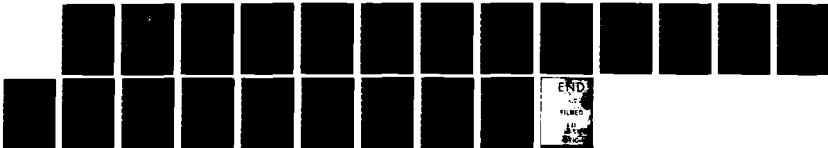
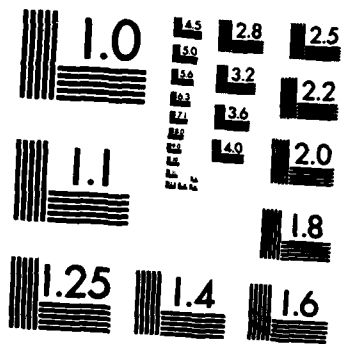


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DEVELOPMENT OF A CONTINUOUS MODE SEQUENCING CONCEPT FOR EJECTION SEATS

Louis A. D'Aulerio
Aircraft and Crew Systems Technology Directorate
NAVAL AIR DEVELOPMENT CENTER
Warminster, PA 18974

JANUARY 1983

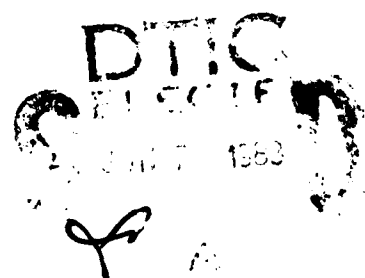
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20. ABSTRACT (Continued)

ejection seat event sequencing concept whereby seat subsystems are activated and deployed based on a detailed analysis of airspeed and altitude at the time of ejection. The analysis of this concept and the results of a computer study undertaken to estimate the possible performance improvements offered by this concept will also be presented.

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ABSTRACT

The need to provide safe egress from aircraft during low altitude, high speed and adverse attitude ejections requires the development of highly sophisticated and complex escape systems. Traditionally, the operation of an ejection seat has relied on the functioning of pyrotechnic and mechanical devices which are activated based almost exclusively on timing considerations alone, with little or no inputs from actual environmental conditions. In order to provide greater ejection seat performance it is desirable to activate these devices based on accurate and comprehensive environmental data. This report presents an ejection seat event sequencing concept whereby seat subsystems are activated and deployed based on a detailed analysis of airspeed and altitude at the time of ejection. The analysis of this concept and the results of a computer study undertaken to estimate possible performance improvements will also be discussed.

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INTRODUCTION

One of the primary tasks of an escape system, aside from promptly removing the pilot from a stricken aircraft, is to quickly and safely deploy the parachute. In present escape systems, the deployment of the parachute is based either on a fixed time delay or on a determination of whether the ejection speed and altitude exceed predetermined limits. In either case, the requirement to safely deploy the parachute mandates the selection of a rather lengthy time delay for very high ejection speeds. This delay is crucial since it allows the seat/occupant sufficient time to decelerate to a safe parachute deployment speed to prevent the destruction of the parachute during deployment and the imposition of unacceptably high forces on the occupant. However, the time required to decelerate to a safe speed is obviously dependent on the magnitude of the initial ejection speed. As a consequence, the selection of a fixed time delay for very high speed ejections imposes a penalty on lower speed ejections, where the time required to reach a safe parachute deployment speed is shorter. This report describes the study undertaken to develop a sequencing concept whereby the time to deploy the parachute would be determined based on the magnitude of the speed at ejection. The study utilized the data obtained from numerous tests conducted with two ejection seats presently in the U.S. Navy inventory. In addition, the GESS (Generalized Escape System Simulator) 6-DOF computer program was exercised to provide an assessment of the potential performance improvements gained by the implementation of this sequencing concept.

DISCUSSION

The main objective of this investigation was to develop a timing and sequencing scheme that would allow the parachute to be deployed as quickly as

possible and at the same time not increase the loads imposed on the occupant. In order to optimize the time of parachute deployment, two parameters must be investigated: altitude and velocity at the time of ejection. For low level ejections, altitude differences of a few hundred feet do not significantly alter the deployment characteristics of the parachute. Velocity, on the other hand, plays a crucial role since the loads generated by the parachute are directly related to the square of the velocity. Therefore, parachute deployment was considered to be independent of altitude for low level ejections, and the emphasis was placed on a close scrutiny of ejection velocity.

The standard scientific paradigm was used in the investigation: collect data, analyze data, form hypothesis, and test the hypothesis. No ejection seat tests were actually conducted, but rather the data from previous tests conducted at the SNORT (Supersonic Naval Ordnance Research Track) facility of the Naval Weapons Center, China Lake, were used. The only criteria used in the selection of tests from this data base for further investigation was that the complete trajectory history of the ejection had to be available. This resulted in 44 candidate tests, all of which were conducted in the last 5 years using two different ejection seat types presently in the U.S. Navy inventory.

The analysis of the test data was conducted in two steps. First, the very high speed tests (600 KEAS or more) were culled from the data and the time of parachute release (Pack Open), and the velocity at that point in time, were extracted. The data is presented in Table 1 in terms of averages for each seat type, where the values have been rounded for simplicity. There are some problems with the data: first of all, the velocities are determined by

differentiating the space position data obtained from film coverage of the tests and this procedure can introduce errors. Second, the fact that differences in seat configuration, such as variations in the dummy size and clothes, and slight differences in velocity, temperature, and density at the time of ejection are not thoroughly taken into account could affect the data. Despite these inaccuracies, information can still be extracted: for any one test one can never be sure that certain features of the data are real or artifacts of the errors, but when all the tests are examined together certain facts show through. The data in Table 1 indicates differences between seat types in both time of, and velocity at, parachute release for high speed ejections, the shorter time being associated with the higher Pack Open velocity. These differences arise from variations in physical seat design, type of parachute used, and parachute deployment procedures. In the second step of the analysis, the data for each seat type were analyzed in terms of the time required to reach the Pack Open velocity for various ejections above that speed. A scatter diagram of this data for each seat type, along with a linear least-square best fit is shown in figures 1 and 2. The data from these two figures was used to generate tables of Pack Open times as a function of ejection speed which give, in a loose sense, a continuous timing for low to very high speed ejections and hence the name Continuous Mode. These times, as well as the potential gains in terms of quicker parachute release, are shown in Tables 2 and 3 for seat types A and B, respectively. It should be pointed out that the selection of these discrete times for parachute release satisfies the requirement that the loads imposed on the occupant not increase over the present systems. The last phase of the analysis was an attempt to identify any potential performance improvements that could be achieved by implementing

the continuous mode timing concept. Because it was not feasible to actually implement and extensively test this concept due to the limited scope of the investigation, a computer simulation effort was undertaken to provide the type of trends required to indicate whether Continuous Mode can in fact offer performance improvements. The Generalized Escape System Simulator (GESS) computer program developed at NADC was exercised extensively to compare the performance of the Continuous Mode concept to the normal operation of each seat type analyzed. The results of this analysis are presented in tabular form in Table 4. A typical computer generated plot, showing the simulated seat trajectories with both continuous and normal mode of operation and the assumed aircraft path, is depicted in figure 3.

CONCLUSIONS

The results presented in Table 4, and depicted in figure 3, indicate that considerable improvements in ejection seat performance could be achieved by the implementation of the continuous mode sequencing concept outlined in this report. The performance improvements are characterized by a quicker system response and operation, with no increase in acceleration loads imposed on the occupant, and by a reduction in the amount of ground clearance required by the escape system to successfully recover an occupant under high sink rate conditions. It is felt that this sequencing concept can easily be implemented with readily available and proven microprocessor and airspeed/altitude sensing technology. Naturally, the function of the airspeed sensor is to measure the speed at ejection and to relay this information to the microprocessor. It is envisioned that the microprocessor would provide the computing capability required to analyze the velocity/altitude input from the sensors and select the appropriate parachute release time. In addition, the microprocessor would

provide an inherent and extremely accurate clock to insure that the parachute is released at the selected time. Further investigation is recommended to define the sequencing modes for other escape systems and to possibly refine the speed ranges for the two systems considered in this report, and to specify the requirements needed to insure the correct functioning of an all-electronic timing and sequencing system for ejection seats.

HIGH SPEED TEST DATA
(600 KEAS or Greater)

Seat Type	Average Time To Pack Open	Average Speed At Pack Open
A	1.600 sec	250 KEAS
B	1.700 sec	225 KEAS

TABLE 1 - Average High Speed Test Values for Seat Types A and B

SEAT TYPE A

Velocity At Ejection (KEAS)	Present System (sec)	Time To Pack Open Continuous Mode (sec)	Timing Improvement (sec)
251-300	1.600	0.650	0.950
301-350	1.600	0.800	0.800
351-400	1.600	0.800	0.700
401-450	1.600	1.050	0.550
451-500	1.600	1.200	0.400
501-550	1.600	1.350	0.250
551-600+	1.600	1.600	0.000

TABLE 2 - Continuous Mode Timing as a Function of Ejection Speed for Seat Type A

SEAT TYPE B

Velocity At Ejection (KEAS)	Present System (sec)	Time To Pack Open Continuous Mode (sec)	Timing Improvement (sec)
228-300	1.700	0.900	0.800
301-350	1.700	1.000	0.700
351-400	1.700	1.100	0.600
401-450	1.700	1.200	0.500
451-500	1.700	1.350	0.350
501-550	1.700	1.500	0.200
551-600+	1.700	1.700	0.000

TABLE 3 - Continuous Mode Timing as a Function of Ejection Speed for Seat Type B

CONTINUOUS MODE SIMULATION

Velocity At Ejection (KEAS)	Dive Angle (Degrees)	Decrease in Required Ground Clearance (Ft AGL)	
		SEAT A	SEAT B
251-300	10	70- 85	80- 70
"	30	200-240	170-200
351-400	10	85- 80	85- 70
"	30	185-235	180-205
451-500	10	55- 60	50- 55
"	30	150-170	135-150

TABLE 4 - Continuous Mode Simulation and Potential Performance Improvements for Seat Types A and B

SEAT TYPE A
TIME TO REACH PACK OPEN VELOCITY (250 KEAS)
vs
VELOCITY AT CATAPULT IGNITION

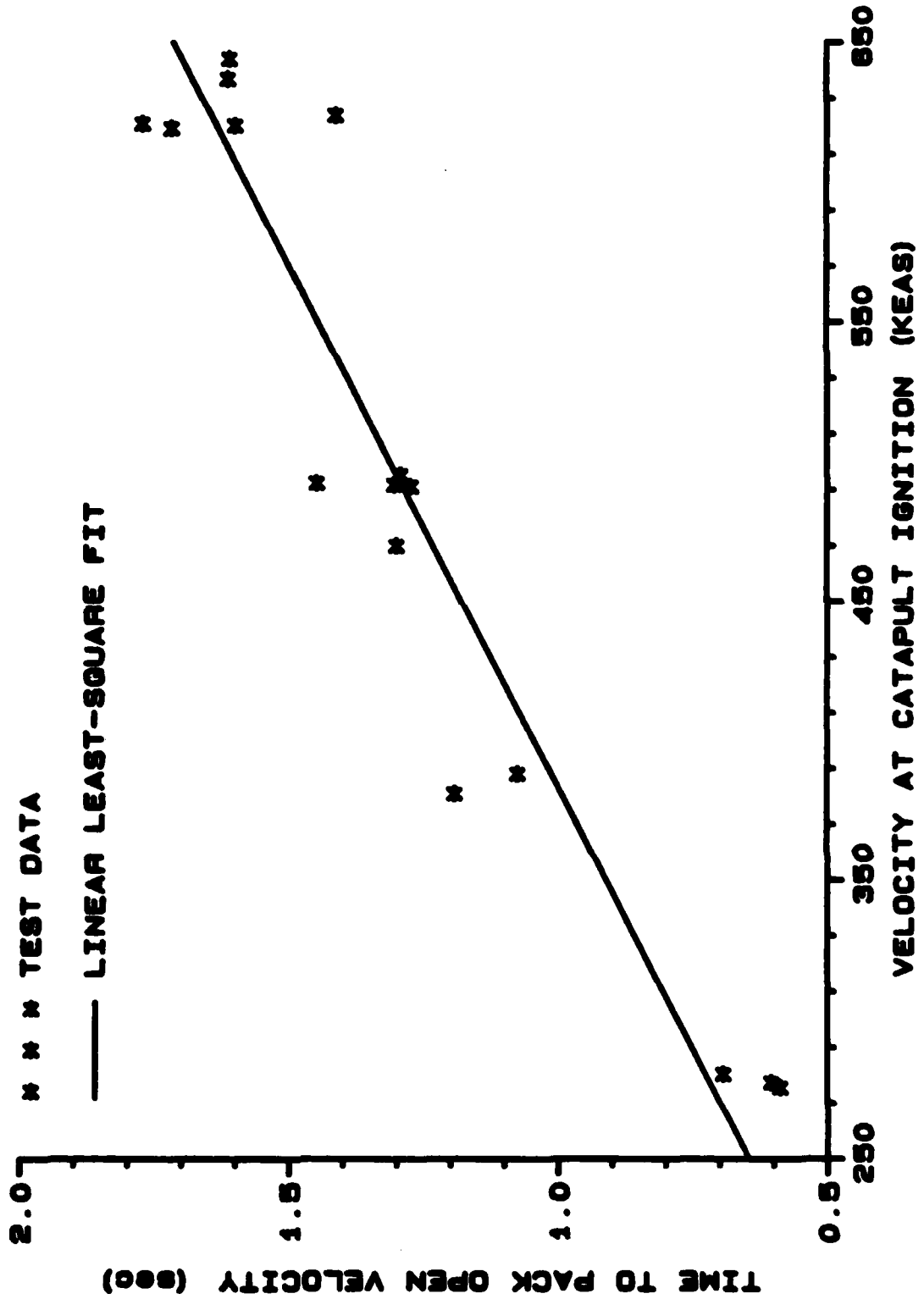


FIGURE 1 - Time to Reach Pack Open Velocity as a Function of Ignition Speed for Seat Type A

SEAT TYPE B
TIME TO REACH PACK OPEN VELOCITY (225 KEAS)
vs
VELOCITY AT CATAPULT IGNITION

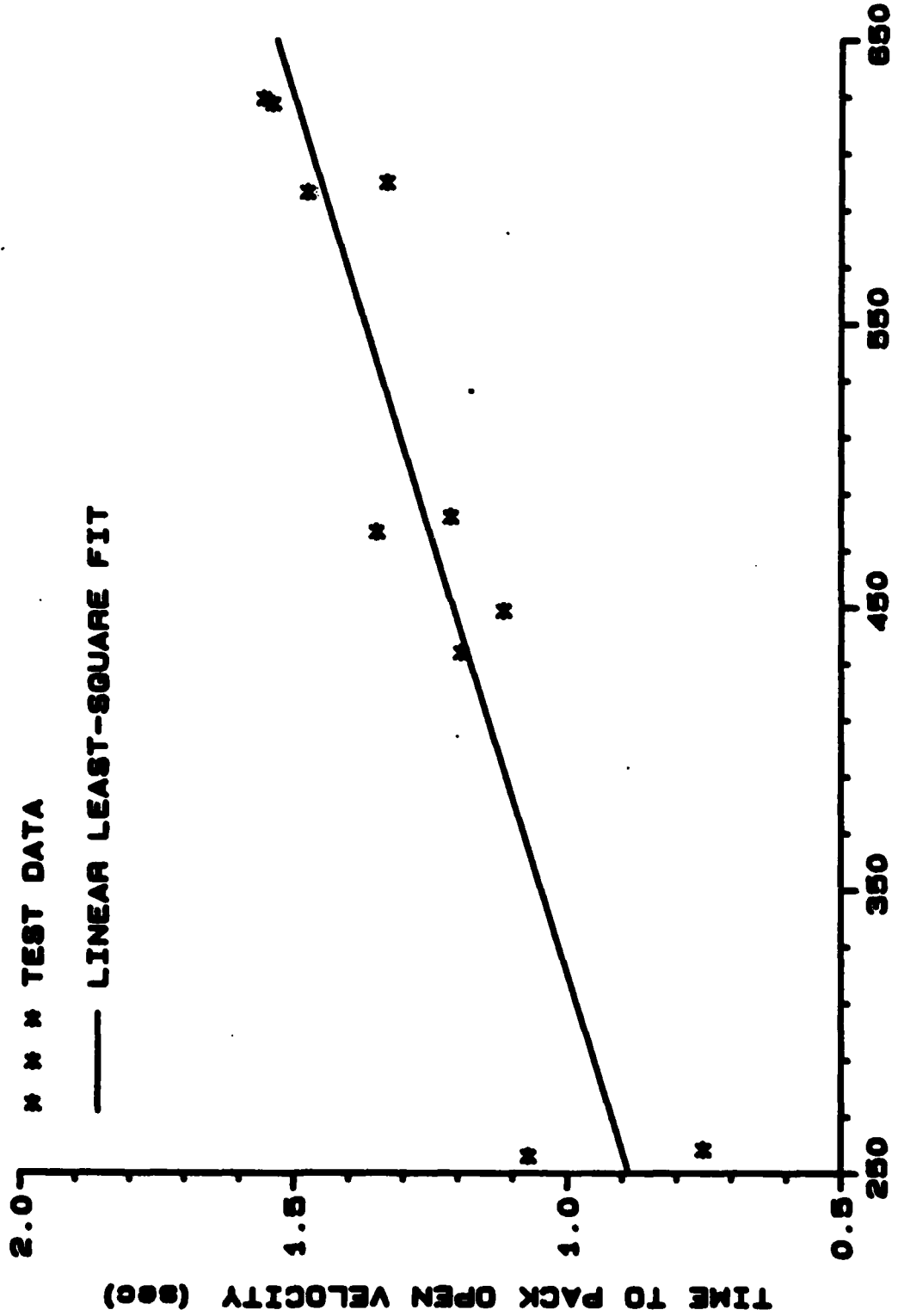


FIGURE 2 - Time to Parachute Release as a Function of Ejection Speed for Seat Type B

CONTINUOUS MODE ANALYSIS - COMPUTER SIMULATION
 400 KEAS - 1000 FEET - 30 DEGREES DIVE - 98% OCCUPANT

○ NORMAL EJECTION
 ▲ CONTINUOUS MODE SEQUENCING

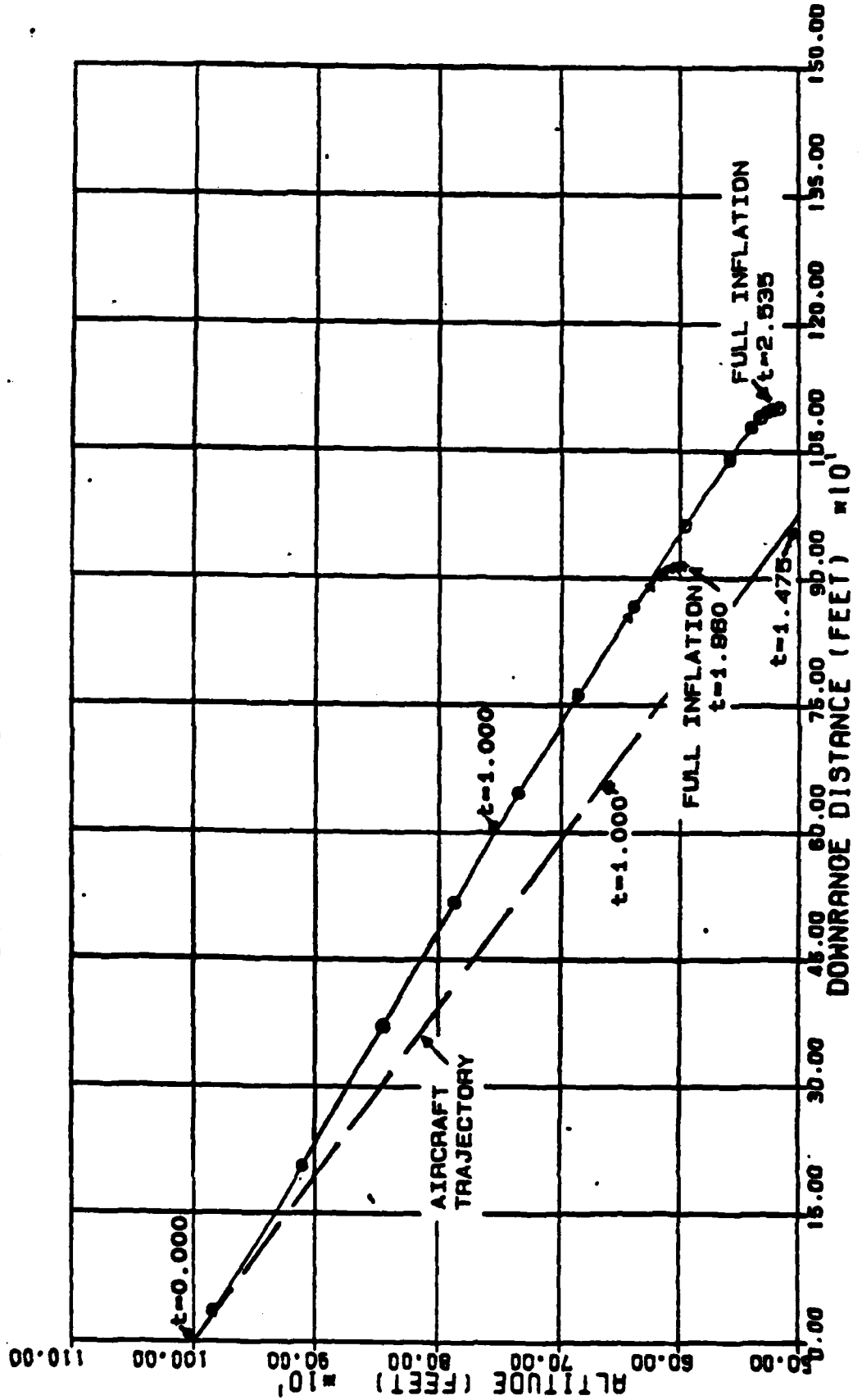


FIGURE 3 - Computer Simulation Comparison of Continuous and Normal Timing Modes

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