Advanced Subminiature Telemetry (ASMT) Wireless Instrumentation

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Outline

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- Project Execution
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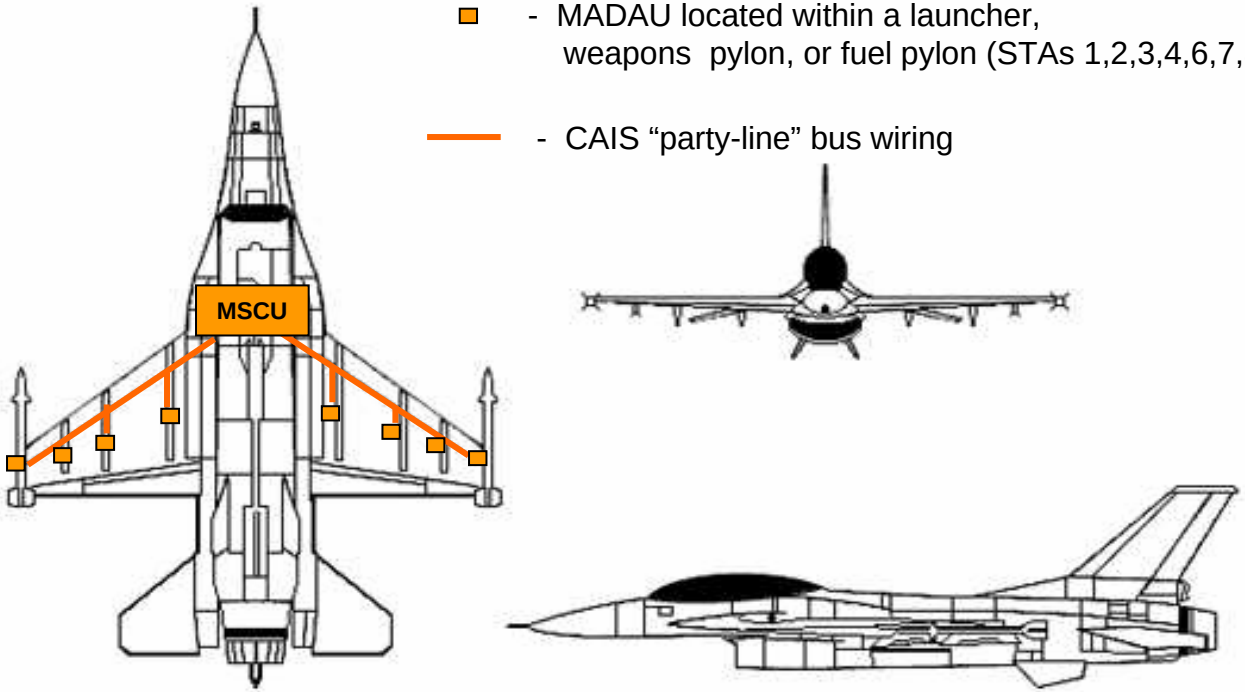
Project Motivation

Existing Instrumented Flutter Aircraft (typical)



- MSCU (Mini System Controller Unit) located on aircraft operates as a bus controller unit for MADAUs located in launchers and pylons.
- CAIS “party-line” bus wiring interconnects MCAIS system.
- MADAUs provide signal conditioning for accelerometers located in launchers and pylons.

Project Motivation

Existing Instrumented Flutter Launcher (LAU-129)

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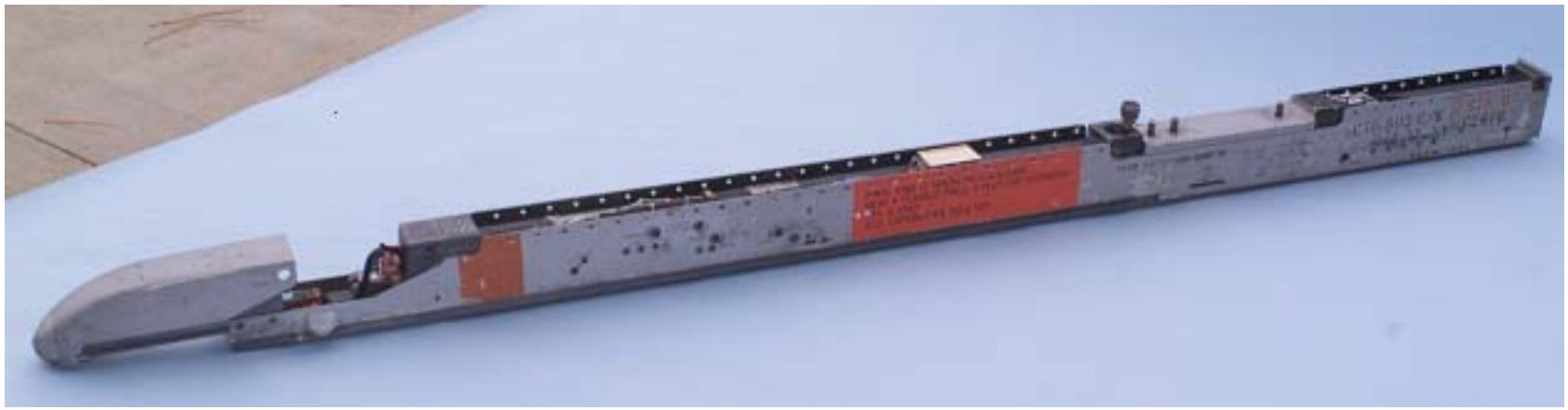
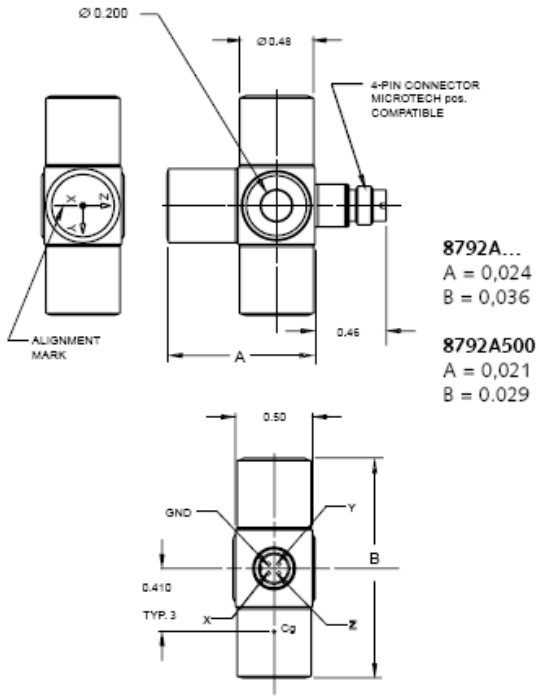


Each LAU-129 flutter launcher instrumented with triaxial accelerometers (2 each) to measure vibration along following axes:

- Forward Normal (primary), Forward Normal (backup), Forward Lateral.
- Aft Normal (primary), Aft Normal (backup), Aft Lateral.

Project Motivation

Accelerometers Mounted in Flutter Launchers (LAU-129)



- 2 each Kistler piezo-electric triaxial accelerometers (P/N 8792M04) mounted in each LAU-129 launcher (Fwd & Aft).

Technical Requirement

Data Collection (1 of 2)

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- Frequency range of interest = 0-50 Hz.
- Desired sample rate of 200 samples/second/channel (threshold), 400 samples/second/channel (objective).
- Resolution 12 bit minimum.
- Provide Discrete control I/O.
- Provide simultaneous data collection wireless and wired.

Technical Requirement

Data Collection (2 of 2)

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- Auto/Manual Calibration or Zeroing.
- Control/Command system via RS232 interface.
- IRIG-B time input for sample time stamping.
- Test points with each stage of signal conditioning.
- 10 υsec timing accuracy.
- Programmable gain and offset.

Technical Requirement

Network Architecture (1 of 2)

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- Must have network configuration time less than 1 sec.
- Must have minimum data throughput of 250 Kb/s.
- Maximum acceptable transfer delay of 25 ms.
- Maximum acceptable delay variation of 1 ms.
- Selectable Authentication and Encryption.
- Appropriate QoS services to guarantee timing, constant or average bit rate and BER.

Technical Requirement

Network Architecture (2 of 2)

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- Network Addressable Modules.
- Non-Interfering.
- Sufficient bandwidth capacity.
- Non-proprietary and well documented interface.
- A handheld device, e.g Bluetooth-enabled iPAQ, must be able to join network and have command and control access to sensor nodes without the need to reconfigure the entire network.
- Provide full operation up to 20 ft LOS.

Project Execution

In Dec 05, the *ASMT Initial Test Capability Project was initiated.*

- Objective:

  Develop and flight test an initial ASMT system optimized to measure low frequency vibration; validate performance against legacy system.

- Goal:

  Deliver wireless, network based instrumentation capability to 46TW which supports F-16 flutter flight testing.

Project Execution

Dual Path Approach

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External Installation:

- Develop wireless transducer instrumentation based on a standard.
- Provide for quick reaction flutter flight test capability
  - Instrument LAU-129 launcher with 2 each remote sensor modules (installed external to launcher using electro-cleavable adhesive).
  - Each sensor contains a MEMS triaxial accelerometer.
  - Provide for SSR data collection.
- Provide for wireless control bi-directional communication
  - Provide for wireless control of a pod (Cockpit to Station).

Internal Installation:

- Develop wireless transducer instrumentation based on a standard.
- Provide for quick reaction flutter flight test capability
  - Instrument LAU-129 launcher with 2 each remote sensor modules (installed internal to launcher).
  - Each sensor interfaces with Kistler triaxial accelerometer.
  - Provide for SSR data collection.
- Provide for wireless control bi-directional communication
  - Provide for wireless control of a pod (Cockpit to Station).

Teletronics Technology Corporation (TTC) will design, develop, and deliver hardware to support this dual path approach.

ASMT System Design

ASMT Initial Capability Architecture

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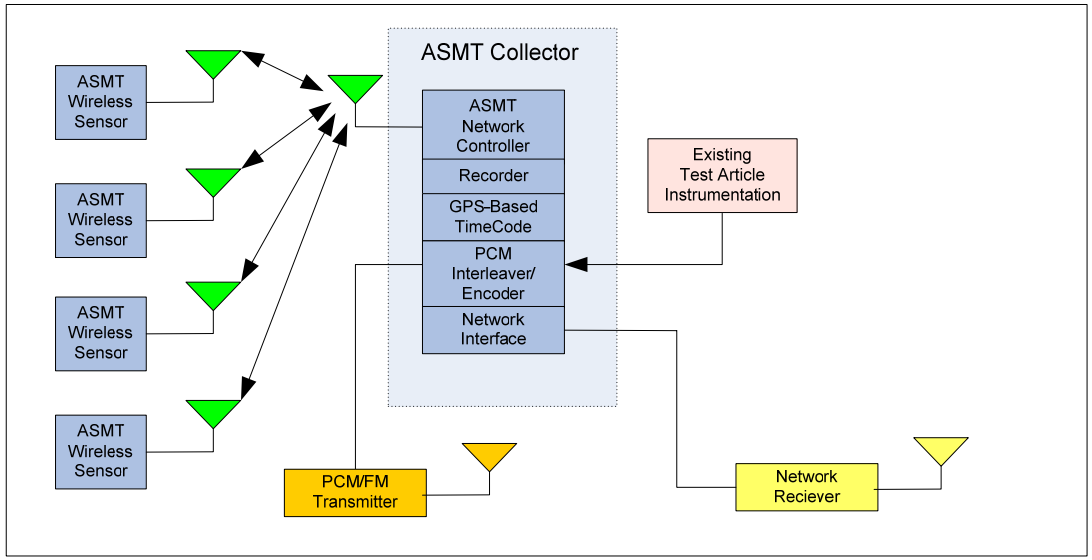

- Fixed Star Topology:
  - Low data latency requirement.
  - Routing decisions are delegated to upper level access points.
  - Huge power saving.

ASMT System Design

ASMT Initial Test Capability Architecture

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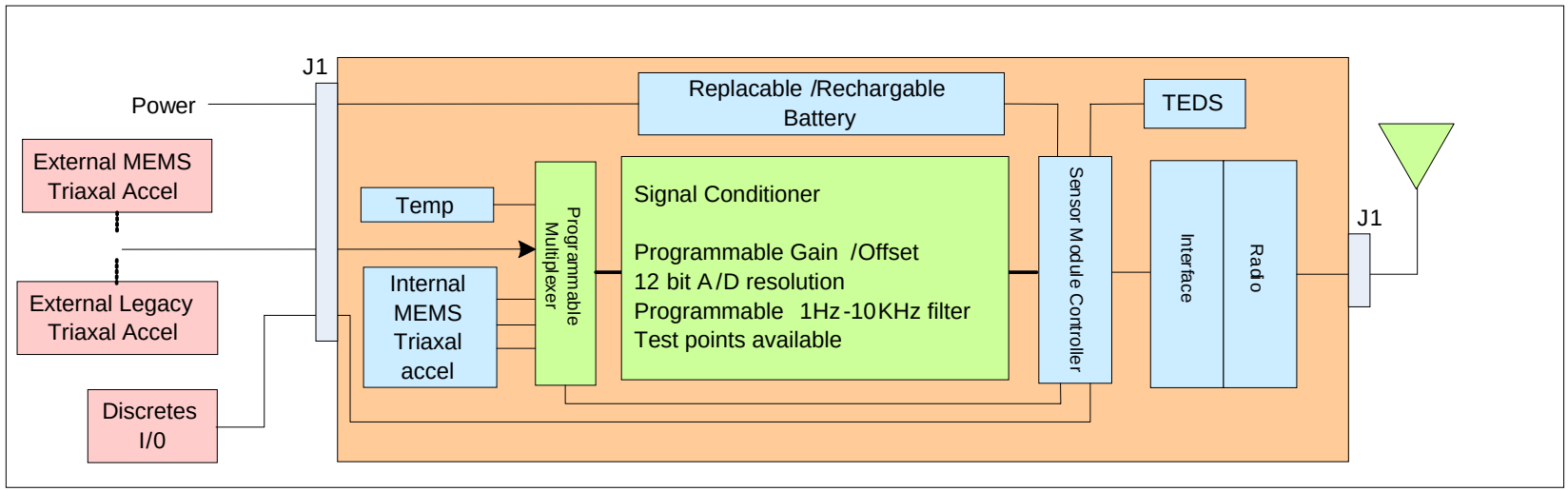
ASMT Remote Sensor (notional)



- Can actively change its sampling mode, the transducer it samples, and its signal conditioning configuration.
- Can wirelessly transmit sampled data to its assigned ASMT data collector.
- Can be remotely calibrated.
- Contains:
  - On-Board system temperature sensor and power management circuit.
  - The interface to accept discrete and analog inputs.

ASMT System Design

ASMT Initial Capability Architecture

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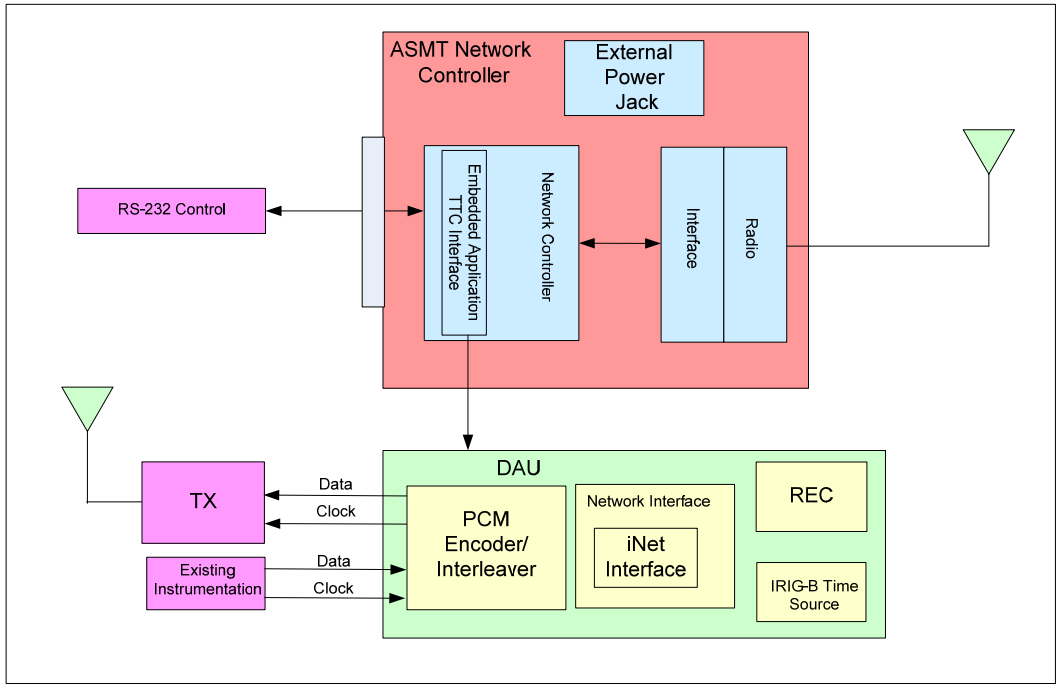
ASMT Controller



- Accurately merges ASMT Sensor data with existing instrumentation data.
- Provides IRIG time synchronization to the wireless network modules.
- Provides an IRIG time stamp of merged data stream.
- Provides IRIG 106 PCM telemetry capability.
- Provides data recoding capability. (capacity min 1 GB)

ASMT System Design

Communications

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- ASMT Network Radio Interface: IEEE-1451.5/Bluetooth.
- ASMT Basic Network Protocol: IEEE-1451.0.
- ASMT Controller Network Interface: IEEE-1451.1 COM.
- ASMT Remote Sensor TEDS: IEEE-1451.5.

ASMT System Design

Communications

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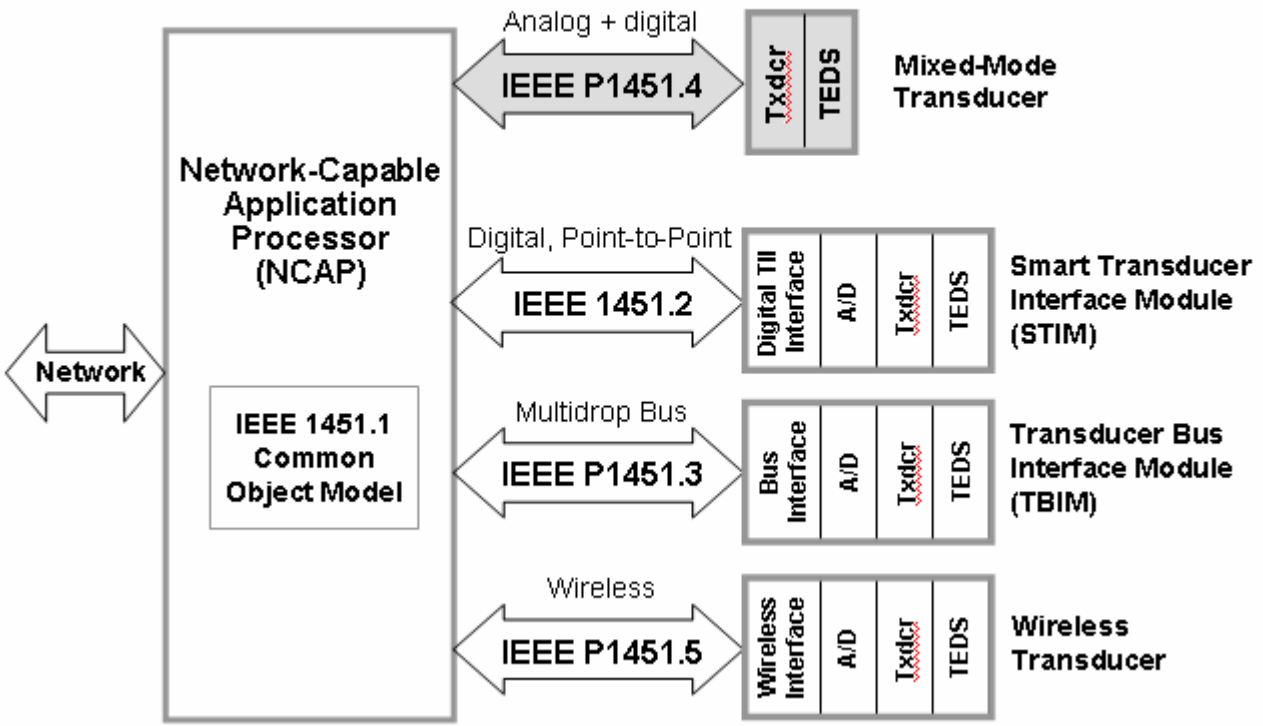
IEEE 1451 Family of Smart Transducer Interface Standards



ASMT System Design

Communications

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TEDS Examples

	Example 1: Accel Template	
	IEPE Accelerometer	
Basic TEDS	Manufacturer ID	43
	Model ID	7115
	Version Letter	B
	Serial Number	00731F
Standard Transducer TEDS	Sensitivity @ ref.	1.094E+03 mV/g
	Reference freq.	100.0 Hz
	Reference temp.	23 °C
	Measurement	± 50 g
	Electrical output	± 5 V
	Quality factor	300 E-3
	Temp. coefficient	-0.48 %/°C
	Direction (x,y,z)	x
User/Cal Info	Measurement ID	23
	Calibration date	April 15, 2002
	Cal. Initials	DCB
Calibration Table or Curve		

	Example 2: Bridge Output Template	
	Bridge (mV/V) Load Cell	
Basic TEDS	Manufacturer ID	21
	Model ID	19
	Version Letter	D
	Serial Number	0008451
Standard Transducer TEDS	Measurement	± 100 lbf
	Electrical output	± 3.01 mV/V
	Bridge impedance	350 Ω
	Excitation, nominal	10 VDC
	Excitation, min.	7 VDC
	Excitation, max.	18 VDC
	Response time	5 ms
User/Cal Info	Measurement ID	2
	Calibration date	June 3, 2001
	Cal. Initials	HTA
Calibration Table or Curve	Calibration Look-Up Table (or multi-segment polynomial curve)	kg / Out (mV/V): 0.00 / 0.001; 10.00 / 0.1996; 20.00 / 0.4002; ... / ...; 100.00 / 2.001

ASMT System Design

Power

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- External Sensor unit with integrated accelerometer will require battery power.
- Internal Sensor unit will be powered from +28 Volt aircraft supply.
- Sensor module will provide required excitation.
- Target is 4 hours of continuous operation.
- Power down mode for period between preflight calibration and flight data collection.
- Current estimate of sensor power requirements is 500–1000 mW-h.

ASMT Implementation

TTC ASMT Initial Test Capability System

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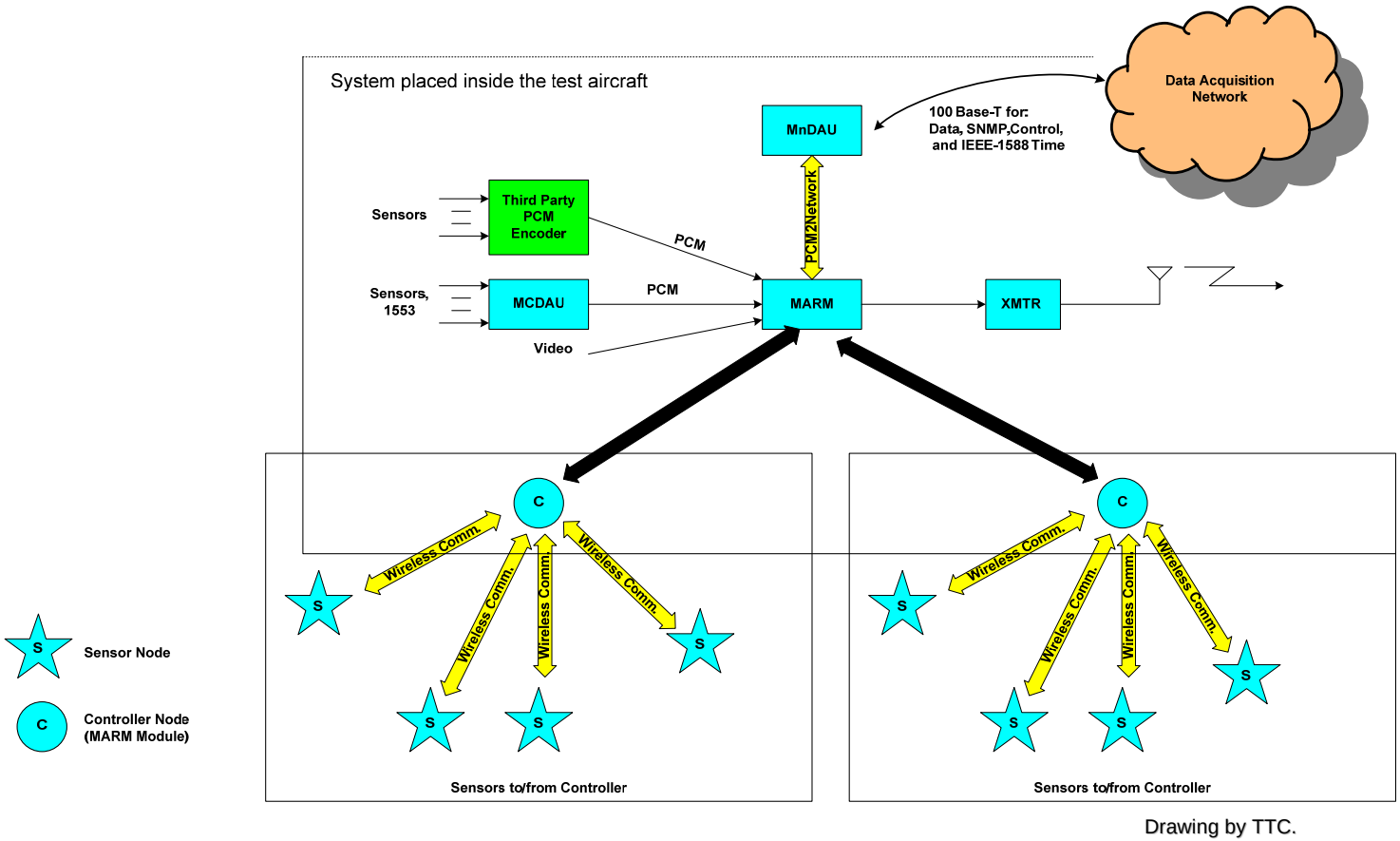
System Diagram



Drawing by TTC.

ASMT Implementation

TTC ASMT Initial Test Capability System

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- Controller module will reside within the TTC MARM Unit.
- MARM will allow up to two controller modules.
- Each controller will communicate with up to four sensor modules.
- Distance from controller antenna to sensor module antenna is 30 feet maximum LOS.
- Acquired data by controller module will be merged into the the MARM telemetry PCM output.

ASMT Implementation

TTC ASMT Initial Test Capability System

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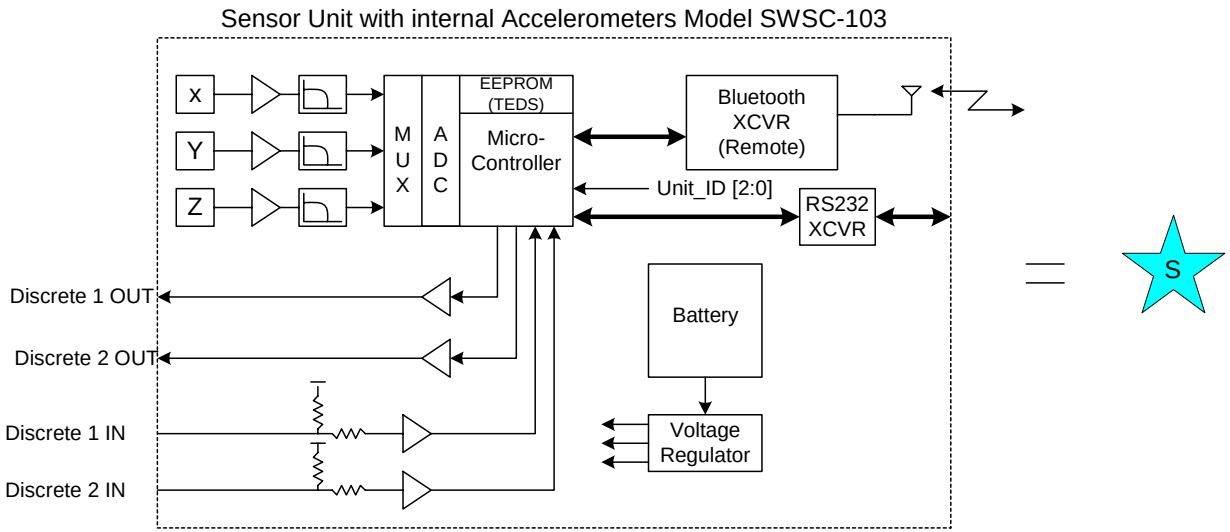
Low Frequency Sensor Module with Internal Sensor



Drawing by TTC.

- Built-in MEMS triaxial accelerometer.
- Built-in Battery.
- Based on Bluetooth 1.2 (using internal antenna).
- Temperature and discrete channels.

ASMT Implementation

TTC ASMT Initial Test Capability System

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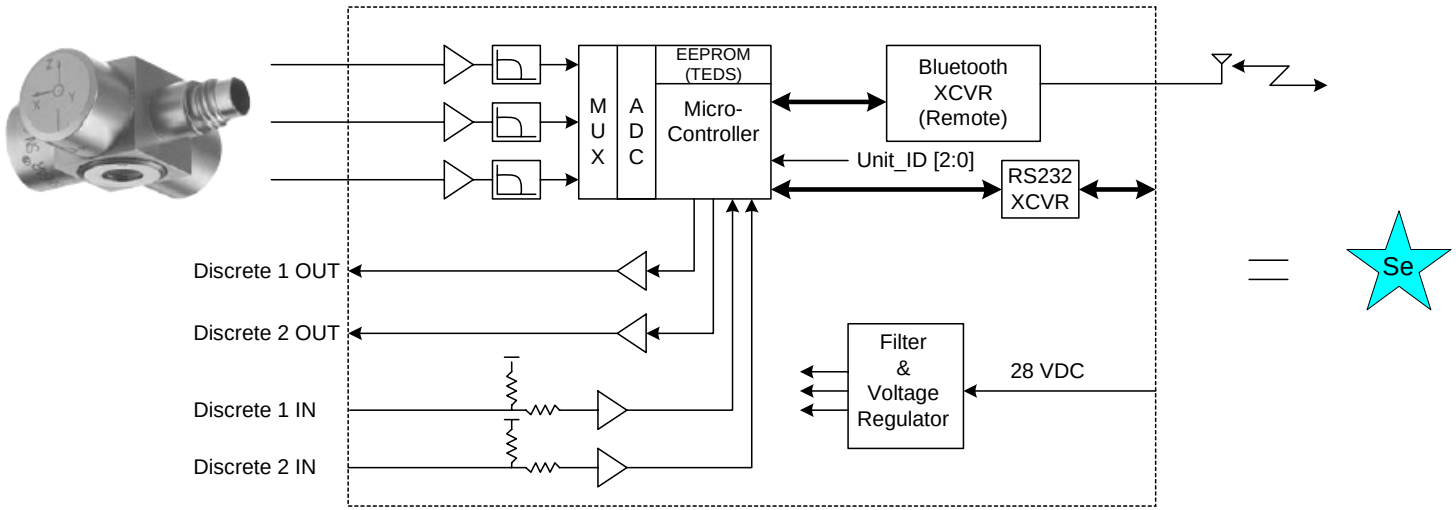
Low Frequency Sensor Module with External Sensor

Sensor Unit with Kistler piezo triaxial accelerometers (P/N 8792M04) Model SWSC-103E



Drawing by TTC.

- External triaxial accelerometer (Kistler P/N 8792M04).
- Requires 28VDC supply for:
  - Module power.
  - Sensor excitation.
- Based on Bluetooth 1.2 (using external antenna).
- Temperature and discrete channels.

ASMT Implementation

TTC ASMT Initial Test Capability System

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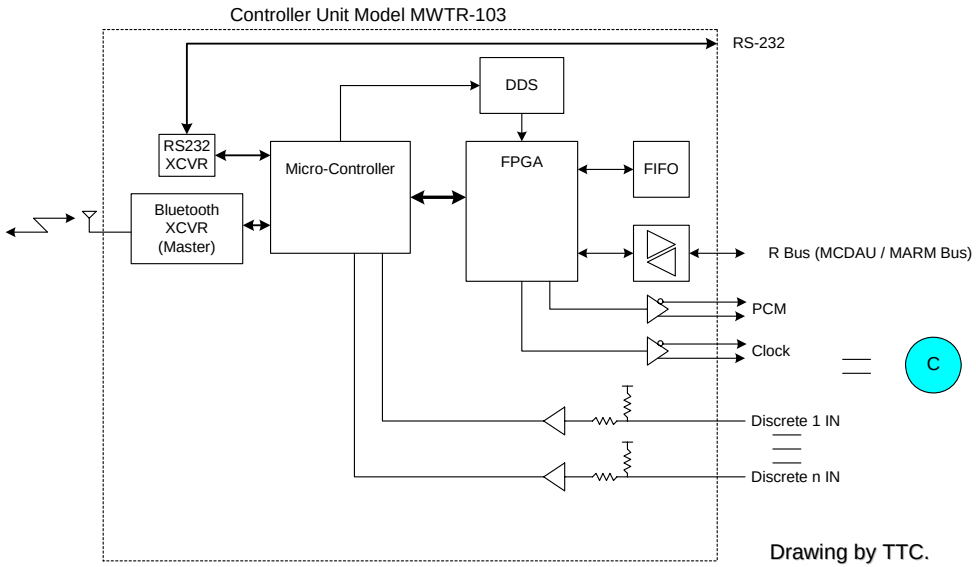
Controller Module



- Interface to the host McDAU or MARM system.
- Based on Bluetooth 1.2 (using external antenna).
- Communicates with sensor modules for:
  - Setup and discovery.
  - Calibration.
  - Data acquisition (sensor data collection).

Project Status

Power

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- Possible Battery Technologies for use in sensor module:
  - LiMnO2 – Primary (Non-rechargeable).
    - Highest power density available.
    - Meets environmental requirements now (-40C to + 72C).
    - Requires physical access to sensor module for battery replacement.
  - Li-Ion – Secondary (Rechargeable).
    - High power density but lower than LiMnO2.
    - Does not currently meet environmental requirements
      - Most current Li-Ion batteries are specified for –20C to +60C operation.
    - Permanently installed batteries would simplify packaging requirements.
    - Requires electrical connection to sensor module for recharging.

Project Status

IEEE-1451

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- 1451.0 and 1451.5 are not yet released.
- There are currently no 1451.5 compliant devices in the market place.
  - The first application of 1451.5 in the commercial market is expected to utilize 802.11.
- 1451.5 provides great detail of 802.11x, but is very vague (very little detail) of the Bluetooth application.
- 1451.1 On-the-Wire (Aiglent/Boeing) being investigated.

A complete implementation of IEEE-1451 is not possible at this point. The ASMT Initial Test Capability project will implement as much of the functionality as possible with currently available hardware and software.

Antenna Considerations

- Antenna will use class 2 (2.5 mW).
- The self powered remote sensor unit will have an internal antenna. This may be part of the Bluetooth transceiver unit , may be a PC board micro strip antenna or a PC board mounted antenna.
- Module packaging will facilitate antenna function.
- Details regarding antenna type selection and installation locations for external accelerometer sensor module and sensor control unit are still TBD.

Antenna size and characteristic are being evaluated.

Bandwidth Limitations

- Bluetooth V1.2 devices, although clocked at 1 MHz, in reality can only offer a theoretical maximum throughput of 721 kbps.
- Based on available whitepapers, actual measured payload throughput only ranges from 350 to 550 kbps while interference can significantly reduce these numbers.
- Meeting the target requirement of 4 tri-axial, low frequency sensor module operating at 400 sample/sec/axis requires:
  - 400 samples X 3 axes X 4 sensor X 16 bits /sample = 76.8k bits /sec = 9.6k bytes/sec.
- The above implies that Bluetooth 1.2 would support the target data throughput with ample time available for re-transmissions of data packets as required to provide a robust wireless link.

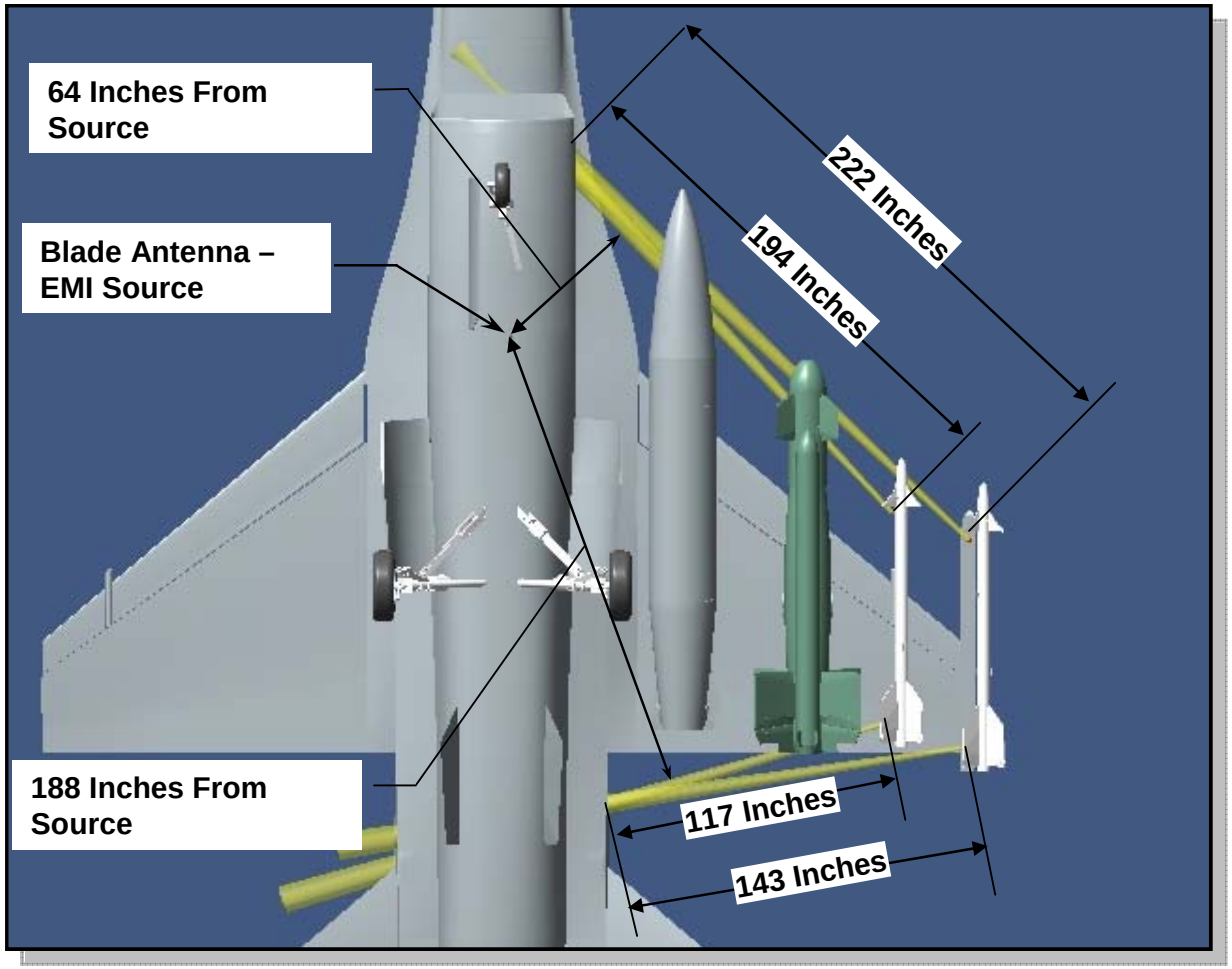
The actual network performance will have to be evaluated.

Spectrum Limitations

- Aircraft RF frequencies may interfere with the Bluetooth frequency band of operation.
- Bluetooth requires line of sight between antennas.
- Commercially available Bluetooth devices include:
  - No transmission power level control.
  - Class 2 (2.5 mW for 10 m) power level.
  - Integrated radio and processor.
  - No access to the Bluetooth stack.
  - Version 1.2 to allow for external antenna use.

Project Status

Bluetooth



View showing the relative distances of the lower TM blade antenna EMI source to the transceiver antenna cones. View also showing relative distances from each transceiver to a possible antenna location on the fuselage.

Project Status

Bluetooth

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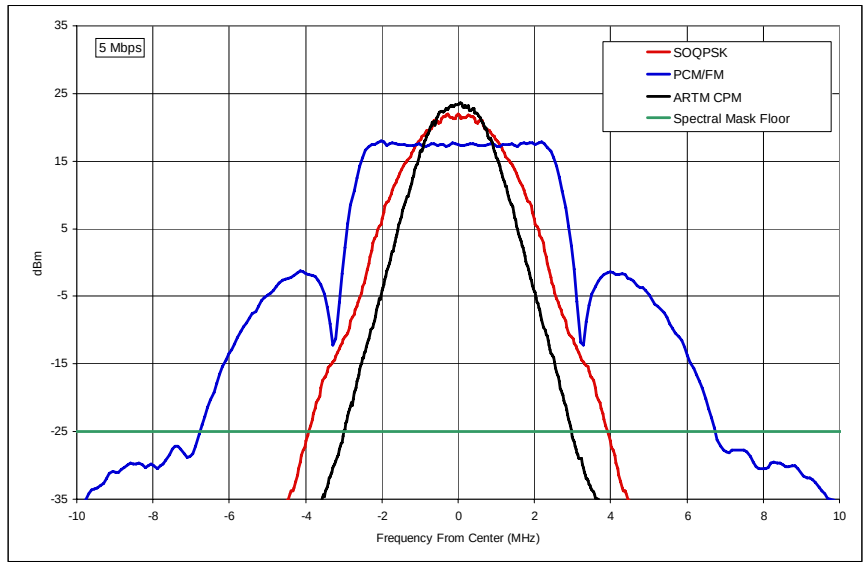
- Bluetooth operates at frequency of 2.4GHz to 2.48GHz.
- To achieve error rate of $1x10^{-3}$ (0.1%) the receiver must have sensitivity of –70 dBm or better.
- If an aircraft is using a 20 W (43 dBm) telemetry transmitter at the S band range, one has to evaluate the frequency band skirt to guarantee Bluetooth frequency operation.



All emitting RF frequencies and their power level must be fully evaluated to ensure proper operation.

Summary

The ASMT Initial Test Capability Project hopes to:

- Demonstrate reliable wireless data collection.
- Provide 46TW a quick reaction/non-intrusive instrumentation capability.
- Implement network-based data acquisition.

Goal : Provide a proven non-intrusive, network based instrumentation system which has potential to support a variety of tri-service test and training needs.