SPECTRUM EFFICIENT TECHNOLOGY TODAY, TOMORROW and BEYOND

Tom Young - **USAF**
Mark Santiago - **JACOBS/TYBRIN**
Mark Radke - **JACOBS/TYBRIN**
Spectrum Efficient Test Technology Area
AFFTC Edwards AFB, CA.

Abstract

In preparation for the onslaught of the commercial wireless appetite, we, the test community, must continually invest in methods to better utilize the Department of Defense (DoD) Radio Frequency (RF) spectrum allocations and or leverage the shared commercial space. There is an ever increasing demand for the limited physical allocations within the RF spectrum for wireless communications. This has never been more prevalent within the test community as it is today with the continuing encroachment of the commercial wireless communication systems. These commercial entities are investing billions of dollars to insure that the bandwidth demands of the public are met which in turn will affect the DoD allocations and usage.
Based on the need for increasing data rates, number of simultaneous tests, number of test participants and competition from the commercial sector, the test community must continually improve our efficiency of use within the wireless communications space. To accomplish this, the Test Resource Management Center (TRMC) has identified a Test Technology Area (TTA) Spectrum Efficient Technology (SET) that targets methodologies to more efficiently and effectively utilize this wireless test asset. The SET team has broken down the problem space into three distinct domains; wireless technologies, telemetry networking, and spectrum management. The idea therein is to maximize efficiency within the legacy use of the RF spectrum, while improving the utilization of this constrained resource with technology investment. Much of this work requires leveraging commercial technologies/trends and applying these technologies to the dynamic test environment problem space.

I. Introduction

For decades the Department of Defense has had access to portions of the Radio Frequency spectrum as a dedicated resource to use or not use as required. As weapon system complexity has increased the need for additional real-time data (RF bandwidth) continues to increase; in an environment of ever shrinking DoD spectral resources (as shown in figure 1). The Presidential Memorandum titled "Unleashing of the Wireless Broadband Revolution" outlines the coordinated efforts within the Federal Government (Federal Communications Commission (FCC), National Telecommunications and Information Administration (NTIA)) to identify and

free up 500 MHz of wireless spectrum to support next generation wireless services [1]. Targets of opportunity for the spectrum sell off or repurposing as it is sometimes referred are the DoD Test and Training RF resources, e.g. 1755MHz- 1850MHz used for Air Mobile Telemetry [2].

The FCC's National Broadband Plan sets forth two primary goals and objectives:
1. Affordability of and Accessibility to High Capacity Fixed Broadband
   - By 2015, at least 100 million households should have affordable access to actual download speeds of at least 50 Mbps and actual upload speeds of 20 Mbps
   - By 2020 at least 100 million households should have such affordable access to actual download speeds of 100 Mbps and actual upload speeds of 50 Mbps.
2. U.S. Should Lead the World in Mobile Innovation
   - 300 MHz of newly available spectrum by 2015
   - Total of 500 MHz of newly available spectrum by 2020 [3]

Preparing the DoD enterprise for the future we must consider the dedicated spectrum resources like never before; a shared resource with industry. As the demand for more and more wireless spectrum increases, there is a resounding need to bring efficiencies to the government business model for weapons system testing. With the need for additional RF spectrum increasing within the DoD and the realism of shrinking budgets, the services are being forced to re-evaluate the dedicated RF resource utilization.

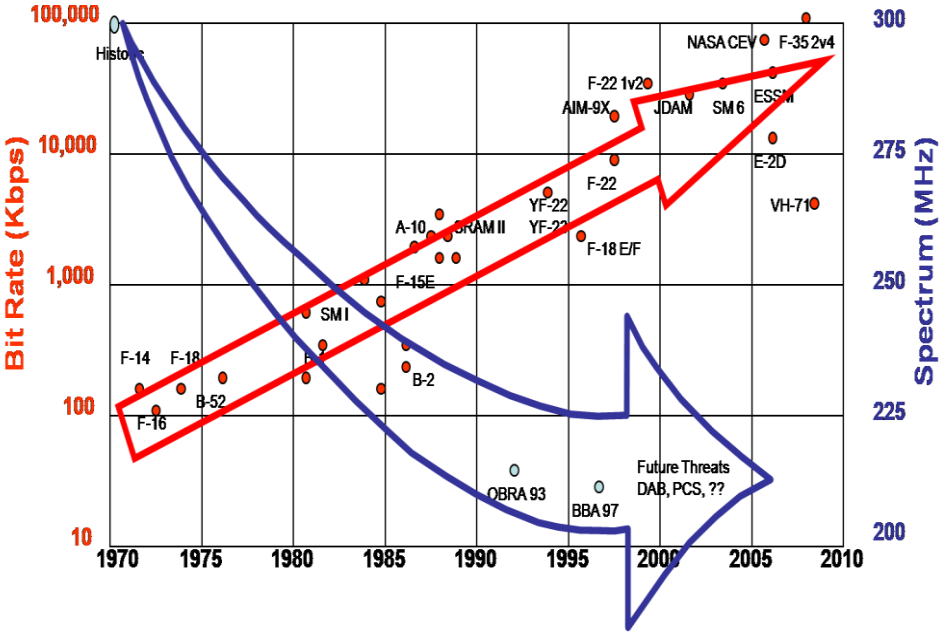

Figure 1: Real-time Data Rates versus Spectrum Availability

II. **Background**

The beginning of the Spectrum Efficient Test Technology Area dates back to the formulation of the Test and Evaluation Science and Technology Program. The DoD established the T&E/S&T program in 2002 to develop new technologies and processes for future T&E requirements as well as to expedite the transition of new technologies from the laboratory environment to the T&E

community. The T&E/S&T Program is a *6.3* advanced technology development program that matures applicable *6.2* applied research from DoD Service Laboratories and Test Centers, industry, and academia to provide new capabilities required for the testing of future weapon systems [4]. The T&E S&T program moved under Test Resource Management Center in 2005 to balance their ongoing mission activities. The TRMC mission is to plan for and assess the adequacy of the Major Range and Test Facility Bases (MRTFB) to provide adequate testing in support of development, acquisition, fielding, and sustainment of defense systems; and, maintain awareness of other T&E facilities and resources, within and outside the Department, and their impacts on DoD requirements [5].

As an integral piece of the TRMC portfolio the T&E S&T program objectives complement a sister joint investment program for capability developments, the Central Test & Evaluation Investment Program (CTEIP). Technology maturation under the T&E S&T program provides a logical path for a synergy of aligned investment to reduce risk within the CTEIP 6.4 budget activity. The T&E S&T's mission is to investigate and develop new technologies required to test and evaluate our transforming military capabilities. This includes any system that makes our war fighters more survivable and effective in combat. Additionally, maturing test technologies from Technology Readiness Level 3 to 6 (description in figure 2) for follow on to either CTEIP or an MRTFB T&E need.

As one of eight active TTA's within the T&E S&T program portfolio, SET's mission is to investigate, develop, and mature technologies to optimize the utilization of the DoD spectrum resource for Test and Evaluation. The SET program office is headed up out of the Air Force Flight Test Center (AFFTC), Edwards Air Force Base, California. The SET is one of two Test Technology Areas managed by the Air Force and a primary motivation for the location is the proximity of past and present activity in spectrum and network telemetry efforts. One of those efforts is the integrated Network Enhanced Telemetry (iNET) program, a current CTEIP effort that is in the midst of establishing the first network enabled communications link between the ground and the airborne test platform. The collaborative efforts between SET's technology maturation / risk reduction work and iNET's capability development work showcases the synergy between the T&E S&T program and CTEIP.

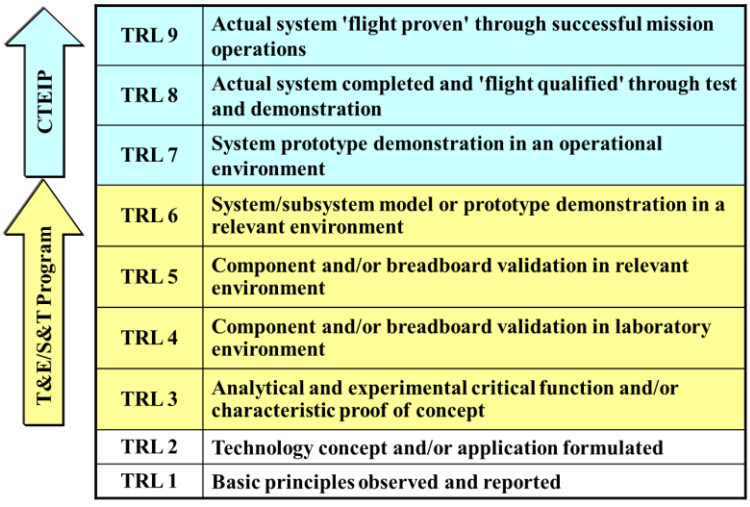

Figure 2: Technology Readiness Levels

III. Technology Development Methodology

To better understand the specific challenges of the DoD test environment in addition to the constraints that are actively being pursued by the private sector, the needs of the T&E Community must be gathered, analyzed, and addressed. As with the other Test Technology Areas, SET works collaboratively with the Services and DoD to make certain that the relevant T&E needs and technology challenges are being addressed. The process to meet future spectrum needs is continuously being re-evaluated to ensure development of new technologies maintains the required test infrastructure to "keep pace" with our evolving military capabilities.

Addressing Tri-Service Needs within the Scope of Spectrum

The overarching T&E need for SET is to develop technologies and techniques to more effectively utilize the available RF spectrum within the confines of test. Additionally to reduce the dependence on the currently defined and constrained RF resource identified as the DoD spectrum allocations.

From a project perspective the best approach to attaining these very generic goals is to separate the need into attainable, workable units. These workable units are better known as technology domains across the T&E S&T portfolio. For Spectrum Efficient Technology the domains are: Wireless Technologies, Network Telemetry and Spectrum Management. Later in the discussion these domains will be addressed in more detail but at present it is important to show the relationship T&E needs and the SET Domain Areas. As the needs stand today they are broken down into the three domains areas and overlap of the needs will occur between areas. The needs represented below were identified in the 161 use cases put together via the Common Test and Training Range Architecture (CTTRA) workshop held in November 2003 [6]. Additionally these needs were vetted through the Tri-Service working group that develops the Spectrum Efficient Technology Roadmap as well as the topics for spectrum technology development.

1. Wireless Technology Needs – The ability to support desired number of simultaneous test participants, and concurrent tests at ever increasing bitrates with the same RF resources.
    I. Need to support increasing data rates and link performance
    II. Need to support multiple test participants simultaneously
    III. Need to support multiple concurrent tests
    IV. Need for increased data quality in challenging environments
2. Telemetry Network Needs – The current Serial Streaming Telemetry paradigm doesn't have the capability for uplink or the ability to change the static data format onboard test article.
    I. Need for more flexible telemetry infrastructure
    II. Need for communications optimized for the TM environment
    III. Need for improved data transmission paradigms
3. Spectrum Management Needs – The current spectrum scheduling methods are not agile enough to support dynamic T&E environments.
    I. Need for solutions for spectrum and access management
    II. Need for solutions for management of the telemetry network infrastructure
    III. Need for management of telemetry network performance
    IV. Need for unified management tools for data and spectral resources

Technology Domains

Within the SET project construct there are the three domain areas as previously described; Wireless Technologies, Network Telemetry, and Spectrum Management. To retain the ability to test in this rapidly changing environment SET must prove out innovative alternatives to legacy systems and methodologies. To accomplish this, "game changing" technologies and approaches must be introduced within all of the domains. However the wireless technologies domain shows more promise for accomplishing the advancement of the more bits per hertz.
Within SET, the Wireless Technology Domain is defined as the investigation of improvements into RF technologies; modulations and waveforms, RF hardware components, improved access techniques and alternative wireless technologies that leverage spectrum not currently used for telemetry.

The areas of investigation and investment include but are not limited to the advancement in legacy link performance and advanced data transmission techniques. Based on the maturity of technology, RF spectrum areas such as the Super High Frequency above 15 Gigahertz (GHz) is a logical next step. Promising areas for development and demonstration with the least amount of technology maturation specifically target the 27 GHz. frequency ranges. Additional investment into Free Space Optics communication for the test community is also encouraged and continuing to lessen the demand for radio frequency spectrum.

As with wireless technologies the Telemetry Network Technology Domain provides for promising efficiency gains by developing commercially available technologies and tailoring them to the dynamic test environment. Several prominent areas for focus are; protocol development, distributed infrastructure methodologies and data access techniques that enable flexibility in telemetry communications. This domain primarily targets the current iNET network architecture approach of "hub and spoke. However much of the future development will be in advancing the next generation of telemetry networks into a combined environment using Mobile Ad-hoc Network (MANET) techniques.

One legacy test system that is overdue for a change is the test communities approach to wireless data communication using serial streaming telemetry. Telemetry is without doubt a target of opportunity when it comes to technology investment, due primarily to its inherently spectral inefficient nature. Thanks to the ground breaking work that has been underway over the past several years with iNET, SET has the opportunity to focus on additional difficult challenges with respect to furthering the future of network telemetry. Several of these challenges are expressly targeted at the network environment and the collaboration between the Services applications for the test & training environments. These investigations and investments into solving network related issues within a dynamic telemetry mission scenario will provide additional insight into techniques for handling other less complex test data types.

The last area identified within the spectrum domain is improvement using robust, automated management techniques that will allow a more effective/ efficient utilization of the required RF spectrum. As defined by SET the Spectrum Management Domain developing tools to provide

flexible and agile access to spectrum, enabling management of telemetry network resources, test planning and system performance. The idea of management techniques to enable significant efficiencies for the spectrum environment is not new. The MRTFBs have recognized the shortfall in the manually intensive frequency scheduling and allocation process that is the test business paradigm.

Case in point, Patuxent River Naval Air Station has begun discussions with one of SET's principle investigators to continue development of a tool to meet the next generation frequency needs of the Navy. The Spectrum Management System (SMS) is in its final phase geared toward implementation and will be focused on the integration and demonstration into the relevant test environment. The technology provided by SMS uses additional information prior to developing the daily or weekly frequency map including; geographic location, RF characteristics and flight plan to establish a feasible frequency use / reuse plan in near real-time.

Roadmap development

SET's Roadmap identifies a time phased technology development plan that using the domains discussed earlier (Figure 3). Roadmap development based on needs is a fairly straightforward process; the challenge is understanding the gaps that are not addressed in the technology development. Based on this primary concern the SET team formulated a plan to reinvent the Spectrum Efficient Technology Roadmap. To attack this issue head on first, the problem space had to be well understood. Comprehending the operational context of today's test environment is crucial and what will the operational concept look like in the future. The development of today and tomorrow's ConOps coupled with the T&E needs began to identify holes in the domain areas. Additional decomposition using the objective tree method began filling the holes within the technology development for answering specific needs. Several ideas stood out at this point that needed an answer:

What is the overarching vision of Spectrum Efficient Technology?

> Is it a number, how efficient? Is it a technology goal? Or is it just a common sense approach to a problem, using a sensible proven technological methodology?

How can we achieve this goal or vision given budgetary and time constraints?

> Before addressing the questions posed, one other piece of the overall technology development process requires a brief description. Then and only then during the vision description will an attempt be made to formulate and answer.

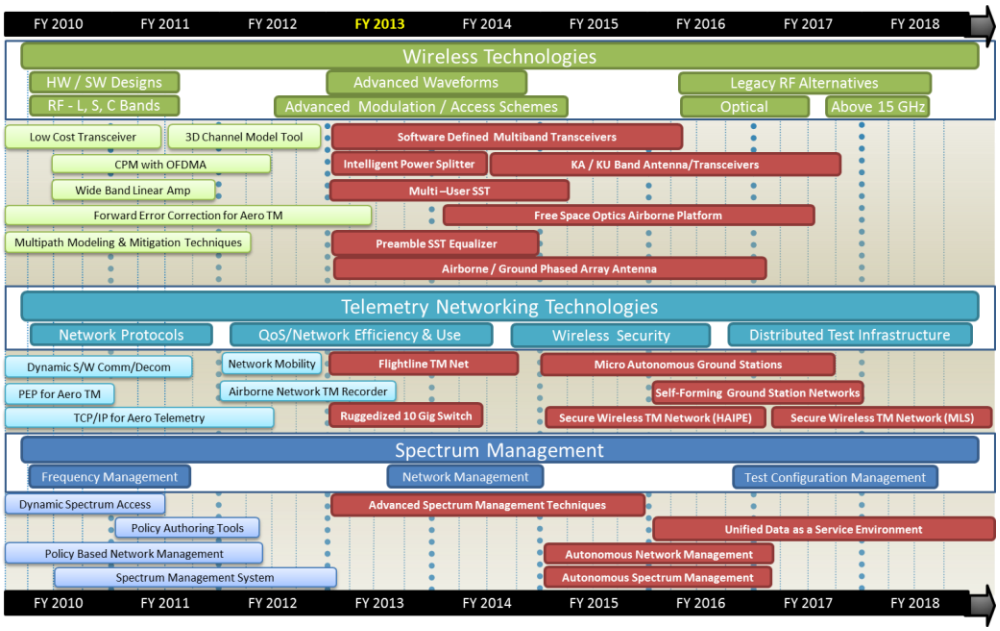

Figure 3: Spectrum Efficient Technology Roadmap

BAA Process

The Broad Agency Announcement process is much like a Request For Proposal process only less formal, without an in depth specification. Less like an acquisition, this process describes several or many general technology topics of interest, in search of a solution. T&E needs drive the process; these needs are developed through various events that roll up into a validated list of prioritized needs. These needs are derived from various DoD sources, such as the DoD Strategic Plan, the S&T Tri-Service Reliance Panel and other sources such as the SET Tri-Service technical working group. With that information SET formulates and publishes topics for which proposals are submitted by parties in industry, academia, and government. Eventually we enter into contracts with selected technologists for carrying out specific projects to meet the identified T&E need (as depicted in Figure 4). Simplistic as this process appears on the surface, it is a process full of rigor and validation ensuring successful S&T project contract awards that takes nearly a year to complete.

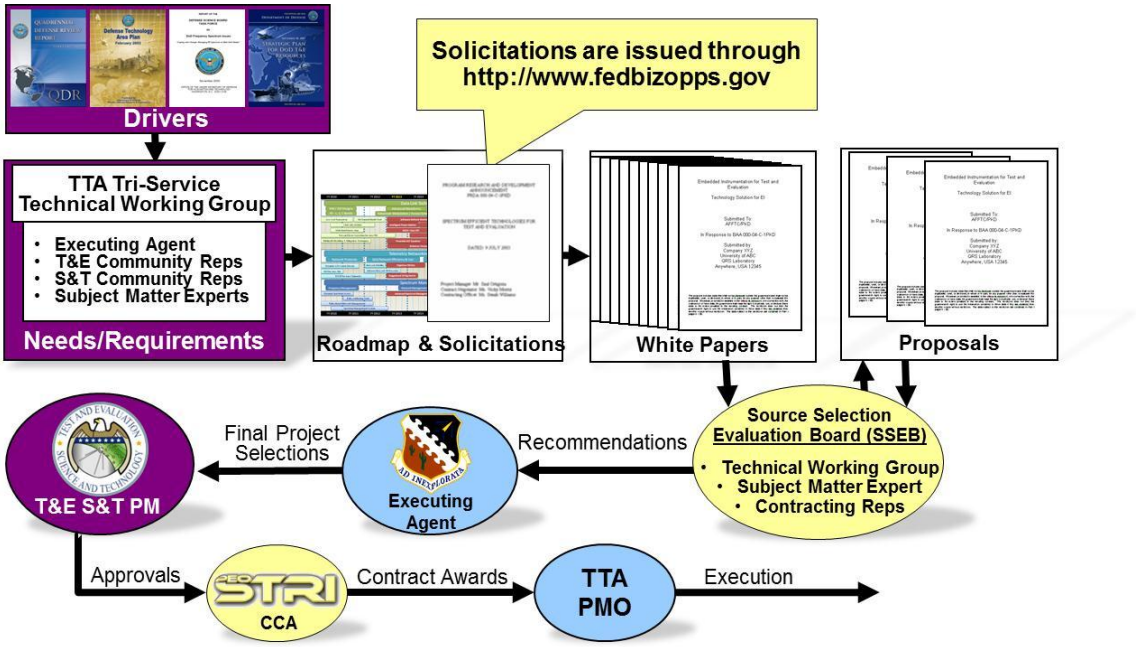

Figure 4: Broad Agency Announcement Process

IV. Vision

The challenge for the vision is developing an approach that flows into a time phased investment strategy providing a cohesive plan for the path forward for Spectrum Efficient Technology. SETs vision requires characteristics that are far reaching yet attainable and must fit within the scope of spectrum efficiency. To realize SET's long term vision of "Seamless Range Communications", as depicted in Figure 5, many of the enabling technologies surrounding the vision must first be met. "Seamless Range Communications" represents the ability of a test article to communicate with its environment (e.g. other vehicles, ground networks, airborne networks) and have the ability to move from one range complex to another seamlessly. This is the sensible approach referred to under the roadmap development area, using a similar methodology to the cellular technology and applying it to the dynamic test environment. Instead of meeting a goal of producing a certain percentage of efficiency, it is more logical approach to re-use a mature technology for the test application and create a more efficient use of the spectrum resource across the board. With the technology development domains that have been created to tackle these spectrum issues, SET endeavors to work towards this end through improved management tools, a flexible TM framework, improved wireless performance.

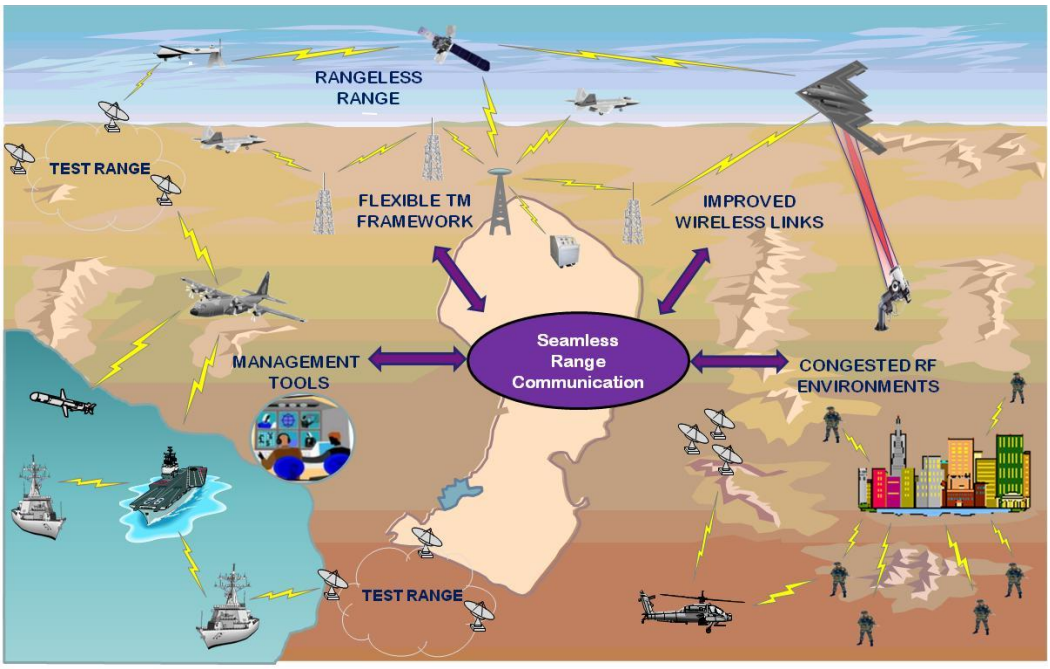

Figure 5: Vision Graphic

V. Conclusion

Thus in recognition of these challenging dynamics, we the test community must invest in methods to better utilize our limited physical allocations in the RF environment. To enable the MRTFBs to attain this objective the DoD empowered the Test Resource Management Center to aid in identifying and building a solid, supportable test infrastructure. The mission of SET remains to investigate/ mature technologies to optimize the usage of spectrum used for Test and Evaluation. To accomplish this SET develops new technologies required to either reduce risk within a capability or provide technology development for a follow on capability. The goal is to ensure we the test community "keeps pace" with our evolving military weapons system developments. RF spectrum is one of the test community's most valuable resources and without RF allocations open air testing could not be accomplished. As the DoD, we must use this precious resource wisely and more efficiently because one day we will find ourselves directly conflicted with the public for spectrum utilization.

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