Bulletin 40
Part 6
(of 7 Parts)

THE SHOCK AND VIBRATION BULLETIN

DECEMBER 1969

A Publication of
THE SHOCK AND VIBRATION
INFORMATION CENTER
U.S. Naval Research Laboratory, Washington, D.C.

Office of
The Director of Defense
Research and Engineering

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The 40th Symposium on Shock and Vibration was held at the Chamberlin Hotel, Fort Monroe, Virginia and the NASA Langley Research Center, Hampton, Virginia, on 21-23 October 1969. The National Aeronautics and Space Administration was host.

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H. A. Gaberson, Naval Civil Engineering Laboratory, Pt. Hueneme, California, and R. H. Chalmers, Naval Electronics Laboratory Center, San Diego, California

*This paper not presented at Symposium.

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*This paper not presented at Symposium.

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*This paper not presented at Symposium.

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*This paper not presented at Symposium.

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*This paper not presented at Symposium.

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*This paper not presented at Symposium.

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*This paper not presented at Symposium.

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*This paper not presented at Symposium.

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TRANSPORTATION

SIMULATION OF DYNAMIC LOADS ON EJECTED MISSILES

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Missiles carried by today's high speed aircraft are subject to severe dynamic environments during ejection. These environments are a result of the ejection velocities required to successfully clear the parent aircraft pylons, other missiles being carried and the weapons bay itself. Tests must be conducted to verify predicted structural dynamic responses and ejection forces produced during missile launch.

The successful accomplishment of these test objectives presents some interesting laboratory challenges. This paper discusses the test techniques used to produce the environments for measuring the velocities, strain, translation, pitch rates, gas pressures, accelerations, and dynamic structural modes. The structural design of the missile ejection bed and the design of an arrest mechanism which would arrest the missile at less than the ejection 'g' load with no damage to the missile itself were accomplished.

At The Boeing Company, the reaction structure and the arresting mechanisms were built and the tests were completed. A total of 40 simulated ejections and arrests were done. Photos, high speed movies, and a discussion of the data and test events will be presented.

The design, development, and successful production of a missile requires verification of many design assumptions, parameters and calculations. Many of these verifications need to be accomplished at a time before final decisions are made and production begins. It was during the early phases of a missile program when the Boeing Engineering Test Labs were given the requirements to plan and conduct a test program to measure the dynamic responses of a missile during the first six inches of travel after an explosive actuated ejection. The environmental parameters affecting the launch were to be simulated. The missile was to be of production configuration. The missile "carry" configuration was to be simulated. The missile ejectors were to be mounted to a structure which would simulate actual attachment to the pylon and aircraft wing. The reaction structure to which the ejectors were to be mounted was to be designed to represent "worst case conditions", that is, simulate a very stiff reaction structure. The missile would be ejected vertically downward from the simulated wing and from a 45° launch position from a simulated pylon. Low temperature conditions representing high altitude launches and high temperatures representing aerodynamic heat conditions were to be simulated. Aerodynamic air loads and aircraft maneuver "G" loads were to be simulated. Safety standard operation procedures were to be written. Breadboard fire control systems were required. Safety precautions were to be paramount throughout the program.

With these requirements specified in a formal Test Procedure Sheet, the test responsibility was given to the Dynamic Environments Group of the Engineering Test Labs. The various engineering approaches to the problems, the test simulation designs, and subsequent tests are discussed herein.

THE MISSILE

The missile to be ejected was a production configuration missile. The missile airframe contained all bulkheads and secondary structure. Production type electronic section

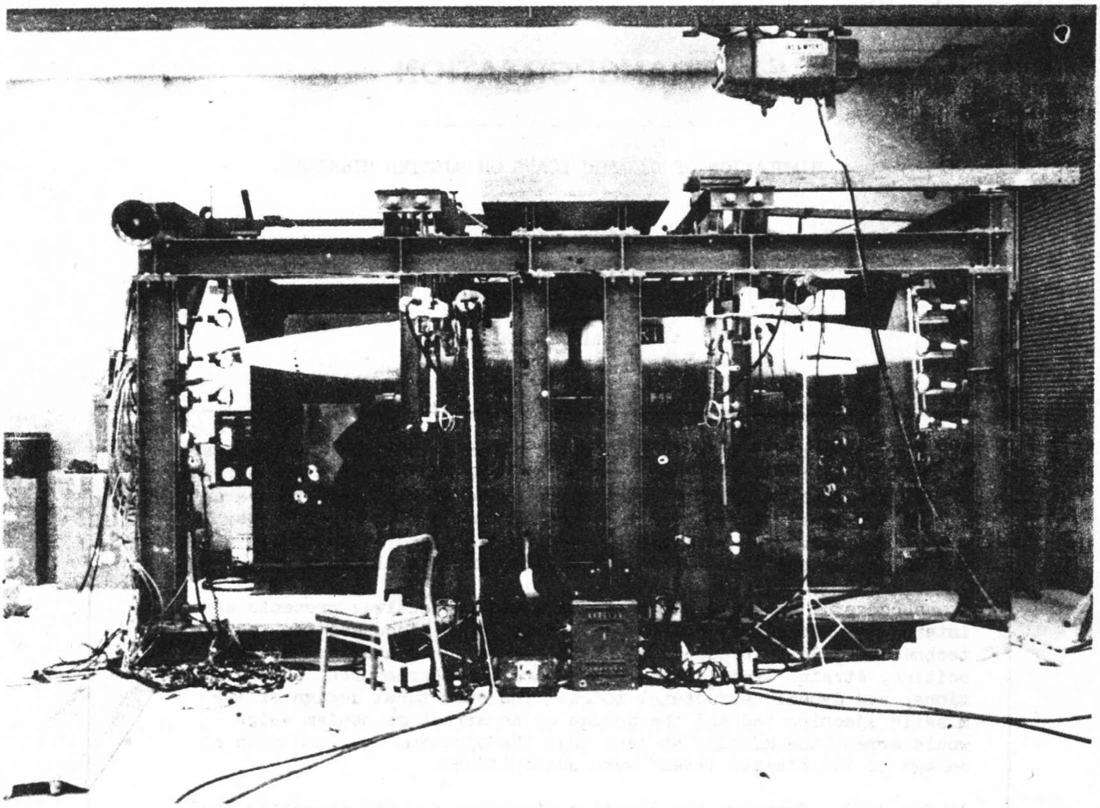

FIGURE 1 - A MISSILE IS INSTALLED IN THE FIXTURE FOR A SIMULATED LAUNCH

castings and control section forgings were used. Simulated components were used with approximately the same mass and stiffness as the actual components. The sway braces, attachment lugs and ejector contact points on the missile were production configuration. A prototype tail cone was installed. A full inert motor case was used.

Earlier tests had been conducted on the test missile to determine mode shapes, frequencies, and damping factors for the "static" free flight condition.

EXTERNAL LOADS

The aerodynamic loads could affect the missile dynamic characteristics and ejection flight path. For example, if the loads were large enough, the missile could "twist" or slip off the pad provided for the ejection piston foot before the end of the desired piston stroke. Therefore, careful consideration was given to the proper application of the loads to assure correct simulation. The simulated aerodynamic loads were designed to act on the missile during the first 6 inches of travel.

The simulated air loads were applied to the missile through the use of preloaded shock cord. The selection of shock cord with the desired mechanical properties, i.e. load-deflection, size, number of strands, and initial preload, provided an acceptable simulation of the loads. The loads were applied to the missile through hooks designed to be released by lanyards after the prescribed distances were traveled. Each load was produced by individual hydraulic jacks attached to the reaction structure.

SIMULATED WING STRUCTURE

A reaction structure to simulate the wing was designed. Several ideas were considered but calculations showed that they were not stiff enough to react the force and maintain small deflections to accurately read the total force output from the ejector with force gages installed between the ejector and simulated wing.

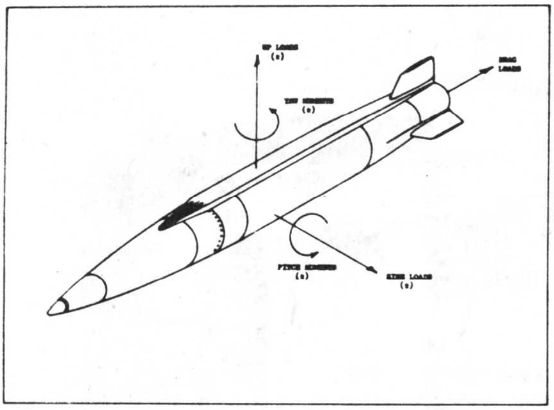

FIGURE 2 - THE LOADS SIMULATED DURING THE SIMULATED MISSILE LAUNCH

Also to satisfy the "worst case" condition requirement, every pound of force generated by the ejector should be imparted to the missile instead of using energy to deflect the reaction structure. Therefore, a mass loaded structure with a short load path between the force and reaction force was designed. The force from the ejector was designed to be in direct line with four 10 inch channels back to back. These channels were continuously welded to two one inch thick steel plates. Thirty six thousand pounds of lead blocks were then placed on the channels. This mass-stiffness structure maintained deflections within the required limits.

MISSILE ARRESTING SYSTEM

The missile arresting system was the most interesting facet of the test fixture design. Many ideas were evaluated in several "brain storming" sessions. The missile was required to be arrested with a maximum of 10 psi on the skin surface. The arrest deceleration was required not to exceed 10 G's. An arresting distance of about 24 inches would be required to satisfy these conditions. Water tanks were considered. Many ejections were required. The turn-around time between launches was important. Sawdust, woodchips, popcorn, styrofoam spaghetti, air cushions and sand pits were considered. After many calculations, none of the systems seemed to satisfy the arresting requirements. Yielding stainless straps were considered. Electrically actuated brake systems were considered. The actuation of these systems was too slow. The entire sequence of events, ejection free flight, and arrest was less than 70 milliseconds. A satisfactory arresting system with high reliability was not yet designed. Why not approach the problem in a simple manner? The problem: stop a one ton missile with a high velocity by controlled deceleration and without rebound. Why not solve the problem by absorbing the energy with strands of shock cord and a mechanical lock system to prevent return motion when the downward velocity was zero? Such a system was designed. A nylon net with the proper area to satisfy the missile surface area pressure was suspended between two horizontal pipes. Three pipes were then welded to each of the two horizontal pipes. Two spring loaded latching "dogs" were installed on each of the six vertical pipes. The force required to stop the missile was calculated. Elongation curves were plotted to select the proper length and number of shock cords necessary to stop the missile in the prescribed distance. The only reaction at impact would be the mass-acceleration loading of the moving parts and the preload on the shock cord. The sharp initial impact would be mechanically filtered by 2 inches of felt padding and the nylon webbing.

The arresting system would work for the vertical launches but how could the system be used for the 45° launches? A velocity "direction changer" was designed. The ejection path of the missile in a 45° ejection was calculated. A steel "plow" was designed to be tangential to the missile motion after 6 inches of travel. The "direction changer" was designed with a parabolic curve to deflect the missile into a vertical path. No impact would be experienced by the missile as it theoretically would travel tangential to the plow and "slowly" be deflected downward by the curved portion of the plow. The radius of the curve was designed large enough to limit the "G" load during direction change to an allowable limit. The only unwanted result would be a small rotational motion created by the firctional force between the "direction changer" and the missile. However, this would be of no significance to the

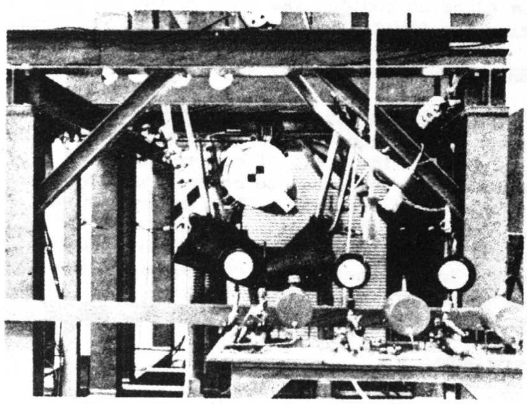

FIGURE 3 - EACH EXTERNAL LOAD WAS INDEPENDENTLY APPLIED TO THE MISSILE BY USE OF HYDRAULIC SYSTEMS

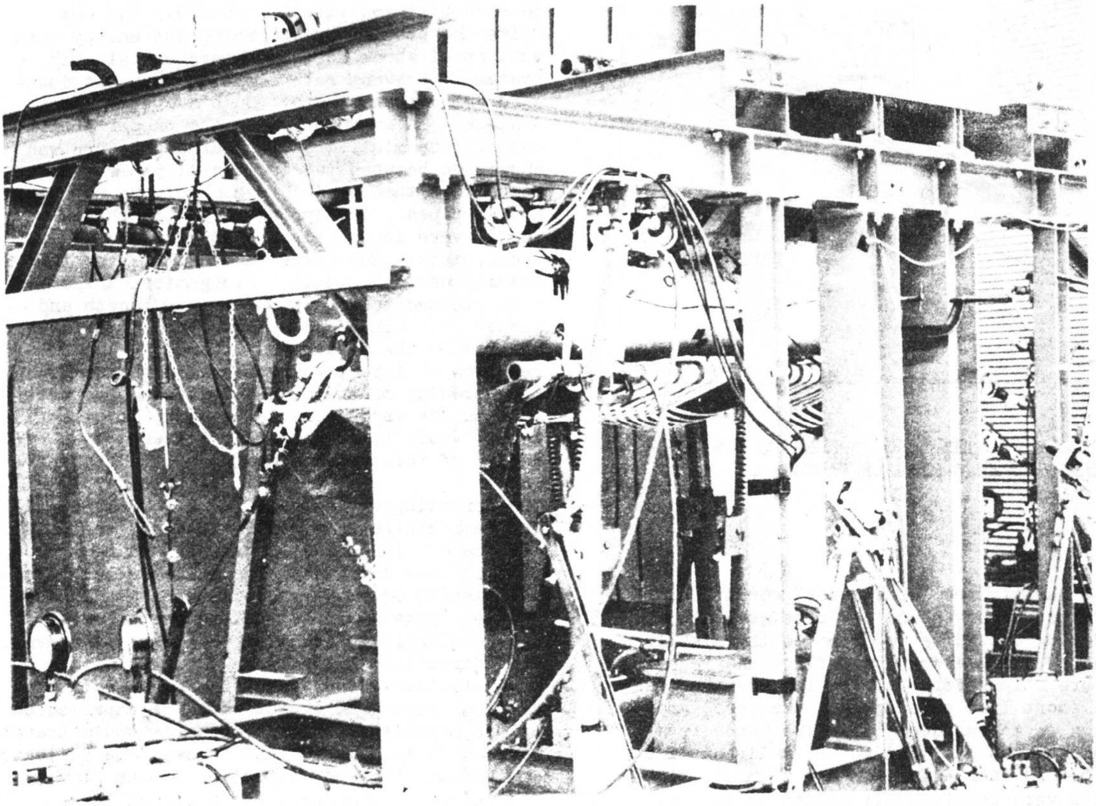

FIGURE 4 - THE REACTION STRUCTURE, THE 36,000 LBS. OF LEAD, AND THE ARRESTING MECHANISM CAN BE SEEN IN THIS PHOTO. (NOTE "DOGS" ON EACH OF THE VERTICAL ARRESTING MECHANISM STRUCTURE.)

data since no contact was made to the missile during the first 6 inches of travel as required.

THERMAL ENVIRONMENTS

An insulated box was built around the ejector. LN_2 was piped into the box and distributed by holes drilled in a coil of copper tubing. Thermocouples were used to control the LN_2 flow for temperature control. The same system was used for the "hot" condition except that radiant heat exchangers were used to convert the LN_2 into a "hot" gas. Thermocouples were used to control the radiant heat input to the LN_2 heat exchanger.

INSTRUMENTATION

During some of the missile ejections, load cells were installed between the ejector and the reaction fixture. This data was used to determine the effect of various ejector cartridges and temperatures on the resultant force experienced by the simulated aircraft wing. Accelerometers were placed at each end and at the center of the missile. This data showed the frequencies of the free flight modes and the maximum accelerations experienced by the missile during launch. Strain gages were installed on the missile in critical areas. The missile was statically load calibrated prior to the dynamic missile launch. The bending moments developed in the missile during the ejection were calculated from this data. Pressure transducers were installed in the gas pressure chambers of the ejector. Cartridge performance curves provided by the vendor were verified. Electrical deflection indicators were installed at each end of the missile in two axes. The data from these were used to calculate the displacement history and rotational translation during launch. High speed motion pictures were taken with grids positioned behind the missile. The motion pictures were used as a redundant method of calculating the pitch rate of the missile and for observing the overall test events. Computer programs were used for data reduction of the dynamic data obtained with the instrumentation.