DOCKET NO. SA-519

EXHIBIT NO. 16F

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

EMAS Computer Model Report
(12 pages)

December 5, 1999, Revised February 2, 2000

To: Peter Mahal

From: Bob Cook

Subject: Little Rock Overrun Accident - American Airlines Flight 1420 – MD 82
National Transportation Safety Board Number DCA99MA060
June 1,1999

1. **Introduction** The National Transportation Safety Board (NTSB) requested that Engineered Arresting Systems Corporation determine the benefit of an Engineered Material Arresting System (EMAS) for the subject accident. This report covers the design of a possible EMAS for runway 4R and the analysis of the MD 82 encountering the arresting system under conditions similar to those of the subject accident.

2. **Factual Data** On June 1, 1999 an MD 82 aircraft overran the available length of runway and skidded some 750 feet beyond the end of the runway.(A sharp drop off occurs after about 450 feet from the end of the runway.) In the vicinity of the runway end, the aircraft veered beyond the left edge of the runway and then turned back to the runway safety area within the edge extension of the runway (See Figure 1) as indicated by the track data developed at the accident site (note the different X-Y distance scales).

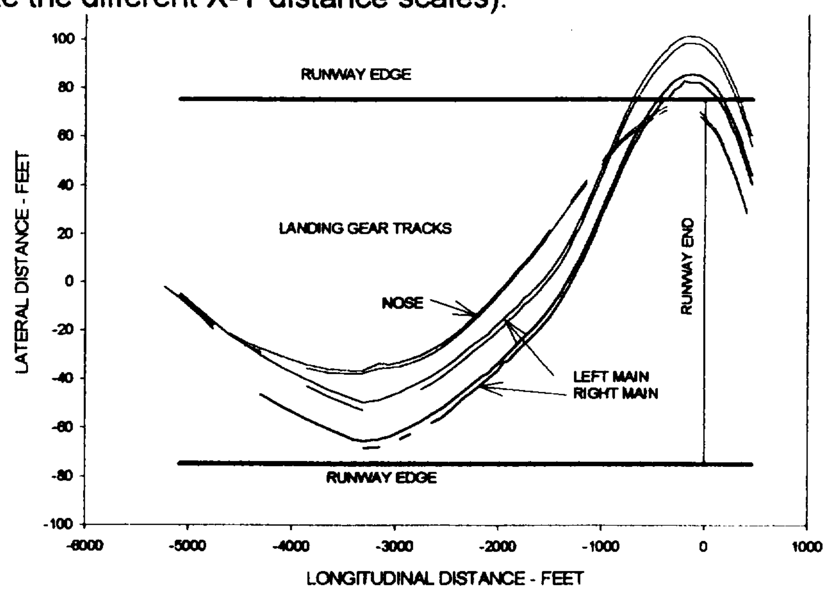

Figure 1. Landing Gear Tracks Obtained From Accident Site –Runway 4R

The aircraft was traveling at a speed of about 98 knots as it departed the runway and it was yawed (see Figure 2) approximately 20 degrees relative to the ground path as determined from Figure 3. The aircraft gross weight was approximately

128,000 pounds and the center of gravity was at 16.7% MAC as determined from flight planning documentation.

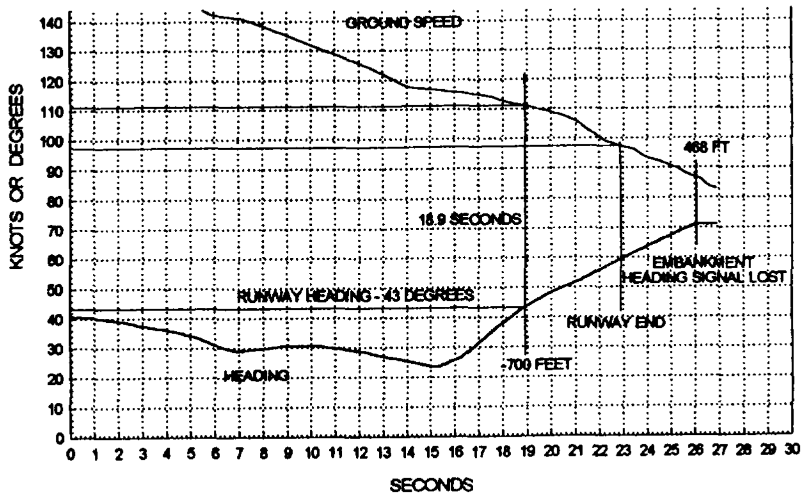

Figure 2. Determination of Overrun Initial Conditions

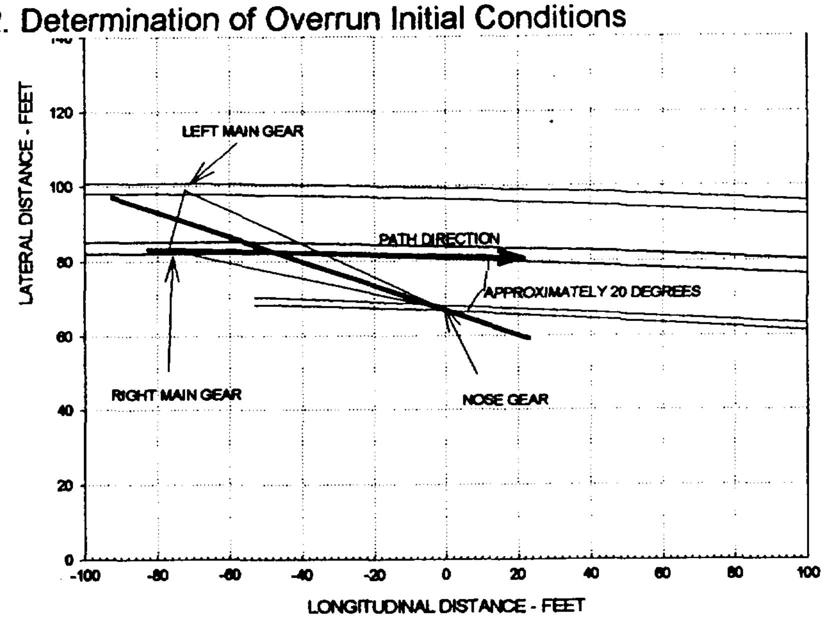

Figure 3. MD 82 Yaw Angle

The aircraft heading was approximately the same as the runway direction at -700 feet (Figure 1). Since the heading and ground speed were on the aircraft flight data recorder time-histories it was possible to derive the time that this event occurred. The ground speed at that time was about 112 knots (Figure 2.). By integrating the ground speed time-history after that point to obtain the distance traveled it was possible to arrive at the speed that the aircraft left the end of the runway.

3. **Computer**

The computer program used to predict the performance of aircraft while in an Engineered Material Arresting System (EMAS) was modified to accommodate the large yaw angle of the MD 82 as it departed the end of the runway. The computer program was written as a mirror image of the accident for preparer convenience and to keep action in the positive quadrant.

The initial conditions for the analysis were as follows:

1. Ground speed = 98 knots
2. Gross weight=128,000 LB
3. Center of gravity = 16.7% MAC
4. Yaw angle = 20 degrees
5. Yaw rate = .069 radians/second (counter clockwise)
6. Lateral velocity = 8 knots
7. Roll angle = 2 degrees Right wing down
8. Offset from runway = 15 feet

Figure 4 shows the simulated MD 82 aircraft path using these initial conditions. The X's are measured points from the data indicated in the Factual Data paragraph above.

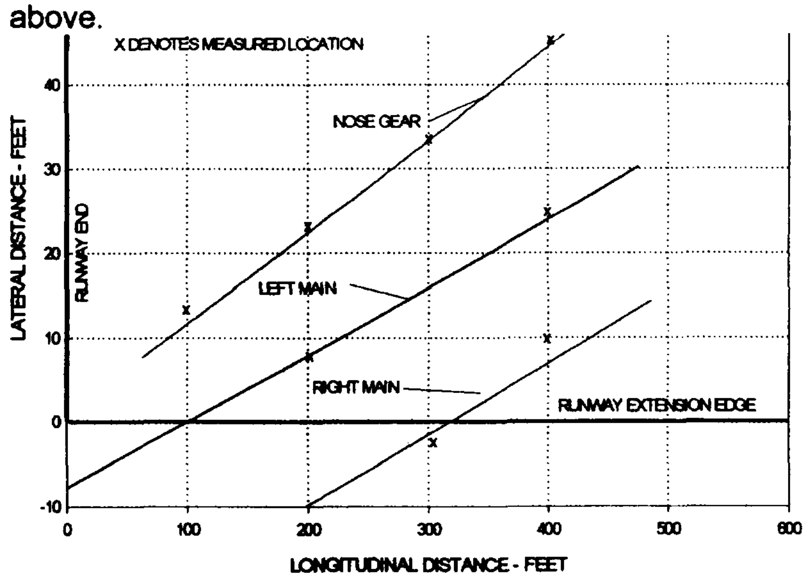

Figure 4. Simulated MD 82 Overrun Track

Figure 5 is a comparison of the MD 82 speed as simulated and measured.

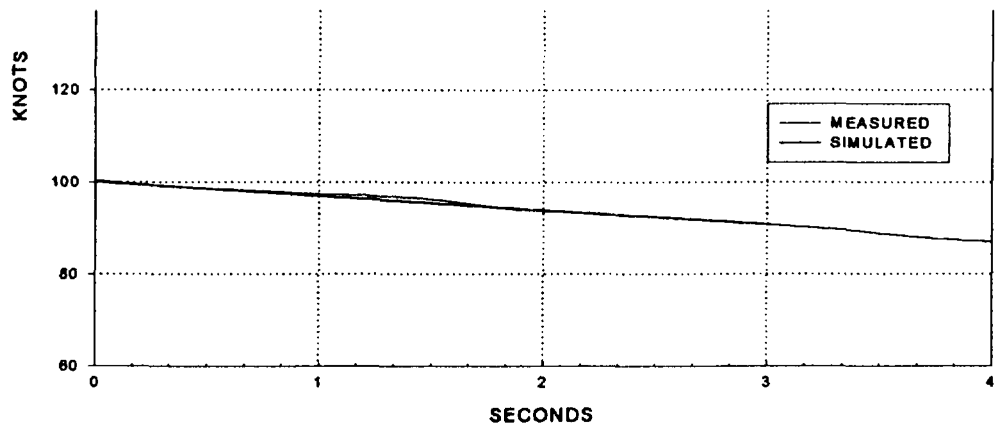

Figure 5. Comparison of MD 82 Simulator Speed and Measured Data

The results above indicate that the MD 82 simulator is a reasonably accurate representation of the motion of the aircraft during the overrun.

4. Estimated EMAS Performance for this Accident An EMAS was designed (AC 150/5220-22) to suit the conditions that existed at the end of runway 4R. The rigid ramp as assumed to be 100 feet long with a maximum height of 3 inches and starts 1 foot beyond the runway end. The EMAS has an initial height of 6 inches which tapers to a maximum depth of 21 inches in 120 feet. The total length of the EMAS (Ramp + Bed) is 402 feet. The EMAS Cellular Cement strength is "80 Strength". An MD 82 computer simulation with the above initial conditions and with this EMAS in place was conducted. (Additional analyses are contained in Appendix A.) The results were as follows:

4.1. **Deceleration** Figure 6 shows that the speed of the aircraft was reduced to about 70 knots by having an EMAS located at the end of the runway. The speed at approximately the same position without the EMAS was about 85 knots. Note the right main gear does not enter the EMAS until more than 200 feet past the end of the runway because the aircraft was partially off the runway at the exit. The main gear of aircraft are the main drag producers in an EMAS so losing the right main gear drag until near the midpoint of the EMAS was a significant loss in the overall deceleration of the aircraft.

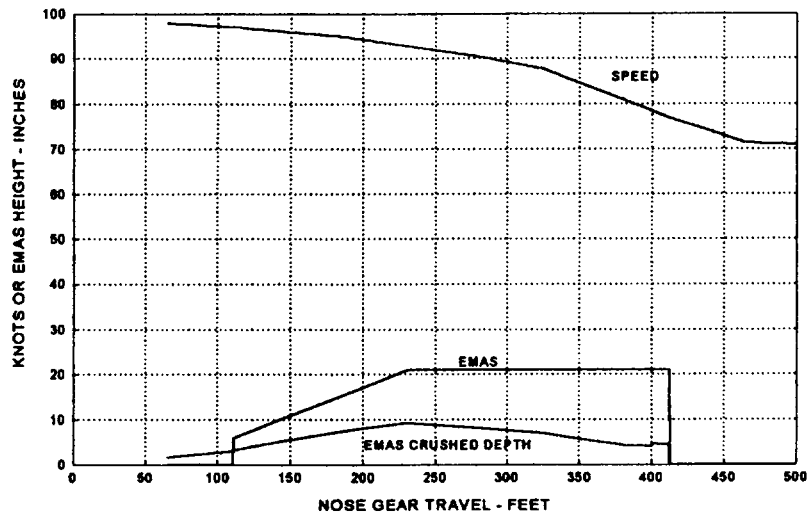

Figure 6. MD 82 Speed Reduction with an EMAS Present

4.2 **Track in EMAS** Figure 7 shows the estimated track of the MD 82 in the EMAS. The side loads resulting from the EMAS on the MD 82 nose landing gear causes the nose of the aircraft to veer into the center of the runway. At 400 feet past the runway end the nose gear is at 59 feet laterally from the edge. Without the EMAS, the nose gear was about 45 feet laterally from the edge. The main gear tracks were about the same with or without the EMAS.

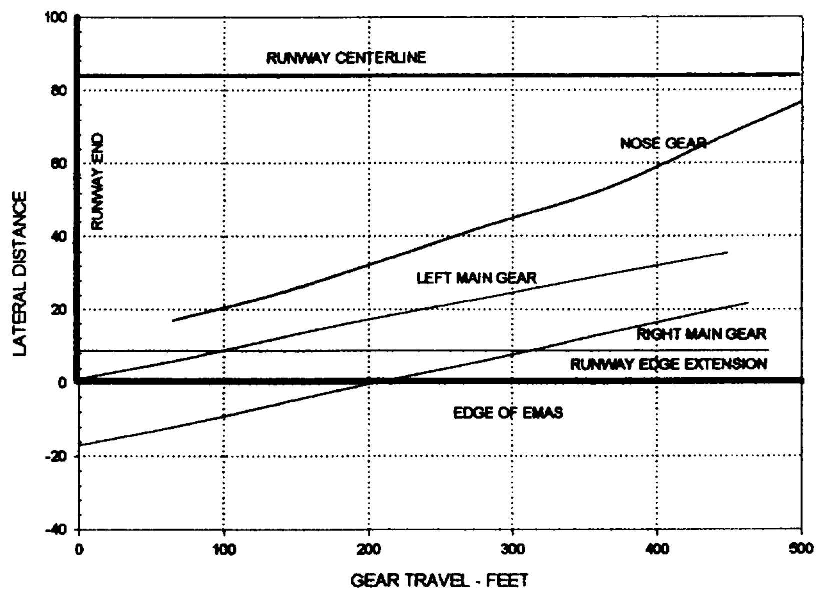

Figure 7 Wheel Tracks in EMAS

4.3 **Aircraft Roll Angle** As a result of the side loads produced by the EMAS on the MD 82 landing gear, the aircraft roll was somewhat higher than recorded during the accident. During the accident the roll angle was about 2 degrees. As simulated, the roll angle of the MD 82 was about 5 degrees as shown on Figure 8. The MD 82 wing tip clearance to the ground is about 9 feet. This would indicate that the wing tip is higher than the EMAS surface since this roll angle produces a drop of 4.5 feet at the tip of the wing leaving a clearance of 4.5 feet. The EMAS was assumed to be 21 inches deep (1.75 feet) - maximum.

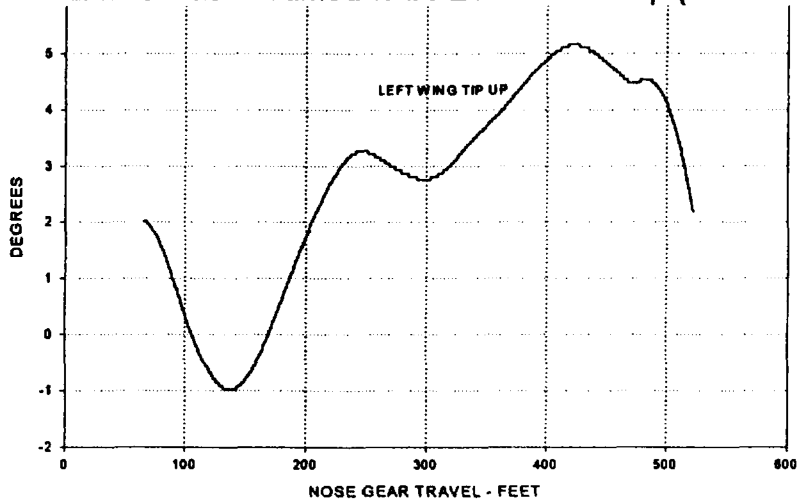

Figure 8 MD 82 Roll Angle during Accident Simulation with EMAS

4.4 **Landing Gear Loads with EMAS** Figure 9 (top) shows the nose gear loads of the MD 82 during the simulated arrest. The nose gear loads while in the arrestor are in operating limits. The nose gear could fail at about 450 feet as a result of exiting the EMAS.

NOTE:The x axis of this figure was truncated at the beginning because the early start loads are of a transient nature resulting from the simulation program and are not representative of the actual case. These loads damp out quickly and the representative loads are simulated after this short time interval.

The right main gear loads (Figure 9 bottom) are high because the aircraft is being supported mainly by that gear since the aircraft has a relatively high roll angle as a result of the side loads produced by the EMAS. However the loads remained within operating limits

Figure 10 shows the left main gear loads within operating limits. The loads decrease as that gear is lifted as a result of the MD 82 roll during the time it is in the EMAS.

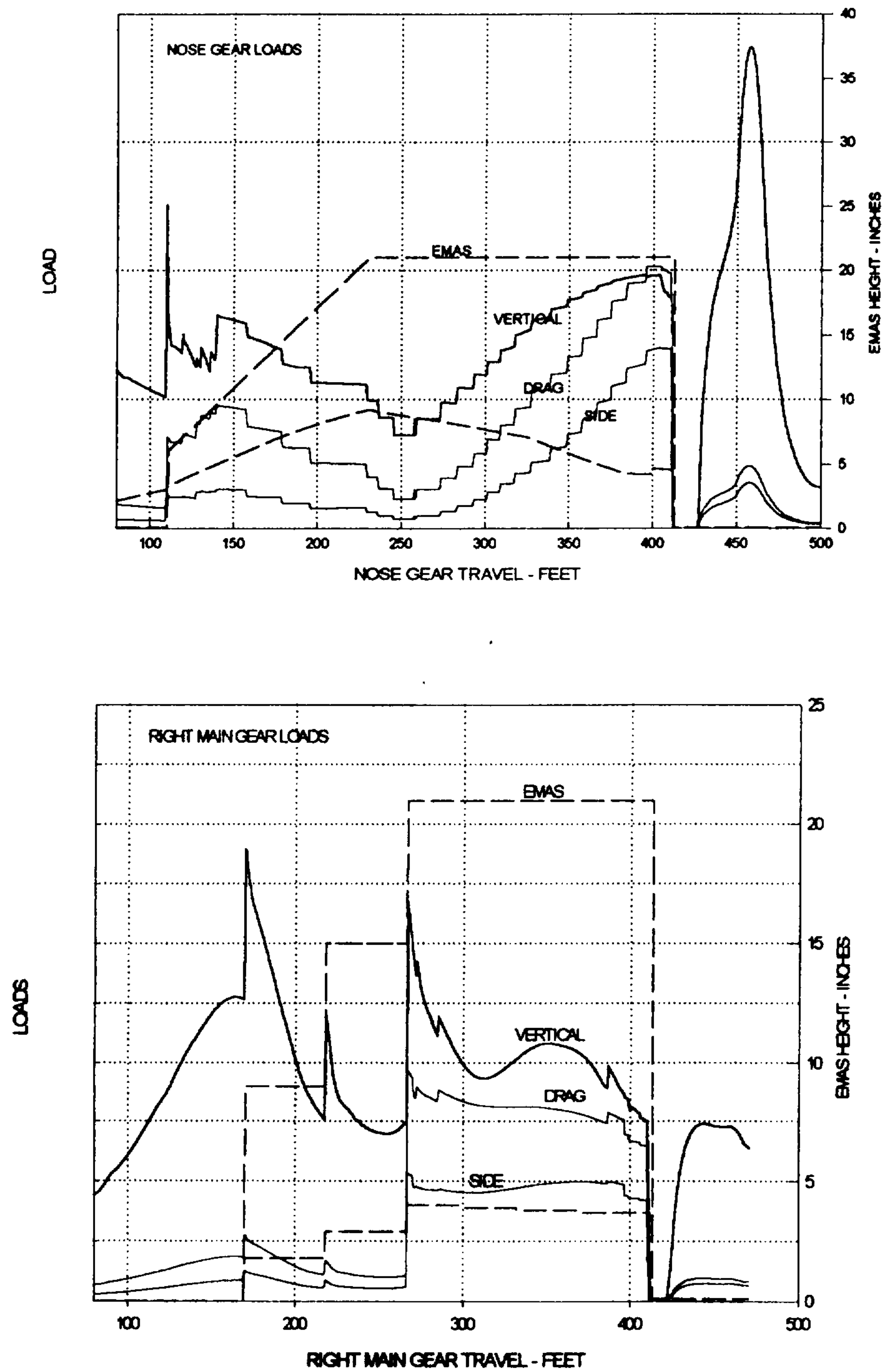

Figure 9 Nose and Right Main Gear Loads with EMAS

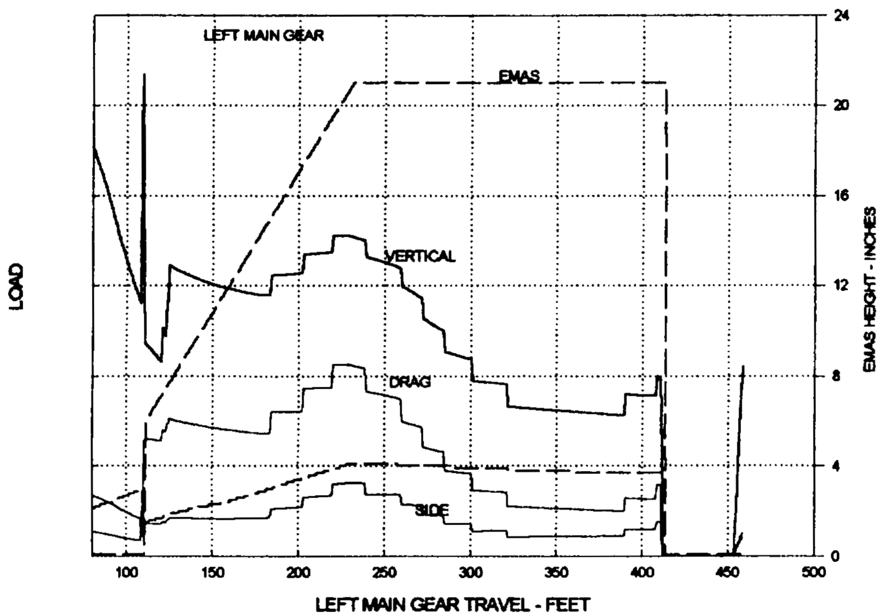

Figure 10 Left Main Gear Loads with EMAS

5. Conclusions

5.1 The benefit of EMAS in this MD 82 event would have been limited by the aircraft traveling partly outside the extended runway edges, resulting in the airplane being unable to use the full length of the EMAS.

5.2 The MD 82 would not have stopped within the safety area had an EMAS been present at the time of the accident. The velocity upon leaving the safety area would have been about 15 knots lower than occurred during the accident. This would reduce the energy of the accident by about 32 percent.

5.3 The presence of an EMAS in this accident could lead to a nose gear failure as a result of the drop off at the back of the EMAS.

APPENDIX A

Since the arrestor as designed by the FAA Circular AC 150/5220-22 did not stop the MD 82 it was considered advisable to compare the arrestor performance with that of a 1000 foot safety area under the same operating conditions. Figure A1 shows the MD 82 speed performance for both the EMAS and the FAA prescribed 1000 foot safety area.

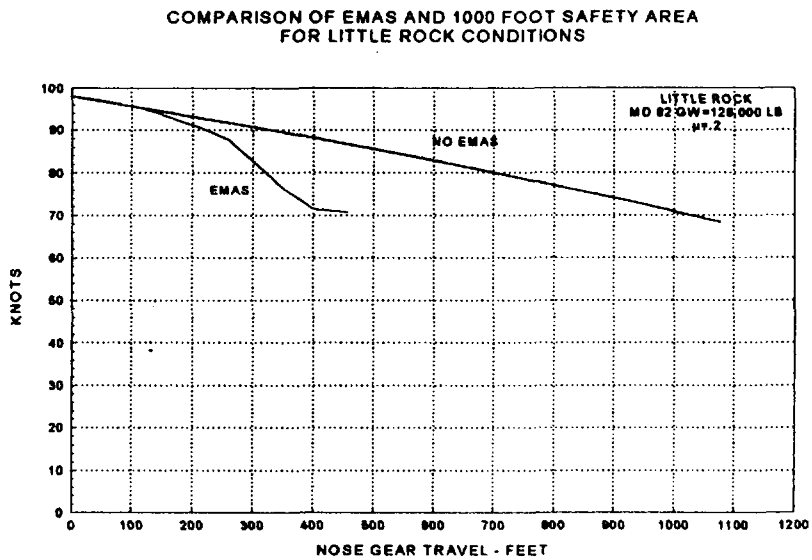

Figure A1 MD 82 Performance Comparison with and without EMAS

Here it is plain to see that the aircraft would be traveling at about 70 knots if this accident had occurred in a 1000 foot safety area. With the EMAS in place the speed was reduced to about 70 knots in the 450 feet available. This would indicate with an EMAS installed, the existing 450 foot safety area would provide the same stopping capability as the standard 1000 foot safety area without EMAS, at least for this accident.

In addition it was decided to determine the size arrestor that would be required to stop the MD 82. It was found that an arrestor about 650 feet long would have been adequate (see Figure A2).

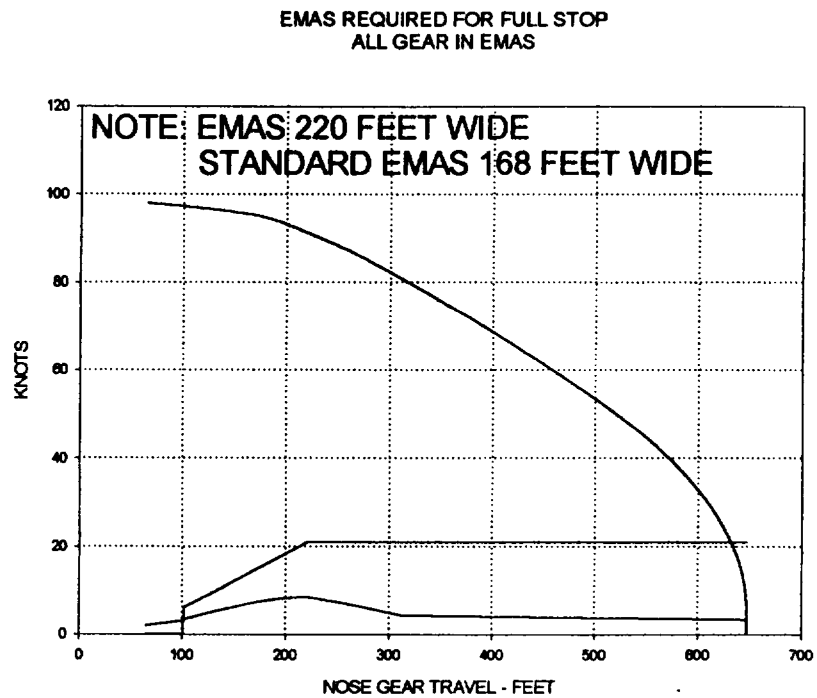

Figure A3 EMAS Required to Stop MD 82

To determine the length of EMAS which would have been able to stop the MD 82 from 98 knots it was assumed that the arrestor was sufficiently wide that all landing gear were in the arrestor from the beginning. Note that inthis case, the speed at 450 feet (end of existing safety area) the speed would have already been reduced to about 60 knots.

Finally, Figure A3 shows that an EMAS would have stopped the MD 82 in 650 feet but that for a standard safety area the aircraft would still be traveling about 70 knots at 1000 feet

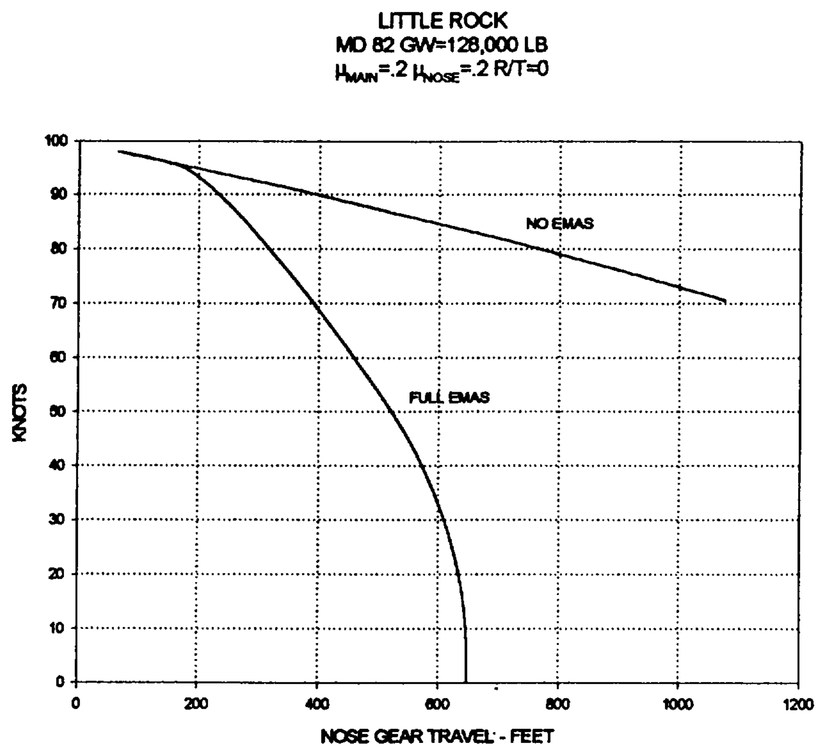

Figure A3 Comparison of EMAS and Safety Area Performance