SOFTWARE DEFINED RADIO SOLUTIONS

Commercial Solution "Eyes on Target" for taking JTRS to the Battlefield and in support of Homeland Security Applications

Mark R. Turner (Harris Corporation, Rochester New York; e-mail: mark.turner@harris.com)

ABSTRACT

The Joint Tactical Radio System (JTRS) Program continues to be a key U.S. Defense Department-wide transformational program with the purpose of supporting the U.S. DoD objective for information superiority on the battlefield. JTRS is a driving force behind the advancement of military Software Defined Radio (SDR) solutions and associated technology to meet the growing demand of war-fighters' communications needs, including: voice, data and video. The JTRS Software Communications Architecture (SCA) [1] continues to mature through specification evolution, the testing and certification of multiple implementations and recently with the release of a set of Application Programming Interface (API) definitions.

This paper discusses the changing objectives of the JTRS Program to an "Enterprise Business Model" with the intention to maximize competition and increase industry accountability. A commercial development approach to JTRS that meets these challenging objectives will be described, which includes the deployment of thousands of Harris Hand-held radios with the only JTRS Information Repository waveforms and Cryptographic Equipment Applications (CEAs) operating in the Battlefield today.

The Harris AN/PRC-152 Hand-held radio is National Security Agency (NSA) Type 1 certified [1] and "certified SCA compliant" without waivers by the JTRS JPEO [2]. Harris has developed an SCA based Project 25 Waveform for the AN/PRC-152 (C) Hand-held radio to support interoperability between the military and various first responders in support of multi-organization responses to such events as Hurricane disaster relief.

In addition, as militaries move towards network centric operations and the proliferation of situational data on the battlefield, the development of networking waveforms to support these capabilities has become a significant area of technological investment. This paper offers a practical view of solutions for the "Last Tactical Mile" within the context of JTRS Wireless Tactical Networking Vision. These solutions discussed will include heterogeneous, high assurance, EIP (Everything IP) networking waveforms, with scalable capabilities including: true multi-talker voice communications and coalition solutions.

1. INTRODUCTION

"JTRS Program - A Story of Evolution and Change"

The overall purpose of the JTRS Program to contribute enabling technology for information superiority on the battlefield remains unchanged, the objectives of the JTRS Program have evolved significantly from initial Program inception. The following summarizes current, key JTRS Program objectives:

1. Increased focus on transformational communications (i.e., networking) in support of growing war-fighter needs for data (i.e., in support of situational awareness applications).
2. A subset of current force communications, reducing breadth of demand for legacy interoperability.
3. An "Enterprise Business Model" that emphasizes product development in the context of a cohesive systems engineering view of the JTRS application space.
4. Evolutionary acquisition, providing incremental capabilities to the war-fighter over time, as opposed to trying to provide most capabilities as quickly as possible.
5. Reduction in the number of form factors or types of platforms from 26 down to 13.

Even with incorporation of these significant changes to the JTRS Program objectives, several key characteristics of JTRS do remain the same today, including:

- Broad frequency spectrum coverage (2 MHz – 2GHz).
- Multiple, simultaneous channel operations with re-transmission across bands and waveforms.
- Programmable Information Security (INFOSEC) in accordance with NSA Cryptographic Modernization Program requirements.
- Portability of waveform applications software across radio domains and platforms.
- Scalable solutions to enable additional future capacity in conjunction with modular and pluggable technology insertion.

2. JTRS ENTERPRISE BUSINESS MODEL

"A Product Line approach to JTRS"

The "Enterprise Business Model" is a significant change from the original structure of the JTRS Program and is intended to maximize competition in order to provide lower cost and better product availability to the Government. In addition, the Enterprise Business Model is anticipated to facilitate greater industry accountability, such as what capabilities can be provided to the Government when, and for what cost. There are two key underlying principles regarding the JTRS Enterprise Business Model, the first is that JTRS products shall be built on common standards and specifications (including both DoD and commercial standards), and the second principle is that in order to enhance the portability and reusability of JTRS software, an "open source" environment with Government Purpose Rights shall be utilized.

2.1. JTRS Information Repository

The "open source" environment defined by the JTRS "Enterprise Business Model" is commonly referred to as the JTRS Information Repository (IR) and is intended to provide multiple, critical functions, including:

- Accessibility to approved JTRS documents for viewing and downloading. This includes specifications, such as the SCA specification [1] and API definitions [2], as well as software artifacts.
- Reference model implementations with software design documentation and specifications (i.e., representation of the base waveform).
- ALL ported implementations (i.e., target waveforms).
- Open Forum pages to facilitate online discussions.
- Tracker database to report and store comments, such as: software defects, support and feature requests
- General and project-specific news items.

The JTRS IR requires continued growth and evolution to provide the intended value, including establishment of operational policies and practices. Several questions will need to be addressed, including:

- Which organizations will be granted access to the contents of the JTRS IR and what, if any reciprocity will be required? Will access be different for different organizations?
- Will the JTRS IR include target implementations beyond waveform applications, and if so how will developer's Intellectual Property be accommodated?
- How will configuration management of target waveforms be handled? Will aspects of target implementations be merged back into reference or base waveform implementations?
- How will comments and requests for change be handled, equally from any submitting organization, weighted based on industry consensus, and/or driven by program priorities?

2.2. Software Communications Architecture

The SCA consists of a set of rules and protocols, which define a Common Open Standards Architecture for SCA applications. The JTRS SCA utilizes Component Based Development (CBD) technology, which promotes the advent of interchangeable software parts, built to predefined specifications. With respect to SDR solutions, the ability to reuse existing software components across multiple radio applications in an open framework, and the encapsulation of hardware specific capabilities and platform services through well-defined APIs are the lynchpins for facilitating true waveform portability, from practical application, affordability and time-to-market perspectives.

The software components which provide for the management and execution of SCA applications and devices comprise the SCA Operating Environment (OE). The SCA supports implementation of waveform application software that can be re-used or "ported" across multiple radio sets (platforms and/or form factors). A Board Support Package (BSP) binds the OE to specific radio set hardware. The OE and BSP can be considered "platform software", collectively providing an appropriate abstraction of the underlying radio set hardware implementation. Refer to Figure 2.2-1 for a high level block diagram of the SCA.

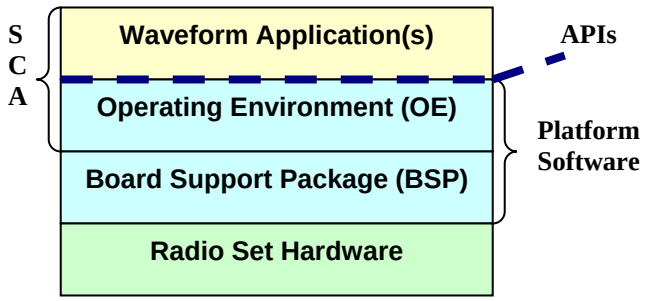

Figure 2.2-1 SCA High Level Block Diagram

In April 2007, the JTRS JPEO published the SCA API Release 1 suite of documents [5] that include a set of 15 specific API definitions, all approved for public release with unlimited distribution. These API definitions support several primitive platform interfaces including an Audio Port interface, a Serial Port interface, an Ethernet interface and a Vocoder service among others. Various

organizations, such as the SDR Forum are currently evaluating these APIs for potential broad applicability outside of the U. S. DoD arena. It is unclear at this time if the JTRS JPEO will accept or process comments/suggestions regarding these API definitions. This ambiguity must be resolved before widespread application of these APIs can be supported outside of DoD specific requirements.

2.3. SCA Compliance Testing

The JTRS Test and Evaluation Laboratory (JTeL) is responsible for providing development and test support for SCA compliance certification, specifically waveform application and Operating Environment testing for the JTRS JPEO based on JTRS standard APIs and SCA requirements. The JTEL generates test reports and recommendations of tested products to the JTRS JPEO for final determination.

SCA compliance testing involves verification of product compliance with operating environment requirements defined by the SCA specification (and ultimately the requirements associated with published APIs). This testing utilizes a combination of test methods to verify SCA requirements, including automated testing with the JTRS Test Application (JTAP) tool, manual code inspection and semi-automated testing. The SCA Compliance testing process and tools continue to mature and harden. A BETA version of the JTAP tool was released in August 2007 to support SCA v2.2.2. Additional policies, processes and practices are required for SCA compliance testing to accommodate future demands.

1. Will all software versions of JTRS capable radios be required to complete full SCA compliance testing before fielding (this is both a cost and timeliness concern). For example, maintenance versions of radio software released in support of production needs, which do not impact SCA requirements of the software baseline, will likely be numerous due to the rate of component obsolescence.
2. It is unclear what level of capacity can be provided by the JTEL in support of products developed under the JTRS Program, products developed outside of the JTRS Program for U.S. DoD application and all other SCA applications.
3. How many revisions of the SCA will be supported through JTEL testing? Limiting to only the current released version creates potential cost and timeliness issues for both the Government and industry.

The development of an SCA compliance testing strategy to address these and other issues is important to the successful adoption the SCA outside the JTRS Program. The SDR Forum is currently working on developing potential strategies, which may include self-certification and supporting certification for multiple versions of the SCA concurrently.

2.4. JTRS Radio Certification Business Model

In order to facilitate procurement and deployment of JTRS radio products, in January, 2007 the JTRS JPEO published a specific set of requirements to achieve JTRS radio product certification [3].

1. SCA certification as approved by the JTRS JPEO (with certification testing executed by the JTeL).
2. Utilization of software and artifacts from the JTRS Information Repository (IR) as defined above.
3. Adheres to the requirements specified by the NSA Unified INFOSEC Criteria (UIC) and JTRS security specifications.
4. Includes a programmable Cryptographic Subsystem.
5. Complies with all requirements defined in JTRS ORD 3.2.1, unless specific requirements are waived by the Government.
6. Software components developed under Government direction and expense are submitted to the JTRS IR with Government Purpose Rights.

3. JTRS VIA COMMERCIAL DEVELOPMENT

"Providing JTRS to the War-fighters today"

The JTRS program has a renewed focus on the use of an evolutionary acquisition approach, providing for multiple procurements with increasing capability and functionality over time. Through increasing degrees of interoperability, military communications will evolve from the current state of single-function legacy systems, to full integration of tactical radio communications across joint and coalition operations. Evolutionary acquisition is intended to allow the JTRS Program to keep pace with developing commercial technology, maintain required interoperability with existing communications networks and ultimately with the Global Information Grid (GiG). The open architecture nature of the SCA is intended to facilitate the development of JTRS capable radios through commercial innovation and investment. The development of JTRS capable radios through private industry investment can directly lower the Government System Design & Development (SD&D) costs, facilitate price competitiveness throughout the product life-cycle, stimulate continual technological advancement and ensure a high level of industry accountability.

Bringing essential radio communications capabilities to the field in the form of JTRS technology is a

measurable success for the updated objectives and principles behind the JTRS Program. Harris Corporation continues to be an active participant in multiple aspects of the JTRS Program, with diverse experience across several U.S. Government contracts. Harris has leveraged this Government Program experience with an unprecedented military SDR background to develop and deploy the first privately funded JTRS capable radios to the War-fighters.

3.1. Harris funded JTRS Hand-held Radio

Harris has strongly embraced the vision of JTRS, coupling broad technical knowledge and experience with significant private investment to develop highly capable and cost effective military SDR solutions for JTRS applications. The Harris AN/PRC-152 (C) Hand-held radio embodies these JTRS Program objectives and principles while maintaining focus on the needs and perspective of the War-fighter, where the emphasis is on capability, not technology. For example, the ability to communicate using multiple waveform applications provides mission flexibility as opposed to single dedicated capability legacy solutions. Interoperability, communications range and battery life performance are each viewed as significantly more important by the user community than abstract technical detail and data rights (i.e., Government Purpose Rights). The Harris AN/PRC-152 (C) Hand-held radio was first delivered to the U.S. Army in October 2005 and is widely deployed in U.S. DoD areas of operation around the world (refer to Figure 3.1-1).

Figure 3.1-1 AN/PRC-152

The AN/PRC-152 (C) has been developed by Harris as part of the Falcon® III radio family, a suite of JTRS capable tactical radios. The AN/PRC-152 (C) is an NSA certified Type 1 [1] secure military radio that initially operates in the 30 – 512 MHz frequency range and has both 5W and 50W transmit power out configurations. **Harris has delivered more than 16,000 AN/PRC-152 (C) Hand-held radios**. The AN/PRC-152 (C) Hand-held radio supports several key JTRS waveform applications, including:

- VHF/UHF LOS (AM/FM)
- HAVEQUICK
- SINCGARS ESIP
- Mil-Std-188-181B
- High Performance Waveform (HPW) - SATCOM
- COBRA transmit only personnel recovery waveform)
- APCO P25 (public safety waveform)

The AN/PRC-152 (C) Hand-held radio has a fully capable JTRS hardware architecture, including a Harris Sierra™ II based Cryptographic Subsystem that ensures the portability of JTRS IR waveform applications. The AN/PRC-152 (C) Hand-held radio completed certification by the National Security Agency (NSA) in August 2005, executed through a Commercial COMSEC Evaluation Program (CCEP) agreement [1]. All applicable Type 1 security requirements specified by the NSA UIC for JTRS were met by the AN/PRC-152 (C) Hand-held radio as well as the overall re-programmable security objectives of the NSA Cryptographic Modernization program.

3.2. SCA Operating Environment Certification

The AN/PRC-152 (C) Hand-held radio successfully completed SCA Compliance testing by the JTeL and received formal notification on July 12, 2007 from the JTRS JPEO, that the AN/PRC-152 Operating Environment is certified as "SCA Compliant to SCA v2.2 [2]. The AN/PRC-152 (C) Hand-held radio is the first and only platform to be certified SCA compliant without waivers.

Initial SCA certification for the AN/PRC-152 was completed in July of 2006 [3], with waivers for 14 of the 735 SCA v2.2 requirements, where 12 of these items were related to the same topic area of SCA device launching. The Harris alternative SCA device launching implementation is a performance saving optimization and provided exactly the same results as usage of the standard implementation in a more direct and efficient manner. Note that device launching is only applicable at system startup time and has no impact on waveform application portability or operation, as confirmed in the JTEL test report. The remaining 2 waived requirements were considered extremely minor and in fact were removed from SCA v2.2.2. Harris updated the AN/PRC-152 Operating Environment for the requirements which received waivers and completed the subsequent testing with full compliance. In addition, radio startup performance was maintained due to other system initialization improvements.

3.3. Waveform Design, Porting and Performance

Harris is a highly experienced JTRS waveform application developer. The VHF/UHF LOS and HAVEQUICK waveform applications developed by Harris are the first and only JTRS Information Repository waveforms to be ported and fielded**.** These waveform applications were originally designed and developed by Harris in accordance with the waveform and radio form factor requirements established under the JTRS Ground

Mobile Radio (GMR) Program. Harris subsequently ported these two waveform applications to the AN/PRC-152 (C) Hand-held radio. Most of the scope of work to port these waveform applications to the AN/PRC-152 (C) Hand-held radio was due to the implementation of different APIs. The AN/PRC-152 (C) Hand-held radio APIs were optimized to support specific radio form factor performance requirements (i.e., power-on time, waveform switching time, battery life).

Harris also employed a "right size" waveform design concept to target the performance and memory footprint requirements of the smallest, and most processing disadvantaged radio form factor (in this case a Hand-held radio form factor). "Right size" waveform design is intended to ensure that the waveform application will be readily portable to the smallest common denominator platform and can be easily "scaled up" to more capable platforms. "Right size" waveform design includes a combination of multiple design and analysis techniques, including: component granularity, performance and data flow allocation. Without the use a "right size" waveform application design concept it could be extremely difficult and costly to port a developed waveform application to a small platform ("scaling- down").

It is essential that waveform application implementations are capable of meeting all waveform performance specifications and real-life expectations (i.e., range, jamming, co-site interference). Harris carefully developed and tested all SCA waveform applications for the Falcon III family. Measurements were captured and reviewed throughout the development process to ensure key performance standards were achievable. The AN/PRC-152 (C) Hand-held radio was tested in real-life conditions against standard Combat Net Radio performance parameters (i.e., jamming scenarios, co-site interference, and battery life) with comparable or better performance. In addition, the AN/PRC-152 (C) Hand-held radio powers up to a usable state (able to communicate) within 30 seconds and is able to switch between installed waveform applications (i.e., VULOS to HAVEQUICK) within 5 seconds.

3.4. Homeland Security Applications

Harris continues to develop new waveform applications for the AN/PRC-152 (C) Hand-held radio. An SCA version of the APCO P25 mobile subscriber waveform was developed by Harris and is a currently available product feature. The P25 is the standard for digital Land Mobile Radio devices, specifically designed for federal, state and local communications interoperability The P25 standard is administered by the TIA standards committee TR-8. P25 defines a number of communications protocols that can be mixed or matched dependent on system configuration and user requirements, including: analog mode, conventional or trunked modes, secure or clear communications, voice and/or data.

The incorporation of the P25 waveform enables the AN/PRC-152(C) to interoperate with the commercially available APCO P25-based radios. The addition of the APCO P25 waveform to tactical radios enables military and agency users, including the National Guard and Reserves, the FBI, and FEMA, to communicate with first responders in support of Homeland security applications (i.e., terrorism, natural disasters). The AN/PRC-152(C) is the first military tactical radio to support the P25 waveform. The initial release of P25 in the AN/PRC-152 (C) includes the Common Air Interface, 25kHz analog mode and DES security. Future releases of P25 are planned to include trunked operations and additional security capabilities (i.e., AES and Type 1).

4. NET-CENTRIC OPERATIONS

"The last tactical mile through wideband networking"

As stated in [1] "JTRS is to contribute to DOD's goal of network centric warfare operations by introducing new wideband networking waveforms that dramatically increase the amount of data and speed at which data can be transmitted. As such, these waveforms would facilitate the use of maps, imagery and video to support the decision making of tactical commanders at all echelons."

4.1. JTRS Wireless Tactical Networking

The architectural vision for JTRS networking solutions includes integration across multiple heterogeneous networking environments, including: ground, air and space networks. Stub networks will be focused on end user applications, while transit networks will provide interconnection across multiple stub networks and into the GiG. There are several key characteristics associated with JTRS wireless networking, including:

- The common element of the networking waveforms will be the ability to pass Internet Protocol (IP) traffic, both in secure and un-secure environments.
- MANET protocols utilized to hide network mobility and dynamics
- Black IP routing capabilities to allow encrypted IP packets to traverse multiple RF subnets without intermediate decryption.
- HAIPE to provide high assurance data security across non-secure networks, also supporting encrypted traffic transfer at multiple security levels.

4.2. Advanced Networking Wideband Waveform

Harris has developed the Advanced Networking Wideband Waveform (ANW2) that is targeted as a potential solution for NATO, coalition and other international markets. The ANW2 is a self-synchronizing, Time Division Multiple Access (TDMA) waveform that does not require GPS to achieve synchronization. Full ad-hoc networking capabilities are utilized in ANW2, including: passive, pro-active and reactive protocols. An important feature of ANW2 is the incorporation of a dedicated digital voice interval for traditional Combat Net Radio and multi-talker voice capability (true party line).

Even though military communications are moving more and more towards the use of data, there will still be a significant need for on-demand, high-priority voice communications. Voice-over-IP (VOIP) solutions may someday accommodate this demand, however War-fighters need Push-to-Talk (PTT) solutions today and ANW2 ensures timely voice communications which meet current mission operations (in addition to IP data communications). The ANW2 utilizes a robust set of Signals in Space to accommodate real-world conditions, with bandwidths ranging between 500 KHz to 5 MHz, and on air rates of 20 Kbps to 10 Mbps. ANW2 has been designed to support secure communications using IPSEC or HAIPE (for high assurance) dependent on mission security requirements.

4.3. Wideband Networking Man-pack Radio

Harris is currently developing a Falcon® III Man-pack Radio (RF-7800D-MP) on private investment which supports a similar set of capabilities and narrowband waveforms as described for the AN/PRC-152 (C) Hand-held radio, as well as hardware and software architectures that support high-speed, wideband networking waveforms such as the ANW2 described above.

The RF-7800D-MP is a single channel, secure military radio that initially operates in frequency up to 2000 MHz with both 20W and 50W transmit power out configurations (refer to Figure 4.3-1). The RF-7800D-MP radio can support all of the same narrowband waveform applications as deployed on the AN/PRC-152 (C) Hand-held radio, plus ANW2 and other wideband waveforms when they become available. Harris has implemented an SCA version of the ANW2 on the RF-7800D-MP, demonstrating SCA based, wideband networking capabilities since the fall of 2005.

Figure 4.3-1 RF-7800D-MP Radio

5. CONCLUSIONS

"Take Away Messages"

- JTRS Program has incorporated significant changes to meet mission objectives, most notable utilization of an Enterprise Business Model which emphasizes standardization and open source software for Government use.
- Harris is a prominent player in the military SDR industry world-wide and a significant contributor to the JTRS Program, fielding JTRS capable radios through a commercial development model.
- More than 16,000 Harris Falcon® III AN/PRC-152 (C) Hand-held radios have been shipped to date, the **FIRST AND ONLY** JTRS capable radios to have completed full NSA Type 1 certification [1], received SCA certification with no waivers from the JTRS JPEO [2] and are deployed with ported JTRS Information Repository waveform applications. An impressive accomplishment since this radio was developed, certified and deployed at private expense.
- An SCA version of the P25 waveform has been developed by Harris for the AN/PRC-152 (C) Hand-held radio to facilitate interoperability between the military and first responders in support of Homeland security applications.
- Harris has developed the Advanced Networking Wideband Waveform (ANW2) in conjunction with the RF-300M man-pack radio capable of wideband networking communications.

6. REFERENCES

[1] Military & Aerospace Electronics, "Harris wins NSA certification for AN/PRC-152 software defined handheld radio", 25-Aug-2005.

[2] News Release – Harris Corporation, "Harris Corporation's Falcon III AN/PRC-152(C) Radio Receives Milestone Certification from JTRS Joint Program Executive Office", 5-September-2007.

[3] Microwave Journal, "Harris receives SCA certification for Falcon III AN/PRC-152", February 2007.

[4] JTRS Joint Program Executive Office, "Software Communications Architecture Specification", Version 2.2.2, 15-May-2006

[5] JTRS SCA API Definitions, Release 1, April 2007 http://sca.jpeojtrs.mil/downloads.asp?ID=apis

[6] JTRS Joint Program Executive Office, "JPEO JTRS Announces Business Model for Certifying JTRS Radios". JPEO-NR-2007-001. 16-Jan-2007.