Adding New Instrumentation to Aircraft Platforms

Mark Jordan
AV-8B Weapon Separation Test Team Lead
NAVAIR 5.1.6.6
Air Vehicle Stores Compatibility Division
Fighter and Attack Branch 2
HGR 201, Suite 1A
21960 Nickles Rd
Patuxent River, MD 20670

Mark.Jordan@navy.mil

ABSTRACT

Legacy aircraft platforms face many hurdles; when it comes to testing these include but are not limited to: shrinking budgets, low priority, and lack of instrumentation. These hindrances to test programs are not likely to change in the near future. New low cost interchangeable instrumentation systems are needed to fill the gap between current test capabilities and future requirements.

In recent years, advances in technology have allowed instrumentation systems to greatly shrink both in size and cost. Some of these new instrumentation systems are designed to fit inside of a MK 80 series fuze well and are designed to look like existing bomb components. One of these is a small form factor instrumentation system nicknamed "6 DoF, " because it transmits six degree of freedom information to a ground station. The 6 DoF is a completely self-contained instrumentation system that requires no aircraft interface to operate. The 6 DoF has provided a low cost data collection device for weapon separation test programs for the last couple of years.

With the success of the 6 DoF instrumentation systems in weapon separation test programs, the question was raised if a similar system could be used for captive carriage loads and flying qualities test programs.

To meet this need a new low cost, under $30,000, instrumentation system has been developed. This system is designed to receive data from external strain gauges and accelerometers. This new system is a block upgrade of the 6 DoF instrumentation system that has had the internal sensors removed, and has had plugs installed, to take inputs from external sensors. Now instead of having to instrument a specific aircraft for a test program, a store could be instrumented to collect the same data. This system is designed to not only allow the instrumentation to be moved from one type of aircraft to another, but also to allow the instrumentation to be moved from one type of store to another.

Legacy platforms through the use of these low cost reusable instrumentation systems will be able to continue to provide new capabilities to the fleet even under reduced funds.

Jordan, M. (2005) Adding New Instrumentation to Aircraft Platforms. In *Flight Test – Sharing Knowledge and Experience* (pp. 12-1 – 12-12). Meeting Proceedings RTO-MP-SCI-162, Paper 12. Neuilly-sur-Seine, France: RTO. Available from: http://www.rto.nato.int/abstracts.asp.

1.0 INTRODUCTION

When a new or existing weapon is to be integrated for use on a tactical aircraft it is necessary to determine if the weapon can be safely carried and deployed. To determine if the weapon is safe to use flight-testing must be conducted and the data from this flight test must be in a usable format that can be analyzed post flight.

There are many ways to collect flight test data from photogrammetrics and cinetheodolites to capture store separation and ballistic characteristics to fully instrumented aircraft to capture loads and flying qualities flight characteristics. The main draw back to these systems is that they require a combination of specifically built aircraft and ground instrumentation systems and in most cases require the aircraft to be extensively modified. These systems are not only complex and require dedicated assets but also are very costly, with some systems easily exceeding a million dollars.

The question then is what is the best way to collect the flight test data in a usable format. The six degree of freedom (6 DoF) instrumentation unit and captive carriage miniature telemetry (CCMT) unit provide a low cost highly accurate method of collecting flight test data. These systems do not require aircraft modification and have minimal support requirements.

This paper presents information the current 6 DoF and CCMT used to gather quantitative data from weapon/store separation tests and loads and flying qualities tests respectively.

2.0 LIMITATIONS TO FULLY INSTRUMENTING AIRCRAFT

Fully instrumented aircraft are still a necessary component to new tactical aircraft and precision weapon development. The initial test flights of a new aircraft to verify loads and flutter limits would be one type of test program that would require a fully instrumented aircraft. While this type of instrumentation is necessary, it does come at a high cost in both time and money. Traditional onboard instrumentation systems cost in excess of $1,000,000 and can take years to fully instrument an aircraft between planning, design, manufacturing, and installation.

The other main consideration is what do you do with a highly modified and instrumented aircraft once the testing the instrumentation was installed for is complete. Many of the onboard instrumentation systems are specifically designed for a test program and cannot be used effectively for other test programs. This sole use stems from the way these unique systems are installed and the amount of instrumentation that has been added to the aircraft. Because most of the onboard instrumentation systems are unique, they have their own specific maintenance requirements and they may affect normal aircraft maintenance, since part of the instrumentation may have to be removed in order to perform routine aircraft maintenance. With this added cost of maintaining the instrumentation, the instrumented aircraft may aircraft have the onboard instrumentation removed once the test program for which the instrumentation was installed is completed. This allows the aircraft to be used for other purposes without the high cost of maintaining a unique instrumentation system.

3.0 INSTRUMENT AS NEEDED APPROACH

With the longevity of some of today's aircraft, many platforms are attempting to expand existing capabilities to allow legacy platforms to remain useful in modern conflicts. Because many of the legacy platforms used today have been in service for twenty or more years, aircraft originally instrumented for flying qualities testing have either had their instrumentation removed or are no longer in service. For these programs, a new

approach was needed because legacy platforms do not have the time or the money to fully instrument an entire aircraft from scratch. The solution to this problem was to find a low cost existing instrumentation system that could be easily adapted to many different applications. The Weapon Separation 6 DoF Unit proved to be this low cost existing instrumentation system the could be modified to allow multiple different applications. The 6 DoF unit allowed the possibility of instrumenting an aircraft without having to modify the aircraft and allowed the instrumentation to be installed and removed as easily as loading and downloading a weapon from the aircraft.

4.0 WEAPON SEPARATION 6 DOF UNIT

The current weapon separation instrumentation system in use by the US Navy and other agencies was developed mainly to be used in MK 80 series bombs with no modification to the bomb. These instrumentation systems were nicknamed "6 DoF" units because they transmitted 6 degree of freedom information from the bombs during flight, weapon separation, and after store release. The 6 DoF unit was designed initially to be installed in a MK 80 series bomb by using a shape adapter that made the 6 DoF look like a MXU-735 steal nose plug, Figures 1 and 2. Since its inception a second shape adaptor has already been implemented that allows the 6 DoF to look like a DSU-33 and allows the 6 DoF to be easily installed in the aft fuse well of a MK 80 series bomb when the DSU-33 radome is removed from the adapter.

Figure 1: Weapon Separation 6 DoF Unit

Figure 2: Weapon Separation 6 DoF Unit in 500 lb JDAM

The 6 DoF unit is not only easy to use it is also highly adaptable. The 6 DoF unit is powered by a Li-Ion battery that provided two hours of continuous operation. The internal tri-axial accelerometer and three rate gyros are user configurable through a Microsoft Windows based instrument configuration utility (ICU) program. The ICU program allows the user to also adjust the 0.5-Watt S-band transmitter in 0.5 MHz steps from 2200.5 to 2299.5 MHz and adjust the range and cut off values of the internal filters. The health and status of the 6 DoF unit can be monitored through the ICU program. The ICU also generates output files compatible with the telemetry attribute transfer standard (TMATS) format that can be used to configure ground stations to receive and decode the PCM data stream from the 6 DoF unit.

Because the 6 DoF unit is capable of capturing and transmitting at over 6,000 samples per second there are few weapon separation programs that would require a more capable instrumentation system. The 6 DoF units are used to collect both event data and trend data. Some examples of data collected with the 6 DoF Unit and how the data is used are shown in Figures 3 and 4. Figure 3 shows how a 6 DoF unit can be used to validated that the delay time set on a MK 20 and the actual delay time correspond. Figure 4 depicts the trajectory of a

1000 lb bomb released from an F-18 plotted using a Virtual Store Separation program. With its high capability and low cost, about $20,000, the 6 DoF has allowed may programs to increase the amount and quality of data collected during weapon separation test programs, while at the same time reducing overall program costs.

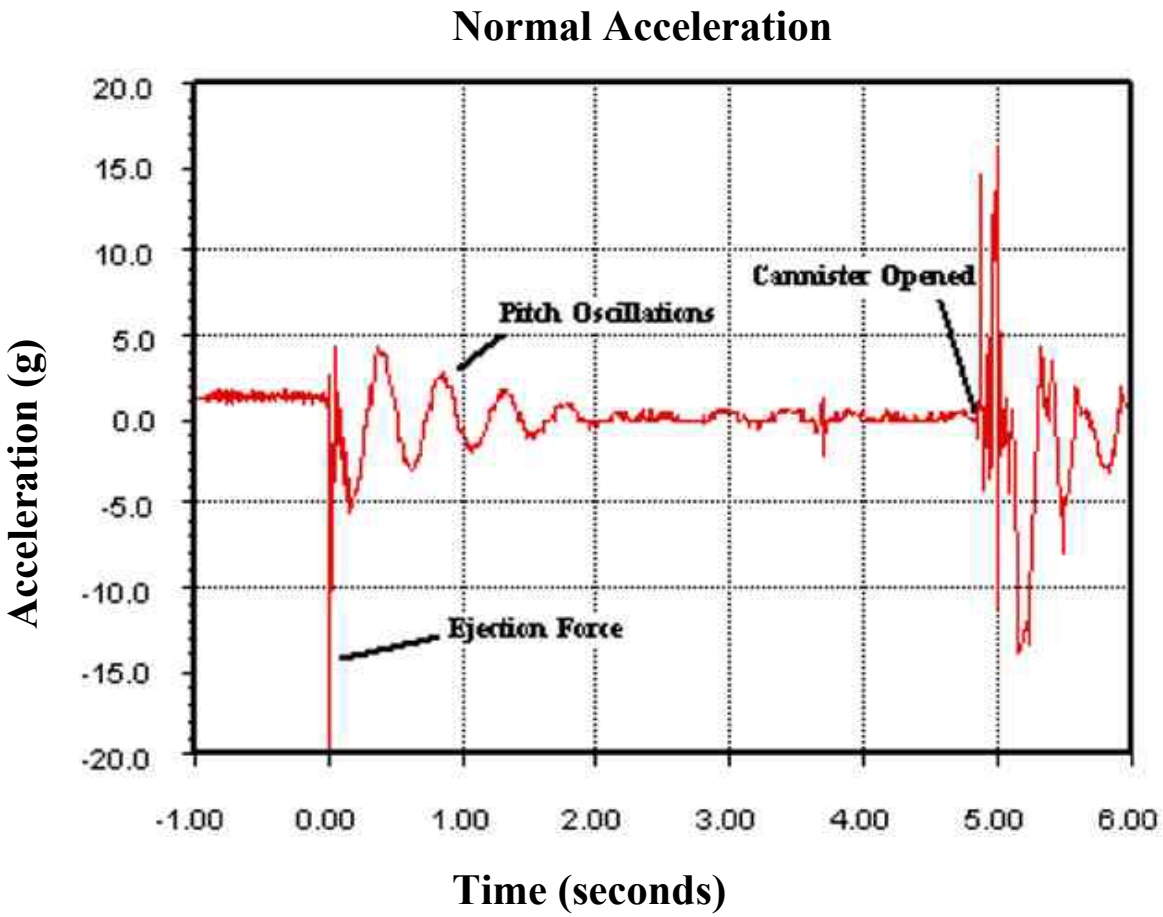

Figure 3: Plot of Normal Acceleration for Mk 20 Rockeye

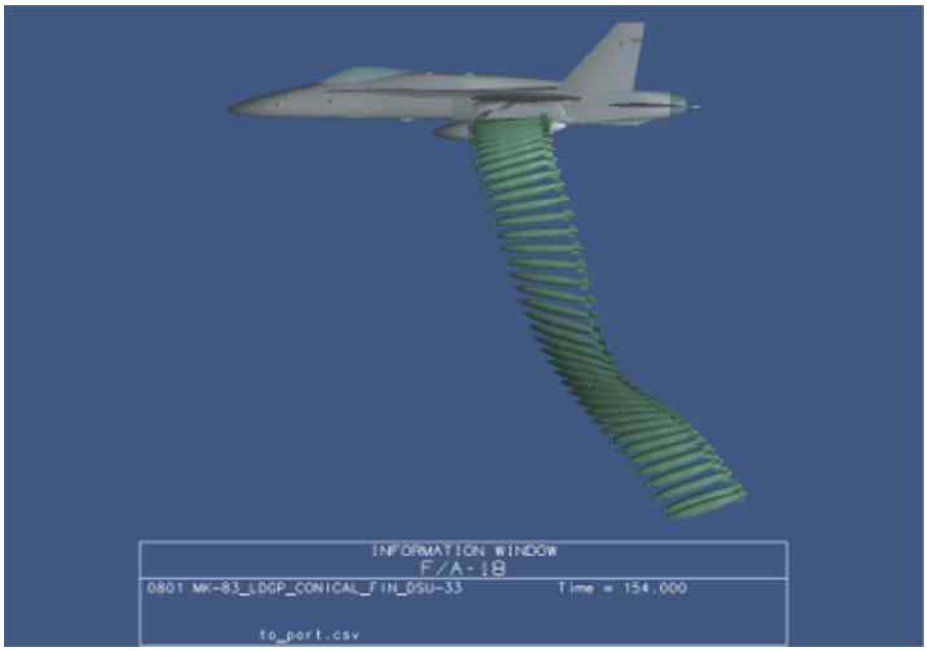

Figure 4: Weapon Separation 6 DoF data displayed in Virtual Store Separation Program

5.0 CAPTIVE CARRIAGE MINIATURE TELEMETRY UNIT

With the success of the 6 DoF unit used for weapon separation test programs the question was raised "Could an instrumentation system similar to the 6 DoF unit be created for captive carriage and flying qualities test programs?" The answer to this question is already in its second generation. The first generation was just a modified 6 DoF unit that had its internal accelerometers and rate gyros removed and plugs installed to allow external instrumentation to be connected, Figure 5. While this system looked patched together it did perform superbly especially because the internal hardware and software was slightly modified to allow the modified 6 DoF to transmit over 40,000 samples per second. Multiple programs including the AV-8Bhave already used these first generation units. The AV-8B used the modified 6 DoF to capture JDAM 1760 Umbilical Mission Store Interface lanyard pull force during store release. Figure 6 shows the AV-8B 1760 umbilical release lanyard hook instrumented with a strain gauge to measure pull force.

Figure 5: Modified 6 DoF Unit

Figure 6: External Strain Gauges mounted on AV-8BUmbilical Lanyard release hook

The first generation units while useful do have limited applicability because the only instrumentation they can receive data from is one external tri-axial accelerometer and four external strain gauges. To overcome these limitations a second generation modified 6 DoF unit was designed, Figures 7 and 8. Because this second generation modified 6 DoF unit no longer was a six degree of freedom telemetry unit, it was renamed the Captive Carriage Miniature Telemetry (CCMT) unit.

Figure 7: Captive Carriage Miniature Telemetry Unit

Figure 8: Captive Carriage Miniature Telemetry Unit installed in MK 80 Series Store

The CCMT is the most flexible miniature telemetry unit yet. The CCMT allows for both internal and external sensors. Currently the CCMT can be configured with one internal tri-axial accelerometer and four external signal-processing units, Figure 9. These external signal-processing units are currently configured to either take one tri-axial accelerometer or three strain gauges. With the available configuration the CCMT will transmit up to fifteen sensor channels and battery voltage. If less than fifteen sensors are required then the

CCMT will transmit additional health parameters in addition to battery voltage. Because the CCMT are battery powered and have a useful life of about two hours, monitoring battery voltage will allow the user to determine if the CCMT is approaching the auto shut down point.

Figure 9: Interface for external instrumentation on Captive Carriage Miniature Telemetry Unit

One of the first platforms to use the CCMT will be the AV-8B to clear additional loadouts for the GBU-12. In this test program two CCMT will be used each with a total of three tri-axial accelerometers and six strain gauges. Figures 10, 11, and 12 show external instrumentation that will be used with this test program. The CCMT will be configured to transmit at 6,250 samples per second, which will provide more than enough data to support the loads and flying qualities flights planned for this test program.

Figure 10: External Tri-Axial Accelerometer

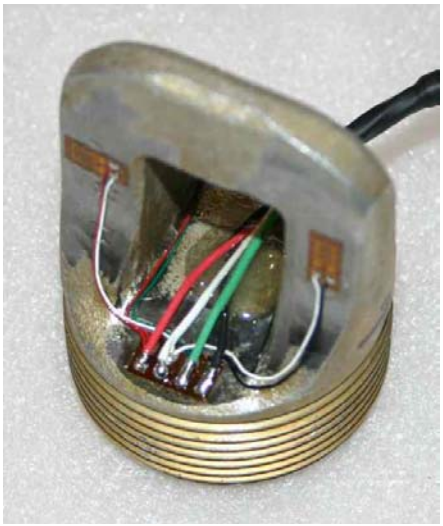

Figure 11: External Strain Gauges mounted on MS3314 Bomb Lug

Figure 12: External Load Cell mounted on BRU-36 Sway Brace Pad

While the CCMT is slightly more expensive then the 6 DoF unit with a cost of $30,000, it is significantly less than the cost of designing and installing a custom instrumentation system to be used for loads or flying qualities programs. The greatest benefit of the CCMT is that once the unit is purchased by a program it can be used by other programs with little or no cost. Future programs will only have to have program specific parts instrumented and may have to purchase new external signal-processing units if a different number of a specific type of sensor is needed.

Because of its flexibility the CCMT will allow many legacy platforms to easily instrument existing aircraft for most loads and flying qualities test programs. This will allow many programs that were thought to be impossible to be accomplished with a low cost of instrumentation.

6.0 FUTURE APPLICATIONS

Future applications can be easily broken down into two categories how we get the data and what we do with the data once it is collected. For the 6 DoF Unit we know exactly which parameters we are monitoring so the only question is what we do with the data. Currently we use the 6 DoF data to determine separations characteristics for the first half second to second after store release, but we do collect 6 DoF data from store release to ground impact. An attempt is underway to use this data to determine ballistic trajectory of a store. Ballistic trajectory tests currently rely heavily on cinetheodolite data for trajectory analysis. If successful, ballistic flight tests could be combined with weapon separation tests at no additional cost.

The CCMT on the other hand does not have a predetermined set of parameters that are being monitored but instead is configured specifically for each program. This ability to adapt provides an almost limitless set of future applications.

The greatest advance for the 6 DoF and the CCMT will be in cost reduction. As costs of these units go down, more and more programs will be able to utilize both the 6 DoF and the CCMT in the future.

7.0 SUMMARY

Six degree of freedom telemetry units and captive carriage miniature telemetry units have proven to be valuable tools for measuring weapon separation characteristics, in-flight loads, and flying qualities characteristics. With the ease of use and versatility of the 6 DoF and CCMT, the use of these data collection packages will only increase in the future. This increase will decrease the average cost of a certification program while increasing the quality of data products from flight and ground test programs. These two packages will provide the stepping-stone for the future of low cost flight test instrumentation.

8.0 REFERENCES

[Getson 2003] E.S. Getson, TELEMETRY SOLUTIONS FOR WEAPON SEPARATION TESTING, Patuxent River, MD: ITEA Conference, 2003