NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Washington, DC

April 27, 1999

Silkair MI185 Trajectory Study

A ACCIDENT

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

B GROUP

No group was formed for this activity.

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 Board is participating in the investigation under provision of Annex 13 to the International Convention on Civil Aviation.

D DETAILS OF INVESTIGATION

Introduction

Some wreckage items were found away from the main impact point in the river. It is desired to determine when these items departed the aircraft.

Ballistic analysis was applied to help determine when the items not found with the main wreckage departed the aircraft. In ballistic analysis, the trajectory of a wreckage object is traced with a time step simulation from an initial condition to the location of the wreckage object on the ground. The initial condition is described with six quantities. Three of these describe the object's initial position (East-West coordinate, North-South coordinate and altitude). The remaining three describe the object's velocity vector (airspeed, flight path angle and heading).

A wreckage object's trajectory from its initial condition is determined by its mass and aerodynamic characteristics. These characteristics are combined into one term, the ballistic coefficient[1] that determines the trajectory of the object. A foam ball, for example, has a very low ballistic coefficient. When released from an initial condition, a foam ball, having very low inertia compared to its drag, will decelerate very rapidly and then fall slowly moving almost exclusively with the wind to its ground location. A bowling ball, on the other hand, is an example of a high ballistic coefficient object. A bowling ball, having a high inertia compared to its drag, will decelerate slowly and continue along its initial heading with very little displacement due to the wind.

Each initial condition corresponds to a ballistic ground locus curve of wreckage location points representing the possible ground locations for objects launched from this initial condition. The position of an object on this ballistic ground locus curve is determined by its ballistic coefficient. On the high ballistic coefficient end the ballistic ground locus curve will asymptotically approach the initial heading of the object. On the low ballistic coefficient end, the ballistic ground locus curve will asymptotically approach the wind direction.

In practice there will usually be some scatter about this ballistic ground locus curve. Trajectory analysis assumes that objects depart the main wreckage with an initial velocity equal to the velocity of the main wreckage. The dynamics of the breakup can, in some cases, impart initial velocities relative to the main wreckage. This could be true of balance weights thrown off in flutter for example. Trajectory analysis also assumes that the wreckage fell with a constant ballistic coefficient from the moment of separation from the aircraft main body. In reality, wreckage will fall in a dynamic mode initially and can, on occasion, switch between falling modes as it descends. During this dynamic mode forces on the wreckage will result in a departure from a pure ballistic trajectory for a period which can introduce error in the ground location. Finally, implicit in trajectory analysis is the assumption that the wreckage items fell in a ballistic manner, without a stable lift vector (an object that flies in circles can be treated as ballistic). On occasion in-flight

[1] Ballistic Coefficient = Weight/(Drag Coefficient * Area)

breakups can produce objects with a stable lift vector that can land well away from the ground locus curve. Typically scatter is more evident with low altitude events where the initial dynamics are a greater portion of the trajectory.

Procedure

Ballistic ground locus curves were determined for selected points along the flight path. Trajectories establishing these ground locus curves were determined using program BALLISTIC for ballistic coefficients ranging from 1 to 40.0.

Ballistic ground locus curves were established for the following candidate wreckage separation points.

- The point that FDR data ended.
- The last radar point before the decent (at 35000 ft).
- The radar point at 34600 ft.
- The radar point at 31900 ft.
- The radar point at 27000 ft.
- The radar point at 19500 ft.
- A Simulation flyout position at 10000 ft
- A Simulation flyout position at 5000 ft

The initial velocity vectors (airspeed, heading and flight path angle) for the first two points were determined from FDR data (radar showed no change in flight state at 35,000 ft). The initial velocity vectors for the next four points were determined from a simulation. The initial position and altitude were obtained from radar for the first six points. The position and initial conditions for the last two points were determined from a simulation[2]. It is important to note that there are several simulation scenarios that will match the data. While flying through the radar data these simulations must all have a similar velocity vector at each radar point. Below the last radar point however, the flight path is less restricted, as the time of impact is not known. Accordingly, care should be used in interpreting the 10000 ft and 5000 ft cases. The initial conditions are:

<u>The point that FDR data ended</u>

Altitude	= 35000 ft	Airspeed	= 416 KTAS
East Position	= 3.905 Nmi	Flight Path Angle	= 0.0 deg
North Position	= -9.3382 Nmi	Heading	= 340 deg

<u>The last radar point before the decent (at 35000 ft)</u>

Altitude	= 35000 ft	Airspeed	= 416 KTAS
East Position	= 1.82 Nmi	Flight Path Angle	= 0.0 deg
North Position	= -3.8279 Nmi	Heading	= 340 deg

<u>The radar point at 34600 ft</u>

Altitude	= 34600 ft	Airspeed	= 433 KTAS
East Position	= 1.5937 Nmi	Flight Path Angle	= -16.5 deg
North Position	= -2.9961 Nmi	Heading	= 357 deg

[2] The simulation case is presented on page 47 to 54 of <u>Silkair MI185 Simulation Study</u>, May 6, 1999

The radar point at 31900 ft

Altitude	= 31900 ft	Airspeed	= 509.5 KTAS
East Position	= 1.4256 Nmi	Flight Path Angle	= -37.5 deg
North Position	= -2.0471 Nmi	Heading	= 338.7 deg

The radar point at 27000 ft

Altitude	= 27000 ft	Airspeed	= 576.9 KTAS
East Position	= 0.911 Nmi	Flight Path Angle	= -43.1 deg
North Position	= -0.9309 Nmi	Heading	= 353.4 deg

The radar point at 19500 ft (the last radar point)

Altitude	= 19500 ft	Airspeed	= 617.8 KTAS
East Position	= 0.8834 Nmi	Flight Path Angle	= -65 deg
North Position	= -0.1666 Nmi	Heading	= 339.5 deg

The simulation position at 10000 ft

Altitude	= 10000 ft	Airspeed	= 640 KTAS
East Position	= 0.60395 Nmi	Flight Path Angle	= -62.4 deg
North Position	= -0.18606 Nmi	Heading	= 288.3 deg

The simulation position at 5000 ft

Altitude	= 5000 ft	Airspeed	= 626 KTAS
East Position	= 0.13238 Nmi	Flight Path Angle	= -54.8 deg
North Position	= -0.03836 Nmi	Heading	= 291.7 deg

Winds

Winds used in the trajectory analysis 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 using McIDAS. The accuracy of these input winds will impact the accuracy of the trajectory results.

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

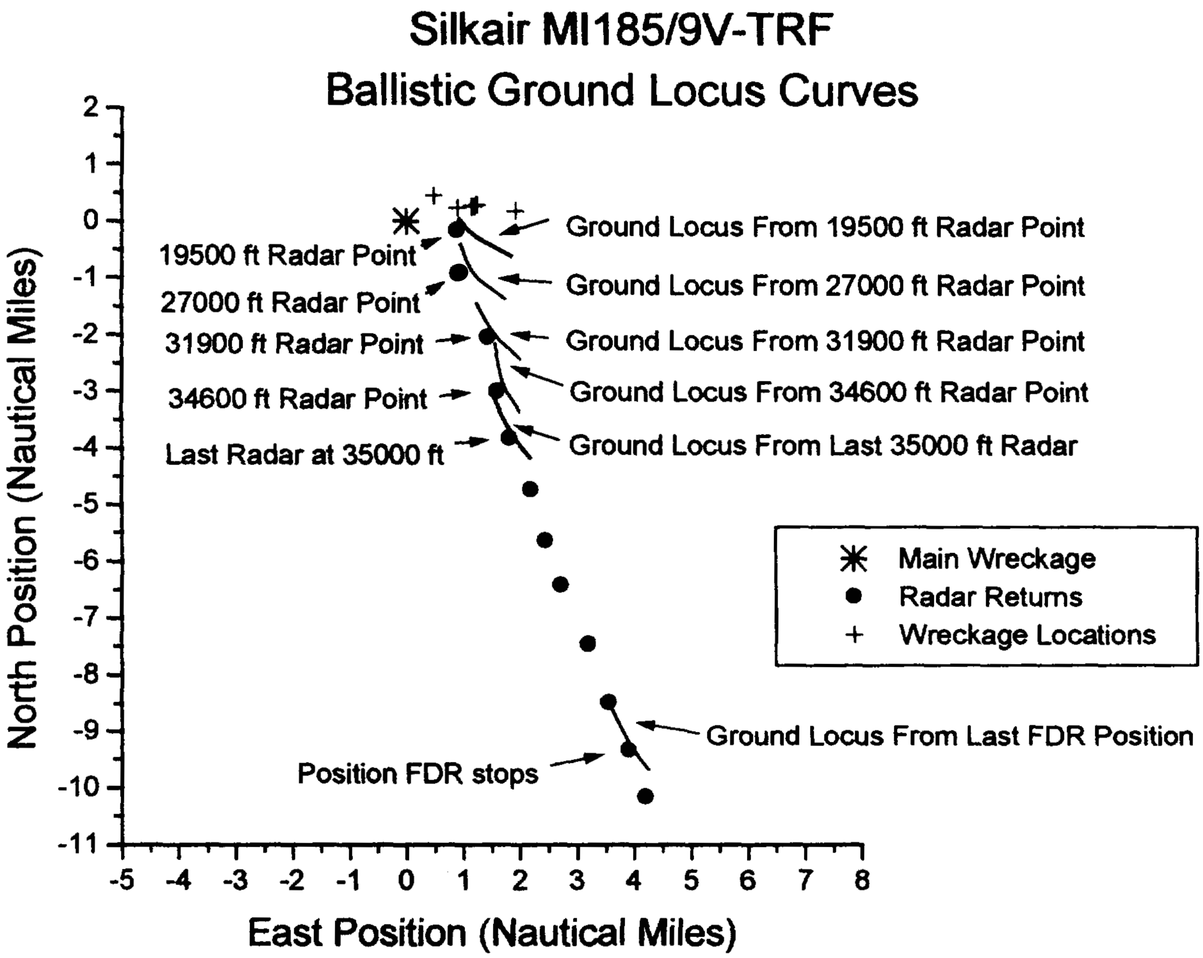
Wreckage Locations

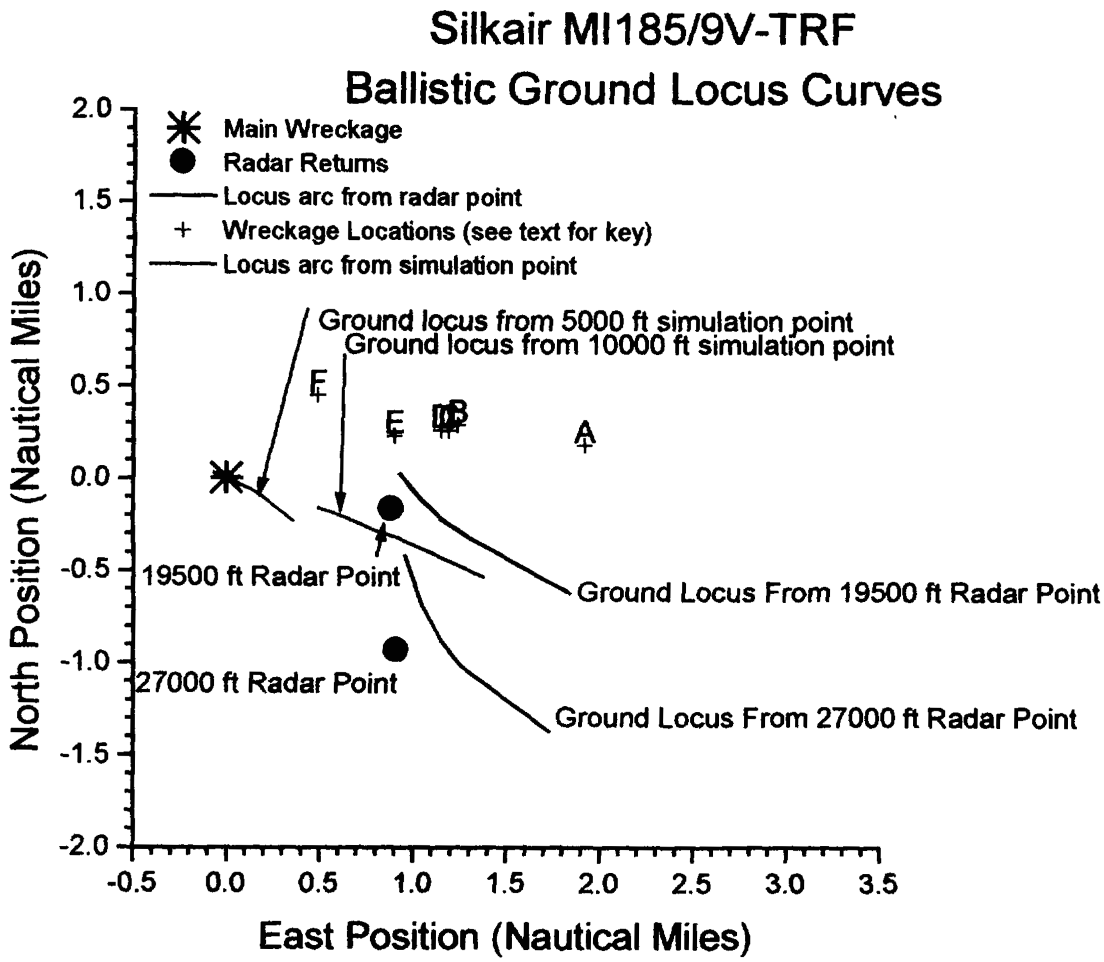
Wreckage locations used in this study are summarized in the following table relative to the main wreckage. Other smaller pieces were found in the area but, since their locations are not reliably known, they were not used.

Part	Description	East (N Mi)	North (N Mi)
A	R/H Elevator Piece	1.92	0.18
B	R/H Stab Tip Piece	1.24	0.29
C	R/H Stab Inbd Piece	1.19	0.26
D	L/H Stab Tip Piece	1.15	0.26
E	Rudder Tip Piece	0.9	0.23
F	L/H Elevator Piece	0.49	0.45

Results

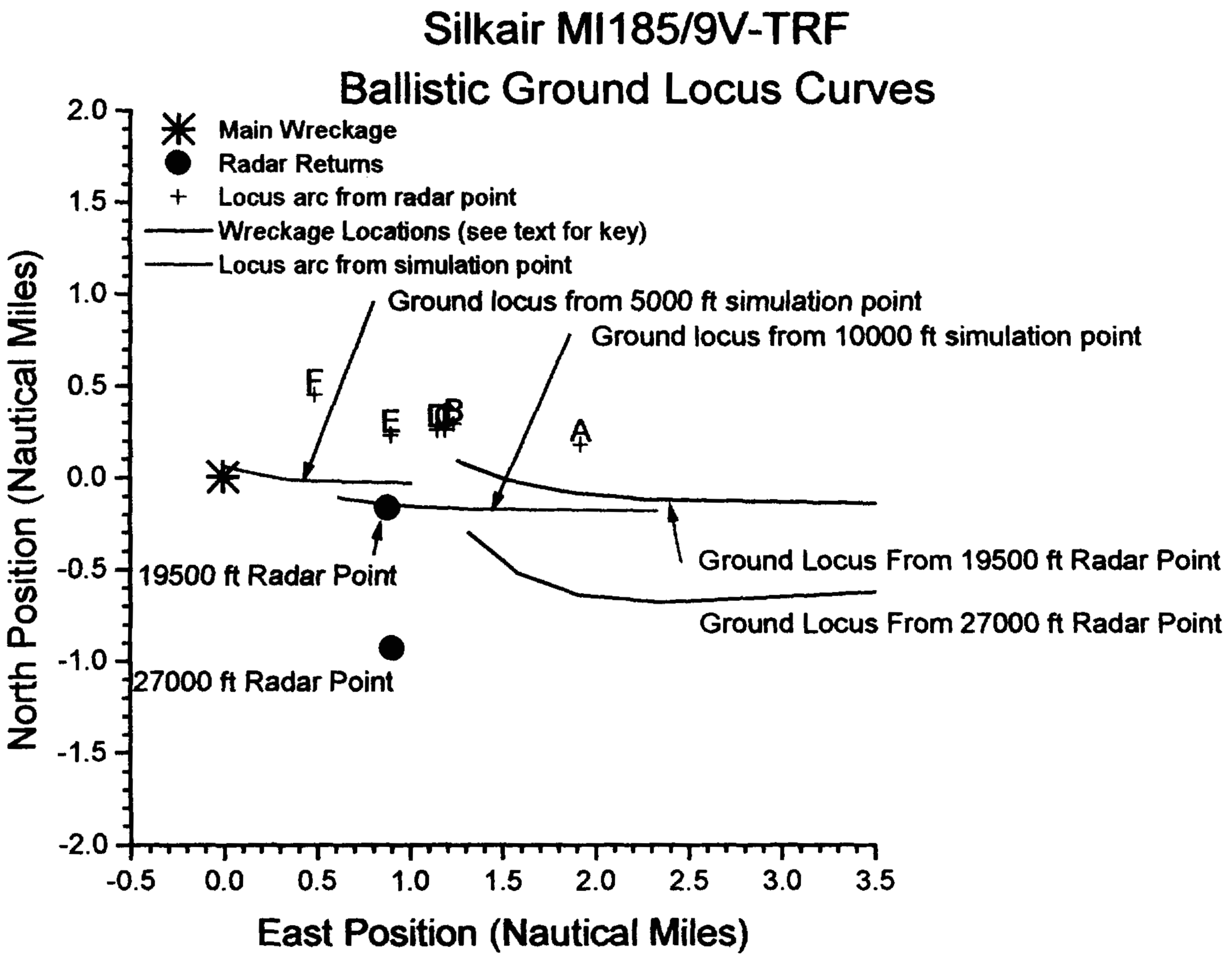
The resulting ballistic ground locus curves for the various launch locations are shown, together with radar positions and wreckage locations in the following map plots. Again note that ballistic coefficients used to define the ground locus curves were between 1.0 and 40. Light pieces with a ballistic coefficient less than 1.0 would be expected on a continuation of the South East side of the ground locus curves.





Note again that there are multiple simulations that can get from the last radar point to the crash site. An aircraft path that traveled further North between the last radar hit and the crash site would be required to produce a ground locus curve North of the crash site.

As previously mentioned, the low altitude portion of the winds were obtained from Palembang at 11:00 UTC. This was about 1 ¾ hours after the accident at some distance from the accident site. The alignment of the wreckage ground positions indicates a Westerly wind. The East/West size of the wreckage ground distribution and the fact that Part A, a right hand elevator piece, should have a ballistic coefficient greater than 1.0 indicates that the winds used to develop the previous plot may be slower than the actual winds. Accordingly, to gain some insight into the effect of a higher speed wind from the West, the 19,500 ft, 10,000 ft and 5,000 ft breakup altitude cases were re-run replacing the light and variable winds measured at Palembang with a constant 20 kt wind from the West. The results are displayed in the following plot.


Silkair MI185/9V-TRF
Ballistic Ground Locus Curves
Main Wreckage
Radar Returns
Locus arc from radar point
Wreckage Locations (see text for key)
Locus arc from simulation point
Ground locus from 5000 ft simulation point
Ground locus from 10000 ft simulation point
Ground Locus From 19500 ft Radar Point
Ground Locus From 27000 ft Radar Point
19500 ft Radar Point
27000 ft Radar Point
North Position (Nautical Miles)
East Position (Nautical Miles)

Conclusions

For the separated wreckage items to reach the ground at the locations given with the given winds, they would need to have separated below the 19500 ft radar point (after 9:12:40). This is at least 32 seconds after the aircraft had begun its rapid decent and at least 1:20 after the last FDR data record. An earlier separation point would require higher winds from the South that in turn would produce a North/South oriented ground locus curve rather than the documented East/West orientation.

[redacted]

Dennis Crider
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