ADVANCED SUBMINIATURE TELEMETRY: A NEXT GENERATION INSTRUMENTATION SYSTEM

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ABSTRACT

In performing its mission, the Air Force SEEK EAGLE Office (AFSEO) conducts a wide variety of tests with heavy emphasis on open-air flight tests. As budget pressures drive a reduction in the number of test sorties, maximizing the amount of quality data from each flight test is of paramount importance. This paper describes an AFSEO effort to develop a low cost, intelligent, subminiature telemetry and sensor system based on modern commercial wireless technologies. The instrumentation system is completely self-contained and can be externally mounted, thus eliminating the requirement for extensive aircraft modifications and minimizing the need for specially instrumented test aircraft. The system will make maximum use of Commercial Off The Shelf (COTS) components to reduce cost and insure availability. MicroElectroMechanical Systems (MEMS) technology will be incorporated as the technology matures.

KEY WORDS

Telemetry, Wireless Sensors, Data Acquisition, Airborne Testing, Spread Spectrum

INTRODUCTION

The Air Force SEEK EAGLE Office (AFSEO) was chartered by the Secretary of the Air Force in December 1987. The mission of the AFSEO is to provide the Air Force increased warfighting capability through central management of the aircraft-store certification process. Certification is the formal process by which aircraft-store loadout configurations are tested, analyzed, and authorized for use. Typical stores requiring certification include conventional and nuclear munitions, suspension equipment, tanks, and pods carried externally or inside internal bays on military aircraft. The USAF aircraft-store certification program encompasses aircraft-store loading, carriage, and release. Within these categories, eight primary technical areas are considered by AFSEO in evaluating safety of flight and functional performance. These technical areas include fit and function, electromagnetic compatibility/interference, flutter, loads, flying qualities, store separation, ballistics, and safe escape. Each of these disciplines requires sensor measurements and telemetry to evaluate safety of flight and functional capability. Typical measurement requirements include flutter (requires distributed accelerometers on aircraft wings, tails, and fuselage), loads (requires distributed strain gauges on aircraft, stores, and suspension equipment), store separation trajectories (requires gyros, accelerometers, and pressure transducers on stores), and acoustics (requires distributed pressure sensors within aircraft internal bays).

The AFSEO uses a variety of test and analysis techniques in performing its mission. These include various modeling and simulation techniques, ground tests and flight tests. For a number of years, a mainstay in the certification process has been specially instrumented aircraft and stores. This approach is very expensive and inefficient since major aircraft modifications are required and all certification-related testing must be scheduled around availability of a limited number of instrumented test aircraft.

There are a number of external pressures that impact the way AFSEO will conduct certification-related testing in the future.

Reduced Budgets and Manpower – With the rising cost of flight testing and instrumentation, and the continuing reductions in DoD budgets and manpower, new methods and approaches must be found.

Acquisition Reform – This process resulted in major reductions in the number of aircraft and stores available for testing. Because of the reduced number of flight tests, more will have to be accomplished during each test to adequately evaluate performance in the same operational environment. This will significantly increase the number of parameters that need to be measured on each flight.

Increased Complexity of Aircraft and Stores – With today's complex aircraft and stores, there is no reasonable way to test every aircraft-store configuration throughout the operational envelope. There will have to be increased reliance on digital modeling and simulation in order to focus the few open-air tests that will be possible.

Validation of Digital Modeling and Simulation Tools – With increased reliance on digital modeling and simulation, more and better test data is needed to validate these codes and increase confidence in the simulation results.

Frequency Spectrum Availability – The ongoing auctioning off of the frequency spectrum will continue to decrease the available spectrum for test and evaluation. There is a continuing need for more efficient use of the available spectrum.

The Air Force SEEK EAGLE Office is aggressively investigating ways of maintaining and improving the efficiency of the aircraft-store certification process in this changing environment. To ensure the future viability of the aircraft-stores certification process, insertion of evolving technologies is essential. This paper will describe how the AFSEO is investigating the development of a low-cost, intelligent, miniature telemetry and sensor system through coordinated Small Business Innovative Research (SBIR) projects.

PROJECT GOALS

The primary goal for the Advanced Subminiature Telemetry (ASMT) project is to maximize the amount and variety of data that can be collected on each flight test mission, while significantly reducing the test and instrumentation cost. The principal focus of the ASMT project is development of a new generation integrated instrumentation system consisting of sensors, data acquisition components, and telemetry devices for providing cost-effective flight test data. A major objective is development of a portable system that could be used on inventory aircraft and stores without requiring permanent modifications, thus reducing the need for specially instrumented aircraft and stores. The instrumentation system components can be externally mounted and will be small enough to minimize interference with flow fields around the aircraft, suspension system, and store. The ASMT concept is illustrated in Figure 1. The heart of the system is an intelligent software controlled transceiver. The transceiver will be able to

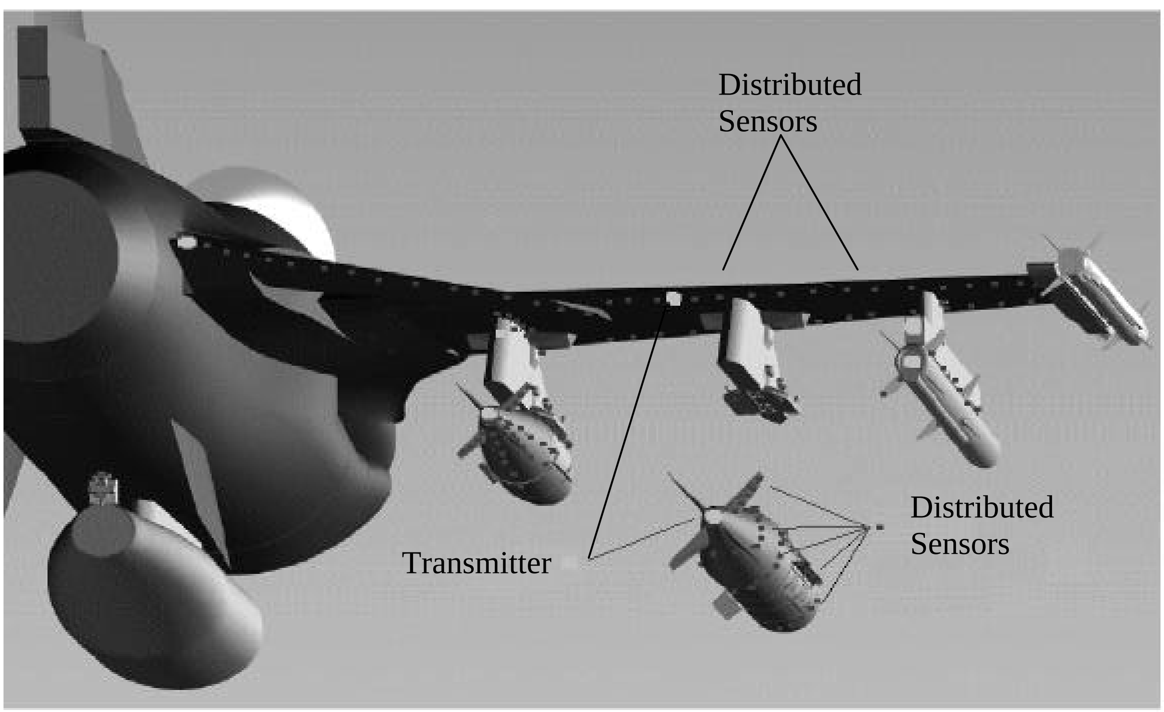

Figure 1. ASMT Concept

accept inputs from a variety of distributed sensor types including both analog and digital devices. Specific sensor types will include rate sensors, accelerometers, inertial measurement units, pressure transducers, strain gauges, and temperature sensors. The transceiver and sensors will be attached to the aircraft or weapon using an electro-cleavable adhesive providing ease of attachment and removal. The residual epoxy can be easily removed from the aircraft and components without the use of environmentally hazardous chemicals. Therefore, any inventory aircraft or weapon system could be used to support AFSEO test requirements and returned to operational status immediately after testing is completed. The transceiver and sensors will make maximum use of COTS components to reduce cost and ensure availability of critical system components. MEMS technology will be incorporated as the technology matures. Desired characteristics of the Advanced Subminiature Telemetry System (ASMT) are summarized in Table 1.

Characteristic	Goal
System Approach	Integrated telemetry unit with flexible sensor interface Software controlled using laptop or desktop PC
Installation	"Apply and remove" adhesives-No permanent modifications to aircraft or store
Cost	Less than $1000 for integrated telemetry unit (ITU) transceiver (not including sensors)
Operating Range	20(minimum) up to 50 miles
Number of Channels	Up to 18 channels
Sensor Interface	Hard-wired and wireless, software configurable
Frequency	Dual band - Upper S Band: 2360-2390 MHz Commercial ISM Band: 2400-2483.5 MHz
Modulation	GMSK and spread spectrum (frequency hopping)
Data Formats	Compatible with existing range receivers based on IRIG-106 format
Size/weight	Minimum effect on weight, balance and flowfield, credit card size transceiver
Power	Internal battery or external power source, Up to 7 hour transmit time at 200 mw average transmitter power
Interfaces	GPS and existing range infrastructure
Raw Data Rate	Up to 200 kilobits per second per ITU
Sample Rate	Up to 1000 samples/second per channel
Accuracy	Up to 24 bit resolution
Encryption Capability	Level III initial, Level I and II desired

Table 1. ASMT Desired Characteristics

PROJECT STATUS

Development of the ASMT system concept is being accomplished using a combination of SBIR funding and Air Force funding. Three coordinated SBIR projects are currently underway.

- ASMT Phase II SBIR
- Electro-cleavable Adhesive PHASE II SBIR
- Wireless Sensor Phase I SBIR

A Phase I ASMT SBIR effort was completed by two contractors in March 1999. At the end of Phase I, feasibility of the ASMT concept was successfully demonstrated using a prototype transmitter operating in the 902-928 MHz band. The transceiver unit successfully acquired inputs from an accelerometer, strain gauge, pressure transducer, and thermistor and transmitted the information via a wireless link to a prototype base station receiver. A two-year Phase II ASMT SBIR project was initiated in June 1999 with Cleveland Medical Devices, Inc. to develop a system specification, finalize the ASMT system design, and deliver prototype hardware and software. Specific activities during Phase II include design of the dual-mode transmitter, ground receiver base station, remote activation and control system, sensor interface, data acquisition system, power system, and antenna. At the end of Phase II, the contractor will deliver eight integrated telemetry units and a base station with control and display software. A flight test demonstration is planned for the fourth quarter of FY01 to demonstrate proof-of-concept.

An interim test of a preliminary prototype ASMT system has recently been completed. A Mark 84 2000 pound bomb was instrumented with four externally mounted three-axis accelerometers and two prototype ASMT transceivers (Figure 2). Acceleration data were collected for eight static ejections from

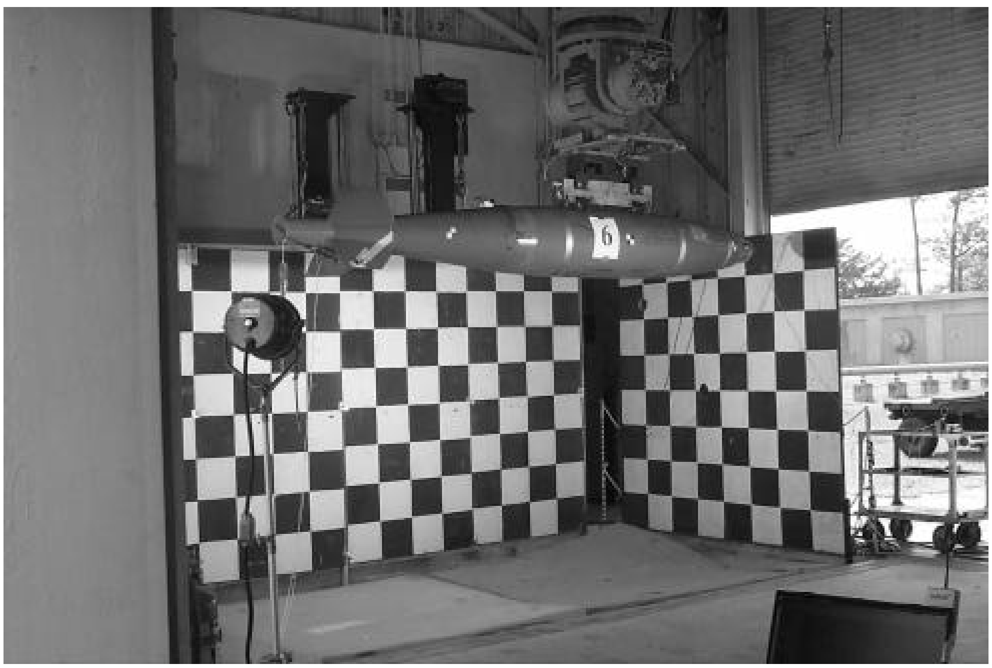

Figure 2. Static ejection test setup

an MAU-12 ejector rack using standard ejector charges and orifice settings. Preliminary analysis indicates that the transceivers and receivers performed as planned. Detailed analysis of the test data is underway.

One of the major problems with an externally mounted instrumentation system utilizing large numbers of widely distributed sensors is the maze of wires required to connect the sensors to the transmitter unit. High speed aircraft testing can damage sensor wires and gluing them down and removing them is a time consuming process. These wires also provide a source for electromagnetic interference. The incorporation of inexpensive easily applied and removed wireless sensors would provide a major benefit to the ASMT concept. Using wireless sensors, the ASMT transceiver would operate as a repeater, receiving low power signals from the sensors, and relaying the information to a ground receiver. Two Phase I SBIRs were initiated in April 2000 to investigate the feasibility of utilizing miniature wireless sensors with the ASMT system.

In a related effort, an electro-cleavable adhesive is being developed by EIC Laboratories under a Phase II SBIR contract. The adhesive will be used for attaching the ASMT system components to the surfaces of aircraft, stores, or suspension equipment. In addition to its function as an adhesive, the cured epoxy is also capable of being electrochemically disbonded on demand in a relatively short time by application of a nominal dc voltage across the bond. The objective is to be able to attach and remove the telemetry and sensor system components with minimum or no modifications to the aircraft.

The first phase of testing to evaluate the performance of the adhesive has been completed. The primary goals of this phase of testing were to determine baseline strength of the adhesive, evaluate degradation of the adhesive bond strengths due to environmental extremes, and to investigate the capability to electrochemically disbond simulated telemetry system components from typical aircraft materials after exposure to environmental extremes. The tests made extensive use of MIL-STD-810E procedures and parameter limits and were designed to expose the test items to conditions believed to be most likely to impact the strength of the adhesive bonds. The tests included exposure to high humidity, temperature shock, vibration, mechanical shock, salt fog, rain, high temperature, low temperature, acceleration and combinations of these environments. Analysis of the test results indicates that the electro-cleavable adhesive is relatively insensitive to environmental extremes and can potentially be used for attachment of telemetry system components to aircraft surfaces. The tensile and shear forces required to break the adhesive bond on the test items were significantly higher than the maximum forces predicted to occur in the worst-case flight environment. Future tests of the adhesive will include acoustic effects, airframe dynamic effects, and ultimately flight tests with simulated and actual telemetry system components adhesively bonded to an F-15 or F-16 aircraft.

CONCLUSIONS

The ASMT concept can provide an attractive cost-effective alternative for instrumentation of aircraft and stores. Principal advantages of the ASMT system include the following:

* Modern wireless system design for maximum spectral efficiency and reliability
* Potential to instrument any inventory aircraft or inventory munition to support test missions
* Flexibility for a wide range of testing configurations with a variety of sensors
* Compatible with existing range systems
* Small, externally mounted system – minimal to no aircraft or store modifications required
* Maximum use of COTS components