5 Flight Tests

5.1 Overview

A long series of flight tests were conducted to develop the major components of the Glidersonde and to demonstrate the viability of the basic concept. Initially the project planners had envisioned developing this navigation system in two steps:

1. Constructing a breadboard navigation system by laying out the components on an “iron bird” and using a ground vehicle to transport this layout in an open area thus allowing the very basic functions of the navigation algorithm to be checked.

2. Placing the navigation system in a prototype Glidersonde that had a dual control system as described earlier in this report and fine tuning the navigation parameters.

It became obvious, after the first couple of glider tests, that a third intermediate stage was needed to speed the development phase of the project. This new second phase was conducted using powered aircraft that were about the same size and flying characteristics as the Glidersonde. During this new second phase of the project, several different aircraft were used for flight tests. Some of these aircraft were powered by small two cycle engines and are discussed in section 5.2. The final set of fight test were conducted with the Glidersonde lifted aloft by a helium filled balloon and these test are documented in section 5.3.

5.2 Powered Flight Tests

During the development of the computer navigation system, several different powered small aircraft were used to test different aspects of the system. These aircraft ranged in wing span from 60 to 100 in (1.5 to 2.5 m) and were powered with two-cycle engine ranging in displacement from 0.40 to 3.2 cu in (6.6 to 52.0 cc). In nearly all of these flights, the aircraft was primarily under the control of the ground-based pilot. Control would be turned over to the computer navigation system during the flight for relatively short periods of time at first extending to longer periods near the completion of this phase as the navigation system matured.

Using powered aircraft increased the flexibility of the flight test program because of the reduced operational costs and the reduced exposure of the aircraft to damage. Although the vibration environment in a powered aircraft placed severe demands on the electronics, it also served to help the research team learn how to harden the system.

Because the telemetry system was very susceptible to vibration and noise in the powered aircraft, it was not used for most of the powered flight tests. Feedback on the performance of the navigation system was obtained by visually observing the flight. Consequently, most of these flights were restricted to a distance within the visual acuity of the investigators, approximately 500 meters.

The powered test fell into two categories:

1. Navigation system tests
2. Balloon release system tests

The navigation tests were conducted by manually flying the powered aircraft to a starting point, usually as far away from the pilot as visual acuity would allow, and then relinquishing control to the navigation system. Success was generally measured by whether or not the vehicle would turn and return home which was set at the point of origin of the flight. Many of these tests were conducted to observe how the navigation system performed under various wind conditions and various starting locations relative to home.

Other powered tests were conducted to verify that the on-board altimeter and the computer would measure the altitude and release the balloon mechanism at the appropriate time. The balloon release was made visible to ground based observers by attaching a paper streamer to the mechanism (in place of the balloon) and then flying the aircraft to higher and higher altitudes. Although the observers estimation of the actual release altitude was crude, it did serve a useful purpose in the project.

The last powered test conducted was a two-mile (3.2 km) flight to a home location. This test was conducted by manually flying the aircraft to about a 400 foot altitude, adjusting the throttle for a very gentle climb, heading the aircraft intentionally away from home, and turning control over to the computer. The craft successful turned around and navigated to the distant home location. It arrived at the home location well in advance of the observation team, due to significant tail winds, and was seen circling around the target location. At this point in the project, the team felt the navigation system was ready to be placed in a glider for final testing and demonstration.

5.3 Balloon Powered Flight Tests

Flights tests of the Glidersonde prototype were conducted over about a two-month period from the middle of March to the middle of May 1999. The craft used was that described in section 3 of this report.

The flight tests that were conducted by launching the Glidersonde with a helium filled balloon are listed in Table 5-1. The first six tests listed, conducted on April

27, had an altimeter on-board but the altimeter data was not telemetered down to the ground station; hence, it was not recorded

Table 5-1 Balloon Launched Glidersonde Flight Tests

No	Date	Flight No	Max Range [m]	Max Altitude [ft]
1	4/27	1	300	Not recorded
2	4/27	2	500	Not recorded
3	4/27	3	850	Not recorded
4	4/27	4	315	Not recorded
5	4/27	5	150	Not recorded
6	4/27	6	700	Not recorded
7	5/7	1	400	1000
8	5/7	2	580	1500
9	5/7	3	400	1500
10	5/7	4	550	2150
11	5/10	1	1000	2400
12	5/10	2	700	2500
13	5/11	1	400	2400
14	5/11	2	920	3300
15	5/11	3	350	5200
16	5/11	4	300	4300
17	5/12	1	1400	3100
18	5/12	2	2200	5100
19	5/12	3	3040	7650

A complete data set from all of these flights is shown in Appendices A and B. Some of the highlights are discussed in this section.

In every one of the tests conducted with the Glidersonde, the navigation system has performed as intended. A typical if short flight is illustrated in Figure 5-1. This figure shows a screen capture of the display of the GSDataCapture program which plots the XY coordinates of the flight path as telemetered down to the ground station. During the flight, this display shows the current location of the glider. The text in the upper left hand corner of the display shows latest data telemetered to the ground along with the maximum altitude recorded for this flight and the home coordinates. The altitude and processor voltage had not yet been added to the telemetry data show those fields are blank in this display.

The current position of the glider is shown in the display as the small X drawn on the screen. The inset in the lower left-hand corner of Figure 5-1 identifies the features shown at the current location. The small drawn from the X visually shows the aircraft heading at this position, in this case, 334 deg. The line drawn toward the bottom of the inset is the path.

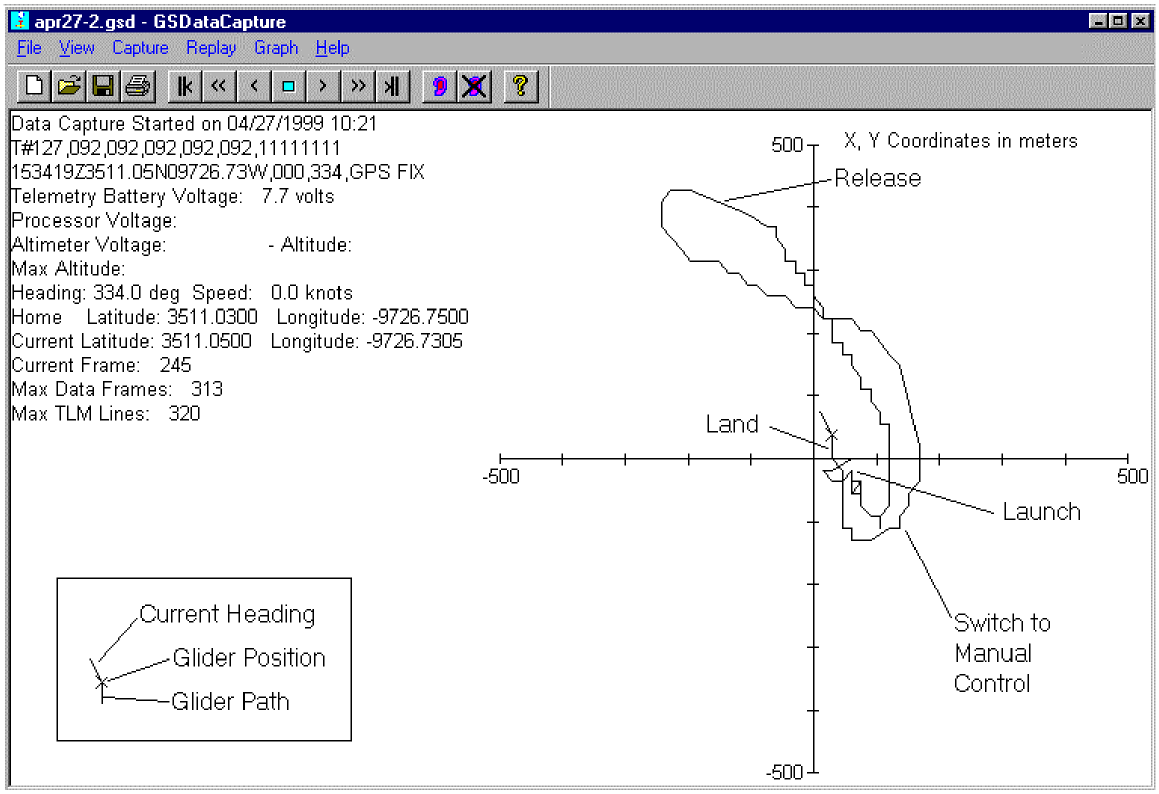

Figure 5-1 Sample Flight Path Data for April 27, Flight 2 Data

Annotations have been added to the plot in Figure 5-1 to show the major events in the flight. These events are somewhat difficult to see in the static display but are very evident when the real-time display or a replay of the flight is seen. After the balloon was launched, it drifts SSE for as few seconds and then moves directly North and then NNW. The balloon was separated from the balloon about 400 m North and 150 m West of the home location. The release altitude for this flight was set for 1000 ft, and, although the altimeter data was not being telemetered to the ground, this release altitude was confirmed visually. The navigation computer then executed a left turn and pointed the vehicle toward home. The craft flew a portion of a circular path around home until, at the point indicated, the pilot assumed control and landed the glider.

This same pattern is seen in all of the path displays shown in Appendix A. In some cases, if the altitude is high when the glider reaches home, the path will show many circles around home. See the May 11, Flight 3 display for an example of this. The path for the third flight on May 12 shows an ascent phase that starts out due South and changes to SE at a location 2 km from home. When the craft separates from the balloon, it first heads SSW and then turns right to an almost Northerly path. Because there was a slight cross wind, the path arcs to the West, but the glider returned home and then circled around home until it was landed.

A sample of the altitude data as a function of time is shown in Figure 5-2. Although there is considerable scatter in this data, the trends are clear. The rate of ascent and descent can be determined from this plot. Linear regression lines were calculated and are shown on the plot.

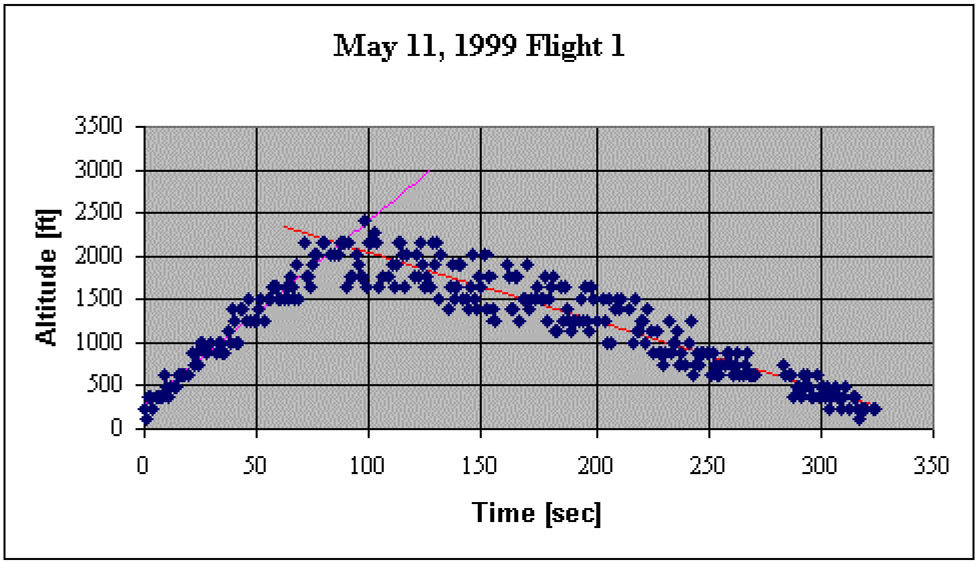

Figure 5-2 Sample Altitude Data for Flight 1 on May 11

A plot of the vehicle speed as a function of time is shown in Figure 5-3. There are several revealing features seen in this plot. Since the altitude is increasing linearly with time for the ascent phase, the first part of the plot, t=0 to t=85 sec, shows the variation of wind speed with altitude. The rapid increase in speed at t=85 sec signals the separation from the balloon. The speed peaks at 50 knots and then drops off rapidly as the vehicle turns upwind. From t=100 to t=130 sec, the vehicle is moving directly into the wind toward home and the average ground speed during this part of the flight is 17-18 knots. At t=130 sec, the glider has reached home and it executes a 360 deg turn that takes about 90 sec to complete. During this turn the average vehicle speed is (17+45)/2 = 31 knots which equals the air speed of the glider. The average wind speed is (45-17)/2 = 14 knots.

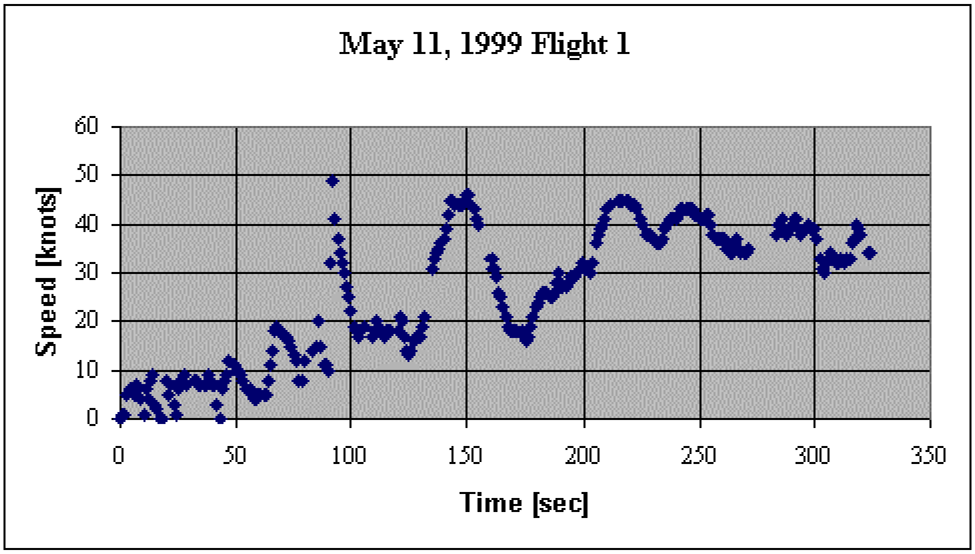

Figure 5-3 Sample Speed Data for Flight 1 on May 11

A sample of heading data from flight 1 on May 12 is shown in Figure 5-4. Here the speed is plotted as a function of heading. The ascent part of the flight is represented by the cluster of points around 200 deg, 20 knots. This shows that the winds were mostly out of the North or NNE and were averaging 20 knots. The descent part of the flight is shown by the points ranging in speed from 20 knots to 70 knots and spanning all headings. Two turns are evident from this plot and the average vehicle air speed is about (65+25)/2 = 45 knots.

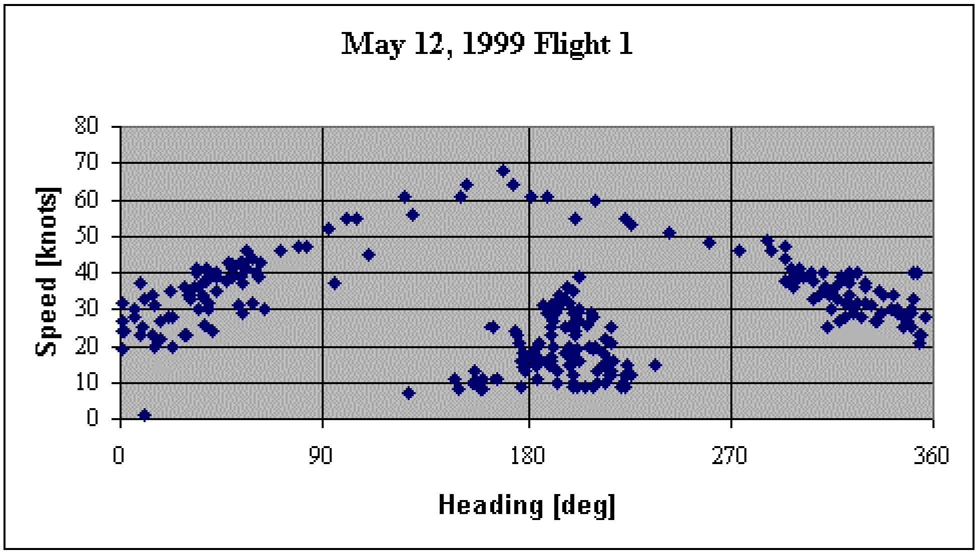

Figure 5-4 Sample Heading Data for Flight 1 on May 12