



## Aircraft Survivability and Vulnerability

### Introduction

Providing pilots with aircraft that are robust in design in order to withstand threats likely to be encountered during combat is one of the most important objectives for the designer. The branches of the United States military perform testing at the Naval Air Warfare Center, Weapons Division (NAWCWD) at China Lake, California to assess survivability and vulnerability to attacks. Tests are conducted on components, subsystems, full-scale aircraft and munitions. Data collected is used to determine areas of weakness in the design and changes are proposed and tested for effectiveness.

### Solution

Survivability tests conducted on aircraft require a wide variety of measurements and thus a variety of sensors. Measurements can include hydrodynamic ram pressures created during impact (dynamic strain gages), axial deformation of the wing tank (static and dynamic strain gages), shock during impact (piezoresistive accelerometers), static and dynamic pressure (4-20mA aerospace pressure sensors), blast pressure (silicon diaphragm bridge), displacement of the wing during loading (string potentiometers) and load applied to the wing (load cells).

Since the test article is subjected to live fire, the measurement system is located in a control room a significant distance from the aircraft. The signal conditioning must support a wide variety of sensors likely to be used for survivability tests with signal bandwidths up to 100 kHz. Precision Filters, Inc. (PFI) 28000 Signal Conditioning System was selected to provide the analog signal conditioning for up to 256 sensors. Conditioning for all of the sensors mentioned above was supported with PFI 28114 quad channel transducer conditioner card. Additionally, two channels were dedicated to measure fuel flow and engine speed using the PFI 28524 frequency to voltage card. The outputs of the signal conditioning system were connected to a National Instruments PXI analog to digital converter system with PFI supplied cables.

One signal conditioning card that could support all measurements would represent a significant savings in maintenance, training, sparing, cabling and thus over all operating cost. Highly automated equipment was required to reduce test setup times and cycle times between test segments since test regimens are constantly changing. The 28114 card provides a high performance, fully programmable, universal solution for conditioning the wide variety of sensors that NAWCWD uses. The 28114 provides constant voltage for bridge type sensors or proprietary 2-wire/4-wire constant current excitation measurement for dynamic strain gages.



Courtesy U.S. Navy

### Solution Highlights

- 256-channel scalable, universal signal conditioning solution
- Support for a wide variety of transducers using one common amplifier module: static and dynamic strain, pressure, acceleration (force), load, displacement, temperature, flow, tachometer
- Balanced constant voltage (zero common-mode) or balanced constant current excitation
- Fully programmable sensor bridge configuration – quarter, half or full-bridge completion, 120, 350 or 1000 ohm completion resistors
- Fully programmable constant current configuration – 2-wire/4-wire (Kelvin) connection.
- Compatible with 4-20mA current output sensors
- Real time display of sensor excitation, sensor resistance and leakage
- Latching overload detectors capture transient overload conditions
- Programmable FLAT/PULSE low-pass filter to optimize system response to measurement requirement
- Wide bandwidth – 100 kHz
- High density – only 42 inches of rack space for 256 channels
- Programmable frequency response for static or dynamic measurements
- Automated validation of sensor, cable, signal conditioner and DAS
- Fully automated NIST traceable calibration tests performed in place

## Solution (continued)



Courtesy NAWCWD

Precision Filters' FLAT/PULSE filter technology allows the user to set the frequency response characteristics of the signal conditioner under program control. For transient tests or tests where time-domain wave shape preservation is important, the PULSE mode characteristic is used.

The PULSE mode provides linear phase response, which is required for time-domain wave shape reproduction and outstanding transient response with low overshoot and ringing. For frequency domain analysis, selecting the FLAT filter characteristic will result in outstanding transfer function flatness and a sharp, selective filter response.

Often live fire tests last only fractions of a second. During the explosive event, the filter can mask temporary input overloads that occur from out of band energy that are not observable by the connected data acquisition system. The 28114 has overload detectors that latch the occurrence of temporary channel saturation conditions, alerting the user that an internal overload occurred during the test and that data for that channel should be scrutinized for validity.

NAWCWD required high performance equipment with features that would ensure valid data collection. Testing is expensive (hundreds

of thousands of dollars or more) and often there is one and only one chance to collect the data. Having worked closely with our customers on many difficult tests, we know the harsh environment of live fire takes its toll on sensors, cables and connectors. It is not uncommon for a sensor or cable to be damaged by shrapnel from a previous test and discovering a failed sensor or cable after subsequent tests is too late, resulting in lost data that can never be recovered. Quick and easy visibility of cable and sensor health allows timely corrective actions that can save crucial data. Test hardware and software in the 28000 Signal Conditioning System allows the system user to easily run a series of automated sensor and cable health checks.

All test and measurement systems require periodic calibration. Typically, this means that test systems are dismantled, cards uninstalled and shipped either to an in-house cal lab or back to the manufacturer, requiring 30 days of down-time. NAWCWD's rigorous test schedule requires automated in-situ calibration as the test schedule does not tolerate one month per year down-time for equipment calibrations. Precision Filters' built-in test hardware and software allows the user to perform NIST traceable calibration tests on-site without removing the system from the equipment rack.

*For more information, please contact Doug Firth, Precision Filters, Inc. at 607-697-9102 or [doug@pfinc.com](mailto:doug@pfinc.com).*

**References:** Weapons Survivability Laboratory (WSL): *Quick Facts!*, 2011  
NAWCWD Corporate Communications: *News Release, One-of-a-kind Testing at NAWCWD Means More Survivable Aircraft*, 2012  
Joint Aircraft Survivability Program Office (JASPO): *Aircraft Survivability*, Spring 2010

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## PFI Equipment Used in NAWC Tests



**Qty. 4 28016 Mainframes with Power Supplies and 28000F-BIF1-FT Control Cards with Built-In Test Support**



**Qty. 64 28114-FX01-LP4FP Quad Universal Transducer Conditioners**



**Qty. 1 28524 Frequency to Voltage Conditioner**



**Qty. 4 28000-TEST Test Subsystem for performing system validation and in-situ NIST traceable calibrations**

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