

# SOFTWARE DEFINED RADIO SOLUTIONS

## Getting to JTRS compliant military SDRs and Beyond

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### ABSTRACT

The Joint Tactical Radio System (JTRS) Program is a key U.S. DoD transformational program with the purpose of supporting the U.S. DoD objective for information superiority on the battlefield. The JTRS Program is a driving force behind the advancement of U.S. Military Software Defined Radio (SDR) solutions and associated technology to meet today's and tomorrow's war-fighters' needs. Military SDR solutions are evolving towards JTRS compliance. This evolution requires continued maturation of the JTRS Software Communications Architecture (SCA) including the Operating Environment (OE) and definition of Application Programmer Interfaces (APIs), the development of standard waveform applications, and the incorporation of key technologies, such as programmable security. This paper discusses the some key objectives and issues with JTRS Program evolution to full compliance and beyond. In addition a description of JTRS security solutions with Sierra™ II is provided along with a summary description and final performance data for the Harris JTRS Step 2B program.

### 1. INTRODUCTION

#### “Harris – Broad JTRS Program Participation”

Harris Corporation is a participant in multiple aspects of the overall JTRS Program, with several U.S. Government contracts including: the Step 2B Program, the Cluster 1 Program, the AMF Program, the Cryptographic Equipment Application (CEA) Program and the SCA Technical Advisory Group (TAG). The JTRS Step 2B Program completed validation of the Software Communications Architecture (SCA) for battery-powered, Man-pack radio platforms using Harris Sierra™ II security technology. Harris Corporation is an integral member of the JTRS Cluster 1 Boeing Team, supporting development of the security architecture for the overall radio system, developing several key hardware Line Replaceable Units (LRUs) for the Cluster 1 JTR Set, developing the Cryptographic Subsystem (CSS) that uses Harris Sierra™ II security technology and also developing waveforms for the JTRS waveform repository. Harris Corporation is a major player on the Boeing AMF Team as the developer of elements of the Joint Tactical Radio (JTR) and RF distribution system for Maritime platforms. The JTRS CEA Program involves the development of software applications, which implement required modes of various

cryptographic equipments. The Harris developed CEAs are targeted for Sierra™ II based cryptographic systems (i.e., the JTRS Cluster 1 radio set). As a participant of the SCA TAG, Harris is supporting the JTRS SCA through technical analysis and evaluation.

### 2. JTRS PROGRAM

#### “Key objectives and associated issues”

The objective of the Joint Tactical Radio System Program is to define and acquire a family of multi-mode, multi-band, programmable SDRs to increase operational flexibility, enhance Joint and Coalition interoperability, and reduce life cycle cost. These radio systems will provide network-centric capabilities and enable mission flexibility for the DoD Joint Vision 2020. As stated in the JTRS Operational Requirements Document (ORD), JTRS is required to provide interoperability across all geographical and organizational boundaries – horizontal and vertical, so as to create an interoperable information transfer capability for Joint and Coalition operations. JTRS will be capable of transmitting voice, data, and video while operating in frequency bands from 2 MHz up to 55 GHz, satisfying ground tactical, maritime, airborne and space based communications requirements.

To facilitate the building of the JTRS family of radios, the JTRS Joint Program Office (JPO) tasked industry to develop and validate the SCA. The SCA consists of a set of rules and protocols, which define a Common Open Standards Architecture for SDR applications with the intent of making maximum use of commercial standards and APIs. This architecture supports implementation of SDR waveform applications and JTRS Set hardware that can be re-used or “ported” across multiple operational environments. Portability is an underlying tenet of JTRS and its development based on the SCA. Portability is intended reduce the cost associated with development of JTRS, since each waveform is built only once. Portability is intended to increase the interoperability among JTRS radio sets built by different vendors. The SCA is also intended to facilitate technology insertion into JTRS radio sets over the platform life cycle and leverage advances in commercial radio markets (i.e., cognitive radio technology).

## 2.1. JTRS Development and Acquisition – Support for commercially developed JTRS radios

The JTRS program is being implemented using an evolutionary acquisition approach. Evolutionary acquisition provides for multiple procurements with increasing capability and functionality during the life of the program. 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 evolving commercial technology and to maintain required interoperability with networks based on U.S. DoD Joint Tactical Architecture (JTA) and commercial standards.

U.S. DoD Service acquisition requirements for JTRS are grouped into common "clusters" based on similarity of requirements and required fielding schedules. The open architecture nature of the SCA facilitates the development of JTRS radios through commercial innovation and investment. Stimulation of commercial investment for the development of JTRS radios directly saves the Government System Design & Development (SD&D) costs, ensures price competitiveness and continual technological advancement. While the specific acquisition model for the procurement of JTRS radios developed using commercial investment has not been formally published, it is clear that the DoD supports this approach through acceptance of SCA OE compliance testing of commercially developed JTRS radio sets by the JTRS JPO at the JTRS Technology Laboratory (JTeL). **The JTRS Multi-band Handheld (MB HH) Radio commercially developed by Harris has been accepted by the JTRS JPO for JTRS OE SCA compliance testing** (refer to Figure 2.1-2). The Harris JTRS MB HH radio is a Type 1 secure military radio that initially operates in the 30 – 512 MHz frequency range and supports several key JTRS waveforms, including: V/U LOS, HAVEQUICK I/II, SINCGARS and COBRA. The Harris MB HH radio has a fully capable JTRS architecture that ensures the portability of JTRS repository waveforms targeted for the HH radio domain. The Harris MB HH radio is being evaluated for Type 1 security requirements compliance by the National Security Agency (NSA)



Figure 2.1-1  
JTRS Hand-held Radio

through a Commercial COMSEC Evaluation Program (CCEP) agreement.

## 2.2. What makes a radio JTRS compliant?

There are several key aspects regarding radio sets and JTRS compliance, including: JTRS ORD compliance, JTRS repository waveform porting compliance and JTRS OE SCA compliance. The JTeL is tasked by the JTRS JPO to provide multiple JTRS related compliance services and also serves as the repository of all SCA-certified JTRS waveforms. Specific JTeL SCA compliance services include:

- JTRS waveform acceptance and SCA-compliance recommendations.
- JTRS OE SCA-compliance recommendations.

JTRS ORD Compliance involves satisfying specified radio set requirements for a given radio domain. A radio set that is verified to meet ALL specified JTRS ORD requirements, and has passed all associated certifications (i.e., security, waveform interoperability, SCA compliance) can be defined as fully JTRS ORD compliant. Radio sets that meet some or most of the specified requirements in the JTRS ORD are not fully JTRS ORD compliant, until such time ALL of these requirements are satisfied. The documented JTRS Program objectives for evolutionary acquisition support the notion of partial JTRS ORD compliance on the path to full JTRS ORD compliance. It is reasonable to expect that partial JTRS ORD compliance with an evolution to full compliance would apply to all JTRS radio developments, whether Government or commercially funded. It is critical to future JTRS success that a clear policy is established regarding the acceptability of evolutionary acquisition for commercially funded JTRS radio platforms.

JTRS Waveform Porting Compliance involves “porting” waveforms from the JTRS waveform repository to JTRS SCA OE compliant radio sets by radio set providers. Radio sets with ported waveforms are then tested by the Joint Interoperability Test Center (JITC) for interoperability against specific waveform standards with legacy equipment. Until such time that standard JTRS waveforms are developed, certified and placed in the JTRS waveform repository, radio set developers must rely on other waveform implementations, which can vary from pure legacy implementations, to legacy implementations that have been updated to utilize a JTRS OE. JTRS SCA compliant radio sets that use legacy waveforms as an interim solution, should be designed to accept waveforms from the JTRS waveform repository in the future to truly be considered on the path to full JTRS ORD compliance.

Waveform porting complexity can vary dramatically, from minimal code changes to support unique platform capabilities, architectures and interfaces to almost complete re-writes of waveform application software. This can involve moving components designed and certified for execution on General Purpose Processors (GPPs) to Digital Signal Processors (DSPs) or Field Programmable Gate Arrays (FPGAs), or moving components across/within the Information Security (INFOSEC) boundary. As noted previously a key objective of JTRS is to use waveform porting to minimize development cost, but also as a means to ensure interoperability. The JTeL has developed plans to evaluate the portability and performance of waveform applications prior to acceptance into the JTRS waveform repository (refer to [2] and [3]). There are however, no specific requirements or guidelines for the level of acceptable modification to JTRS repository waveforms when porting to JTRS radio sets. A radio set provider could conceivably re-write a significant portion of a JTRS repository waveform code, even removing most of the interfaces with a JTRS SCA compliant OE and potentially be regarded as JTRS compliant. Radio set providers could also develop JTRS SCA compliant radios with hardware architectures that are not capable of executing JTRS repository waveforms without significant code modification or hardware modification. It is incumbent on the JTRS JPO to define criteria for acceptable porting levels to ensure that the key JTRS Program tenants of interoperability and low life cycle costs are achieved.

JTRS SCA Compliance involves verification that a radio set OE meets specified requirements of the JTRS SCA. The JTeL is responsible for performing OE SCA compliance testing on vendor radio sets as documented in [1]. The JTeL supports multiple models for conducting OE SCA compliance testing. All of these models rely on use of the JTRS Test Application (JTAP) software to validate compliance with operating system, middleware and Core Framework requirements of the SCA. The JTAP analyzes a radio set's OE against SCA defined interfaces and behaviors. Since standard implementations for radio services, devices and security APIs are not currently defined by the SCA, these elements cannot be tested for compliance at this time.

### **2.3. Applications Programmer's Interfaces – Real Standardization is Needed**

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, both from practical application and affordability perspectives. The standardization of SCA APIs is essential in order to meet this objective. Today the path to universal adoption of standard APIs for the JTRS SCA is unclear. The SCA API supplement as it exists today provides a framework for the development of APIs, but does not provide detailed API definitions required to ensure waveform application interoperability. The latest version of the JTRS SCA Specification [4] has expanded the interface framework to support the abstraction of software elements in both the DSP and FPGA domains. While this framework sets the stage for increasing the portability of lower level software elements, it also does not define specific interfaces for broad usage. The ongoing JTRS Cluster programs (i.e., JTRS Cluster 1, JTRS Cluster 2) are in a position where the radio service API definitions are being developed as part of these specific programs. API definitions range in complexity from straightforward voice digitization services to broad system configuration control services. Other JTRS cluster programs (i.e., Cluster 5) and commercial developments of JTRS radios will have to re-define and develop these APIs (which will likely be different than the set of APIs already in development on the aforementioned existing JTRS cluster programs). The result is that waveform portability is at risk, as the level of software modifications required to port waveforms across radio sets will be significantly higher than if all radio sets were being developed to a set of standard API definitions.

The Object Management Group (OMG) Software Based Communications (SBC) Domain Task Force (DTF) has put forward APIs as part of the Platform Independent Model and Platform Specific Model for SDR specification, however these APIs are not necessarily aligned with those being developed and used under current JTRS cluster programs. It is essential that radio service API definitions converge into published standards that can be applied consistently across JTRS radio developments, or the waveform portability and radio set interoperability objectives of the JTRS Program will not be achieved.

The JTRS JPO has defined an API standardization policy and process, where interested parties can submit candidate APIs for inclusion into the SCA. Unfortunately to date, this process has not resulted in the adoption or publishing of standard SCA APIs. Harris has submitted Input/Output Service Definition API to the JTRS JPO for consideration to be included in the SCA API supplement. Harris I/O API uses the SCA API Supplement building blocks and supports a VoiceDevice and a DataDevice that can be configured and enabled to support waveform

applications with simultaneous voice/data modes (i.e., Mil-Std-188-181B).

### 3. INFORMATION SECURITY SOLUTIONS

#### “Programmable security for SDRs”

Information Security (INFOSEC) is a key component to the success of the JTRS Program, including the development and deployment of a programmable INFOSEC module. Without a programmable INFOSEC module the flexibility and growth capability of a JTRS-compliant system will be limited by legacy cryptographic equipment or require expensive hardware upgrades. The rapid evolution of the Internet and advent of wireless networking is dictating the development of next-generation cryptography. The development and integration of programmable cryptographic modules will allow JTRS compliant radio sets to download new cryptographic algorithms and functions in conjunction with new or updated waveform capabilities.

#### 3.1. Sierra™ II SDR INFOSEC Solutions

The Harris Sierra™ II security devices are fully NSA certified for Type 1 operation and provide advanced INFOSEC solutions across all JTRS radio domains and for other applications. Harris Sierra™ II devices are small in size and are designed with a scalable, building block architecture based on the latest System-on-a-Chip (SoC) technology (refer to figure 3.1-1). This scalable architecture facilitates a combination of cryptographic and key management functions into a single chip or allocation of these functions across multiple chips for solutions, which require multiple levels of security. The Sierra™ II cryptographic functions include a broad set of capabilities, including: encryption and decryption, transmission security, authentication and integrity, certificate and policy management.



Figure 3.1-1 Sierra™ II

Sierra™ II devices provide an optimal combination of hardware and software components to maximize performance: including throughput and power utilization. The Sierra™ II device fully supports the demanding throughput performance and high assurance requirements of the JTRS Wideband Networking Waveform (WNW) as well as for high-band satellite data links. Sierra™ II devices employ chip level power

management, automatically disabling unused internal circuitry dependent on security channel configuration to minimize power consumption (not possible with software only security device implementations). The unique scalability of the Harris Sierra™ II architecture, make it the only INFOSEC solution able to meet the broad requirements across the diverse set of JTRS domains.

#### 3.2. Cryptographic Equipment Applications

A Cryptographic Equipment Applications (CEA) is Software Product Configuration Item that implements one or more operational modes of cryptographic equipment. CEAs are developed uniquely for a particular cryptographic hardware device (i.e., Sierra II). Harris is under contract with the JTRS JPO to develop a suite of CEAs for the JTRS JPO Library. Harris Sierra™ II software utilizes a modular, building block architecture, which facilitates the porting of CEAs across all JTRS radio domains and specific hardware platforms with minimal porting cost and time (refer to figure 3.2-1).

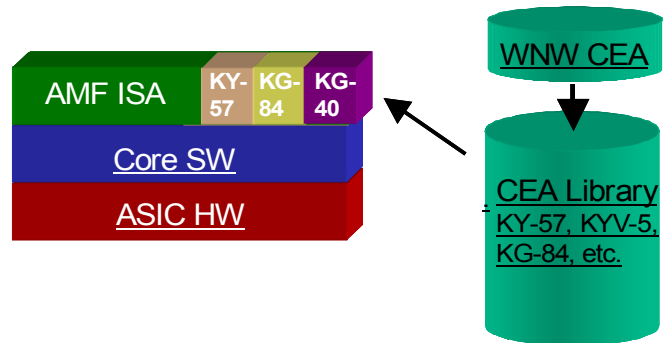


Figure 3.2-1 Sierra™ II Software Architecture

The lowest layer of the Sierra™ II software architecture consists of the essential software burned into the ASIC hardware. The next layer is the Core Software Application, which provides a set of essential services (operating environment) for CEAs, such as file services and key management. These first two layers of the Sierra™ II software architecture are certified by the NSA, in conjunction with the Sierra™ II ASIC hardware as basis for each individual host embedment to build upon. The Independent Software Application (ISA) layer supports platform specific hardware/software interfaces, which are unique for each host embedment. The CEAs required to support a waveform application and other radio platform functions are extracted from the JTRS JPO CEA Library and integrated with the platform specific ISA. The integrated ISA/CEA executable image is signed by NSA following the certification process and upon installation, is stored within a Sierra™ II based Cryptographic Subsystem (CSS) following signature authentication.

Harris has completed the software development of multiple CEAs, including: KG-84, KY57/58, KGV-8 (for the Link-16 waveform) and KGV-13 (for the EPLRS waveform). These CEAs have been delivered to the JTRS Cluster 1 Program for initial radio set integration and testing.

Sierra™ II meets the cryptographic requirements for U.S. DoD Type 1 IP network system solutions (such as the JTRS WNW noted previously). This includes support for systems that employ High Assurance Internet Protocol Interoperability Specification (HAIPIS) V1.3.5 and V2.0 capabilities. The next generation HAIPIS is evolving to meet additional needs including: bandwidth efficient requirements, error tolerant requirements, and foreign releasable requirements. Sierra™ II can be updated through software to support these new capabilities.

#### 4. HARRIS JTRS STEP 2B PROGRAM

##### “Final Results Summary”

The objective of the JTRS Step 2B Program awarded to Harris was to validate the SCA for man-portable, battery powered platforms. While these platforms are constrained by size, weight, and power, they often require increased performance for system turn-on time, system reconfiguration time and multi-channel operation. Harris completed final deliveries for the JTRS Step 2B Program in July 2004.

##### 4.1. Step 2B Program Approach

Harris performed SCA validation effort by building the JTRS Manpack Test-bed Radio (JMTR), which is a platform based on the AN/PRC-117F (C) Manpack Radio (refer to Figure 4.1-1). The JMTR is a single channel radio, which provides continuous, frequency spectrum coverage from 30 MHz to 512 MHz and multi-mode operations for both VHF/UHF LOS and BLOS UHF Tactical Satellite missions.



Figure 4.1-1 JMTR

For the Step 2B Program Harris built an SCA OE, including development of a Core Framework, platform devices and services, and two JTRS waveform applications. The OE and waveform applications were installed on the JMTR and presented to the JTRS JPO through a series of increasingly capable demonstrations. The JMTR platform was updated with new digital processing technology,

including Harris Sierra™ II devices in order to support full SCA V2.2 requirements.

##### 4.2. Step 2B Program Key Milestones

During the Step 2B Program, Harris completed the first ever over-the-air JTRS waveform demonstration with the JMTR in April 2001. This demonstration included successful VHF/UHF LOS digital voice communications between a JMTR and legacy radios. In June 2003, Harris demonstrated the first ever over-the-air JTRS SCA security supplement compliant secure communications. This demonstration used the VHF/UHF LOS waveform application with digital voice and KY-57 encryption, between the JMTR, a Harris JTRS MB HH radio and other secure legacy radios. In September 2003, a JMTR was delivered to the Government JTRS Test and Evaluation Laboratory (JTeL) for Government testing and evaluation. The JMTR platform was upgraded in July 2004 with a Sierra™ II based Crypto-Subsystem. Harris is currently in discussions with the JTeL regarding use of the JMTR as a representative hardware set.

##### 4.3. Step 2B Program Results and Observations

A series of validation tests were executed as part of the Harris Step 2B Program in order to measure and analyze the performance of the JMTR, as well as compare it to legacy systems. The following tables provide performance data collected during the Harris Step 2B Program, including INFOSEC. Note that since the JMTR was developed as a validation radio set, not all software efficiency and power management optimizations were implemented in this platform. Table 4.3-1 provides a summary comparison of various timing performance measurements between a legacy AN/PRC-117F (C) Manpack Radio, and the JMTR.

Table 4.3-1 Radio System Startup Time Comparisons

Timing Performance Item	JMTR	Legacy Radio
Power up to Application	22 secs	14 secs
Application switch time	7 secs	3 secs
Parameter change time	200 ms	< 100 ms
Rx/Tx turnaround time	28 ms	16 ms

Table 4.3-2 provides a timeline allocation of JMTR startup processing. Note that a significant amount of time is spent loading information from non-volatile storage to volatile storage.

Table 4.3-2 JMTR Startup Time Allocations

Startup Element	% of Time
Kernel loading	24%
Load drivers, FPGAs, flash file system	34%
Load CF/OE executables	30%
Launch CF/OE	12%
TOTAL	100%

Table 4.3-3 depicts comparison measurements for battery life between the JMTR and the legacy radio. Measurements were taken using an 8:1:1 duty cycle, between radio receive, transmit and idle states.

Table 4.3-3 Battery Life Comparison

Waveform characteristics	JMTR Battery Life relative to Legacy Radio
181B BLOS Application 56Kbps	95%
VHF/UHF LOS Application running FM Voice	99.6%

The SCA V2.2 compliant Core Framework developed by Harris was optimized for battery-powered platforms, and is referred to as CF-Lite. These optimizations conserve platform processing power and storage requirements, in order to reduce critical system power-up and application-switching times to field usable levels, while maintaining the integrity of waveform application interfaces (and therefore ensuring waveform portability). Power-up and application switch times, as well as memory storage capacities are significantly impacted by the use and performance of the eXtensible Markup Language (XML) to describe system and software component characteristics. XML files are parsed both at system start-up time and during the waveform instantiation process. The CF-Lite pre-parses XML inside the radio set on waveform application installation (local or over-the-air) and stores the information in a significantly more concise and efficient format, improving the performance of platform power-up and application switch times. Harris has submitted SCA Change Proposals (CPs) to the JTRS JPO that cover all optimizations related to the CF-Lite.

From Step 2B Program experience it is clear that optimizing software efficiency is essential to meet the challenging battery life and operational performance requirements of small JTRS radio sets (as well as for larger JTRS radio sets). While Moore’s Law provides benefits in

terms of increasing processing performance and packaging density, power utilization and thermal dissipation challenges are exacerbated by the former improvements. Refer to Figure 4.3-1 for a representation of processing performance demands across the evolution from legacy waveforms to SCA structured versions of legacy waveforms to new SCA waveforms (i.e., WNW).

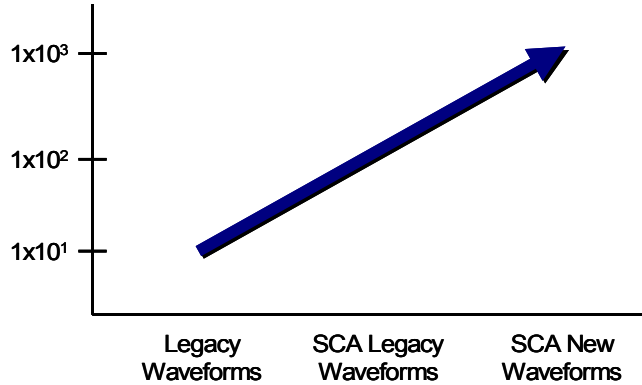


Figure 4.3-1 Waveform Processing Performance

## 5. CONCLUSIONS

### “Take Away Messages”

Harris is a prominent player in the military SDR industry, and significant contributor to the development of JTRS radio sets across multiple domains. Harris Sierra™ II provides fully capable, NSA certified, security solutions optimized for an unmatched combination of small size, high performance throughput (i.e., WNW) and power management. There are several key issues that need to be addressed for the JTRS Program to meet its key objectives of interoperability and life cycle cost savings. These issues include: formalizing an acquisition model for commercially developed JTRS radio sets, defining appropriate evolutionary levels of JTRS compliance, specifying waveform porting compliance requirements and JTRS SCA API standardization. Harris Corporation is committed to working with the U.S. DoD to address and resolve these issues ensuring the ultimate success of the JTRS Program and beyond for the development of future military SDRs.

## 6. REFERENCES

- [1] JTRS Technology Laboratory, “Operating Environment Test and Evaluation Plan”, Version 1.0, 17-September-2003.
- [2] JTRS Technology Laboratory, “Waveform Portability Assessment Plan”, Version 1.0, 17-September-2003.
- [3] JTRS Technology Laboratory, “Waveform Performance Assessment Plan”, Version 1.0, 17-September-2003.
- [4] JTRS Joint Program Office, “Software Communications Architecture Specification”, Version 3.0, 27-August-2004