NASA SEAT EXPERIMENT AND OCCUPANT RESPONSES

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NASA EA-SEAT SHOWING INSTRUMENTATION

Figure 1 is a rear view of the NASA energy-absorbing transport seat showing longitudinal and normal (vertical) accelerometers attached to the rear tube of the seat structure. This seat was located on the left side of the aircraft in the rear (body station 1220) at what was designated row 14 in the instrumentation list. On the right side of the aircraft in the same row, there was placed for comparison an unmodified standard seat (NASA standard seat) of the same basic structure, but without an energy absorbing tube. Three dummies were placed in each NASA seat with each center dummy instrumented with accelerometers and lap belt load cells. The instrumented dummies in the EA- and standard seat were designated dummies 14B and 14E, respectively.

The planned crash scenario was for a 17 ft/s sink rate with attitude 1 degree nose up. For this scenario, the rear section of the aircraft near the two NASA seats would impact the ground first, generating a vertical pulse that was expected to cause the energy absorbers to stroke and to provide a comparison between an unmodified standard and an EA-seat.

Two unfortunate events prevented a good comparison: 1) The roll of the aircraft caused wing impact which reduced the vertical velocity and caused the nose to be the first part of the fuselage to impact the ground; 2) A pool fire developed in the rear of the aircraft and both seats were totally consumed by the fire.

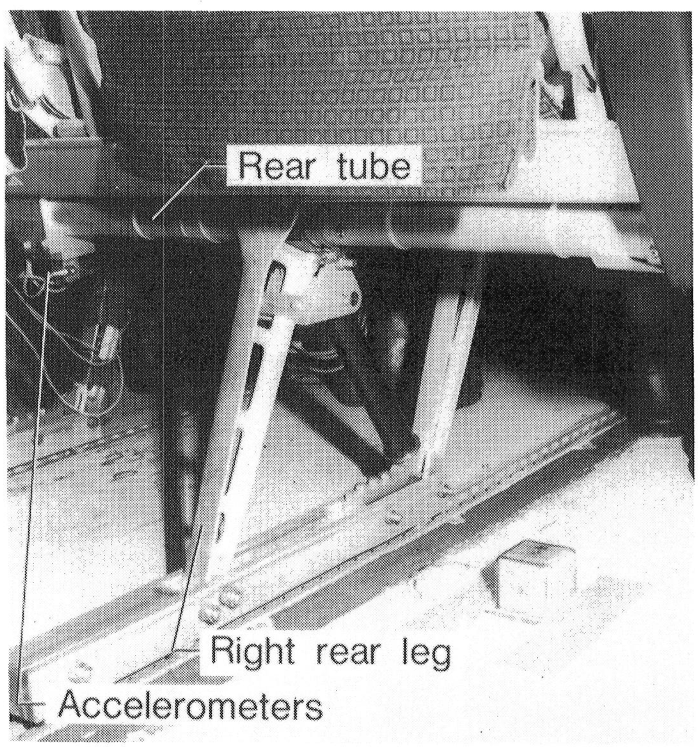


Figure 1

SEATED HUMAN TOLERANCE TO HEADWARD ACCELERATIONS

Figure 2 summarizes seated human tolerance limits to acceleration along the spinal direction with the stopping force pointed toward the head. Accelerations along the longitudinal direction will not be discussed because the CID accelerations were very low in the longitudinal direction. In addition, the human body can withstand greater acceleration in the longitudinal direction. Human tolerance is a subject that creates a lot of controversy, even among the experts. Human subjects cannot be used to determine permanent injury levels, and the accelerations and durations from accident data are only estimated. Well-restrained volunteers have mapped out non-injurious acceleration levels and durations as shown in the figure. Human surrogates such as hogs and chimpanzees have been used to establish estimated human severe injury levels.

In the CID crash, the acceleration levels were low but of relatively long duration. Many pulses exceeded 0.1 seconds and some were of nearly 0.2 second duration. Most of the voluntary exposure was for durations less than 0.1 seconds.

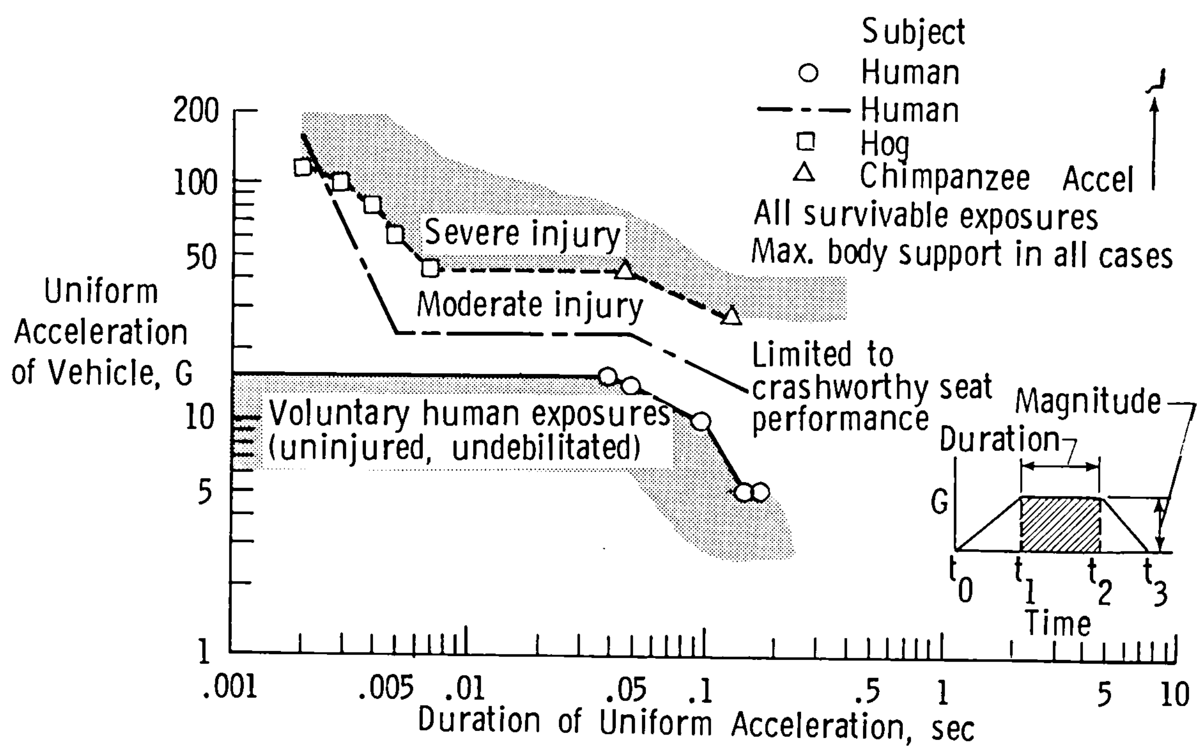
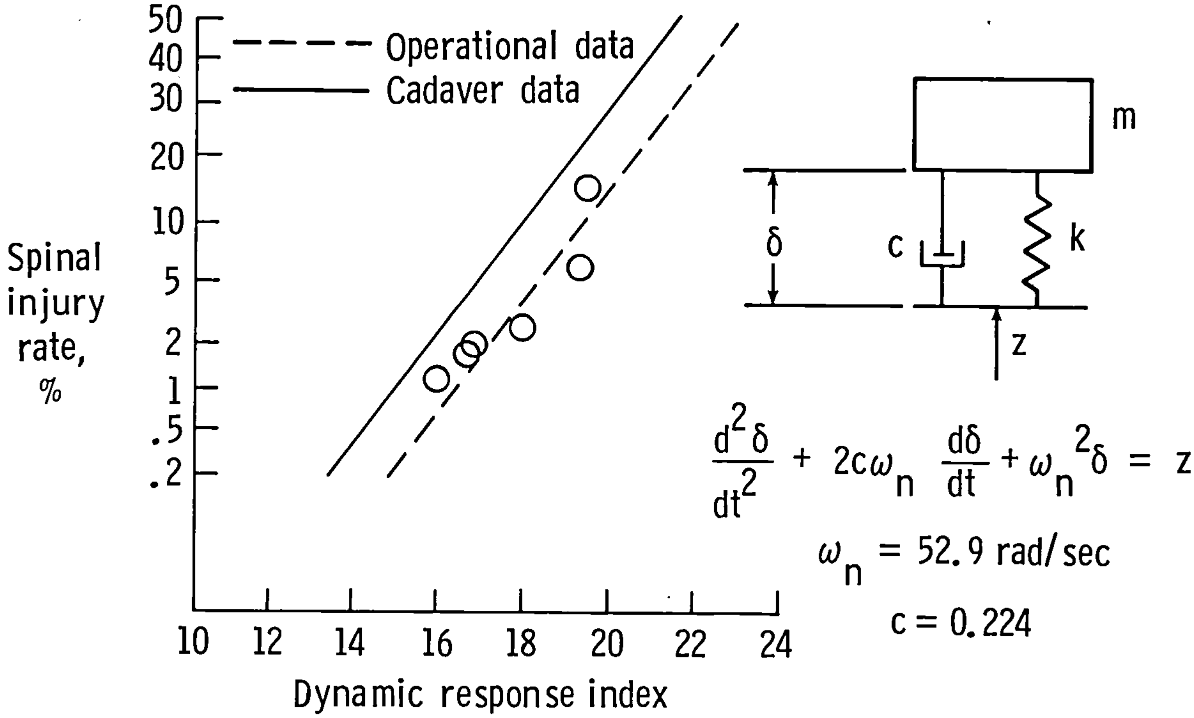


Figure 2

DRI MODEL

The Dynamic Response Index (DRI) model (ref. 1) was developed by the Air Force as an aid for studying injury to pilots who had ejected from high-speed aircraft and for specifying ejection seat performance. In this model, mass M is the upper torso mass, K is the spinal stiffness, and C is the spinal damping constant. The acceleration input (Z) forces the upper body and is generally taken to be the "vertical" seat pan acceleration for the Air Force ejection seat. For our purposes, the normal pelvis acceleration will be used since it is located directly above the seat pan and is the acceleration input that is forcing the upper body mass. Omega is 2 pi times the natural frequency. The equation in figure 3 is simply the equation for a forced simple harmonic oscillator. The DRI can be shown to be the maximum output acceleration of the mass M driven by forcing acceleration Z.

The plot on the left shows spinal injury rate as a function of DRI from cadaver (solid line) and from emergency ejections (dashed line).



$$\frac{d^2\delta}{dt^2} + 2c\omega_n \frac{d\delta}{dt} + \omega_n^2\delta = z$$

$$\omega_n = 52.9 \text{ rad/sec}$$

$$c = 0.224$$

Figure 3

NASA EA-SEAT PERFORMANCE

In figure 4 the dummy (14B) pelvis normal acceleration (along the spine) for the primary ground impact (wing cutter data not considered) is compared to the EA-seat normal (to floor) acceleration. Notice that the dummy pelvis acceleration follows the EA-seat acceleration rather closely except that it lags slightly in time. Also note that the peak acceleration is less than four G's, with the average acceleration down in the 1 to 2 G range and with durations approaching 0.2 seconds. Referring to figure 2, one can see that these levels are quite low and in the non-injurious range. This seat was designed to begin stroking for a normal input acceleration of approximately 8-10 G's. Since the input acceleration is well below that value, the graphite/epoxy energy-absorber would act as a solid member with no stroking.

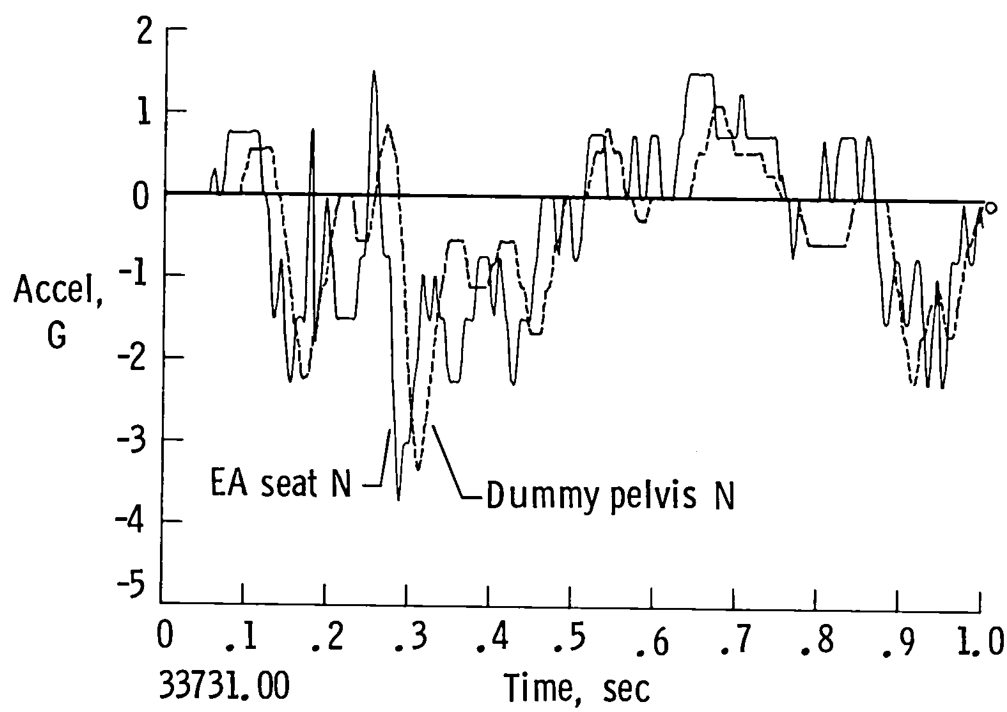


Figure 4

Figure 5 uses the same format as figure 4 except that the NASA standard seat and dummy 14E pelvis accelerations are compared. Notice that the normal dummy pelvis acceleration in the standard seat also follows the seat normal acceleration quite closely except for some time lag. Since the input pulse was below the stroking level for the EA-seat, both seats and both instrumented dummies experienced comparable acceleration pulses.

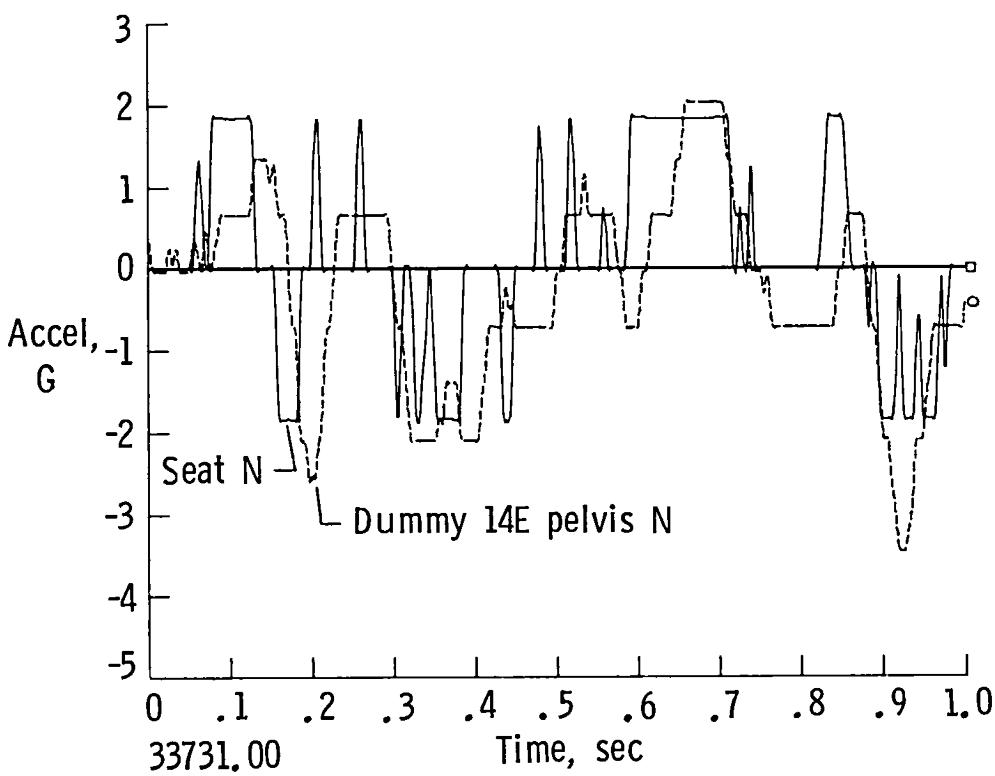


Figure 5

PILOT PELVIS ACCELERATION AND CONTINUOUS DRI

The dummy pilot received the highest normal (spineward) acceleration because the pitch rate imparted by the wing impact caused the aircraft nose to hit first with the highest vertical velocity. Figure 6 shows that the pilot normal pelvis acceleration peaked at 18.3 G's with base duration of about 0.07 seconds. The average acceleration over the 0.07 seconds is about 10 G's. In addition, the continuous DRI was plotted using the pelvis acceleration as the forcing acceleration. The peak DRI lags the input and slightly exceeds it at 19.8. By comparing the peak and average acceleration for 0.07 seconds with the curve in figure 2, one can see that the acceleration borders the moderate injury range. Referring to figure 3, a DRI value of 19.8, would indicate a 10-percent chance of spinal injury.

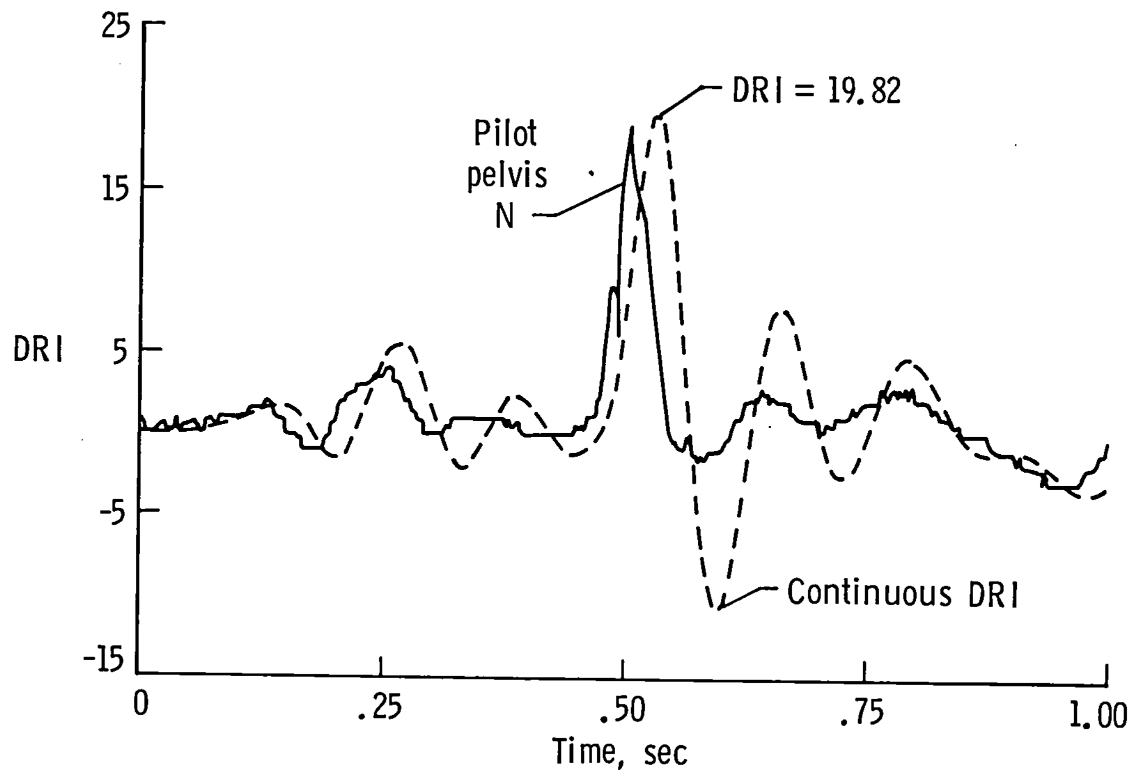


Figure 6

CID PLAN VIEW

Figure 7 is used to show the location of the various seats in the aircraft. The NASA EA- and standard seats were located at body station 1220 which is the 14 th row of seats. The pilot seat is considered row 1 and the attendant's seat near the main door is row 2. The seats at body station (BS) 540 are row 3 etc. The x-coordinate in inches measured from the nose is also given. (For example, the x-coordinate for body station 540 is 410 inches from origin at the nose.)

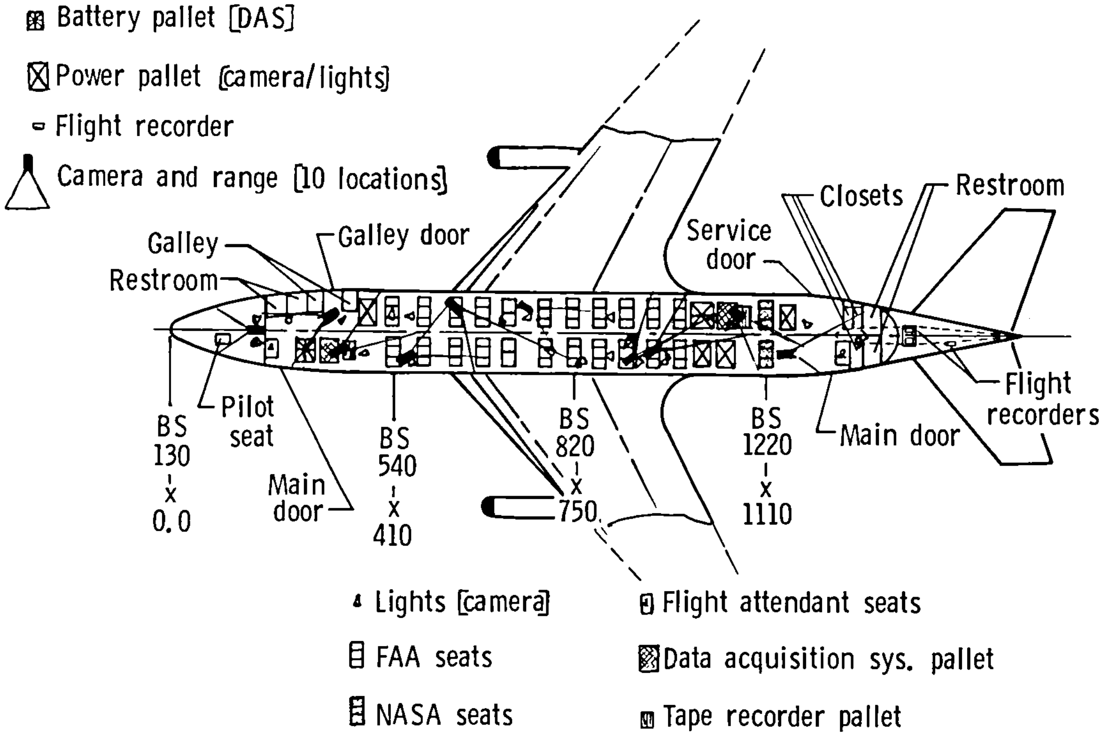


Figure 7

DUMMY OCCUPANT RESPONSE, DRI VERSUS DUMMY LOCATION

The dummy DRI was calculated for each instrumented dummy with good data traces and plotted versus the aircraft x-coordinate. The pilot was the only occupant that received a moderate acceleration. All of the other dummies received mild non-injurious accelerations. The number in front of each data point is the row number. The letter refers to the location from left to right with A being the far left seating position and F being the far right seating position. All instrumented dummies were located in the center position of each triple seat, thus they are in locations B and E (fig. 8).

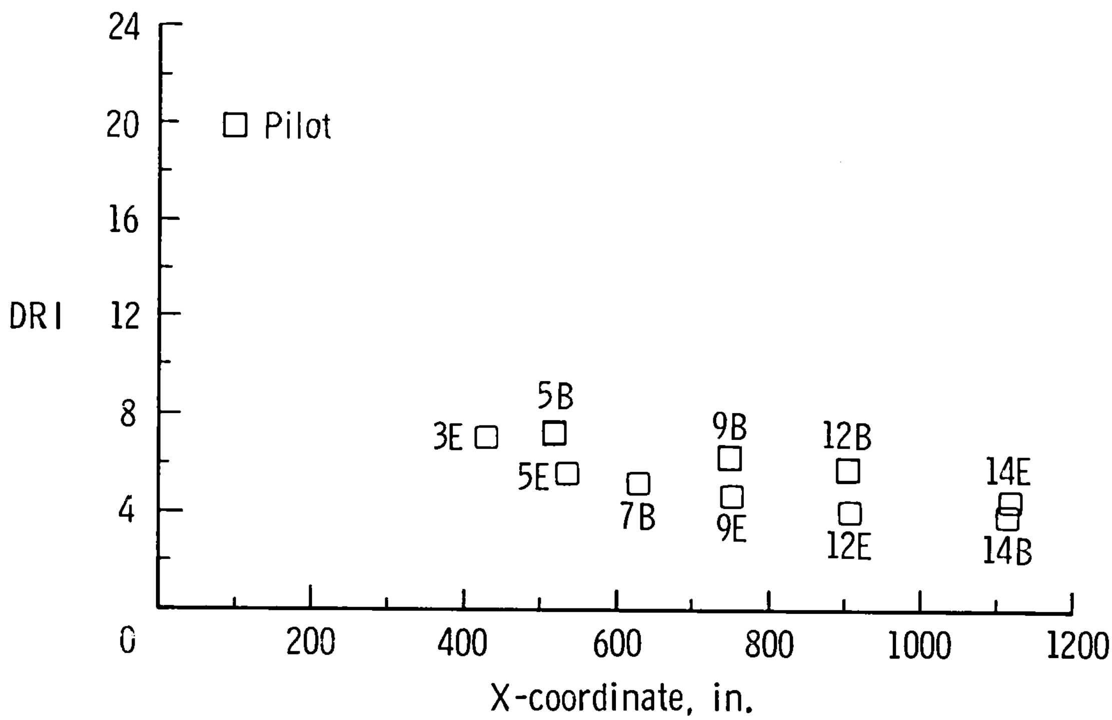


Figure 8

SUMMARY

In summary (fig. 9), the acceleration levels at the rear of the airplane were quite low and were below the stroking threshold of the NASA EA-seat. Therefore, dummies in the standard and EA-seat responded approximately the same.

All longitudinal accelerations were quite low for the primary impact with very low forces measured in the lap belts. The vertical (spineward) acceleration levels measured in the dummies were also relatively low and very survivable from an impact tolerance standpoint. The pilot with an 18 G peak acceleration received by far the highest vertical acceleration and could have possibly received slight spinal injury.

- Acceleration level below stroking threshold for NASA EA seat
- Acceleration levels measured in dummies were relatively low
    - Very survivable from human impact tolerances standpoint
    - Pilot received about 18 G's, the highest measured
- Injury criteria
    - Pilot had chance of receiving spinal injury

Figure 9

REFERENCES

1. Brinkley, James W.; and Shaffer, John T.: Dynamic Simulation Techniques for the Design of Escape Systems: Current Applications and Future Air Force Requirements. AMRL-TR-71-29, Paper No. 2, U.S. Air Force, Dec. 1971. (Available from DTIC as AD 740439.)

2. Military Specification, MIL-S-9479: Seat System, Upward Ejection, Aircraft, General Specification For. Department of Defense, Washington, D.C., March 1971.