: In CrossWorks, there is a global variable tab for inspecting global variables. If this is selected, you will experience dramatic slowdowns during debugging as Rowley updates ALL of these variables.

To avoid this slowdown while debugging, simply look at other watch windows and don't use the global watch display.

5. User_Main() structure

User_Main() is where the users code typically goes. It is a pseudo-RTOS state machine that executes certain functions based on interval times. Full examples are provided with the software, but an example is shown below. Some significant items are:

- Task times – the task break down consists of 1 msec, 5 msec, etc. tasks. Put your required code call into the appropriate section (i.e. don't call it faster than it needs to, or slower).
- Protected sections – if a section is called out as protected, it is important to other background functions and should not be removed unless you know you don't need it. This is how the Monkey base code operates to provide sensor data and manage com protocols without user intervention.

```
void User_Main(void)
{
 //Main loop
 // Note that this is the time / tasking loop.  There are protected areas in this section you should leave alone.
 //
 // State machine for task processing by user is in user_process()

 #if defined CFG_SDCARD
   bLoggerOK = sd_init(); //Init SD card logger if enabled
 #endif

 gThruputCnts = 0;
 gLED_Heartbeat = 1; //Enable heartbeat

 User_Init();

 //Start processing loop
 while (1)
 {
   gThruputCnts++;

    //Pseudo-tasking occurs here
   if (time_1ms_flag) // 1ms (1000 Hz) tasks
   {
      /*----------------------------------------------------------------------*/
      /* BEGIN PROTECTED -- DO NOT REMOVE -- UNIT WILL NOT OPERATE CORRECTLY */
         //Handle serial port receipt
         Main_SerialPort_Process(); //Handles double buffering of input from serial coms
         //Parse now that the interrupts seem over (RX FIFO has been emptied)
         SSP1_Parse_CHIMU();
         //Parse GPS
         GPS_Parse();
         //Process uplinked waypoints - Event handler will indicate if there is a complete set waiting for you
         Waypoint_Process();
         //INS filter processing
         #ifdef CFG_INSFILTER
         INS_Filter_Process();
         #endif
         #ifdef CFG_BMP085
         Baro_Process(1000); //Updates pressure sensor at a 1 second rate.  Maximum update rate is about 40 msec
         #endif
      /* END PROTECTED -------------------------------------------------------*/
      /*----------------------------------------------------------------------*/

      User_Process(); //Handles user processing (like mode switches, etc)

      time_1ms_flag = 0;//Clear time tick
   }

   if (time_5ms_flag) //5ms (200 Hz) tasks
   {
      //No Tasks
      time_5ms_flag = 0;//Clear time tick
   }


   if (time_10ms_flag) //10ms (100 Hz) tasks
   {
      //No Tasks
```

```
        time_10ms_flag = 0;//Clear time tick
    }


    if (time_20ms_flag) //20 ms (50Hz) tasks
    {
        /*-------------------------------------------------------------------*/
        /* BEGIN PROTECTED -- DO NOT REMOVE -- UNIT WILL NOT OPERATE CORRECTLY */
            Control_Process(); //Handle control functions (servos) at 50Hz
            #ifdef CFG_USE_MONKEY_TELEMETRY
            TX_Com_Process();          //Handles output messages
            #endif
        /* END PROTECTED -----------------------------------------------------*/
        /*-------------------------------------------------------------------*/
        time_20ms_flag = 0;//Clear time tick
    }

    if (time_100ms_flag) //100ms (10 Hz) tasks
    {
        /*-------------------------------------------------------------------*/
        /* BEGIN PROTECTED -- DO NOT REMOVE -- UNIT WILL NOT OPERATE CORRECTLY */
            ADC_Process(); // 10 Hz, start a burst ADC read.  Global gADC holds result.
            CHIMU_Process();
        /* END PROTECTED -----------------------------------------------------*/
        /*-------------------------------------------------------------------*/

        //Below is for SD card logging of standard data set if card is present
        //Called at 10 Hz, but only writes to disk after 10 entries
        #if defined CFG_SDCARD
            SD_StandardLogging(TRUE);
        #endif

        time_100ms_flag = 0; //Clear time tick
    }

    if (time_1000ms_flag) //1000ms (1 Hz) tasks
    {
        System_Check_CPU();  //Checks CPU load and puts it into Monkey output message as needed

        time_1000ms_flag = 0; //Clear time tick

    }
  }//Loop back around

}
```

Figure 6. Sample User_Main() function

6. Common Functions

Common used functions in the open source area include (but are not limited to):

(To be documented at a later date. Functions are numerous. For now, please browse the reference manual online to see the full set of source code available functions in the Monkey code base.)

7. Library Functions

Special functions can be found in the libraries. These functions are designed in many cases to make it easier to access special hardware functions on the X-Monkey. Libraries represent proprietary code that you have access to, but cannot change or view the source. The libraries currently include:

- **UserFunctions** – a collection of functions that are most commonly used.
- **SDCard** – functions for accessing the micro SD card file system. Some of these functions are repeated in **UserFunctions** for convenience.
- **INS** – an inertial navigation system library
- InertialSensors – for accessing on board MEMS sensor data (different than CHIMU access, which is in the common source area).
- **GPS** – handles GPS parsing and module control functions
- **GNC** – guidance, navigation and control functions (access may be limited)

Many of the commonly used library functions are found in the **UserFunctions** library. A brief description of those functions located in **UserFunctions** as of release 4.0 is shown in Table 1.

This is just a quick example of some of the functions. **A comprehensive list of all functions, defines and variables in the code can be found in our detailed software description.** Please note that the latest detailed software description can be found in our online software reference manual. This manual can be found here:

http://www.ryanmechatronics.com/public_files/user_manuals/platforms/X-Monkey/X-MonkeySoftwareUserGuide/html/index.html

Table 1. Current set of Functions in UserFunction Library

GPS Functions

int	**GPS_SetDataRate** (int rate)
	Set GPS Data Rate (output rate)
void	**GPS_SetFilter** (unsigned char filter)
	Set GPS Filter Type.
void	**GPS_MessageEnable** (unsigned char msgid, unsigned char enable)
	Enable / Disable GPS Messages.
void	**GPS_ColdStart** (void)
	Coldstart software reboot of GPS.

Power Control Functions

void	**Power_GPS** (int poweron)
	Power Management for GPS.
void	**Power_CHIMU** (int poweron)
	Power Management for CHIMU.
void	**Power_Aux3_3V** (int poweron)
	Power Management for Auxiliary Power.
int	**Power_Sleep** (void)

	Sleep (Idle) mode control.
int	**Power_DeepSleep_WDT** (unsigned int minutes, unsigned int seconds)
	Deep Sleep mode control - WDT.
int	**Power_DeepSleep_RTC** (unsigned int minutes, unsigned int seconds)
	Deep Sleep mode control - RTC.
int	**Power_BoostFromLowPower** (int enabled)
	Boost processing mode control.
LED Control Functions	
void	**Led_Control** (unsigned long led, int on)
	LED On/Off control for Monkey board.
void	**Led_Blink** (unsigned long led, int blinks)
	LED Blocking Flash function for Monkey board.
GPIO Functions	
int	**GPIO_Configure** (int channel, int direction, int pullup, int ISRenable, int risefall)
	GPIO Configure Required to set GPIO to outputs or return to inputs.
int	**GPIO_Output** (int channel, int value)
	GPIO Output Sets or clears an output GPIO.
int	**GPIO_Value** (int port, int pin)
	GPIO Value Returns high/low state of any port/pin combination Note that all port pins not configured as ADC can be queried, this is not limited to P2.12 or P2.13)
SD Card Functions	
int	**SD_Mount** (void)
	Mount SD Card.
int	**SD_FileOps** (char *fileptr1, char *fileptr2, int cmd)
	SD Card File Operations.
int	**SD_Log_Data** (char *data, int btw, unsigned int *msec, unsigned int *fsize)
	SD Card Logging Operations.
UART COM Control Functions	
void	**COM_BaudRate** (int com, unsigned short baud)
	UART baud rates.
int	**COM_Putch** (int com, int ch)
	UART Putch.
unsigned short	**COM_Space** (int com)

	UART TX Queue Space.
const char *	**COM_Puts** (int com, const char *string)
	UART Puts.
int	**COM_Write** (int com, const char *buffer, unsigned short count)
	UART Write.
void	**COM_TxFlush** (int com)
	UART TX Flush.
int	**COM_Getch** (int com)
	UART Getch.

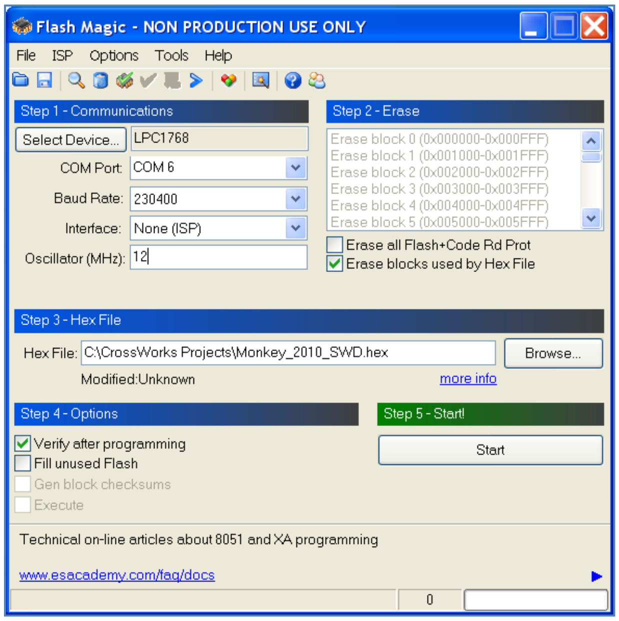
SPECIAL System Control Functions

void	**SYSTEM_ClockOut** (int clock, int enable)
	System Clock Out.
int	**SYSTEM_RTC_Check** ()
	Check RTC.

8. Appendix A – Serial Port Reprogramming Example

Steps to load a new Hex file (firmware image) into the X-Monkey board

1) Download and install the latest version of *FlashMagic* from this site: (http://www.flashmagictool.com/)
2) Power down Monkey
3) Remove CHIMU module (if present) from Monkey board (to be on the safe side)
4) Plug USB node or other USB to serial converter into Monkey
5) Press the **S2** button on Monkey and **KEEP IT HELD DOWN FOR THE NEXT STEP!**
6) Power up Monkey (or, press the **S1** button and release it)
7) Release the **S2** button.
8) Run *FlashMagic* and reprogram
   a. Open settings file (.fms), or if .fms file is not available, select settings shown below



Step 1 - Communications

LPC1768

COM Port: COM 6

Baud Rate: 230400

Interface: None (ISP)

Oscillator (MHz): 12

Step 2 - Erase

Erase block 0 (0x000000-0x000FFF)
Erase block 1 (0x001000-0x001FFF)
Erase block 2 (0x002000-0x002FFF)
Erase block 3 (0x003000-0x003FFF)
Erase block 4 (0x004000-0x004FFF)
Erase block 5 (0x005000-0x005FFF)

☐ Erase all Flash+Code Rd Prot
✓ Erase blocks used by Hex File

Step 3 - Hex File

Hex File: C:\CrossWorks Projects\Monkey_2010_SWD.hex

Modified:Unknown

Step 4 - Options

✓ Verify after programming
☐ Fill unused Flash
☐ Gen block checksums
☐ Execute

Step 5 - Start!

Technical on-line articles about 8051 and XA programming

www.esacademy.com/faq/docs

   b. Change COM port to your com port
   c. Change path to .hex file to where you stored the hex file to download
   d. Press the "start" button, it will flash and verify
   e. If it fails, try pressing the reset button on the Monkey board and try again
   f. If it still fails, try powering the unit via a USB cable so grounds are common
   g. If it still fails, drop the baud rate to 57600
   h. If it still fails, cycle power on the Monkey and try again
9) Close *FlashMagic*
10) Power board down
11) Put CHIMU back on (be **CAREFUL ABOUT PIN ALIGNMENT**!)
12) Power up without any buttons pressed and verify new code is running