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Integrated Data Acquisition Solutions for Aerospace Platforms with highly restrictive space and weight requirements and harsh environmental conditions

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Abstract

Space and weight are key factors in designing, mounting and installing data acquisition systems on UAV and missile development programs. Additionally, there are an increasing number of measurements and avionic busses that must be captured reliably and transmitted to the ground. This paper discusses the challenges faced by the current generation of solutions and proposes and integrated and expandable solution that addresses these challenges, meeting the requirements while future proofing the platform architecture for additional data acquisition requirements.

Key words: Data Acquisition, Missile Test, UAV Test, Integrated Solutions, Miniature-DAU

The components of Missile Data Acquisition Systems

Missile Data Acquisition Systems (DAS) are generally made up of 5 key component groups:

1. Data Acquisition Unit (DAU)
2. PCM transmitter
3. Multi-band antenna
4. Flight Termination Receiver (FTR)
5. Battery pack

The DAU is usually required to gather data from multiple input sources and encode them into a PCM frame for transmission to the ground during test. The type of data generally gathered includes

- Vibration
- Acceleration
- Temperature
- Pressure
- Strain
- Voltage
- GPS parameters
- Seeker information
- Video

A PCM transmitter is generally chosen to meet the specific needs of the flight test program. A dual band wrap around antennae mated with PCM transmitters and FTRs meeting the required RF and operating frequency power for the flight test environment are commonly chosen for missile test programs. UAV programs will have different requirements for a multiband antenna, but RF power and operating frequency are still key considerations. FTR systems are generally kept separate for safety of flight considerations although FTR systems usually monitor some key parameters from the DAU and the battery system onboard.

Given the restricted space and weight requirements of missile and UAV platforms, typical aircraft power of 28V is not available. Battery packs are generally used for power, but these can need to be large depending on the platform requirements and duration of flight required for the test programs. Different components of the system will also require different voltages and current capabilities, making the battery pack complicated.

Optional components

Missile systems are often used in very short test flights, placing tough requirements on the amount of data that can be gathered during the flight. Typically, a sub set of the data is all that can be transmitted, therefore, where possible, a rugged, crash survivable recording unit is an ideal solution for missile systems to record the all the data that is required to be gathered as part of each missile test firing.

Integrated Solutions

Leveraging new technologies and integrating the major components into reduced SWaP packaging offers a new paradigm in data acquisition solutions for UAV and missile applications. The following section discusses desirable features of DAUs and batteries.

DAU

A miniature, rugged, expandable DAU is the ideal solution. In comparison the traditionally available systems, it would be advantageous to have one that has added new functionalities, increases the number of signals and measurements acquired while reducing the size of the box[1].

Modular DAUs are typically available in different sized chassis lengths depending on the solid chassis chosen or how many modules are stacked in a slice of bread design (one where modules are bolted together to form the chassis). Slice of bread form factors are more flexible for altering size whereas a solid modular chassis is more rigid and makes the addition of new modules to meet new requirements easier to achieve.

Another two features that would make a DAU better suited to UAV and missile programs are the ability to daisy chain chassis and to field remotely mounted modules. Daisy chaining of chassis allows users to add multiple DAUs without the need for external switches to synchronize and gather data from slave DAUs into the master DAU for transmission PCM.

The ability to place modules closer to the sensors removes the need for long cable runs from the sensors to the DAU which lowers weight and improves the accuracy of the readings. Such can be achieved using a point to point link between each user slot and the chassis controller. This technology makes it possible to virtually extend the chassis backplane, allowing a signal conditioning module to be placed into the tightest of spaces. This also offers better heat dissipation due to the relative surface area the module has to draw the heat away from the module.

Battery

Traditional battery solutions have many draw backs when it comes to UAV and missile test applications. They can be bulky, heavy, slow to charge, have a slow power up time when turned on and require DC-DC converters to turn the voltage into the correct supply levels for each part of the telemetry system.

A DAU generally requires 28V supply capable of driving up to 80W of power. Transmitters require +/-4V to +/-6V DC 1-2 ampere supplies – these can generally be driven off the same 28V power as the DAU, but require DC-DC converters built into the transmitter.

FTRs typically share power off its own battery power as well as off the 28V power as the DAU, consuming up to 5.7W. But these systems are generally run off a separate battery pack for safety of flight considerations.

The latest generation of thermal batteries offer substantial improvements over the traditional battery solutions. They are totally inert before their activation, they can store power indefinitely, offer substantial savings in weight and size, and they can be used for short or long operating runs (95 seconds to 1 hour, making them ideal for missile applications). They are extremely robust and maintenance free without self-discharge for up to 10 years. They can be configured to give out multiple current and voltage outputs from a single battery, removing the need for bulky DC-DC converter assemblies on board for the different elements of the system.

But one of the main advantages of thermal batteries over traditional battery solutions is their fast activation. With traditional battery applications, the data acquisition system would have to be activated well before firing to allow the DAU to power up. This results in requirements for longer running batteries and therefore heavier systems. Thermal batteries activate almost instantly, which, along with an ideal near zero DAU boot time, is an advantage for missile test.

Integrated Solution Options

This section will walk through various options of a flight telemetry system for missile test programs, highlighting how improved DAU topologies can offer an improvement in SWaP and performance over more traditional data acquisition systems and how the various components of the full system can be integrated into a very compact package, without compromising on performance or functionality.

Missile and UAV test programs generally go through various stages of test flights, where the data gathering requirements vary depending on the tests being performed. During the initial unguided test shots, data from vibration, accelerometers, temperature, strain, pressure, voltages and calorimeter and radiometer inputs are required. As the test program progress the requirement for these decreases and more guidance and video data is required. The DAU should be able to capture any of the above, in any combination, and be easily configurable to meet all requirements.

System Assumptions

There will be a concentration on a missile application, due to the tighter space and weight constraints this will place on the system. The data acquisition system is to be mounted in the warhead section of the missile.

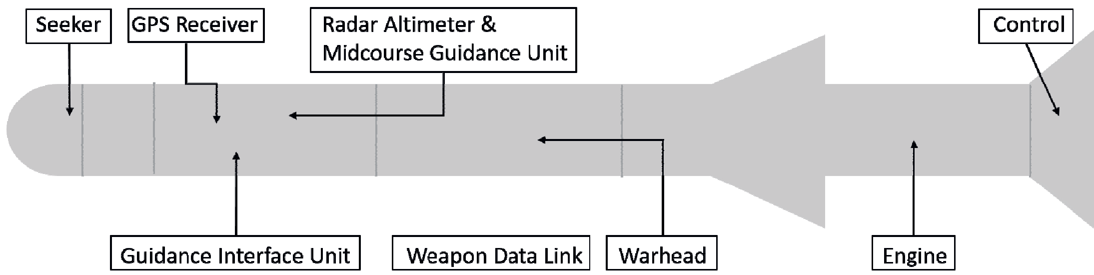

Fig. 1. Cross Section of Typical Guided Missile

GPS, seeker, pressure and video data all come off the front end of the missile. Vibration, acceleration and strain are all measured off the control and stabilizing surfaces. Voltage measurements are taken from the battery pack and off various other missile components throughout the missile. Temperatures are measured mostly at the engine stages of the unit. In this example, the system will be configured to gather the following signal list:

- Vibration – ICP sensors 6 channels sampled at 2,048 Hz
- Acceleration – single ended voltage, 2 x 3 axis accelerometers, 6 channels sampled at 2,048 Hz
- Temperature – 4 channels RTD, 4 channels thermocouple samples at 32 Hz
- Pressure – RS-485 data, 4 channels, Honeywell PPT sensors – sampled at 128 Hz
- Strain – full bridge, half bridge, 8 channels sampled at 256 Hz
- Voltage – 16 channels – monitoring battery voltages etc. sampled at 64Hz
- GPS NMEA data – RS-232 data, 1 channel, 115,200 bps, 1 Hz sampling rate
- Seeker Data – RS-485, 1 channel, 5 Mbps, sampled at 2048 Hz
- Video Data – HD-SDI H.264 compressed, 2 Mbps input, sampled at 2,048 Hz
- PCM encoder – Takes data from all of the above, transmitting out at 6 Mbps

Option 1: 13 user slot Acra KAM-500 chassis

This would have a size envelope of (H x L x W) 98.5 mm x 280 mm x 80 mm and an estimated weight of 2.9 kg[2]. The transmitter would be a separate unit, wired to the PCM encoder for the input data and the output wired to the wrap around antenna. This would have a size envelope of (H x L x W) 33 mm x 83 mm x 57 mm. The transmitter generally requires 5W, drawing 1A. The FTR will be considered as a separate component for safety of flight reasons.

The battery pack would be required to supply up to 4.5A to the DAU, up to 1A to the transmitter and 200mA to the flight termination receiver.

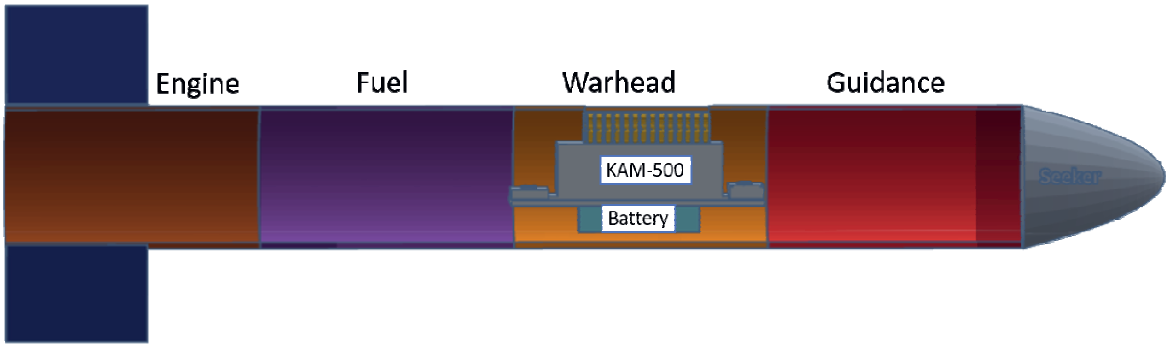

Fig. 2. Generic missile cross section

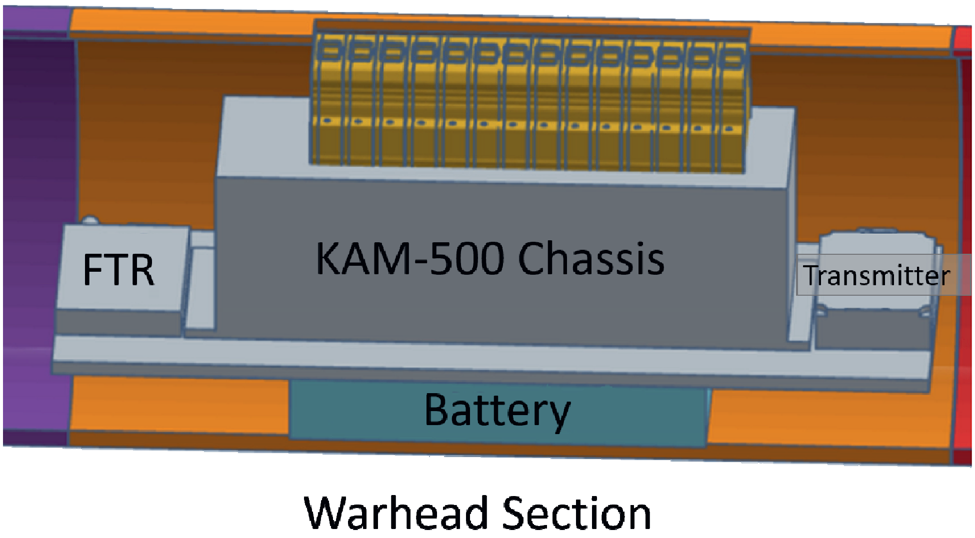

Fig. 3. Component parts of missile data acquisition system

This entire Data Acquisition package, including backshells, would require a warhead space of over 220mm.

Option 2: 9 user slot Axon

Moving to a 9 User slot Axon chassis offers a 38% saving in volume over the KAM-500 solution and a 52% saving in weight, while still offering flexibility and room to expand to add further measurements modules.

The vibration and accelerometer channels could be combined to one module type, the AXN/ADC/401, an 8 channel flexible analog module that can be configured to handle differential ended, single ended, full bridge, half Bridge, ICP, RTD (2/4 wire), RTD (3 wire), AC coupled, or thermocouple measurements on a channel by channel basis. Users would need two of these to capture the 6 vibration and 6 accelerometer channels, leaving 4 spare channels.

The RTD and thermocouple channels could be combined into a single AXN/ADC/401, with 4 channels configured for RTD inputs (individually selectable RTD types per channel) and 4 channels configured for Thermocouple (individually selectable TC types per channel).

The GPS Data, Honeywell pressure sensors and Seeker data are all RS-232 / RS-422 / RS-485 signaling, but at different rates. These could all be captured by the AXN/UBM/401, a 16 channel RS-232 / RS-422 / RS-485 module which handles data at up to 10 Mbps. Using the above example configuration, there would be 10 free RS-232 / RS-422 / RS-485 channels available for future expansion.

The strain measurements could be captured by either the AXN/ADC/401 or the AXN/ADC/404, a 12 channel bridge module. The 16 voltage measurement inputs could be captured by the AXN/ADC/405, a 24 channel differential ended analog to digital converter module. The video requirements could be met with the AXN/VID/401, a video compression module offering both H.264 and H.265 compression.

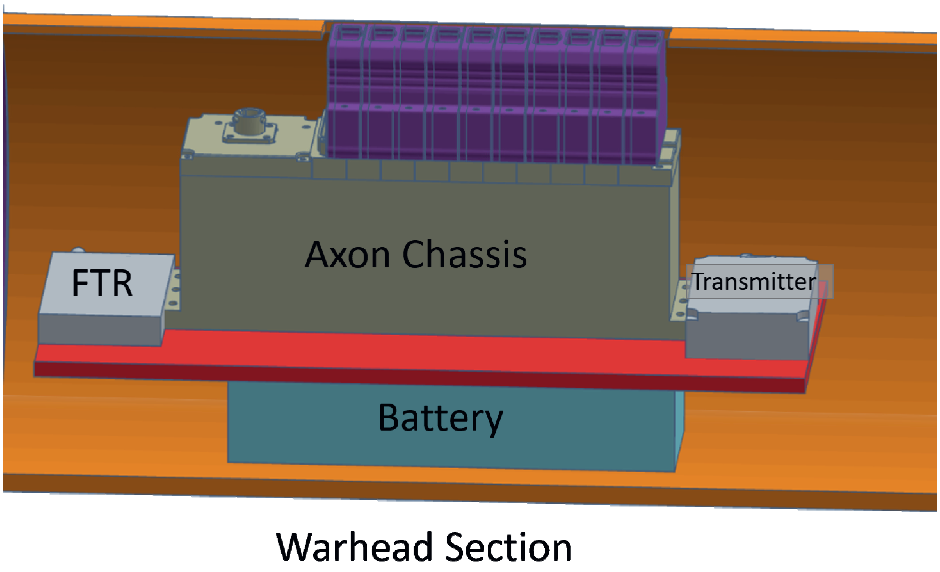

Fig. 4. Axon 9 user slot data acquisition system

This entire data acquisition package, including backshells, would require a warhead space of over 200mm, but with a 52% saving on weight and a 38% smaller DAU.

Option 3: 6 user slot Axon with a transmitter integrated into a module

A standard transmitter is (H x L x W) 33 mm x 83 mm x 57 mm, this includes the casing and power circuitry to turn the 28V aircraft supply into the voltages to run the transmitter. A standard Axon user module is (H x L x W) 12 mm x 65 mm x 52 mm - it is easily conceivable that the transmitter could be modified to take the power off the Axon backplane and fit into a user slot in the Axon chassis. This would save more volume in the overall system and the 100W power available from the Axon PSU is more than capable of driving the transmitter.

Then by taking advantage of the remotely mounted module Axonite chassis, the data acquisition could be moved out of the warhead area, closer to the sensors. Moving to a 6 user slot axon chassis offers a 49% saving in volume over the KAM-500 solution and a 62% saving in weight, while still offering flexibility and room to expand to add further measurements modules.

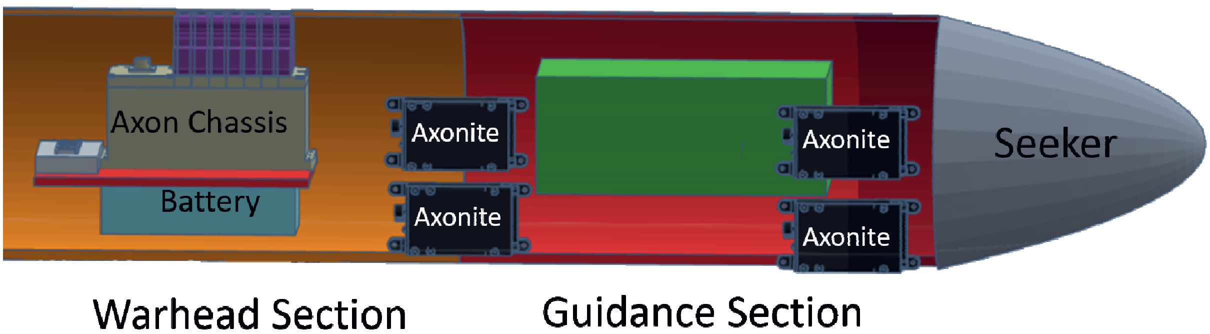

Fig. 5. Axon 6 user slot data acquisition system, transmitter in Axon DAU.

Option 4: 3 user slot Axon with two Axonite extender modules

Taking this a step further, a 3 user slot Axon chassis with two Axonite extender cards, each of which can connect to four Axonites, and the transmitter incorporated into the Axon chassis as before, even further weight and space could be saved in the warhead section.

Moving to a 3 user slot axon chassis offers a 65% saving in volume over the KAM-500 solution and a 71% saving in weight, while still offering flexibility and room to expand to add further measurements modules.

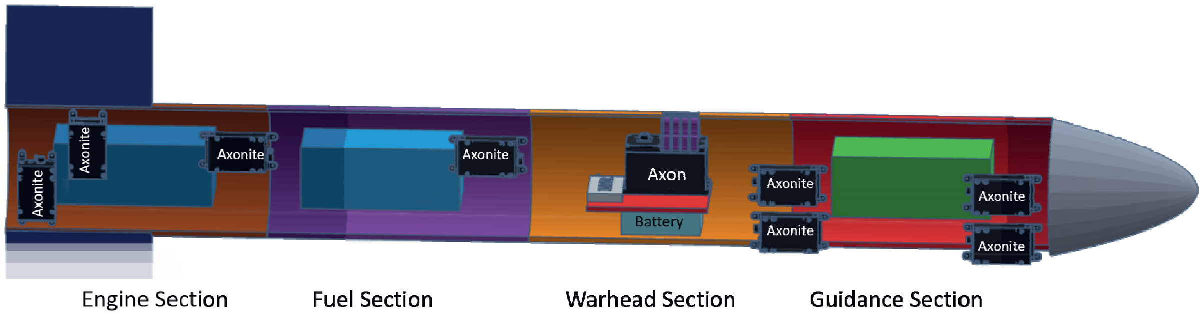

Figure 6: Axon 3 user slot & 8 Axonite data acquisition system, transmitter in Axon

Option 5: Soup can implementation

Taking this to the extremes of what is possible - the extender card (AXN/EXT/404) is a single PCB module requiring 24 pins in the top block to handle all the signal and power for the 4 Axonites. Two of these could be combined into one double PCB card, taking 48 pins in the top block. The encoder card could be placed into the slot where the transmitter card is, making essentially a 2U Axon.

Tailoring the design to fit into the smallest package possible, with the transmitter and battery pack incorporated into a single unit the package size can be greatly reduced. The FTR is still kept separate. The Axon "Soup Can" is a proposal of how, taking advantage of the remotely mounted modules, the Axonites, and incorporating the transmitter and the battery pack, a package can be constructed to fit even the tightest of spaces.

The example below comes in 4 main parts, transmitter, battery pack, front plate and top plate. The top plate holds the Axon controller and the 2 x 4:1 Axonite extender cards. It will contain a specially designed backplane to handle the 2 in one Axonite extender cards.

Using custom designed thermal batteries to provide the required voltages for the flight duration, the need for large DC-DC converters can be removed and a miniature battery pack can be incorporated into the unit. The battery pack is designed to be at the bottom of the unit to offer better centre of gravity.

Figure 7: Axon soup can exploded view

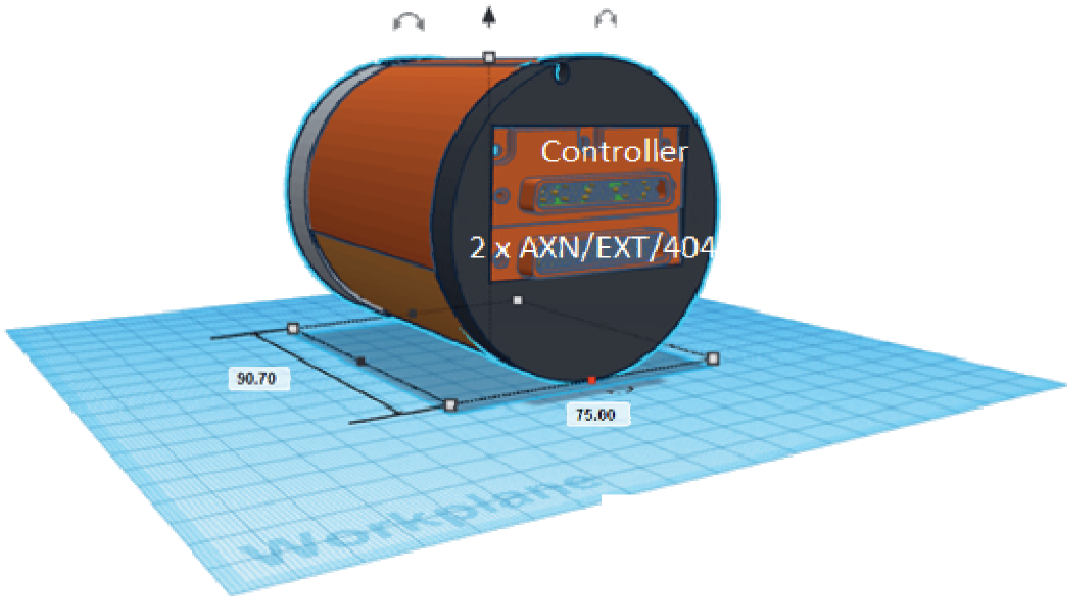

Figure 8: Axon soup can length, 90.7 mm, width, 75 mm

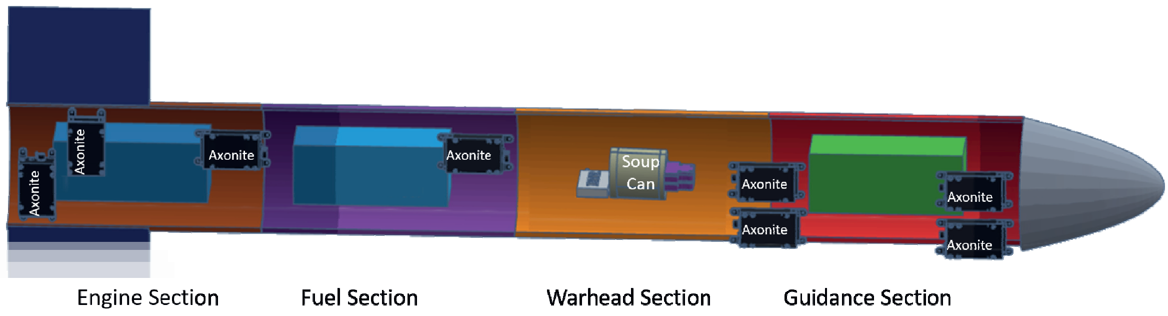

Figure 9: Axon soup can installed

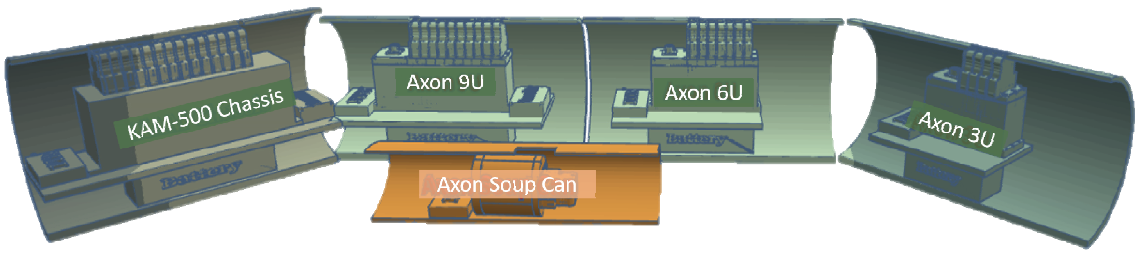

Figure 11: Telemetry pack sizes

Recording

For UAV applications, where space may not be as limited as missile applications and the UAV will be recovered after each test flight, Axon offers the AXM/MEM/401 module. This is an integrated recorder module that records traffic directly off the backplane onto a media card. The card is both removable for data extraction and can be accessed through the Ethernet ports of the controller to download and format the card when the DAU is in accessible. The AXN/MEM/401 can record data in PCAP, iNET-X, IENA, DARv3 and Chapter 10 as required by the program.

However, in missile test, the unit is often not recoverable, so a crash survivable memory module is required. To meet this Curtiss-Wright can offer a Crash Protected Memory Module (CPMM) – used in our Flight Data Recorders (FDR). This is a 64 GB solid state memory array with crash survivability exceeding ED-112A [3](the latest regulations), ultra-compact and light weight (1.3 Kg).

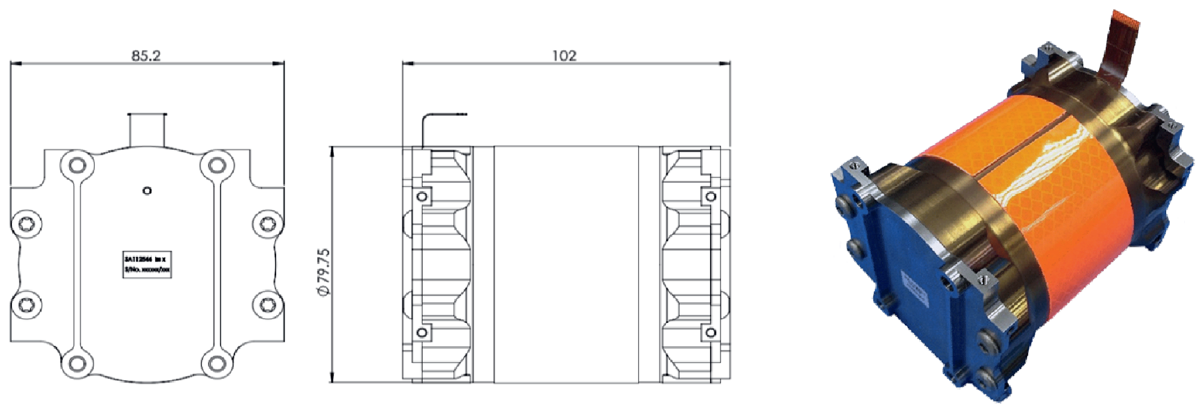

Figure 12: Crash Protected Memory Module

The CPMM adheres to ED-112A defined crash survivability tests, which include

- Fire intensity High: 1100°C for 60 minutes
- Low: 260°C for 10 hours
- Impact shock: 3,400 G for 6.5 ms
- Penetration resistance: 500 lb from 10 ft ¼ inch contact point
- Static crush: 5,000 lb for 5 mins per axis

- Shear/Tensile strength: 6,000 lb for 1 minute each axis
- Fluid immersion: Immersion in aircraft fluids for 24 hr
- Water immersion: 30 day sea water
- Hydrostatic pressure: Equivalent to depth of 20,000 ft

Environmental

The requirements for each individual missile program are unique, so any solution would be tailored to meet these, however theese are typicaly higher than those for standard flight test. Axon is designed to meet the vibration, shock and acceleration levels encountered in such applications.

- Shock**:** 100g for 11 milliseconds in each direction of the three major axes, terminal peak
    - sawtooth, 12 shocks.
    - 250g for 6ms in each of the three major axes, half sine, 12 shocks.
- Vibration**:** Sinusoidal: 10g peak
    - Endurance: Random, 0.83g2/Hz peak, 10min/axis
    - Functional: Random, 0.20g2/Hz peak, 60min/axis
- Acceleration**:** 16.5g for 1 minute in each direction of three mutually perpendicular axes.

Curtiss-Wright have been providing solutions into missile and space applications for many years. Leveraging this experience we know that the below levels are achievable:

- Shock: 120g
- Vibration: 30g
- Acceleration: 50g

Conclusion

This paper shows that significant savings in weight and space can be made when combining the latest technologies in batteries with the next generation of DAUs. Solutions can tailored to meet the smallest of missile and UAV vessels, without compromising on performance or environmental requirements.

References

[1] D. Buckley, The Challenges of Data Acquisition in Harsh Remote Places, European Telemetry and Test Conference, Nürnberg, Germany (2016)
DOI 10.5162/etc2016/4.1

[2] Curtiss-Wright, Online, Available from: https://www.curtisswrightds.com/products/flight-test/data-acquisition/acrakam500/kamchs13u.html (2015)

[3] EUROCAE, ED-112A – MOPS for Crash Protected Airborne Recorder Systems, Online, (2013), Available from: https://eshop.eurocae.net/eurocae-documents-and-reports/ed-112a/