Data Acquisition for Flight Tests using Handheld GPS and Electronic Flight Instrument System

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Data Acquisition for Flight Tests using Handheld GPS and Electronic Flight Instrument System

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This paper addresses the data acquisition system designed in order to gather flight test data for two different aircraft for the AERO flight test class at Cal Poly San Luis Obispo. It summarizes the system, data acquisition devices, methods used, data comparison and validation, and step-by-step procedures to properly gather data for reduction and analysis. Also, the paper gives examples of initial data reduction processes and analysis. It provides a simple MATLAB code that allows data to be extracted from a handheld GPS as well as a procedure to gather data from a black box recorder in Cal Poly's RV 7 aircraft. It also explains the use of Google Earth in presenting flight data. Lastly, it investigates the use of Smartphone sensors to gather data and explains why it is not viable solution.

I. Introduction

THE challenge of using GPS to gather flight test data is its poor data rate limitation and the inability to determine the attitude of the aircraft. The GPS is limited to 1 Hz which brings problems with maneuvers that require a much higher sampling rate. It is also limited to only giving a position and ground speed rather than attitude or acceleration which most flight test maneuvers require. This paper attempts to solve these problems with these limitations.

Most modern flight tests use highly accurate inertial navigation system (INS) combined with GPS to solve the navigation solution. Roll, pitch, and yaw rates as well as acceleration in X, Y, and Z are integrated over time to get accurate attitude and position of the aircraft. With the GPS, the solution can be updated using a Kalman filter to rid drifting errors within the inertial sensors. The data recording system is also more likely to be able to gather data at a much higher rate. Because of the limitation of not being able to acquire a sophisticated system, a simple system using a handheld GPS is developed. In addition to the handheld device, the system includes the use of a black box recorder that is able to gather attitude data but is still limited to the same 1 Hz data rate.

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II. Data Acquisition Devices and Integration

Two different types of aircraft are used while collecting flight test data. The first aircraft is a Cessna 172 shown in Fig. 1. Since the Cessna 172 contains all analog instruments, a GPS receiver discussed later is used to collect flight test data. The GPS receiver is mounted to the yoke of the Cessna 172 to allow hands free operation. The procedure on setting up the mount and GPS in the Cessna 172 is shown in Appendix A under the Cessna 172 aircraft section.

Figure 1. Cessna 172 aircraft

The other aircraft used is the RV 7 shown in Fig. 2. This aircraft contains its own data recording device that will be discussed later. The handheld GPS receiver is also used along with the data recorder. The RV 7 is unique in that it gathers much more data than the GPS alone. The all-in-one electronic flight instrument system (EFIS) gathers all data available from its sensors.

Figure 2. RV 7 Aircraft

The GPS used is Aviation quality Garmin GPSMAP 495 as shown in Fig. 3. The 12 channel GPS receiver is able to track locations over a period of time. This feature allows one the ability to gather flight test data, extract it from the device, and subsequently save it onto a computer. The GPS has a removable antenna, and a USB cable that allows the device to interface with the computer. The extendable antenna can replace the stock antenna to extend the receiver to a visible location. The receiver contains multiple functions and uses to allow pilots to correctly navigate. Most functions are not used for the purpose of gathering flight test data and will not be explained in detail. Refer to Appendix A for a step-by-step procedure on how to gather data using the GPSMAP 495. The GPS receiver can be used in both the Cessna 172 and the RV 7.

Figure 3. Garmin GPSMAP 495

The EFIS used for the RV 7 aircraft is the MGL Stratomaster Enigma system similar to what is shown in Fig. 4. This system automatically records flights and saves them to an external SD data card. This card can be placed into a computer and recorded flights can be extracted. This system has the added benefit of recording much more data than a handheld GPS. The system has its own GPS receiver and several other systems that are useful for flight tests. The EFIS contains an Attitude Heading Reference System (AHRS) that gathers information on bank, pitch, and yaw angle of the aircraft. It also gathers

Figure 4. MGL Stratomaster Enigma EFIS system

useful air data such as Baro altitude, vertical speed, and true airspeed. All this data is also limited to the same 1 Hz data rate. See Appendix B for a full detailed procedure on how to use the EFIS in the RV 7 to extract data.

The last method to acquire data is the use of a Smartphone. Most modern Smartphone's contain accelerometers, rate gyros, magnetometer, and a GPS receiver. Some free applications allow access to these sensors and record it to a text file. The particular Smartphone used for this data acquisition system is a Motorola Atrix 4G similar to that shown in Fig. 5 loaded with a free data recording application. This device is desirable since it is able to record at a much higher rate between 1 and 10 Hz. Additionally, the interface is simple and easy to transfer to a computer. But this method of data collection comes with many challenges. The device is sensitive to placement and must be mounted and strapped down to the aircraft. Also, it needs to be aligned to the aircraft's centerline and placed where it is able to receive GPS signal. The engine adds additional noise to the data from vibration and from magnetic interference. All these must be considered and addressed if this method is to be used properly.

Figure 5. Motorola Atrix 4G Smartphone

III. Post Flight Data Extraction Methods

The following section describes the file input/output process, file formats, example outputs, as well as an overview of a developed MATLAB code that reads in Garmin GPS text file data and the use of Google Earth for data presentation.

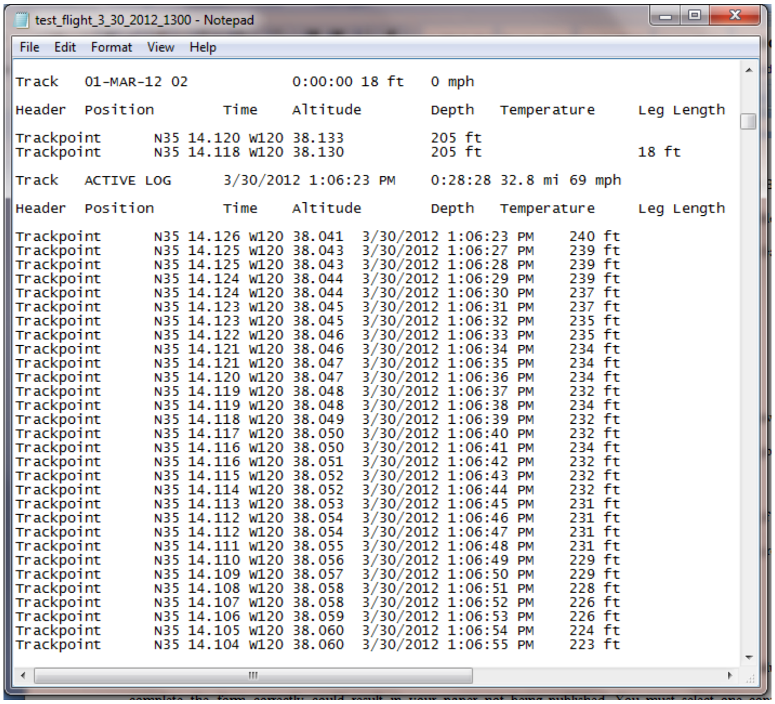
A. GPS data extraction using MATLAB

One of the main challenges in extracting data from the GPSMAP 495 is organizing the data into a readable and easily presentable format. MATLAB is an excellent tool that is able to not only post-process the data, but also has the ability to filter through complicated text file formats. A MATLAB function was developed to eliminate this problem of a non-standard text file that contains many characters and header lines. Figure 6 shows an example of the Garmin GPSMAP output text. The MATLAB function developed is easy to use and requires only one input to the function. The input must be a character string of the exact file name of the GPS text file including the file extension.

The output of the function is all the numeric data presented in the text file organized in a data structure by their respected names. MATLAB data structures are used to eliminate the need for having multiple outputs to the function, allowing the user to only require one output. It is recommended to learn how to use MATLAB data structures prior to using this function. An example of the MATLAB syntax to call this function is shown,

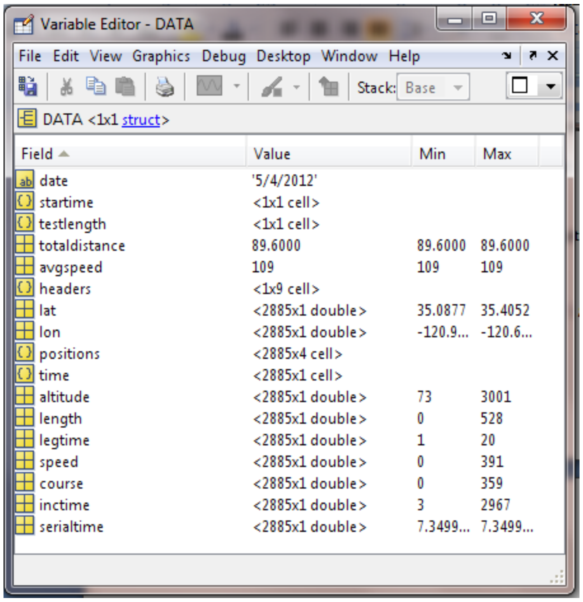
```
DATA = importmygps('GPS_text.txt');,
```

and the output "DATA" is the data structure which contains multiple variable fields. Double-clicking on the "DATA" variable in MATLAB will open the variable editor and allow the user to see the available fields. An example of the variables available for use is shown in Fig. 7. To access a field in the data structure, the user can simply use the syntax, DATA.lon, to gather all longitudes recorded during the flight test. Most of the fields within the data structure are self explanatory. Important to note that all units are English Standard (ft, mi, etc.) and all units are presented in the text file. The "length" field is the distance traveled in the given time interval (usually 1 second). The "speed" field is the average speed in that 1 second time frame. Several time variables are presented. The "legtime" field is the time interval and is, for the most part, always 1 second. The "inctime" field sums the previous times to an array of time elapsed. Lastly, "serialtime" is the standard time recorded from a datum and incorporates the date within the time keeping process. This is useful for data




```
Track    01-MAR-12 02             0:00:00 18 ft    0 mph

Header   Position         Time    Altitude         Depth   Temperature     Leg Length

Trackpoint      N35 14.120 W120 38.133            205 ft
Trackpoint      N35 14.118 W120 38.130            205 ft                   18 ft

Track    ACTIVE LOG       3/30/2012 1:06:23 PM    0:28:28 32.8 mi 69 mph

Header   Position         Time    Altitude         Depth   Temperature     Leg Length

Trackpoint      N35 14.126 W120 38.041  3/30/2012 1:06:23 PM    240 ft
Trackpoint      N35 14.125 W120 38.043  3/30/2012 1:06:27 PM    239 ft
Trackpoint      N35 14.125 W120 38.043  3/30/2012 1:06:28 PM    239 ft
Trackpoint      N35 14.124 W120 38.044  3/30/2012 1:06:29 PM    239 ft
Trackpoint      N35 14.124 W120 38.044  3/30/2012 1:06:30 PM    237 ft
Trackpoint      N35 14.123 W120 38.045  3/30/2012 1:06:31 PM    237 ft
Trackpoint      N35 14.123 W120 38.045  3/30/2012 1:06:32 PM    235 ft
Trackpoint      N35 14.122 W120 38.046  3/30/2012 1:06:33 PM    235 ft
Trackpoint      N35 14.121 W120 38.046  3/30/2012 1:06:34 PM    234 ft
Trackpoint      N35 14.121 W120 38.047  3/30/2012 1:06:35 PM    234 ft
Trackpoint      N35 14.120 W120 38.047  3/30/2012 1:06:36 PM    234 ft
Trackpoint      N35 14.119 W120 38.048  3/30/2012 1:06:37 PM    232 ft
Trackpoint      N35 14.119 W120 38.048  3/30/2012 1:06:38 PM    234 ft
Trackpoint      N35 14.118 W120 38.049  3/30/2012 1:06:39 PM    232 ft
Trackpoint      N35 14.117 W120 38.050  3/30/2012 1:06:40 PM    232 ft
Trackpoint      N35 14.116 W120 38.050  3/30/2012 1:06:41 PM    234 ft
Trackpoint      N35 14.116 W120 38.051  3/30/2012 1:06:42 PM    232 ft
Trackpoint      N35 14.115 W120 38.052  3/30/2012 1:06:43 PM    232 ft
Trackpoint      N35 14.114 W120 38.052  3/30/2012 1:06:44 PM    232 ft
Trackpoint      N35 14.113 W120 38.053  3/30/2012 1:06:45 PM    231 ft
Trackpoint      N35 14.112 W120 38.054  3/30/2012 1:06:46 PM    231 ft
Trackpoint      N35 14.112 W120 38.054  3/30/2012 1:06:47 PM    231 ft
Trackpoint      N35 14.111 W120 38.055  3/30/2012 1:06:48 PM    231 ft
Trackpoint      N35 14.110 W120 38.056  3/30/2012 1:06:49 PM    229 ft
Trackpoint      N35 14.109 W120 38.057  3/30/2012 1:06:50 PM    229 ft
Trackpoint      N35 14.108 W120 38.058  3/30/2012 1:06:51 PM    228 ft
Trackpoint      N35 14.107 W120 38.058  3/30/2012 1:06:52 PM    226 ft
Trackpoint      N35 14.106 W120 38.059  3/30/2012 1:06:53 PM    226 ft
Trackpoint      N35 14.105 W120 38.060  3/30/2012 1:06:54 PM    224 ft
Trackpoint      N35 14.104 W120 38.060  3/30/2012 1:06:55 PM    223 ft
```

Figure 6. Garmin GPSMAP 495 example text file



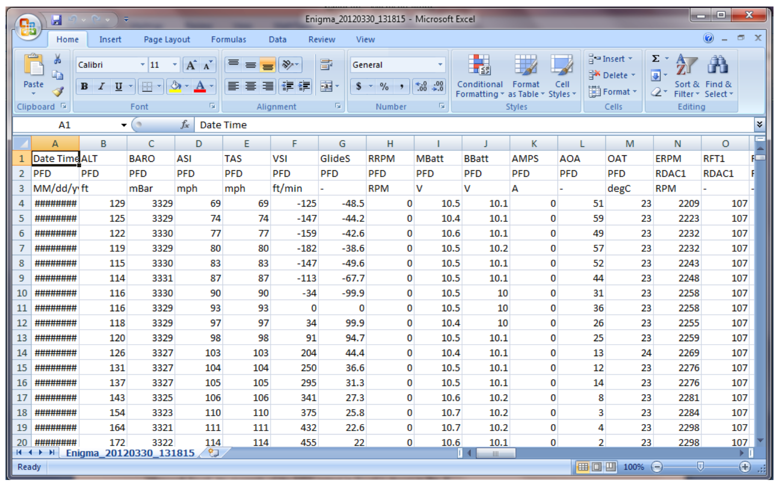
Field	Value	Min	Max
date	'5/4/2012'		
startime	<1x1 cell>		
testlength	<1x1 cell>		
totaldistance	89.6000	89.6000	89.6000
avgspeed	109	109	109
headers	<1x9 cell>		
lat	<2885x1 double>	35.0877	35.4052
lon	<2885x1 double>	-120.9...	-120.6...
positions	<2885x4 cell>		
time	<2885x1 cell>		
altitude	<2885x1 double>	73	3001
length	<2885x1 double>	0	528
legtime	<2885x1 double>	1	20
speed	<2885x1 double>	0	391
course	<2885x1 double>	0	359
inctime	<2885x1 double>	3	2967
serialtime	<2885x1 double>	7.3499...	7.3499...

Figure 7. MATLAB's variable editor of data available from the Garmin GPSMAP 495

lineup with other devices and will be shown later. Refer to MATLAB's help documentation to explain serial time in detail as well as using data structures. The developed MATLAB function "importmygps.m" is shown in Appendix C and can be copied and pasted into MATLAB to run the function.

B. Data extraction using MGL Stratomaster Enigma EFIS

The output file from the RV 7's EFIS is a simple standard format that does not require a special function or method. As shown in the procedure in Appendix B, the output is a comma separated values text file with the extension ".csv" and can be opened in a variety of programs. The easiest program to see what data is available is Microsoft Excel. An example of the EFIS output in Excel is shown in Fig. 8. Additionally, MATLAB can be used as well. MATLAB recognizes the file format and can place the data in a large matrix of values. It is done by using the "importdata" function and easy to use import wizard Graphical User Interface (GUI) that allows the user to select options pertaining to how the data is organized. The options include the number of header lines the file has and how the data is delimited. To use this option,



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Date Time	ALT	BARO	ASI	TAS	VSI	GlideS	RRPM	MBatt	BBatt	AMPS	AOA	OAT	ERPM	RFT1
2	PFD	PFD	PFD	PFD	PFD	PFD	PFD	PFD	PFD	PFD	PFD	PFD	PFD	RDAC1	RDAC1
3	MM/dd/y	ft	mBar	mph	mph	ft/min	-	RPM	V	V	A	-	degC	RPM	-
4	#########	129	3329	69	69	-125	-48.5	0	10.5	10.1	0	51	23	2209	107
5	#########	125	3329	74	74	-147	-44.2	0	10.4	10.1	0	59	23	2223	107
6	#########	122	3330	77	77	-159	-42.6	0	10.6	10.1	0	49	23	2232	107
7	#########	119	3329	80	80	-182	-38.6	0	10.5	10.2	0	57	23	2232	107
8	#########	115	3330	83	83	-147	-49.6	0	10.5	10.1	0	52	23	2243	107
9	#########	114	3331	87	87	-113	-67.7	0	10.5	10.1	0	44	23	2248	107
10	#########	116	3330	90	90	-34	-99.9	0	10.5	10	0	31	23	2258	107
11	#########	116	3329	93	93	0	0	0	10.5	10	0	36	23	2258	107
12	#########	118	3329	97	97	34	99.9	0	10.4	10	0	26	23	2255	107
13	#########	120	3329	98	98	91	94.7	0	10.5	10.1	0	25	23	2259	107
14	#########	126	3327	103	103	204	44.4	0	10.4	10.1	0	13	24	2269	107
15	#########	131	3327	104	104	250	36.6	0	10.5	10.1	0	12	23	2276	107
16	#########	137	3327	105	105	295	31.3	0	10.5	10.1	0	14	23	2276	107
17	#########	143	3325	106	106	341	27.3	0	10.6	10.2	0	8	23	2281	107
18	#########	154	3323	110	110	375	25.8	0	10.7	10.2	0	3	23	2284	107
19	#########	164	3321	111	111	432	22.6	0	10.7	10.2	0	4	23	2298	107
20	#########	172	3322	114	114	455	22	0	10.6	10.1	0	2	23	2298	107

Figure 8. EFIS output example of the CSV file in Excel

1. Simply double-click on the .csv file located in the current directory and the import wizard menu will appear as shown in Fig. 9
2. Select column separators to "Tab" (It usually automatically knows and selects the correct one)
3. Select the number of text header lines the file has to 3 (It usually automatically knows and selects the correct one)
4. Click the Next button and it will bring up the option that allows the user to change the name of the variables (default is named "data")
5. Click Finish to save the data to the workspace

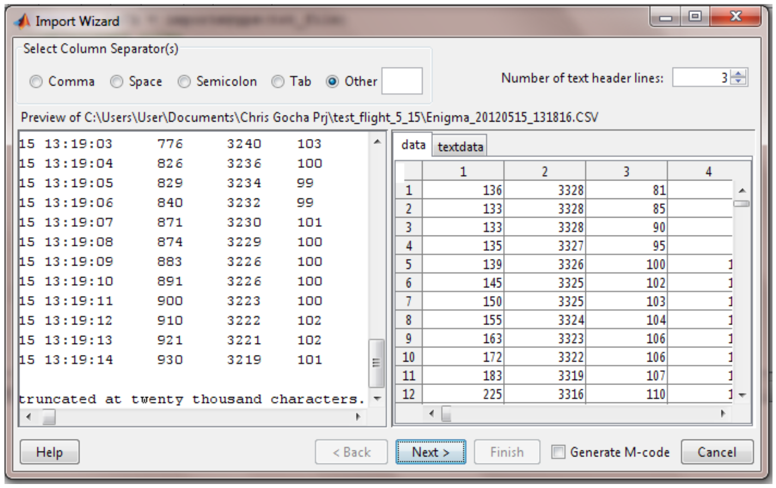


Figure 9. Example of importing CSV files into MATLAB

C. Data presentation using Google Earth

The use of Google Earth to present the recorded flight is a powerful tool that allows the user to observe problems during the flight, identify outliers in the GPS data, and mark points in the flight path of where maneuvers occurred. This, along with a video recording, provides a complete summary of the flight test.

Google Earth accepts two file types. The Garmin Database file with the extension ".gdb" and Google Earth files with the extension ".kml" which both can be opened and displayed. As mentioned before, the Garmin GPSMAP 495 outputs Garmin Database files. The EFIS can save Google Earth files directly through the use of the Enigma Black Box Viewer as shown in Appendix B. The limitation of using Google Earth files is that the speed information does not get saved to the track like Garmin Database files. It is recommended to use the .gdb file to present the data within Google Earth.

IV. Flight Test Results

After investigating the process for collecting data and loading the results onto the computer, the procedure is performed on the system and is tested in both aircraft. Multiple tests were conducted and the data verified with the predicted flight path and were compared against each device used. This section outlines the results from those tests.

A. RV 7 Flight Test Using Garmin GPSMAP 495 and Smartphone

The first flight test conducted in the RV 7 was a simple taxi and takeoff and land while remaining in the pattern. The GPSMAP 495 and the Smartphone sensors were used for this flight. First, the data from the Garmin GPS is presented using Google Earth and is shown in Fig. 10. An elevation profile can be created and shown in Google Earth. This allows the user to investigate the profile to insure that no outliers exist that may have been caused by poor GPS signal. Speed and altitude information are displayed in the elevation profile in Google Earth.

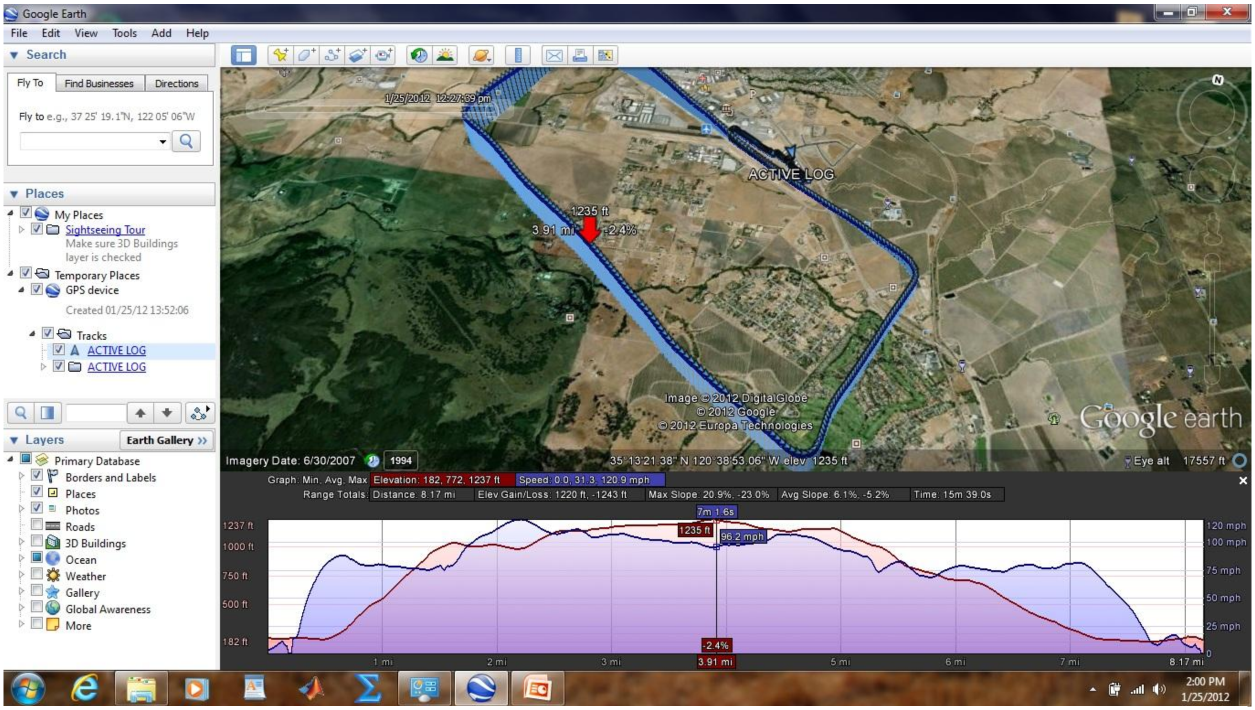


Figure 10. Google Earth presentation of RV 7 flight test while flying one traffic pattern

The next step is a comparison of the GPS receivers in the Smartphone and Garmin devices. Since the antennas are placed at different locations in the aircraft, a slight difference between the two receivers is expected. The latitude and longitude from both devices is plotted on top for comparison and shown in Fig. 11. The Garmin GPS tracked the path correctly without any problems. The Smartphone's receiver had major trouble tracking when the aircraft engaged in a turn. Since the antenna in the Smartphone is located internally, when the aircraft banks the wing of the aircraft blocks a portion of the sky and disrupts the GPS signal. Because of these problems, it is recommended that the Smartphone is placed carefully within the aircraft in order to mitigate this problem.

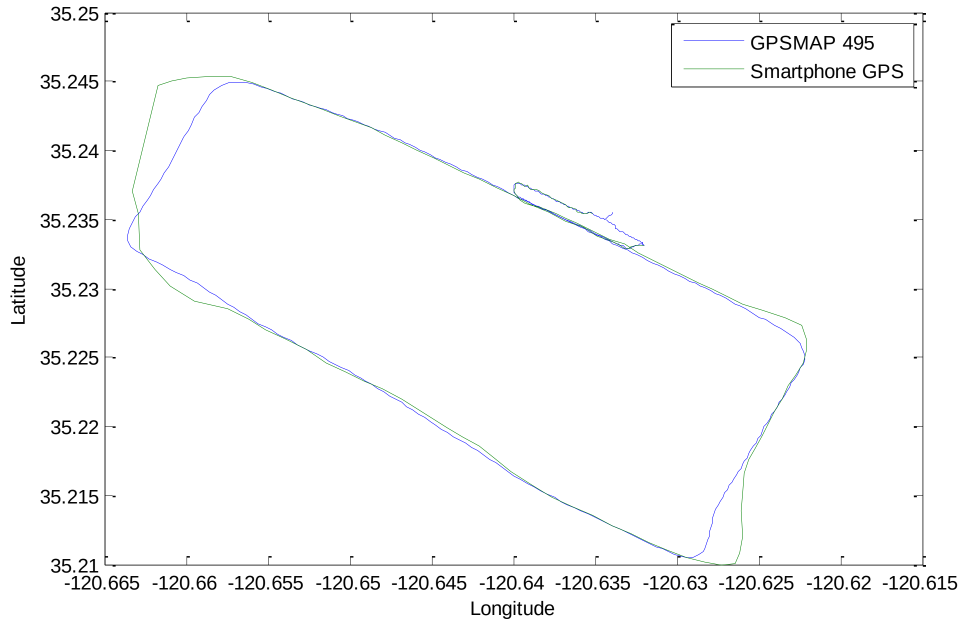


Figure 11. Latitude and Longitude of GPS receivers in the Garmin GPS and the Smartphone

Similarly, GPS altitude is compared and shows poorer performance from the Smartphone's GPS receiver as shown in Figs. 12 and 13 as the data from the Smartphone appears to be discretized. Intermittent loss of signal could cause the data to jump and be discontinuous. Also, this can be caused by similar reasons as mentioned before. GPS altitude alone is already hard to determine and usually inaccurate which makes the Smartphone's solution even worse. Based on these results, it is not recommended to use the Smartphone's GPS receiver to gather flight test data.

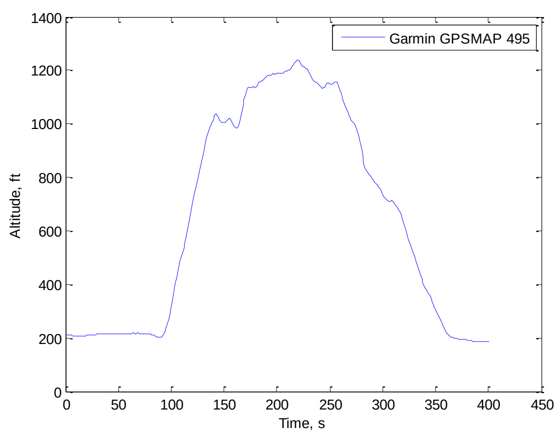


Figure 12. GPS Altitude for Garmin GPSMAP 495

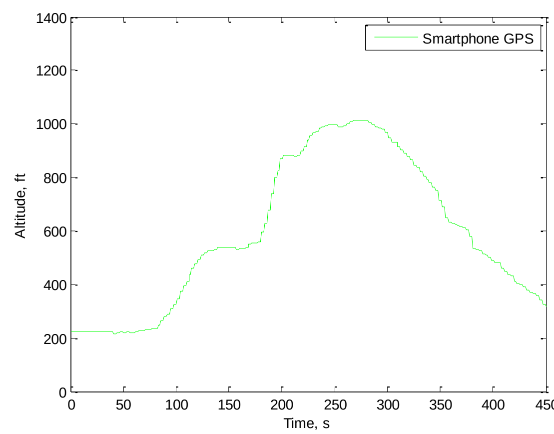


Figure 13. GPS Altitude for Smartphone's GPS receiver

Along with the GPS receiver, the Smartphone recorded information from the accelerometers and magnetometers to gather inertial data at a 10 Hz data rate. The results of the accelerometer data from the same flight are shown in Fig. 14. The results show extreme noisy data that is unacceptable. The worst noise occurs in the vertical acceleration. Although the average of the vertical acceleration occurs around 10 m/s and is expected since it was mostly a 1G flight, the sensor was not able to gain steady measurements within the flight. Engine vibration and unsteady flight conditions could create this range of accelerations. Likely the cause is the poor accelerometers themselves. Smartphone accelerometers are not designed for this type of task but rather to run simple applications to determine basic orientation of the device.

Similarly, the orientation sensors (magnetometers) are recorded on the Smartphone device. The results from the magnetometers on the same flight pattern are shown in Fig. 15. The data shows very noisy and undeterminable results. The orientation in the x-direction, which is similar to the magnetic heading, had a lot of interference during the first 100 seconds of the flight. It is expected that during the first 100 seconds, the orientation in x should be runway heading which is around 290 degrees. The results show the orientation around north, jumping between 5 degrees and 355 degrees.

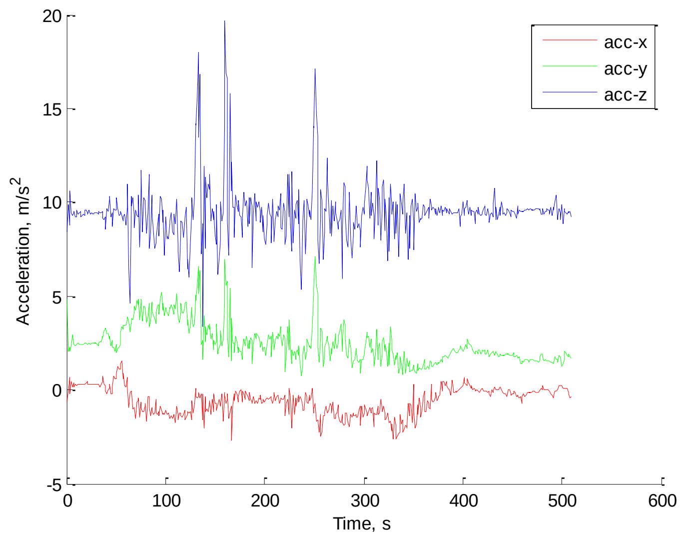


Figure 14. Accelerometer Data from flight test on Smartphone Device

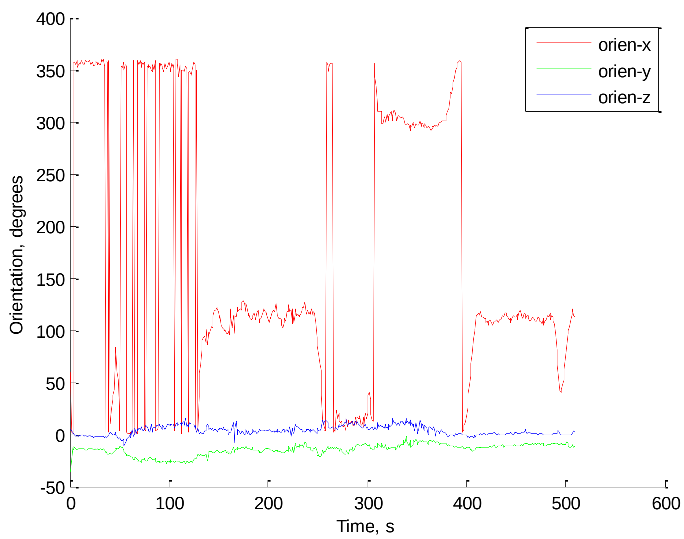


Figure 15. Magnetometer Data from flight test on Smartphone Device

B. RV 7 Flight test Comparing Garmin GPSMAP 495 and EFIS

During this flight, three traffic patterns are conducted at San Luis Obispo Regional airport. The data is collected using the RV 7 aircraft. Both the Garmin GPSMAP 495 and EFIS recorder are used. The data is recorded and displayed again using Google Earth as shown in Fig. 16.

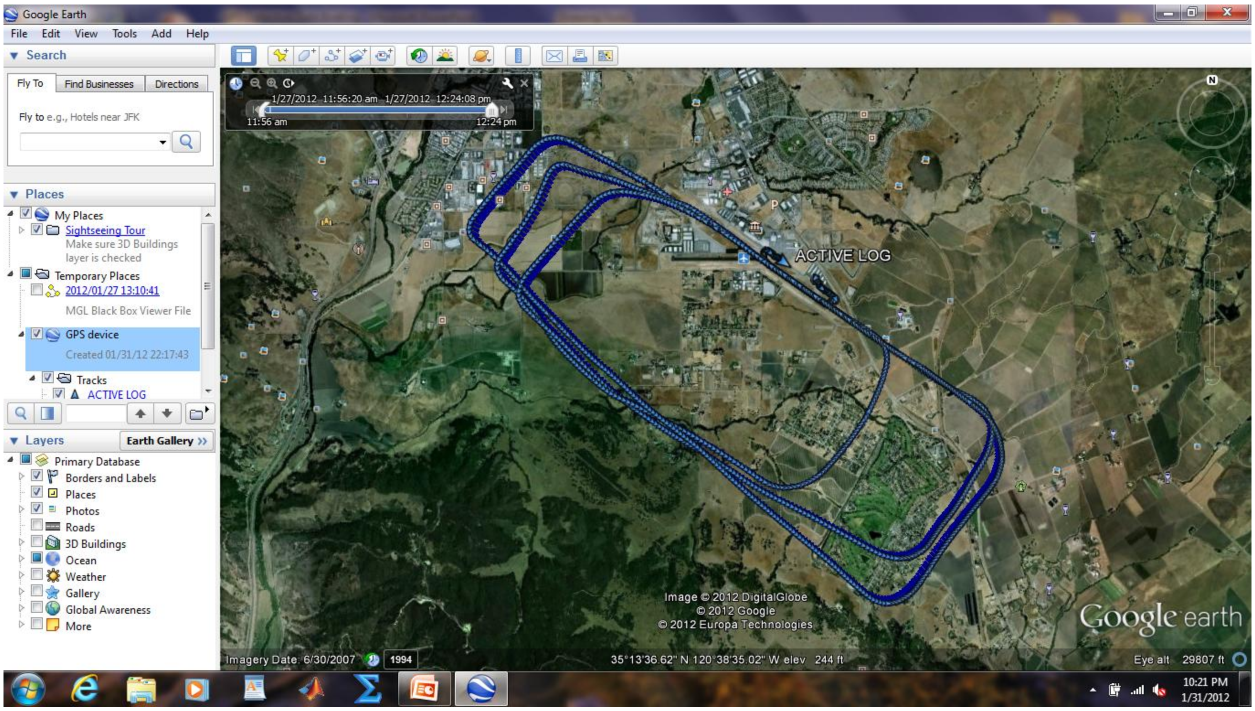


Figure 16. Google Earth presentation of RV 7 flight test while flying 3 traffic patterns

The GPS receivers on both the handheld GPS and the EFIS are compared and verified. Latitude and Longitude are plotted simultaneously for comparison. The results are shown in Fig. 17. Both devices track the flight quite well. The results from the EFIS GPS and Garmin are almost exactly the same. The slight differences between the two sets are due to antenna position. The Garmin GPS's antenna is located on the windshield and to the right

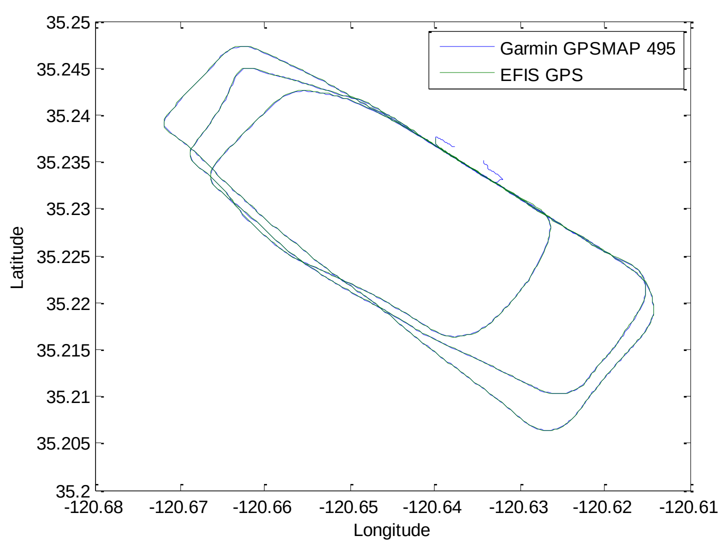


Figure 17. Latitude and Longitude of GPS receivers in the Garmin GPS and the EFIS

as shown in the procedure in Appendix A. The EFIS GPS's antenna is located along the centerline and on top of the dashboard of the aircraft. Although the distance between these two antennas is less than 3 feet, it can cause a small difference in the data. Unlike the Smartphone's GPS receiver, the EFIS GPS receiver is much more accurate and similar to the Garmin GPSMAP 495. Based on these results, it is recommended to use both to gather flight test data.

In order to line up the two data sets, serial time is used from the time stamps given from both methods. The results from this, using longitude, are shown in Fig. 18. It shows that the data does not match up with time. The cause of this could be that Garmin GPSMAP 495 does not take daylight savings time into consideration so the difference between the two are approximately 1 hour. In order to match up the data, this difference in time needs to be added or subtracted and then readjusted to line up. Once this is achieved, data lineup is possible. It is found that the exact difference between the EFIS GPS and the Garmin GPS is 1 hour 3 minutes and 37 seconds. This difference is converted into serial time and re-plotted. Figure 19 shows the new adjustment between the two data sets.

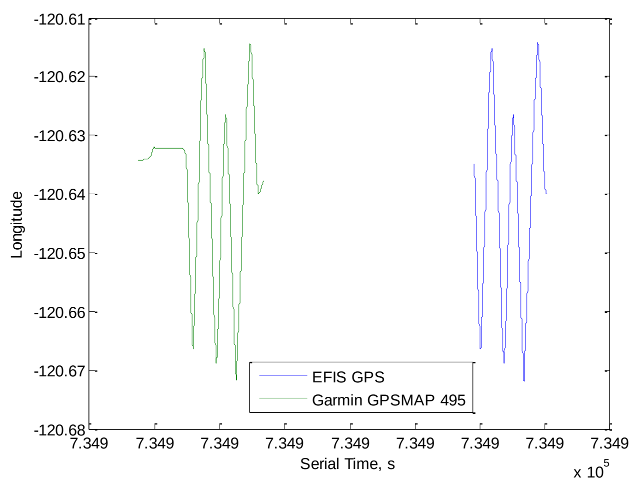


Figure 18. Time mismatch between EFIS GPS receiver and Garmin GPS

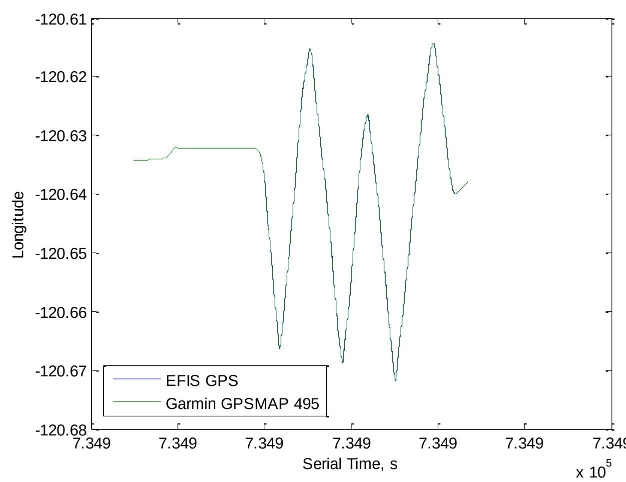


Figure 19. Time adjusted correctly between EFIS GPS receiver and Garmin GPS

The benefits of the EFIS recorder are that it is able to gather attitude data such as bank, pitch, and yaw angle from the AHRS. Form the same traffic pattern, this information is sub plotted and investigated as shown in Fig. 20. The results from this plotting are expected. Bank angle is correctly recorded as the RV 7 turns. The turns are performed at 2G and shown in the bottom subplot. The headings match runway heading, at or around 290 degrees, beginning at initial takeoff and through the 3 patterns unlike the Smartphone data. Pitch angle follows the pattern as well during all takeoffs and landings. Problems arose initially with the data because the AHRS was multiplying the

data by 10. To rectify this problem, these particular sets were then divided by 10. Although the data is at a 1 Hz recording rate, this data provides useful information on the attitude of the aircraft which is nonexistent with the GPS alone.

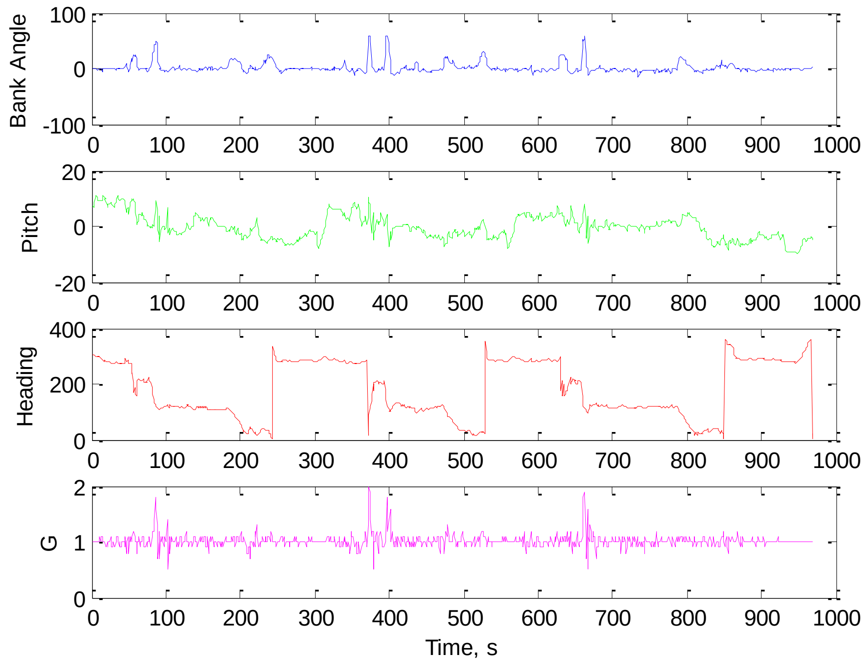


Figure 20. Example of some AHRS data from EFIS while performing 3 traffic patterns

V. Conclusion

Although the results from the flight test data is limited to the 1 Hz data rate, the information gained from using this system allows users to obtain data that is not available through manual handwritten methods. This system eases the extent of handwritten data within the aircraft and during the flight tests because of the automation of this flight recording data acquisition system. Data is not longer interpreted through human error which was all that was available initially. The data gained is valid and follows the flight quite well with the exception of the Smartphone device. The Garmin GPSMAP 495 is a versatile tool to track and provides adequate results to further reduce the data and gain ground acceleration and vertical speed. The RV 7's EFIS provides much more data that the handheld GPS alone and is recommended for use if the flight test requires attitude of the aircraft and air data. Although the Smartphone device provides much higher data rate than the Garmin GPS or the EFIS, the internal hardware is not up to par with this application. In conclusion, the Smartphone is not recommended for this application. As an

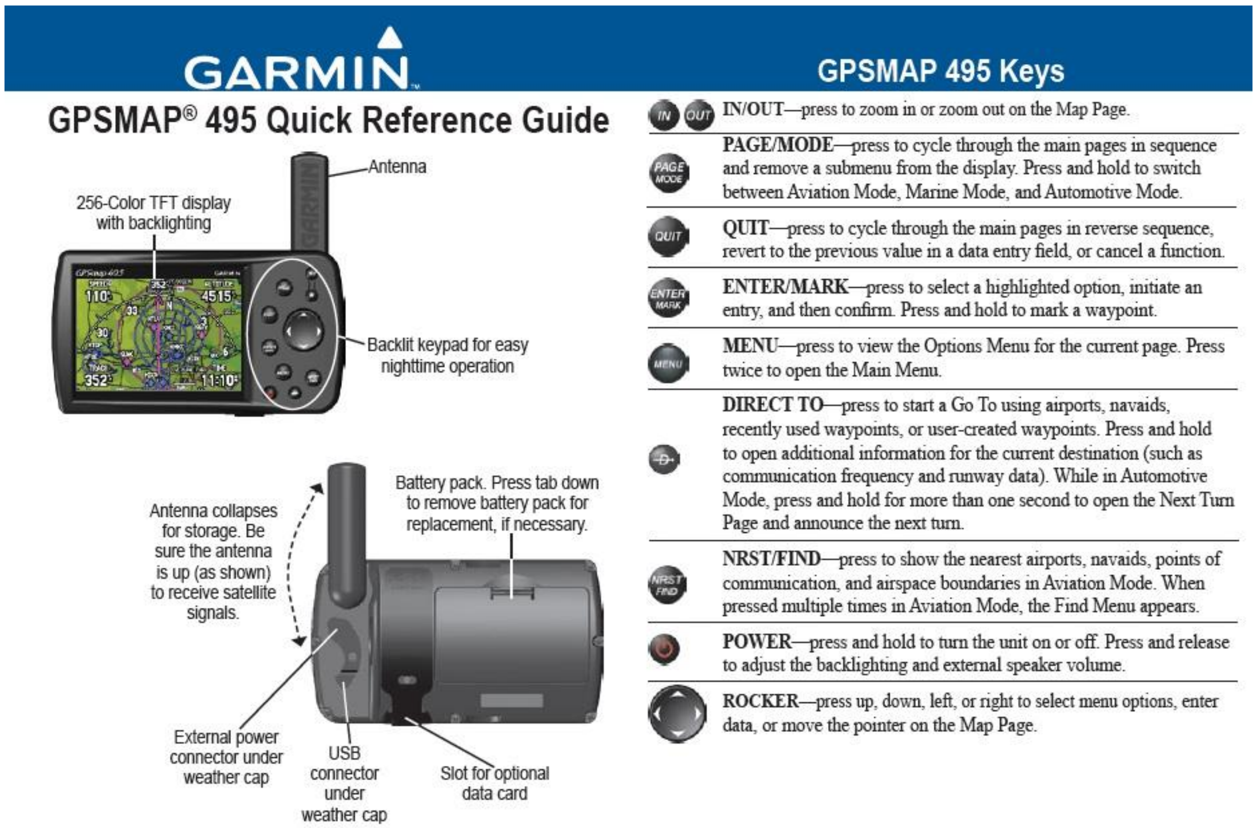
improvement, a more sophisticated recording system can be acquired to improve the 1 Hz limitation. Future suggestions would continue with this work and provide data interpolation and filtering to get differentiable values.

Appendix

A. Garmin GPSMAP 495 detailed procedure

Preflight Setup

Please see below for reference to the device



IN/OUT—press to zoom in or zoom out on the Map Page.

PAGE/MODE—press to cycle through the main pages in sequence and remove a submenu from the display. Press and hold to switch between Aviation Mode, Marine Mode, and Automotive Mode.

QUIT—press to cycle through the main pages in reverse sequence, revert to the previous value in a data entry field, or cancel a function.

ENTER/MARK—press to select a highlighted option, initiate an entry, and then confirm. Press and hold to mark a waypoint.

MENU—press to view the Options Menu for the current page. Press twice to open the Main Menu.

DIRECT TO—press to start a Go To using airports, navaids, recently used waypoints, or user-created waypoints. Press and hold to open additional information for the current destination (such as communication frequency and runway data). While in Automotive Mode, press and hold for more than one second to open the Next Turn Page and announce the next turn.

NRST/FIND—press to show the nearest airports, navaids, points of communication, and airspace boundaries in Aviation Mode. When pressed multiple times in Aviation Mode, the Find Menu appears.

POWER—press and hold to turn the unit on or off. Press and release to adjust the backlighting and external speaker volume.

ROCKER—press up, down, left, or right to select menu options, enter data, or move the pointer on the Map Page.

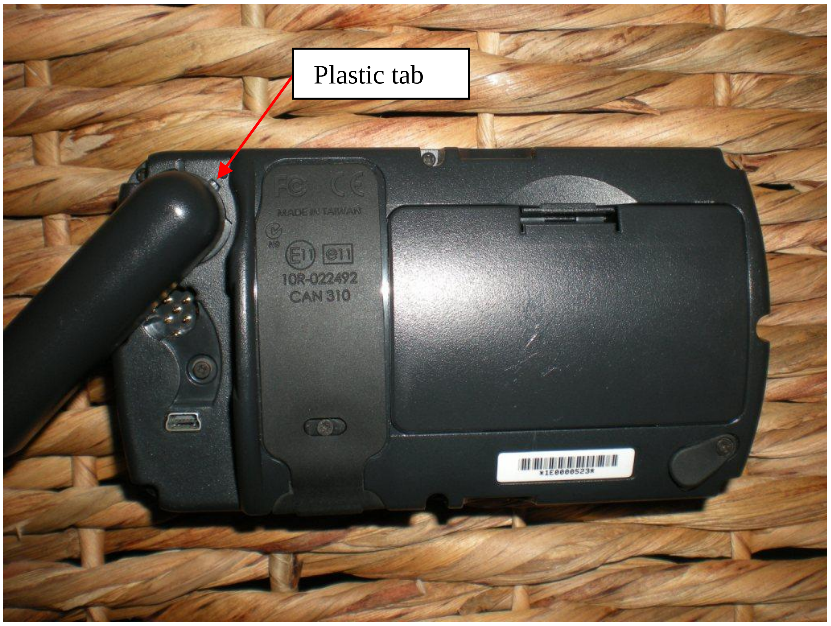
ADVISORY: Familiarize oneself with the device prior to flight testing. It is recommended to know how to use the GPS and how it works.

CAUTION: Do not turn GPS on until instructed to do so. This could cause GPS to search for an active signal when signal is obstructed, and results in longer time to get a lock-on. It is recommended to know how to use GPS simulation mode. Refer to GPS documentation GPS simulation

External Antenna Setup

Due to limited signal strength of the GPS, an external antenna is essential in order to get proper signal. It is highly suggested that you use this in every flight. The external antenna is shown below:

1. Turn the GPS onto the battery side and place the antenna between the 7 and 8 o'clock position
2. Insure the small plastic tab, located near the pivot, is shown to allow the antenna to be removed as shown below



3. Carefully pull the antenna up until antenna is removed
4. Attach external antenna to the GPS by attaching the external antenna connector onto the antenna stub on the GPS
5. Rotate slightly until it fits all the way in
6. Then rotate clockwise to lock into place as shown below

Preflight Data Setup and GPS Start Up

CAUTION: Ensure oneself outside when turning GPS device on and the external antenna is attached. Turning the GPS on in the hanger is not advised and will cause GPS to take much longer to get a satellite lock-on.

To ensure the correct data is recorded, clear the active track log from the GPS.

1. Turn the GPS on by pressing and holding the power button until the device beeps
2. Accept the Warning page by simply pressing the enter button
3. The GPS page is shown now; navigate 4 pages down via Rocker to the Tracks page
4. Navigate to the right and down via Rocker button to the "Clear" onscreen option and press enter

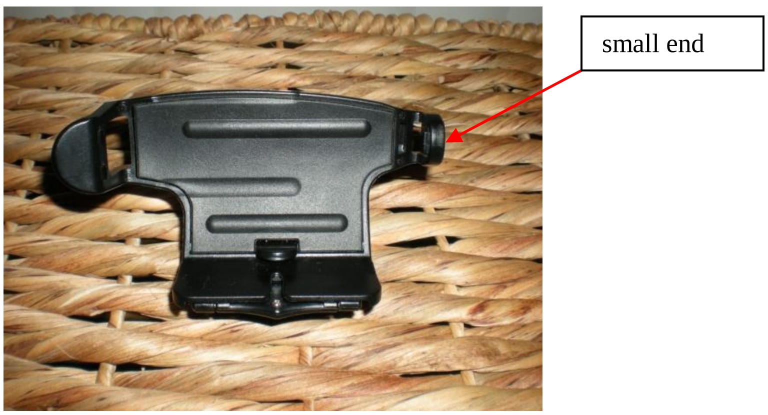
Note: The Active Track Memory Used should read 0%

RV 7: In Aircraft Operations

The following procedure will occur while in the RV 7 aircraft prior to takeoff. Ensure that the aircraft is outside the hanger and is visible for GPS satellites to lock on.

Things that you will need:

- Dash mount adapter for the GPS



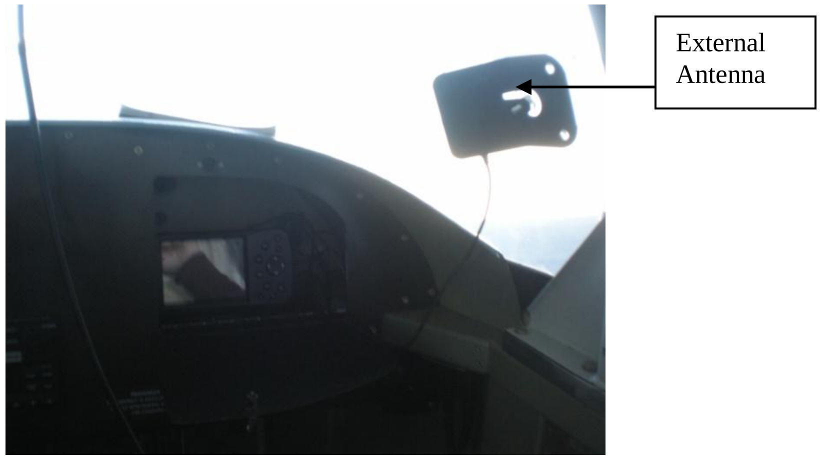
Begin Data Collection Procedure

Before you strap in:

1. Open glove box
2. Carefully place GPS onto dash mount adapter by hooking the small end of the dash mount adapter first then sliding large end around the GPS until it clicks: see picture above
3. Locate Garmin dash mount in glove box as shown below

4. Slide the device from right to left on the Garmin dash mount until it clicks
5. Ensure the device is visible and secure in place as shown below

6. Lock the Garmin dash mount by siding the lock switch from left to right
7. Place external antenna on the right flat part of the windshield via suction cups as shown below



8. Ensure satellite lock-on by navigating to the GPS page
9. Once lock-on is set, return to the tracks page
10. Ensure that the recording interval is set to 00:00:01 (1 per second data rate)

After you strap in:

11. Once engines on and about to taxi out, record flight by changing the record mode from “OFF” to “Fill” This will begin recording the flight
    a. The “Wrap” option is if you want the data to wrap over the old if memory if it fills. This will not be necessary for these flights.
    b. It uses approximately 11% of active memory for 20 minutes of recording

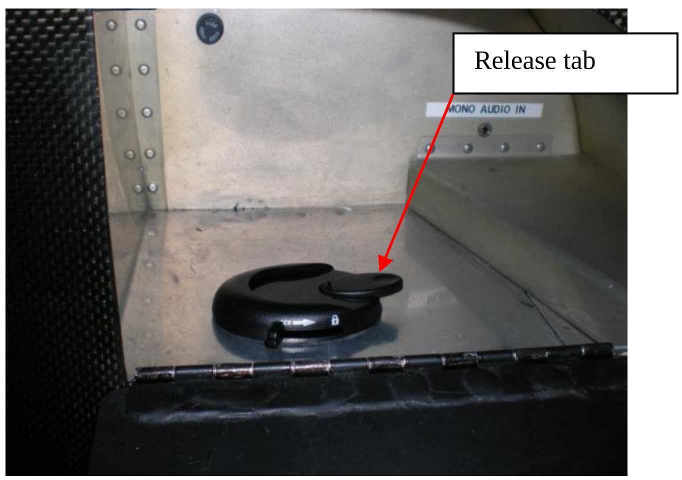
12. At the end of flight, set the record mode to “OFF” to stop the recording

CAUTION: Do not clear the **Active Track Memory** even if you save the Track! This clears useful speed data that is only available on Active Tracks

Post-flight Operations

CAUTION: Do not pull on external antenna to remove as it may break. Remove by de-suctioning the suction cups

1. Very carefully remove external antenna from window
2. Unlock GPS from the Garmin dash mount located in the glove box
3. Push and hold down on release tab and slide the GPS to the right to remove



Cessna 172: In Aircraft Operations

CAUTION: Ensure oneself outside when turning GPS device on and the external antenna is attached. Turning the GPS on in the hanger is not advised and will cause GPS to take much longer to get a satellite lock-on.

The following procedure will occur while in the Cessna 172 aircraft prior to takeoff.

Things that you will need:

- Yoke mount for the GPS

Begin Data Collection Procedure

Before you strap in:

1. Attach yoke mount to the yoke of the Cessna 172 as shown below

2. Secure GPS on yoke mount by hooking small end first and then slide large end until snaps
3. Place external antenna on flat part of the window as shown below

4. Ensure satellite lock-on by navigating to the GPS page
5. Once lock-on is set, return to tracks page

6. Ensure the recording interval is set to 00:00:01 (1 per second data rate)

After you strap in:

7. Once engines on and about to taxi out, record flight by changing the record mode from “OFF” to “Fill” This will begin recording the flight
   a. The “Wrap” option is if you want the data to wrap over the old if memory if it fills. This will not be necessary for these flights.
   b. It uses approximately 11% of active memory for 20 minutes of recording
8. At the end of flight, set the record mode to “OFF” to stop the recording

CAUTION: Do not clear the **Active Track Memory** even if you save the Track! This clears useful speed data that is only available on Active Tracks

Post-flight Operations

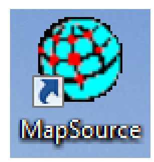
CAUTION: Do not pull on external antenna to remove as it may break. Remove by de-suctioning suction cups

1. Very carefully remove external antenna from window
2. Remove yoke mount

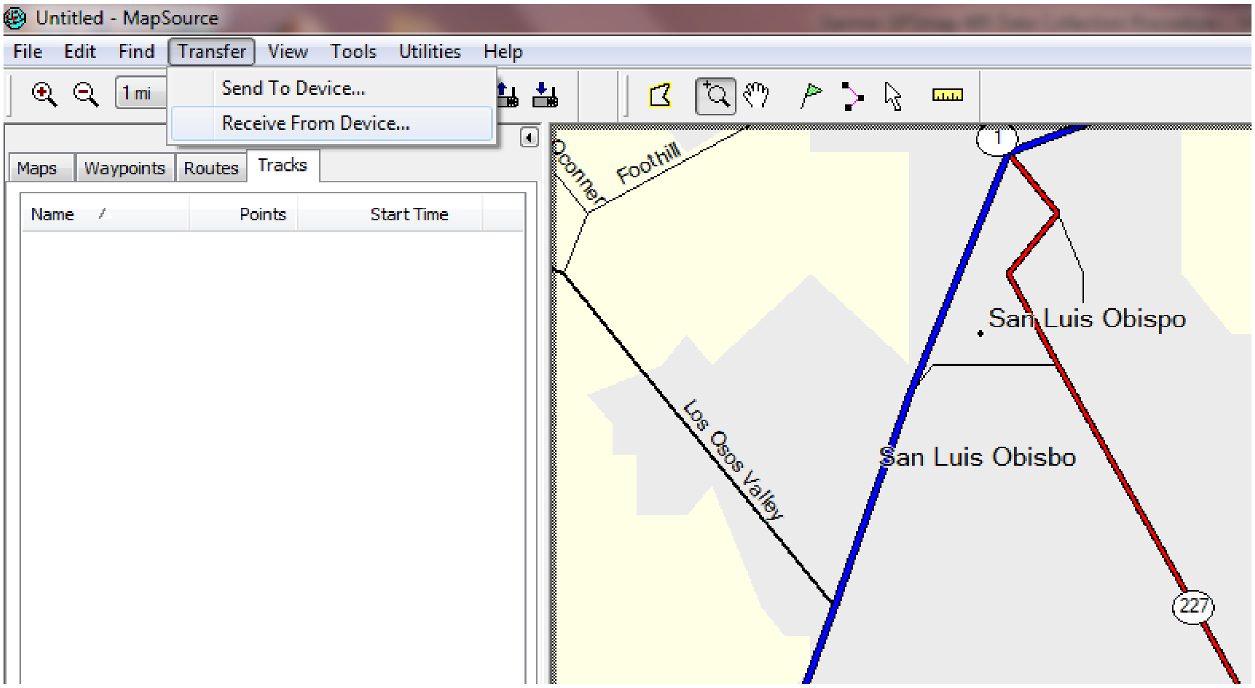
Data Recovery and Acquisition

Obtain data from the GPS device as soon as possible to ensure no loss of data. It is suggested that you obtain data within the hanger and send data to yourself.

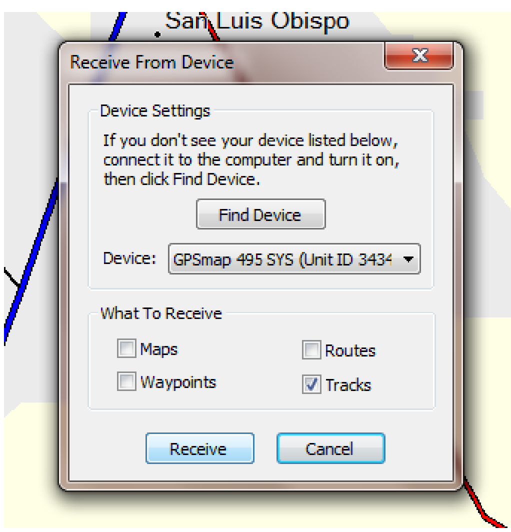
1. Connect the GPS to the USB cord and connect GPS to the flight test computer



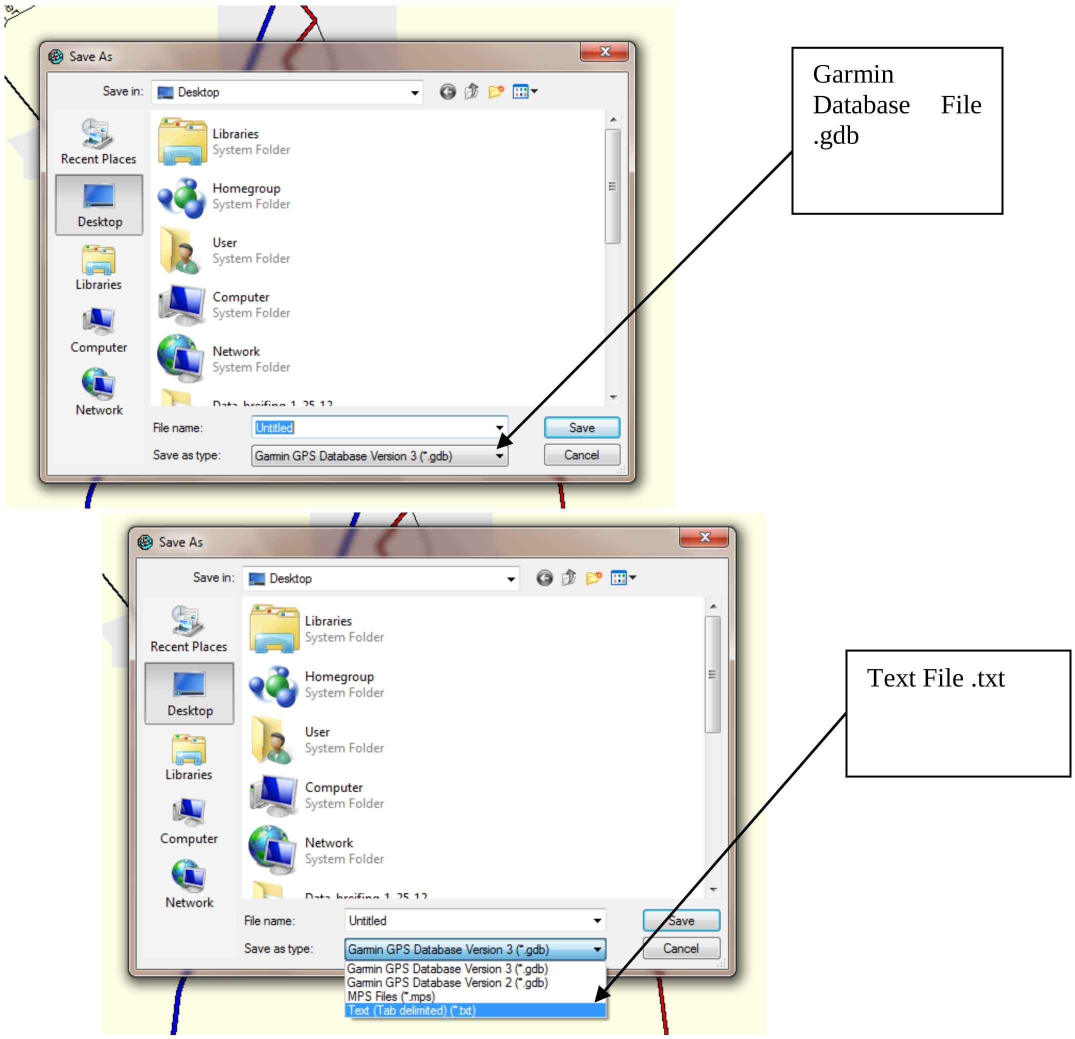
2. Open MapSource program located on the Desktop



3. Under Transfer menu, click on "receive from device"
4. Ensure GPSmap 495 is shown under "Device" and "Tracks" is selected and click on "Receive." GPS will beep when complete. See image below.



5. Save two files: a Garmin database file (.gdb) and a text file (.txt)



B. EFIS RV 7 detailed procedure

MGL Stratomaster Enigma EFIS Overview

All RV 7 flights are automatically recorded to the removable flash SD memory data card. The flight is recorded as soon as the engine RPM reaches 2,000. It stops when it drops below 2,000 for a period of time.

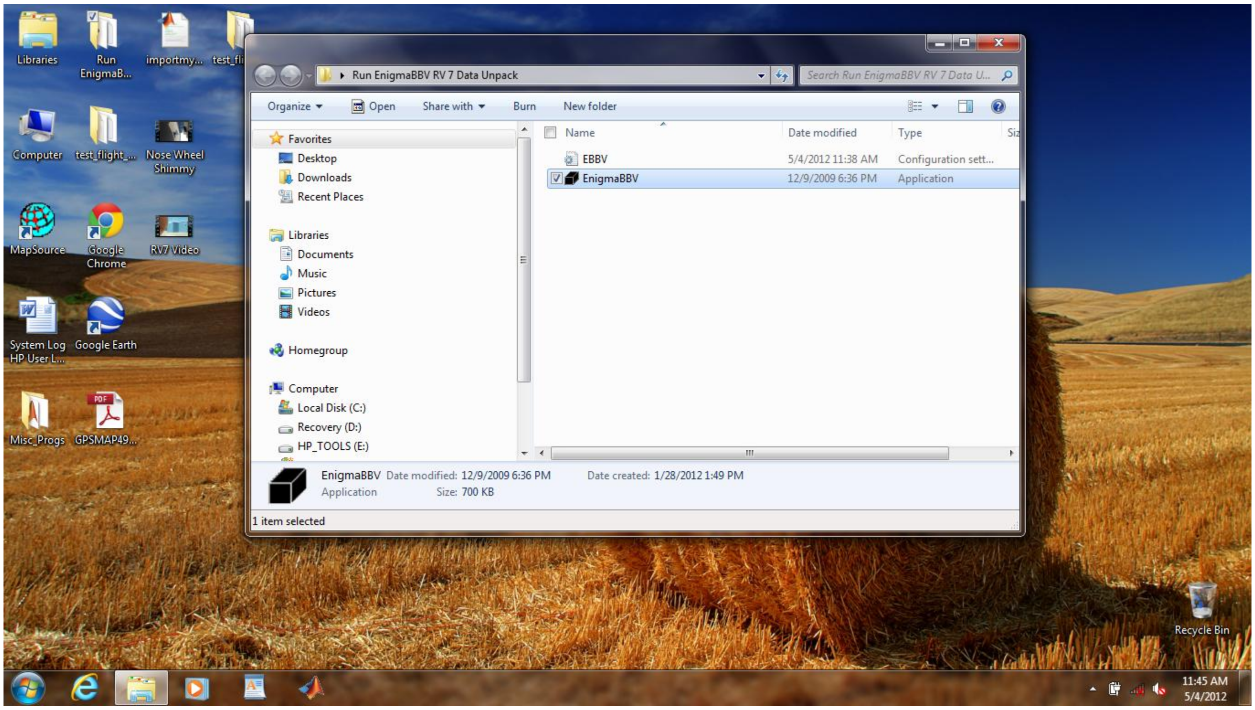
Note: No need to manually record RV 7 flights as it is recorded automatically to the SD data card.

Once flight has ended, obtain data from the RV 7 EFIS system as soon as possible to ensure no loss of data. It is suggested that you obtain data within the hanger and send data to yourself.

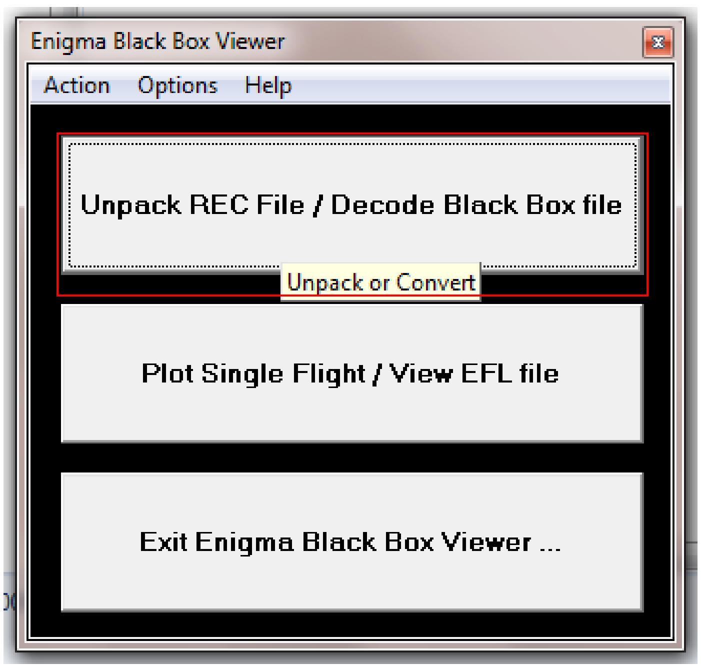
End of Flight Procedure

6. Remove data card from the EFIS system

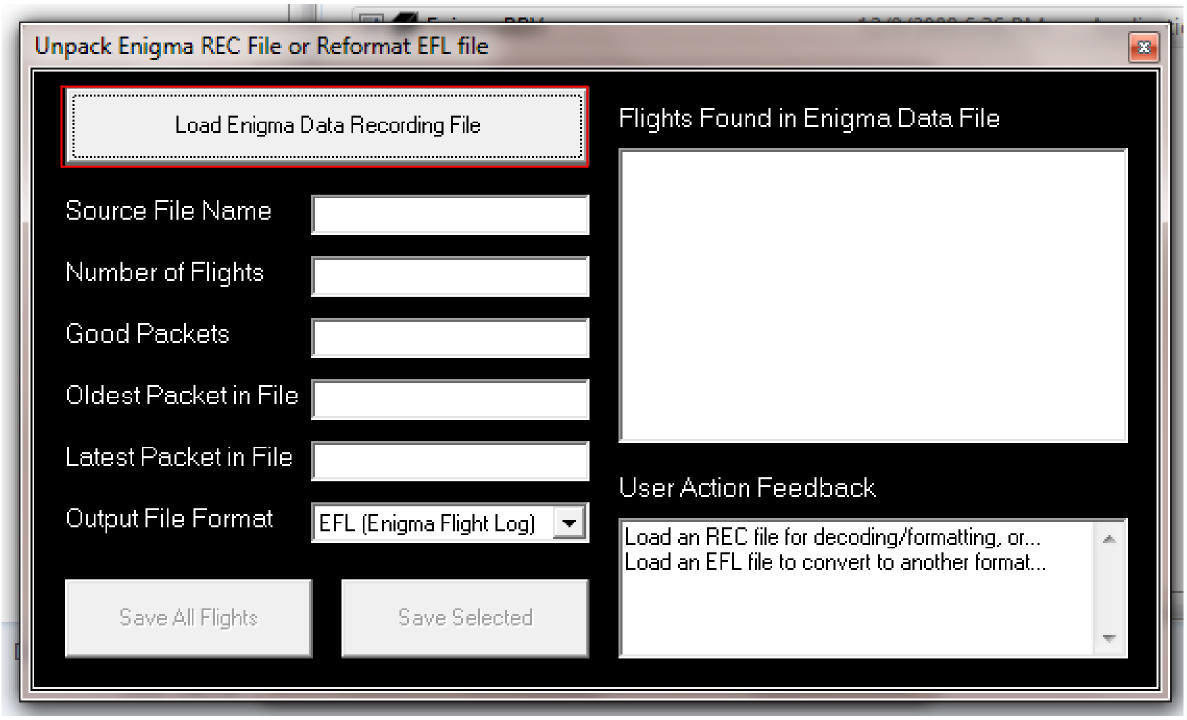
7. Insert SD card into SD card slot on flight test computer
8. Open the EnigmaBBV.exe application located in the Run EnigmaBBV RV 7 data unpack directory on the desktop



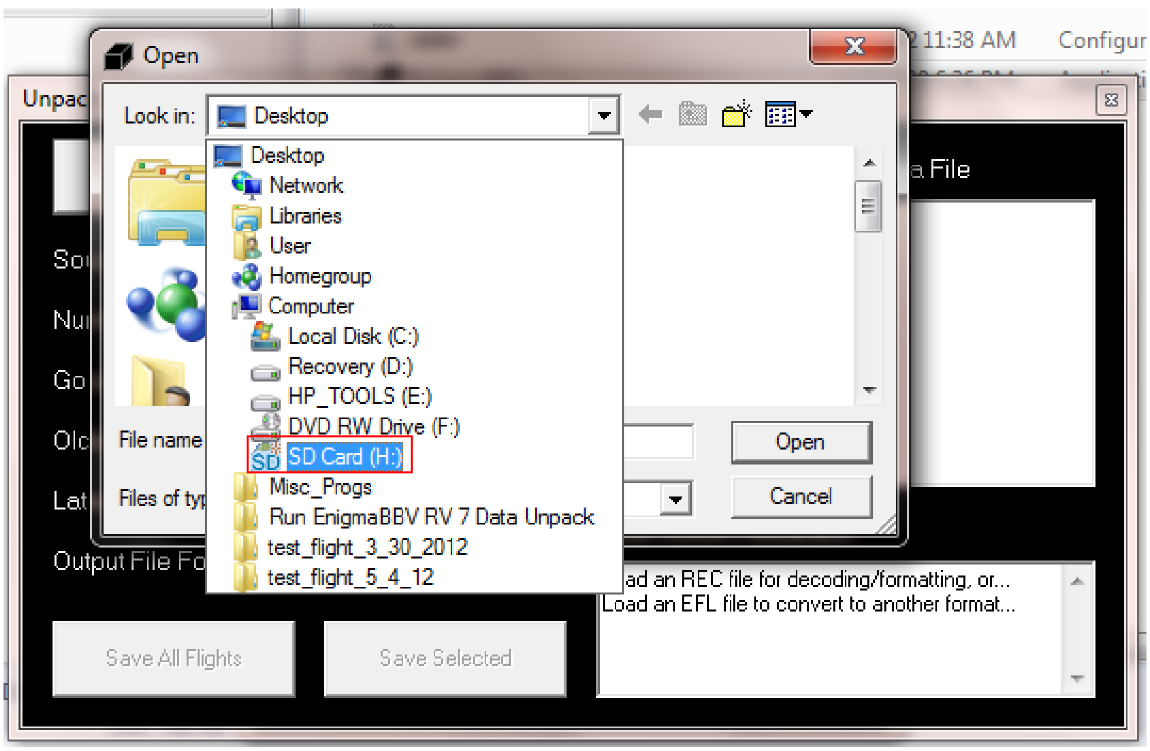
9. Once the Enigma Black Box Viewer is open, unpack REC file



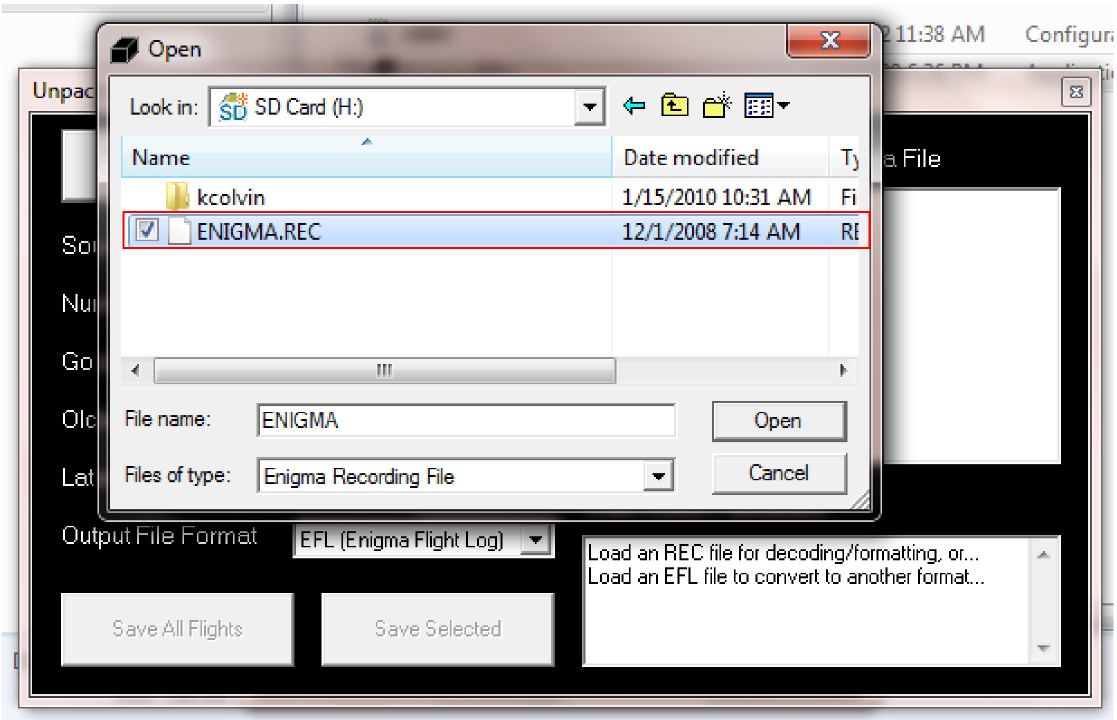
10. Load Enigma Data Recording File



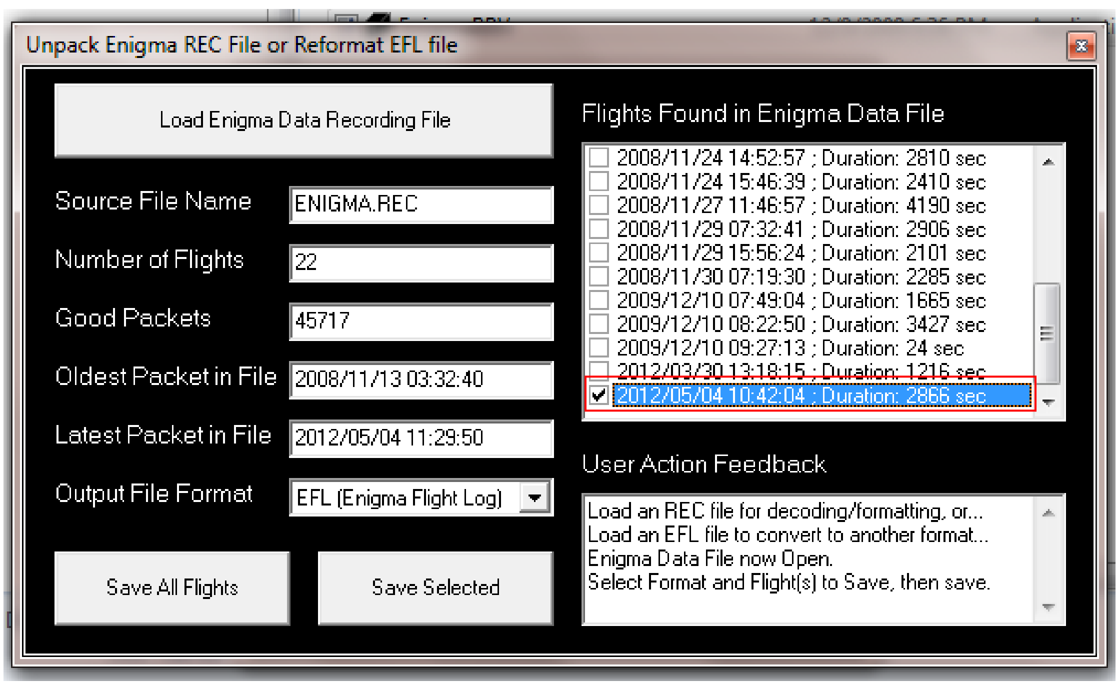
11. Change the directory to the SD Card (H:)



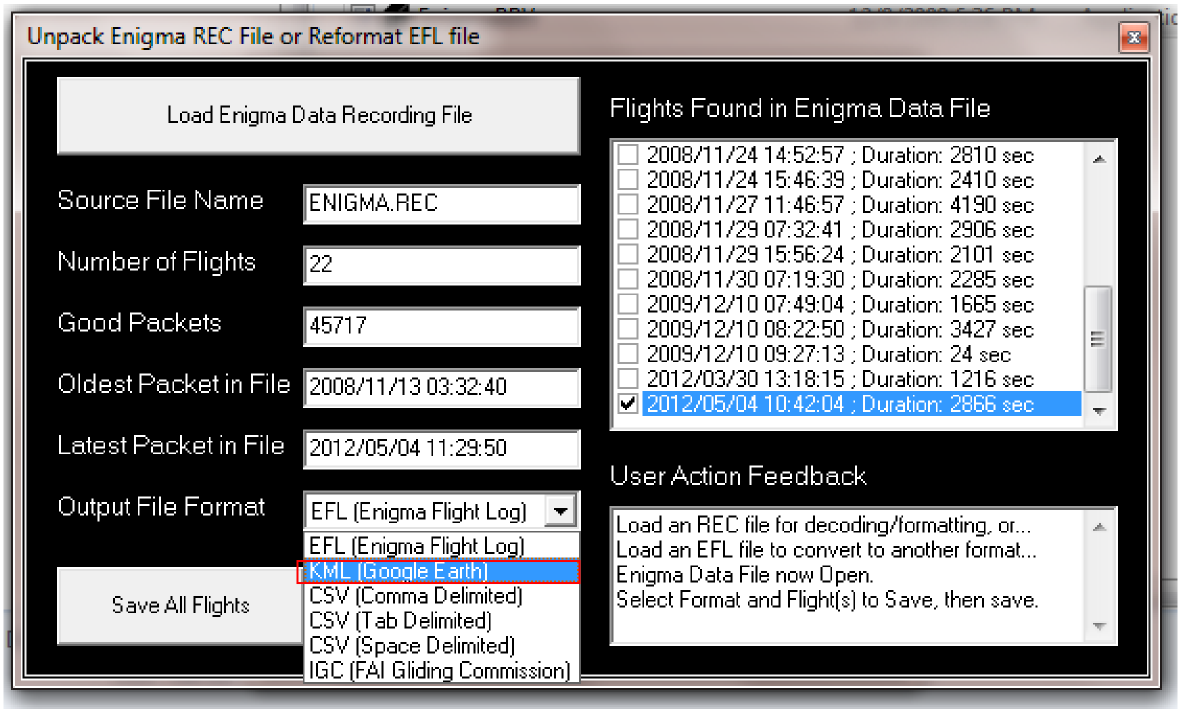
12. Select the Enigma REC file in the SD Card directory



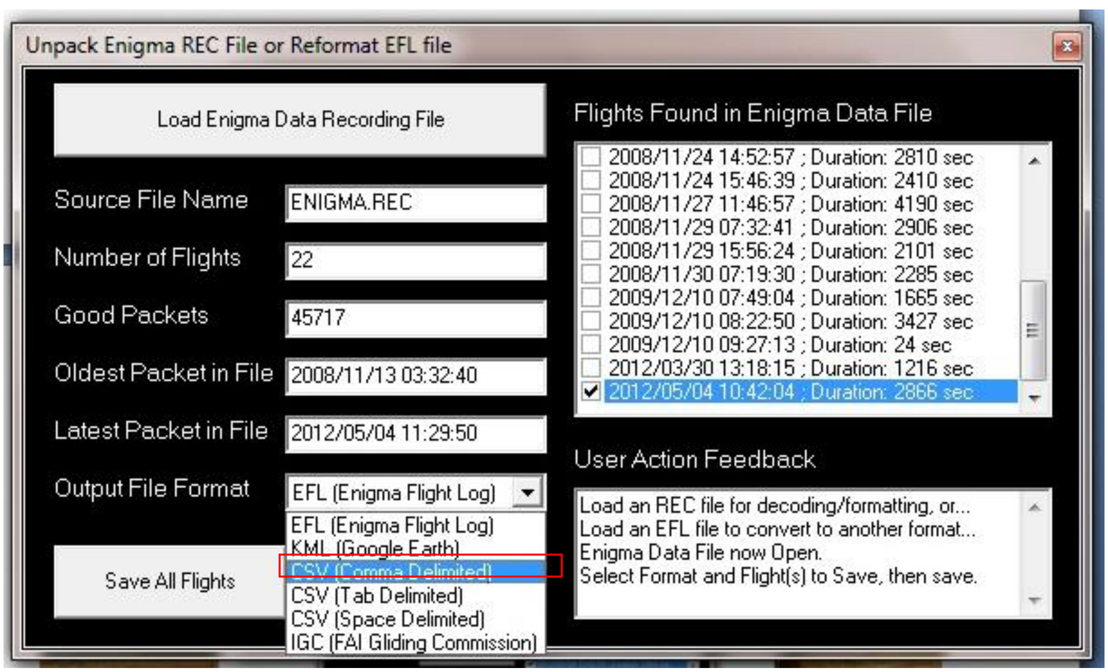
13. The Flights Found in Enigma Data File list will become populated and select your flight by date and time



14. Select KML (Google Earth) from the Output File Format dropdown menu and save the selected



15. Repeat steps 8 and 9 for and save CSV (comma delimited) file



C. MATLAB code for GPS text file

```matlab
function DATA = importmygps(txt_file)
%CHRISTOPHER GOCHA
%UPDATED Feb 6, 2012
%MATLAB FUNCTION FILE THAT IMPORTS THE GPS TEXT FILE TO SYBOLIC AND NUMERIC
DATA
%FOR FURTHER PROCESSING
%QUESTIONS? CGOCHA@CALPOLY.EDU ;
%YOU MAY CHANGE THE CODE IF YOU WISH

file=fopen(txt_file);  %<----Opens text file
C=textscan(file, '%s'); %reads in the file; creats a cell array of strings
Cnum=str2double(C{1,1}); %converts strings into numbers if possible
len=length(C{1,1});
%-----------------
%this loop indicates where the active log starts in the file
for i=1:len
    if strcmp(C{1,1}{i,1},'ACTIVE')
        ind=i;
        break;
    end
end
%------------------
%stores basic information about the log into the data structure
DATA.date=C{1,1}{ind+2,1};
DATA.startime{1,1}=C{1,1}{ind+3,1};
DATA.testlength{1,1}=C{1,1}{ind+5,1}; %ft
DATA.totaldistance(1,1)=Cnum(ind+6,1); % mi
DATA.avgspeed(1,1)=Cnum(ind+8); % mph
%------------------
%indicates the headers of the gps data
for i=1:5
    DATA.headers{1,i}=C{1,1}{ind+10+i,1};
end
j=6;
for i=7:2:13
    DATA.headers{1,j}=C{1,1}{ind+10+i,1};
    j=j+1;
end
%------------------
%the next series of loops gathers further information and stores data
%------------------
%obtains position lat and long in cell array format
j=1;
int=17;
n=ind+35;
for i=n:int:len
    if strcmp(C{1,1}{i,1}(1),'N')

DATA.lat(j,1)=str2double(C{1,1}{i,1}(2:3))+str2double(C{1,1}{i+1})/60;
    else
        DATA.lat(j,1)=-
(str2double(C{1,1}{i,1}(2:3))+str2double(C{1,1}{i+1})/60);
    end
    if strcmp(C{1,1}{i+2,1}(1),'W')
        DATA.lon(j,1)=-
(str2double(C{1,1}{i+2,1}(2:4))+str2double(C{1,1}{i+3,1})/60);
    else
```

```
DATA.lon(j,1)=(str2double(C{1,1}{i+2,1}(2:4))+str2double(C{1,1}{i+3,1})/60);
    end

DATA.positions(j,:)={C{1,1}{i,1},str2double(C{1,1}{i+1}),C{1,1}{i+2,1},str2do
uble(C{1,1}{i+3,1})};
    j=j+1;
end
%----------------
%time stamp string in 12 hour format HH:MM:SS
n=ind+40;
j=1;
for i=n:int:len
    DATA.time{j,1}=C{1,1}{i,1};
    j=j+1;
end
%----------------
%altitude, in ft
n=ind+42;
j=1;
for i=n:int:len
    DATA.altitude(j,1)=Cnum(i,1);
    j=j+1;
end
%-----------------
%length of segment, in ft
n=ind+44;
j=1;
for i=n:int:len
    DATA.length(j,1)=Cnum(i,1);
    j=j+1;
end
n=ind+46;
j=1;
%-----------------
%time length of the segment in seconds
for i=n:int:len

DATA.legtime(j,1)=str2double(C{1,1}{i,1}(3:4))*60+str2double(C{1,1}{i,1}(6:7)
);
    j=j+1;
end
%-----------------
%average speed in the segment, mph
n=ind+47;
j=1;
for i=n:int:len
    DATA.speed(j,1)=Cnum(i,1);
    j=j+1;
end
n=ind+49;
j=1;
%-----------------
%locates, removes ° character, and changes the course to numeric;
%units are degrees
for i=n:int:len
    k=1;
```

```
    temp=' ';
    while ~strcmp(C{1,1}{i,1}(1,k),'°')
        temp(1,k)=C{1,1}{i,1}(1,k);
        k=k+1;
    end
    DATA.course(j,1)=str2double(temp);
    j=j+1;
end
%------------------
%This loop sums the individual segment times and indicates the time after
%the log began in seconds,time 0 - test time
DATA.inctime(1,1)=DATA.legtime(1,1);
for i=2:length(DATA.time)
    DATA.inctime(i,1)=DATA.inctime(i-1,1)+DATA.legtime(i,1);
end
%------------------
%Creating a serial time vector
d=date;
for i=1:length(DATA.time)
    DATA.serialtime(i,1)=datenum(DATA.date)+(datenum(DATA.time{i,1})-
datenum(sprintf('1/1/%s',d(8:11))));
end
fclose(file);
clear C Cnum ans i ind int j len n file temp k
```