NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Washington, DC

May 6, 1999

Silkair MI185 Simulation Study

A. ACCIDENT

Location:	Palembang, Indonesia
Date:	December 19, 1997
Time:	0913 Coordinated Universal Time (UTC)
Aircraft	Boeing 737-300
NTSB#	DCA98RA013

B. GROUP

Group activity was limited to report review.

C. SUMMARY

On December 19, 1997, a Silk Air B-737-300, registration 9V-TRF, was en route from Jakarta, Indonesia to Singapore at 35,000 feet (ft) mean sea level (msl), when it disappeared from the radar screen and crashed at the mouth of a river about 33 miles northeast of Palembang, Indonesia. The 7 crewmembers and 94 passengers on board received fatal injuries and the airplane was destroyed. The government of Indonesia is conducting the ongoing investigation of the accident. The Safety Boards is participating in the investigation under provision of Annex 13 to the International Convention on Civil Aviation.

D DETAILS OF INVESTIGATION

Introduction

Neither Flight Data Recorder (FDR) nor Cockpit Voice Recorder (CVR) information was available for the time of Silk Air MI185's descent. Prior to the cessation of the recording, the FDR recorded a normal cruise at 35000 ft. Radar data showed that this cruise continued for a time before the beginning of a rapid descent and departure from normal flight.

In addition to the radar data, the accident location is known. Further, examination of the wreckage showed that the stabilizer was at 0.5 deg nose down at impact. This is the main trim flaps up limit. The power setting was above 90% n1 max at impact.

Several pieces of the horizontal tail were found separate from the main wreckage. Both a trajectory analysis and a flutter analysis indicated that these pieces separated from the main wreckage late during the decent. Depending on the tail loading during separation, this could produce an abrupt change in pitching moment that could be modeled as an abrupt change in stabilizer angle.

It is not possible to determine unique flight control time histories during the departure based on the limited data available. However, it is possible to explore control time histories that do match available data and eliminate several hypothetical scenarios that do not.

Procedure

Simulations were conducted with the Safety Board's 737-300 NT workstation based simulation. These simulations were all started at 09:12:01 from the following trim state using an estimated weight of 109920 lbs. and an 18% center of gravity.

Altitude	35000 ft
Airspeed	251 kts
Heading	340 deg
Control Column	1.59 deg
Level Flight	

A trim to this state produced the following results:

Pitch Angle	3.591 deg
Stabilizer Angle	-1.064 deg
Elevator	1.884 deg
N1	47.91 %

This trim state assumes, as indicated by the radar data, that the aircraft maintained a steady cruise from the last FDR record to the beginning of the departure.

Winds

Winds used in this simulation study are summarized in the following table. Data from the surface to 12000 ft came from a balloon launched from Palembang. Data for higher altitudes was obtained from the Medium Range Forecast Model [MRF] 12/19/97 1200Z. The data was obtained from a NTSB weather specialist using McIDAS. The accuracy of these input winds will impact the ground track (the overhead map and the East and North vs time plot). There will be a minor secondary affect on the aircraft dynamics.

Altitude (ft)	Wind Direction (Deg)	Wind Speed (knots)
0.	10.	4.0
1000.	10.	4.0
2000.	325.	5.0
3000.	305.	8.0
4000.	305.	16.0
6000.	270.	11.0
7000.	270.	14.0
8000.	275.	12.0
9000.	305.	19.0
11000.	340.	9.0
12000.	340.	10.0
19283.	35.	1.7
24929.	114.	3.4
31861.	97.	10.8
36037.	93.	15.7
40919.	75.	26.9

Results

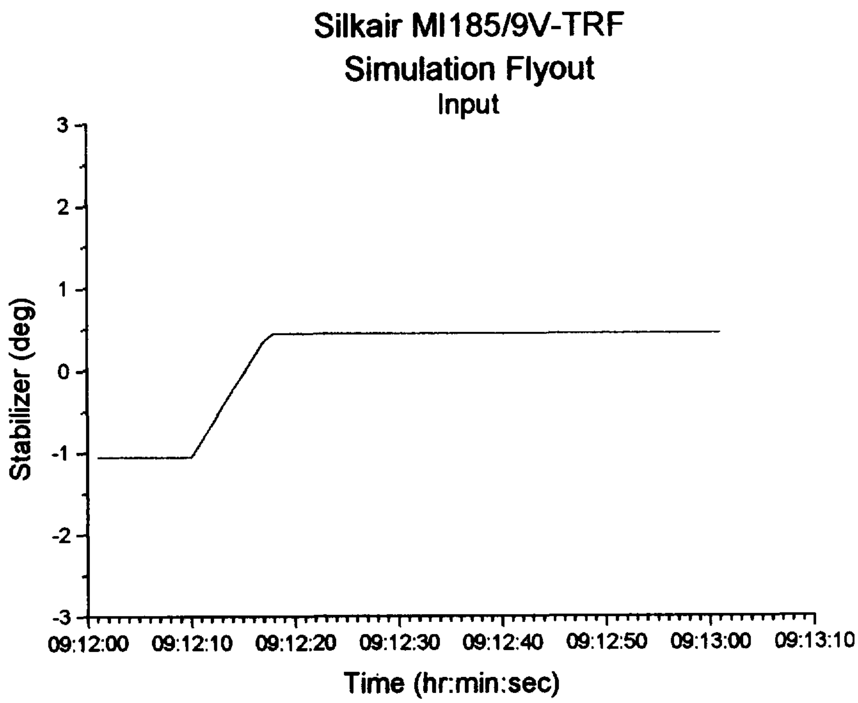
The simulation results are presented on the following pages. The North and East vs. time plots include a tolerance band for the radar. This tolerance band was taken from the radar tolerance boxes on the map plots. Two sides of this tolerance box result from the fact that radar returns are identified as being from a discrete segment of the radar circular arc. The remaining two sides of the box come from the radar's range accuracy. The actual position of the aircraft can thus be anywhere within the tolerance band (the starting points for each curve can of course be shifted up or down to remain in these bands). However, the accuracy of the winds also creates an uncertainty in these plots. For example, in all cases, a minor increase in South wind component would produce a better match on the North position vs. time plots. Also note that the simulation does not account for yaw damper action. This could slightly affect the results of some simulations after the start of the upset.

Pitch Control Failure Scenarios

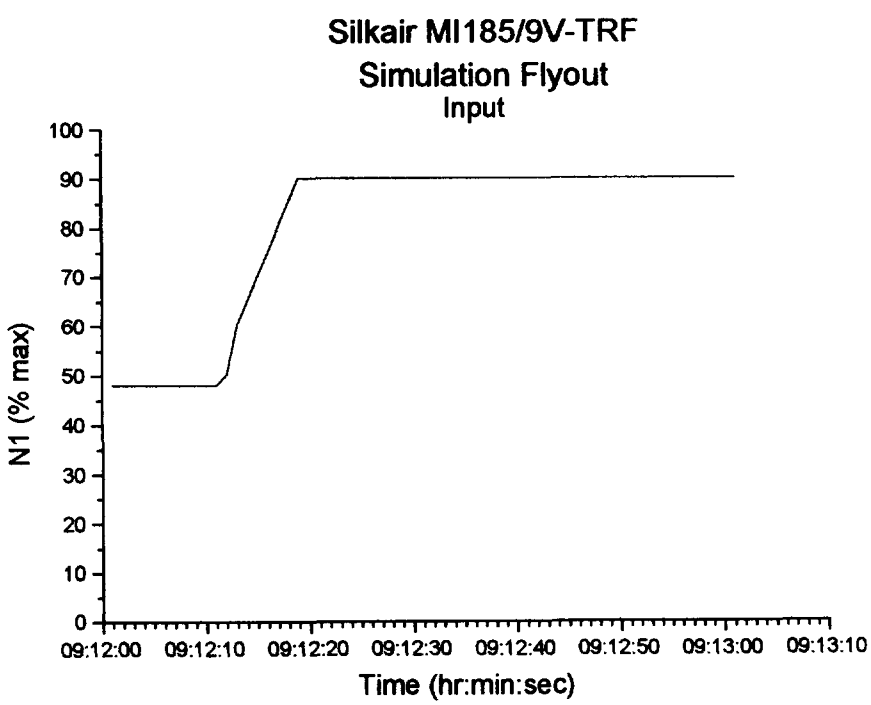
Both a runaway stabilizer trim scenario and an elevator hardover scenario were investigated. Neither matched the available data since radar shows that the path curved to the East of a straight path. These failure scenarios also excite an uncorrected phugoid motion. A combination pitch over and turn through the radar points will be presented in the matching maneuvers section.

Runaway Stabilizer Trim Scenario

As mentioned previously, examination of the wreckage showed that the stabilizer was at 0.5 deg nose down at impact. As can be seen in the following plots, a runaway stabilizer input alone will not match the data. Wheel, rudder and column remain neutral for this simulation.

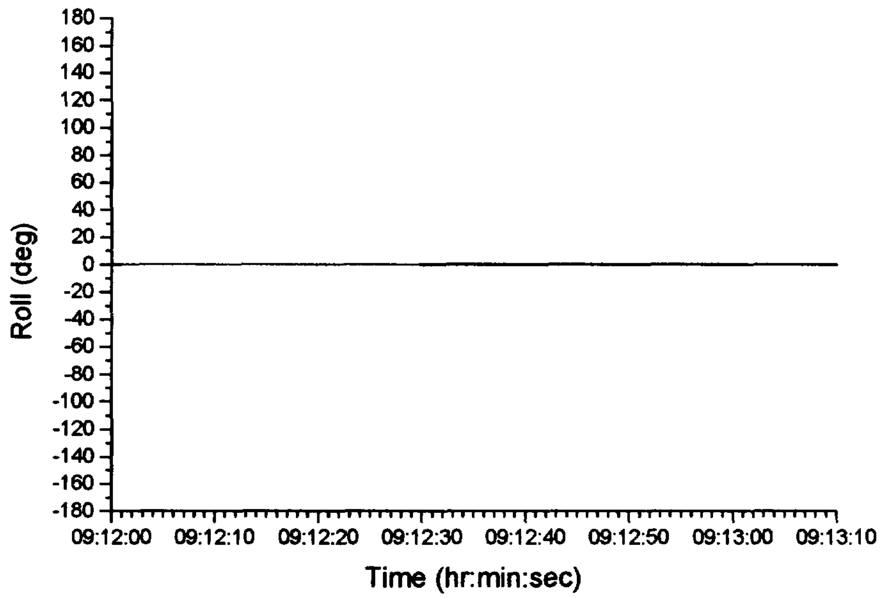


Silkair MI185/9V-TRF
Simulation Flyout
Input
Stabilizer (deg)
3
2
1
0
-1
-2
-3
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

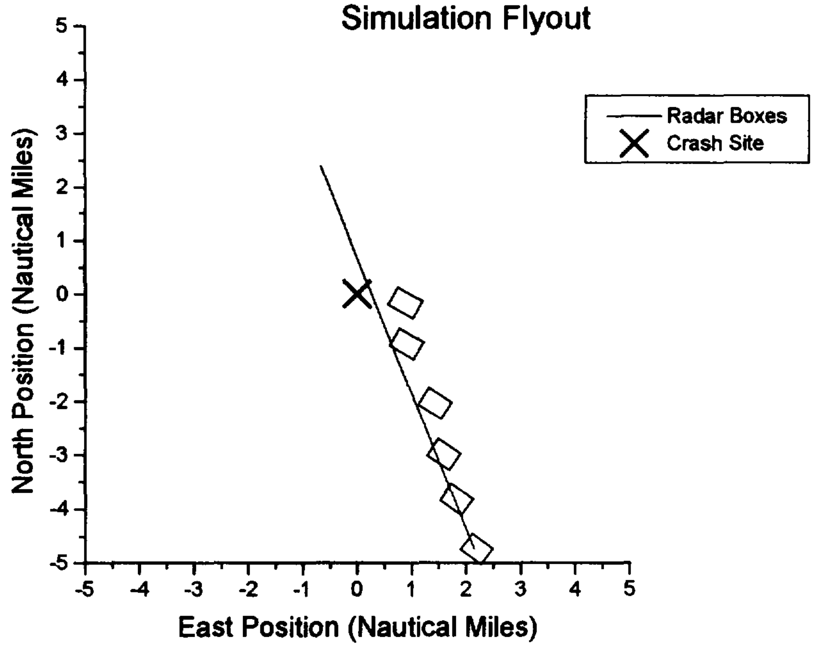


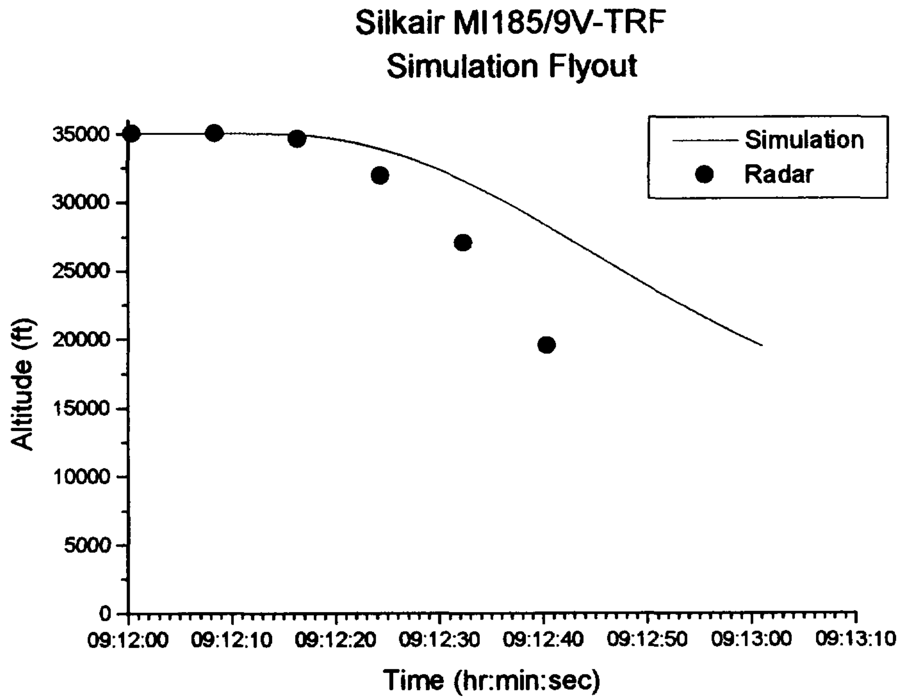
Silkair MI185/9V-TRF
Simulation Flyout
Input
N1 (% max)
100
90
80
70
60
50
40
30
20
10
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

Silkair MI185/9V-TRF
Simulation Flyout



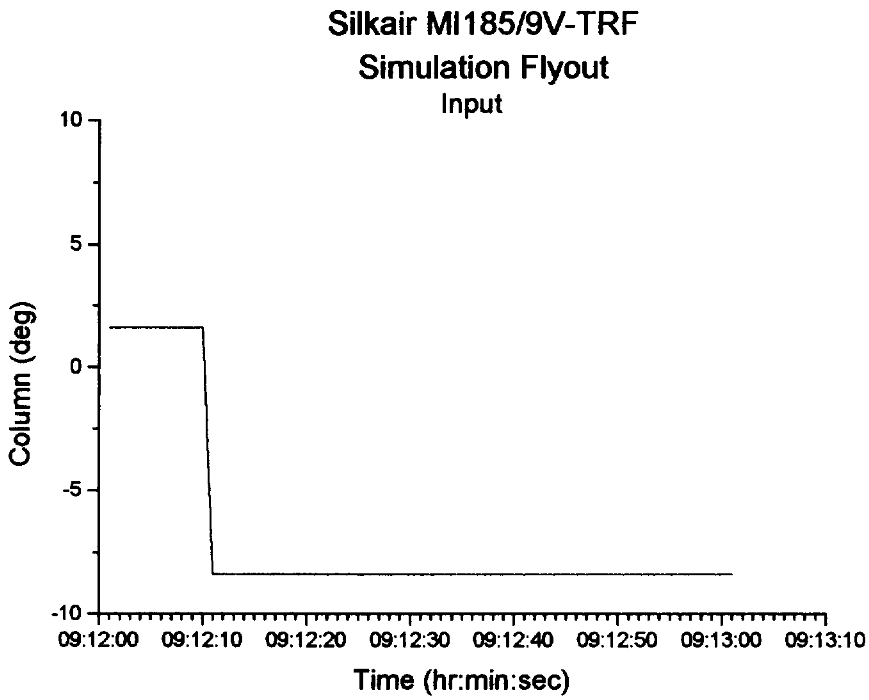
Silkair MI185/9V-TRF
Simulation Flyout

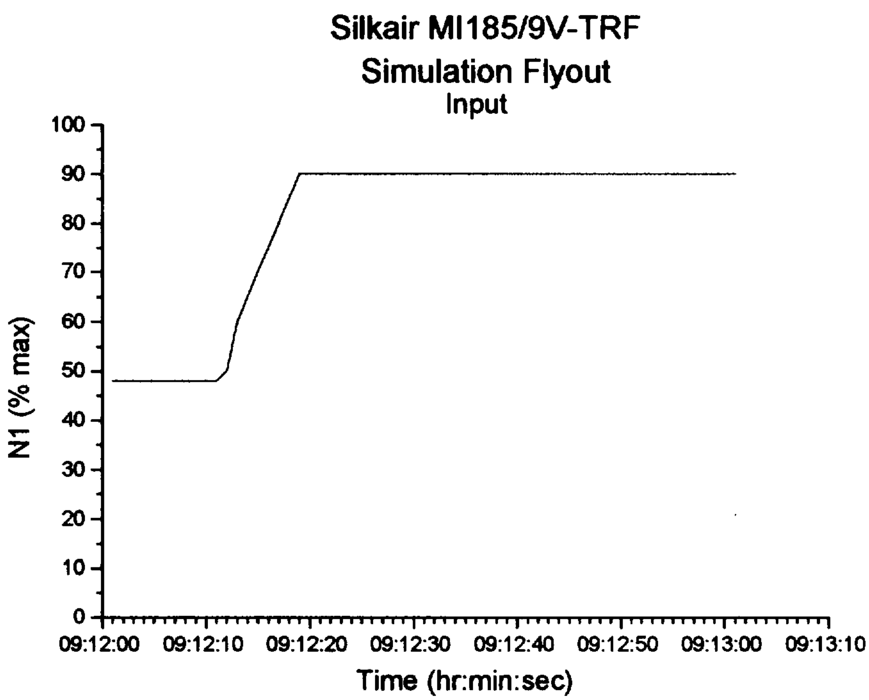


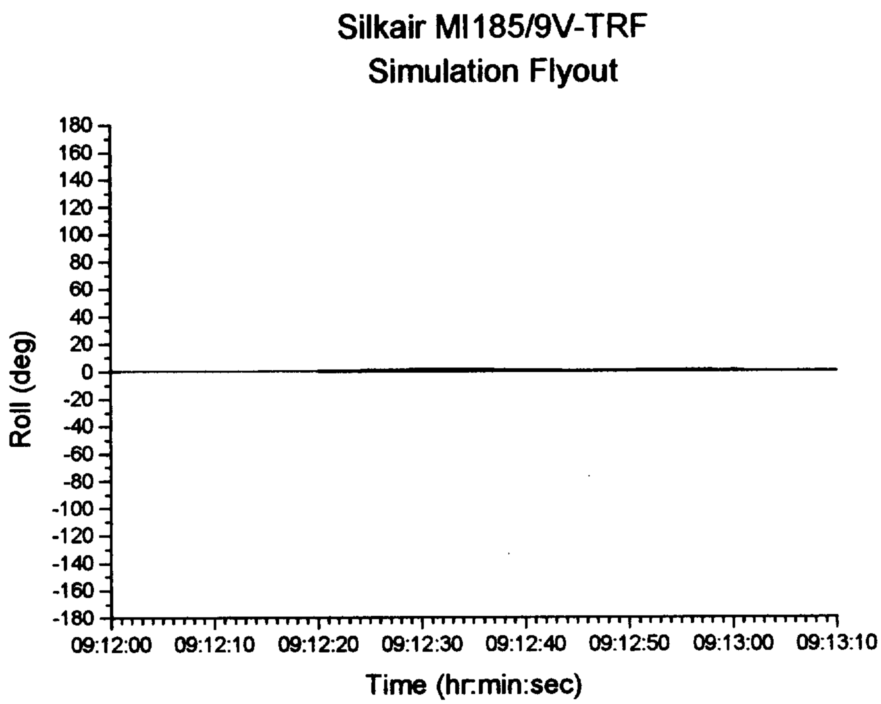


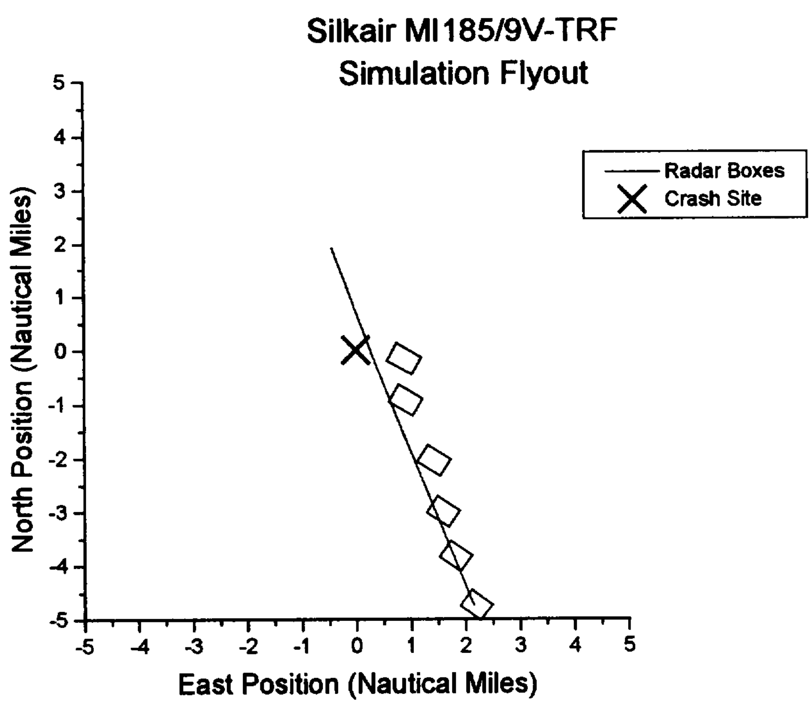
Elevator Hardover Scenario

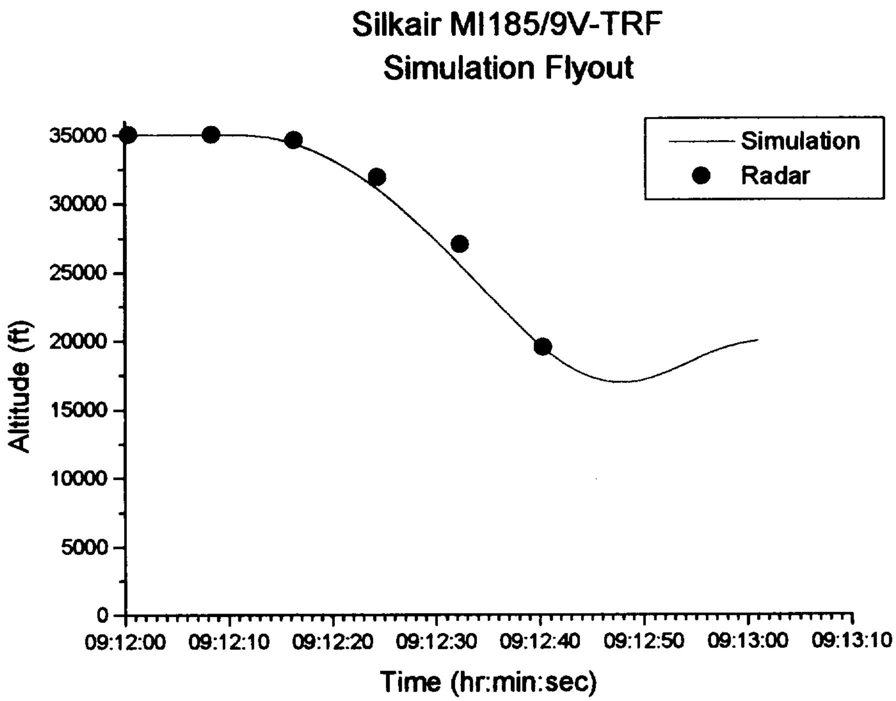
As can be seen in the following plots, an elevator hardover input alone does not match the data. The hardover is simulated with a full nose down column. Wheel and rudder remain neutral for this simulation, while stabilizer remains at its trim value. Note that this simulation experiences a numerical dynamic instability in the elevator after 9:12:32. The simulation has missed the radar points prior to this time, however.


Silkair MI185/9V-TRF
Simulation Flyout
Input
Column (deg)
10
5
0
-5
-10
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Input
N1 (% max)
100
90
80
70
60
50
40
30
20
10
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Roll (deg)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
North Position (Nautical Miles)
Radar Boxes
Crash Site
5
4
3
2
1
0
-1
-2
-3
-4
-5
East Position (Nautical Miles)

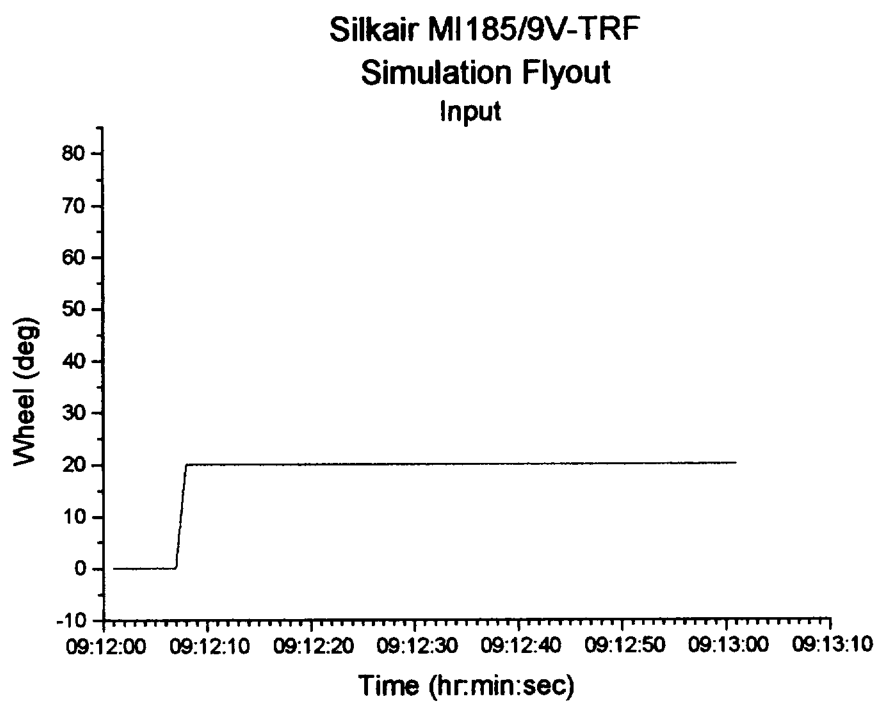


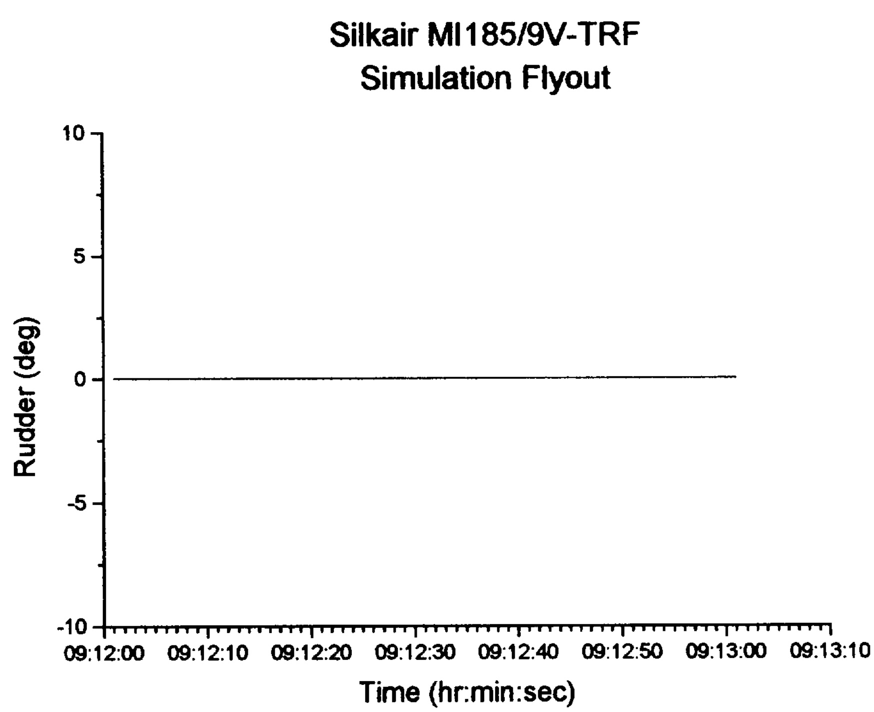
Roll Control Failure Scenarios

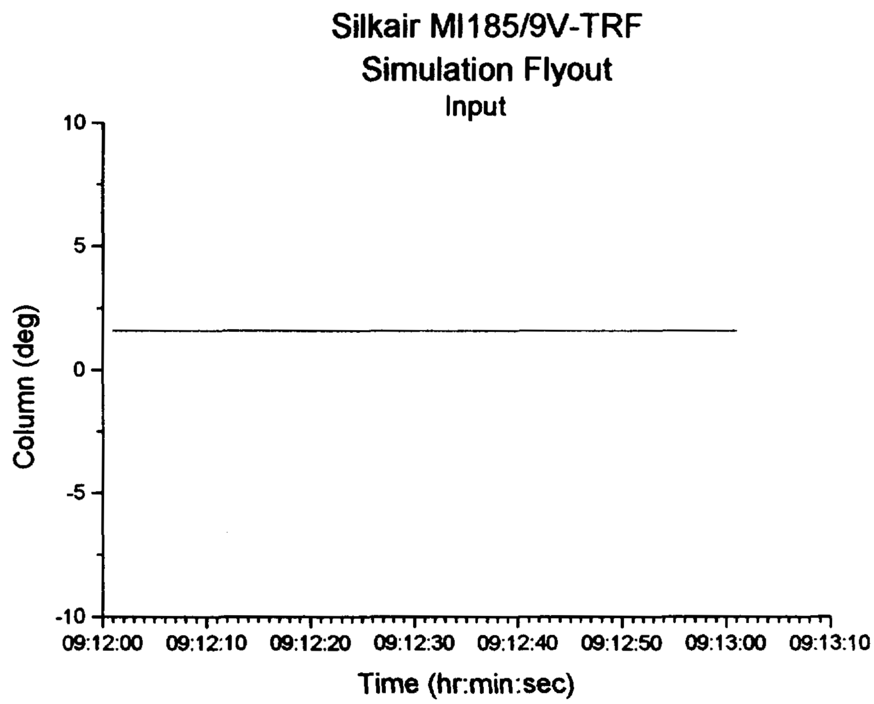
The only roll control failure scenario tested in this study was an autopilot hardover failure.

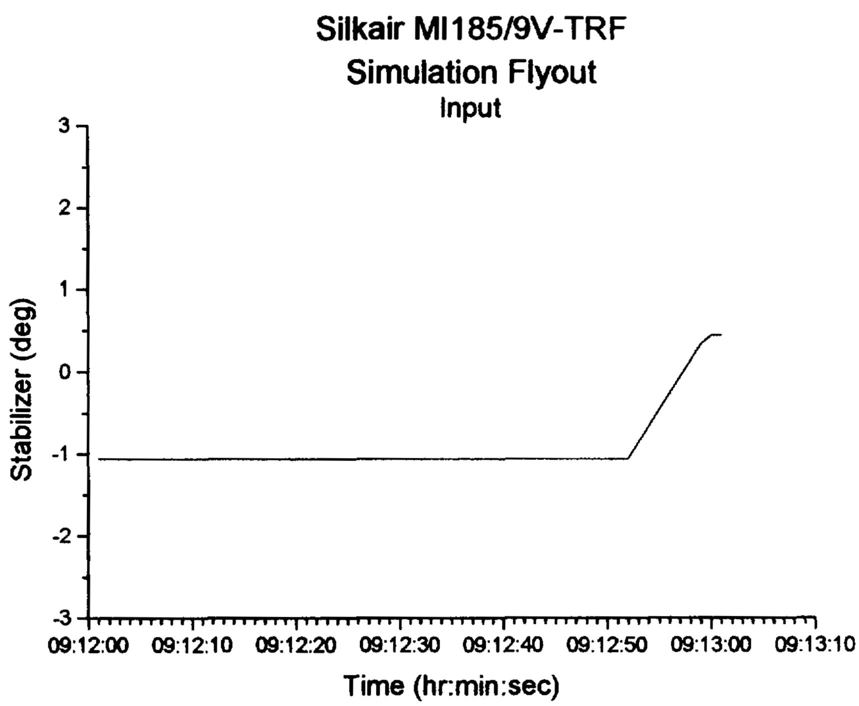
Autopilot Roll Hardover

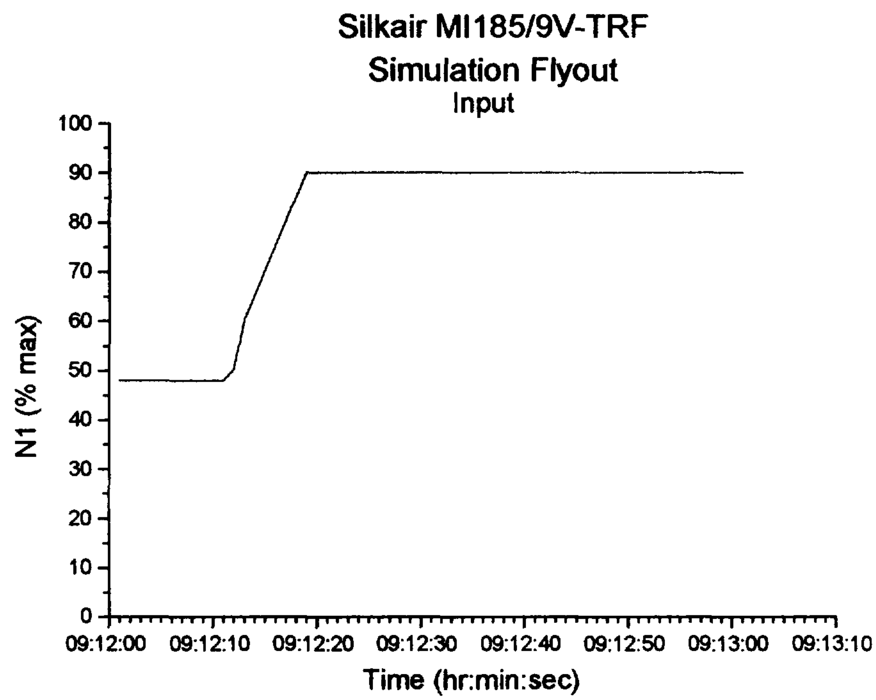
A wheel command to the 20 deg max autopilot wheel authority did not produce a match. In addition to the no column input case shown, various column inputs were tried. These showed no promise of getting a match.

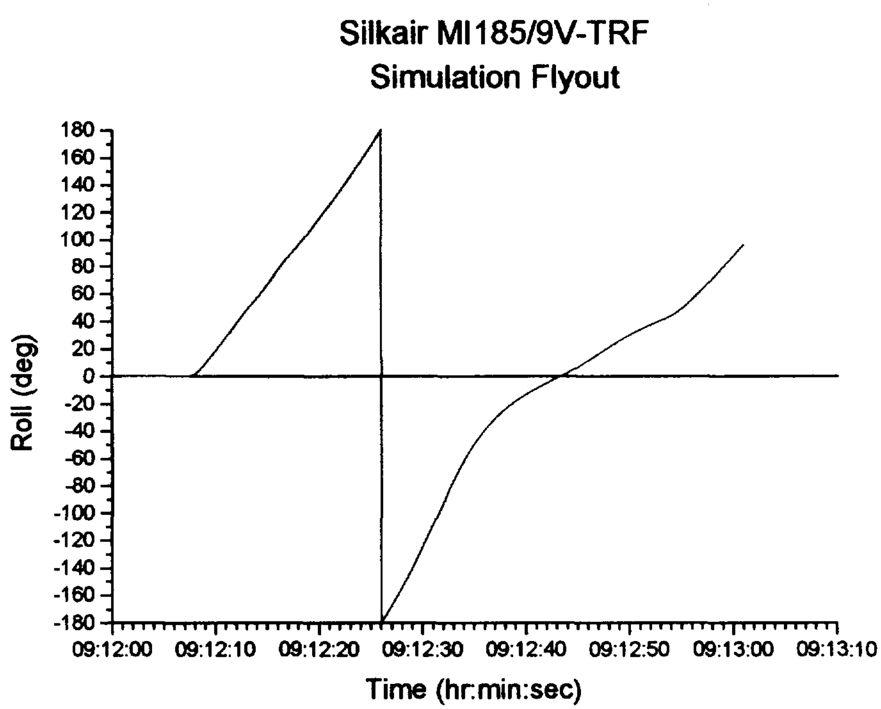

Silkair MI185/9V-TRF
Simulation Flyout
Input
Wheel (deg)
80
70
60
50
40
30
20
10
0
-10
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

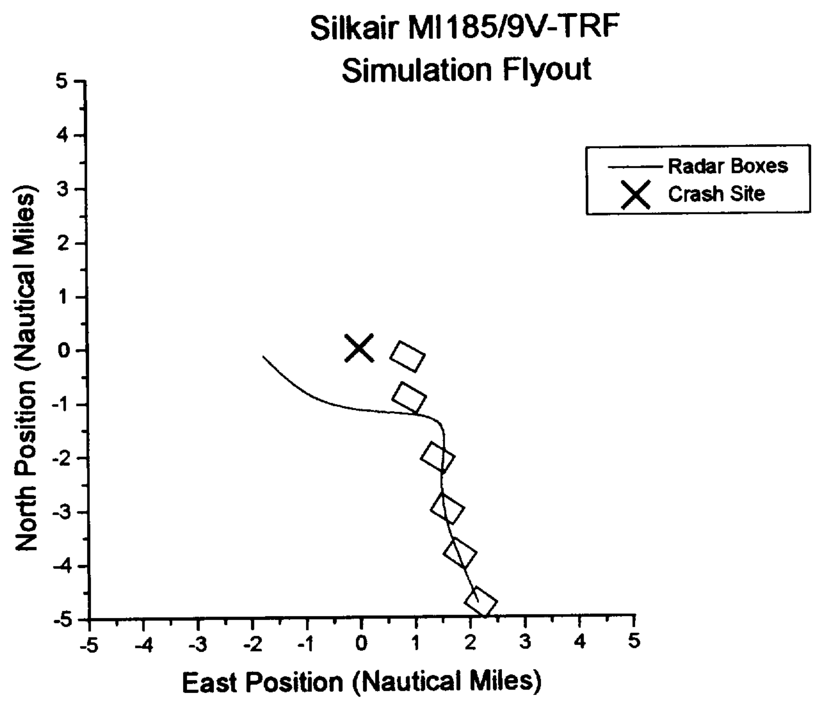

Silkair MI185/9V-TRF
Simulation Flyout
Rudder (deg)
10
5
0
-5
-10
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Input
10
5
0
-5
-10
Column (deg)
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

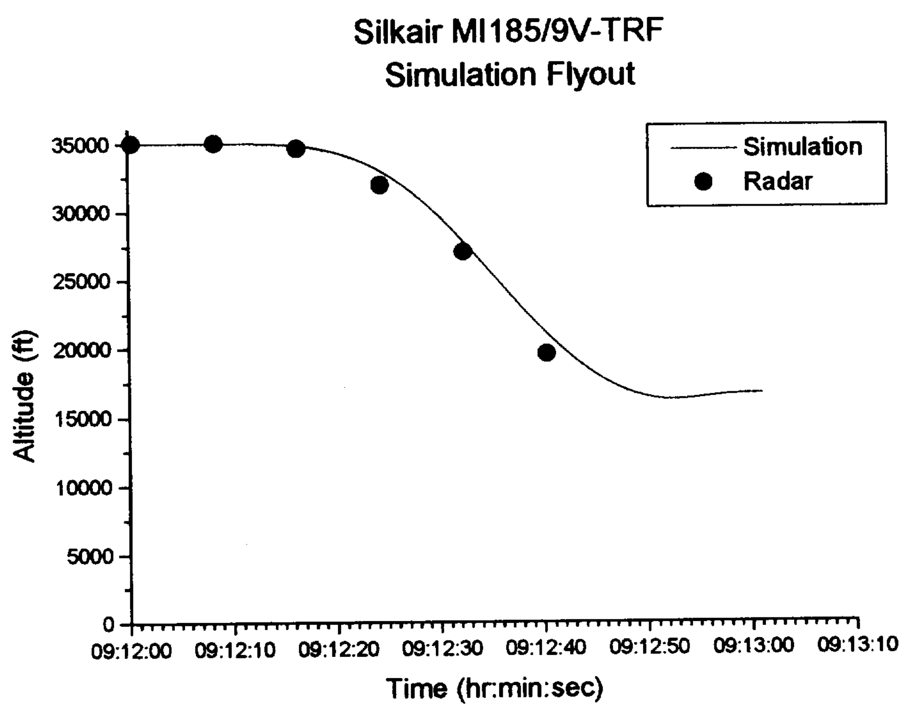

Silkair MI185/9V-TRF
Simulation Flyout
Input
3
2
1
0
-1
-2
-3
Stabilizer (deg)
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Input
N1 (% max)
100
90
80
70
60
50
40
30
20
10
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Roll (deg)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)



Silkair MI185/9V-TRF
Simulation Flyout
Radar Boxes
Crash Site
North Position (Nautical Miles)
East Position (Nautical Miles)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
-4
-3
-2
-1
0
1
2
3
4
5



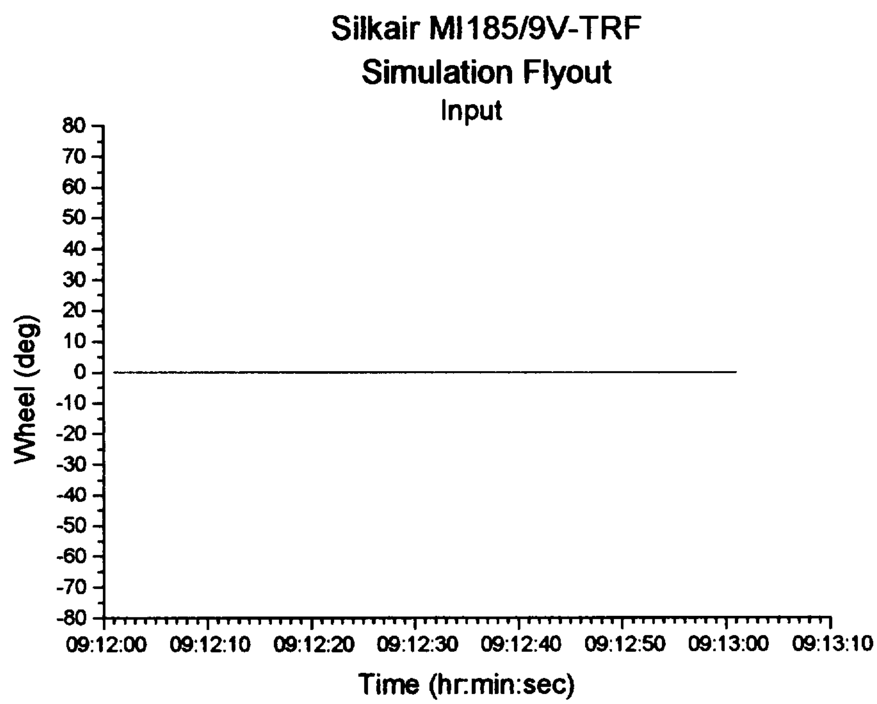
Silkair MI185/9V-TRF
Simulation Flyout
Simulation
Radar
Altitude (ft)
35000
30000
25000
20000
15000
10000
5000
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

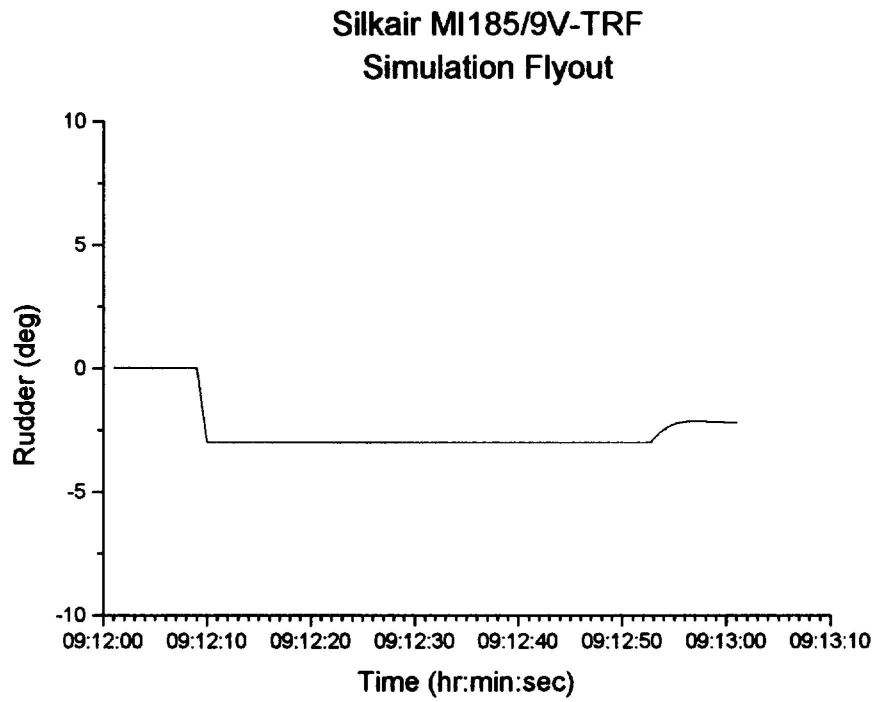
Rudder Failure Scenarios

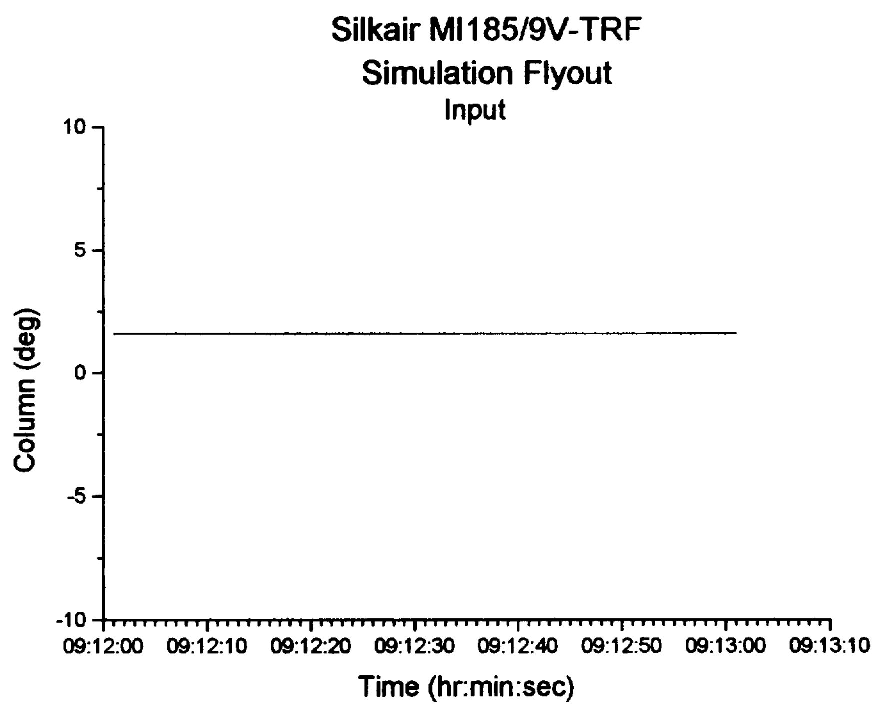
Rudder hardovers with several pilot responses and a yaw damper hardover were investigated. None of these failures matched the data unless pro departure roll control was added. This case is included in the matching maneuvers section of this report.

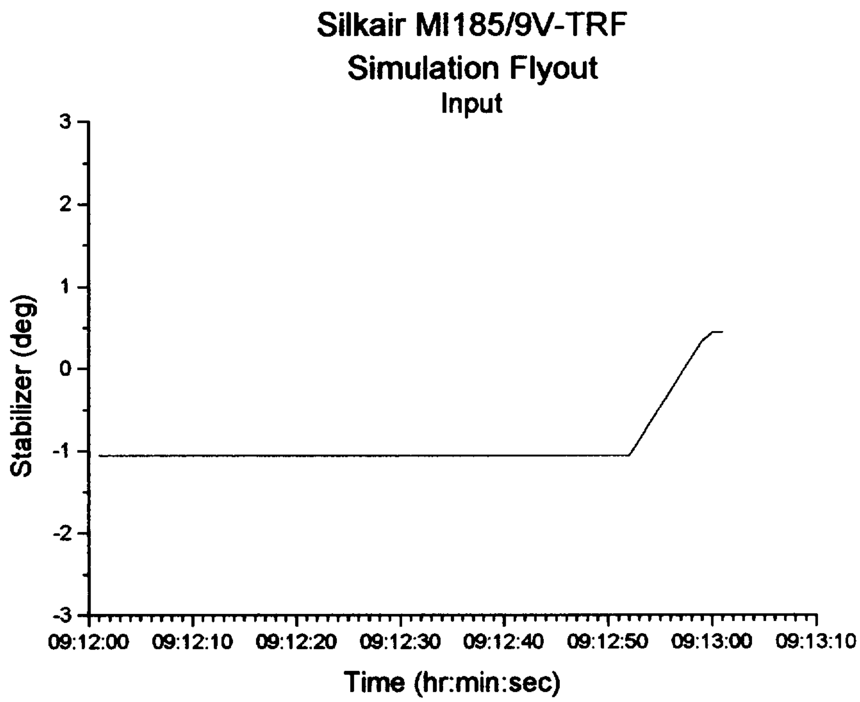
Yaw Damper Hardover

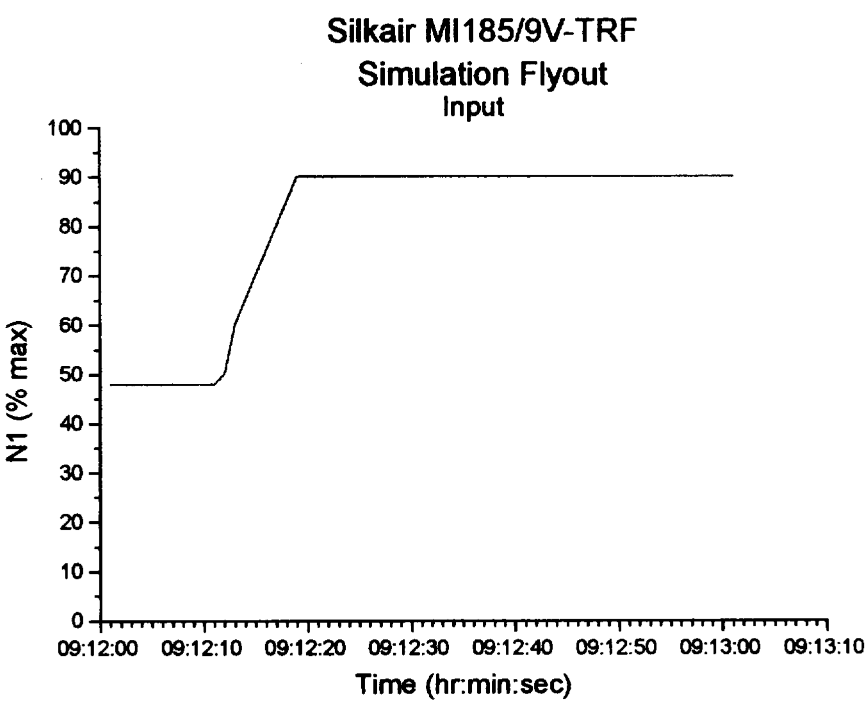
The effect of a yaw damper hardover with no wheel response is shown in the following plots. As can be seen, the yaw damper hardover does not come close to matching the data. If the autopilot was operational, the opposing wheel would cause a milder aircraft response even further from the radar data. Similarly, yaw damper failures below hardover would be milder and further from the radar data. Accordingly, based on the results from this hardover, these milder variants were not pursued.

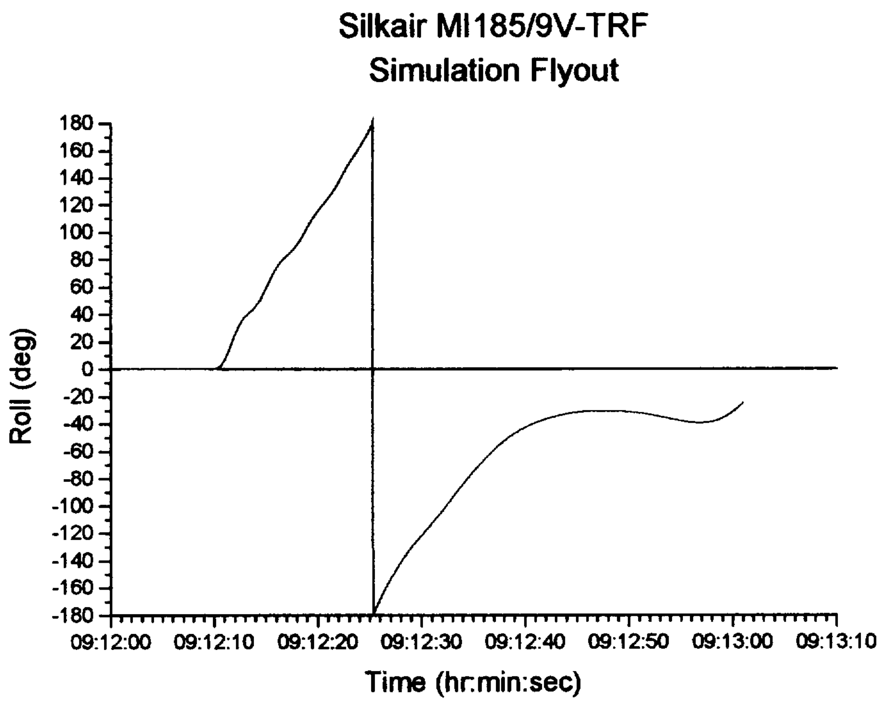



Silkair MI185/9V-TRF
Simulation Flyout
10
5
0
-5
-10
Rudder (deg)
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

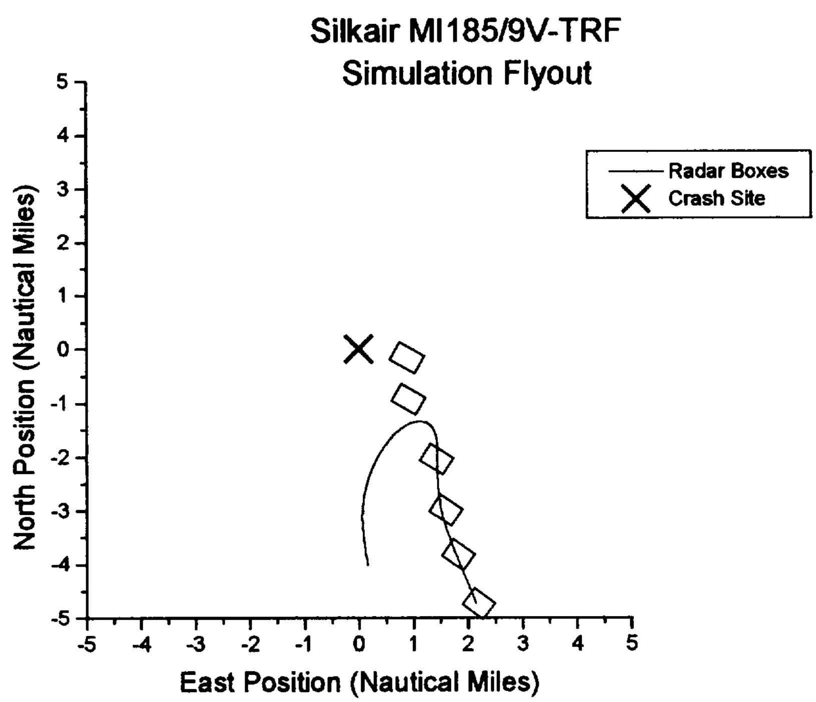

Silkair MI185/9V-TRF
Simulation Flyout
Input
10
5
0
-5
-10
Column (deg)
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Input
Stabilizer (deg)
3
2
1
0
-1
-2
-3
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

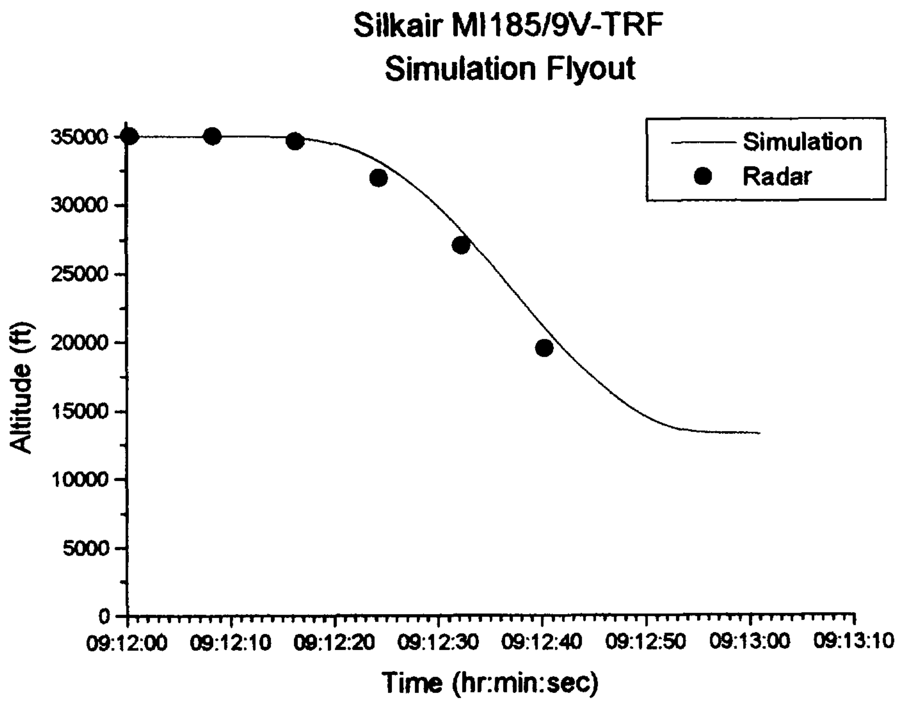

Silkair MI185/9V-TRF
Simulation Flyout
Input
N1 (% max)
100
90
80
70
60
50
40
30
20
10
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)



Silkair MI185/9V-TRF
Simulation Flyout
Roll (deg)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
09:12:00 09:12:10 09:12:20 09:12:30 09:12:40 09:12:50 09:13:00 09:13:10
Time (hr:min:sec)



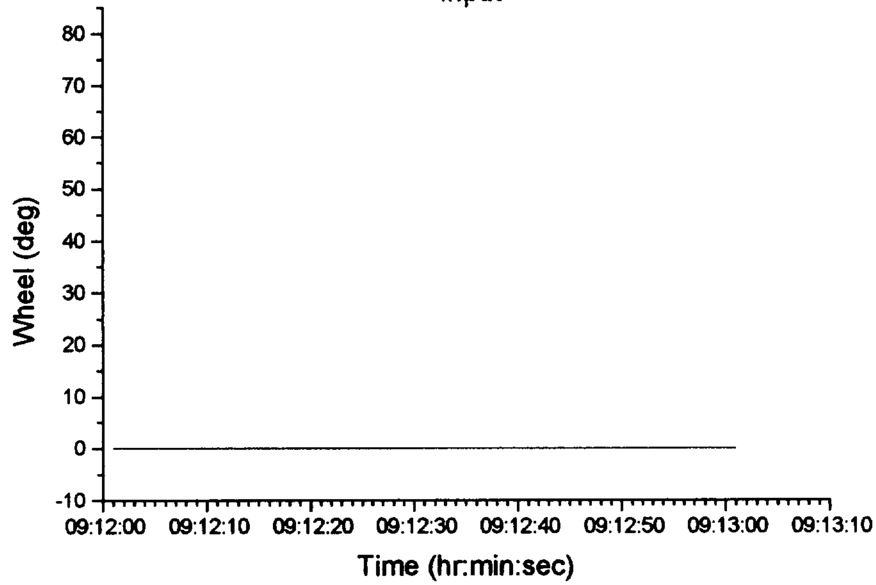
Silkair MI185/9V-TRF
Simulation Flyout
Radar Boxes
Crash Site
North Position (Nautical Miles)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5 -4 -3 -2 -1 0 1 2 3 4 5
East Position (Nautical Miles)



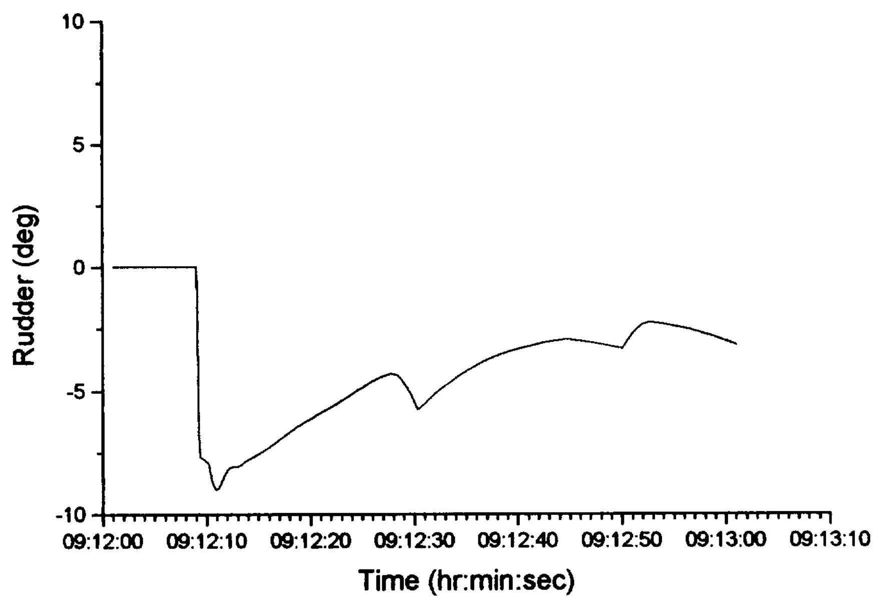
<u>Rudder Hardover (No response)</u>

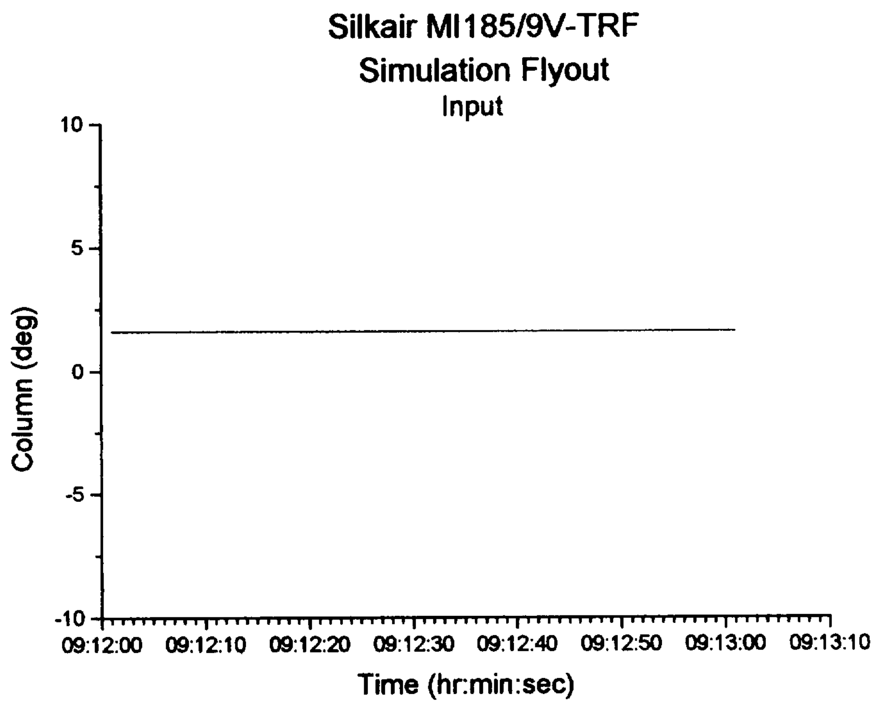
Control input and selected aircraft response parameters for the rudder hardover case are presented on the following pages. As can be seen, a rudder hardover with no other control input does not match the data. As speed increases, the rudder deflection decreases due to blowdown. This, coupled with aerodynamic changes due to increasing Mach number, slows the roll.

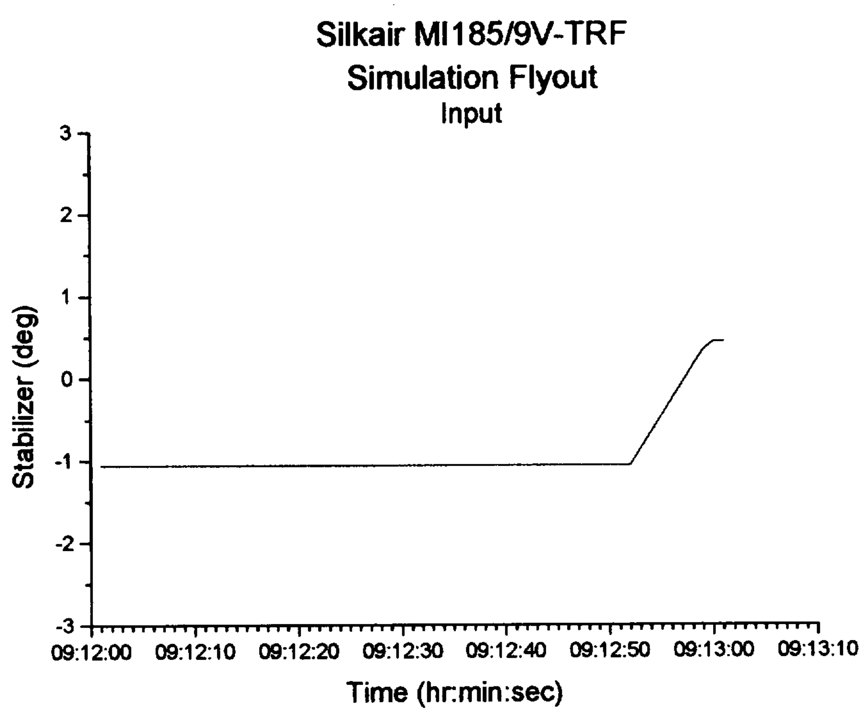
Silkair MI185/9V-TRF
Simulation Flyout
Input

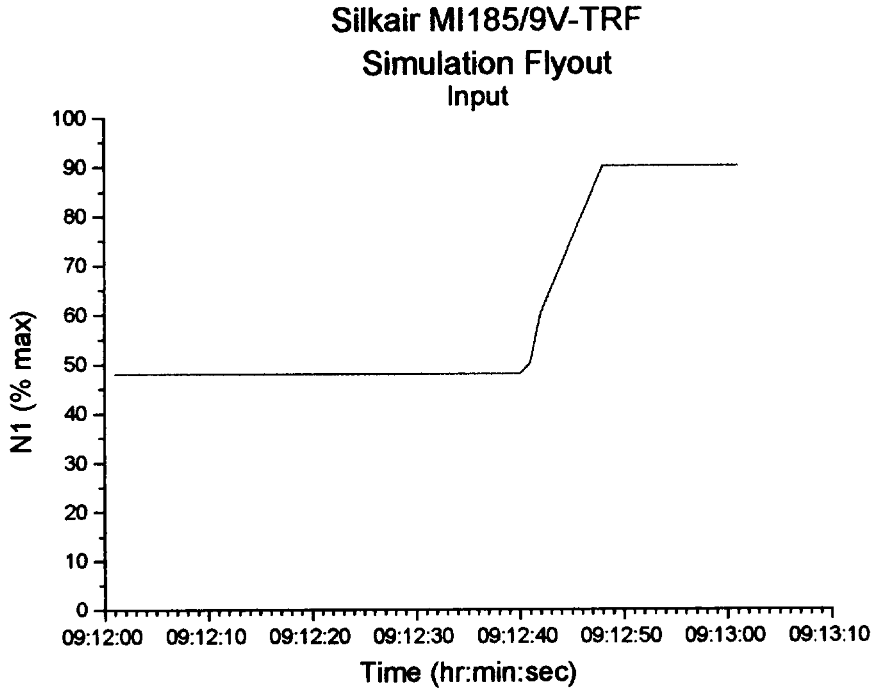


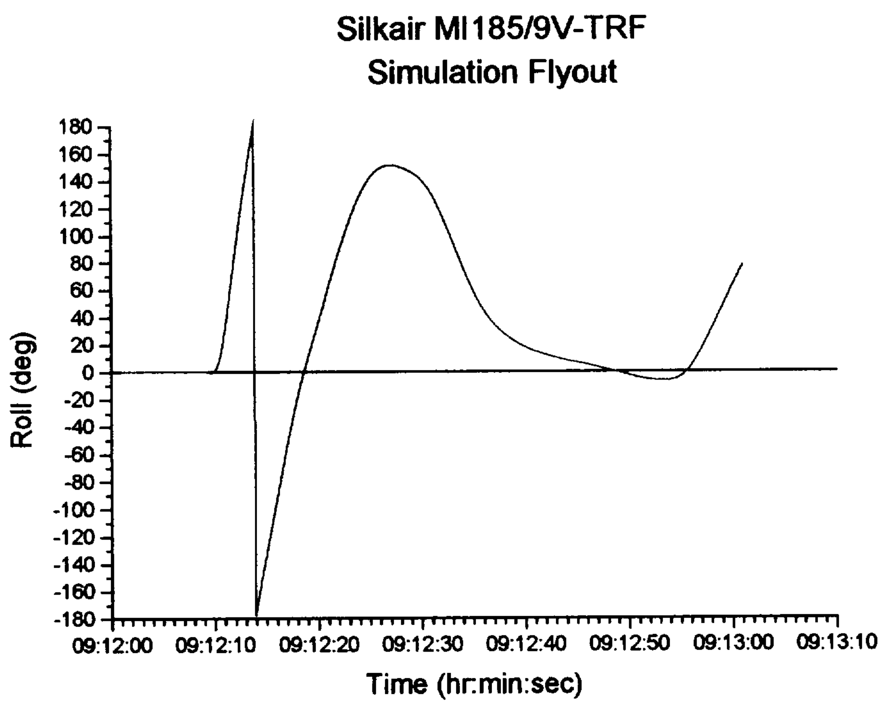
Silkair MI185/9V-TRF
Simulation Flyout

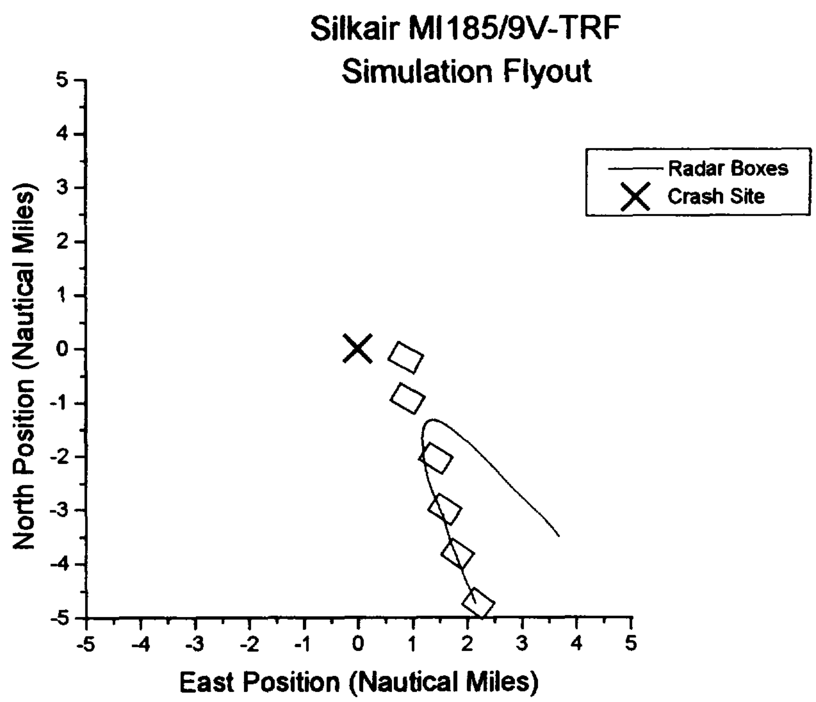


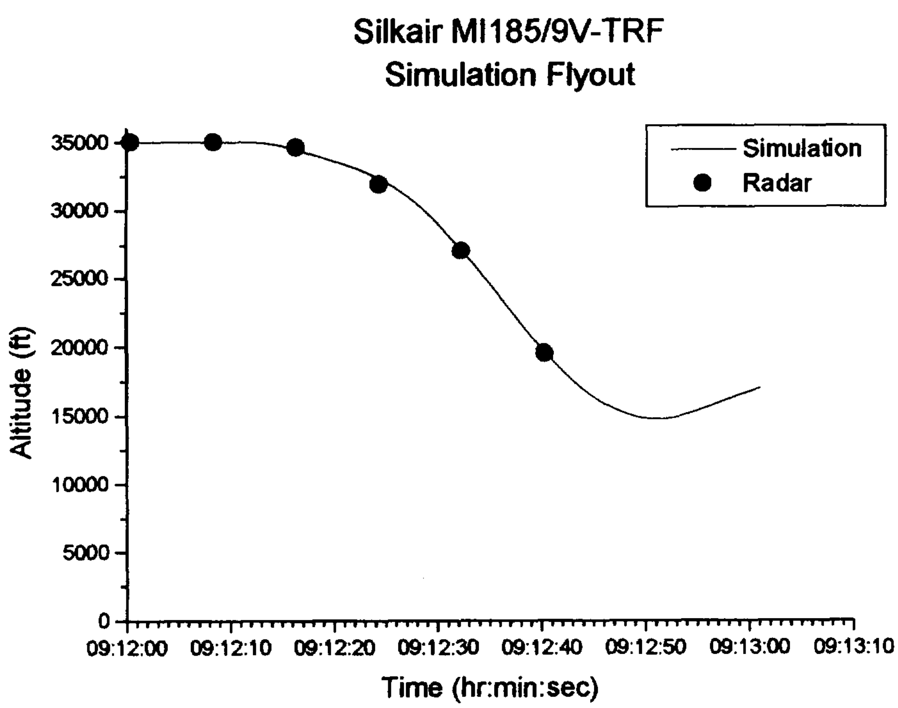

Silkair MI185/9V-TRF
Simulation Flyout
Input
Column (deg)
10
5
0
-5
-10
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Input
Stabilizer (deg)
3
2
1
0
-1
-2
-3
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Input
N1 (% max)
100
90
80
70
60
50
40
30
20
10
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

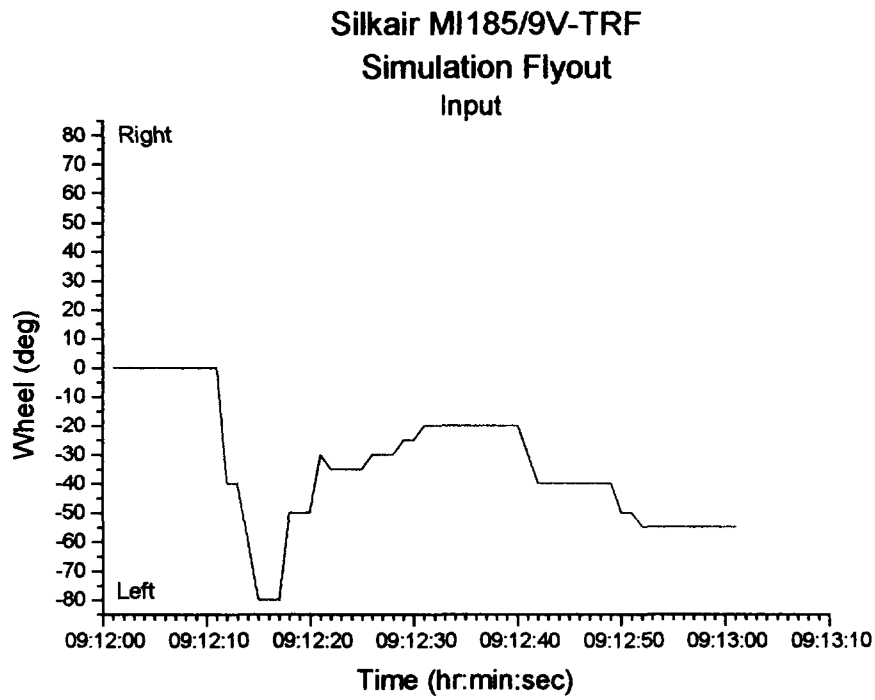

Silkair MI185/9V-TRF
Simulation Flyout
Roll (deg)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

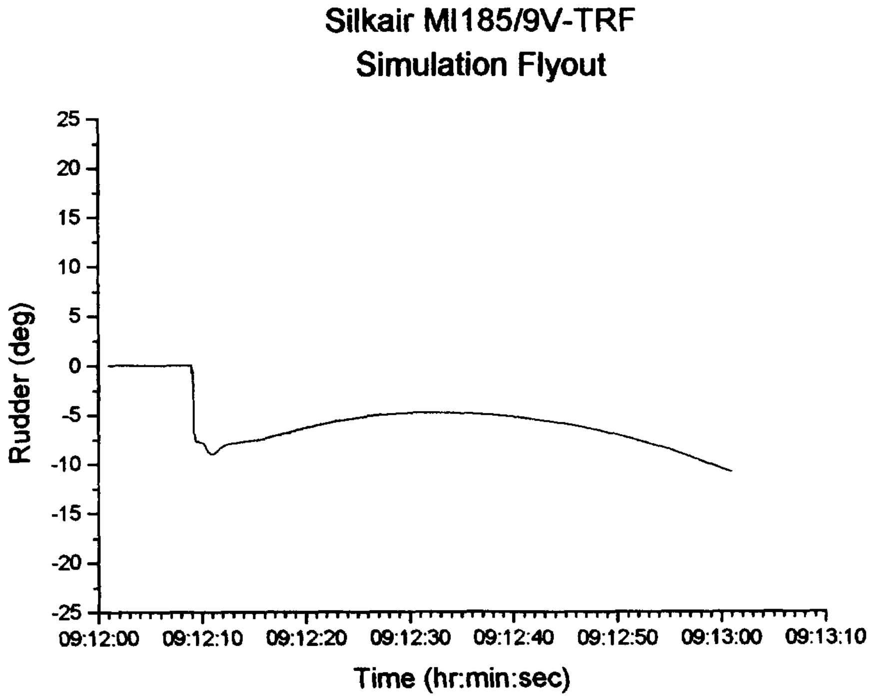

Silkair MI185/9V-TRF
Simulation Flyout
Radar Boxes
Crash Site
North Position (Nautical Miles)
East Position (Nautical Miles)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
-4
-3
-2
-1
0
1
2
3
4
5

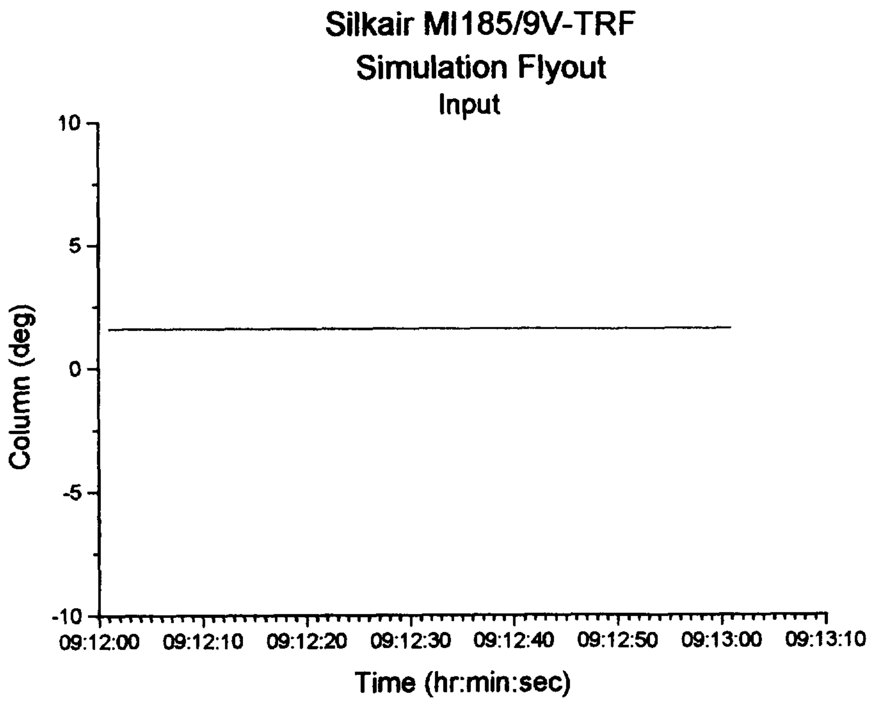

Silkair MI185/9V-TRF
Simulation Flyout
Simulation
Radar
Altitude (ft)
35000
30000
25000
20000
15000
10000
5000
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

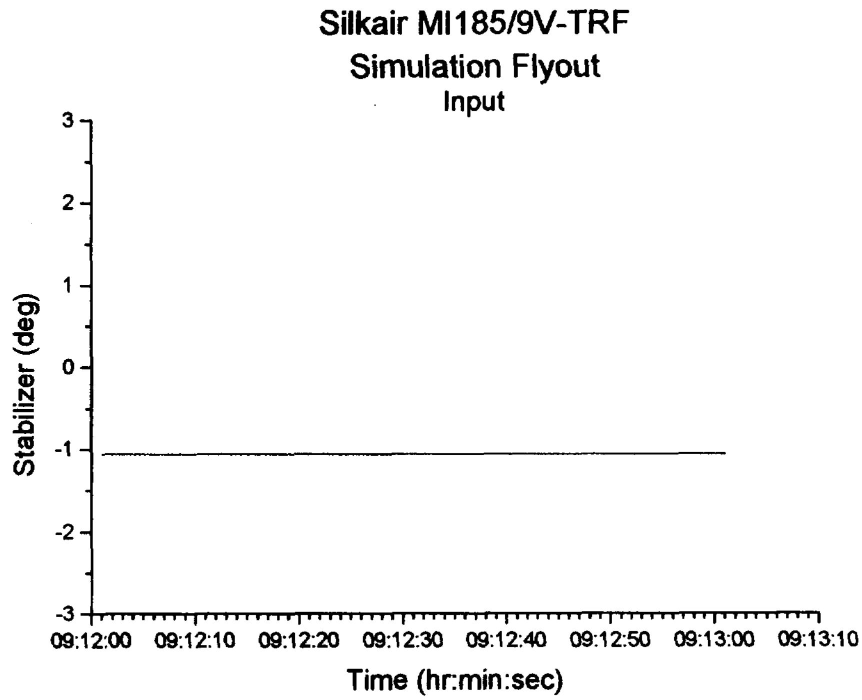
Rudder Hardover (with pilot response against the roll)

Control input and selected aircraft response parameters for this case are presented on the following pages. As can be readily seen, a rudder hardover with pilot response against the roll does not match the data.

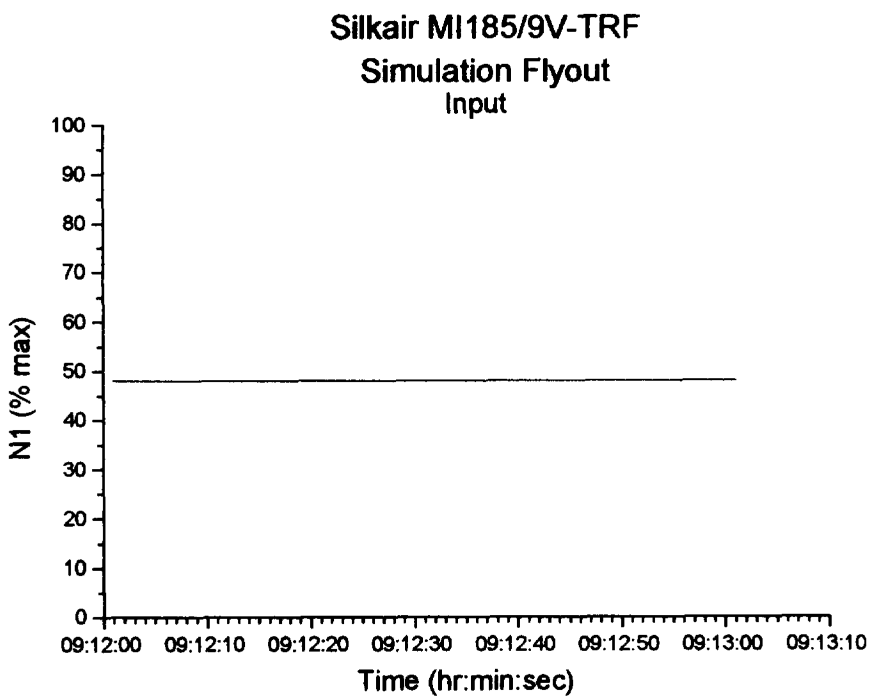



Silkair MI185/9V-TRF
Simulation Flyout
Rudder (deg)
25
20
15
10
5
0
-5
-10
-15
-20
-25
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

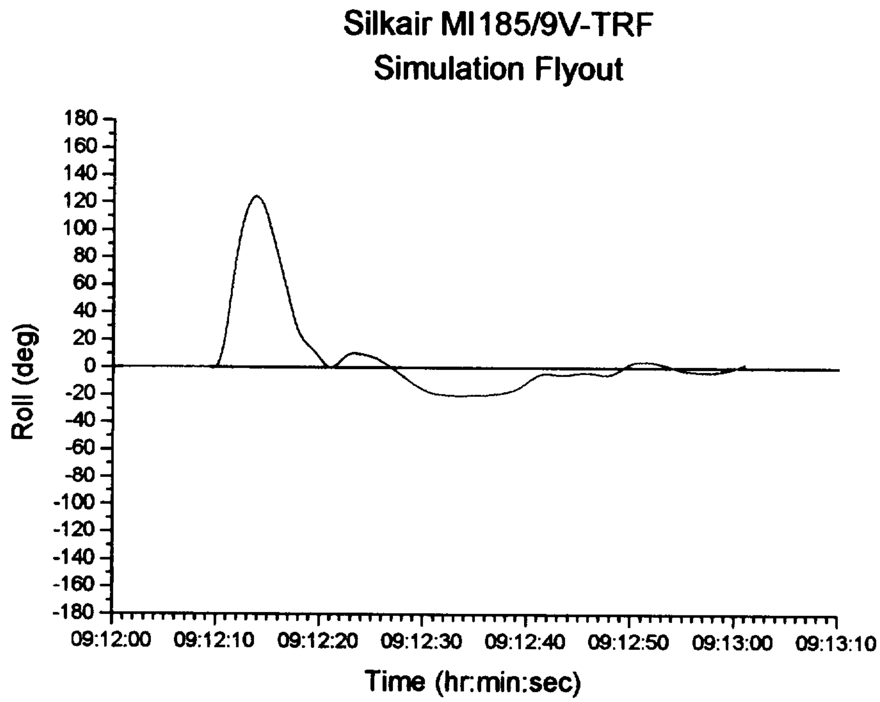

Silkair MI185/9V-TRF
Simulation Flyout
Input
Column (deg)
10
5
0
-5
-10
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)



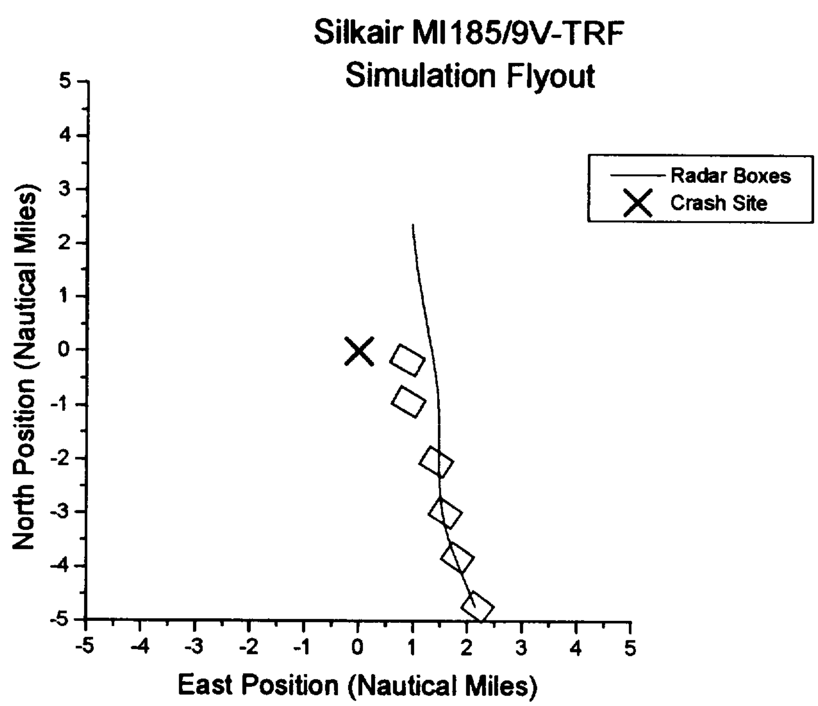
Silkair MI185/9V-TRF
Simulation Flyout
Input
Stabilizer (deg)
3
2
1
0
-1
-2
-3
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)



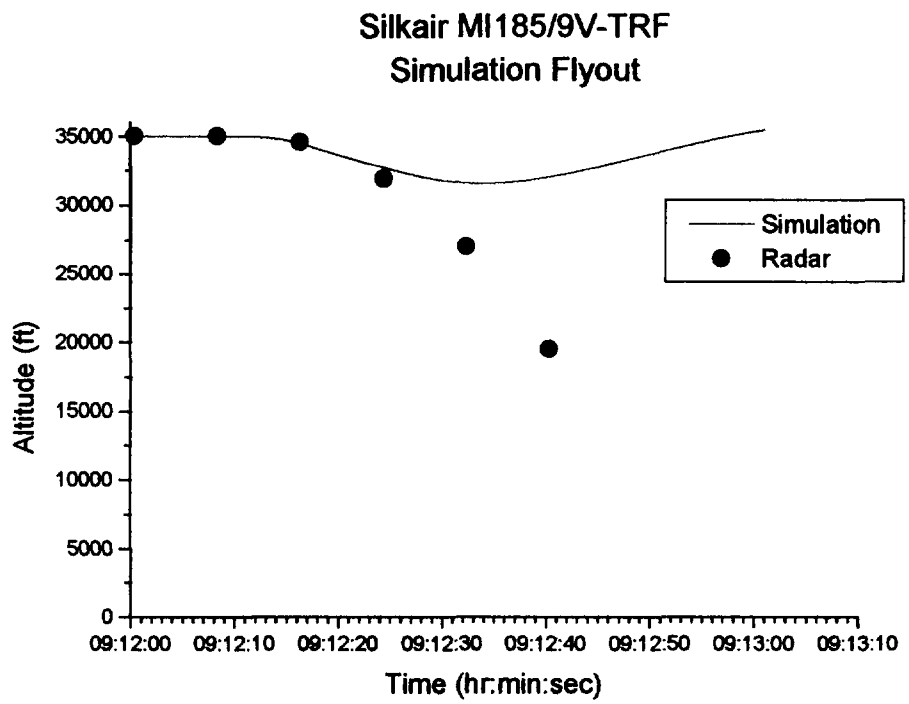
Silkair MI185/9V-TRF
Simulation Flyout
Input
N1 (% max)
100
90
80
70
60
50
40
30
20
10
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)



Silkair MI185/9V-TRF
Simulation Flyout
Roll (deg)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

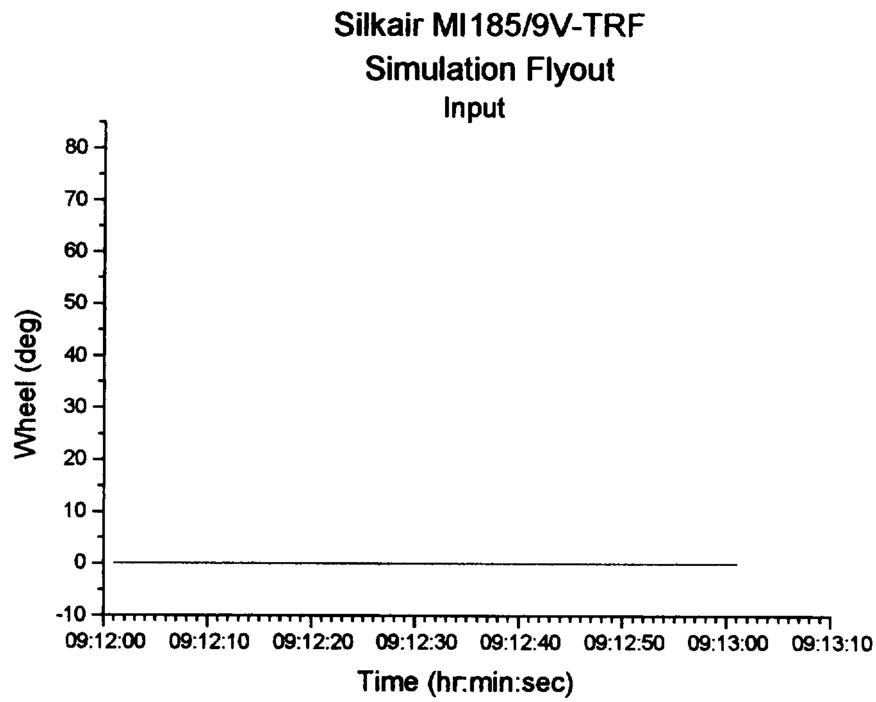


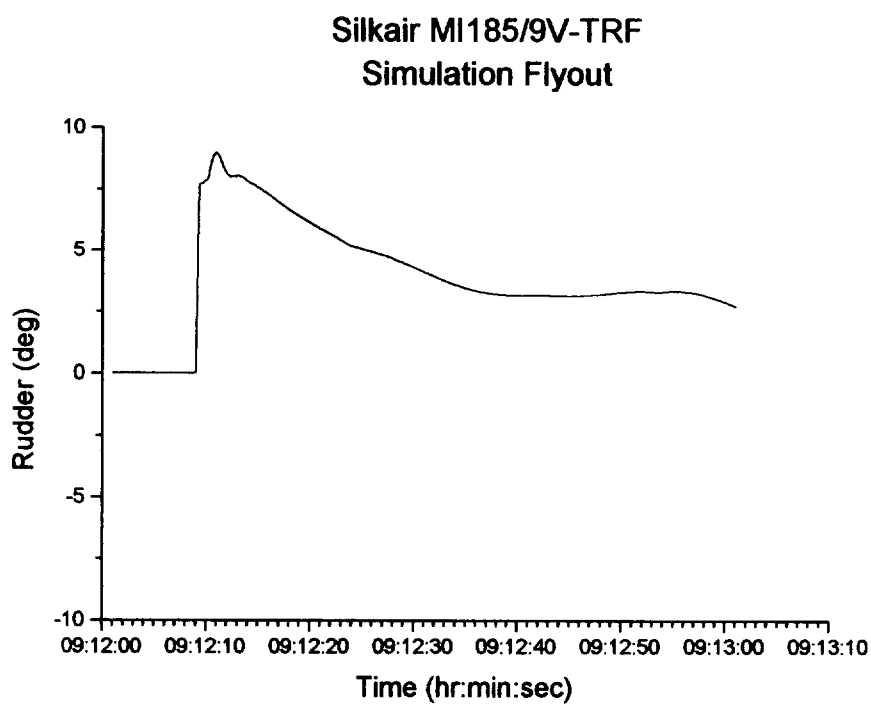
Silkair MI185/9V-TRF
Simulation Flyout
Radar Boxes
Crash Site
North Position (Nautical Miles)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
-4
-3
-2
-1
0
1
2
3
4
5
East Position (Nautical Miles)

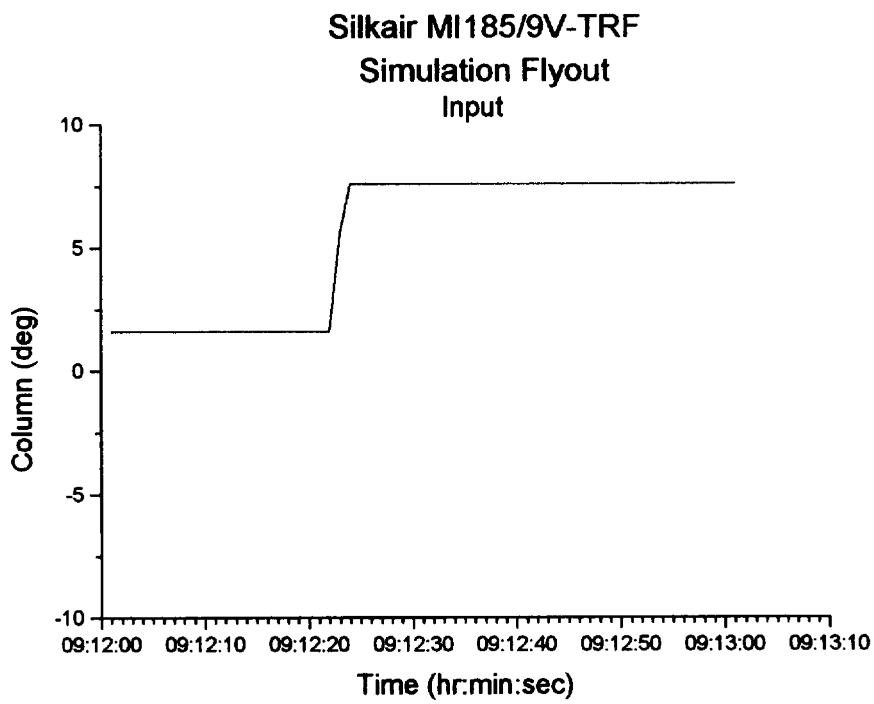


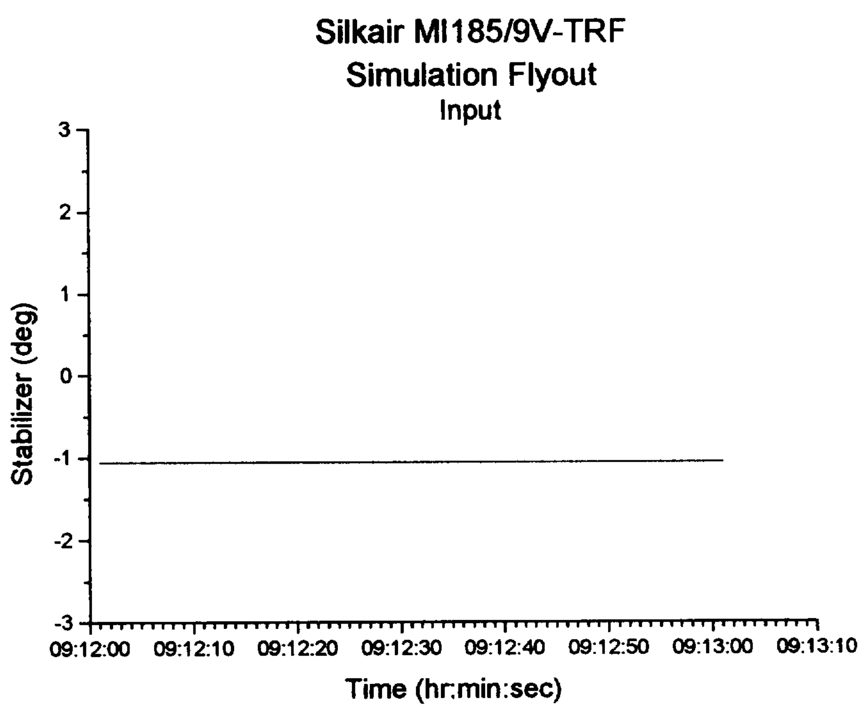
<u>Rudder Hardover (with pull up)</u>

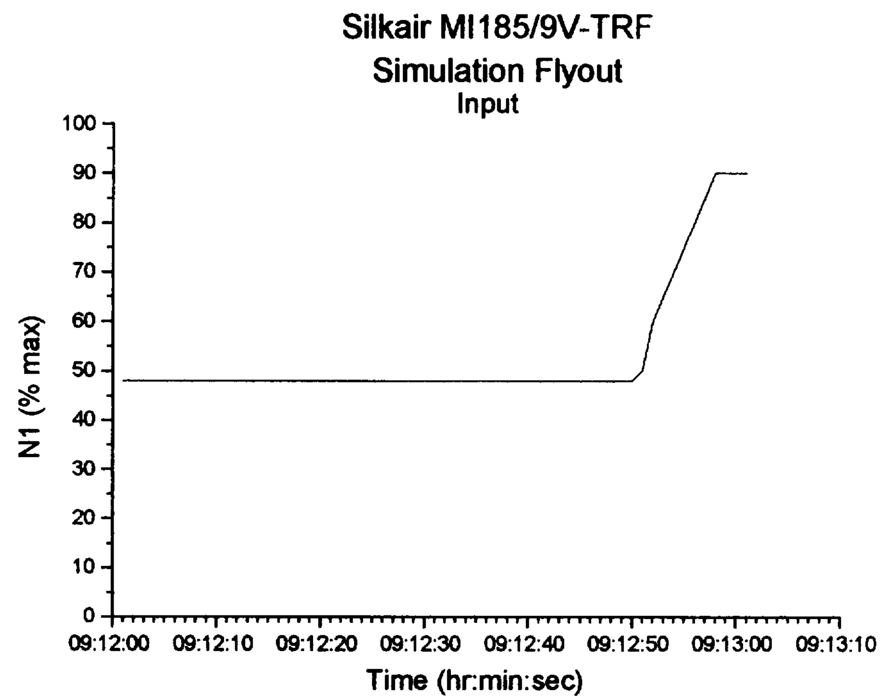
One way to continue the roll started by a rudder hardover is to apply nose up column. Control input and selected aircraft response parameters for this scenario are presented on the following pages. As shown, though this does continue the roll, the increased load factor causes a deviation from the radar track.

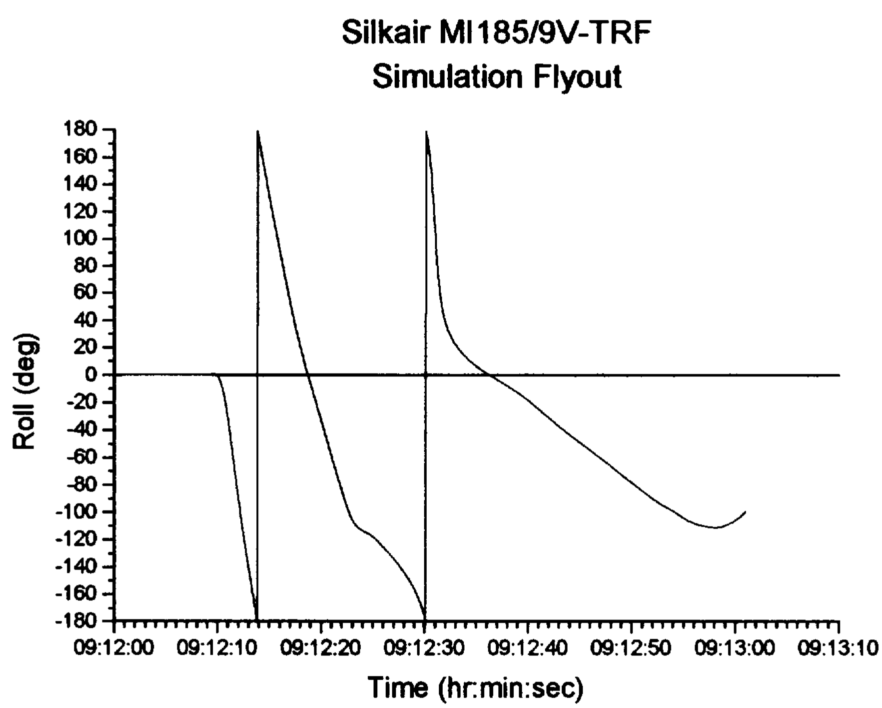

Silkair MI185/9V-TRF
Simulation Flyout
Input
Wheel (deg)
80
70
60
50
40
30
20
10
0
-10
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

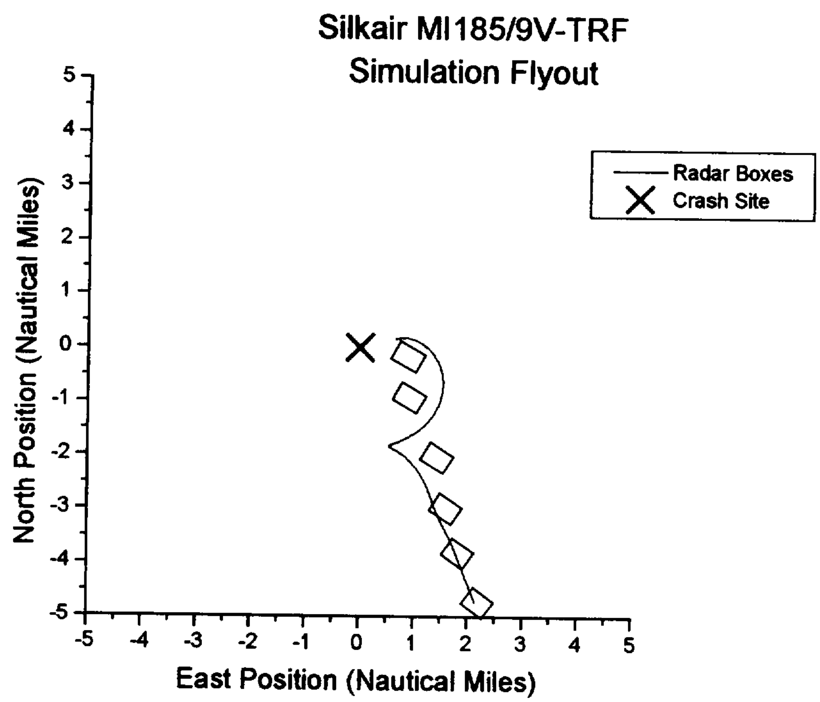

Silkair MI185/9V-TRF
Simulation Flyout
Rudder (deg)
10
5
0
-5
-10
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Input
Column (deg)
10
5
0
-5
-10
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

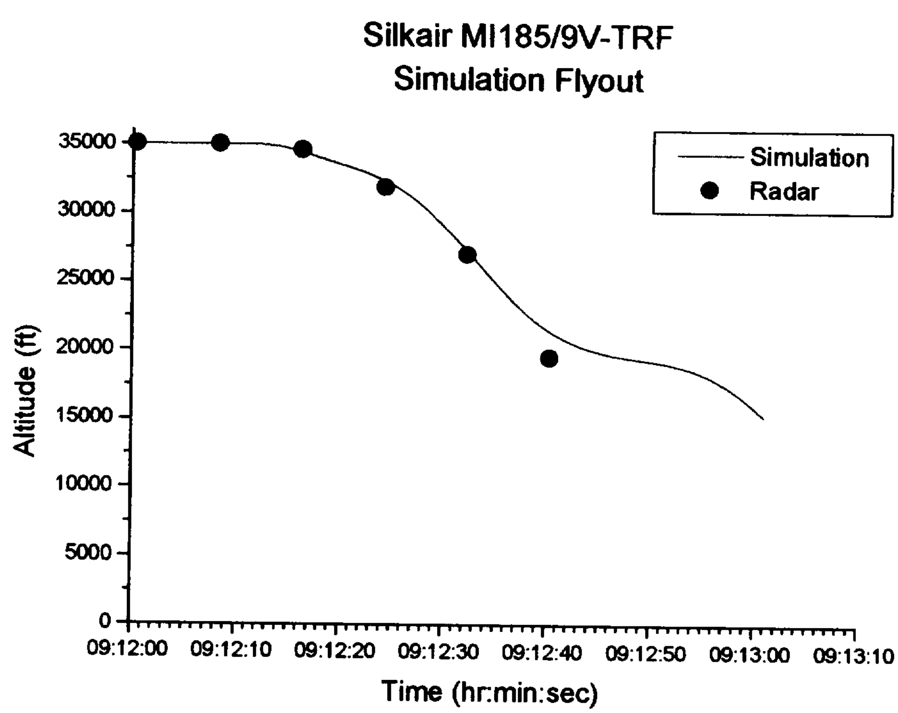

Silkair MI185/9V-TRF
Simulation Flyout
Input
Stabilizer (deg)
3
2
1
0
-1
-2
-3
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Input
N1 (% max)
100
90
80
70
60
50
40
30
20
10
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Roll (deg)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)



Silkair MI185/9V-TRF
Simulation Flyout
Radar Boxes
Crash Site
North Position (Nautical Miles)
East Position (Nautical Miles)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
-4
-3
-2
-1
0
1
2
3
4
5



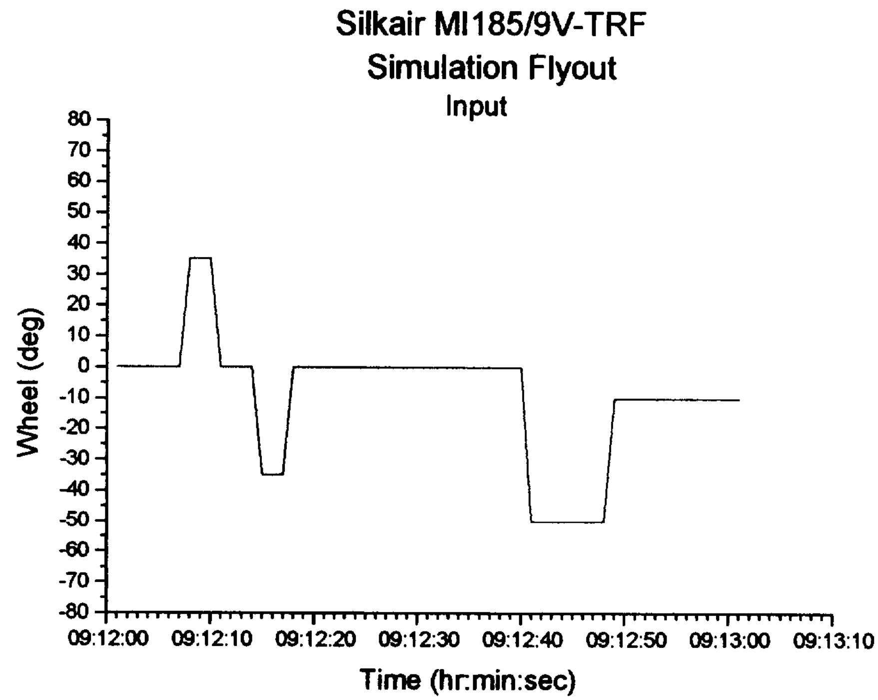
Silkair MI185/9V-TRF
Simulation Flyout
Simulation
Radar
Altitude (ft)
35000
30000
25000
20000
15000
10000
5000
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

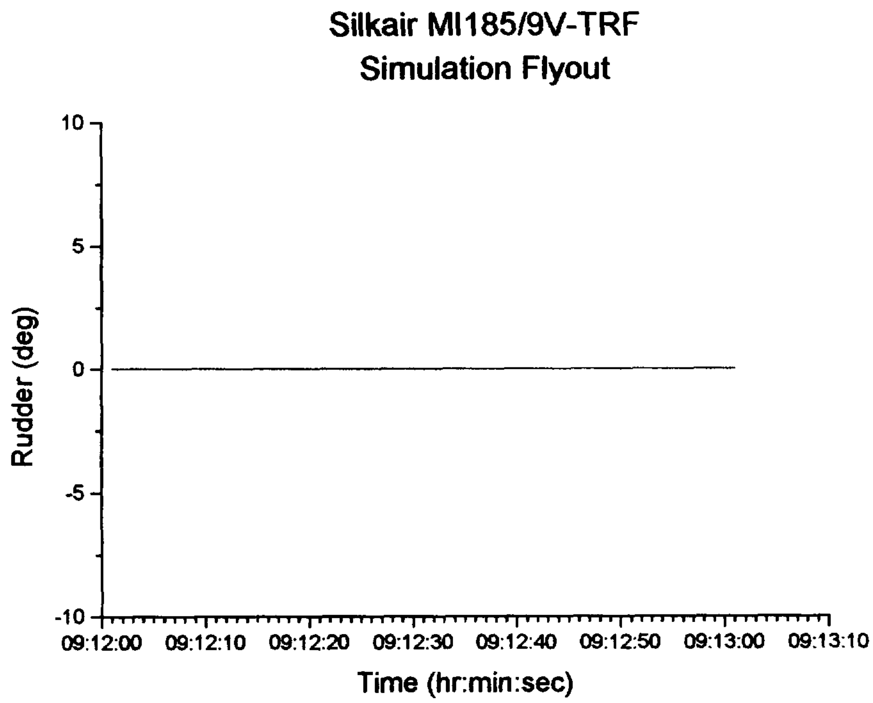
Matching Scenarios

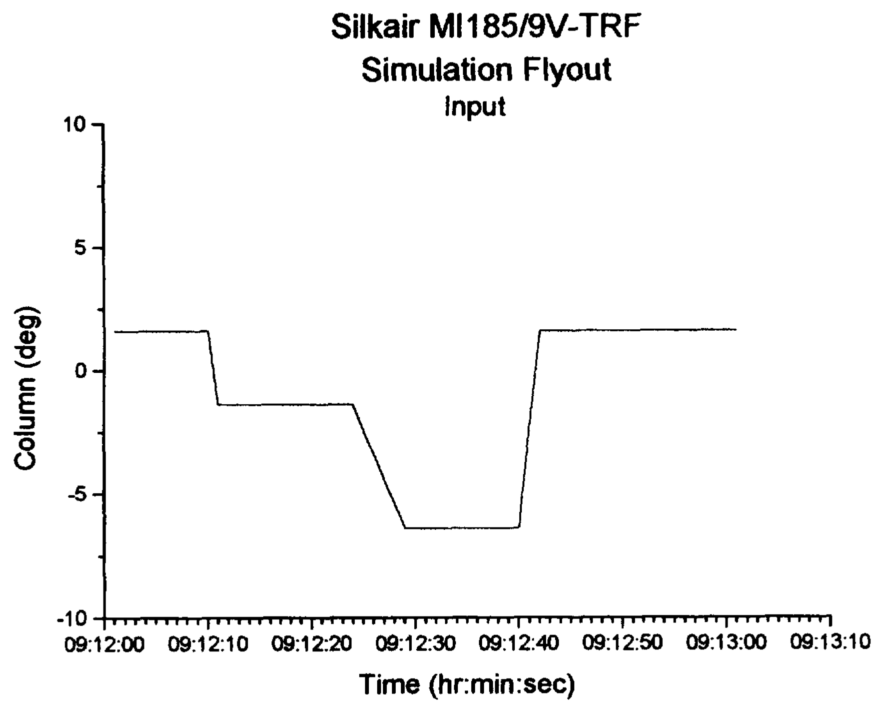
Several scenarios were identified that provide a match of the available data. These solutions all involve a combination of control inputs.

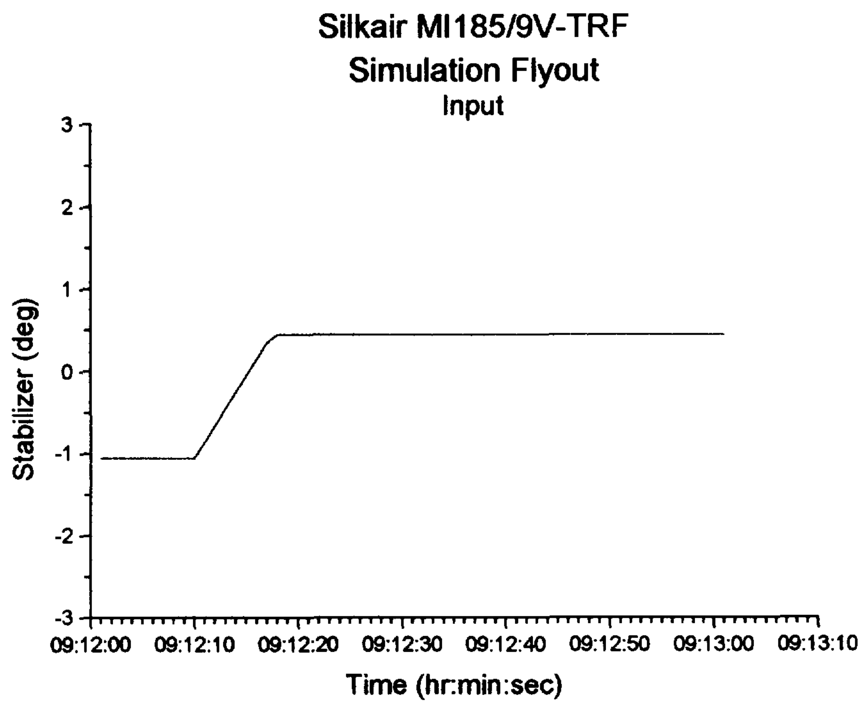
Pitch over Scenario

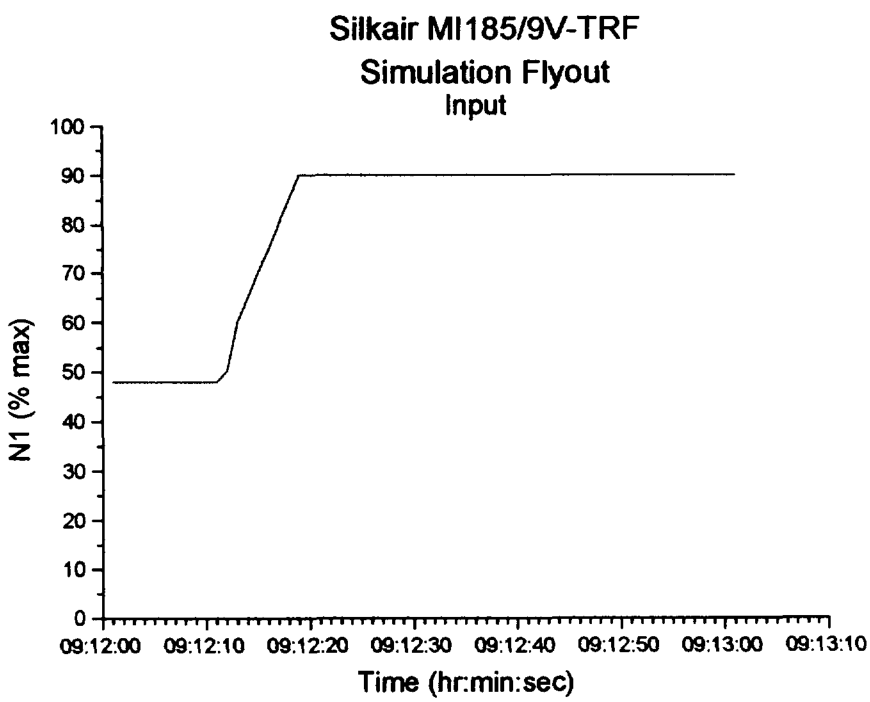
A pure pitch over scenario will miss the radar points since the radar points do not follow a constant heading line. However, with the addition of roll input, a pitch over can match the data. The control input and resulting match are presented in the following plots. Note that nose down column must increase from the initial departure level to match the data.

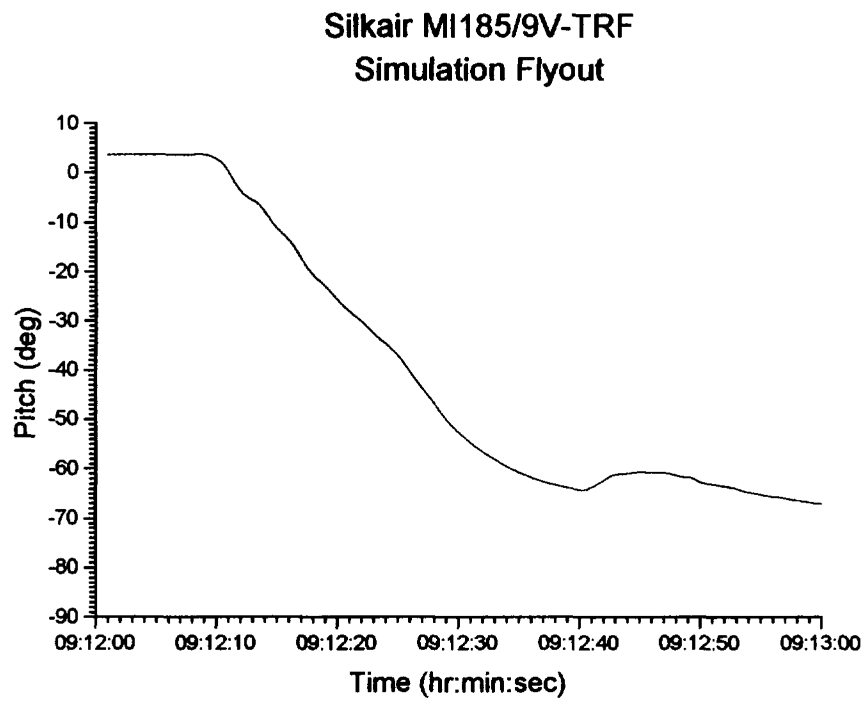


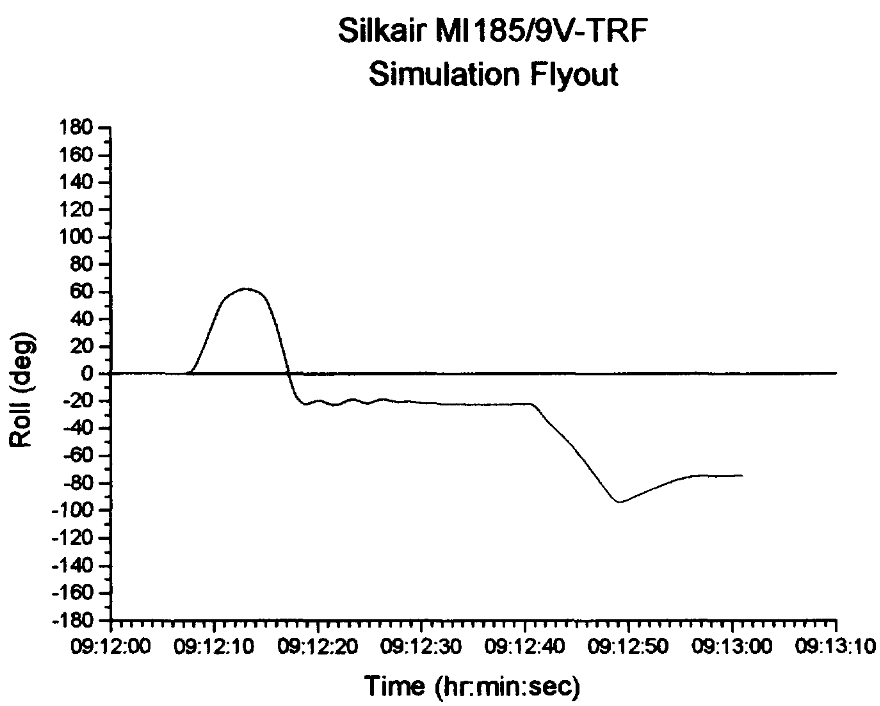

Silkair MI185/9V-TRF
Simulation Flyout
10
5
0
-5
-10
Rudder (deg)
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

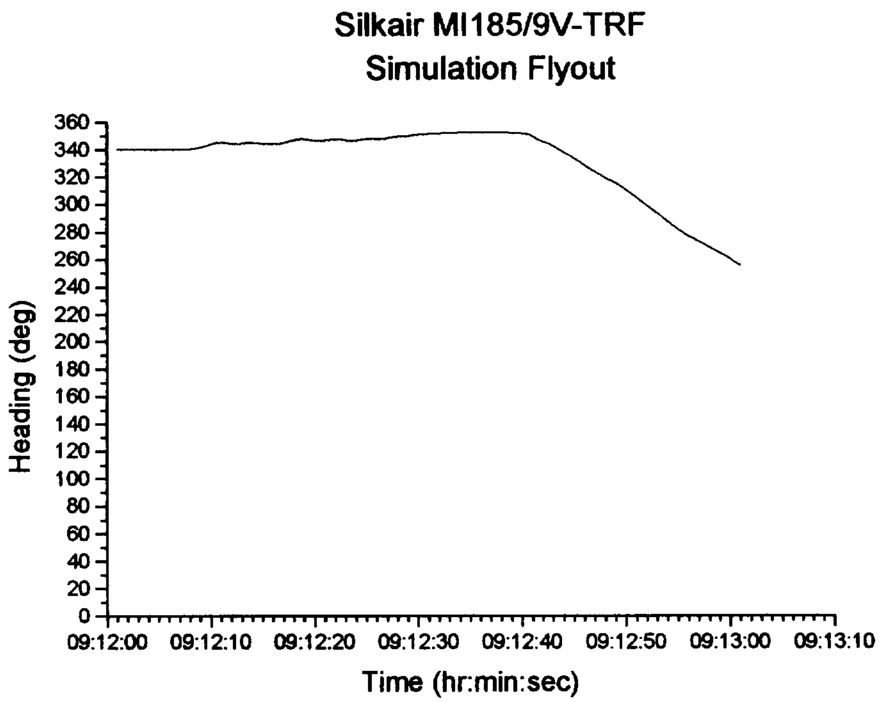

Silkair MI185/9V-TRF
Simulation Flyout
Input
10
5
0
-5
-10
Column (deg)
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

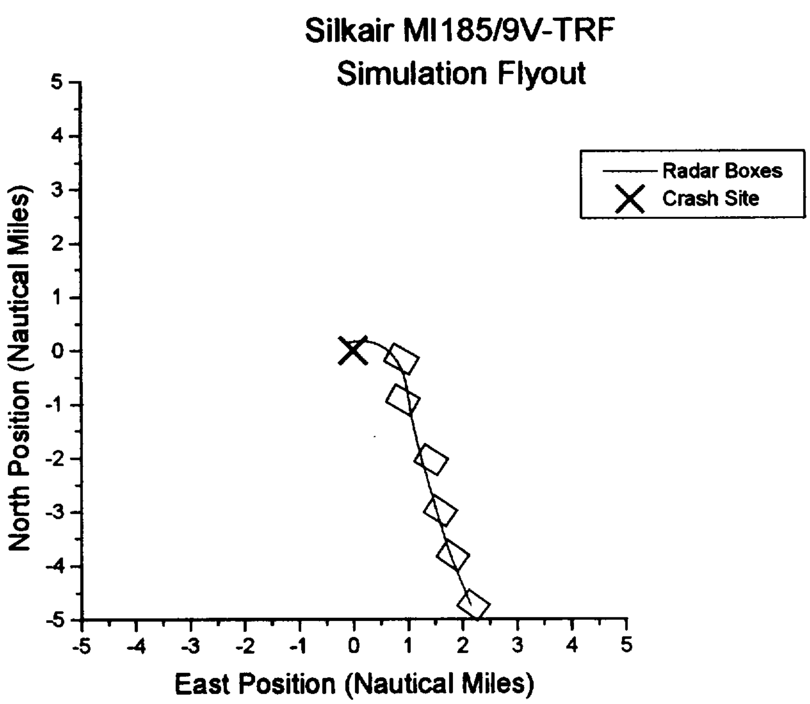

Silkair MI185/9V-TRF
Simulation Flyout
Input
Stabilizer (deg)
3
2
1
0
-1
-2
-3
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

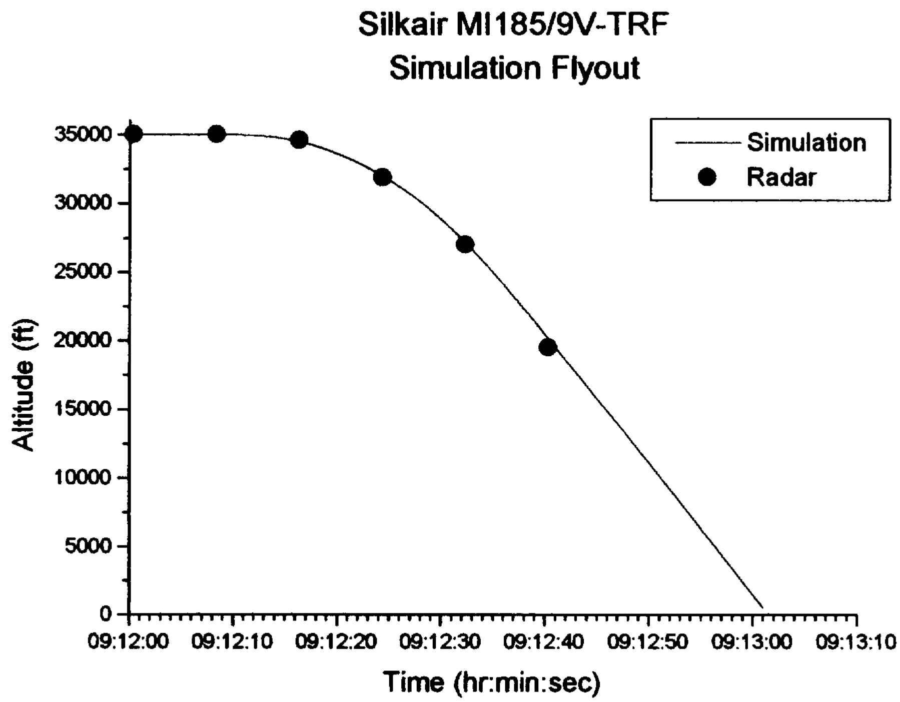

Silkair MI185/9V-TRF
Simulation Flyout
Input
N1 (% max)
100
90
80
70
60
50
40
30
20
10
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Pitch (deg)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
Time (hr:min:sec)

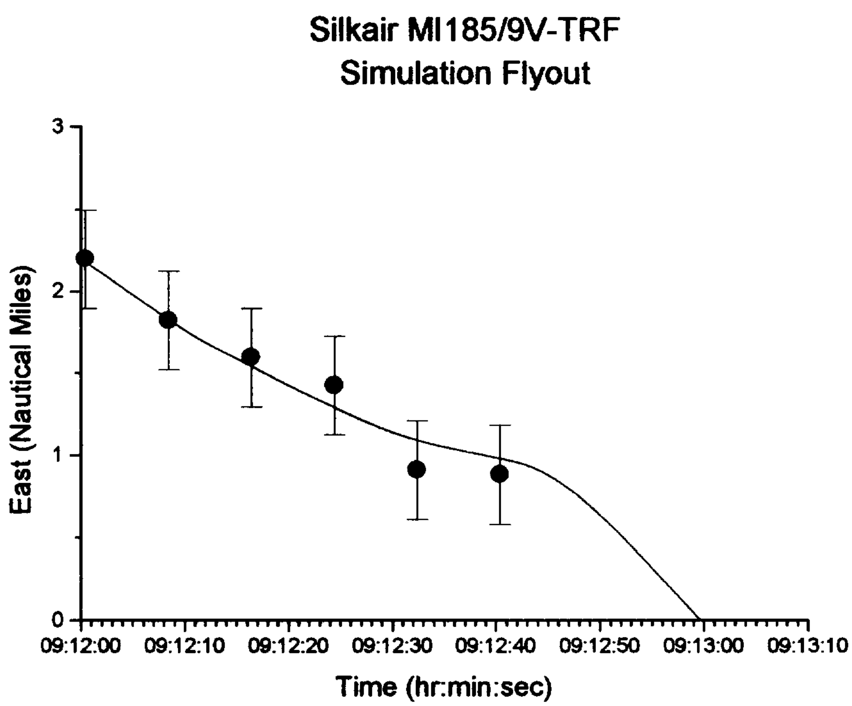

Silkair MI185/9V-TRF
Simulation Flyout
Roll (deg)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Heading (deg)
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

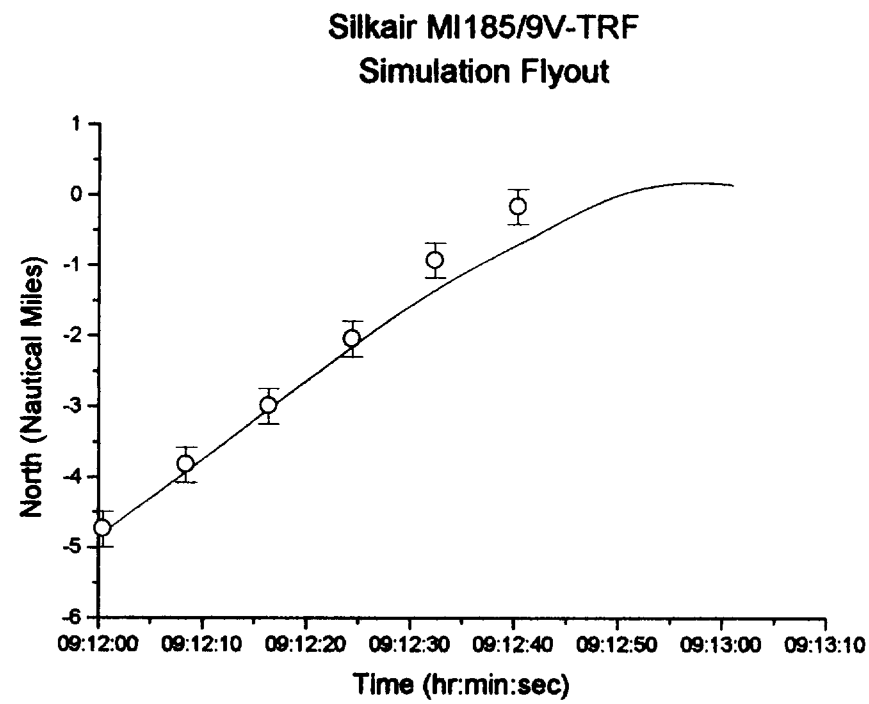

Silkair MI185/9V-TRF
Simulation Flyout
Radar Boxes
Crash Site
North Position (Nautical Miles)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
-4
-3
-2
-1
0
1
2
3
4
5
East Position (Nautical Miles)

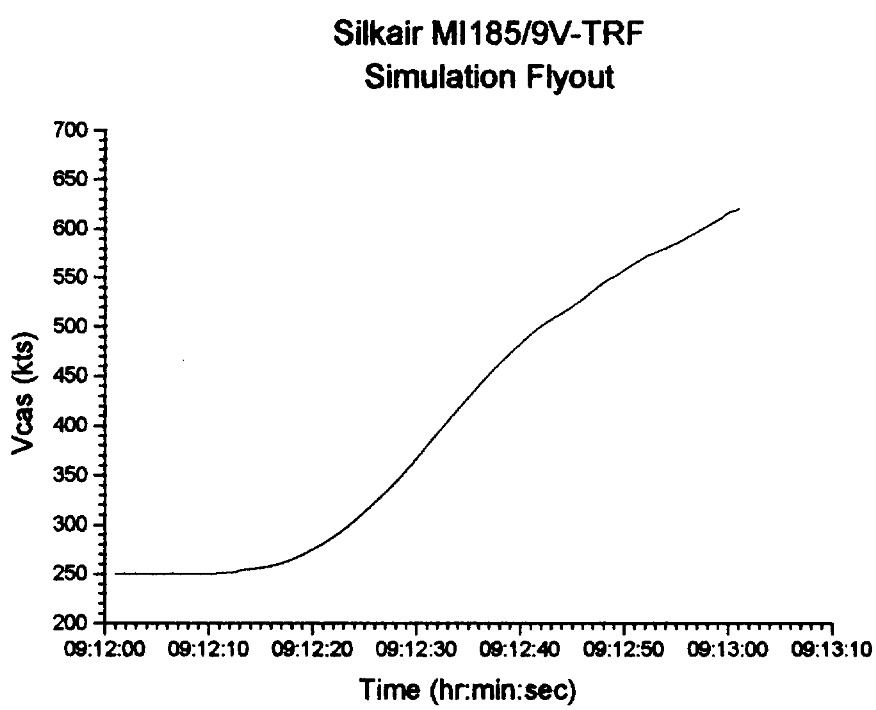


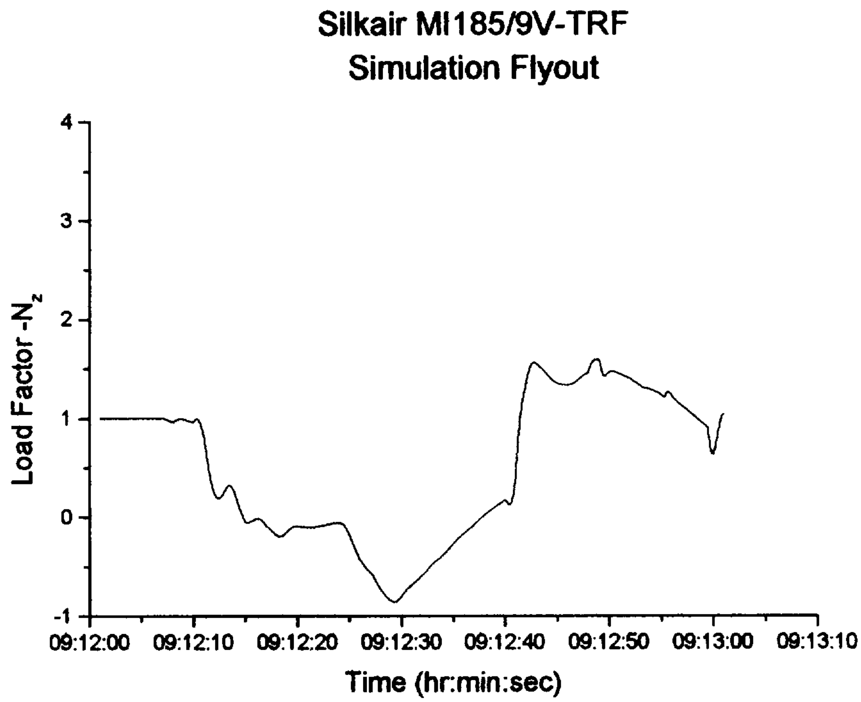
Silkair MI185/9V-TRF
Simulation Flyout
Simulation
Radar
Altitude (ft)
35000
30000
25000
20000
15000
10000
5000
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)



Silkair MI185/9V-TRF
Simulation Flyout
East (Nautical Miles)
3
2
1
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

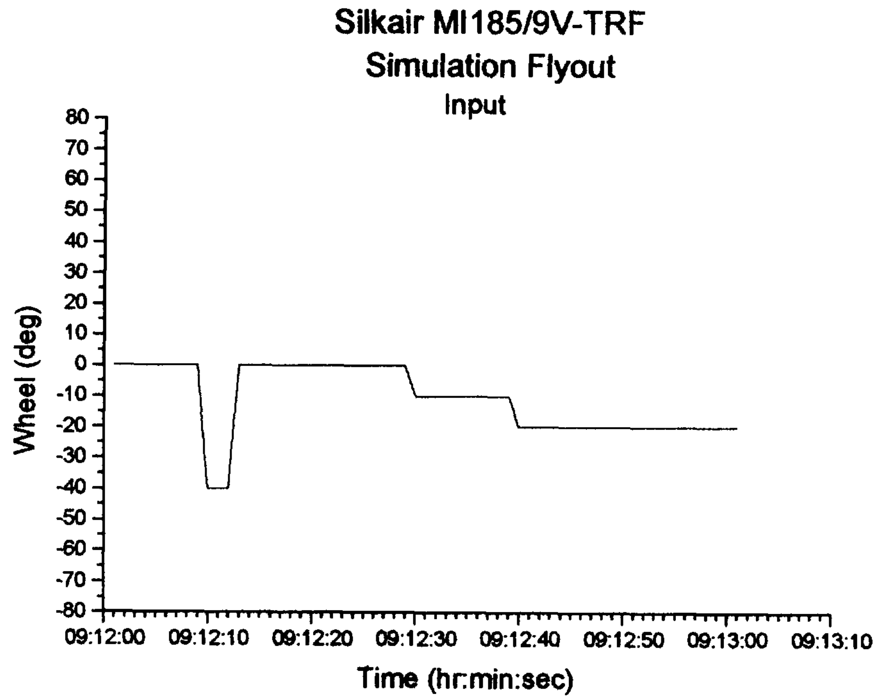

Silkair MI185/9V-TRF
Simulation Flyout
North (Nautical Miles)
1
0
-1
-2
-3
-4
-5
-6
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Vcas (kts)
700
650
600
550
500
450
400
350
300
250
200
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

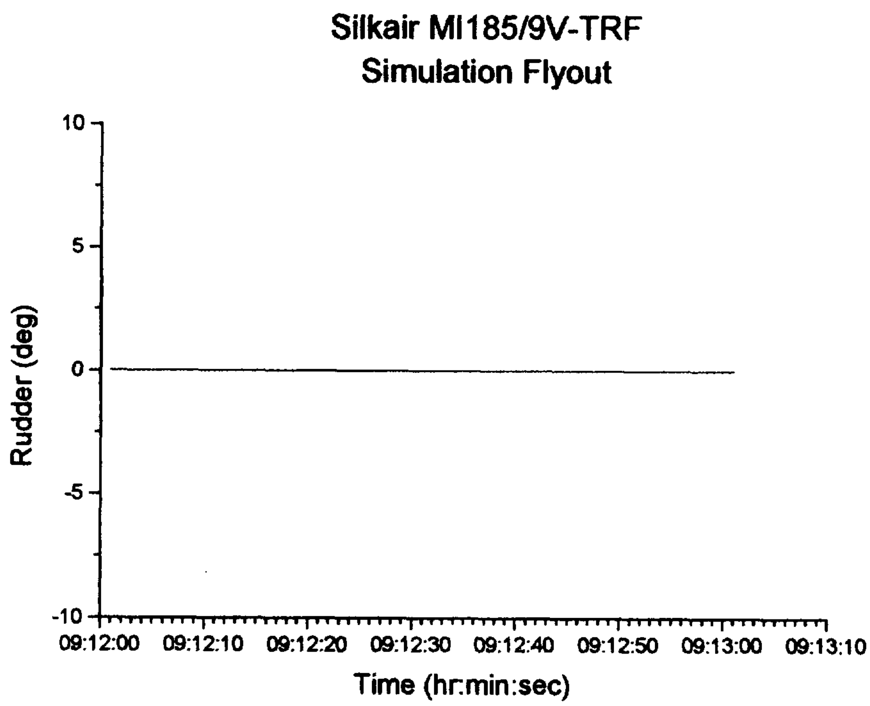


<u>90 deg bank descent Scenario</u>

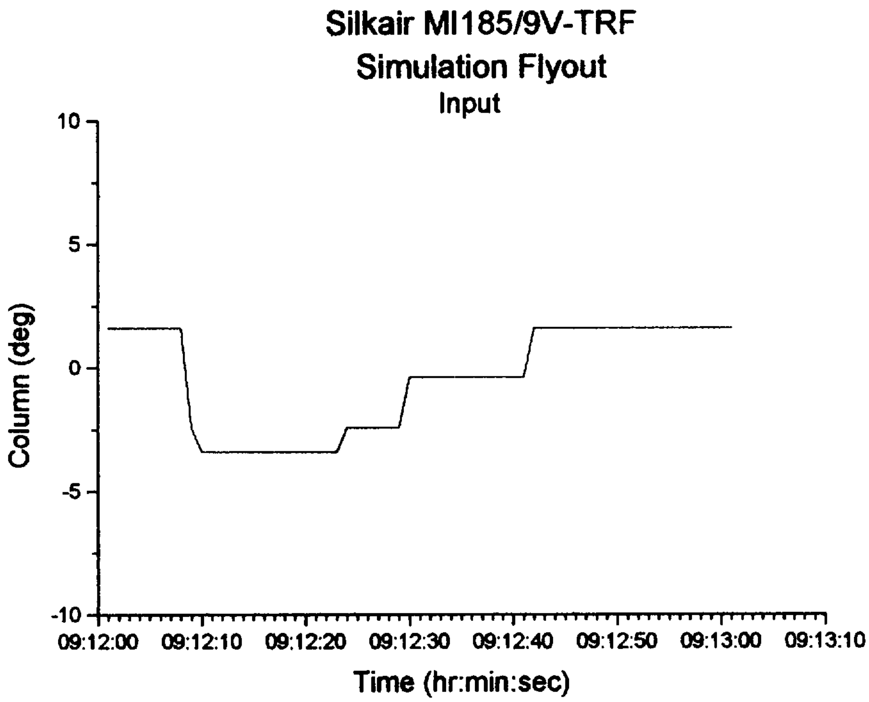
Another scenario that matches the data consists of a roll to a near 90 degree bank angle together with forward pressure on the column. The control input and resulting match are presented in the following plots. Again note that control input must change with time.

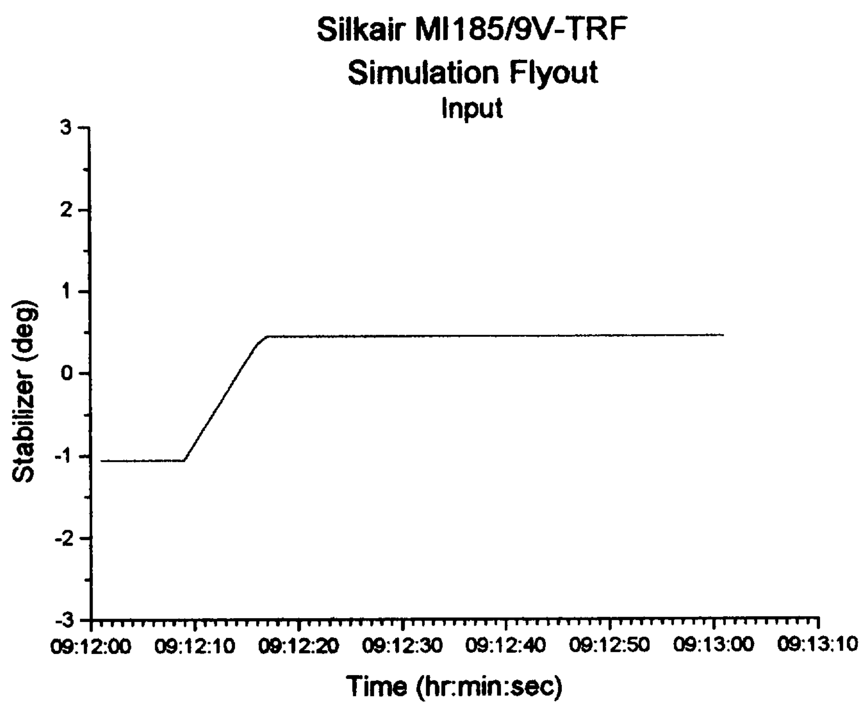


Silkair MI185/9V-TRF
Simulation Flyout
Input
Wheel (deg)
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

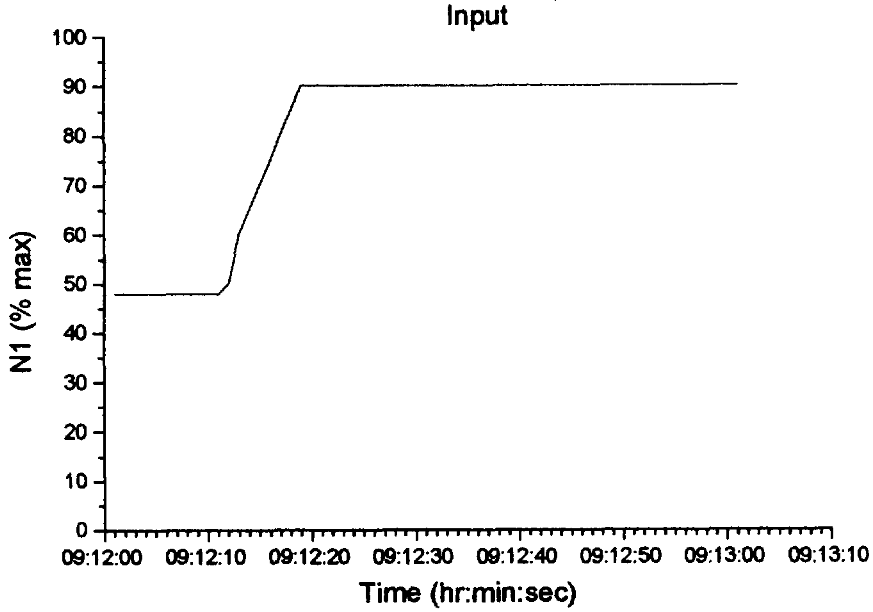


Silkair MI185/9V-TRF
Simulation Flyout
Rudder (deg)
10
5
0
-5
-10
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

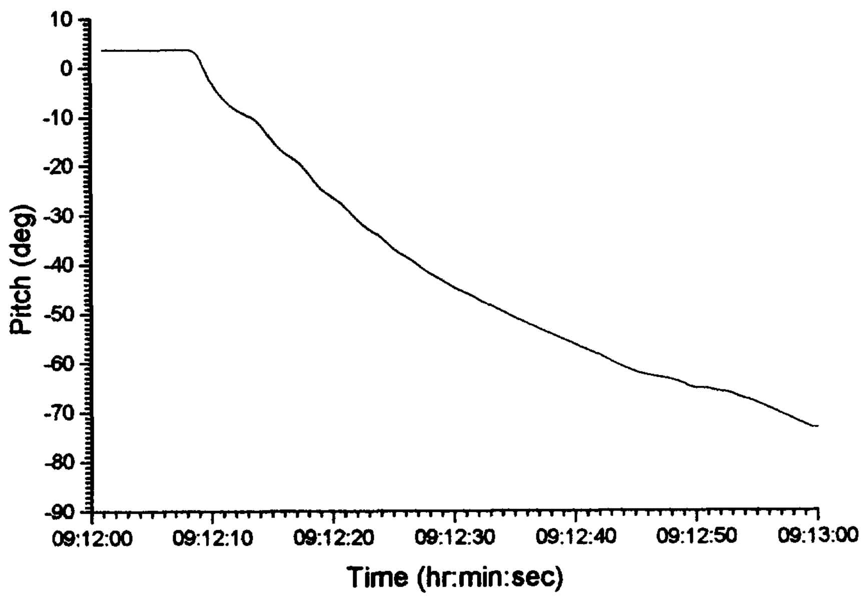

Silkair MI185/9V-TRF
Simulation Flyout
Input
Column (deg)
10
5
0
-5
-10
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Input
Stabilizer (deg)
3
2
1
0
-1
-2
-3
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

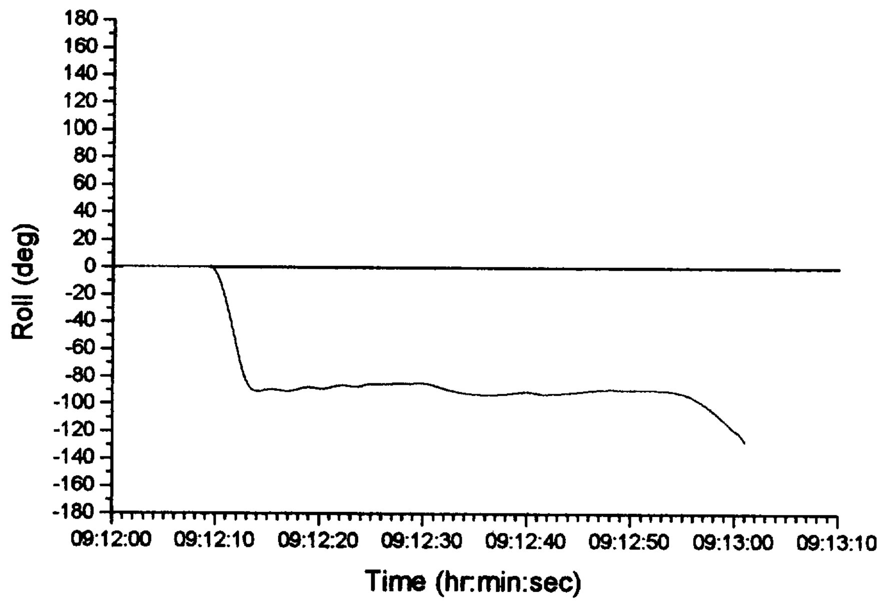
Silkair MI185/9V-TRF
Simulation Flyout
Input



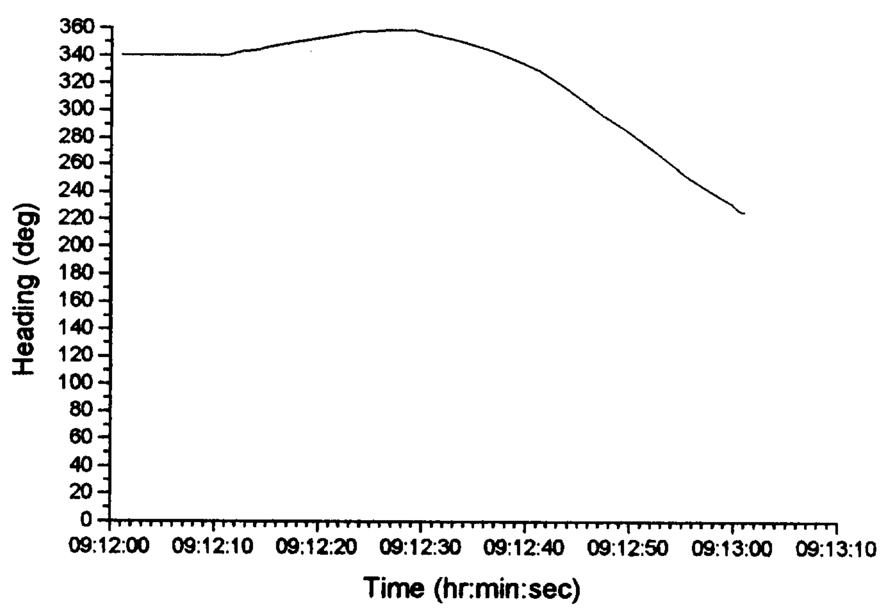
Silkair MI185/9V-TRF
Simulation Flyout

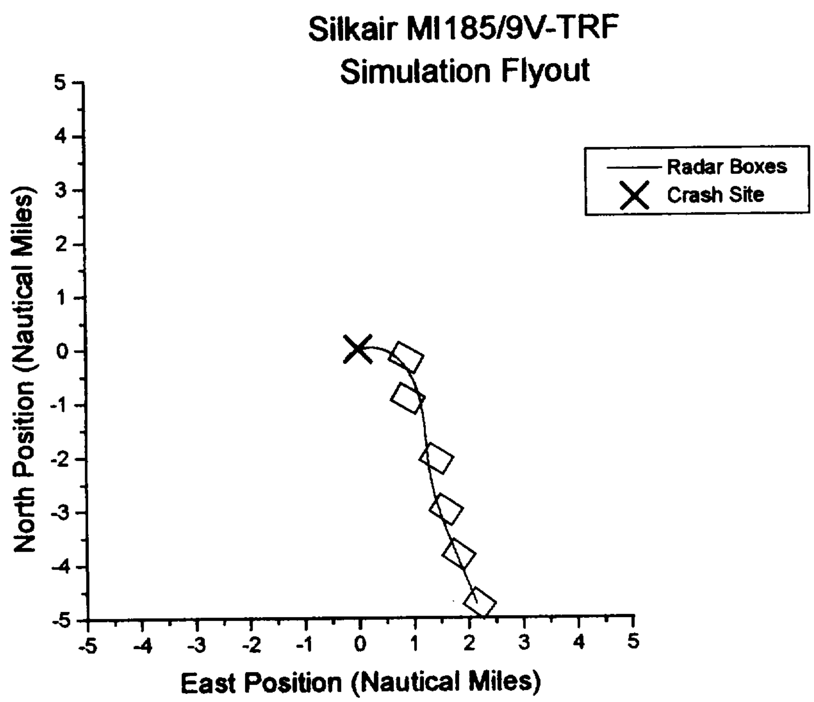


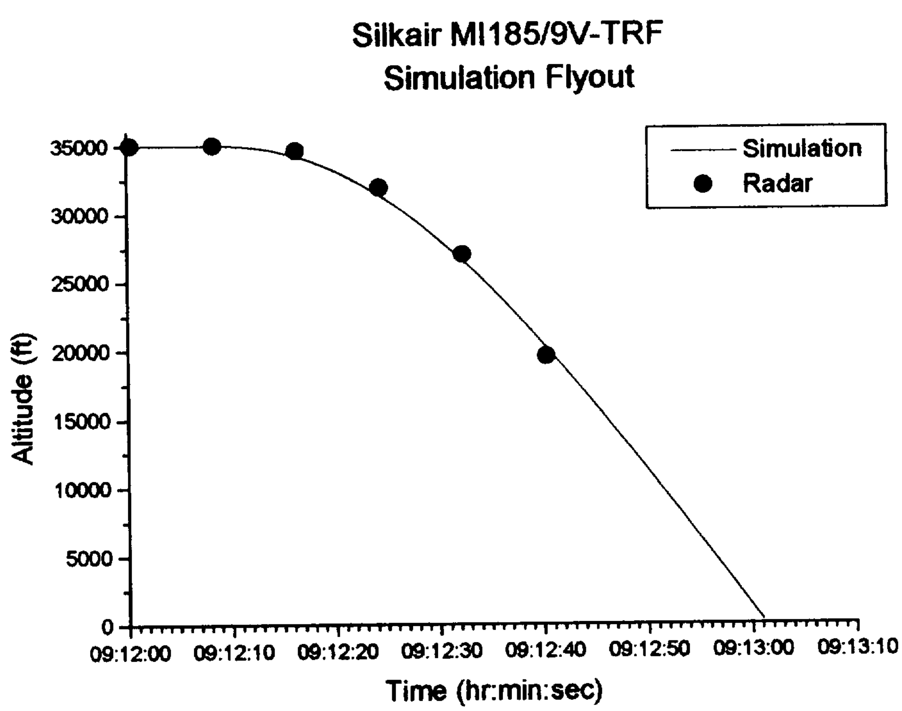
Silkair MI185/9V-TRF
Simulation Flyout

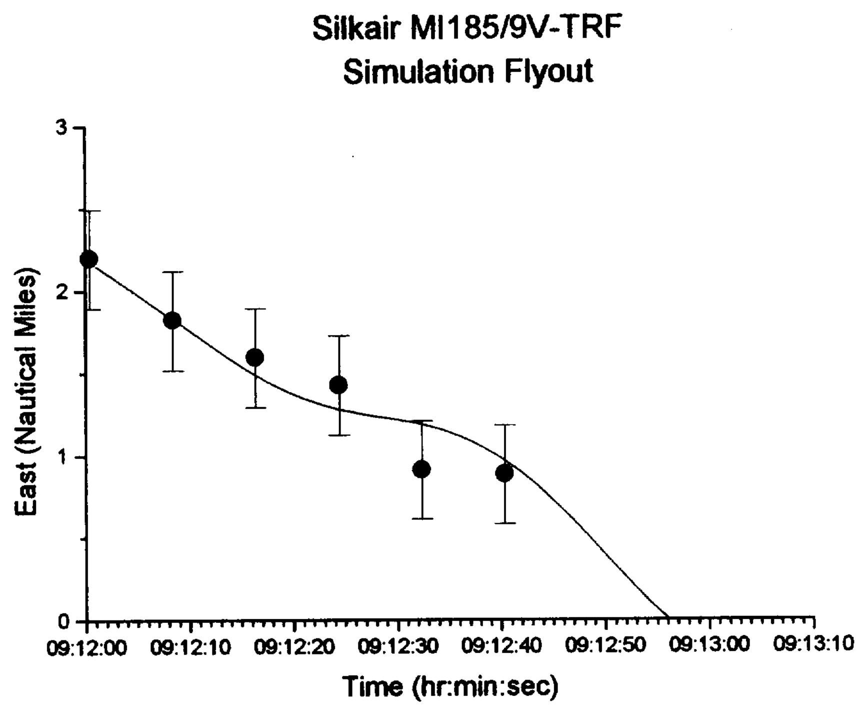


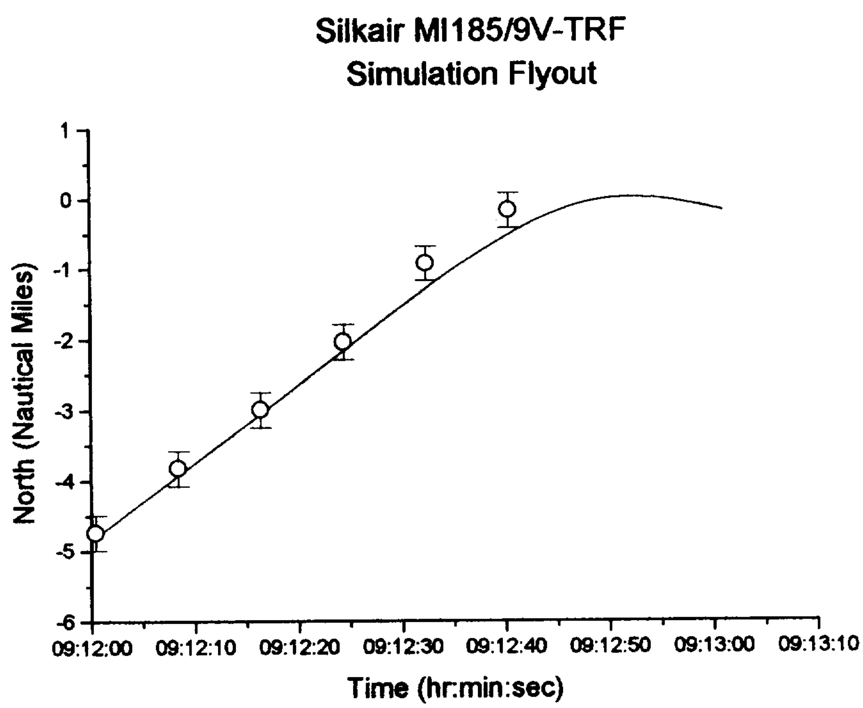
Silkair MI185/9V-TRF
Simulation Flyout

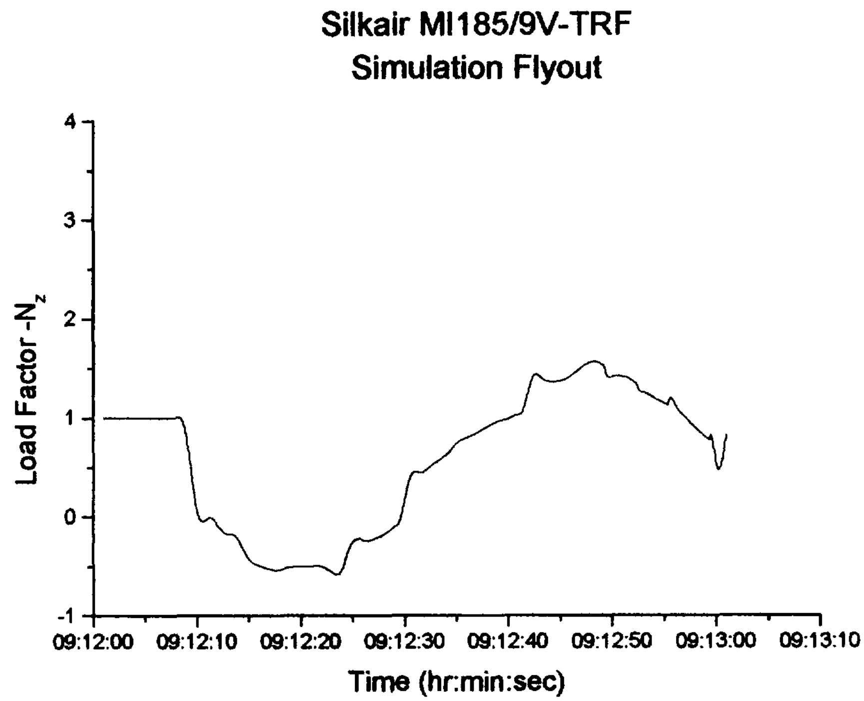



Silkair MI185/9V-TRF
Simulation Flyout
Radar Boxes
Crash Site
North Position (Nautical Miles)
East Position (Nautical Miles)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
-4
-3
-2
-1
0
1
2
3
4
5


Silkair MI185/9V-TRF
Simulation Flyout
Simulation
Radar
Altitude (ft)
35000
30000
25000
20000
15000
10000
5000
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
East (Nautical Miles)
3
2
1
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

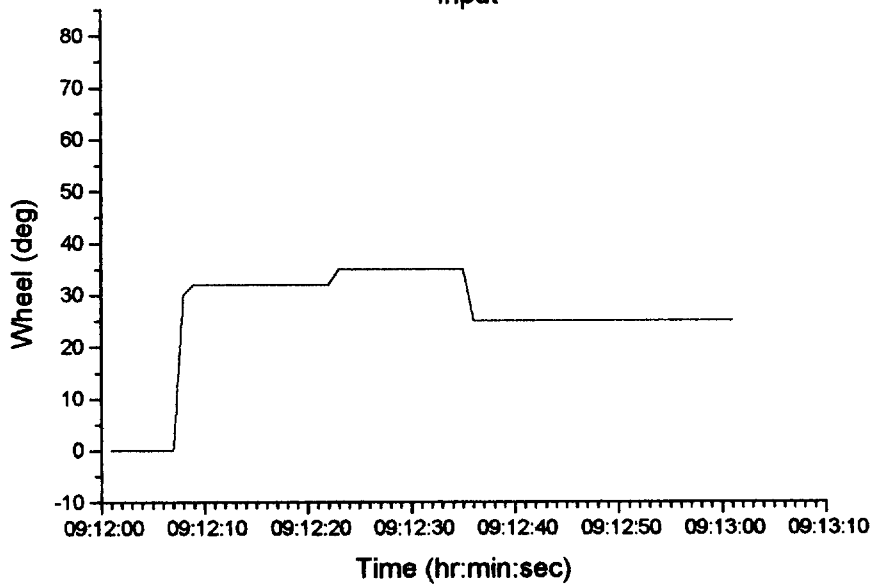

Silkair MI185/9V-TRF
Simulation Flyout
North (Nautical Miles)
1
0
-1
-2
-3
-4
-5
-6
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)



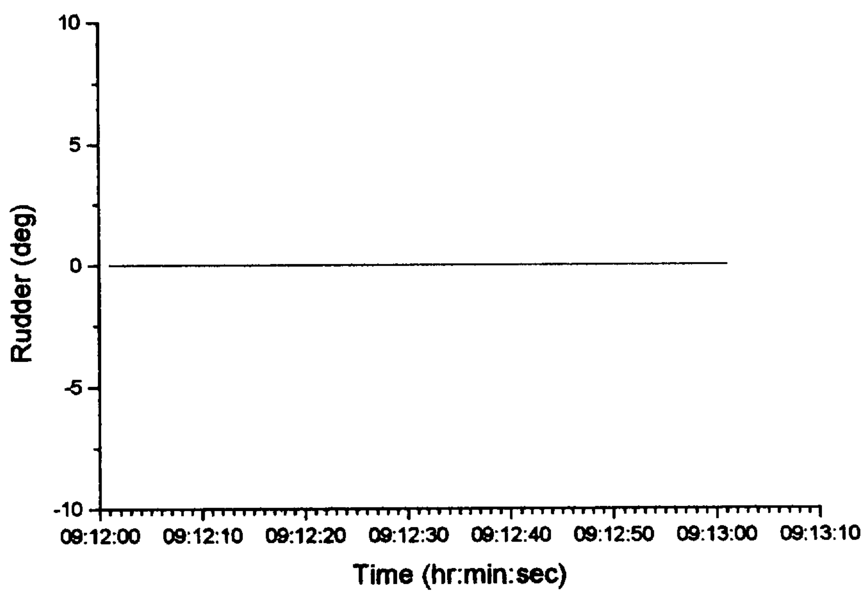
Continual Roll Scenario A

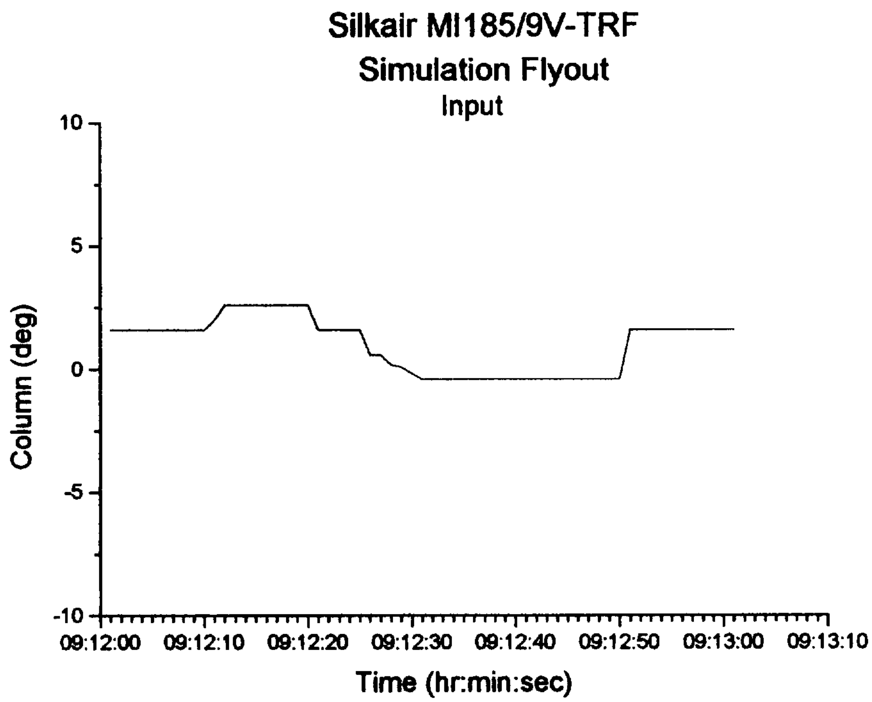
Another scenario that matches the data consists of two rolls to the right. The control input and resulting match are presented in the following plots.

Silkair MI185/9V-TRF
Simulation Flyout
Input

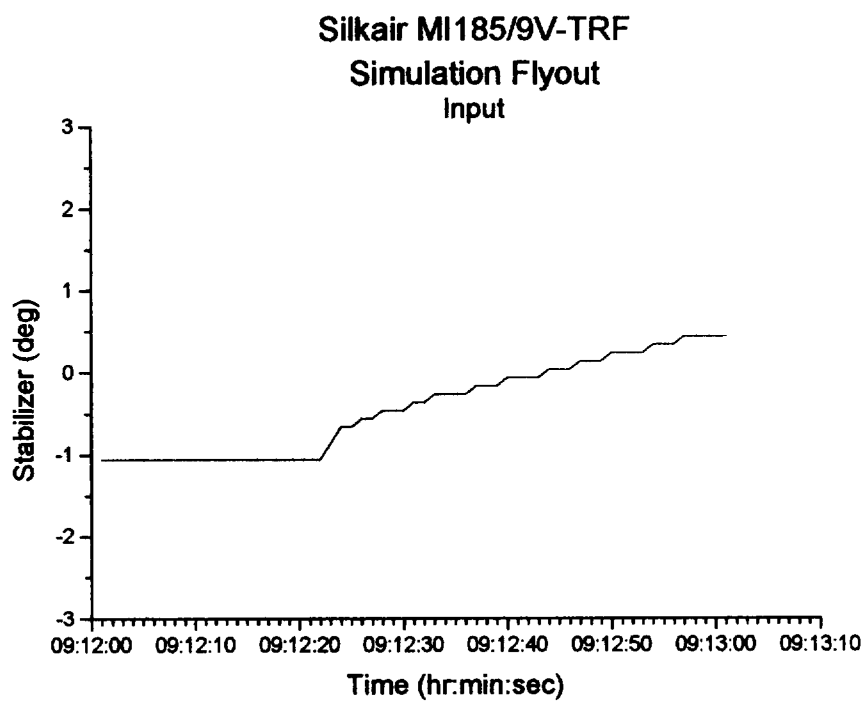


Silkair MI185/9V-TRF
Simulation Flyout

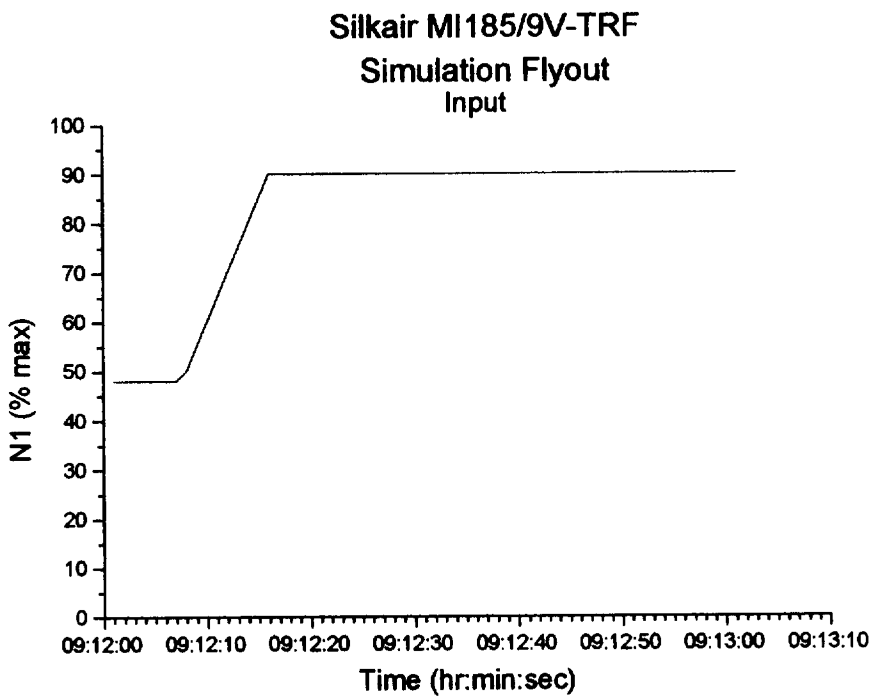




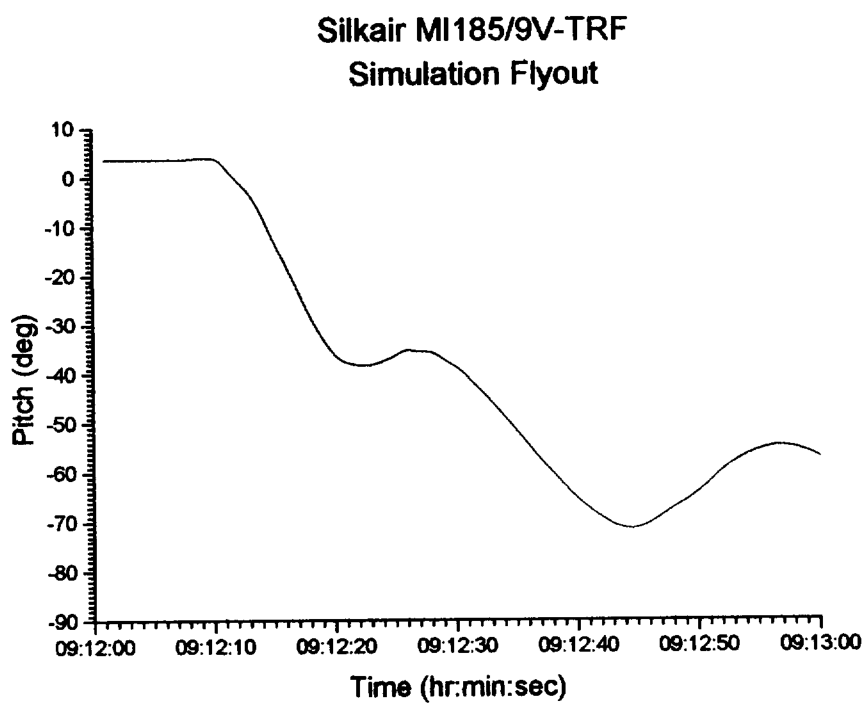
Silkair MI185/9V-TRF
Simulation Flyout
Input
10
5
0
-5
-10
Column (deg)
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)



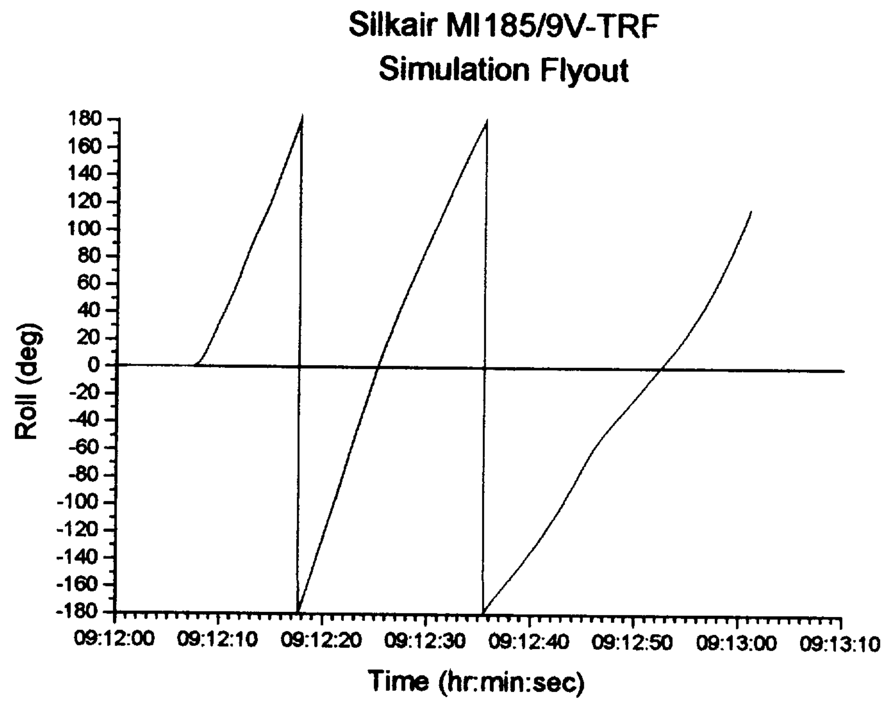
Silkair MI185/9V-TRF
Simulation Flyout
Input
3
2
1
0
-1
-2
-3
Stabilizer (deg)
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

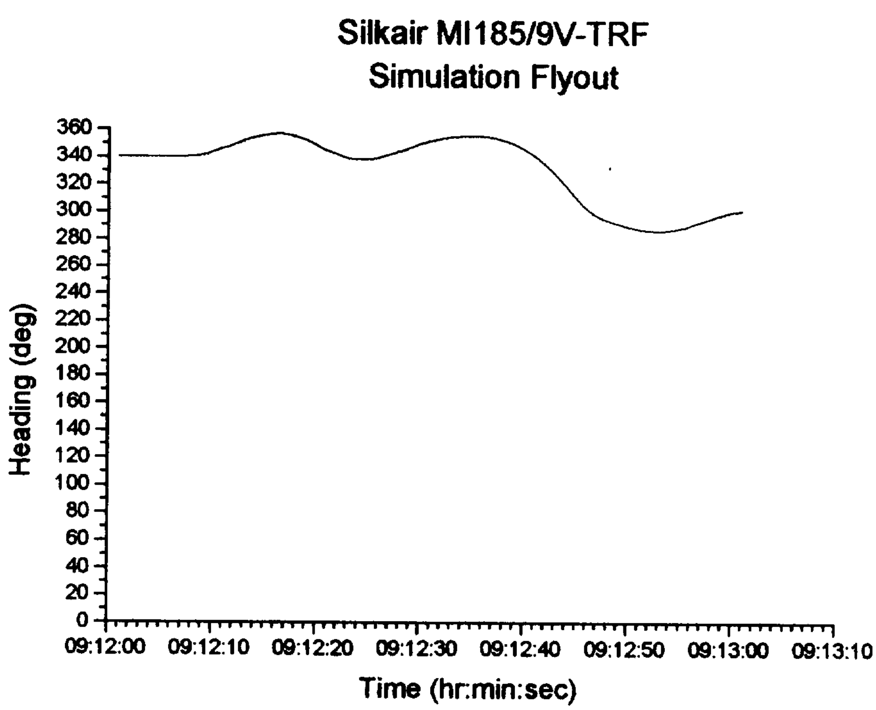


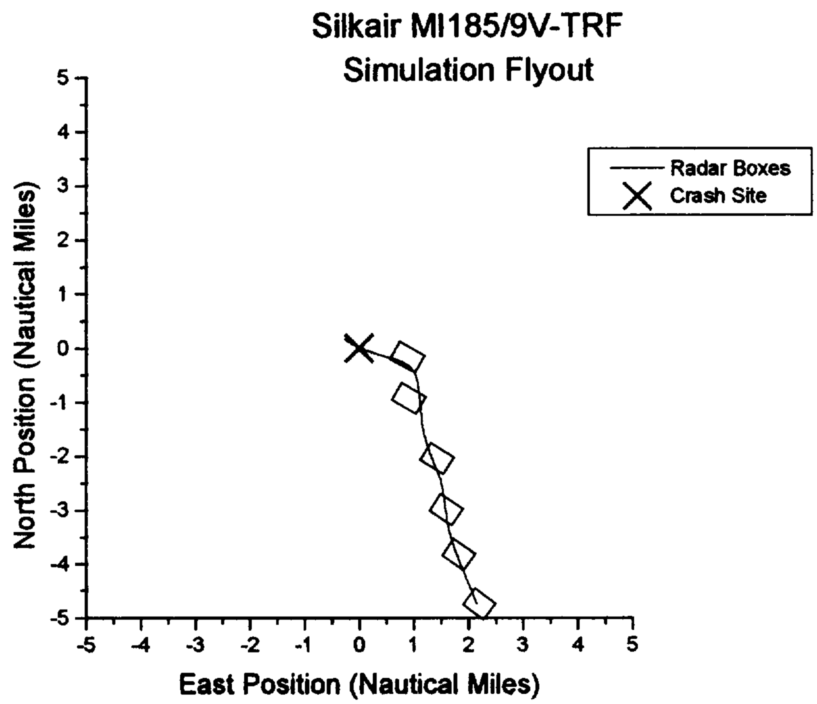
Silkair MI185/9V-TRF
Simulation Flyout
Input
100
90
80
70
60
50
40
30
20
10
0
N1 (% max)
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

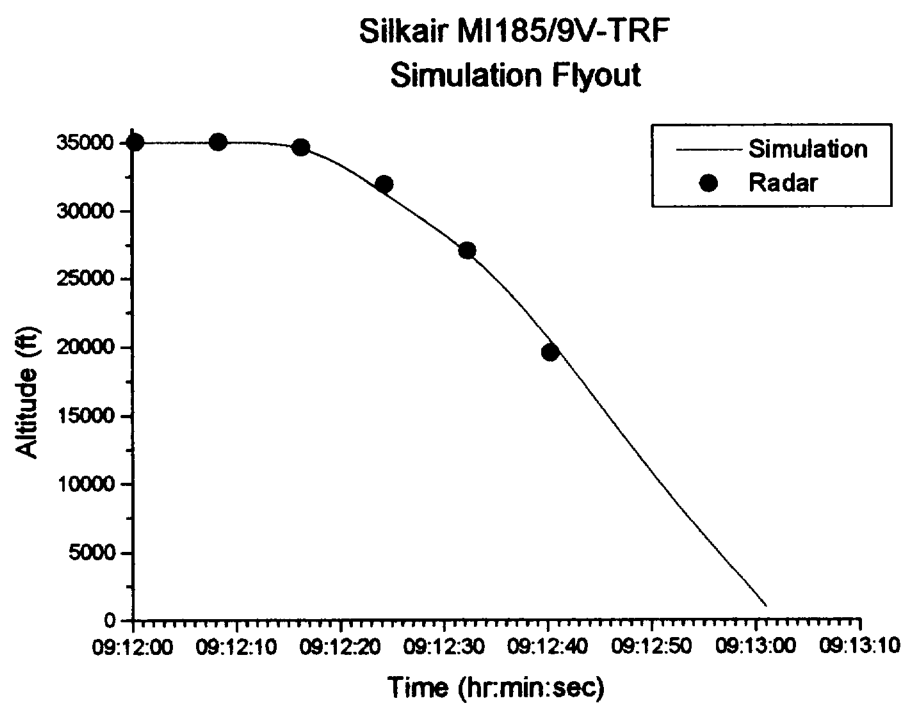


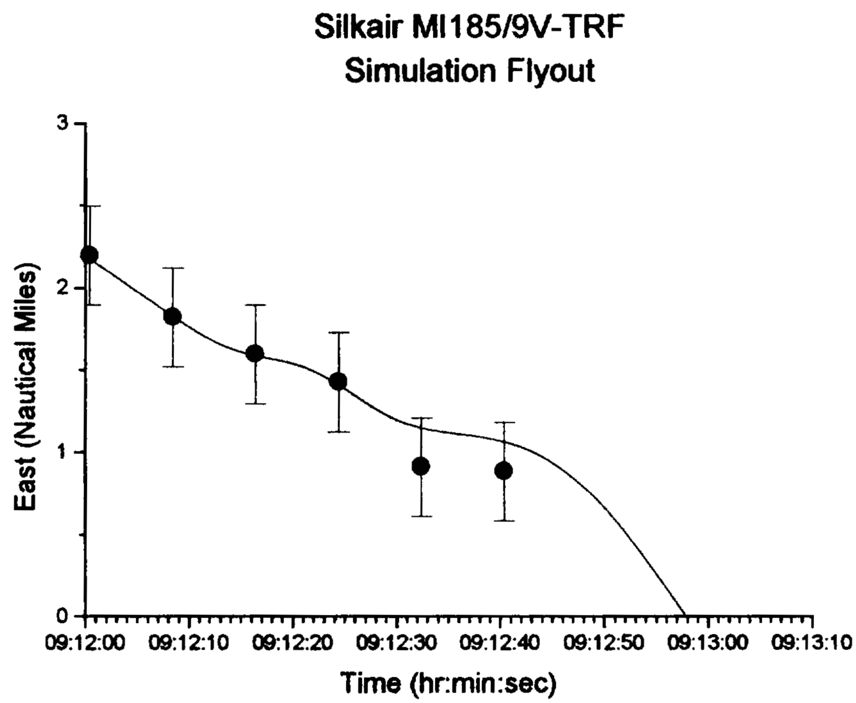
Silkair MI185/9V-TRF
Simulation Flyout
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
Pitch (deg)
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
Time (hr:min:sec)

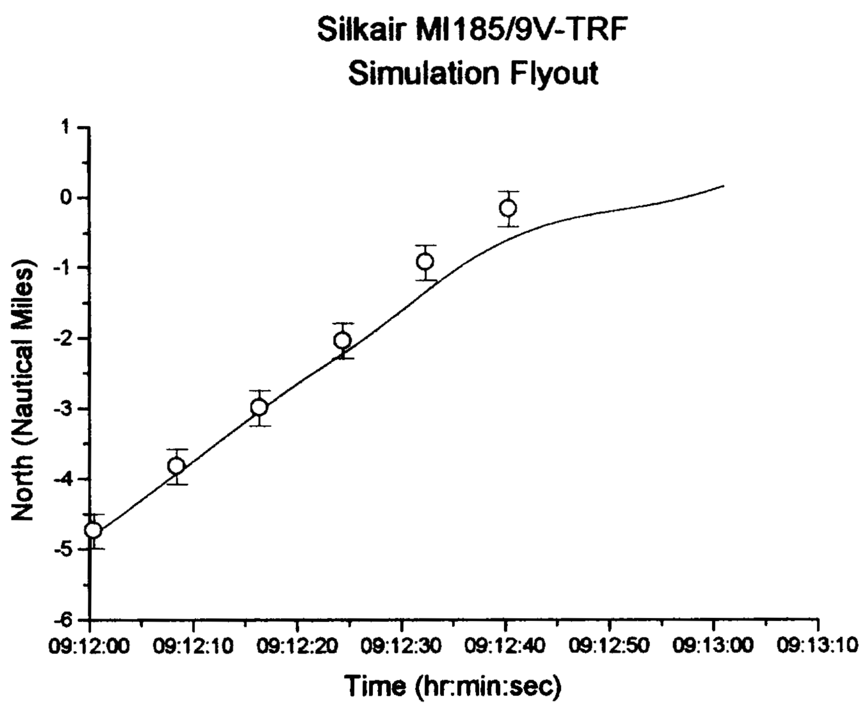

Silkair MI185/9V-TRF
Simulation Flyout
Roll (deg)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

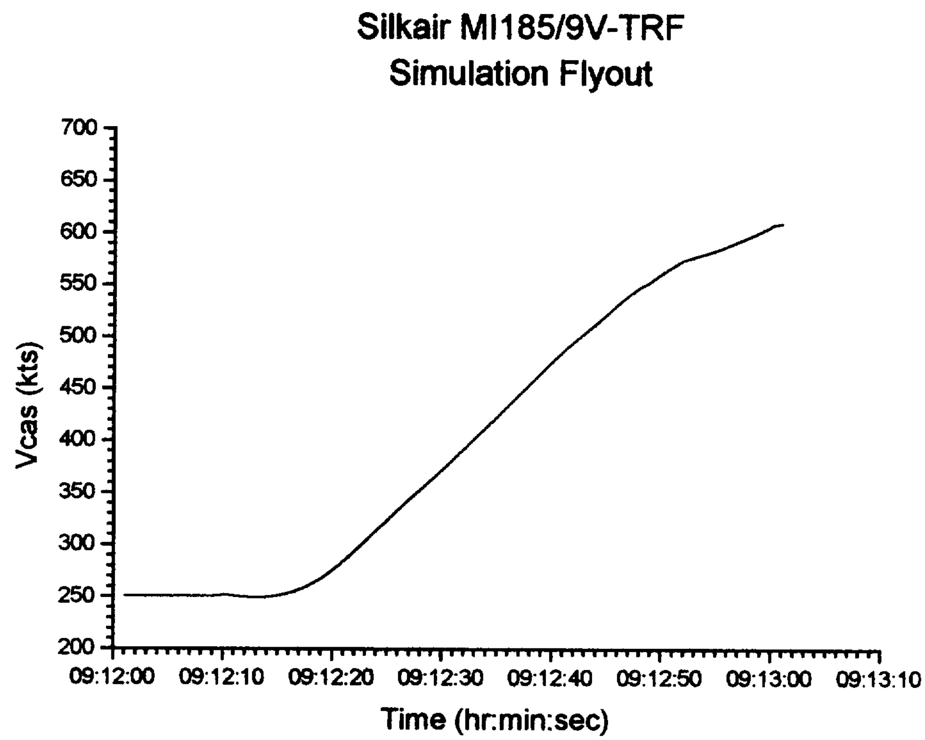

Silkair MI185/9V-TRF
Simulation Flyout
Heading (deg)
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

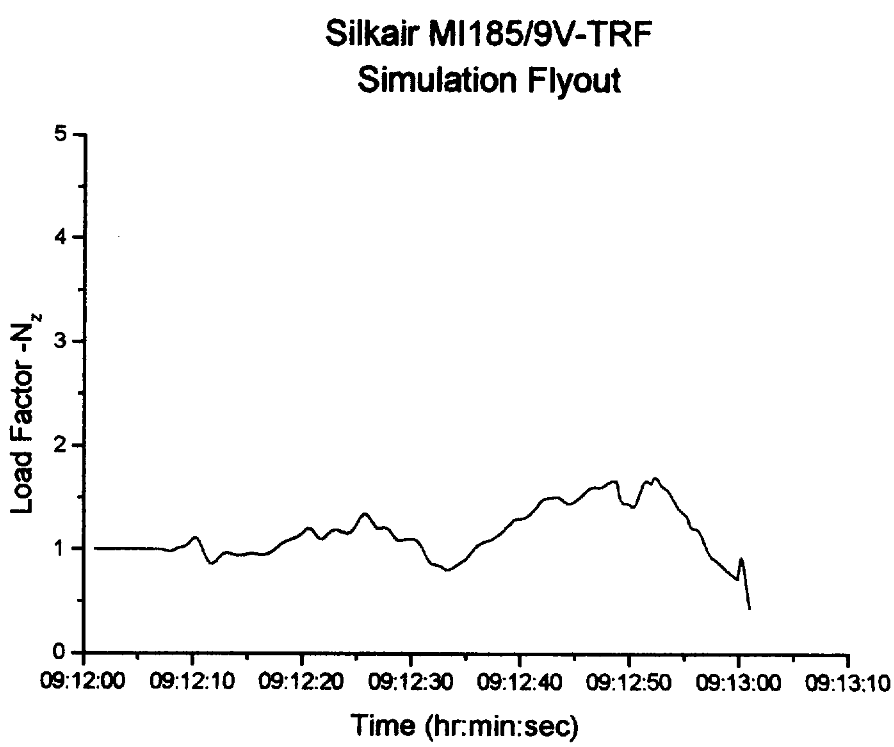

Silkair MI185/9V-TRF
Simulation Flyout
Radar Boxes
Crash Site
North Position (Nautical Miles)
East Position (Nautical Miles)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
-4
-3
-2
-1
0
1
2
3
4
5


Silkair MI185/9V-TRF
Simulation Flyout
Simulation
Radar
Altitude (ft)
35000
30000
25000
20000
15000
10000
5000
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
East (Nautical Miles)
3
2
1
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

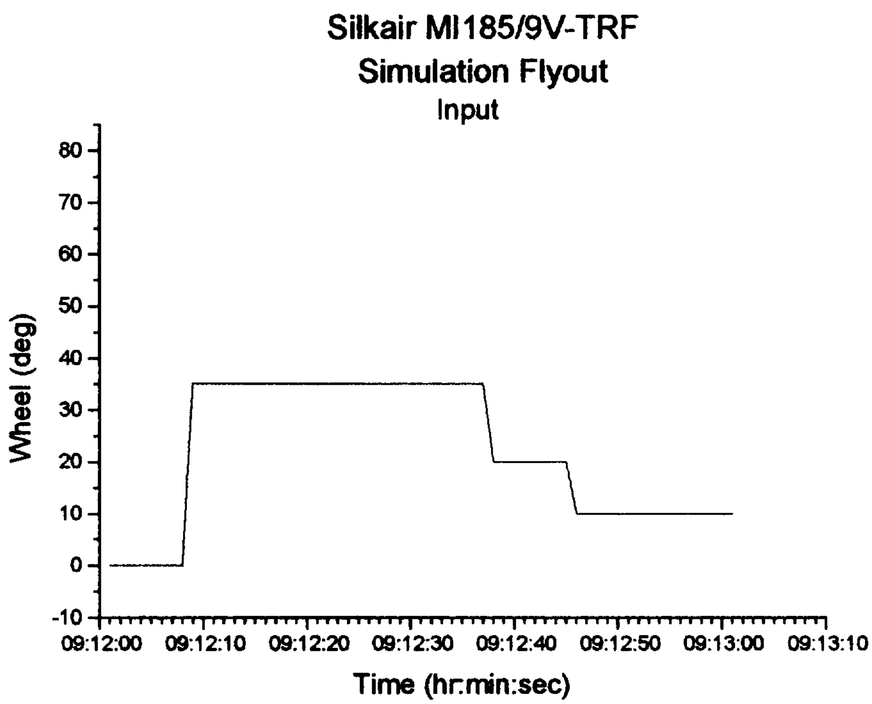

Silkair MI185/9V-TRF
Simulation Flyout
North (Nautical Miles)
1
0
-1
-2
-3
-4
-5
-6
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
700
650
600
550
500
450
400
350
300
250
200
Vcas (kts)
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

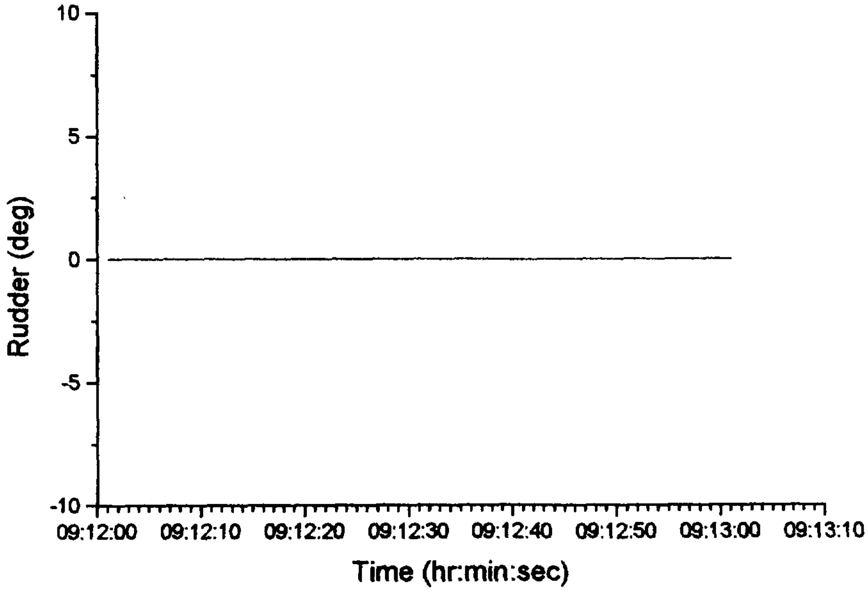

Silkair MI185/9V-TRF
Simulation Flyout
5
4
3
2
1
0
Load Factor -N
z
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

Continual Roll Scenario B

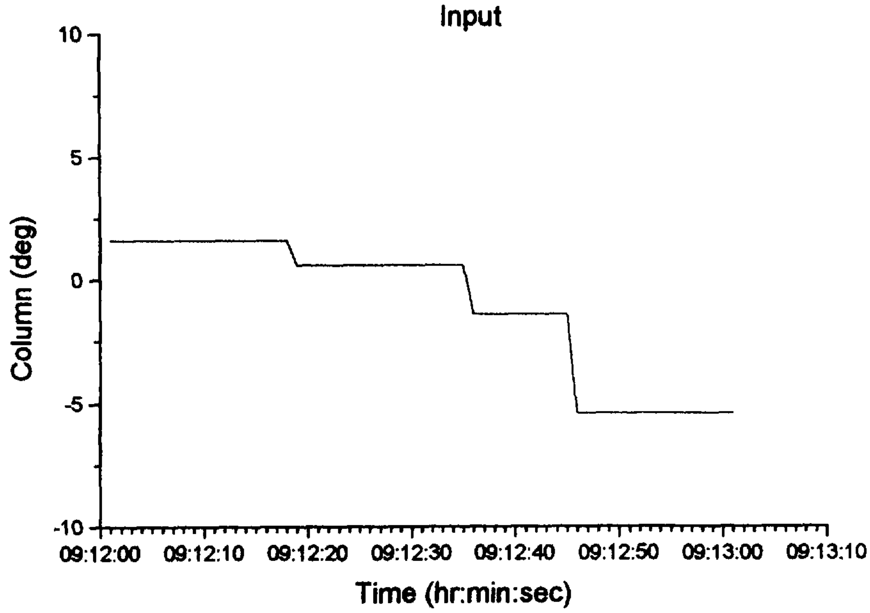
Another two right rolls scenario that matches the data with different control input was also developed. The control input and resulting match are presented in the following plots.

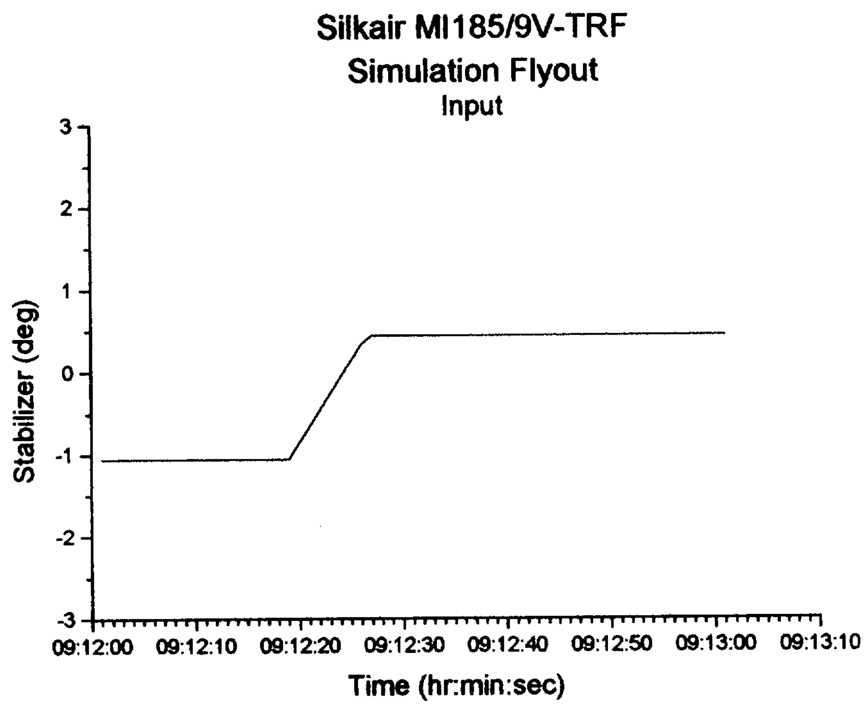


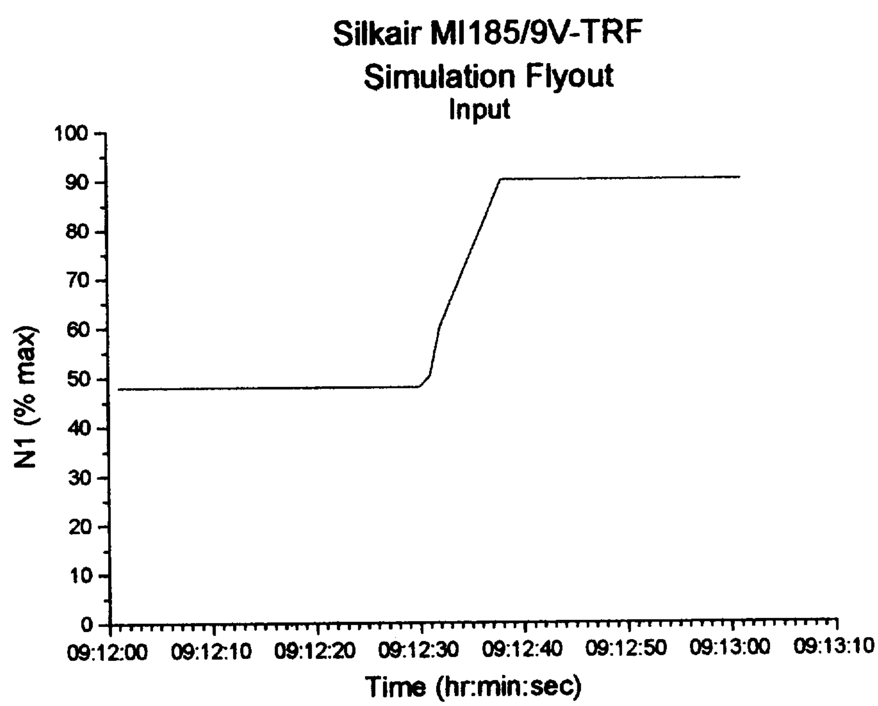
Silkair MI185/9V-TRF
Simulation Flyout

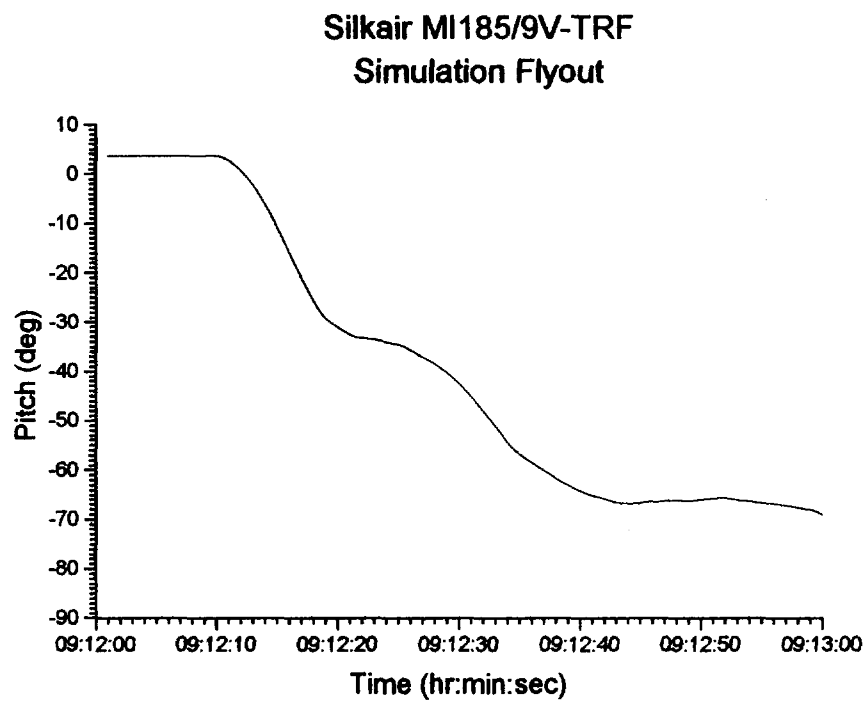


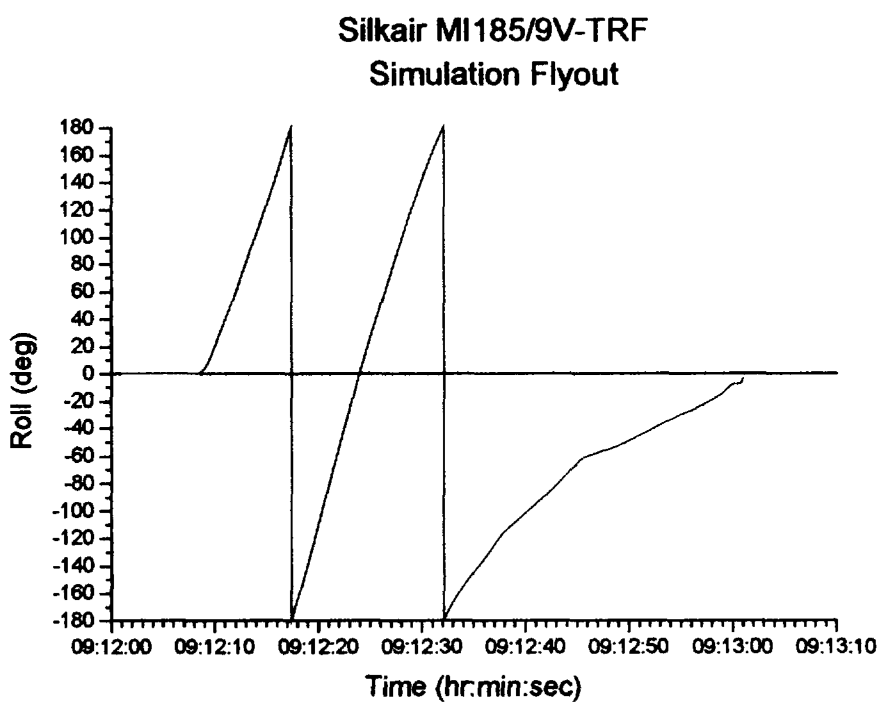
Silkair MI185/9V-TRF
Simulation Flyout
Input

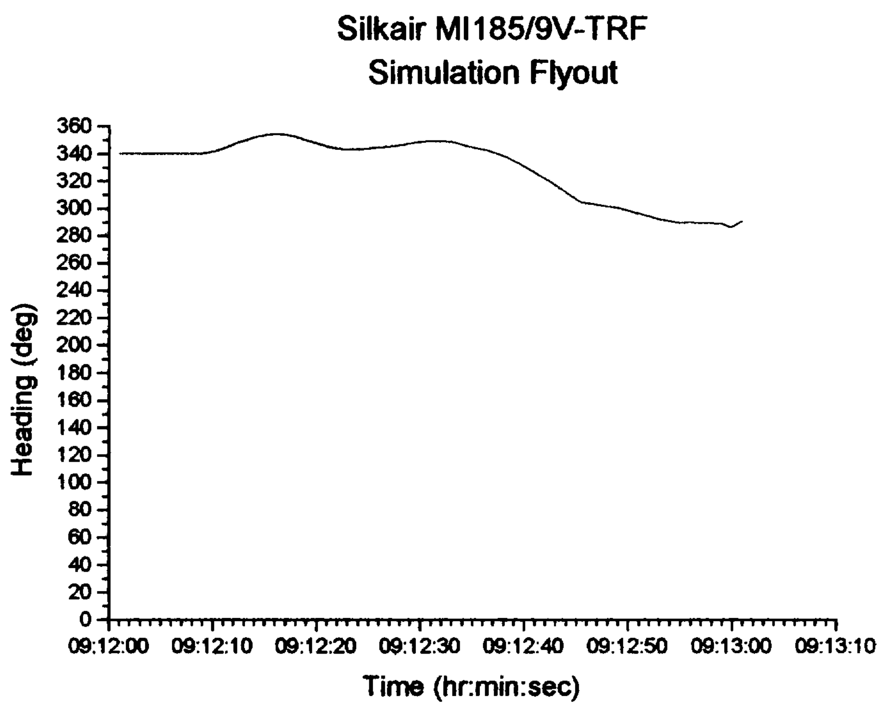


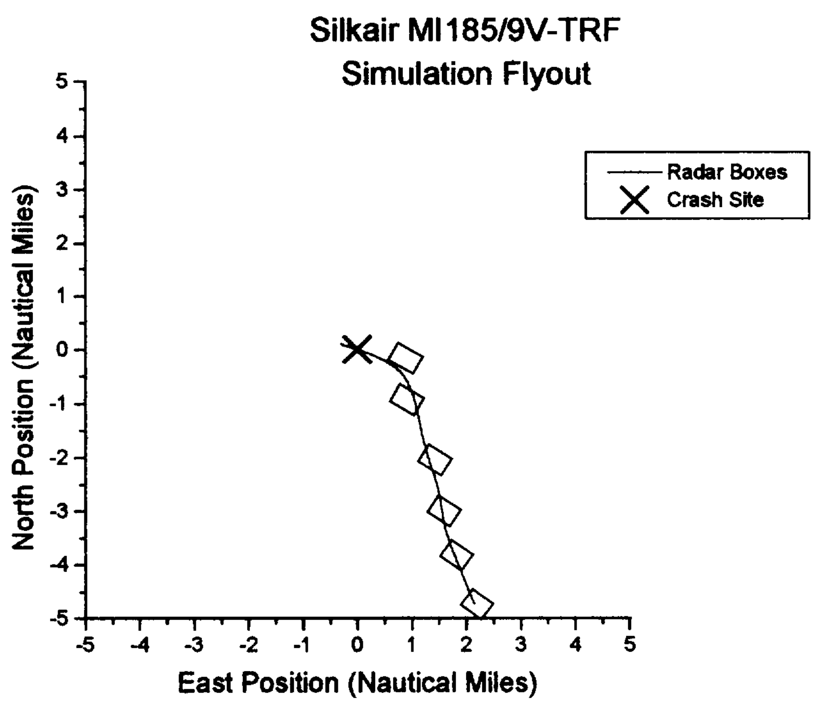

Silkair MI185/9V-TRF
Simulation Flyout
Input
Stabilizer (deg)
3
2
1
0
-1
-2
-3
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

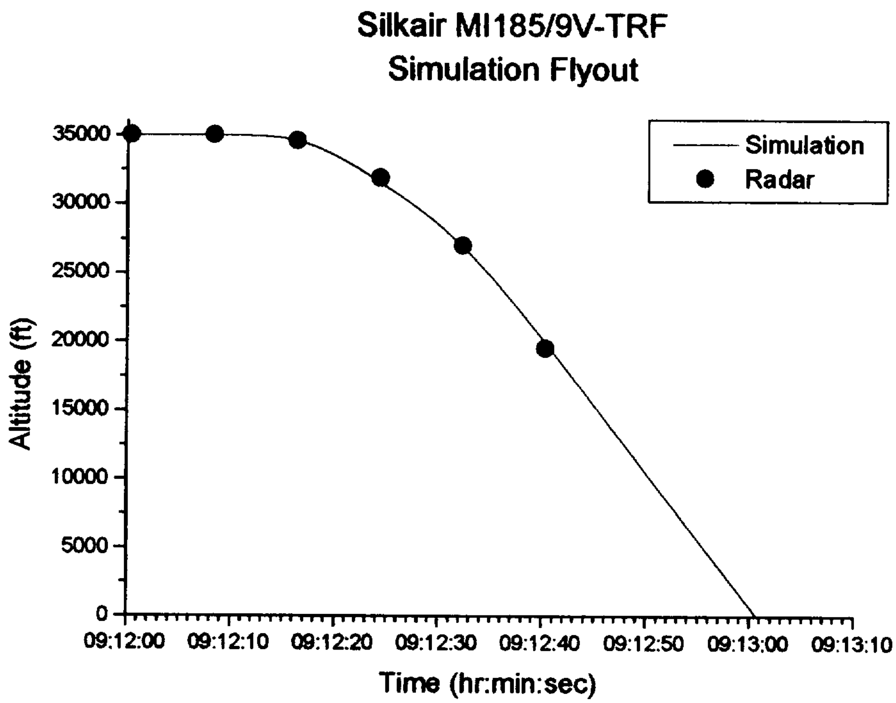

Silkair MI185/9V-TRF
Simulation Flyout
Input
N1 (% max)
100
90
80
70
60
50
40
30
20
10
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

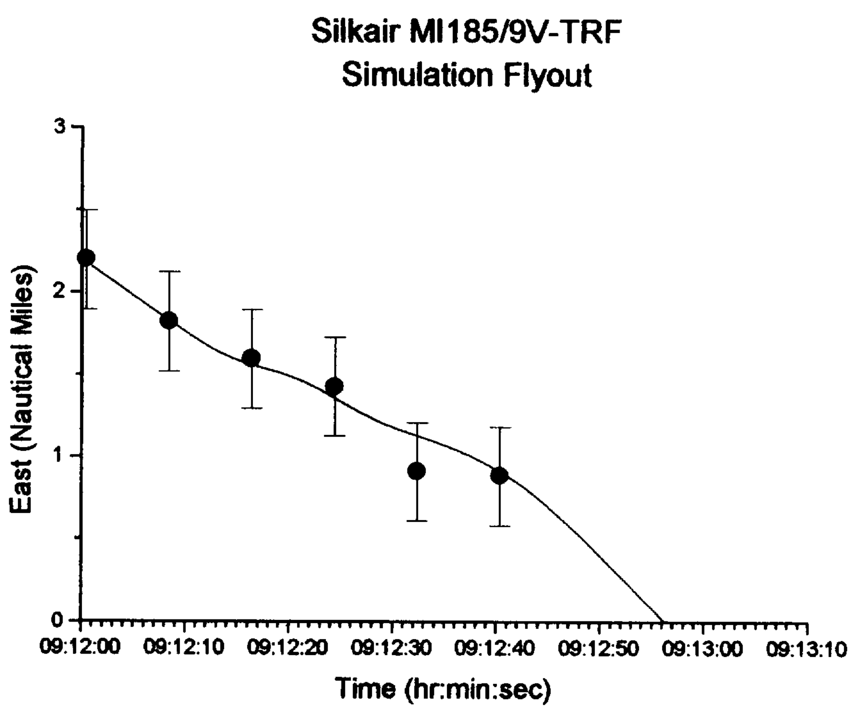

Silkair MI185/9V-TRF
Simulation Flyout
Pitch (deg)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
Time (hr:min:sec)

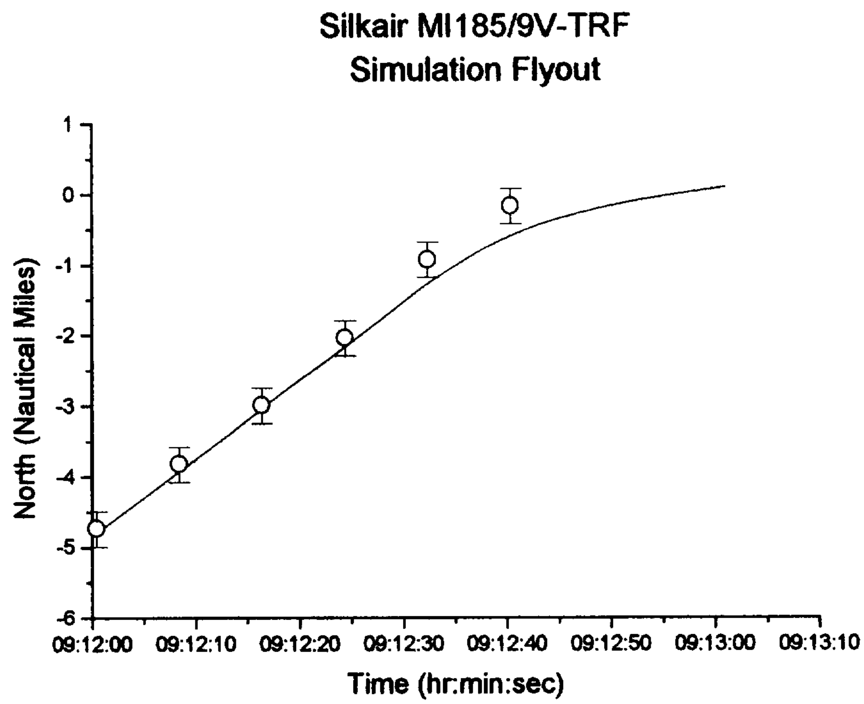

Silkair MI185/9V-TRF
Simulation Flyout
Roll (deg)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

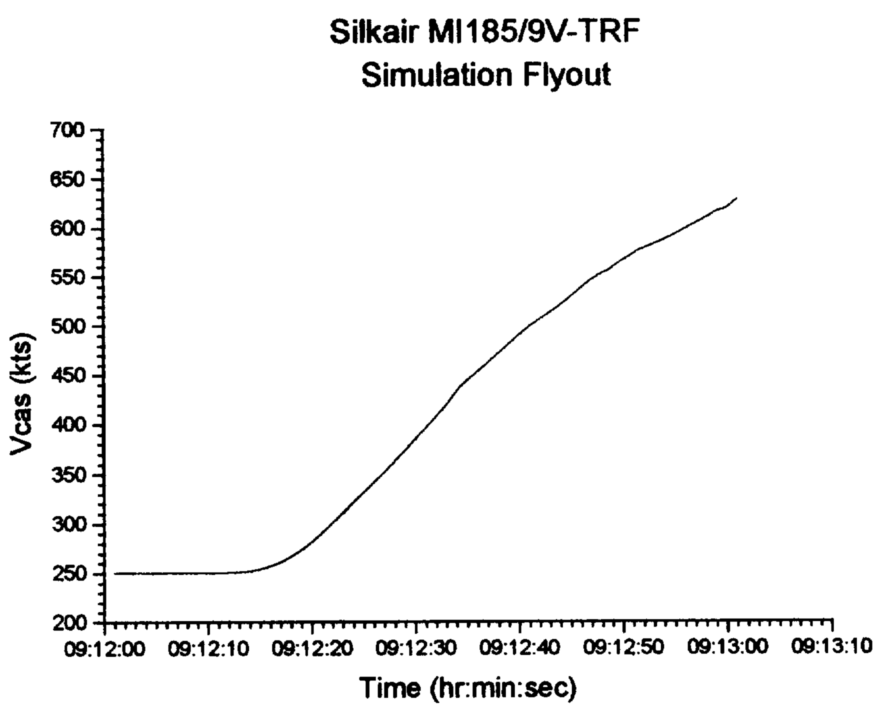

Silkair MI185/9V-TRF
Simulation Flyout
Heading (deg)
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
North Position (Nautical Miles)
5
4
3
2
1
0
-1
-2
-3
-4
-5
Radar Boxes
Crash Site
-5
-4
-3
-2
-1
0
1
2
3
4
5
East Position (Nautical Miles)

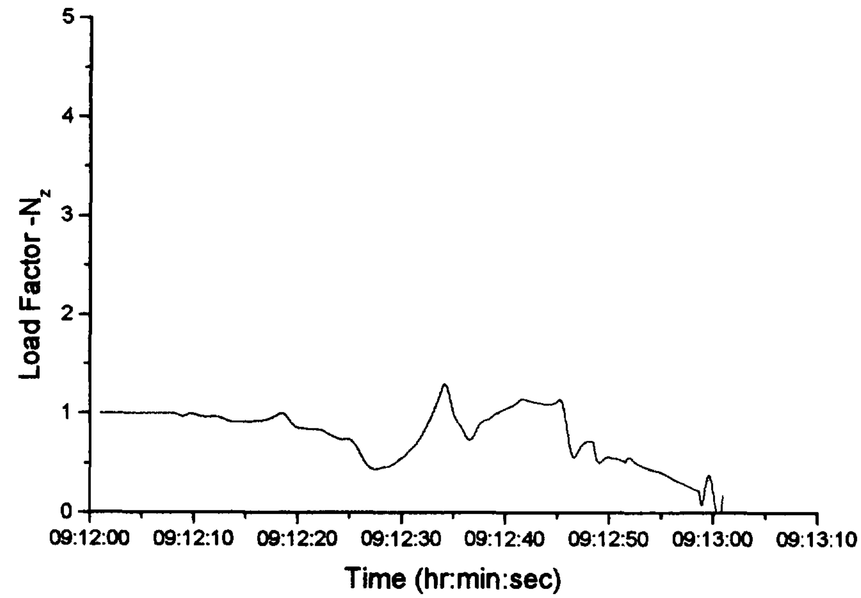

Silkair MI185/9V-TRF
Simulation Flyout
Simulation
Radar
Altitude (ft)
35000
30000
25000
20000
15000
10000
5000
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
East (Nautical Miles)
3
2
1
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
North (Nautical Miles)
1
0
-1
-2
-3
-4
-5
-6
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

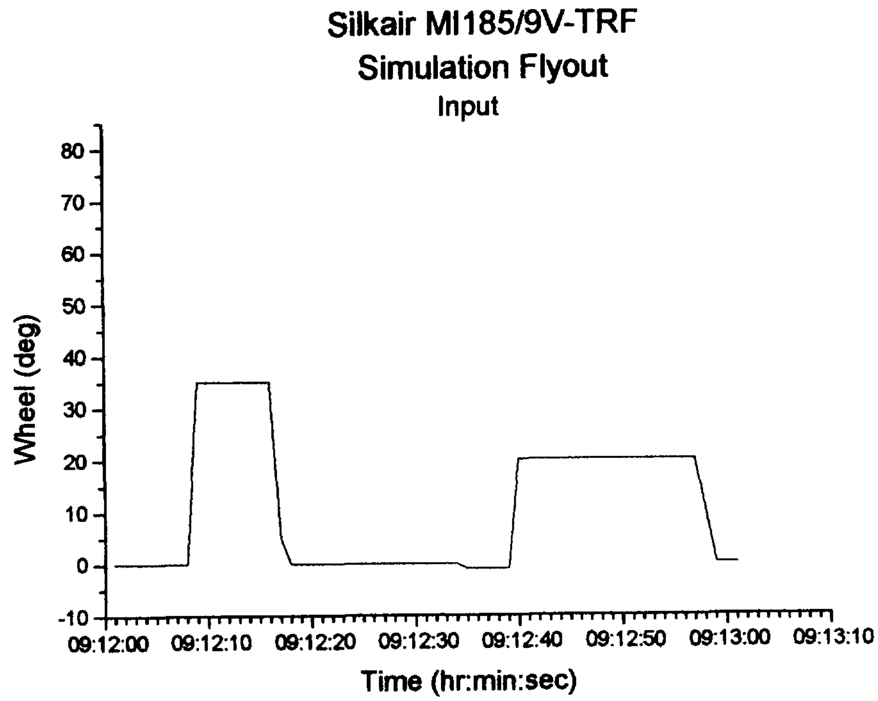

Silkair MI185/9V-TRF
Simulation Flyout
Vcas (kts)
700
650
600
550
500
450
400
350
300
250
200
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

Silkair MI185/9V-TRF
Simulation Flyout

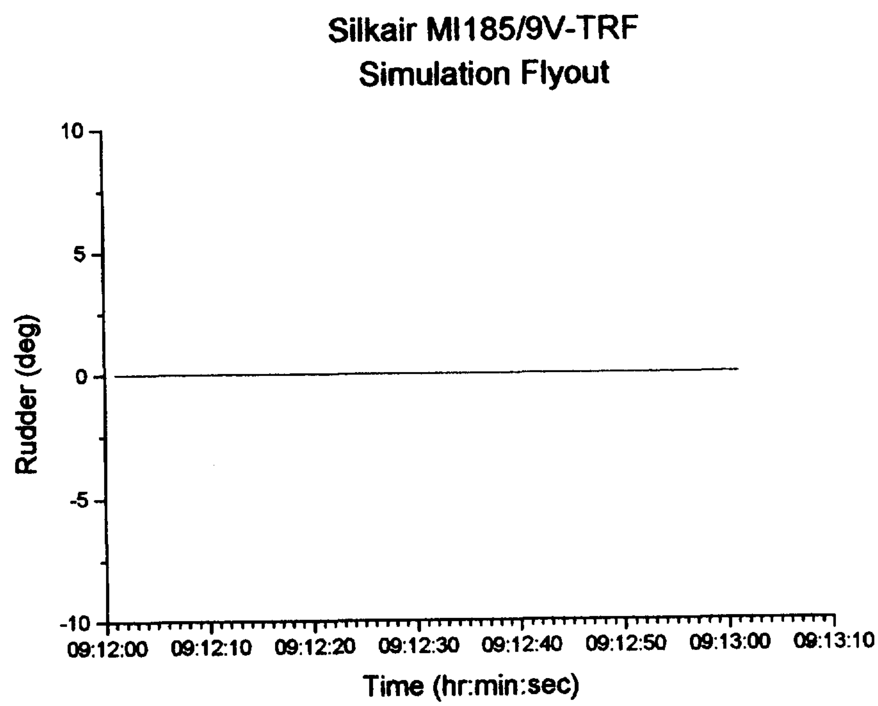


Inverted Descent Scenario

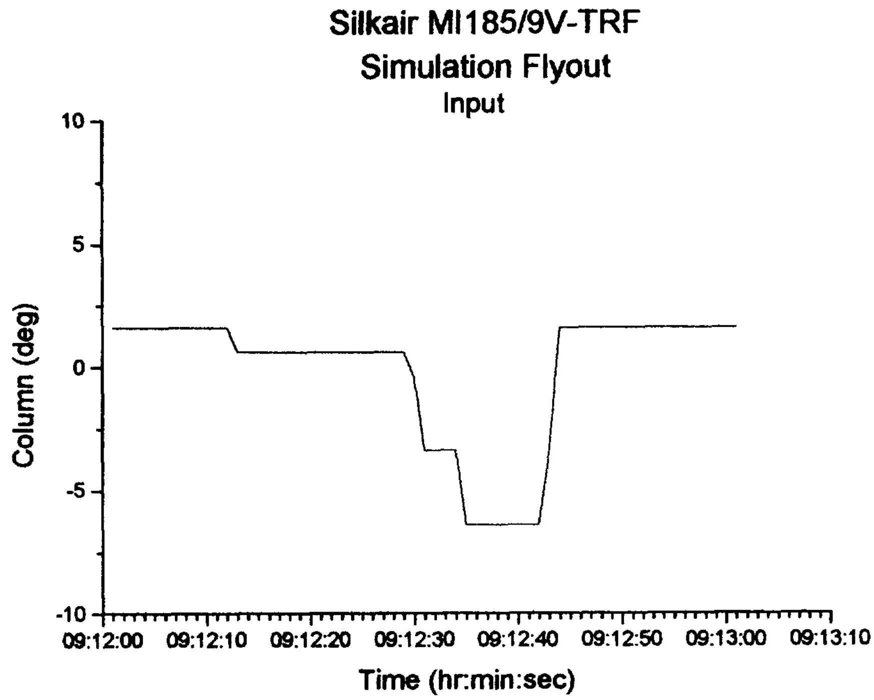
The data can also be matched with a rapid roll to inverted flight. The aircraft is then held inverted for 23 seconds followed by a roll right side up as pitch goes beyond 60 degrees nose down. The control input and resulting match are presented in the following plots.

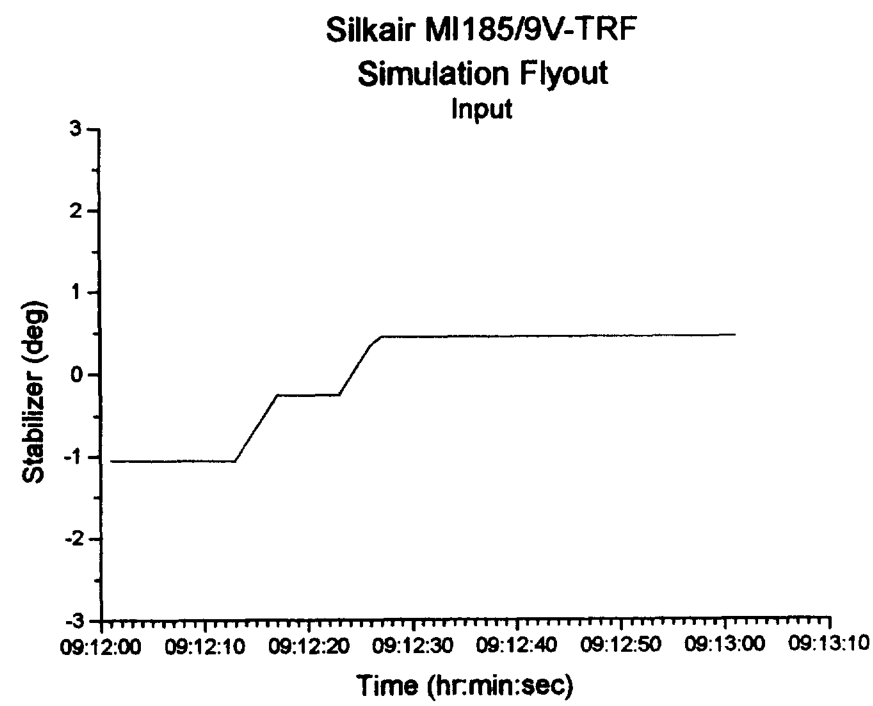


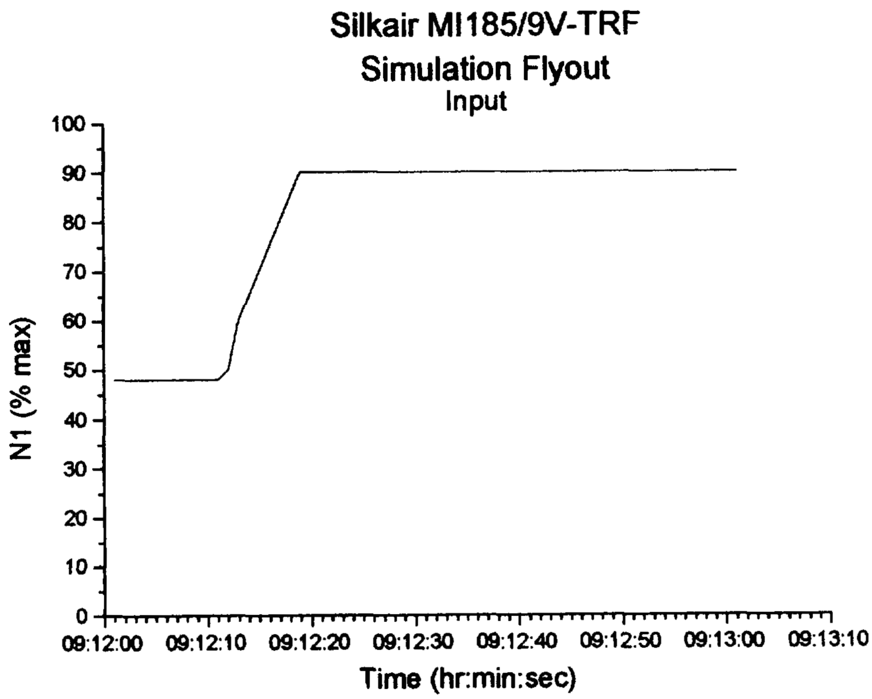
Silkair MI185/9V-TRF
Simulation Flyout
Input
Wheel (deg)
80
70
60
50
40
30
20
10
0
-10
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

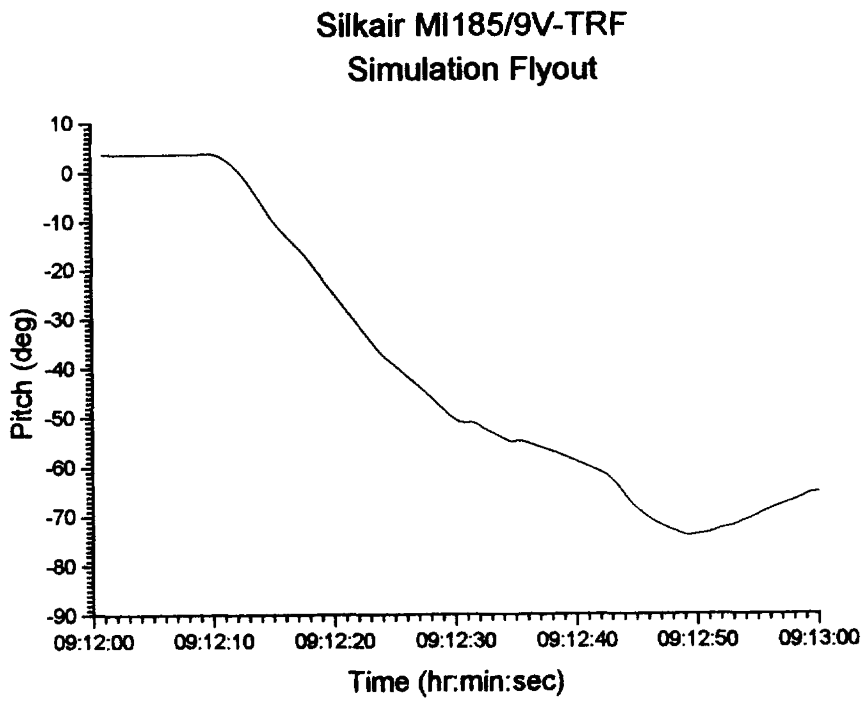


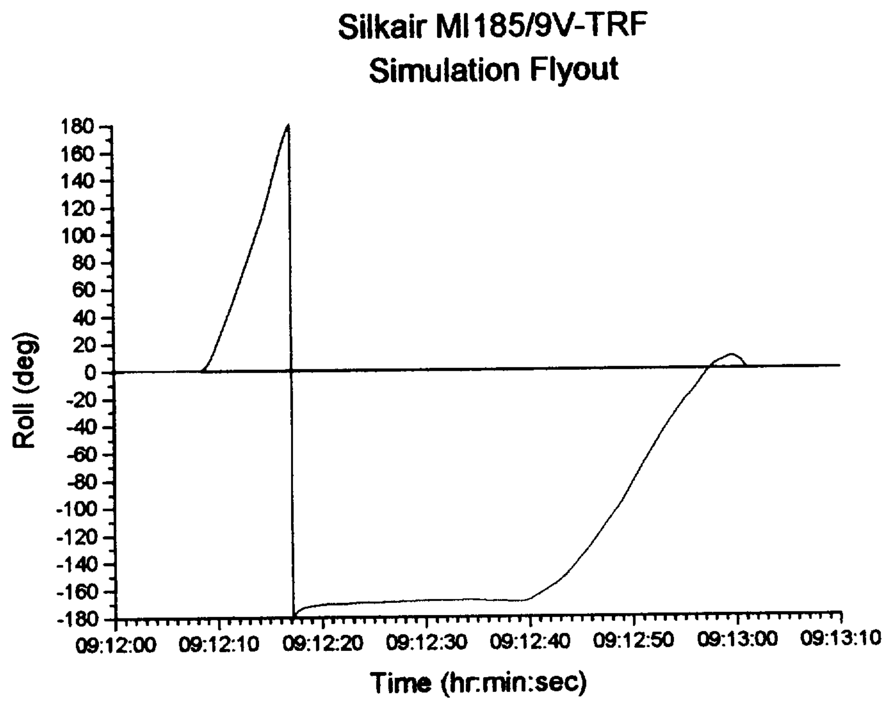
Silkair MI185/9V-TRF
Simulation Flyout
Rudder (deg)
10
5
0
-5
-10
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Input
10
5
0
-5
-10
Column (deg)
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

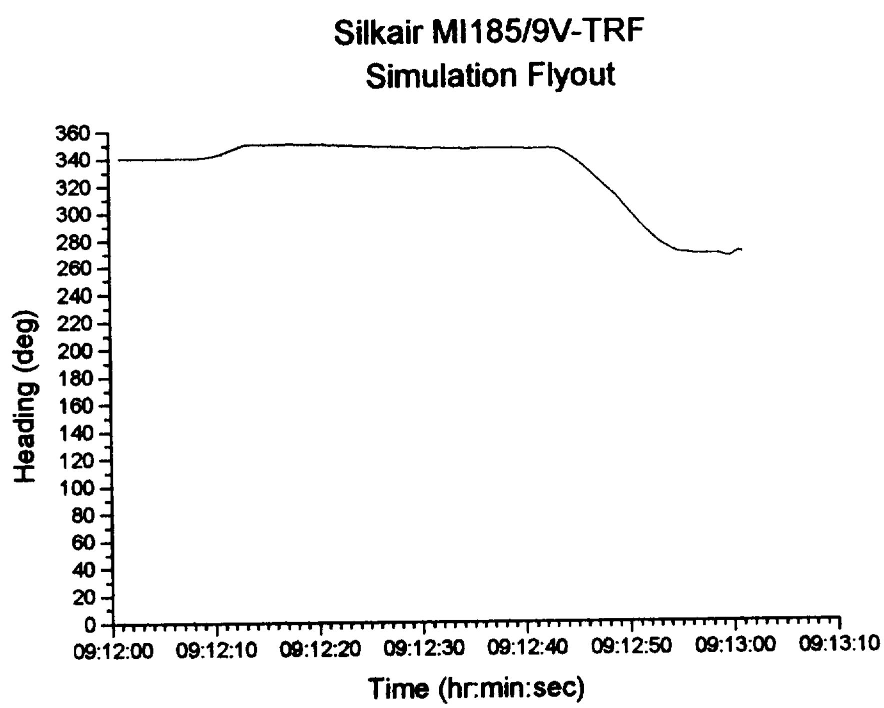

Silkair MI185/9V-TRF
Simulation Flyout
Input
3
2
1
0
-1
-2
-3
Stabilizer (deg)
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Input
N1 (% max)
100
90
80
70
60
50
40
30
20
10
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

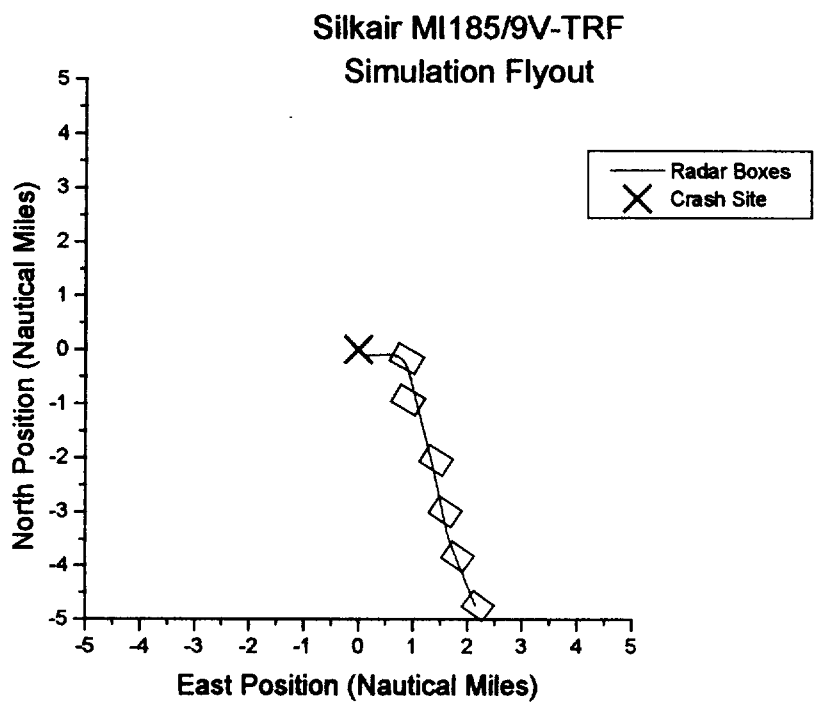

Silkair MI185/9V-TRF
Simulation Flyout
Pitch (deg)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
Time (hr:min:sec)

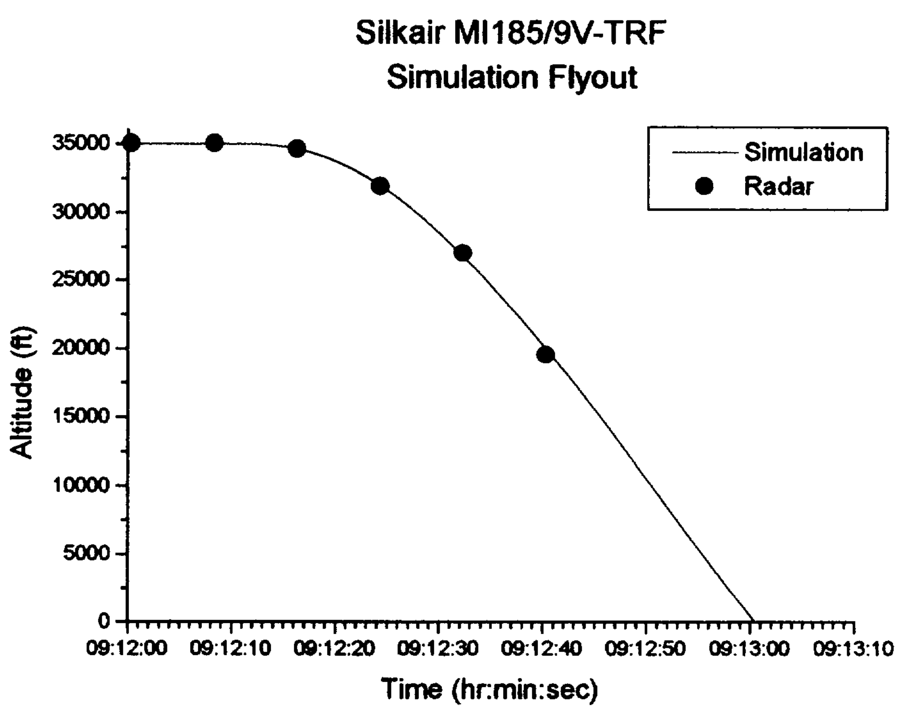


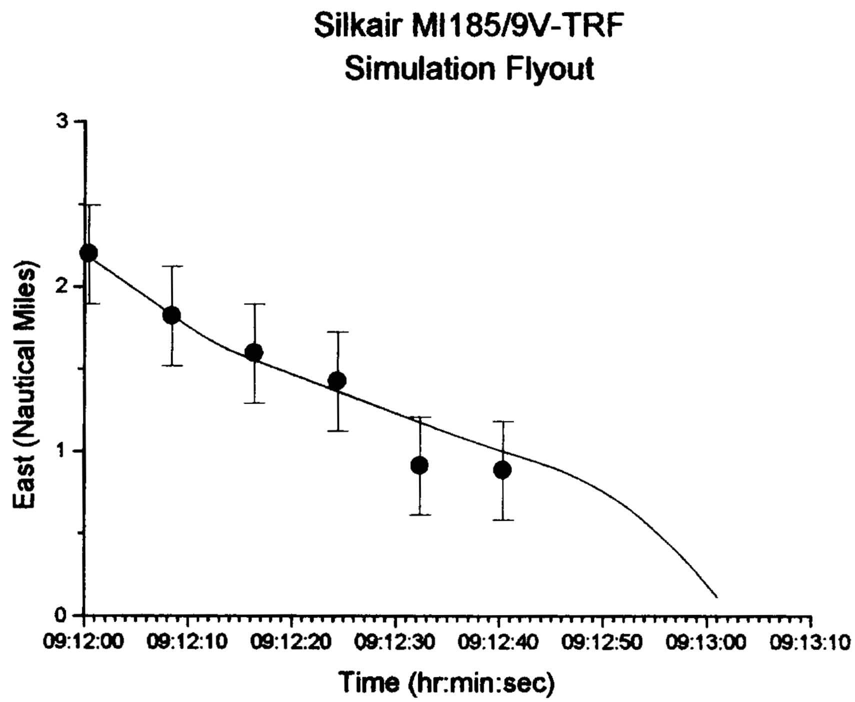
Silkair MI185/9V-TRF
Simulation Flyout
Roll (deg)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

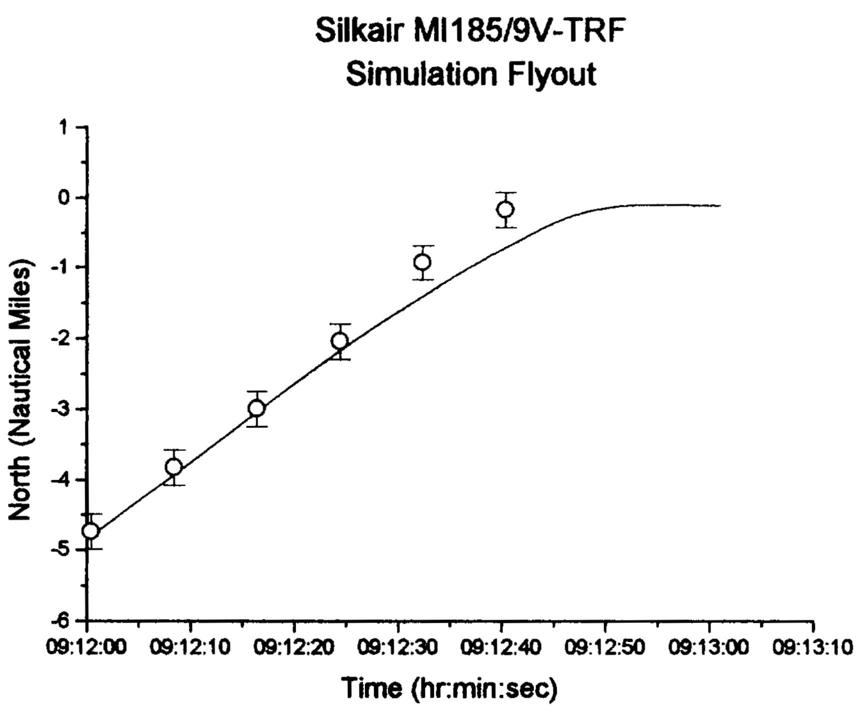


Silkair MI185/9V-TRF
Simulation Flyout
Heading (deg)
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

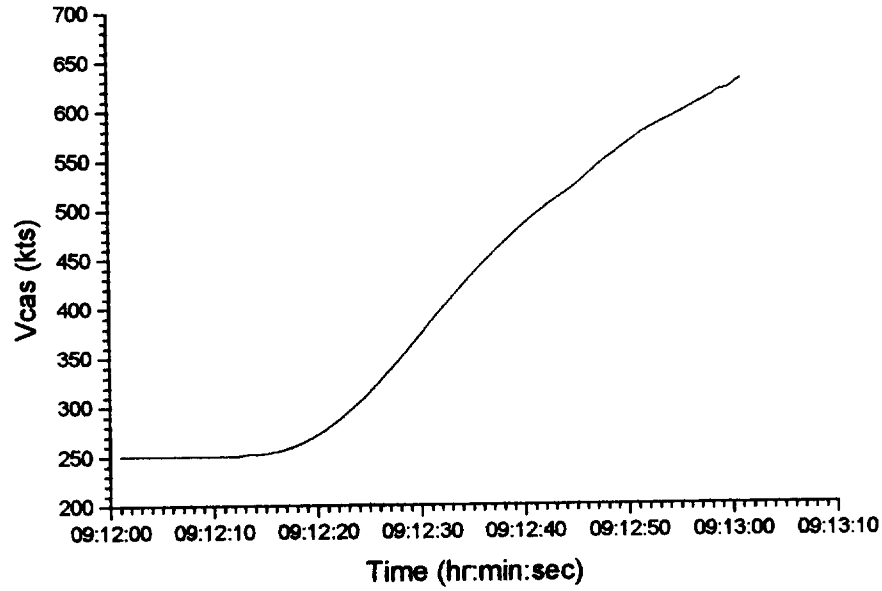

Silkair MI185/9V-TRF
Simulation Flyout
Radar Boxes
Crash Site
North Position (Nautical Miles)
East Position (Nautical Miles)
5
4
3
2
1
0
-1
-2
-3
-4
-5
-5
-4
-3
-2
-1
0
1
2
3
4
5


Silkair MI185/9V-TRF
Simulation Flyout
Simulation
Radar
Altitude (ft)
35000
30000
25000
20000
15000
10000
5000
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

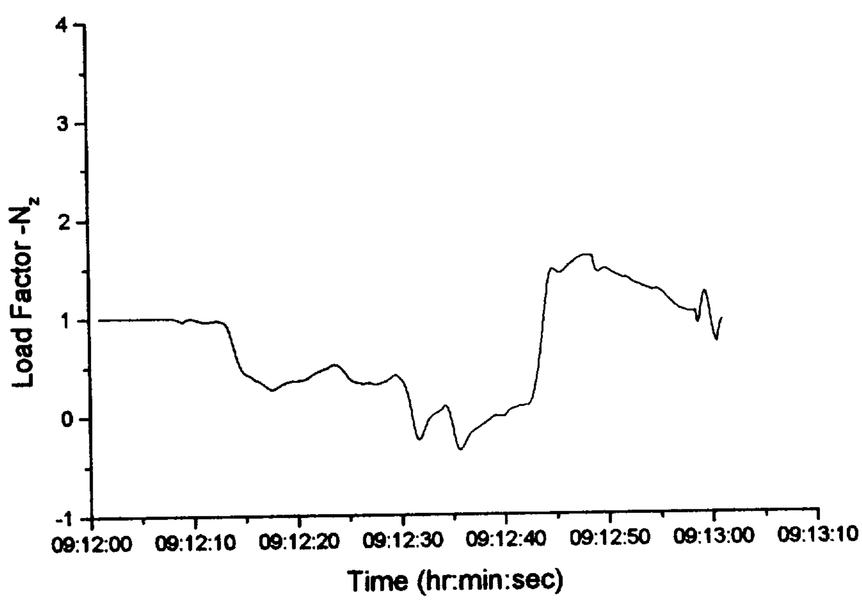

Silkair MI185/9V-TRF
Simulation Flyout
East (Nautical Miles)
3
2
1
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
North (Nautical Miles)
1
0
-1
-2
-3
-4
-5
-6
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

Silkair MI185/9V-TRF
Simulation Flyout

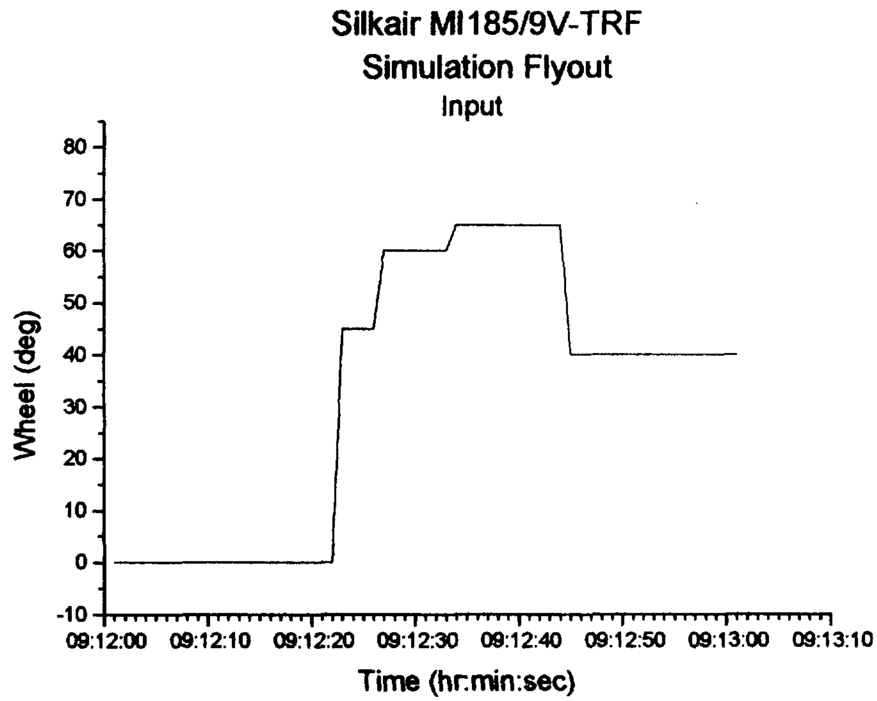


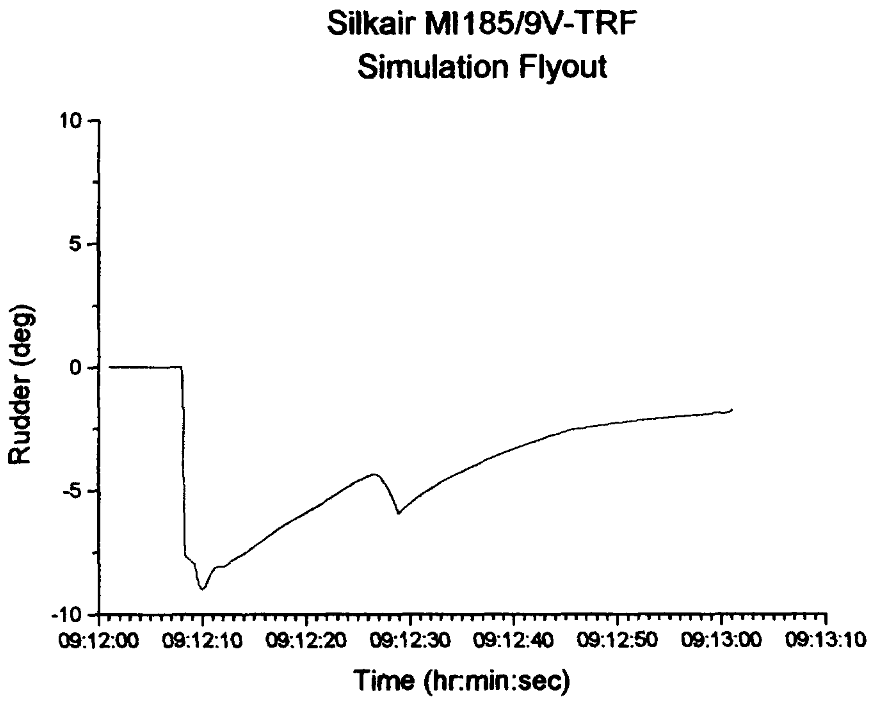
Silkair MI185/9V-TRF
Simulation Flyout

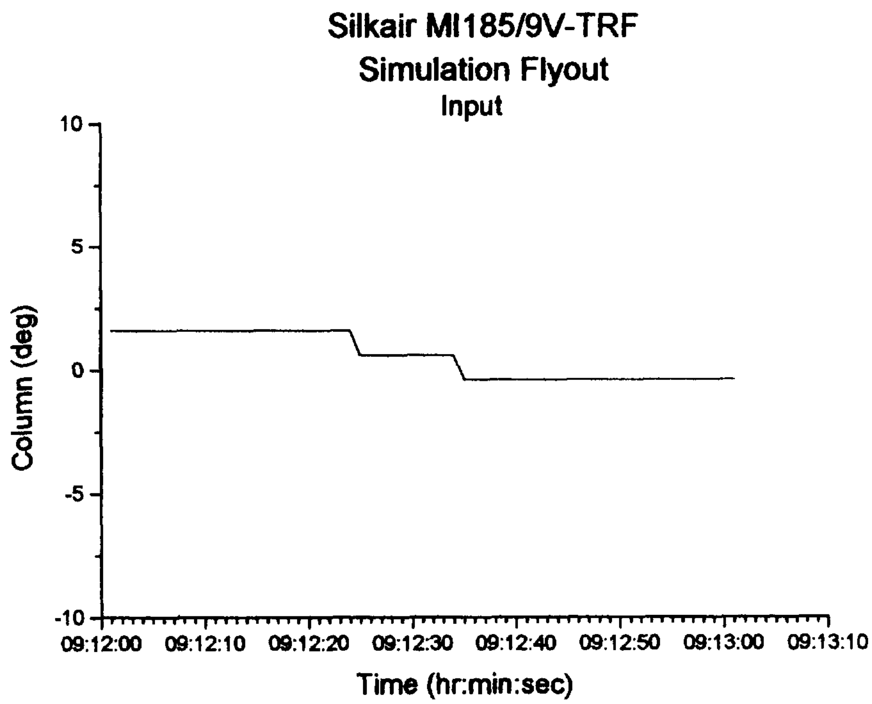


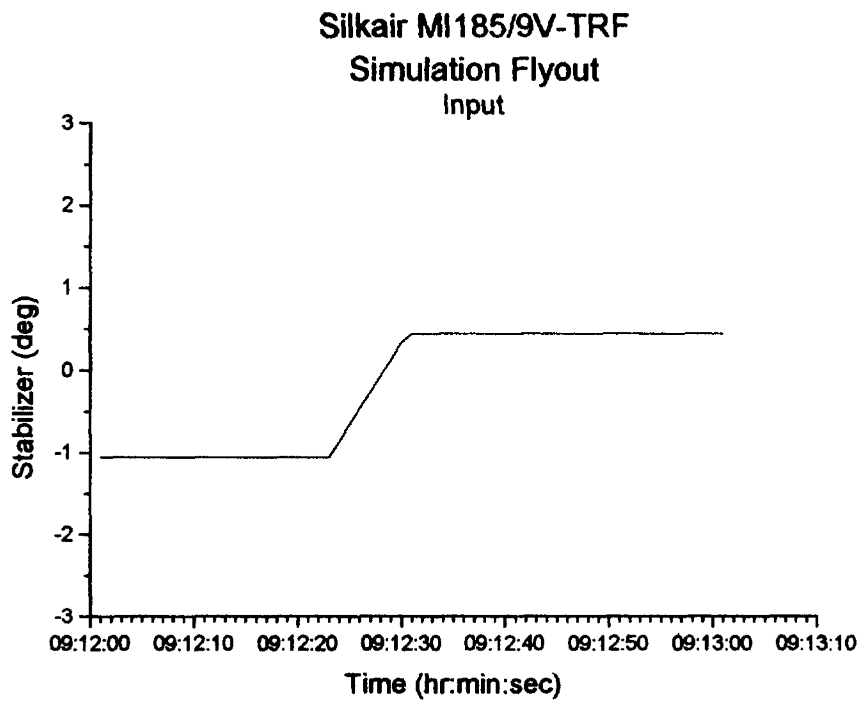
Rudder Hardover (with pro departure wheel)

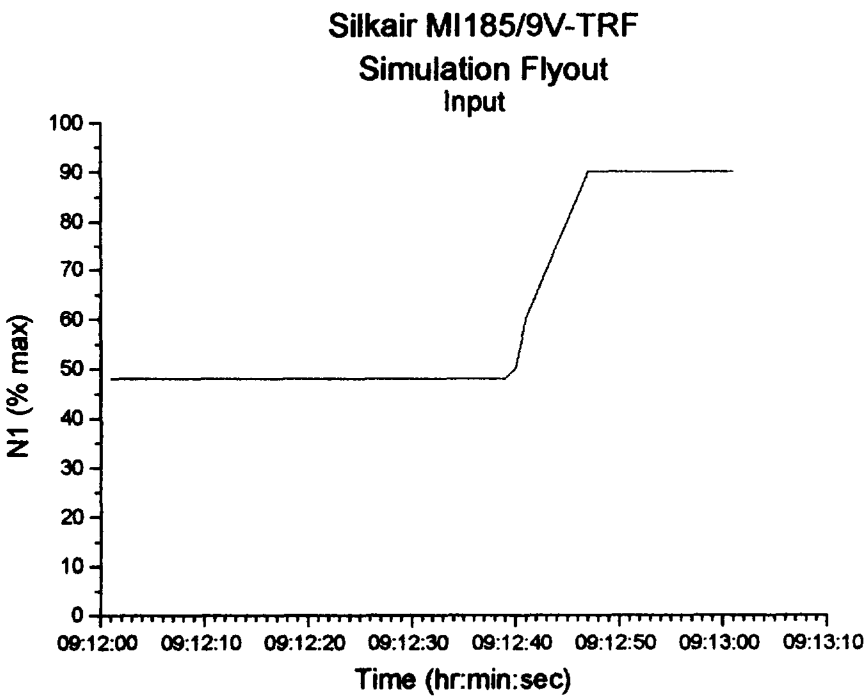
It is possible to match the data with a scenario that adds a pro roll wheel input about 15 sec after the rudder hardover. This continues the roll from the rudder that would normally begin to slow. The control input and the resulting data match are presented on the following pages. Note that this requires the application of nose down column and stabilizer as well as the pro departure wheel.

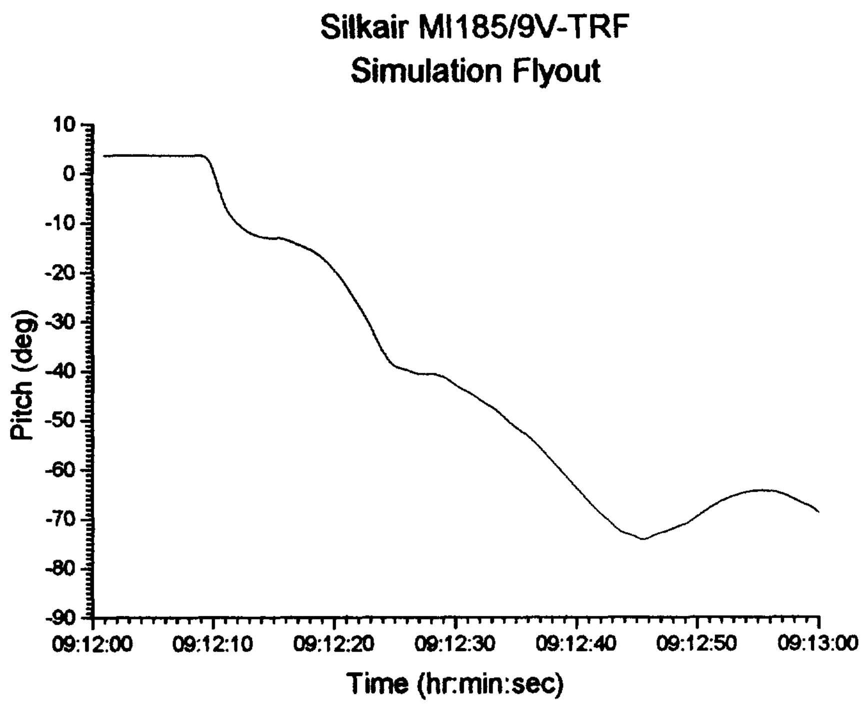


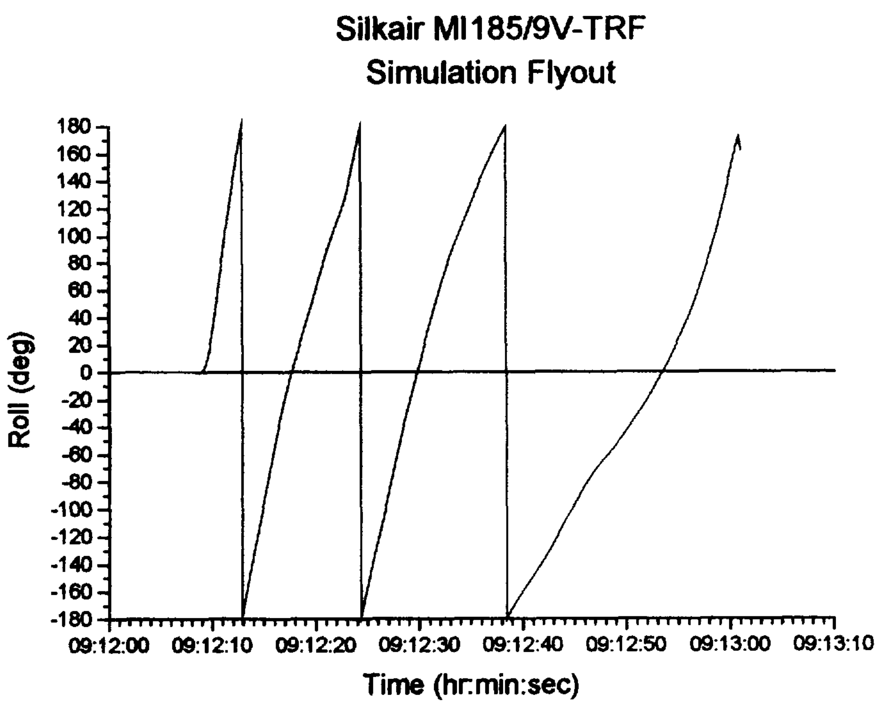

Silkair MI185/9V-TRF
Simulation Flyout
Rudder (deg)
10
5
0
-5
-10
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

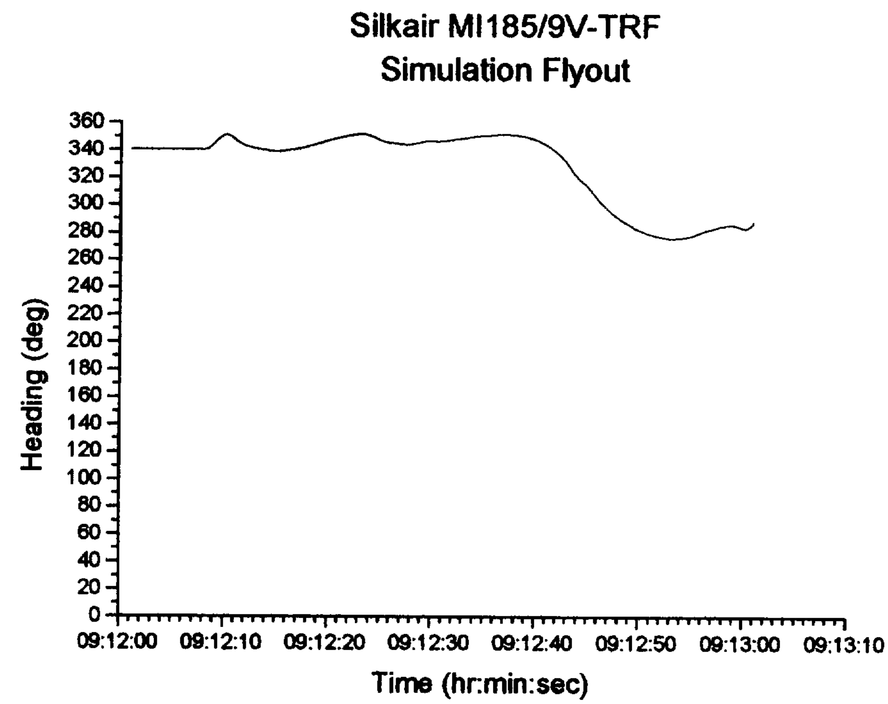

Silkair MI185/9V-TRF
Simulation Flyout
Input
Column (deg)
10
5
0
-5
-10
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

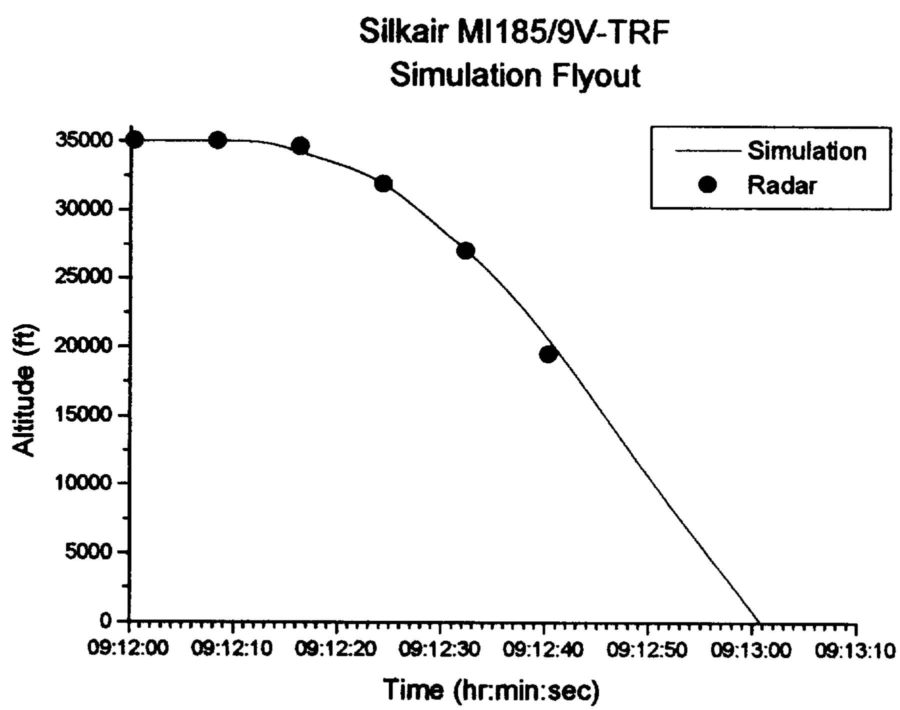

Silkair MI185/9V-TRF
Simulation Flyout
Input
Stabilizer (deg)
3
2
1
0
-1
-2
-3
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

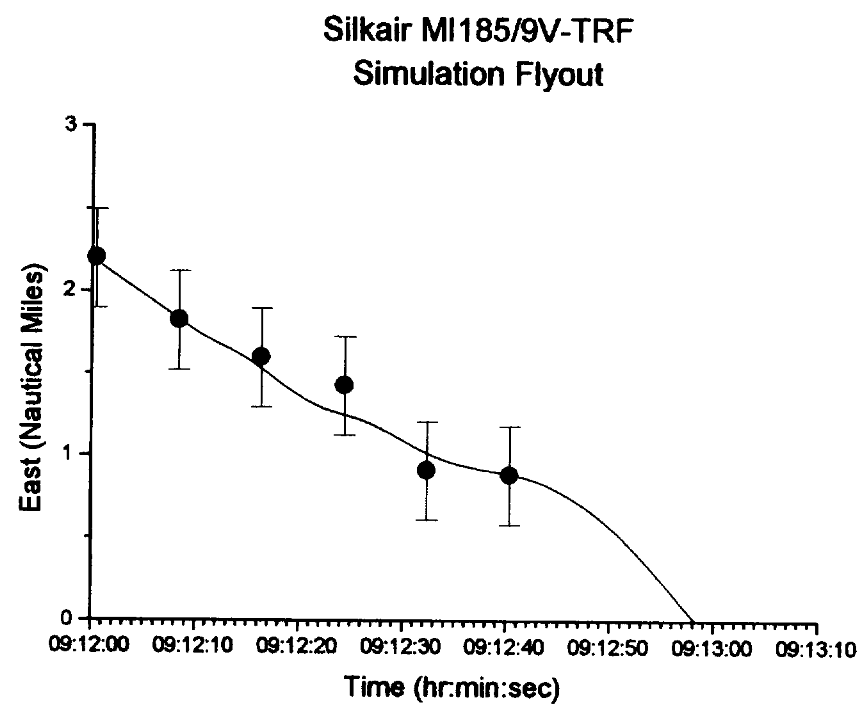

Silkair MI185/9V-TRF
Simulation Flyout
Input
N1 (% max)
100
90
80
70
60
50
40
30
20
10
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

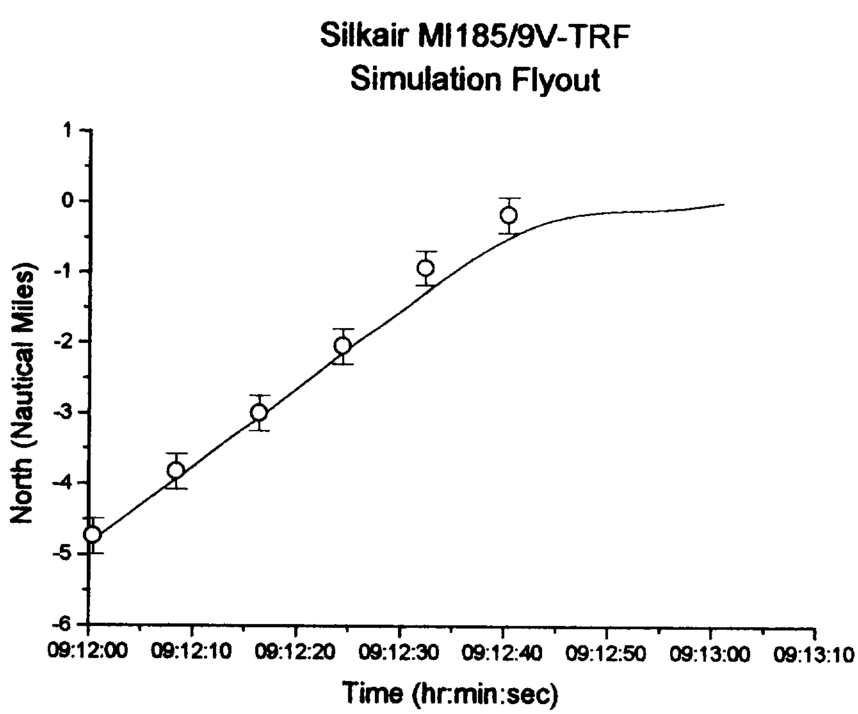

Silkair MI185/9V-TRF
Simulation Flyout
Pitch (deg)
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
Time (hr:min:sec)

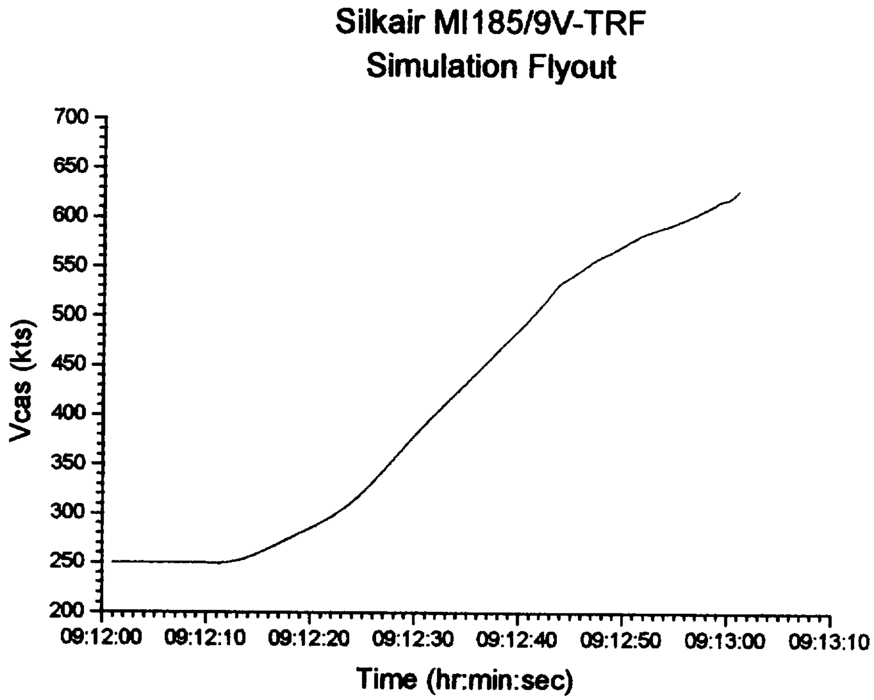

Silkair MI185/9V-TRF
Simulation Flyout
Roll (deg)
180
160
140
120
100
80
60
40
20
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

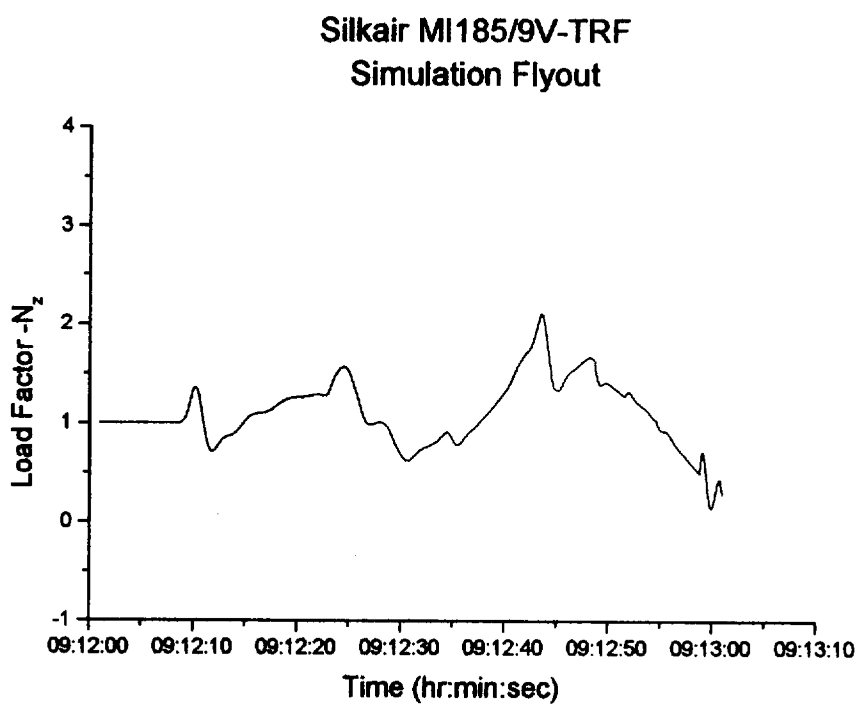

Silkair MI185/9V-TRF
Simulation Flyout
Heading (deg)
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Simulation
Radar
Altitude (ft)
35000
30000
25000
20000
15000
10000
5000
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
East (Nautical Miles)
3
2
1
0
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
North (Nautical Miles)
1
0
-1
-2
-3
-4
-5
-6
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Vcas (kts)
700
650
600
550
500
450
400
350
300
250
200
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)


Silkair MI185/9V-TRF
Simulation Flyout
Load Factor -N_z
4
3
2
1
0
-1
09:12:00
09:12:10
09:12:20
09:12:30
09:12:40
09:12:50
09:13:00
09:13:10
Time (hr:min:sec)

Conclusions

Airplane response to pitch control failures, rudder control failures and autopilot roll failures has been investigated. Pitch control failures and autopilot roll failures do not match the available data. Yaw damper failures do not match the available data. A rudder hardover failure will not match the data unless accompanied by adverse pilot action.

Several scenarios have been identified in which active pilot control will produce a match with the radar data.

[redacted]

Dennis Crider
Aerospace Engineer Performance