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Gunfire Loads Are Simulated in A-10 Fatigue Testing

By BRYAN DUTTON (ISWR), SEBASTIAN GRASSO (ISER), KEN GRUBE (ISER), and JAMES VAUGHAN (ISWR)

If you walked by or worked near the El Segundo building 202 Structures Test Lab in January or February, you couldn't help hearing what sounded like a Gatling gun firing at a very high speed. Air Force representatives who witnessed the testing said it sounded like the real thing.

A full scale fatigue test of the USAF A-10A aircraft is currently being performed by Northrop Grumman in order to certify the aircraft for an additional lifetime of service. The GAU-8 30 mm Gatling gun mounted in the fuselage nose fires 3900 rounds per minute and is an integral part of this weapon system. In addition to flight maneuver spectrum testing, requirements for additional life certification included a simulation of gun loads in the full scale test under conditions that accounted for the long term effects of gunfire recoil and counter recoil loads and actual dynamic response of the structure. A spectrum of simultaneously applied axial and lateral loads derived from previous flight test measurements was applied for nearly one million cycles. Dynamic replication of the gunfire recoil loads on a full scale airframe test article was a technical challenge that was met and successfully achieved by Northrop Grumman A-10 IPT team members from ISWR El Segundo and ISER Bethpage.

Unique load application and reaction test fixtures were designed and installed to execute the gun firing fatigue load breakout test. The reaction fixturing included longitudinal fixed load reaction links located at the aircraft pylons at the wing root and a lateral load reaction fixture attached to the lower fuselage skin in close proximity to the lateral load introduction location. The test article rested on three fixed vertical supports located where the aircraft is balanced during flight spectrum testing. The flight spectrum load cylinders were left attached but

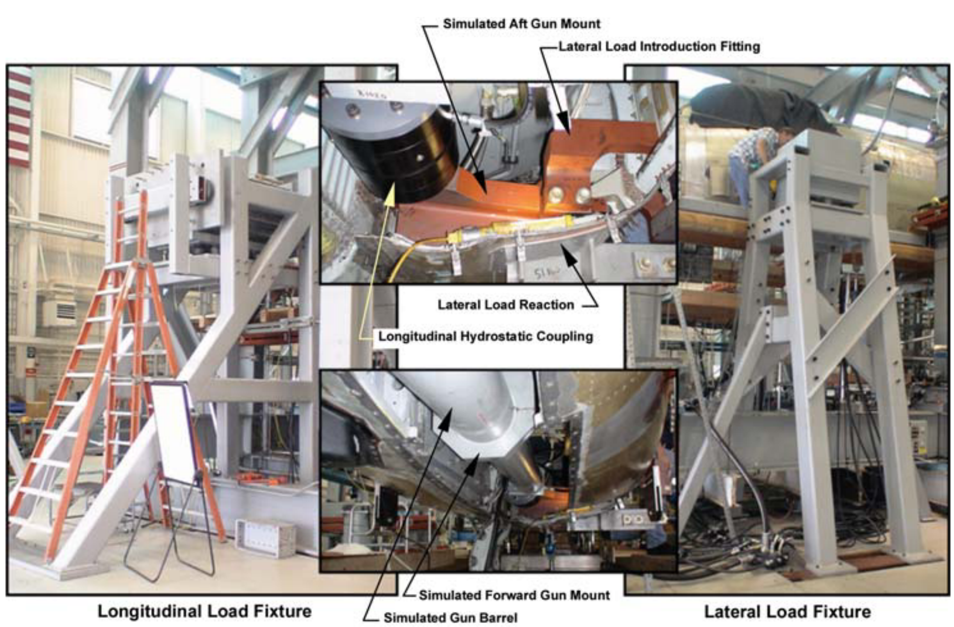

Figure 1. Gun Fire Test Fixture – General Arrangement

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A-10 Fatigue Testing *(from page 1)*

hydraulically isolated, preventing inadvertent load application. Both longitudinal and lateral loads were applied simultaneously to the gun attach points at 60 hertz to simulate the recoil and counter-recoil loads imparted during actual gun firing. The load introduction equipment and test fixtures are shown in Figure 1.

The complexity of performing a dynamic load application test at the high frequencies representative of actual gun fire rates with synchronized multiple load inputs (longitudinal and lateral) required an in-depth detailed dynamic analysis be performed to specify unique load application equipment and a control system capable of meeting the test requirements.

NGC engineers worked with the application engineering staff at Team Corporation to procure two purpose designed servo-actuators to apply the axial and side loads. The actuators have close coupled accumulators and an integral high flow servo-valve. Figure 2 shows the actuator setup for the lateral load application; the longitudinal load is similar. The 3 stage flapper nozzle valve arrangement shown was needed to support the required loads application rates of 60 hertz with

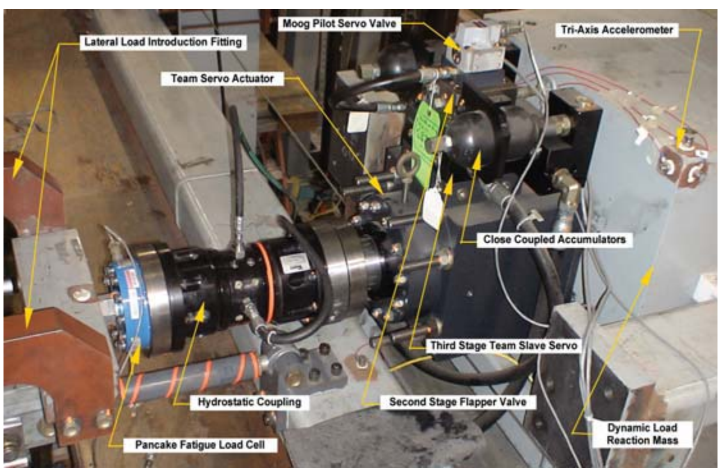

Figure 2. Gun Fire Test – Lateral Load Test Actuator

potential displacements of +/-0.25 inches. The valves are comprised of a Moog pilot valve and an industrial flapper servo valve capable of approximately 5 GPM. This flapper valve is the primary input to a Team Corporation slave stage servo valve capable of 40 GPM.

The longitudinal load was applied at the nose of the aircraft through a simulated gun barrel that accommodates two Team Corporation hydrostatic spherical couplings. The specified 12,620 peak load value was measured at the aft gun mount fitting. The peak lateral load of 4,340 pounds was applied at the simulated aft gun mount through a hydrostatic spherical coupling and split fitting that ensured all applied lateral load was reacted through the LHS of the fuselage frame at FS 238.00. The hydrostatic spherical couplings ensured that the dynamic load was isolated and applied in only one axis. Applied loads were measured and controlled via feedback from calibrated load cells installed at the points of load application to ensure that the correct loads were input to the critical aircraft structure. Applied actuator loads were reacted by counterbalance masses suspended on air bearings on free standing support frames, mitigating dynamic load transfer to the facility structural load frame and reducing total system deflections.

Accurate control of applied test loads presented a significant engineering challenge due to the required test frequency and potential dynamic response of the aircraft structure and load reaction system. The solution was the utilization of Team Corporation supplied high fidelity load introduction actuators and hydraulic system components and the implementation of a FCS/Moog control system that had the ability to select control between force and position. The control system's seamless transition between position and force allowed for primary control feedback on position with the secondary outer loop control closed on load to aid the stability and accuracy of the applied loads. The FCS/Moog proprietary FasTEST® waveform replication software contained complex closed loop algorithms that performed transfer function iterations to reduce error signal and allow optimization of the desired waveform.

The applied load spectrum and profile was determined from historical A-10 operational and flight test data. The required number of test cycles was determined from survey of actual fielded aircraft gun usage data and was reduced to rounds fired per flight hour. The loads were applied in "bursts" of 100 rounds with counter recoil loads applied in the middle of each gun burst (the recoil load was performed in the middle rather than the end of each burst so the support fixtures would not have to "catch" the inertial mass after the tension load was applied). A total of 982,730 load cycles were applied, demonstrating gun support structure strength for a second service life. A typical representation of applied gunfire loads is shown in Figure 3 indicating an average cyclic frequency of 60.6 hertz. ■

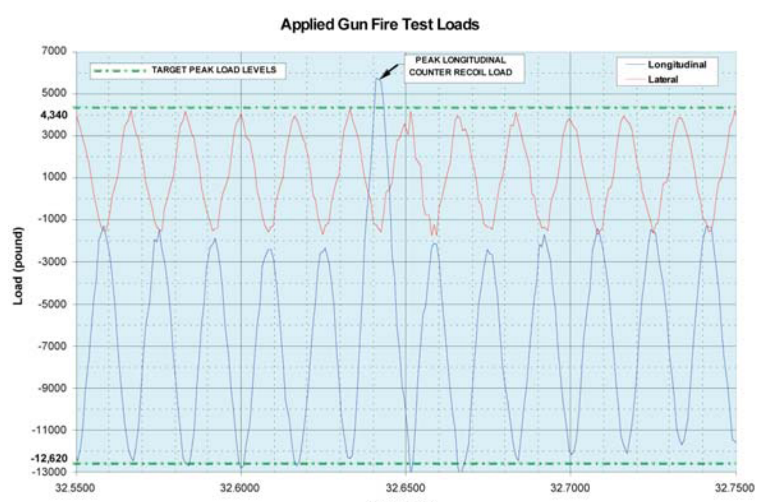

Figure 3. Gun Fire Test – Applied Loads