Enhanced Flight Termination System (EFTS)

Flight Demonstration and Results

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Agenda

- **Introduction**
- **Organizations and Geography**
- **Demonstration Purpose and Goals**
- **Demonstration Phases**
- **Current Upgrades for EFTS**
- **Questions**

Program Background

- **Current flight termination system (FTS) operates in UHF frequency band (420 – 450 MHz)**

- **2 Major Common Types of FTS**
  - Standard analog system (Uses three tones in a simple logic sequence to initiate termination, similar to FM radio)
  - High alphabet system (Uses combination of an eleven character, frequency modulated, tone pattern)
    - γ Secure but not encrypted

- **EFTS initiated and propelled because of key events**
  - Global Hawk inadvertent termination in Mar 1999
    - γ AF/CV and AFMC/CC tasking based on findings
    - γ Investigate encryption of command destruct links
  - NASA Inspector General assessment letter in Aug 99 and subsequent recommendation letter in Aug 00
    - γ Explore low-cost, lightweight space COMSEC for FTS
  - Strategic Target System inadvertent termination in Nov 2001

Program Background (cont.)

- **Range Commanders Council (RCC) Range Safety Group (RSG) study task, initiated in Apr 00 and completed in Apr 02, to select and document a robust, affordable, reliable technology that provides an encrypted FTS capability**
  - EFTS Program team formed (Air Force, NASA, RSG, Telemetry Group, Telecommunications & timing Group, Academia, NSA, Industry)
  - Continuous Phase Frequency Shift Keying (CPFSK) aka PCM/FM selected as modulation
  - Triple Data Encryption Standard (TDES) selected for security
  - Digital message format
  - Forward Error Correction (FEC) to protect against interference
- **Prototype phase, initiated in May 02 and completed in Jan 04, to validate proposed technology for range safety application**
  - Prototype flight termination receivers and ground-based addressable Encoder for command transmitter developed by L-3 Cincinnati Electronics (L-3 CE)
  - Functionality validated on F-15B testbed aircraft at Edwards Air Force Base (AFB)

Program Background (cont.)

- **Development of EFTS receiver and ground systems, initiated in Jan 04 and completed in Apr 07**

  - Receiver contracts awarded August 04 to L-3 CE to develop equipment that meet environmental requirements for Missile, Unmanned Aerial Vehicle, and Space-Launch applications

  - Ground Systems contract awarded August 05 to L-3 CE for development of ground system equipment (encoder, monitor, and Triple DES Unit)

- **Testing**

  - Acceptance and qualification testing on flight termination receiver initiated in Oct 2005 and completed Apr 07

    - γ Qualification test report accepted Aug 07

  - Acceptance testing on ground equipment initiated in Dec 2005 and completed in Nov 2006

EFTS Message Field Definitions

Triple DES Encrypted

Authentication Check

Link Integrity Check
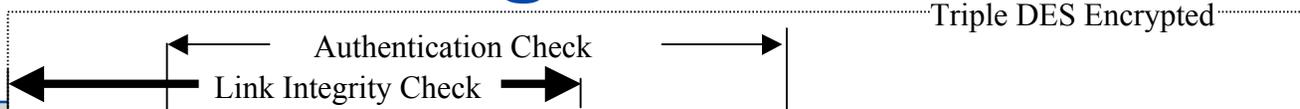
Frame Synch (19 Bits)	Check Channel	Range ID	TX ID	Vehicle ID	Counter	Command	User Defined	Future (1 Bit)	FEC (60 Bits)

Field	Description
Check Channel	**Used for link integrity check**
Range ID	**Identifies range where message frame originated**
Transmitter ID	**Identifies specific transmitter on range**
Vehicle ID	**Identifies specific FTRs in the vehicle**
Command counter	**Used for command authentication to prevent spoofing. Counter is tied to specific transmitter**
Command	**Command set for FTS (default, monitor, optional, arm, terminate, test, disable, command counter clear, wireless enable, wireless commit, fail-safe enable, fail-safe disable)**
User defined	**Reserved for user specific purposes**

Organizations and Geography

Demonstration Purpose and Goals

- **Gain experience using EFTS in an operational environment**
  - Setup and configuration
  - Factory and preflight testing
  - Operations and monitoring
  - Post flight data reduction
- **Provide confidence in the use of the EFTS components developed under the Central Test and Evaluation Investment Program (CTEIP)**
  - L-3 CE Encoder, Monitor, Triple Data Encryption Standard (DES) Unit (TDU) and Flight Termination Receivers (FTR)
  - National Security Agency (NSA) generated key and key loading devices
  - Configuration, monitoring, and recording software
- **Integrate into and existing range infrastructure to demonstrate scalability of system components**
  - Transmitter site - Button press to radiation
  - Monitor site - Record and monitor signal in real-time
  - Vehicle - Integrate into existing vehicle test package
- **Provide a command controller (CC) that generates the EFTS waveform using an existing range infrastructure**
  - CC is interface between switch closures and EFTS encoder
  - CC generates unencrypted EFTS message based on switch inputs and provides to encoder
  - Commercial off the shelf (COTS) L-3 CE encoder generates encrypted waveform conditioned for exciter input
- **Provide a report documenting the results of the demonstration**

Potential EFTS Benefits to AMRAAM

- **With Range Safety approval, the system can provide a user feature that enables the telemetry transmitter power to be adjusted and may extend mission times**

- **EFTS FTRs are field programmable, minimizing required spares and raising system availability times**

- **EFTS data link has a dramatically increased FTR addressing space over current IRIG systems, and possible vehicles per mission**

- **Designed compatibility between existing system and the EFTS system minimizes the required modifications to the vehicle, range, and mission operations**

- **Digital receivers may require less re-testing for shelf life than tone based receivers**

- **EFTS provides additional security against inadvertent activation**

Demonstration Phases

- **Demonstration Planning**
  - Development of demonstration goals
  - Vehicle and range selection
  - Program issues (funding, schedule, etc.)
- **Demonstration Development and Implementation**
  - Transmitter system
  - Monitor system
  - Vehicle system
  - Specialized test equipment
- **Demonstration Performance**
  - Captive Carry Integrated Test Vehicle (ITV)
  - Live Fire
- **Documentation**

Demonstration Planning

- **Development of Demonstration Goals - EFTS Program developed objectives and goals for selection of a demonstration site and vehicle**
  - Primary goal of demonstration was defined to obtain operational experience with EFTS and develop a heritage of use
  - Areas of operational experience include: Mission planning, pre-flight configuration and testing (vehicle and ground systems), mission monitoring and recording, vehicle termination, developing mission procedures, and post mission data reduction and other post mission activities

- **Vehicle and Range Selection**
  - Worked with AMRAAM Program Management Office (PMO) and others to find suitable vehicles/programs to support the EFTS demonstration
  - AMRAAM selected because of interest in future use of EFTS by AMRAAM program, familiarity of EFTS by range personnel at Eglin AFB, and availability of existing operational environment to support EFTS testing with available program funding

- **Program Issues (Funding, Schedule, etc.)**
  - EFTS, CTEIP, and AMRAAM Program offices met regularly to ensure program objective would be met

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Demonstration Development and Implementation

- **Areas of Development Focus**

  - **Transmitter system** - Integrate EFTS transmitter (Tx) components into Eglin AFB transmitter system

  - **Monitor system** - Integrate EFTS monitor components into Eglin AFB infrastructure for mission use

  - **Vehicle system** - Integrate EFTS FTR into existing AMRAAM test package, named Non-Developmental Item-Airborne Instrumentation Unit (NDI-AIU)

  - **Test equipment** – Baseband Output Signal Simulator (BOSS), Portable EFTS Test Set (PETS), Monitor and Record Software, Video Monitoring, Range Interface Test Set and Archival, Encoder Simulator

  - **Transportable system** - Integrate EFTS Tx Equipment in a portable transit case

    - γ Simplify site-to-site relocation

Demonstration Development and Implementation (cont.)

- **Edwards AFB Integration (Edwards, CA)**
  - Purpose - Integrate and test all EFTS components in a lab environment
    - γ EFTS CC and EFTS Encoder interfaces were tested at L-3 CE prior to Tx system delivery
  - CC, Encoder, TDU, and DTD used with configuration software and COTS exciter
- **AMRAAM Integration (Raytheon - Tucson, AZ)**
  - Purpose - Integrate and test EFTS receiver in existing test package
  - Use existing AMRAAM test system augmented by EFTS BOSS for testing
  - Key loaded with DTD
- **Eglin AFB Integration at A-3 Test Site (Fort Walton Beach, FL)**
  - Purpose – A-3 test site has exact same system as D-3 test site
  - A-3 test site has RF coverage needed for testing at Eglin AFB prior to shipment to Tyndall AFB
- **Eglin AFB Integration at D-3 Test Site (Cape San Blas, FL)**
  - Purpose – D-3 test site is the operational site for mission
- **Vehicle Pre-Flight Testing**
  - Used TDU and PETS to validate test package on Flight Line 1-7 days prior to test

Transmitter Architecture
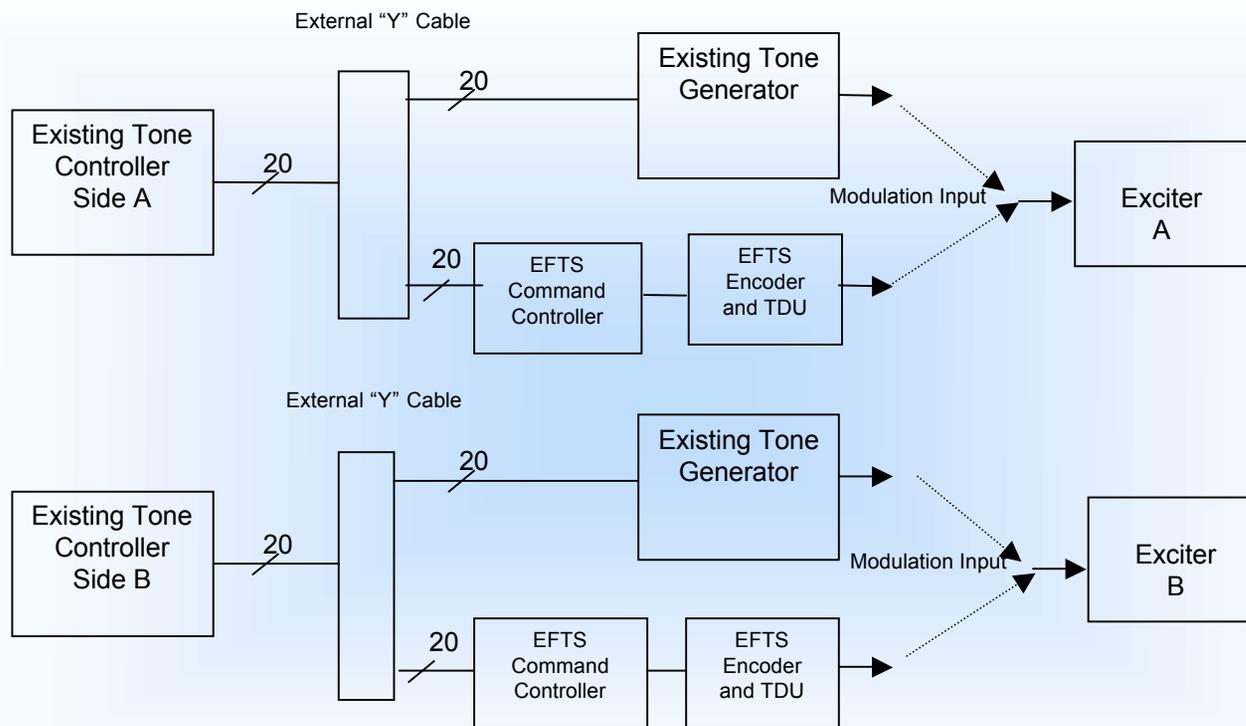
Transmitter System

- **Command Controller and "Y" Interface Cable**
  - EFTS Program developed resources
- **COTS Equipment from L-3 CE**
  - EFTS encoder
  - TDU
- **Developmental Software for PC applications**
  - L-3 CE setup and monitor for encoder
  - L-3 CE monitor and record software
  - Command controller software

L-3 CE Encoder with TDU

Command Controller

Monitor System

- **Purpose - Demodulate and Decode EFTS Waveform**
  - Real time validation of transmitted signal
  - Record and monitor of transmitted signal for post mission data reduction
- **COTS Equipment from L-3 CE**
  - EFTS monitor
- **Developmental Software**
  - PC based configuration
  - PC based display
  - PC based file recording of system
- **Range Assets**
  - Antennas, inter-site distribution, video recording, displays, strip charts (for FTR TM recording)

L-3 CE Monitor with TDU

Vehicle System

- **EFTS FTR is integrated into AMRAAM NDI-AIU at Raytheon Company (Tucson, AZ)**

Test Equipment

- **Baseband Output Signal Simulator**
  - Developed to generate the EFTS waveform, prior to the development of the EFTS Transmitter System
  - Generates the EFTS waveform using TDES key, not generated by NSA
  - BOSS consists of a PC application, a National Instruments Data Acquisition (DAQ) Card, a custom PWB, and cabling
    - γ PC Applications
      - Generate EFTS waveform
      - Allows setting FTR inputs (e.g. Failsafe Enable Pin)
      - Allows monitoring of all FTR outputs (e.g. Check Output Pin)
      - Allows configuration of FTR parameters (e.g. Frequency Range)
    - γ Printed Wiring Board
      - Allows access of all FTR Signals on PWB
      - Provides signal conditioning for DAQ Card
  - Software for configuration and monitoring of FTR
  - Added FTR PWB to access FTR signals
  - Allowed factory testing with published keys

Test Equipment (cont.)

- **Portable EFTS Test Set**
  - Eglin AFB developed the PETS to generate the EFTS waveform and send EFTS commands
  - PETS has a touch screen interface for configuration, and discrete switches that enable commands to be sent
  - PETS integrates a L-3 CE EFTS TDU, allowing NSA generated keys to be used

- **Encoder Simulator**
  - COTS microcontroller card with custom software to simulate EFTS encoder prior for development of CC prior to availability of encoder

- **Range Interface Control Box**
  - Switch box to emulate 20 tone range interface for development of command controller prior to integration at site

Demonstration Sites

CTEIP Demonstration
Live Fire

- **Success!**
  - Live Fire – At approximately 21:06 Zulu on Tuesday, October 16, 2007, an AMRAAM was successfully terminated using an EFTS receiver and successfully demonstrating EFTS

- **Viewing location provided in the Command Control Facility at Eglin AFB**

- **Test report of range demonstration complete**

- **Screens shown for demonstration include**
  - EFTS monitoring software with spectrum analyzer
  - Digital graphical display of aircraft, missile, and target

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Contacts

- **Pat Feeley - CTEIP EFTS PMO**

- **Robert Sakahara - EFTS Technical Program Manager at NASA Dryden**

- **David Tow - NASA Dryden**

- **Dennis Arce - Bourne Technologies, Inc.**

- **Steven Davies - TYBRIN Corporation**

Current Upgrades for EFTS

Ranges Implementing to EFTS

Ranges	Equipment Purchase Dates
Air Armament Center - Eglin AFB	2008-2010
Air Force Flight Test Center - Edwards AFB	2008-2010
NASA - Dryden Flight Research Center - Edwards	2007-2010
Naval Air Warfare Center Weapons Division - Pt. Mugu	2007-2008
Naval Air Warfare Center Weapons Division - China Lake	2007-2008
White Sands Missile Range - NM	2007-2010
NASA – Goddard Space Flight Center / Wallops Flight Facility	2008-2009
Tyndall Air Force Base - Florida	2008-2010
Eastern and Western Ranges Space Command – Colorado Springs, CO	2009-2015

Additional Requirements to EFTS

- **Impacts of Using EFTS**
  - Security
  - COMSEC – training
  - Controlled Cryptographic Item (CCI)
  - Handling of TDU, FTR, and Data Transfer Device (DTD)
    - γ Locked cabinets or controlled rooms/facilities, if not classified missions
    - γ Classified safe is using classified keys (not usually the case)
  - For NASA, any testing, including functional testing, on NSA CCI devices, such as the EFTS FTR, require NASA HQ approval to the test plans / procedures before testing can commence
- **Impact of potential migration to the 370-380 MHz range**
  - This is not related to EFTS, per se – affects both RCC-compliant systems, High Alpha systems, and EFTS systems
  - EFTS ground system equipment can handle it
  - EFTS FTR will require some modification and re-testing / re-qualification
  - Range transmitter systems – exciters, antennae, filters, HPAs, may require some upgrading

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Additional Impacts / Potential Add-ons

- These are items that are foreseen as necessary in the near foreseeable future.

- Configuration software for setup and monitoring of EFTS L-3 CE Encoder

- Configuration software for setup, monitoring, and post-mission archival of EFTS L-3 CE Monitor

- Configuration software for EFTS FTR

- Testing software for EFTS FTR – functional checkout tests, etc.

- Automated Test Sets for EFTS FTRs

Questions??