

ENHANCED FLIGHT TERMINATION SYSTEM PROGRAM - PART TWO

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ABSTRACT

The Air Force Flight Test Center in association with the Range Commanders Council (RCC) Range Safety Group is conducting a program that will explore the next generation of ground-based flight termination technology, known as the Enhanced Flight Termination System (EFTS) program. The first part of the program was successfully concluded in May 2002. The Government is leading this program with support from contractors, academia, and other RCC groups including the Telemetry Group, Frequency Management Group, and Telecommunications and Timing Group. Additionally, the National Security Agency is providing key support along with vendors who design, build and test range safety systems.

This paper will discuss details of the design validation and development phases (part two) of the EFTS program. Redesign of flight termination receivers and ground system modification plans will be discussed as well as flight and ground hardware testing objectives.

KEY WORDS

Flight Termination Systems, Range Safety

INTRODUCTION

The Enhanced Flight Termination System (EFTS) program began with a study that was initiated to explore more robust links for flight termination systems (FTS). These command transmit links are to provide increased security in order to prevent unauthorized activation of flight termination receivers (FTRs), and ultimately, inadvertent destruction of national assets.

The program is organized in three parts. Part One was comprised of the Range Commanders Council (RCC) Range Safety Group (RSG) study that was completed in May 2002. A comprehensive overview of the study can be found in the ITC 2001 proceedings¹. The final product from Part One was a proposed solution for the next generation FTS. Part Two will validate the Part

¹ Steven G. Cronk, Maria A. Tobin, and Robert D. Sakahara, "Enhanced Flight Termination Study - Overview and Status," Proceeding on International Telemetry Conference 2001, International Foundation for Telemetry, 2001, pp. 297-403.

One solution through the prototyping of flight hardware and command transmitting (typically ground-based) equipment. Once the technology is proven, it will then be flight qualified on various platforms (such as missiles, space lift and unmanned aerial vehicles) on several ranges. Program completion in Part Three will yield a system that is fielded for production and deployment on all Department of Defense (DoD) and National Aeronautics and Space Administration (NASA) ranges.

The objective of this paper is to provide an overview and describe some of the details associated with completing parts one and two of the EFTS program.

EFTS PART ONE

The RCC RSG Flight Termination Standing Committee (FTSC) initiated task RS-38 – EFTS study in April 2000. The goal of the study was to investigate more robust command links for flight termination. The task was organized and managed by NASA/Dryden Flight Research Center (DFRC) and the Air Force Flight Test Center (AFFTC) personnel using contractor support from DFRC, AFFTC and Vandenberg AFB. The RCC Telemetry Group, Telecommunications & Timing Group, and Frequency Management Group provided expertise in their associated fields to ensure the task would achieve success. Since improved security was a primary goal of the task, the National Security Agency (NSA) provided representation and guidance throughout the process. Brigham Young University (BYU) also played an integral part in researching and testing a digital solution through the use of modeling and simulation. Range safety vendors volunteered their support by providing practical industry perspective on proposed system component designs, test methods, manufacturing processes and cost estimations. Lastly, the FTSC members kept the team focused by providing their expertise in areas such as current operations, test techniques, equipment capabilities and the needs of the range users.

The study was structured into four phases, which provided milestones for the task. The following information provides an outline of each of the phases.

Phase I - Requirements Definition/Range Infrastructure: In order to determine the specific system equipment being used and the operational practices in place, various members of the range safety community were contacted. Component vendors, individual ranges and users were each surveyed, not only to establish compliance of RCC standards, but also to help develop design guidelines as a basis for exploring new technologies. Phase I was completed in September 2000.

Phase II – Technology Assessment: The examination of these new technologies began in this phase by evaluating approaches provided by team members and range safety vendors. The solutions were weighed by their advantages and disadvantages while considering cost and risk factors. Out of the seven approaches presented, two modulation schemes were deemed the most viable. Continuous Phase Frequency Shift Keying (CPFSK) and Modified High Alphabet schemes were both selected for further evaluation. Also chosen for additional consideration were the two NSA recommended encryption schemes: The Triple-Data Encryption Standard (3DES) and the Advanced Encryption Standard (AES). Phase II was completed in March 2001.

Phase III – Technology Demonstration: Extensive analysis of both modulation formats led to the selection of CPFSK as the optimum scheme for EFTS. CPFSK, commonly referred to as pulse code modulation/frequency modulation, was selected for its supportability, demonstrated effectiveness in the telemetry field and because ranges are already familiar with this format. The 3DES encryption scheme was chosen for similar reasons and for the fact that it requires fewer bits for message authentication as opposed to AES. Additional studies during this phase also included interference modeling, legacy system testing, message format development and operational impact analysis. The definition of certain link parameters, however, such as forward error correction (FEC) and frame synchronization, was transferred to Part Two of the program. Phase III was completed in January 2002.

Phase IV – RCC Standards: The goal in this phase was to determine the potential impacts to the range safety standards by the implementation of EFTS. In some cases, separate RCC tasks were initiated so that unique teams could be assigned to ensure these efforts would be successfully accomplished. Other achievements were the completion of cost estimates and the development of performance specifications that were necessary to acquire the components for the prototype system. Phase IV was completed in April 2002.

The successful and on-time completion of Part One of the EFTS program resulted in the following final products:

- A proposal to further explore the use of a digital system using a CPFSK modulation scheme with 3DES encryption
- System performance specifications and a Request for Proposal (RFP) package for design validation
- Cost estimates for developing EFTS and upgrading the nation's range safety command transmitting infrastructure were provided on schedule with approval from the range safety community

EFTS PART TWO – PHASE I

Scope: The primary focus of the EFTS program Part Two will be to substantiate the proposed data link and provide a fully qualified system that can be installed on all DoD Major Range and Test Facility Bases (MRTFB) and NASA launch and flight research facilities. Phase I will address the pertinent data-link characteristics through extensive testing of prototype FTR and command encoding equipment.

Objectives: The following is a list of objectives to be achieved in Phase I:

- Prototype EFTS airborne FTRs
- Prototype an EFTS encoder

- Resolve technical issues related to the EFTS data link
- Address operational issues related to transmitting a digital message versus analog tones (standard and secure)
- Develop and recommend technical standards and attributes for the communications link, command transmitter and FTRs
- Demonstrate and test prototypes to establish and define system attributes

Approach: The goals of the validation phase are to contract with multiple range safety vendors, validate the EFTS Part One performance specifications and to conduct as much testing as possible with the funding available. A great deal of the testing will be conducted in the laboratory environment with the plan for limited flight-testing. An existing laboratory at Edwards AFB will provide the required space and test equipment to support EFTS. In order to facilitate flight-testing, the ground transmitting systems at both Edwards AFB and Dryden Flight Research Center will be modified. In addition, test aircraft from these centers will be modified and equipped to accomplish airborne testing of the prototype system.

Products: Successfully meeting Phase I objectives will result in the following products:

- Prototype FTR
- Prototype ground-based addressable encoder/exciter
- Tested encryption capability
- Flight test data and test report
- Recommendations for development and qualification
- Government-owned design

Proposed Schedule: The RFP package was released on May 6, 2002 with proposals expected one month later. Evaluations will lead to the selection of a minimum of one FTR and encoder vendor. The vendor(s) will conduct design reviews and factory testing prior to delivery in mid 2003. Immediately thereafter, laboratory and airborne testing will commence with expected completion in the 3rd quarter of 2003.

PART TWO – PHASE II

Scope: Phase II efforts will concentrate on developing the EFTS equipment and ensuring it is flight and environmentally qualified which will provide a complete system that can be integrated on all applicable national ranges along with the necessary documentation for updating RCC standards.

Objectives: The objectives of Phase II are to flight qualify airborne units that meet range user requirements and to certify the ground system components by conducting end-to-end tests on multiple ranges using multiple vehicle platforms.

Approach: The technical approach for Phase II is to conduct extensive testing of EFTS equipment using at least three different flight platforms (missile, spacelift, UAV) on three different ranges. Command transmitting systems at each of the designated ranges will be modified to accommodate the tests.

Products: Successfully meeting the Phase II objectives will result in the following products:

- Fully environmentally qualified and tested FTRs
- RCC standards
- Contract for follow-on production of ground equipment

Schedule: The projected start date for this phase is October 2003. First article units should be delivered in June 2005 with testing to be conducted the following year. Production airborne FTRs should become available in late 2006.

DESIGN VALIDATION ISSUE - SPECIFICATIONS

Objectives: In order to validate the proposed EFTS data-link format, prototype FTRs and encoders will be manufactured and tested. The Edwards AFB contracting office is working with the EFTS team to procure this equipment. The contract for Phase I will be performance-based whereas the development phase units will be built to design specifications derived from the design validation phase.

Approach: Data-link characteristics such as modulation format, coding and message rate were provided to vendors. Other parameters, however, were given as starting points for the vendors to refine during this phase. These include bit rate, carrier deviation, frame synchronization and forward error correction.

Since the FTRs will not be environmentally qualified during the validation phase, the environmental specifications given were based on prerequisites for the installation of electronic equipment on the potential flight test aircraft. The more stringent environmental specifications that the flight hardware will be subject to during the development phase were provided to vendors as guidance. TEMPEST

requirements have also been provided to vendors as guidance but will be a requirement during development.

DESIGN VALIDATION ISSUE - FLIGHT TEST REQUIREMENTS

As noted above, an objective of Phase I will be to validate flight hardware through airborne tests. The extent of flight-testing will hinge upon available funding. In addition to factory testing and laboratory testing the prototype equipment against each of the performance specifications, the following are goals for flight-testing during the design validation phase:

- Validate the effectiveness of the RF data link during straight and level flight
- Validate the effectiveness of the RF data link during low-rate rolls and low-rate turns
- Determine the effects on the RF data link caused by test vehicle acceleration relative to the command transmitter location, exposure to phenomena such as multipath and in the presence of known interference in the FTS frequency range

CONCLUSIONS

Part Two of the EFTS program will provide the range safety community and the range user with a fully qualified and enhanced flight termination system. This system will feature robust command link message formats using digital modulation techniques and NSA approved security providing the national ranges with a superior, low-cost command destruct capability for the future. EFTS will be able to replace the current analog-based systems and meet the challenge of higher-flying test vehicles with increased capabilities.

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