DEVELOPMENT OF AN UNMANNED AIRBORNE TELEMETRY TRACKING AND RELAY SYSTEM†

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ABSTRACT

Aerocross Systems, Inc. is developing a low-cost unmanned airborne telemetry relay system to augment the USAF Air Armament Center's Eglin Gulf Range instrumentation resources. The system is designed to remotely autotrack and relay S-Band telemetry and VHF/UHF voice communications from test articles beyond the line-of-sight of land-based instrumentation. The system consists of a medium altitude/endurance Unmanned Aerial Vehicle (UAV), a Mission Control Station, and a remotely operated telemetry/voice tracking and relay instrumentation suite. Successfully developed and deployed, the system will contribute to lower range costs while enhancing range instrumentation performance.

KEYWORDS

Unmanned Aerial Vehicle, UAV, UAS, airborne, telemetry relay, offset-fed tracking antenna

† This project is conducted under contract FA920004C0322 awarded to Aerocross Systems, Inc., by the USAF Air Armament Center, Eglin AFB, Florida.

INTRODUCTION

As the operational footprint of modern air-delivered weapons systems expands, the ability to test and evaluate these weapons in a representative battlespace throughout their full operational envelope becomes increasingly difficult. Ground-based instrumentation resources limit the test area to within line-of-sight. Manned airborne systems are often used to extend the test area beyond line-of-sight, but these systems tend to be costly, limited in number, and require heavy maintenance. Further, they can subject the operators to “dull and dangerous” missions within a “hot” test area.

Aerocross Systems, Inc. is developing the Mobile Airborne Test Range Instrumentation and Communication System (MATRICS) for the USAF Air Armament Center’s Eglin Gulf Range to augment existing Test Range instrumentation resources. The MATRICS is designed to automatically track and relay instrumentation data from a target 200 miles away, thus providing a target-to-shore range of 400 miles. The MATRICS consists of a medium altitude/endurance Unmanned Aerial Vehicle (UAV), a Mission Control Station, and a high performance telemetry and voice tracking and relay instrumentation suite.

Innovative integration of open source software, affordable COTS hardware, and proven experimental aviation technologies and techniques was essential to Aerocross Systems’ successful development of the MATRICS.

PROBLEM STATEMENT

New combat scenarios necessitate the development of future weapon systems that perform accurately and effectively on the modern battlefield. The mission of the national test ranges is to provide an infrastructure and realistic environment for the development, testing, and evaluation of these future weapon systems.

Proper instrumentation is a prerequisite for effective testing. The national test range infrastructure consists mostly of sophisticated land-based instrumentation assets that are owned and operated by designated range organizations. Additional fixed (land-based) and mobile (air, sea, space-based) instrumentation assets have been added over time to enhance test range capabilities by extending downrange instrumentation coverage.

Historically, the national test range infrastructure has evolved in order to satisfy evolving national needs. During the Cold War era when the theater of operations extended into space, test agencies responded by creating a global network of ground-based tracking stations. When coverage was required beyond the local radio horizon of fixed stations, specialized mobile resources including instrumentation equipped ships, aircraft, and spacecraft were created to augment the existing test range networks. Though many of these specialized mobile assets remain effective in performing their designated missions, the financial resources necessary to acquire, operate, and maintain them are inadequate. Without substantial and sustained funding, the future of these once treasured mobile resources is threatened.

The gradual disappearance of mobile range instrumentation systems from the test range infrastructure is occurring. It began with the decommissioning of the USNS Arnold and USNS Vandenberg range instrumentation ships in the early the 1980's and the USNS Redstone in 1993. The termination of the Advanced Range Instrumentation Aircraft (ARIA) fleet followed in 2001. Most recently, the aging Navy NP-3D Airborne Instrumentation System (AIS) was slated for termination with plans for costly equipment upgrades and transfer to NP-3C platforms. High operating and maintenance costs coupled with inadequate funding led to the demise of these systems. Despite innovative efforts by their respective program offices to preserve their capabilities, the ARIA and AIS programs received sparse funding for systems upgrades and modernization. This ensured their eventual termination. While operating costs can be charged directly to a specific user, the burden of maintenance and upgrade costs must be shared across all existing and potential customers. This economic cycle guarantees a dismal outcome – limited funding leads to limited/outdated functionality; limited/outdated functionality leads to limited customers; and a limited customer base leads back to limited funding. The cycle ends when a system is no longer usable without equipment/maintenance upgrades and funding for such equipment/maintenance upgrades are not available due to the lack of use.

The E-9A Airborne Platform/Telemetry (AP/TM) aircraft program is one of the few remaining resources capable of satisfying extended, over-the-horizon (OTH) test range coverage requirements. Maintenance and upgrade costs for this aging fleet of two aircraft were recently estimated at more than $23M over the next decade. Already considered "national assets" due to the specialized role they play in the national test range infrastructure, the demands placed on these aircrafts will continue to increase as the remaining alternative assets disappear. Other efforts to relieve the availability burden such as the BIG CROW NC-135B Program and Navy C-130F Airborne TM System (ATS) experience similar challenges.

Future, large footprint weapon systems will require a more flexible and affordable test range infrastructure to support development, testing, and evaluation of these systems using realistic test scenarios. The limited availability and high operating cost of existing mobile test range assets threatens the effectiveness of future weapon systems development.

A new way of thinking is required to ensure a cost-effective and efficient means of supporting test ranges and future weapons systems testing to satisfy evolving national needs.

SIGNIFICANCE OF THE OPPORTUNITY

Recognizing the issues posed by limited test range assets and the need for a timely solution, the Air Armament Center's 46th Test Wing challenged the industry for feasible mobile range instrumentation concepts through a Small Business Innovative Research (SBIR) solicitation. The solicitation included the following basic requirements:

The system must support high altitude relay of flight test data over land and water ranges. Ground/shore based instrumentation systems are constrained by line-of-sight limitations and multi-path effects resulting from low elevation angle tracking over a reflective water horizon. A high altitude platform will increase the tracking angle and extend the line-of-sight range to provide a more effective data relay.

The airborne platform must be capable of carrying sufficient electronics payload to enable telemetry and communications relays at distances in excess of 100 NM from land/shore based ground stations. The extended range and lethal nature of items under test require test scenarios that cover extended range while posing negligible safety risks to the general public and national resources.

The airborne platform must be able to carry sufficient fuel for transit to and from the loiter location as well as remain there for up to 8 hours. Realistic test scenarios involving multiple test items and objectives are complex and often lengthy. Eight hours of on-station support enables a full shift of support thereby transferring the support time limitation from equipment to human resources.

The system must support deployment of 10 or more airborne platforms. A realistic test scenario involving multiple test items will most likely exceed the coverage of a single airborne relay platform. Multiple platforms enable greater coverage from a geographical as well as data type and bandwidth perspective.

The system must be able to network multiple platforms together to support multiple tests with multiple test items. A well-coordinated test scenario involving multiple resources requires centralized control and distributed execution capabilities. Multiple airborne platforms must interact effectively to accomplish complex remote control tasks required to support multiple test items.

The airborne platform must be small in size and highly transportable. Deployment requirements are directly related to support complexity and cost. Large logistical footprints increase time, personnel, and other supporting resource requirements. These limitations can render the concept of operations infeasible and result in prohibitive system costs. Airborne platforms that are transportable using existing government or commercial common carriers are required.

The system, including control and relay electronics, must be low in cost to acquire, operate, and maintain. As illustrated by legacy airborne data relay programs, costly systems cannot survive today's limited and competitive budget environment.

Aerocross Systems rose to the challenge with our innovative Mobile Airborne Test Range Instrumentation and Communication System (MATRICS) concept and was awarded a Phase I contract to investigate feasibility and a follow-on Phase II contract to develop a prototype proof-of-concept system. Using limited SBIR funding, Aerocross Systems is nearing completion of MATRICS prototype development. Effectively deployed, the MATRICS will augment existing range instrumentation resources to deliver cost-effective, high-performance, and timely services to range users.

THE MATRICS CONCEPT

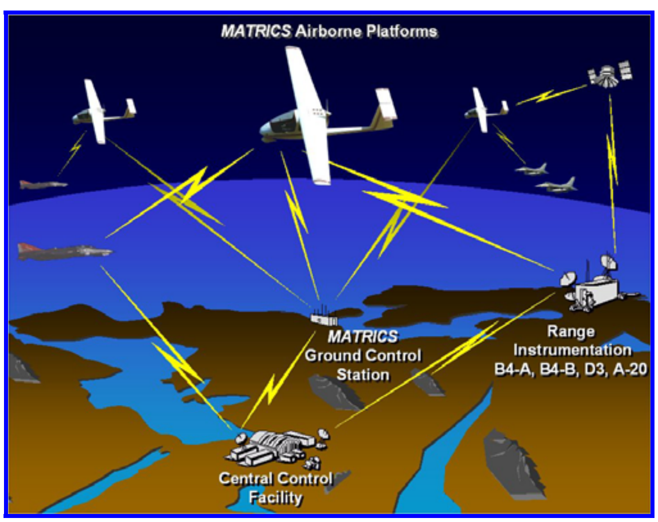
The MATRICS concept combines proven characteristics of existing and legacy airborne data relay systems with those from operational Unmanned Aerial Systems (UAS).

The MATRICS concept of operation includes a single or multiple high endurance, remotely piloted aircraft operating at medium and high altitudes to extend the target tracking and data relay capabilities of existing land/sea/air test targets.

The MATRICS concept aims to merge the effectiveness of existing and legacy airborne range instrumentation technologies proven on ARIA, AIS, and AP/TM systems with the capabilities of Medium Altitude Endurance (MAE) and High Altitude Endurance (HAE) UASs like *Predator* and *Global Hawk*. The result is an affordable system that compliments the capabilities of existing test range infrastructure while negating operational risks to human operators.

While the performance of a single low-cost UAV cannot match the capabilities of existing airborne instrumentation assets, the MATRICS has the potential to exceed the performance of these assets when implemented as a distributed network. Multiple platforms can be staged to increase test coverage footprint and duration, and to enable tracking of multiple targets. Backup platforms can be deployed or placed on alert to increase redundancy. The availability of multiple platforms also allows for maintenance down time while maintaining support readiness. Multiple platforms provide range managers with additional flexibility in tailoring mission support plans.

To be feasible, the MATRICS concept requires an affordable Unmanned Aerial System (UAS) capable of hosting a suitable telemetry tracking and data relay system and other range instrumentation payloads. In support of a proof-of-concept effort, Aerocross Systems is developing the *Echo Hawk* UAS and the *Echo Link* telemetry tracking and relay system. Based on maximum performance predictions, a single MATRICS UAV node can track and relay instrumentation data within a 200-mile radius of the vehicle resulting in a target-to-shore range of over 400-miles. Addition nodes can add redundancy and, with node-to-node communications, can also extend the area of coverage.



MATRICS Concept

ECHO LINK TELEMETRY RELAY SYSTEM

Echo Link is an airborne telemetry relay instrumentation system. Aerocross Systems is developing *Echo Link* to optimize test range telemetry data relay performance from a UAV platform. The *Echo Link* system is comprised of an innovative high performance tracking antenna system and a telemetry front-end/retransmission system. The *Echo Link* is remotely configurable, thus enabling mission operators to change support parameters as required to support multiple successive missions.

Telemetry Tracking Antenna

The telemetry tracking antenna system is a lightweight, dual-axis, S-Band, monopulse autotracking sensor designed to yield the maximum feasible G/T figure of merit performance while operating within a limited swept volume. The system is specified to operate in the telemetry instrumentation frequency band from 2200 MHz to 2400 MHz with a G/T goal of > 4.5 dB/ºK. Swept diameter is restricted to 40" due to aircraft payload bay geometry constraints. To meet these challenging specifications, Aerocross System is employing an innovative technical approach. We are integrating a cavity mode coupler coaxial monopulse feed in an offset fed configuration with a lightweight 36" aperture carbon fiber reflector. The antenna assembly is mounted on a non-orthogonal roll-theta pedestal. The offset fed configuration provides high efficiency/low side lobe characteristics while the non-orthogonal mount axes pedestal contributes to compactness and low weight properties. The rotator assembly features continuous motion axis positioning using low backlash precision gear drives, servomotors with built-in servo amplifiers, and a rotary joint/slip ring assembly. An airborne digital antenna control unit (ACU) manages the antenna system while a remote ground unit provides the controller interface. The ACU features multiple operating modes including autotrack, auto-acquire, tracking threshold, rate memory, position memory, remote, and slave. The local ACU interfaces with the UAV for Command and Control (C^2) as well as attitude information. It is connected to the telemetry RF front-end for demodulated tracking scan data, receiver AGC information, and modulated RHC and LHC RF signal transfer.

Telemetry Front-end/Retransmission System

The telemetry front-end/retransmission system is comprised of a highly integrated board level telemetry processor, a state-of-the-art telemetry L-band transmitter, and an omni-directional retransmission airborne blade antenna. The telemetry front-end processor integrates the functions of two S-Band receivers, a pre-detection diversity combiner, a PCM decom/simulator, an IRIG time code reader, and a bit synchronizer into a single full size PCI PC board. Mission configuration is accomplished pre-mission and in real-time by remote control via the PCI bus through an onboard Payload Management Computer. Baseband telemetry data and clock are forwarded to the L-Band transmitter for relay via the blade antenna. The L-Band transmitter features remote configuration interfaces as well as a dynamic digital pre-modulation filter necessary for shaping the baseband waveform prior to transmission. The telemetry front-end also has provisions for future enhancements including bandwidth efficient modulation, data recording, playback, IRIG time tagging, and reduced rate/alternate format retransmission.

ECHO LINK DESIGN SPECIFICATIONS

Tracking Antenna:

Configuration	3', Offset Fed, Non-orthogonal Roll-Theta Mount
Swept Diameter	40"
RX Frequency	2200 to 2400 MHz
Tracking Technique	Single Channel Monopulse
Gain (2200 MHz)	$\geq$ 22.5 dB
G/T (2200 MHz)	$\geq$ 4.5 dB/ºK
Beamwidth (3 dB)	11º nominal
Polarization	Simultaneous RHCP and LHCP
Axial Ratio	$\leq$ 2.0 dB
VSWR	$\leq$ 2.0:1
Velocity	$\geq$ 20º/sec
Acceleration	$\geq$ 40º/sec^2
Roll/Theta Travel	Continuous/180º
Control	Standard Local and Remote Digital ACUs
Weight	< 90 lbs
Power	24 to 32 VDC

Telemetry Front-end/Retransmission System:

RX Frequency	2200 to 2400 MHz
TX Frequency	1450 to 1550 MHz
RX Noise Figure	Better than 6 dB
TX Power	10W
Modulation	FM
Coding	IRIG 106 PCM
Maximum Data Rate	10 Mbps
IF Bandwidth	0.5 MHz to 20 MHz

VOICE COMMUNICATIONS RELAY SYSTEM

The Voice Communication Relay System is comprised of a pair of URC-200 line-of-sight radios configured as a repeater onboard the UAV platform. The radios are mated to two dual-band airborne blade antennas mounted on the top and bottom of the airframe to provide omni-directional coverage. Two-way simplex operation is accomplished by using two different frequencies. The URC-200 radio set can be remotely configured to operate in the VHF or UHF band. While the baseline maximum transmission power is 10W, the system can be configured to operate at lower power. As required, power amplifiers may be added to increase maximum power to 50W.

ECHO HAWK AIRBORNE PLATFORM

The *Echo Hawk* Unmanned Aerial System (UAS) is a low-cost, high performance, versatile system designed to support airborne missions requiring remote, medium altitude, and long endurance operations. This UAS consists of the *Echo Hawk* Unmanned Aerial Vehicle (UAV) and transportable *Echo Hawk* Mission Control Station (MCS).

Echo Hawk Unmanned Aerial Vehicle (UAV)

The *Echo Hawk* UAV is a combination of light sport aircraft components integrated with flight-proven Command and Control (C^2) technologies. The UAV airframe is an all-composite, high wing, "T" tail pusher with fixed tricycle landing gear. The airframe features a high aspect ratio wing and horizontal tail surfaces that can be removed for easy transportation.

The powerplant for the Echo Hawk is a turbocharged/intercooled Rotax 914 engine turning a three-blade, Airmaster AP332 constant speed propeller. This combat proven, four-cycle, four-cylinder aviation power plant produces 115 HP at full boost and maintains 100 HP up to 10,000 ft MSL. While burning an average of 4 gallons per hour at altitude, this powerplant and the *Echo Hawk* 50 gallon (Mogas, Avgas) fuel capacity gives the UAV an endurance of over 12 hours and a range in excess of 1200 nautical miles.

The *Echo Hawk* UAV includes a 28 VDC engine-driven aviation alternator and mission battery to supply power to the C^2 avionics and payload systems via dedicated buses. The alternator has operational heritage on the Predator UAV and can produce 28VDC/100A at 30,000 ft.

The *Echo Hawk* UAV C^2 suite is comprised of flight proven COTS components for flight navigation, guidance, and control. The UAV can be operated as a remotely piloted platform via redundant line-of-sight radio modems or as a semi-autonomous platform via embedded waypoint navigation and guidance logic.

Echo Hawk UAV

ECHO HAWK UAS BASELINE SPECIFICATIONS

Fuselage Length	20 ft
Fuselage Height	7 ft
Wingspan	41.5 ft
Wing Area	129 sq ft
Maximum L/D	23:1
Empty Weight	750 lbs
Maximum Gross Takeoff Weight	1475 lbs
Useful Load	725 lbs
Airspeed, Stall, V_{SO}	35 KEAS
Airspeed, Never Exceed, V_{NE}	140 KEAS
Cruise Speed, 15,000 ft MSL @ T/V_{MIN}	100 KEAS
Range, 15,000 ft MSL @ T/V_{MIN}	1250 nmi
Endurance, 15,000 ft MSL @ T/V_{MIN}	12.5 hrs
Maximum Altitude	25,000 ft MSL
Powerplant	Rotax 914, 100 HP @ 10,000 ft
Fuel Capacity	50 gal US (Mogas, Avgas)
Payload Volume	4 ft (L) x 2.5 ft (W) x 2 ft (H)
Payload Weight Limit (w/ full fuel)	425 lbs
Payload Power	28 VDC, 100A
Command and Control (C^2)	Remotely Piloted (LOS) Autonomous Waypoint Nav (BLOS)
Sensors	S-Band TM Autotracker Electro-Optical
Communications	Line-of-Sight C^2 Telemetry Data Relay (Echo Link) VHF/UHF Voice Relay
Range Safety	RCC-319, RCC-323 Compatible FTS Ballistic Recovery Parachute

MISSION CONTROL STATION (MCS)

The Mission Control Station is housed inside a 26' cargo trailer that doubles as the mobile transport for the *Echo Hawk* UAS. The baseline MCS includes a UAV Operator Console and a Range Safety/Payload Management Console.

The UAV Operator Console includes standard HOTAS (hands on throttle and stick) pilot interfaces coupled with a live analog audio/video feed from the UAV. Synthetic out-the-window visuals are projected behind the live video feed along with a Head-Up Display (HUD) instrumentation overlay to increase pilot situational awareness. An auxiliary moving map and Head-Down Display instrumentation screen are also provided.

The Range Safety/Payload Management console includes a moving map display for flight following and Flight Termination System footprint predictors. This console doubles as the Payload Control interface for control/reconfiguration of the electronics. The *Echo Hawk* UAV baseline includes an electrically initiated ballistic parachute for emergency recovery.

CONCLUSION

The capabilities stated above are in the final stages of development. The MATRICS is scheduled to begin flight test and demonstration in late 2007. Preliminary findings have supported the feasibility of utilizing Unmanned Airborne Systems to support range instrumentation missions. Future development and enhancements include operational testing, advanced airframe integration, and instrumentation system updates. Multiple networked airborne platforms and additional/alternate payloads can also be investigated.

ACKNOWLEDGEMENT

The authors wish to acknowledge contributions made to this project by the following:

- USAF Air Armament Center, 46th Test Wing, Eglin Gulf Range
- Gaetan Richard, DECS, Inc.
- Don Shae, Overwatch Textron Systems, Tactical Operations
- Martín Uhía Lima and Jorge Vázquez, Colyaer, S.L., Pontevedra, Spain