Business Models for New Entrants in the SDR Tactical Radio Market

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Executive Summary

In order to make informed decisions, contractors, suppliers, module providers, and value chain stakeholders in the worldwide tactical radio communications ecosystem need to understand the various possible business models applicable to introducing SDR technologies in tactical communications programs. This report identifies various possible business models that could enable a successful new generation of tactical radio programs based on examples taken from existing programs.

This Market Report complements the first Market Report issued by the International Tactical Communications SIG from the Wireless Innovation Forum, in September 2011: "SDR Technologies for the International Tactical Radio Market" Document Reference WINNF-09-P-0006 V1.0.0[1].

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[1] Wireless Innovation Forum, "White Paper on SDR Technologies for the International Tactical Radio Market", http://groups.winnforum.org/d/do/4987

Business Models for New Entrants in the SDR Tactical Radio Market

1   Introduction

Software-Defined Radio (SDR) has been defined by the members of the Wireless Innovation Forum (SDR Forum version 2.0), working in cooperation with IEEE on the P1900.1 standard, as a collection of hardware and software technologies where some or all of the radio's operating functions (also referred to as physical layer processing) are implemented through modifiable software or firmware operating on programmable processing technologies[2].

A recent evaluation of tactical radio shipments shows that SDR has become a mainstream technology in defense communications, with more than 200,000 SDR-based tactical radios expected to ship in 2012, and expected to increase annually for at least the next three years (Figure 1).
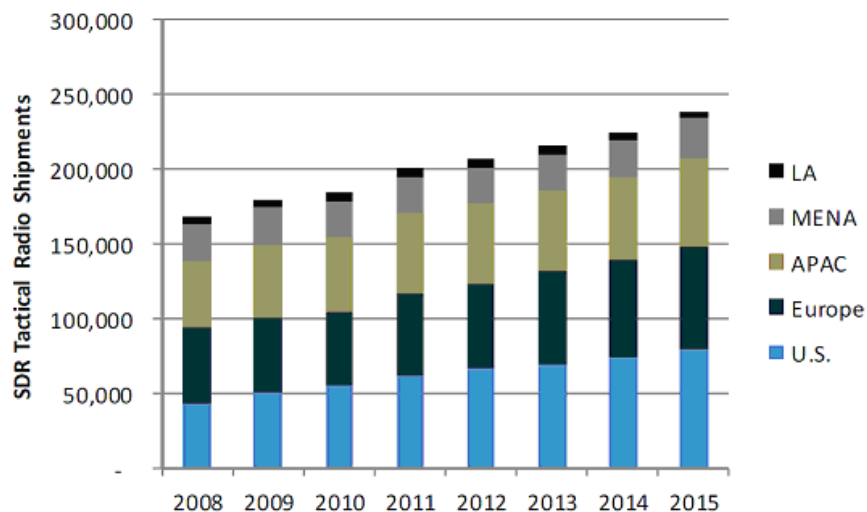
Figure 1: SDR Tactical Radio Shipments 2008 to 2015[3]

The success of SDR has been largely driven by manufacturers and government agencies worldwide that saw the promise of SDR and invested early in its development. Based on this success, a number of new organizations are now exploring the adoption of SDR technology. To support this second generation of SDR tactical radio market adoption, the members of the International Tactical Radio Special Interest Group (ITR-SIG) of the Wireless Innovation Forum have undertaken a project to explore possible business models that can be adopted by value chain stakeholders introducing SDR into their tactical communications programs. By capturing trends from existing programs and leveraging them into lessons learned, the document presents different business models available for international tactical SDR programs.

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[2] Wireless Innovation Forum, "Cognitive Radio Definitions," http://groups.winnforum.org/d/do/1585

[3] Mobile Experts and the Wireless Innovation Forum, "SDR Market Size Study", http://groups.winnforum.org/p/do/sd/sid=3155

Investment models followed by these programs separate into acquisition of the waveforms, acquisition of the radio platform, and integration of the waveform onto the platform for deployment. The models followed in each of these areas generally fall into one of three types:

- Development funded by the government: Under this model, the government procurement authority defines the requirements, selects a vendor to meet those requirements, and then takes the risk that the final products provided by that vendor fully meet operational needs.

- Industry development of Military Off-the-Shelf (MOTS) solutions: This model follows a commercial development cycle, with products developed at industry expense to address the requirements defined by the government. This model places most of the risk on the radio manufacturer, and this risk is compounded by the fact that the commercial model assumes that there are many customers and that vendors compete for market share; however, in the tactical radio market there might only be a single customer for a given product.

- Shared government/industry development: In this model, government and industry coinvest in development, allowing the risk to be shared between both parties. Many variations of this model exist. For example, in one model the government funds an independent waveform development program, with waveforms kept in a repository as Government Off-the-Shelf (GOTS) products to be ported to industry-developed radio platforms supplied separately.

2 SDR Tactical Radio Market Overview

2.1 Evolution in Tactical Communications is being driven by Command, Control, Communications, Computers and Intelligence (C4I) Applications

Evolving C4I requirements drive new networking communications trends. These requirements are a result of increasing diversity in operational situations supported by armies and other land forces; situations ranging from police type operations to high intensity conflicts which are then followed by peace keeping. These operations are often conducted in a combined and joint manner (e.g. joint forces, coalitions) with smaller, more agile forces operating in a very dispersed way.

Information superiority and situation awareness are now essential in modern operations facing uncertain enemies and to provide for friendly forces tracking and protection. Recent operations in various theaters such as Iraq, Afghanistan, Libya, Ivory Coast, and the Atalante operation in the East Africa maritime areas illustrate the diversity of operations required. In addition, fire support coordination requires now near real time information availability in utilizing increasingly complex weapons systems operating under the watchful eye of the media.

Army, Marines and other land forces are now organized, trained and equipped to face these various types of operations, including:

- Urban operation
- Harsh environments (Mountains, Jungle, Desert Areas etc..)
- Coalition forces
- Force projection
- Anti-terrorism and piracy
- Peacekeeping
- Civil protection and evacuation
- Territorial defence (e.g. Switzerland, India, South-Korea etc..)
- Border surveillance and control

These various types of operations, together with an Information Superiority requirement, necessitate new capabilities for tactical communications networking:
- Global connectivity and interoperability
  - All forces need to **share information**
  - Interoperability across **joint** operations (national, international)
  - **Seamless** connection of the various levels of deployed forces, **anywhere and at any time**
- From voice to data networking services
  - **Voice** at any point of the network
  - **Ubiquitous Data Services** providing messaging, chatting, file transfer, data base access and imaging services
- **End to End** services
  - Through **various bearers** and communications systems
  - **Quality of Service (QoS) management**, including near real time services
- Mobility
  - **On the Move** communications at the network (tactical) edge, quick halt and rapid deployment capabilities
- **Information Security & Availability**
  - Reliability of the network architecture
  - Electronic protected measures
  - Encryption

2.2   SDR Market Drivers

This evolution in tactical radio communications is introducing a number of drivers into global SDR programs:
- **Transition to Network Centric Operations (NCO):** NCO describes the introduction of High Data Rate services, full IP networking capabilities and new C4I applications at the tactical edge. The NCO transition applies to all echelons of the Armed Forces organization on the battlefield: from Soldiers and

Armored Fighting Vehicles up to Command Posts. The data throughput requirements in mobile environments to support the various data centric applications (e.g. imaging, sensing information, targeting information, real time situation awareness, battle field management systems, etc.) require a new generation of flexible communications capabilities. SDR technologies inherently provide the flexibility to support voice and various multimedia services on the same platform, and as such National and Regional tactical communication programs are working to define new generation SDR Platforms and Waveforms with a national/regional sovereignty target.

- **Interoperability Waveforms:** One of the key added values of SDR technology applied to the defense market is the capability to host on the same radio platform, several different waveforms. A direct application is obviously the possibility to host some waveforms that are common to different nations or to different units in a same nation armed forces. This is the concept of an interoperability waveform for joint or coalition forces. As a result of SDR, such Coalition Waveforms are beginning to emerge to improve interoperability at the international level on the battlefield.

The worldwide map (Figure 1) highlights this growing international market, driven by the US market programs:

- North-America
    - The US Department of Defense (DoD) precipitated the widespread application of SDR technology in defense communications through the launch of the Joint Tactical Radio System (JTRS) Program[4]. SDR technology has been at the forefront of US activities in Iraq and Afghanistan and with several NATO and coalition forces[5]. New generation waveforms are now becoming reality, and the US Armed Forces are engaging in several important acquisition programs for radios that can support these next generation waveforms and their related networking capabilities[6].

        Some important tests of these new communications capabilities, involve radios developed by privately by industry members as will as those coming from programs funded by the US DoD, are being evaluated by the US Military as part of a series of Network Integration Evaluations (NIE) which have been ongoing since 2011. The most recent of these NIE 13.1 was conducted during October and November 2012[7].

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[4] http://en.wikipedia.org/wiki/Software-defined_radio
[5] Military and Aerospace Electronics, "Software Defined Radio and the JTRS", December 2004, http://www.militaryaerospace.com/articles/print/volume-15/issue-12/features/special-report/software-defined-radio-and-jtrs.html
[6] JTNC, "Our Products", http://jtnc.mil/Pages/Products.aspx
[7] US Army, "Network Integration Evaluation (NIE)", http://www.bctmod.army.mil/nie_focus/index.html

- Canada has begun its Integrated Soldier System Project (ISSP)[8]. The goal of the ISSP is procure a lightweight integrated suite of state-of-the-art equipment for use by dismounted soldiers. The component parts will provide a number of capabilities to soldiers and their chain of command – fire team, assault group, section platoon and company. Key elements include: network-enabled communications for voice and data, orientation and navigational aids for complex terrain, an integrated power and data infrastructure, interface to sensors such as laser range finders and thermal imagers, visual and auditory displays, and digital maps. ISSP will provide integration of communications, command and situational awareness across the soldier network such a immediately available information on friendly force locations, enemy information, and near instantaneous target acquisition. Capabilities such as these require the application of SDR technologies.

- Europe, Middle East and Africa (EMEA)
  - In Europe, the European Secure Software Defined Radio (ESSOR) program was launched in 2009 to provide architecture of Software Defined Radio (SDR) for military purposes and a military High Data Waveform (HDR WF) compliant with such architecture, thus offering the normative referential required for development and production of software radios in Europe[9]. The ESSOR program is being supported by six nations: France, Italy, Spain, Sweden, Finland and Poland.
  - A new generation of national SDR programs have been launched in Sweden (GTRS Program), Germany (SVFuA Program), France (Scorpion and Contact Programs), Italy (Forza NEC program), Turkey and the UAE[10,11].
  - Other programs aiming to introduce some SDR capabilities together with NCO transition and new generation tactical communications systems include Switzerland, Netherlands, Denmark, Norway, Finland, and Poland.

- Asia Pacific
  - SDR programs are underway in South-Korea (TICN and TMMR Programs), Japan and Singapore
  - In India the armed forced have started some important NCO programs in all three armies (Army, Air Force, Navy)[12]. These NCO programs introduce for the associated communications some SDR capabilities.

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[8] National Defence and the Canadian Forces, "Integrated Soldier System Project", http://www.materiel.forces.gc.ca/en/issp.page
[9] OCCAR, "ESSOR: European Secure SOftware defined Radio", http://www.occar.int/36
[10] Proceedings of the 2011Wireless Innovation Forum European Conference on Communications Technologies and Software Defined Radio, http://groups.winnforum.org/p/cm/ld/fid=180
[11] Proceedings of the 2012 Wireless Innovation Forum European Conference on Communications Technologies and Software Defined Radio, http://groups.winnforum.org/e/in/m=1&req=Edit&eid=4
[12] Pucker and Renaudeau, "Conquering Radio Market Challenges", Military Embedded Systems, October 2012, "http://mil-embedded.com/articles/conquering-radio-market-challenges/
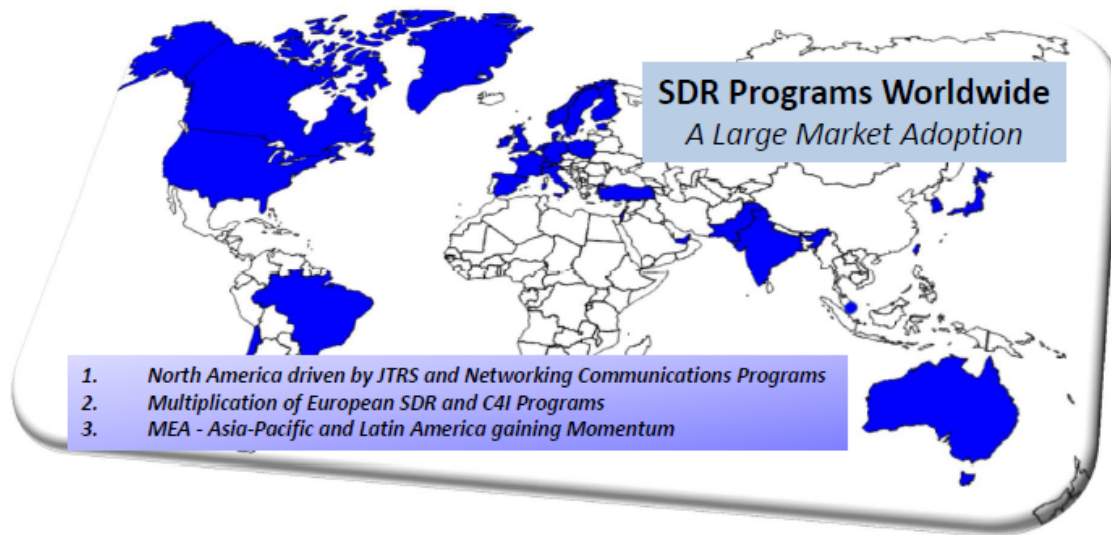
Figure 2: SDR Market is growing with multiplication of new generation tactical communications programs

The following section provides details on some of the programs mentioned above where information is publicly available. The programs are of different types and their business models may therefore differ. The different parameters to taken into account include:

- Waveforms to be utilized
  - Legacy Waveform porting to be included in the program
  - New Waveforms developments
  - Waveform Usage
    - For National usage
    - For Coalition Usage (waveform could be developed by different countries)
- Platforms
  - New Platform
  - Existing Platform

These parameters are supported by the business models presented in Section 1:

- Supply of MOTS (Military off-the-shelf) solution
- Complete development program funded by government and covering new platforms together with waveforms
- Waveform development program funded by government and aimed to be ported on platforms supplied separately

3   SDR Programs Descriptions

3.1   USA

3.1.1   JTRS Program: transition to JTNC

3.1.1.1   JTRS Program

Since its inception in early 1997, the Joint Tactical Radio System (JTRS) has evolved from a loosely associated group of radio replacement programs to an integrated effort to network multiple weapon system platforms and forward combat units where it matters most: at the last tactical mile. The program was ended on 30 September 2012 and transitioned to the Joint Tactical Networking Center (JTNC)[13].

Program Vision

By developing and implementing an open architecture of cutting-edge radio waveform technology, multiple radio types (e.g., handheld, ground-mobile, airborne, maritime) are now capable of communicating with one another. The ultimate goal was to produce a family of interoperable, modular, software-defined radios that operate as nodes in a network that provides secure wireless communication and networking services for mobile and fixed forces, consisting of U.S. Allies, joint and coalition partners, and in time, disaster response personnel.[14]

The JTRS Program effort was categorized in three main categories:

- Waveforms: Development of new ad-hoc networking waveforms and as well porting of legacy waveforms to ensure backwards compatibility.
- SDR Architecture Standard : Development of the SCA standard and associated APIs
- Platforms: Development and Procurement of SDR Platforms, including the Ground Mobile Radio (GMR) Platform and the Handheld, Manpack and Small Form Factor (HMS) platform.

Waveforms

A subprogram of the JTRS Program referred to as the Network Enterprise Domain (NED)[15] was responsible for delivering, maintaining, upgrading, and enhancing:

- Portable, interoperable, transformational networking waveforms
  - WNW : Wideband Networking Waveform
  - SRW : Soldier Radio Waveform
  - MUOS : Mobile User Objective System
- Legacy waveforms to maintain current force interoperability
  - Sincgars

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[13] http://jtnc.mil/Press%20Releases/JTNC_Release_001_Final.pdf
[14] JTNC, "Joint Tactical Networking Center", http://jtnc.mil/Pages/Home.aspx
[15] JTNC, "Our Products", http://jtnc.mil/Pages/Products.aspx

- UHF Satcom
- EPLRS
- HF
- Havequick II
- Link-16
- Cobra
- VHF and UHF LOS
- Bowman VHF

- Network management capabilities through management tools to configure and operate, in a single network vision, all the different waveforms.

Figure 3: An Adaptive & Joint Network at the Tactical Edge[16]

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[16] JTRS Presentation - Greater Los Angeles Chapter of the Association of the United States Army (GLAC-AUSA) Symposium - June 2011 - JPEO JTRS BG Michael Williamson,
http://www.ausaglac.org/files/PDF/Symposium2011/Symposium_Presentations/williamson.pdf

3.1.1.2   The JTRS Ground Mobile Radio (GMR) Program

The JTRS GMR Program was stopped in 2011 by a letter sent on 13rd October by US DOD to congress[17]. The immediate cause of the cancellation of this ambitious program (multiple channels, multiple legacy waveforms support, support of new waveforms such as SRW and WNW) indicated in the letter is the critical cost increase due to the reduction in quantity requirements from approximately 90,000 to 10,000 units. Some alternatives to this program of record are given in the documents, such as Non-Developmental Item strategy with a smaller affordable radio.

The end of this program is quite important for the acquisition strategy for SDR radios in the US, as it opened doors to new acquisition processes with more off the shelf products and limited funded development efforts. This opens the way for the transition to the JTNC program.

3.1.1.3   JTNC – Joint Tactical Networking Center

The JTNC was officially launched on 1st October 2012. The role of the JTNC is to provide to wireless software defined tactical networking solutions to US joint forces and to coalition forces[18]. The JTNC is pursuing the waveforms developments and porting efforts from the past JTRS program and also the management applications. More specifically, the JTNC home page states:

- The JTNC centrally manages, develops and sustains current and future Joint Tactical Networking applications, waveforms and reference implementations.
- The JTNC performs application standards conformance and interoperability tests against reference implementations.
- The JTNC maintains configuration control of the open standards and interfaces of the software communications architecture.
- The JTNC facilitates industry innovation for future enhancements and communications platforms employing government-owned JTRS and other waveforms, network management services, and software communications architecture.

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[17] Defense News, "US Army to Cancel GMR Contract, Seeks Replacement", Oct 2011, http://www.defensenews.com/article/20111013/DEFSECT02/110130303/U-S-Army-Cancel-GMR-Contract-Seeks-Replacement
[18] http://jtnc.mil/Visitor%20Information/FactSheet_JTNC.pdf

Another key objective of the JTNC is to test and certify devices to ensure interoperability across the end users.

All the Platform related activity, such as the HMS program, was transferred to other US Army program executive offices responsible for tactical radios acquisitions. The JTNC is now clearly focused on waveforms and related interoperability efforts.

3.1.2   NIE – Network Integration Evaluation

3.1.2.1   Overview

The Network Integration Evaluation (NIE) is a series of semi-annual field exercises designed to evaluate deliberate and rapid acquisition solutions, and integrate and mature the Army's tactical network[19]. The exercises involve nearly 3,800 Soldiers and 1,000 vehicles.
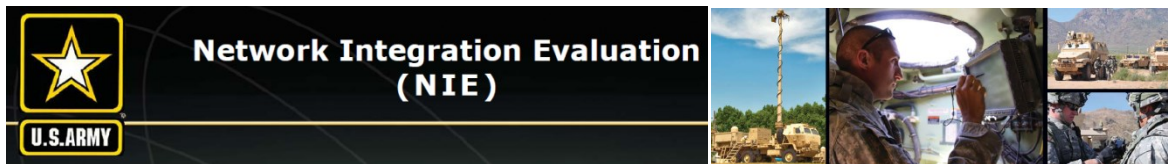
Figure 4: The Army is changing the way it supplies network systems and capabilities to operational units.

The Army has adopted acquisition practices to align the Network through Capability Sets that will enhance vertical and horizontal connectivity, and provide an integrated network baseline from the static Tactical Operations Center (TOC) to the dismounted Soldier. The systems that will comprise the Capability Sets will be assessed through evaluation and test activities, and will be systematically integrated prior to being fielded to deploying units.

The FY13-14 Capability Set meets the following recently adopted network guiding principles:

- Build network capability,
- Enhance battle command/mission command,
- Extend the Network to the edge,
- Implementation of the Common Operating Environment (COE)
- Implementation of nonproprietary waveforms.

The Army is establishing network acquisition practices designed to:

- Foster early and continual involvement of the user.
- Field multiple, rapidly executed increments or releases of capability.
- Promote a modular, open systems approach.

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[19] US Army – NIE web site : www.bctmod.army.mil/nie_focus/index.html

- Provide a Common Operating Environment and nonproprietary waveforms, which will allow industry to build to a standard and enable the launch of nonproprietary and competitive business approaches.

3.1.2.2 Involving Industry: a new relationship and an agile acquisition approach

Industry involvement in the development of the network is critical, and the Army's Network strategy is designed to leverage industry innovation and standards. As part of an agile acquisition approach, the Army will seek network technology improvements from both large and small industry partners to fill hardware and software needs.

The basis of the strategy is the establishment of technical standards to guide materiel and system development. These standards are necessary to speed development and fielding of new capabilities for the operational force. They tell industry up-front and with certainty the parameters within which Army technology (hardware and applications) must fit.

The agile acquisition process requires a semi-annual review of requirements, along with existing and potential solutions; this allows industry to compete at regular intervals. This methodology will enable the Army to be responsive to end users current needs, fielding the latest technology.

Integrated evaluations will provide a means to test and evaluate relevant network capabilities in parallel, and make incremental improvements based upon a disciplined feedback cycle.

3.1.2.3 Towards a new acquisition approach in US?

The NIE reflects an important army acquisition transformation. It targets to reduce drastically the network integration delay, enabling a quicker introduction of new technologies developed by industry into the operations arena.

It gives important opportunities to industry to propose new solutions answering to identified gaps by the Army. (ex. Sources Sought process).

One possibility is that the Army will no longer look for large programs of record to satisfy gaps[20]. Instead, it will search for how to modify or improve the baseline already in place or to provide capability. The Army seeks solution to deliver technical advancement more quickly.

This new approach emphasizes:
- The importance of waveforms developments for the JTNC program, providing common and interoperable WF across the different radio platforms from vendors.
- A trend to favor MOTS technologies acquisition, rather than large and complex development and production programs, with a reduced integration into forces time cycle.

In an effort to improve the Army ability to acquire equipment through the NIE process, changes have been proposed and referred to as the emerging Capability Integration Evaluation process

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[20] Signal Magazine, "Army Transformation in Full Swing", March 2012

(CIE). Beyond Capability Set 14, an RFP (Request for Proposals) process should replace the current sources sought one in order to reduce delays between new capability validations and their acquisition by the Army[21].

3.1.3 Deployed SDR Based Systems

In the past year, the US underwent an acceleration of the acquisition of SDR based equipment for ground forces together with new networking waveform capabilities. This is partly due to the availability or near availability of new capabilities, such as the SRW waveform, and the NIE exercises which showcased new platforms incorporating these capabilities. These acquisitions include:

- *25,000 of the PRC-117G* radios produced by Harris Corporation have been deployed[22]
- *19,250 of the PRC-155 Rifleman* radios, produced by General Dynamics and Thales, have been ordered in two Low Rate Initial Product (LRIP) orders[23] [24]. According to General Dynamics, Department of Defense documents indicate that the Army plans to purchase an additional *190,000 Rifleman* and approximately 50,000 Manpack radios.
- The US DOD has launched inquiries to industry for ground radios capable of supporting the new JTRS networking waveforms :
    - In February 2012, a Sources Sought was issued for a *SRW Vehicle Radio or SRW Applique*. According to the request, up to *5,000 radios* could be procured in the next 2 years. The Government anticipates contract award end of August 2012 with first equipment deliveries starting in October 2012 and ending in February 2013.[25]
    - Following the GMR cancellation, the DoD established a new program, dubbed the Mid-Tier Networking Vehicular Radio (MNVR), which will seek a lower-cost radio with reduced size, weight and power. The JPEO JTRS has issued a draft request for proposals for the MNVR in 2011. The basic strategy outlined in the draft RFP is for the Army to acquire JTRS-compatible "non-developmental" (off the shelf) equipment whose development will not be funded by the government. Developments needed to fulfill the requirements will have to be supported by the industry.
    - An RFP has been issued in August 2012 by the US Government for 2 channels radio supporting WNW and SRW waveforms. Deliveries for tests end 2012 and contract serial delivery staring beginning 2014. The market is estimated up to 10,000 radios.

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[21] ARMY Magazine, August 2012

[22] Harris Press Release – 21st September 2012 - http://www.harris.com/whats_new.asp

[23] General Dynamics Press Release – 7th July 2011 - http://www.gdc4s.com/news/detail.cfm?prid=387

[24] Thales Press Release– 17th September 2012 – "Thales Awarded Second Contract for AN/PRC-154 Rifleman Radios" - http://www.thalesgroup.com/Press_Releases/Countries/United_States/2012/Thales_Awarded_Second_Contract_for_ANPRC154_Rifleman_Radios_9_17_12/?pid=1650

[25] NextGov, "Army seeks 5,000 JTRS vehicle radios", 21 February 2012

These acquisitions of radios with wideband (WB) and high data rates (HDR) capabilities are complementary to the narrowband radios that have been supplied starting in 2007 with the Consolidated Single-Channel Handheld Radio (**CSCHR**) JTRS program[26]. At this date it is estimated that near **150,000 radios**, two versions supplied by Harris and Thales, are fielded in US DOD forces.

3.2 European Programs

3.2.1 ESSOR

The ESSOR program which has been established under the umbrella of the European Defence Agency (EDA), sponsored by the governments of Finland, France, Italy, Poland, Spain and Sweden[27]. The program was awarded by the Organisation Conjointe de Coopération en matière d'ARmement (OCCAR) to the dedicated joint venture Alliance for ESSOR (a4ESSOR S.A.S.) in charge of managing the industrial consortium composed of the following respective National Champions: Elektrobit, Indra, Radmor, Saab, Selex Elsag and Thales Communications and Security.

The main scope of this project is to provide the normative referential required for development and production of software radios in Europe through the use of:

- The ESSOR architecture of Software Defined Radio (SDR) for military purposes and
- A military High Data Waveform (HDR WF) compliant with such architecture,

The ESSOR Architecture is a Software Defined Radio (SDR) Architecture relying on the already published JTNC Software Communications Architecture (SCA) and Application Programming Interfaces (APIs). The ESSOR Architecture is a complete and consistent Secure SDR Architecture addressing the European military radio-communications market, and fostering on Waveform portability amongst heterogeneous SDR Platforms.

The major program activities are:

- Definition of the ESSOR Architecture
- Specification of the ESSOR HDR Waveform
- Creation of the ESSOR Design Methodology and Development Framework
- Development of the Base HDR Waveform
- Porting of the ESSOR HDR Waveform onto six different SDR platforms selected by the six nations

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[26] http://www.military-information-technology.com/mit-home/288-mit-2010-volume-14-issue-10-november/3641-jtrs-update.html
[27] OCCAR, "ESSOR: European Secure SOftware defined Radio", http://www.occar.int/36
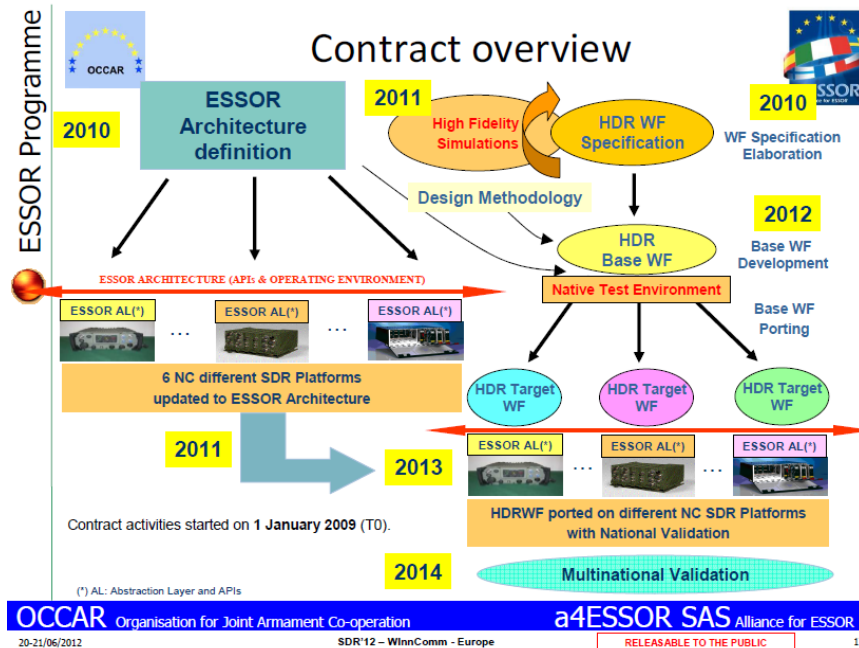
Figure 5: ESSOR Program Milestones Overview[28]

3.2.2 Germany - SVFuA

In 2009, Germany launched an ambitious SDR program, known as SVFuA (Armed Forces Joint Network Radio Equipment in German). The SVFuA program includes the development of a Multi-Channel SDR platform together with WF development and porting into the platform.

The Program has been awarded to different companies that are in charge of different elements:

- Rohde & Schwarz[29]: Waveform operating environment (HW and SW, inc. security module), overall system aspects, and STANAGs 4203 (HF), 4204 (VHF), 4205 (UHF), 4246 (UHF) waveform porting,
- Thales[30]: V/UHF radio module and SEM (VHF) waveform porting,
- Hagenuk[31]: HF radio module,
- Telefunken RACOM[32]: MAHRS (HF) waveform
- Cassidian[33]: Broadband radio module

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[28] Proceedings of the 2012 Wireless Innovation Forum European Conference on Communications Technologies and Software Defined Radio, http://groups.winnforum.org/e/in/m=1&req=Edit&eid=4

[29] http://www.rohde-schwarz.ca/en/news_events/press/press_releases/press-German_Armed_Forces_commissions_Rohde_%26_Schwarz_to_develop_SDR_base_unit.html

[30] http://www.thalesgroup.com/Press_Releases/Countries/Germany/2009/20091216_svfua/

[31] http://www.defpro.com/news/details/6240

[32] http://www.tfk-racoms.com/en/company/history

[33] http://www.cassidian.com/en/web/guest/CASSIDIAN%20develops%20electronics%20for%20the%20german%20Armys%20new%20mobile%20communications%20system
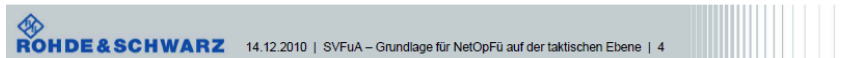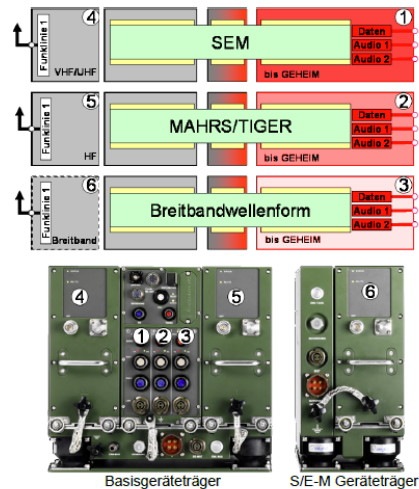
Figure 6: Overview of the SVFuA Program[34]

3.2.3 Sweden – GTRS

The GTRS Common Tactical Radio System, project is planned to be the base for the core system for all future radio communication in the Swedish Armed Forces (SwAF)[35]. Since the beginning of 2000, there has been a cooperative project between the SwAF and JPEO JTRS program.

Figure 7: Sweden GTRS Overview

Rockwell-Collins has delivered radios for the first GTRS phase[36]. Swedish FMV has placed an initial production order worth $20.7 million for FlexNet-Four software defined radios to support

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[34] Proceedings of AFCEA Germany, „Grundlage für NetOpFü auf der taktischen Ebene",14th December 2010, http://www.afcea.de/fileadmin/downloads/Fachausstellung/23._Fachausstellung_2009/Anmeldung/8%20-%202010-12-14%20SVFuA%20ZVEI-AFCEA%20Grundlage%20f%C3%BCr%20NetOpF%C3%BC%20.pdf
[35] Proceedings of SDR Europe, December 2008
[36] Rockwell Collins press release issued on 15th September 2010

the country's Tactical Data Radio System (TDRS) program for advanced ground mobile communications.

3.2.4   France

France has invested for several years in Research and Technology (R&T) studies. These R&T studies, such as PEA NCT or PEA DEPORT, established a baseline for SDR technologies to be used in new tactical communications systems for ground forces and for Air Force and Navy through a tri-services program[37]. The European ESSOR program a cornerstone of the new planned system.

The modernization of the tactical communications, through the Contact program, is linked to the Scorpion program. The Scorpion program is a global project for future combat systems at battlegroup level with following objectives:

- Renovate or modernize armored vehicles (APC, LBT, MBT)
- Improve soldier and equipment protection,
- Increase efficiency of soldiers and weapon systems through networking of information and combat systems.
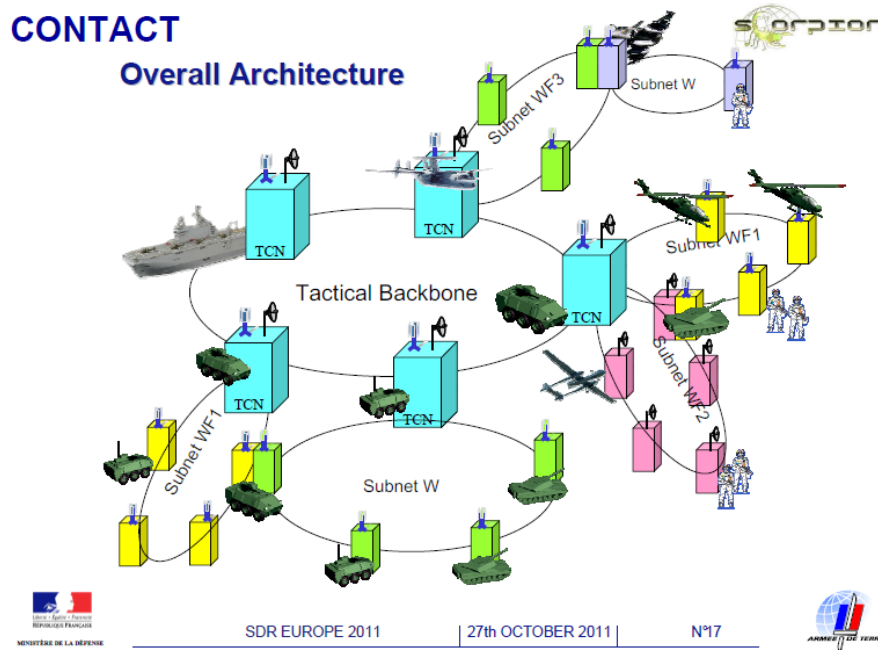
Figure 8: France Contact and Scorpion Programs[38]

The Contact program (French TACTical COmmunications program for Land / Air / Navy forces) is based on SDR technologies and is compliant with the ESSOR architecture. It is a Multi-

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[37] Proceedings of the 2011Wireless Innovation Forum European Conference on Communications Technologies and Software Defined Radio, http://groups.winnforum.org/p/cm/ld/fid=180
[38] Proceedings of SDR Europe 2011, October 2011

Services program delivering several capabilities / waveforms for different radio platforms (land, airborne, navy). It has been awarded to Thales and launched in June 2012[39] [40].

According to press releases and other public information, the first stage is intended to deliver 2,400 vehicle-mounted and 2,000 portable units to equip two combined amphibious brigades and naval vessels. Delivery on the first stage will begin in 2018. A second stage will equip combat, reconnaissance and transport aircraft with a new capacity for air-ground communications. A third stage is aimed at meeting all aeronautical needs and equipping naval ships operating in a naval force.

3.2.5 Italia – Forza NEC

Forza NEC is the digitization program of the Italian MoD[41]. Forza NEC is a Joint Program and is focused mainly on the modernization of the future land forces capability. The vision of the Army chief of staff for this program can be summarized as follow:

"To develop an array of network enabled land units fully integrated into the C4ISTAR Defense Architecture for Brigade size formation that is tactically strong, logistically sustainable and operationally flexible"

The main goal of the first phase (2010-2018) of this program is to acquire a Digitized Brigade (Fo.Me.D. – Forza Media Digitalizzata), an Amphibious Landing Force (LFD – Landing Force Digitalizzata) together with Tactical and Expeditionary Enablers.

Forza NEC Operational Needs and Organization Trends:

- Relevance of Expeditionary Units.
    - In OOTW the first phase of a conflict is often considered the most challenging from a warfare perspective. The role of entry-forces with expeditionary capability is crucial for mission success. Characteristics of these entry forces are:
        - Joint-Combined Interoperability (ship-to-objective maneuver)
        - Multi-role and Multi-Mission C4I Equipment for maximum operational flexibility
        - Heterogeneous Digitized Platforms (airborne, naval and land) with Situational Awareness populate multinational units composed from a Joint Capability Basket

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[39] Thales Press Release, "French Ministry of Defence selects Thales for CONTACT program", June 2012, http://www.thalesgroup.com/Press_Releases/Markets/Defence/2012/French_Ministry_of_Defence_selects_Thales_for_CONTACT_program/?pid=1650

[40] DGA Press Release, "La DGA notifie le program CONTACT", June 2012, http://www.defense.gouv.fr/actualites/economie-et-technologie/la-dga-notifie-le-program-contact

[41] Nones and Marrone, "The Transformation of the Armed Forces, the Forza NEC Program", Edizioni Nuova Cultura, 2012, http://www.iai.it/pdf/Quaderni/iairp_05.pdf

- Increasing Relevance of C4I Units
  - Tactical Command Posts with C4I *on-the-move* capability from Company to Brigade Level
  - One Signal Regiment to support a Brigade Level unit (before was a Battalion)
  - One C4I Platoon to support each Regiment Level maneuver unit
  - One C4I Company to support Regiment Level units that rely heavily on communications (Anti-Air force)
  - One C4I Expert in each section/platoon (maneuver units) to offload lower echelons Commanders from the burden of communication
  - Growing SATCOM capability to support extensive reach-back/reach forward activities reducing staff deployment in operational theatre

- Maximum Priority given to Force Protection (e.g. Anti-RCIED and CID) due to unpredictability of the operational scenario with the risk of mission creeping and fratricide casualties

- Sparse Operations. AoR can exceed 40.000 Km^2 for a Multinational Brigade thus the need for extended ISTAR capability and BLOS connectivity without ICT fixed infrastructure
- MOUT. Military operations in urban environment have specific challenges affecting C4ISTAR equipment and platforms characteristics especially for mobility and local situational awareness.
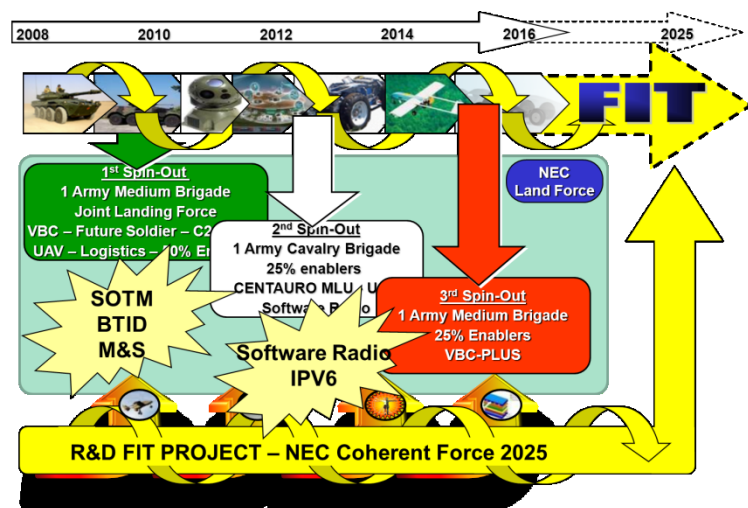
Forza NEC will make an extensive use of Software Defined Radios already developed or under development by SELEX ELSAG (SWave product family) compliant to ESSOR specification[42]:

- 4 channels, Type 1, Ground Vehicular Radio for HF and V/UHF bands
- Single channel Type 3, Ground Vehicular Radio for V/UHF bands
- Handheld Radios, Type 3 for V/UHF bands
- 2 channels Type 3 Man-Pack Radios for HF and V/UHF bands
- Single channel Type 1 Man-Pack Radio for V/UHF bands
- 4 channels, Type 1, Naval Radios for HF and V/UHF bands
- Avionic Type 1 Radio for HF and V/UHF bands

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[42] SoldierMod.com, "Italy's *Soldato Futuro* Moves Towards Production", http://www.soldiermod.com/volume-8/soldato-futuro.html

It will be possible to equip all the SWave SDRs with any combination of legacy waveforms and new generation ones (SBW, HDR, etc.) according to Italian MoD Concept of Operations and derived Communications IER for all the Forza NEC types of SDRs.

3.2.6 Spain

The Spanish investment in SDR technology started in 2005 with the launch of the TERSO program[43]. The program consisted in the development of an SCA based SDR demonstrator and two functional test waveforms to validate the performance and capabilities of the SDR equipment. In 2007 the TERSO program entered its second phase, consisting in the provision of a secure SDR architecture for the TERSO platform. This included the separation in Red / Black domains and the development of a reprogrammable CS/S with an agreed algorithm crypto-suite. Both phases of the program were carried out by Indra, which is closely working with the Spanish MoD in the implementation of the Spanish SDR program.

As stated earlier, Spain is a participant in the ESSOR program, and has also been involved in other international activities such as the technology transfer of MIDS-JTRS and COALWN. The outputs of the ESSOR program and other initiatives are to be capitalized in subsequent phases with the main goal of providing a National capability in military radio communications.

The following picture provides an overview of the Spanish SDR roadmap in order to achieve national sovereignty in SDR communications.
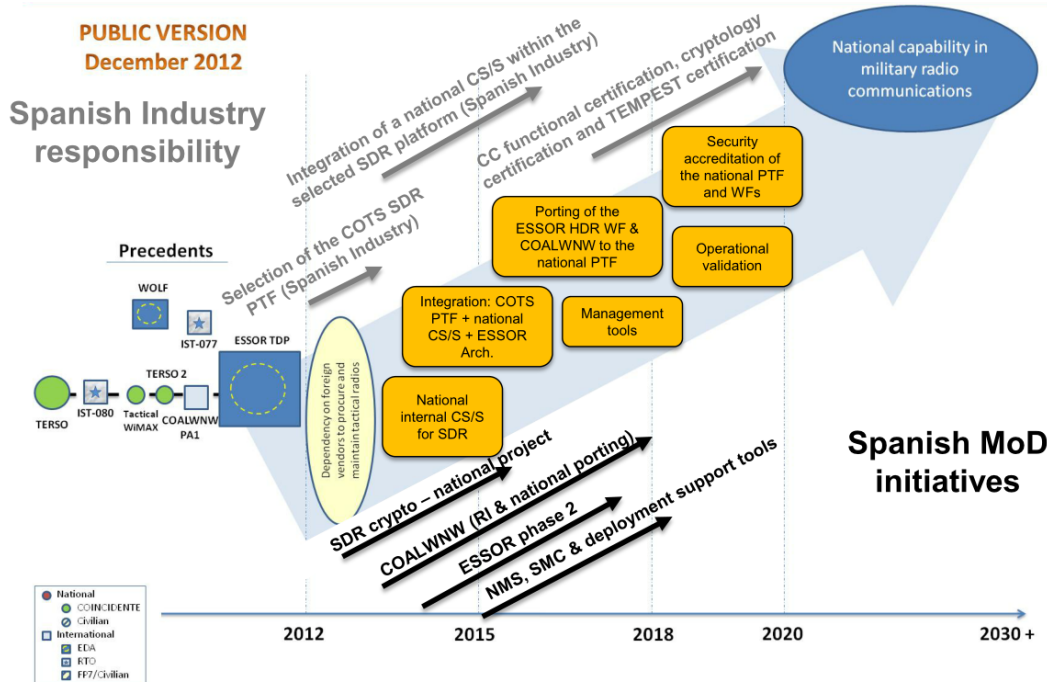
Figure 9: Spanish SDR capabilities timeline

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[43] http://www.defenceiq.com/defence-technology/articles/q-a-with-captain-aurelio-hinarejos-spain-s-essor-n/

3.2.7 *Finland*

Finland has been investing SDR and communication research and development programs since 2003[44]. This investment began with the National SDR demonstrator which included an SDR platform development and a wideband waveform development. The demonstrator measurement campaign led up to the deployment of the Tactical Wireless IP Network which will be supplied by Elektrobit Wireless Communication ltd, acting as a national champion for the Finnish Defense Forces.

Finland has also undertaken a new Research and Experimentation Program for Cognitive Radio Systems (CRS) called TRIAL. This is a TEKES funded Research Program for 2011-2014[45]

- Objectives:
    - Finland is at global top level in the research and development of cognitive radio and networks
        - Finnish companies utilize the business potential of the cognitive radio and networks
        - National and international co-operation
        - Finland is a convincing trial environment place for foreign companies
    - 17 projects started in 2011 (14M€)
        - 9 research projects (2 years)
        - 8 industrial projects (1-2 years)

- Aims and content of TRIAL-program
    - Key players involved including universities, research institutes, regulator, manufacturers, operators, broadcaster, and SMEs:
        - Aalto University, Central Ostrobothnia University of Applied Sciencies (Centria), Digita, DNA, Fairspectrum, Elektrobit, Finnish Communications Regulatory Authority (FICORA), Finnish Defence Forces, EXFO NetHawk, Ministry of Transport and Communications, Nokia, Nokia Siemens Networks, Pehutec, PPO, Renesas Mobile Europe, University of Oulu, University of Turku, Turku University of Applied Sciences, VTT Technical Research Centre of Finland.
    - Activities:
        - Development of trial environments.
        - Research on enablers for CRS.
        - Business aspects.
        - Contributions to CRS related spectrum regulation (e.g. ITU-R WP5A, PT SE43).
    - Some TRIAL Projects include:
        - CORE - Cognitive Radio Trial Environment
        - ENCOR – Enabling Signal Processing and Radio Circuits for Cognitive Radio

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[44] Tapio, et. al., "Finnish Software Radio programme", Proceedings of the SDR 04 Technical Conference and Product Exposition, 2004, groups.winnforum.org/d/do/3286
[45] The Finnish Funding Agency for Technology and Innovation http://www.tekes.fi/programmes/Trial

- Results of TRIAL program will be tailored for military use in parallel MIL CRS projects. Foreseen first benefits/applications of CRS in military communication:
  - More efficient use of available frequency resources
  - Need for minimum/automatic network management in next generation MIL Ad hoc/Mesh networks
  - Secondary / Primary use of white space frequency band
  - Propagation characteristics of 460 MHz – 700 MHz frequency band are good for MIL use

The defense forces require better situational awareness in the field. Forces need effective co-ordination and communication infrastructure, and logistics needs to be planned online. This growing data flow requires the digitalization of command and control systems. High capacity wireless IP backbone solutions build the core of digitalization and enable the creation of a tactical communications network. Software Defined Radio based solutions allow Forces to use less units, resulting in space savings and lower maintenance costs. Such solutions also bring flexibility with multi-channel functionality and enables us to adapt to changes through the whole lifecycle.
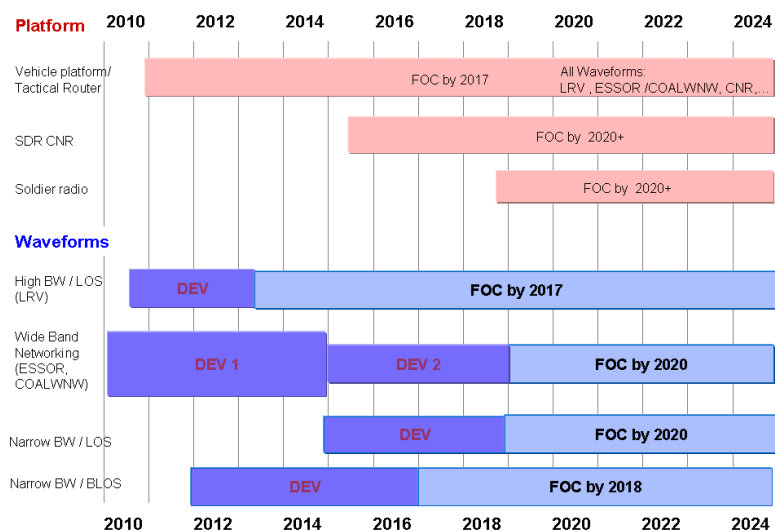
Figure 10: FDF SDR – Possible time lines[46]

The Finnish Defence Forces announced in September 2011 that they will deploy EB's Tactical Wireless IP Network[47]. EB will develop this network and deliver the first pilot series of software defined radios. Related to the project, the Finnish Defence Forces have a purchase option for further development as well as serial purchase of the product. The EB Tactical Wireless IP Network is a stand-alone military wireless broadband network that can be deployed in any location. It enables the formation of an independent IP network that is compatible with existing

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[46] Proceedings of the 2012 Wireless Innovation Forum European Conference on Communications Technologies and Software Defined Radio, http://groups.winnforum.org/e/in/m=1&req=Edit&eid=4
[47] Elektrobit Press release, http://www.prnewswire.com/news-releases/elektrobit-eb-delivered-the-first-series-of-tactical-wireless-ip-network-products-to-finnish-defence-forces-183891961.html

infrastructure, both wire-line and wireless. Being based on Software Defined Radio makes the product versatile, upgradeable and easy to adapt. It enables a mesh network solution with high data rate and automatic network configuration required by battle groups.

Finland is also participating in the ESSOR program where ESSOR HDR WF development has an important role of Finnish defense forces communication systems roadmap.

Figure 10 provides a possible timeline for Finnish defense forces SDR related procurements.

3.3   Rest of the World

3.3.1   South-Korea

South Korea is approaching date for fielding their new Tactical Information Communication Network (TICN), with first trials planned for 2014[48]. Deliverables for TICN are being developed by Samsung Thales, LIGNex1 and Huneed, who are all working on different sub-systems. The TICN program aims to design new tactical communication systems both for the deployable part (higher levels of the network) down to the tactical edge (company, platoon levels). It relies on SDR capabilities for the tactical edge both in platforms and waveforms.

3.3.2   India

India's armed forces have initiated several new C4I and Tactical Communications programs[49,50]. The purpose of these programs is to provide seamless communication networks capable of supporting the NCO transition. This includes networking information from sensors deployed on the battlefield and providing information on a need-to-know basis to all concerned commanders. It covers all the levels of commands from headquarters, deployable command posts down to the soldiers on the battlefield.

The main programs are:
- TCS – Tactical Communication Systems
    - This program will provide a deployable tactical communication solution to Indian Army,
    - This much delayed "Make India" program is now launched after the EOI (Express Of Interest) step downselection of suppliers selected for developing some prototypes. This design, development and prototyping phase is planned for a duration of 18 to 24 months.
- BMS – Battlefield Management System
- F-INSAS – Soldier Program

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[48] The Daily Star, "S. Korea to upgrade military communications network", http://www.thedailystar.net/newDesign/news-details.php?nid=99497
[49] Asian Military Review – www.asianmilitaryreview.com
[50] SP's Land Forces – www.spslandforces.net

Both BMS and F-INSAS are in procurement at the time that this report was written.

SDR technology and solutions are of main interest for tactical communications capabilities for these NCO programs. In addition, the India Navy and Air Force have launched some separate NCO programs relying on SDR capabilities.

3.4 International and Standard WF initiatives

One of the advantages of SDR is the ability to implement common or shared waveforms on tactical radios and for these radios to interoperate between nations for coalition missions. Today, highly mobile forces, projected into remote theatres under joint or allied command, need to share a Common Operational Picture (COP), therefore pushing greater interoperability from application and IP level up to radio level, increasing connectivity between users on the ground, for joint and combined operations. Enhanced interoperability among coalition partners is an essential requirement on the modern battlefield, with multinational coalitions becoming the norm for conducting military operations in hot spots around the world. Ongoing coalitions operations in Iraq, in Afghanistan, or in Libya, highlight this need for interoperability communications means on the battlefield and at the tactical edge.

The interoperability requirements are therefore part of all the recent and ongoing main SDR waveform programs efforts.

3.4.1 ESSOR HDR Waveform

As already described in the previous chapter, the ESSOR program includes the development of a HDR (High Data Rate) networking waveform. This WF is being co-developed by six European nations, and is an example of new generation waveform, answering to NCO requirements, capable to answer to the interoperability challenges of coalition forces operations.

Figure 11: ESSOR HDR WF Overview[51]

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[51] Proceedings of the 2012 Wireless Innovation Forum European Conference on Communications Technologies and Software Defined Radio, http://groups.winnforum.org/e/in/m=1&req=Edit&eid=4

3.4.2 COALWNW Waveform

In June 2009, nine nations (Australia, Finland, France, Germany, Italy, Spain, Sweden, United Kingdom and United States) agreed to jointly develop a wideband networking waveform to pass secure voice, video and data and to enable tactical interoperability among coalition forces. Poland and Canada are said to joint this international project. This waveform is known as the Coalition Wideband Networking Waveform, or COALWNW[52].

The COALWNW capability will be designed, developed, and tested using a three phased approach. The program has entered Phase 2 as of the date of this report.
- Phase 1: Develop Requirements and Specifications
- Phase 2: Procurement
  - Port, Integrate and Test against Reference Implementation and Submit draft STANAG to NATO for consideration with a target completion date in 2015
- Phase 3: Interoperability Test and WF Sustainment
  - Deployment of such Waveform into field forces starting 2018.
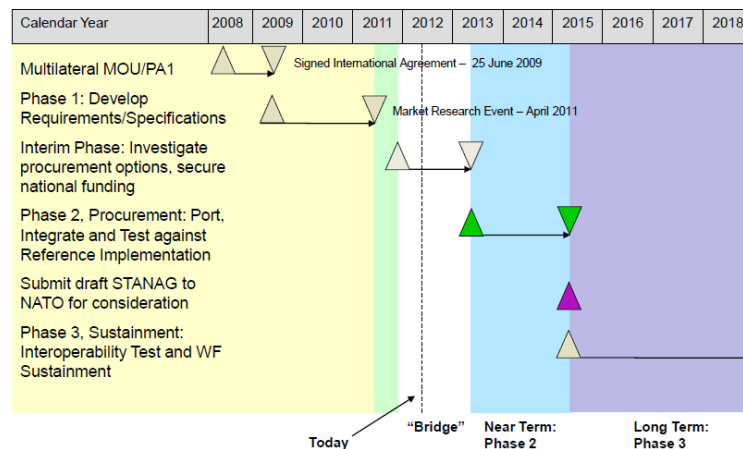
Figure 12: COALWNW Phases and Planning[53]

3.4.3 NATO Coalition Tactical Radio Waveform

NATO has launched some initiatives to provide wireless interoperability solutions for the battlefield through a number of Working Groups (WG). One WG aims at completing the development of the NATO Coalition Tactical Radio Waveform (CTRW), termed Narrow Band

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[52] UK DSTL Press Release – 9 Feb 2011 and France DGA Informations SDR Europe 2009 Conference

[53] Proceedings of the 2012 Wireless Innovation Forum European Conference on Communications Technologies and Software Defined Radio, http://groups.winnforum.org/e/in/m=1&req=Edit&eid=4

Waveform (NBWF)[54]. Work is ongoing between NATO and Industry to define and agree on common waveform standard (a RFI has been published in January 2011 to define the next steps).

In addition, NATO has defined an SDR WF development framework.
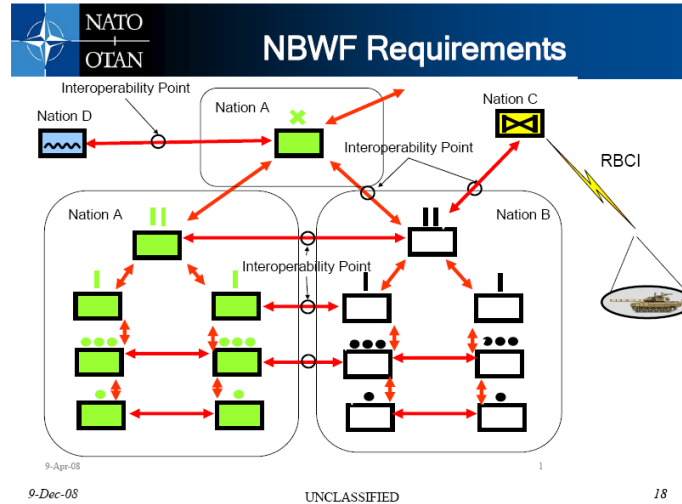
Figure 13: NATO Ensuring Multinational Interoperability for Future Forces[55]

3.4.4 US – UK Initiative : the JTRS Bowman Waveform

The US JPEO JTRS Program is leading a cooperative project between US and UK targeting interoperability on the field between US and UK units, using an SDR approach through the porting of the Bowman WF into US SDR JTRS architecture[56].

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[54] Proceedings of the 2012 Wireless Innovation Forum European Conference on Communications Technologies and Software Defined Radio, http://groups.winnforum.org/e/in/m=1&req=Edit&eid=4
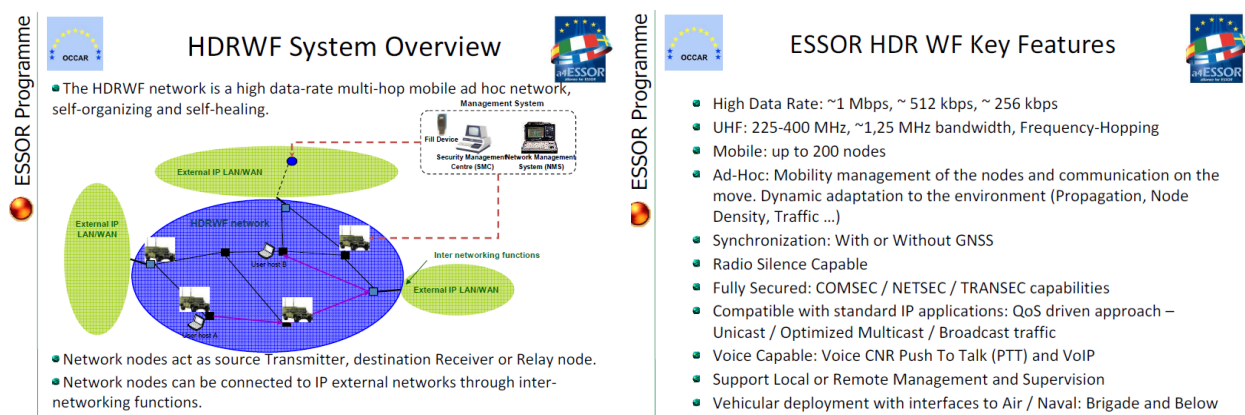
[55] Proceedings of the 2011Wireless Innovation Forum European Conference on Communications Technologies and Software Defined Radio, http://groups.winnforum.org/p/cm/ld/fid=180

[56] From the proceedings of the "International Software Defined Radio 2010 Conference", London, June 2010
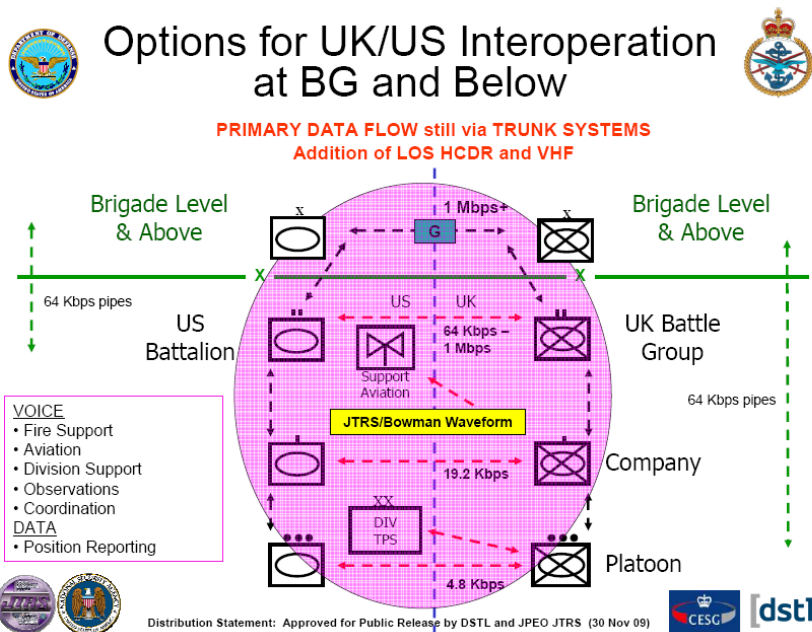
Figure 14: JTRS/Bowman Interoperability

Under the first phase of the collaborative program, the UK Bowman VHF tactical waveform and associated crypto were developed and ported on to a US SCA radio platform. The UK ADR+ VHF waveform (better known as JTRS Bowman waveform) was also added to the US JTRS Information Repository. Live network demonstrations were performed in June 07 and Apr 09. ITT Exelis[57] delivered an update of the JTRS Bowman WF (JBW) to the JTRS Information Repository in 2012 and this waveform has also been ported into the ITT Exelis Soldier Radio Multifunctional SR-M SDR.

3.5 Conclusions

The various SDR programs examples listed in this section illustrate a variety of approaches based on the different elements that could form the programs. These elements can include:

- Development of Waveforms and Platforms
  - To answer to specific requirements from nations : platforms or waveforms,
  - To fund development efforts in areas where there are no off the shelf solutions,
- Porting Waveforms
  - The program could require porting of "legacy" waveforms, i.e. established waveforms that were running in other radios previously and that are still key elements of new generation radios and communications systems requirements, or

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[57] ITT-Exelis Press Release published on 17th Feb. 2012, http://www.exelisinc.com/news/pressreleases/Pages/ITT-Exelis-delivers-updated-JTRS-Bowman-Waveform-for-US-UK-interoperability-.aspx

- The program could develop new capabilities such as high data rate and MANET networking
- SDR Architecture Improvements
  - The program could include a variety of platforms that aim to support the same waveforms (to fulfill the interoperability capabilities): ESSOR, JTNC or COALWNW.
  - The program could seek to have a cost efficient solution for porting the waveform into multiple platforms. Some important efforts have been done in the area of SDR architecture: SCA improvements, various APIs, that could be open or that could be specific to the programs.
- Procurements of MOTS radio
  - Several international programs have procured MOTS radios to address their SDR requirements.

Country	Name	Development Programs		Platform	SDR Archi Improvements	MOTS Radio
		Waveforms				
		Legacy	New			
USA	JTNC	X	X		X	X
Europe	ESSOR		X		X	
France	Contact	X	X	X		
Germany	SVFuA	X		X	X	
Sweden	GTRS		X			X
Italia	Forza NEC	X		X		
Spain						X
Denmark						X
South-Korea	TICN	X	X	X		
Australia						X
NATO	CTRN		X			
International	COALWNW		X			

Figure 15: SDR Programs Elements - Synthesis

4 Business Models for SDR Tactical Radios

4.1 The radio value chain

An evaluation of existing Defense practices shows that the value of a radio is mainly considered at the system or equipment level, and does not take into account the value of the Waveforms or other software elements. Different phases have to be taken into account to build the complete program value:

- Development if any specific requirements need to be addressed
- Procurement of the products (platform or software) resulting from the development phase or in competition with MOTS solutions
- Integration into platforms like vehicles etc., but also integration inside the C4ISR applications chain
- Maintenance: Platform maintenance, software maintenance, corrective or evolution maintenance

Current legacy military communications systems typically conform to the following Life Cycle Cost model :

- Acquisition Costs (Development & Production) 66%
- Operational & Maintenance Costs 34%

4.2   A software business model enabler

In the development stage it is necessary to distinguish between the developments of software and waveforms and the development of the radio platform (hardware). The broad adoption of SDR is raising the importance of software considerably: the hardware platform procured by the government agencies can be software upgraded with some key features introduced, bringing new capabilities to warfighters. This is an important cost savings for the agencies and end users, avoiding costly hardware upgrades, and so a potential business model moving forward is for agencies and end users paying for these software features.

This approach can be seen as a "revolution" in some markets, where software value is today not considered at its just value. An SDR approach provides an opportunity to move from hardware centric business models and pricing strategies towards a more important software based business model. Such a model gives importance to software based products and upgrades introduced into SDR platforms, opening doors to related innovative business models for:

- Software maintenance
- Software functional evolutions providing new added values for end users

4.3   Comparison with Commercial Wireless Infrastructure Industry

The military communications for ground forces are very often compared with commercial wireless industry. Military end users are also often commercial wireless end users, allowing them to make comparisons. Evolutions and performances evolutions can be compared, like shown in Figure 21, but differences in terms of usage and requirements between the commercial and defense markets should be understood.

4.3.1   Common Trends for Requirements

Despite some technical details like security and ruggedization, the global trends are similar between commercial wireless infrastructure and tactical military communications:

- SDR Transition
  - Increased use of software oriented products, permitting some regular SW upgrades providing not only corrective maintenance but also and especially some key functional evolutions providing added value for the value chain.
  - Products should be future proof: investment in CAPEX should be protected, and its productivity should be maximized through some improvements with SW upgrades.

- Applications Requirements
  - Transition from pure voice to voice and multimedia applications (from messaging to video),
  - Spectrum Efficiency and multiband

- Development Cost for Waveforms
  - The complexity of waveforms is increasing together with the multiplication of possible services provided with these waveforms.
  - Cost for development of 3GPP LTE Waveform for a Radio Access Network is similar in magnitude to that of a complex tactical communications networking waveforms.

4.3.2 Business Models Differences – The virtuous commercial wireless cycle

The commercial wireless industry has built its growth in terms of market both in number of users (market penetration) and in terms of services (from mobile voice to advanced multimedia applications and mobile internet access) thanks to a virtuous cycle based on important economies of scale. These economies are directly related to the number of users in the commercial market, which enables price decreases and the development of new technologies and applications.
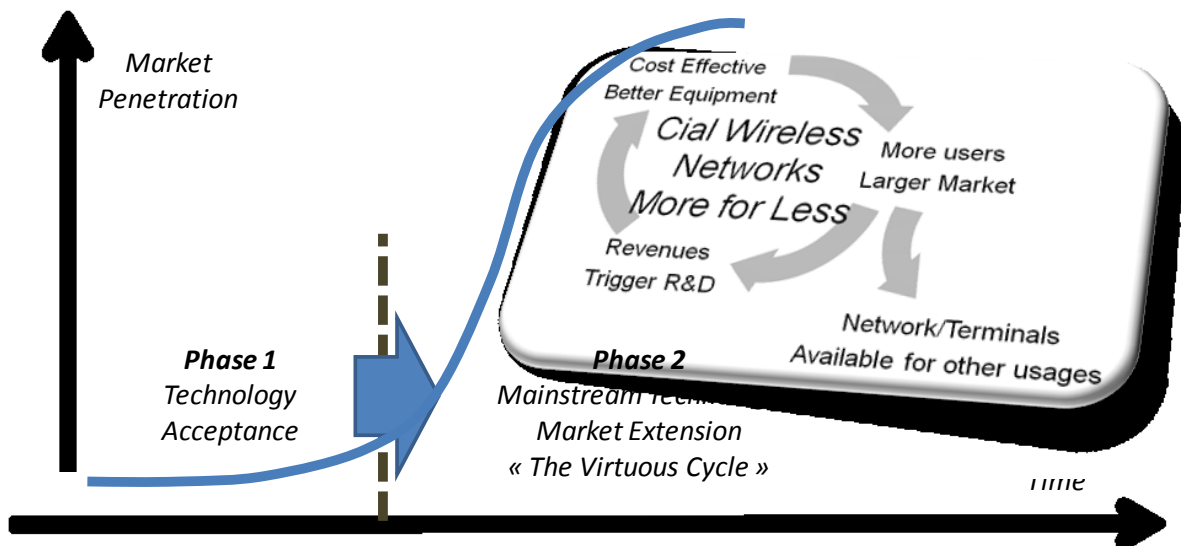
Figure 16: The Virtuous Commercial Wireless Cycle

The Tactical Communications Defense Market is quite different because the source contributing this commercial virtuous cycle is quite limited since the number of users is relatively small. Further, while data from recent Iraq or Afghanistan operations shows the percentage of equipped soldiers with wireless communications systems is increasing , the total number of soldiers, worldwide, is decreasing in a post-Cold War transition. As such, the introduction of new

capabilities and services for the tactical communications market must be based on a combination of:

- Government funding to enable new technologies and new services,
- Adaptation of new technologies provided by the commercial wireless industry

4.3.3   Commercial Wireless Industry business trends & references

Commercial wireless infrastructure industry has been using the SDR technologies for a long time: with the first SDR base stations fielded in beginning 2000. Market studies done by the Wireless Innovation Forum show that today most commercial wireless infrastructure systems are based on SDR[58]. This evolution has been a natural move to answer to the cellular operators requirements and to cope with evolution of this industry:

- More value is seen in the software for new services to be fielded
- SDR has been shown to save some OPEX for the operators,
- Pressure on infrastructure prices has driven a move towards the radio platform commoditization

One can compare this evolution with the recent move from US DOD with JTRS transformed into JTNC illustrating the value is the waveform, and competition in the radio platform.

The commercial wireless industry knows now some important transformations linked to:

- the slowdown of the growth of this market segment (less new end users) or
- the introduction of flat fee offers that reduce the investment capabilities to sustain the end users new requirements (such as introduction of 4G and LTE technologies to answer to growing usage of always connected smart phones, with the success example of iPhone),
- high competition in the market, especially with pressure from the now established China wireless industry,

As the value chain is moving towards software and applications in which the main industry players are concentrating their added value, some important suppliers eco-system have emerged supporting protocol stacks and chipsets. This growth has been driven by the terminals market but as well by the growing Femto-Pico cells market, with usual licensing models for LTE stacks for terminals and base stations emerging.

4.4   Military WF value identification - Market References

It is difficult to identify values of Waveforms, especially in the contact of Defense Market and Tactical Communications, as the value of a waveform depends on different factors. Waveform applications vary in degrees of requirements complexity, from simple waveform to complex and fully featured waveforms. Complexity can be categorized on parameters such as code size or the complexity of their signal processing and networking requirements. Security requirements have also a significant impact on the total development cost of waveform.

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[58] Mobile Experts and the Wireless Innovation Forum, "SDR Market Size Study", 2011, http://groups.winnforum.org/p/do/sd/sid=3155

Another factor that cannot be neglected in military waveform programs is the volatility of the requirements. Lack of detailed specifications and lack of key performance indicators could result in cost overruns.

With these things in mind, some public information is available on the cost of waveforms in the SDR market, coming from different key programs.

4.4.1 JTRS WF Informations

The US DOD Budget gives some interesting values of JTRS WF development contracts[59]. In particular the Budget FY2012 (RDT&E Project Cost Analysis part) shows the following figures:

- Wideband Networking Waveform (WNW) :   105M$ estimation at completion
- Soldier Radio Waveform (SRW) :   90M$ estimation at completion
- Mobile User Objective System (MUOS) :   130M$ estimation at completion

The US government contracted as well for maintenance and support of the Waveforms (Software In-Service Support SwISS); Press Releases of the contracting companies provide the following information:

SwISS Contracts:
- Sincgars WF: 2 years ($22.9M) + 3 year options, for a total $62M[60]
- Bowman VHF WF: 5 years, for a total $49.5M[61]
- WNW WF – 5 years, for a total $64.6M[62]
- SRW WF – For a total $26M[63]
- Link16 WF – 5 years, for a total $64.6M[64]

4.4.2 ESSOR Program

Contract overview of the ESSOR program is given in the different ESSOR presentations[65].

The total ESSOR program contract is valued 106.3ME and is split as follows:
- Common activities 65,5 M€, including
  - ESSOR architecture
  - HDR WF specification
  - HDR Base WF development

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[59] http://www.dtic.mil/descriptivesum/Y2012/ Navy/0604280N_5_PB_2012.pdf
[60] PR by ITT Exelis – July 2009
[61] PR by ITT Exelis – Oct 2010
[62] PR by General Dynamics – Sept 2011
[63] PR by Harris - July 2012
[64] PR by BAE – May 2011
[65] Proceedings of the 2011Wireless Innovation Forum European Conference on Communications Technologies and Software Defined Radio, http://groups.winnforum.org/p/cm/ld/fid=180

- Multinational validation
- Non Common Activities 40,8 M€, including
    - ESSOR architecture implementation on national PTF
    - HDR Target WF implementation on national PTF

4.4.3 Germany SVFuA Program

Information on the cost of the program have been given in the Griephan newspaper[66]. The first phase, development of the radio platform and porting of legacy waveforms, is valued at 187.5ME. The second phase, delivery of the first batch of equipment (1800 radios), is valued at 200ME.

As far as WF porting activity is concerned, the only public information concerns the porting of the HF Waveform, contracted to Telefunken and reported in its annual financial report 2010, at 6.2ME.

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[66] Griephan – edition 4th July 2011 - www.griephan.de

4.5 COTS into tactical communications trends

4.5.1 The Market Segments in Tactical Communications

Tactical and disaster relief operations share the need to rapidly deploy an area communications network where none exists or where assured access to secure communications is critical. As one comes down from high level joint forces headquarters, army corps and divisions, the need for mobility rapidly increases all the way to the edge of the network, where broadband connectivity is increasingly required to support a service oriented architecture and, the ubiquitous smart phone.

The requirement for mobility and for rapid network deployment will also vary with the mission (long term peace keeping versus combat missions) and the operational phase (contact versus stabilization).
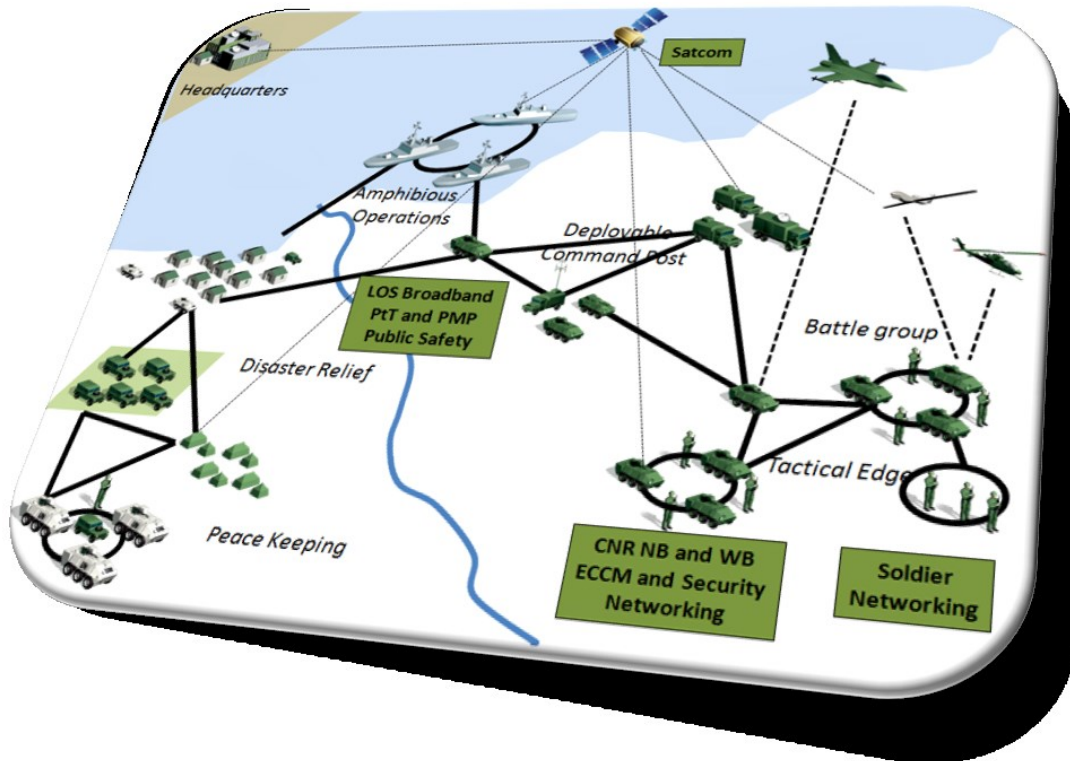
Figure 17: Need for rapidly deployable mobile networks increases closer to the edge

4.5.2 Commercial and Tactical Wireless Communications

The requirements for a distributed, fast projection mobile communication network, added security, range and operation in military or public safety frequency bands challenge the use of commercial networks and technologies for tactical and emergency communications.
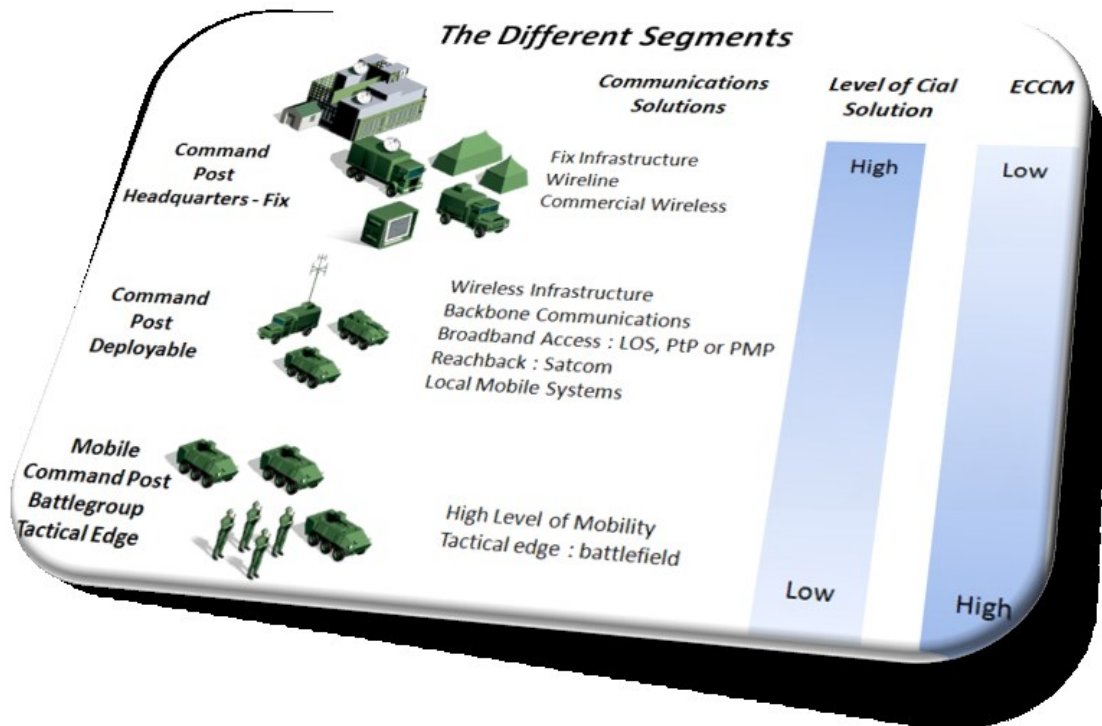
Figure 18: In the past, commercial solutions have been more prevalent in the upper military echelons

Using or leveraging commercial technologies in military applications can decrease both investment and development time. Use of unmodified commercial waveforms would obviously be the most cost effective solution, but military requirements cannot typically be fulfilled by using them directly as specified. A possible exception to that rule might be wireless access to unmodified COTS end devices in missions where good enough security can be offered without change to the device COTS waveform.

Fortunately, Software Defined Radio (SDR) technology allows for the modification of already implemented protocols without the need for expensive modifications of the hardware. The leveraging of existing commercial protocols provides lower implementation costs when creating new waveforms and offers the flexibility to create new versions, increase performance and modify waveforms to serve new emerging use cases as time goes by.

Combining software radio flexibility and commercial waveform specifications can provide a cost effective method of creating new high capacity wireless waveforms that meet military requirements.

	Coverage and Network Design	Security	Services
Commercial Wireless	Frequency 800MHz to 5.8GHz Mainly Capacity Driven Rural Coverage Base Station, Cellular based with multi layers (Macro, Micro, Pico)	FIPS-140-2 Level 1 or Level 2 payload encryption	High number of equal status subscribers share a stressed network PTP service delivery
Military Tactical Edge	Frequency <1GHz Tactical Edge OTM Environement (2-3m ant. height for vehicle, no Base Station) Full mobile Ad-Hoc (MANET), Relay, Mesh	High Security, including FIPS-140-2 Level 2 and higher grades, protocole security (TRANSEC), Anti-Jam, Low Probability of Intercept, Silent Mode etc.	Broadcast (all informed), PTT

Figure 19: Commercial Wireless and Military Communications Requirements

4.5.3 *Existing and emerging COTS technologies in the tactical domain[67]*

In spite of their very specific operational needs, actors in the tactical and emergency response domains can no longer afford to ignore COTS technologies. Due to massive worldwide R&D investments and to the acceleration of technology cycles, commercial technologies have overtaken military waveforms in many performance fields including broadband wireless access and mobility.

Because of their lower cost, high performance and open interfaces, commercial technologies get higher attractions. This trend is not completely new, the latest example being the emergence of the digital wireless technologies in the 90's (GSM, CDMA IS-95 etc…).

Recently, secure WiFi solutions and WiMAX derivative products have been in use in Iraq and in Afghanistan by the US land forces for broadband access below the Brigade level. WiFi mesh 802.11s derivative products are being used by non-combat units in vehicular applications and the new 4G high performance mobile technologies such as 802.16e and LTE have been or are being evaluated by the US DoD, the Canadian DND and several other armies worldwide. There are many press articles related to these trials.

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[67] The material in this section was contributed without supporting references and should be considered "descriptive" text only

Figure 20: Ultra TCS and the Canadian Forces validating the use of ruggedized COTS technology to support ISR applications in 2011

For example, in 2011 Ultra Electronics TCS and the Canadian Forces validated the use of a heterogeneous OFDM Mesh and OFDMA MIMO "COTS+" system to exchange broadband ISR products On-The-Move over large areas in an international military exercise taking place in Arizona. Bidirectional links and ISR video traffic were maintained OTM between a Forward Operation Base and a series of vehicles providing for a minimum aggregate rate of 6Mb/s at a range of 11.5km using commercial frequency bands.

Similarly, Elektrobit and the Finnish Army have been adapting WiMAX 802.16e technology for broadband access applications in the tactical domain. An extensive measurement campaign was performed in 2010 where WiMAX 802.16e, adapted into NATO UHF Band 1 (225 – 400 MHz) was used. The aim of the campaign was to evaluate the feasibility of WiMAX technology in such a representative environment (antenna height, frequency band, season - Finnish winter, summer, fall - slow mobility). It was concluded that technology itself could fulfill most of the major scenarios for the *wireless backbone network* within the FDF.

Following this campaign the Finnish Defense Force has agreed to purchase a Tactical Wireless IP Network, based on WiMAX technology but will be adapted for different frequency bands and modified to offer true MANET capability (no base station or core network support needed).

This new high data rate wireless tactical networking waveform uses the commercial orthogonal frequency-division multiplexing (OFDM) scheme and contains modifications to suit military communications purposes.

Similarly, we have seen multiple offers and trials by all the actors on the tactical communications market such as Selex Elsag, that used WiMAX technology in UHF band for applications for both tactical and maritime scenarios achieving long range high-throughput point-to-point (PTP) and point-to-multipoint (PMP) links, Thales elaborating a Tactical Wireless IP offer already

deployed on the field and Samsung-Thales using WiMAX-Wibro technology for segments of the South-Korea TICN program.

4.5.4 LTE and other promising COTS technologies

Not surprisingly, LTE and LTE-A, the latest 4G commercial mobile technologies, have been attracting a lot of interest from the military and have already undergone some tests under the US NIE program. 802.11 and 802.16 standards also continue to evolve, and with LTE, Bluetooth and 802.15.4 ZigBee there is now a very significant eco-system of commercial wireless technologies that can be harvested for military use.

As LTE technology is adopted for Public Safety applications, as started in the US, we can expect emergence of solutions and features adapted for this market segment.

Usage derivations for tactical communications can therefore be expected: ruggedized hardware, feature adaptations and dedicated frequency bands will benefit armed forces, not only for joint operation Public Safety / Military.

4.5.5 Conclusions: COTS technologies adoption

While the usage of COTS derived technologies is beneficial for segments like disaster relief or peace keeping operations, the deployable command posts with mobility extension (mobile backbone application) application for the tactical edge raises several questions.

Radio Performance features, pushed by commercial wireless industry innovation such as MIMO, smart antennas etc. are as well beneficial and usable by military tactical communications applications for the tactical edge environment and its difficult propagations characteristics (No Cellular capabilities, full mobility, Relaying etc…).

We have seen here above some adaptations made on these COTS technologies:
- Frequency: Adaptation to UHF or Below 1GHz is required for propagation requirements and as well to avoid commercial allocated frequencies usage,
- Networking: While the usage of Mesh, Ad-Hoc networking protocols, radio aware routing protocols etc. features is not required by the Commercial Wireless Infrastructure market, development of such solutions have been made,

Adapting commercial technologies to military requirements can be done with COTS waveforms in a faster and more cost effective way than traditional military waveform development methods. Examples tend to show that existing implementation of commercial waveform, with reasonable rework (for example 2/3 of code reusable), can give significant benefits to customers.

Nevertheless there are still critical requirements in the security domain that reduce the possible adaptation opportunities for the tactical edge area.

Features like TRANSEC, Anti-Jam, Low Probability of Intercept, ECCM, and Fast Frequency Hopping require important efforts.

The total cost of various adaptations of COTS technologies (Frequency band requiring new RF, Networking protocols adaptation, Security features) is quite similar to the development of new waveforms (ESSOR HDR, WNW, SRW, FlexNet-Waveform etc...).

Performance comparisons of Cellular and Tactical Edge Networking waveforms can be made as in the table below, but key differences in terms of application explain the gap between both trends:

- Cellular – Tower link budgets versus tactical edge and Ad-Hoc networking
- Channelization and Frequency resources availability
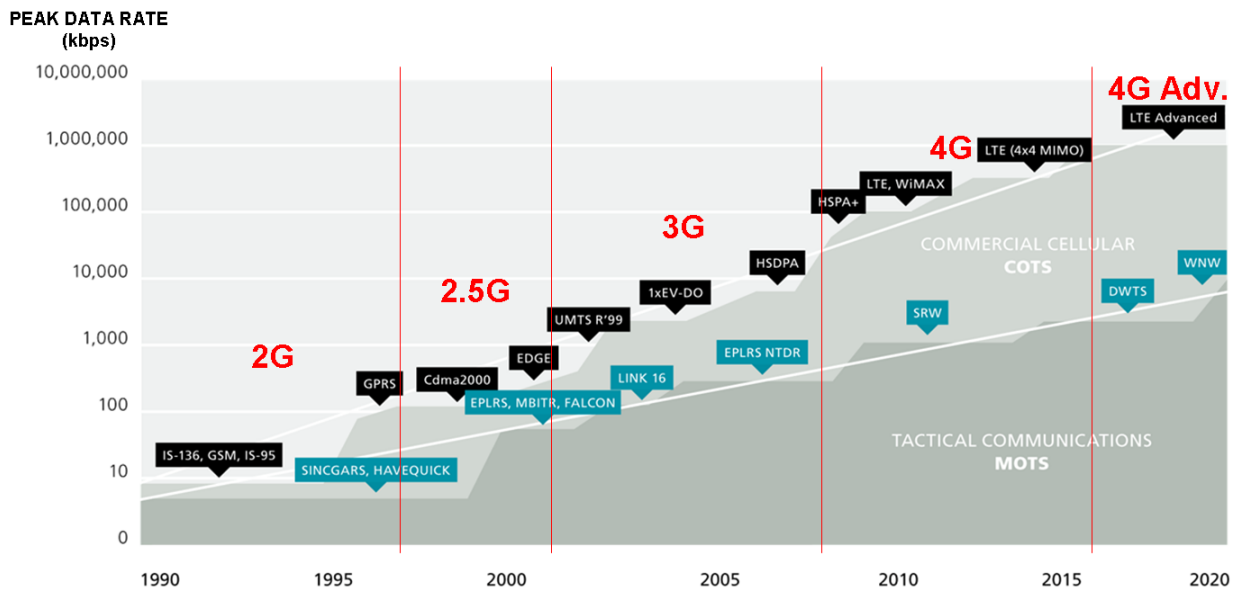- Fixed frequencies versus Security and ECCM features

Figure 21: Wireless Communication technologies trends: COTS vs. MOTS

5 SDR Business Model

5.1 Business Model Examples

5.1.1 JTRS Enterprise Business Model

SDR, with separation of Platform and Waveforms supply, could drastically change the business model of tactical communications market.

The JPEO JTRS has elaborated its Enterprise Business Model[68].

JPEO JTRS is fundamentally changing the way the DoD acquires communications and networks. The JTRS Enterprise Business Model (EBM) is a paradigm shift from typical DoD acquisition and radio industry procurement practices because it is designed to enable more cost effective capability growth by applying the concept of competition to an acquisition strategy. While the typical DoD acquisition model has full and open competition for Engineering and Manufacturing Development (preciously called System Development and Demonstration), a sole source contract is usually awarded for production. This approach produces a closed proprietary solution where intellectual property (IP) is held exclusively by the vendor, almost assuring sole source for production, support and upgrade into the future. This approach removes incentives for efficiency, quality or cost containment.

On the other hand, the JTRS Enterprise Business Model fosters innovation and competition by encouraging innovative and efficient development of radios, relying on the proven principle of competition, enabling faster technological improvements and lower prices to ultimately benefit the warfighter. The EBM's core tenants set forth the rules to which industry must adhere in order to participate in development and production of JTRS products. These core tenants are encapsulated in three management pillars: Open Standards, Common Shared Software and Competition throughout Product Life Cycle.

5.1.1.1 Open Standards Pillar

The Open Standards Pillar provides the foundation for joint networking interoperability by creating a secure Common Enterprise Architecture and establishing other standards such as Application Program Interfaces (APIs), Software Communications Architecture, and key tags. By having open standards, JTRS is building a family of common radios and waveforms that will deliver joint networking across all services. These open standards also allow new products to be adapted and remain interoperable with what already exists.

5.1.1.2 Common Shared Software Pillar

The Common Shared Software Pillar establishes software Information Repository (IR) to maximize software code reuse and reduce new code development costs. This offers industry lower barriers of entry, enabling industry to offer alternative solutions to the DoD. Manufacturers outside JTRS programs of record can borrow waveforms from the repository and

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[68] Source : JPEO JTRS – Q3 2011

develop JTRS compatible radios without the time and development costs typically associated with programs of record.

Furthermore, this pillar negotiates Government Purpose Rights (GPR) for all software, providing a more affordable modernization or pre-planned product improvement (P3I) approach through reduced reliance on proprietary and restricted data rights. When soliciting for potential material solutions, all JTRS Request for Proposals (RFPs) request a minimum of GPR for JTRS waveform and radio operating environment software. This approach mitigates the reliance on sole sources contracts for follow on capability upgrades and sustainment. AMF and JTRS HMS Rifleman Radio are beneficiaries of this software re-use strategy, and are being procured without incurring new waveform development costs, but rather are porting current JTRS waveforms to their respective platforms resulting in a substantial development cost savings.

Finally, this pillar establishes Software In-Service Support (SwISS), enabling rapid JTRS tactical networking capability enhancements, upgrades, and maintenance through software updates.

5.1.1.3   Product Life Cycle Pillar

The Competition throughout Product Life Cycle Pillar drives down unit costs through competitive acquisition strategies in production. Each JTRS production contract is required to qualify at least two sources, which provides significant cost savings through continuous competition. Cost containment plans and robust metrics are used to increase pressure on, visibility into, and transparency of vendor performance. JTRS alters fee structures for contracts, basing fees on measurable results and tying incentives to back-loaded fees. This approach incentivizes productivity and shares accountability for product and capability delivery between DoD and our industry partners.

Through continuous competition, the JTRS acquisition strategy provides a more affordable path for capability growth and sustainment. The JTRS EBM aligns well with the current guidance from the Office of Secretary of Defense to achieve cost savings and efficiencies through improved business management models, to utilize cheaper COTS products and services, and to develop proactive competitive contracting models. The JTRS EBM was designed to be used by other DoD programs going forward as a way to drive down costs to the Department. Currently we know of no other specific entities incorporating the EBM as a major strategic organizational pillar, as in the case of JPEO JTRS. The DoD seems intent to move in the direction of the JTRS EBM, at a minimum incorporating key facets of the EBM wherever and whenever possible to maximize the benefit to the Warfighter for dollars spent.

5.1.2   *JTRS Joint Reference Implementation Laboratory (JRIL)*

While the mission of JTRS has not changed (continuing delivering a family of affordable, secure, interoperable, IP-based networking radio products to all services of the Defense Department), the approach to meeting this mission is evolving to include more non-developmental activities acquired through agile processes.[69]

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[69] www.defensesystems.com/JTRS2012

JPEO JTRS is further extending the JTRS Enterprise Business Model approach to affordably proliferate implementation of networking waveform software by establishing a Joint Reference Implementation Laboratory (JRIL) that will ensure interoperability by managing waveform software releases and testing compliance with applicable standards.

The goal of the JRIL is to facilitate the porting and integration of JTRS software into the JTRS Program of Records (POR), Vendor Funded R&D initiatives, and other radios-based products for the DOD armed forces.

The JRIL will also serve as a critical approving body. The JRIL will serve as the Joint Tactical Network approving authority for all JTRS radio/waveform sets introduced to the DOD end users, thereby ensuring battlefield interoperability between radio form factors and waveform versions.

The JRIL is being established in a phased approach.
- The first phase was initiated in 1QFY12 for the JTRS networking waveforms (SRW, Wideband Networking Waveform (WNW), Mobile User Objective System (MUOS) Waveform) and the JTRS Enterprise Network Manager (JENM). During this phase, the waveform software will be maintained in the same ecosystem it was originally developed on (such as hardware, operating environment, software development tools, etc.).
- The term "gold waveform standard" refers to this waveform software running in this reference implementation of hardware/ operating environment.
- The second phase is to be initiated in out years to migrate all JTRS waveforms to a common reference implementation.

5.1.3   ESSOR

The ESSOR program is a very interesting business model where several nations in Europe join forces to develop a waveform that could be ported in an efficient way into various SDR platforms that could be supplied independently by the different involved nations.

Based on some background and on some national SDR champions (industry players in each country), the program founds some development of a new HDR ad-hoc networking waveform.

5.2   Third Party Waveforms providers and SDR Ecosystem

5.2.1   Third Party Waveforms providers

Third Party WF providers play an important role in the SDR market for Defense. Such providers offer a generic SDR software product to all SDR equipment manufacturers who are contemplating entering the Defense SDR market. Development of specific generic SDR technology is expensive, and third party independent providers of generic SDR software products enable SDR equipment manufactures to lower their total investment. This is because Third Party WF providers reduce development time and risk due to specialization, expertise and use of existing code, process and tools - and therefore offer their products at a lower price. Such competitive pricing is expected to ensure more customers for the Third Party WF providers, thus

they will be able to sell their products to a number of customers and also have a profitable business.

Third Party waveform providers can support a variety of different licensing and procurement models.

The Third Party WF providers' value proposition to the SDR equipment manufactures could be highlighted as:

- Potentially reducing cost and development time because of specialist communications expertise, specialist embedded software expertise and existing framework code, development tools and test tools.
- Lowering the total risk on the SDR equipment manufacturer's product development.
- Providing greater security for "time to market", especially for existing WF standards
- Potentially offering risk sharing with the customer.

The Third Party WF providers' value business model could consist of the following components:

- License fee (payment for background technology in the form of the waveform product).
- NRE fee (payment for customer-specific modifications and services).
- Royalty fee (additional payment per manufactured piece of equipment).

5.2.2   SDR Ecosystem

Together with US and Europe SDR programs, a SDR Ecosystem has been developed, with various suppliers able to provide:

- HW Modules: Especially for fast prototyping steps in order to reduce and optimize the complete development life cycle to ensure an efficient go to market,
- OE SW elements: Various providers are able to provide OE SW elements, such as CF, ORB, or OS SW
- SDR labs: Suite of tools is available in order to specify, to develop or to port Waveforms acc. to international SDR standards.

Wireless Innovation Forum conferences in the US and Europe give a unique possibility of access to these different providers capable of providing building blocks to help and to speed up the development of SDR programs.

5.3 Typical Use Cases

Typical stake holders in SDR programs are:
- Waveform Provider
- Radio SDR Platform Provider
- Integrator: responsible for the integration of Waveform together with SDR Radio platform,
- Procurement Agency acting for End Users
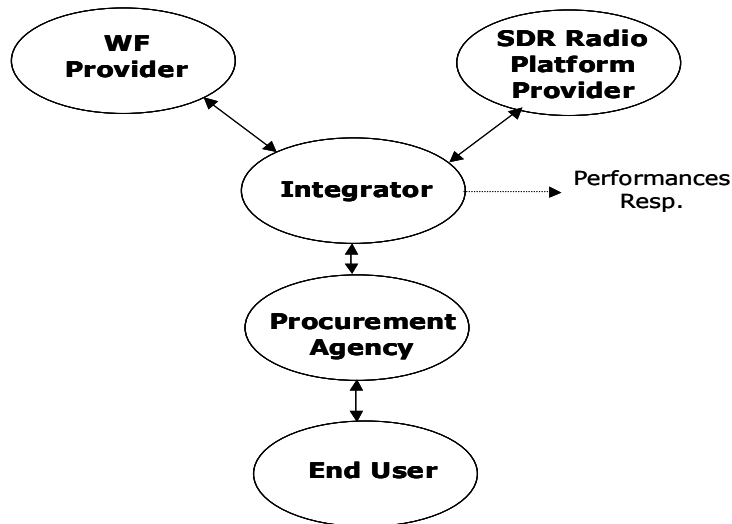
Figure 22: Typical SDR Program Stakeholders

We can envisage four (4) typical use cases:
- MOTS Radios
- Delivery of Platform & Waveform(s) by the Radio Supplier. In this case WF and Platform providers are the same, eliminating the WF integration onto platform responsibilities.
- National SDR programs: programs that split deliveries or developments between WF and SDR Radio Platform. In this case, several scenarios can be envisaged:
  - WF : Development of Waveforms only : could be for national usage only or for coalition interest (Regional / Group of nations)
  - WF and Platform (PTF) : Additionally to WF, some specific requirements for local PTF parts could occur :
    - Specific OE requirements,
    - Specific PTF requirements,
    - This use case is therefore opened to the supply of MOTS Modules: SW & HW Modules, that could be supplied by the SDR radio PTF suppliers (modules of their solutions) or by the SDR Ecosystem (see previous chapter).
  - Full Specifications case: In this case the procurement agency issues detailed specifications of all parts. It is a full development use case that occurs in

nations where local industry is capable of handling such complex programs (involved technologies, and scale of the program). Usually such programs provide some limited opportunities to MOTS Modules providers.

SDR radio Platform and Waveform definitions are depicted in the following figure.[70]

Figure 23: SDR Radio Platform and Waveform
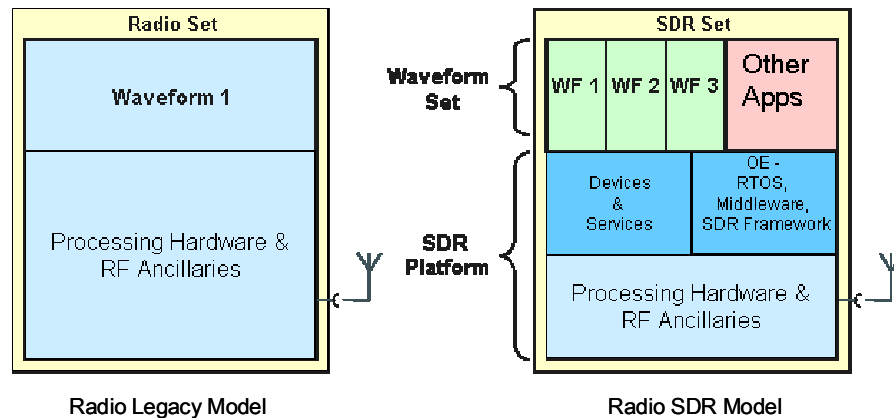
5.3.1   MOTS Radio

The use of MOTS Radio means that the radios are supplied with waveforms, i.e. the same supplier is used for the waveform and for the platform. This simplifies drastically the delivery scheme with the program organisation similar to that of legacy or previous generation use case. The question then is" "Why in this case, should a standard SDR architecture like SCA, be required?"

The reason is that the end user and the procurement agency could request some further WF porting (coalition WF or other). Therefore some SCA or other standard capabilities will provide some future WF porting capabilities future-proofing to the platform, of course, without any guarantee or commitment. SCA capability does not guarantee that all future WF can be downloaded to the platform and put into operation.

But in cases of expected near completion of standard WF with already known performance requirements, some future proof capability can be requested. In this case the procurement agency would like to get confirmation or proof of the International SCA & APIs standard.

An SCA and standard certification process is very difficult to be put into place at the international level (business model aspects: cost to be put in place for setting up test tools and cost to run/execute the certification by an "independent body").[71]

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[70] Wireless Innovation Forum, "White paper on SDR Technologies for the International Tactical Radio Market, WINNF-09-P-0006 Version V1.0.0", http://groups.winnforum.org/d/do/4987

At least conformity tests to the standard could be requested by the procurement agency (through dedicated acceptance tests managed on its own or by test reports provided by industry), but as well by the radio suppliers that could have the willingness to communicate on its standard conformance (Marketing-Communication) and provide in advance some results to its potential customers.

5.3.2 National SDR Program – Waveform

An example could occur in the international market, outside the US and Europe, where a nation would like to acquire some National Sovereignty through a national WF program.

In this case the country will set up a complete program:
- to specify the requirement and the waveform,
- to organise the development of the waveform (through an international RFx process or with local competency)
- to procure the radios independently from the waveform
- to lead the integration step of waveform into the platform (inc. responsibility, performances aspects, interoperability across the various porting etc….)

US and European projects already exist, and can provide examples to help to define complex program organization:
- Coalition WF: ESSOR HDR WF ; COALWNW, NATO WGs
- National WF Programs: US JTNC WF Library Approach

5.3.3 National SDR Program – Waveform and Platform

Increasing in the complexity and the competencies requirements, the procurement agency can decide to set up some specific requirements to adapt some radio platforms versus what is available on the market. Without going to the full specifications (detailed, inc. full performances internal and external), it requires some adaptation to comply with these constraints driven by local specificities. Often the motivation is driven not only by national sovereignty but as well by local industry ramp up (local content could be requested up to 70%).

This sovereignty objective provides some government funding capabilities but it requires some local industry capabilities and skills.

These programs could use some COTS or MOTS modules from radio suppliers or from SDR, SCA & API international ecosystem (OE SW modules, HW SDR radio PTF modules).

5.3.4 National SDR Program – Full Specifications

We see as well several large countries (or groups) with the capability to specify the complete systems and procure it; with capabilities to specify SW & HW parts (National OE, On specifications radio / HW). These specifications can be based on international standards and as

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[71] Wireless Innovation Forum, "Test and Certification Guide for SDRs based on SCA Part 1: SCA", http://groups.winnforum.org/d/do/1559

well on national specificities (to complement some holes and to deal with national only parts – ie. security related topics).

Very often the procurement agency could build its own testing capabilities for acceptances, as shown in the US with JTRS and JTNC experience (JTRS – JTNC certified).

There are several examples of such programs:
- US JTRS
- Germany SVFuA
- Korea TMMR
- France CONTACT

5.4 Business Models Parameters

5.4.1 Funding Models

The SDR programs can be founded through different approaches:
- Government: development on request
- Industry: self investment
- Hybrid

5.4.2 Key Business Models Driving Factors

Many factors influence the Business Model implementation, often with clear limits to its widespread adoption:
- IPR Management: Background and Foreground IPR have to be taken into account and a fair retribution on investments by the different parties (industry background, government development programs) should be secured in order to make the business model operable.
- SDR Deployment Barriers
  - Import/Export Control Restrictions
  - Release of standards information: could be restricted to "regional","multi-national" organization (NATO, Coal etc….).
  - Security constraints, No Foreign Code Rule
- SDR Standardization & Conformity
  - Standards Levels
  - Compliancy to standard, conformance to standard
  - Certification or not
- Interoperability Tests, at the air interface between various WF implementations/porting into different SDR radio platforms.

5.4.3 WF Development & Porting Use Cases

The following sections provide several examples of typical use cases.

5.4.3.1 Case A - Development of new Waveforms

- Government (or group of nations) pays for all of the development of the waveform software and may own the rights to source code
- Industry invests in the development of the waveform and grants license fees (in a sufficient way to make the business model work for competing companies)
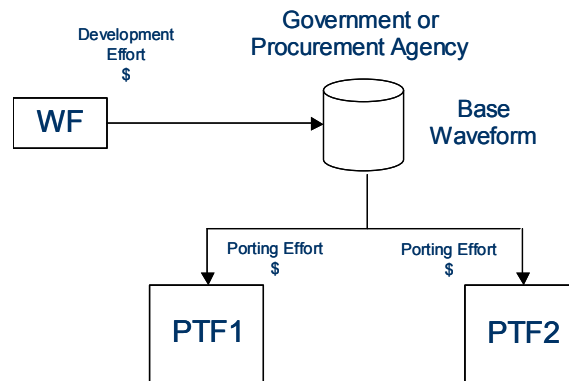
Figure 24: Development of New Waveforms

- Government (or group of nations) pays part of the development costs, which are shared with the contractors and therefore obtains a lower license fee. This is a combination of above cases.

Development of new networking waveforms is quite important: we have seen in previous chapters some different examples in the range of $100M.

This investment should be in regards of potential market. Already 10,000 radios represent a large single market. In this case, it represents an investment of $10k per radio. This WF investment should be put in regard of the market price of radios. The US MNVR and other vehicle programs gives some range from 40 to $100k, ie a WF investment from 10 to 25%.

On top of the development, the porting effort should not be neglected and should be added.

5.4.3.2 Case B - Porting existing Waveform

In new NCO architecture several SDR systems (PTF and WF) could be supplied according to the various end use applications:
- Vehicular platform for ground forces,
- Soldier or dismounted platforms for ground forces,
- Platforms for naval applications,
- Airborne platforms for helos or for fighters or for surveillance aircrafts,
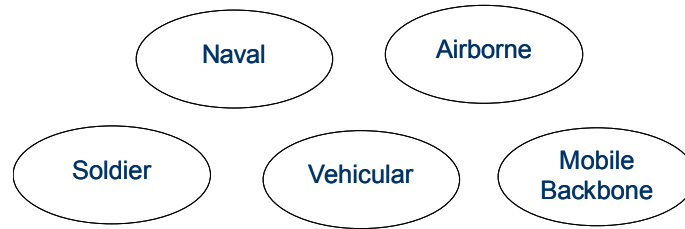
Figure 25: Various SDR Platforms in a Joint NCO architecture

It is highly probable that the procurement agency will not contract a single provider to deliver all these communication systems,

- To keep competition between suppliers,
- Usually the different systems are supplied according different life cycles and acquisition processes.

It is therefore expected that the procurement agency will request the possibility to port the WF1 delivered with PTF1 from Supplier 1 into the PTF2 from Supplier 2 to get some interoperability capabilities, for instance:

- Between ground vehicular and dismounted applications,
- Between ground and airborne platforms,
- Between ground and naval platforms,
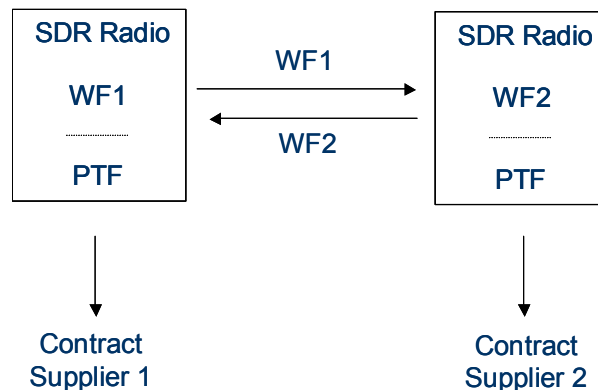
Figure 26: Porting Existing Waveform

To enable this model, the procurement agency could require the supplier to provide the base waveform and provide the support for the porting of the waveform into the other SDR platform under fair and reasonable conditions, and following general practices created in the international SDR development and standardization community like the Wireless Innovation Forum.

This Base Waveform model, by definition platform independent, is further described in the WF development and porting paragraph. It includes some functional specifications, implementation specifications, waveform modeling and codes.

This example highlights the critical IPR aspects where Supplier 1 owns the WF1 to be ported in a competitor (Supplier 2) platform.

A simplified case occurs if the WF is owned and mastered by the procurement agency.

5.4.3.3 Case C - Adapting and Porting Waveform

Because of large investment requirements on one side and extensive lead times on the other, a possible intermediate scenario can be imagined and based on modification and adaptation of existing Waveforms.

Management of the background IPR (owned by party/ies other than the procurement agency, industry or other government) represents the inherent difficulties of this scenario.

The Foreground aspects will be likely managed in a similar approach as Case A.

5.5 Waveform development & porting Framework

The importance of WF porting on various SDR Radio platforms has been highlighted in the different previous chapters use cases (See 6.4.3).

5.5.1 International references

Both US JTNC and ESSOR programs have experience developing waveforms that could be ported into different platforms coming from different radio suppliers.

Waveform development, porting framework or methodologies have been elaborated in order to have an efficient process:
- Minimizing the total effort/cost of porting into different platforms,
- Optimizing the planning,
- Reduce the risk of the total program, in general complex because of various stake holders and split of responsibilities,

In order to achieve these objectives, the concepts of Base Waveform / Target Waveform have been developed.

The Base Waveform is independent from the target radio platform; it is therefore a common development effort derived from Waveform specifications before the porting step, specific to each radio platform.
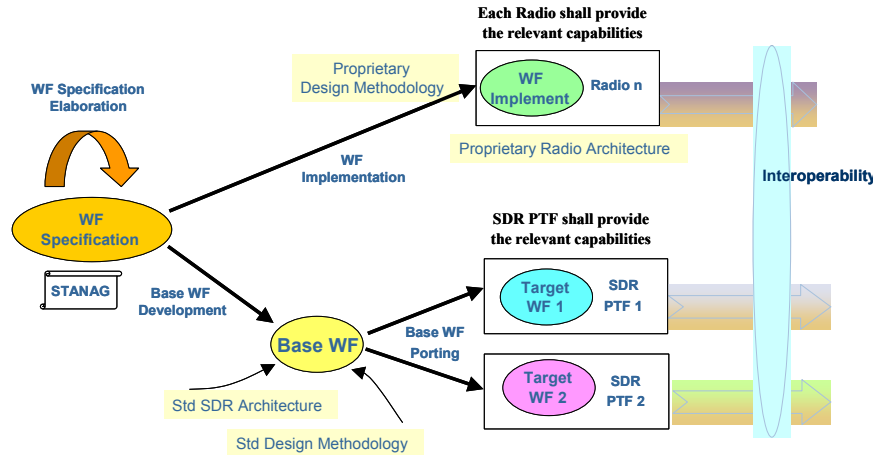
Figure 27: Base Waveform and Target Waveform

NATO has presented its SDR Waveform Life Cycle in various conferences[72] leveraging this Base WF / Target WF approach as depicted in the following slide.
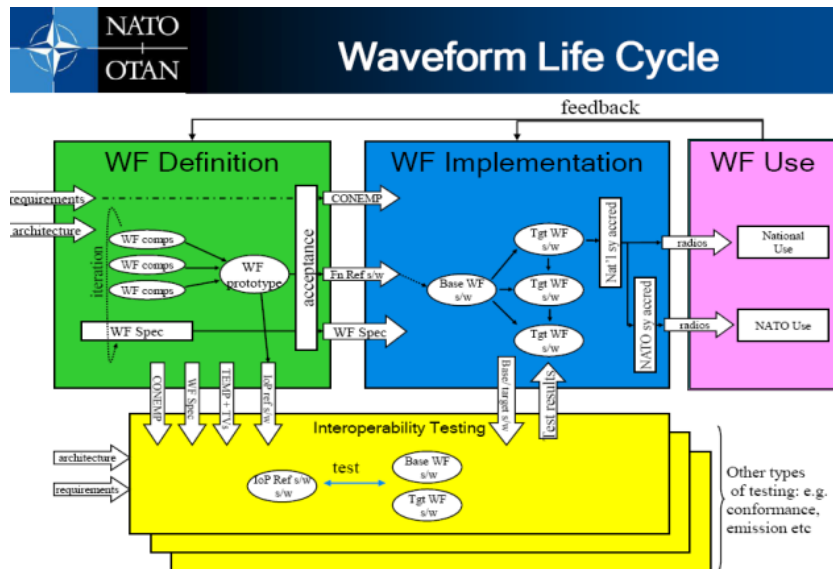
Figure 28: NATO Waveform Life Cycle

As well using the Base WF / Target WF approach, the ESSOR program has largely described its methodology in various SDR conferences, and especially during the SDR'12 WinnComm Europe Tactical Communications Workshop[73].

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[72] NATO presentation in SDR Europe 2010 conference (Roma October 2010) and in Wireless Innovation Forum SCAstandard worksop – Turkey – October 2010

[73] Proceedings of the 2012 Wireless Innovation Forum European Conference on Communications Technologies and Software Defined Radio, http://groups.winnforum.org/e/in/m=1&req=Edit&eid=4

5.5.2 *ESSOR Base WF Methodology for Portability.*

ESSOR Program has developed a dedicated methodology to optimize the Portability process: T*he ESSOR Base WF Methodology for Portability[74]*.

This methodology is based on the Base WF and Target WF approach and uses the ESSOR Architecture APIs.

The ESSOR HDR Base WF main goals are:
- Common HDR WF software code amongst the 6 radios suppliers selected by the 6 nations of the program,
- Initially ported and validated in a common Native Test Environment to de-risk national porting phase on the different SDR platforms,
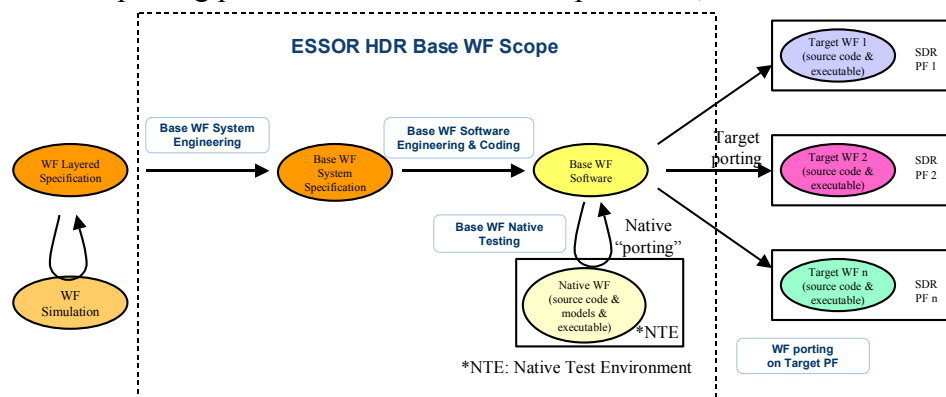

Figure 29: ESSOR Base WF Methodology for Portability

The methodology is generic and portability-focused.

According To the ESSOR program, it goes significantly further than JTNC WF Portability Guidelines[75], while being in line with its principles.

It separates the stable functional software (the Worker / Golden Source) from platform-dependent software (the Container) and enables WF Portability across different OE choices (an essential asset to preserve Portability when the number of possible connectivity increases e.g. CORBA, MHAL Comm …). The methodology covers the complete Base WF development cycle from System Design, Software Design and Coding to Native Verification.

The main purpose of the methodology associated with the ESSOR Native Test Environment (NTE) is to validate the HDR Base WF for de-risking the different SDR platform porting activities.

The NTE is composed of Protocol Native Test Environment (PROT NTE) and Physical Native Test Environment (PHY NTE) which can be interconnected together to perform System Level verifications.

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[74] Proceedings of the 2012 Wireless Innovation Forum European Conference on Communications Technologies and Software Defined Radio, http://groups.winnforum.org/e/in/m=1&req=Edit&eid=4

[75] JTNC - Waveform Portability Guidelines, version 1.2.1, 28 December 2009 – http://jtnc.mil/sca/Pages/portabilityguidelines.aspx

The NTE is a key part of the validation strategy of the complete development life cycle, consisting of:

- Specifications
- Base Waveform Development
- Porting into SDR platform

Each step is associated with an in depth test and validation approach:

- High Fidelity Simulations to validate specifications
- NTE to validate the Base Waveform
- Interoperability Tests to validate the porting step

5.5.3 New WINNF project: State of the art of waveform application portability

A project is currently under way in the Wireless Innovation Forum in order to work in such development and porting framework.

The "*State of the art of waveform application portability*" report will identify the latest developments and trends in the field of waveform portability in SCA based standards and will provide a common understanding of the main challenges involved in application portability using SCA based architectures. It will provide a consolidated view of the waveform portability problem in SCA based architectures and will set the common ground needed to provide an updated set of recommendations for developing waveforms independently of the underlying architectural framework, resulting in an easily portable source code.[76]

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[76] WINNF - SCA Implementers Work Group - http://www.wirelessinnovation.org/Current_Projects

6   Conclusion: SDR for new entrants

There is no single solution and easy answer. The SDR technology does not solve the interoperability issues by miracle, but it helps to find some solutions while ensuring an NCO transition.

SDR Business Models do provide some clear benefits:
- Sharing cost of development among different nations or different suppliers: it is particularly important with significant waveforms and radio platform developments costs with a near stable total addressable market,
- SDR could be a competition enabler, permitting multiple radio platform suppliers; this competition could be seen as a source of innovation with reduced time to market,
- Access to national independence

However significant limiting factors exist, and costs to access these benefits should be investigated:
- Interoperability has a cost and the business model should absorb it,
  - Either through some competition gain; definition and development of an interoperable waveform should be lower than the pricing advantage expected by competition plus the opex gains in a single supplier scenario (single supplier bringing lower operation and maintenance expenditures).
  - Or through government funding,
  - Or by large quantities market
- Introduction of competition has a cost; the cost of interoperability could be solved in SDR with the definition of an interoperable WF. National sovereignty means as well ramping up an independent industry with skills to acquire: it has a cost and a lead time.

An interesting move in the US market has been highlighted recently, trending towards a MOTS Business Model. With the announced stop of the GMR program, the US has shown a transition from complex and long development programs towards a more pragmatic, good enough approach, taking advantage of some MOTS, or near MOTS, solutions (creation of an ecosystem with some building blocks) together with a focus on the importance of networking WF owned by the government to ease the porting of this interoperable WF into different supplied platforms from different vendors.

Multiple other aspects influence the Business Model implementation in the different markets. In particular, the following instances should be carefully analyzed:
- SDR Standards; The desire to port the same Waveform onto multiple and different radio platforms leads to the requirement for standards that lower the cost and reduce the effort inherent in waveform porting.
- WF Interoperability Testing; Porting a common waveform into multiple platforms and used by different units leads to the requirement to establish over the air waveform interoperability centers.
- Security, Information Assurance or Access Restriction; Security and information assurance requirements in the military domain lead to complication of the business

model and often restrict the accessible market. In addition, the access to SDR and Waveform standards could be restricted to a nation or an international organization (such as NATO).

- Legacy Waveforms, New Waveforms and Intellectual Property Rights (IPR); Access to IPR is often required to ensure the porting of waveforms onto multiple radio platforms. For new waveforms, this can be managed from the beginning of the development program, but the issue is problematic for legacy waveforms that are typically owned by the radio manufacturer.

7 Glossary

AFV	Armored Fighting Vehicle
AIFV	Armored Infantry Fighting Vehicle
APC	Armored Personnal Carrier
API	Application Programming Interface
BLOS	Beyond Line Of Sight
BMS	Battlefield Management System
C4I	Command Control Communicate Intelligence
C4ISR	Command, Control, Communication, Computing, Intelligence, Surveillance and Reconnaissance
C4ISTAR	Command, control, communication, computing, intelligence, surveillance, target acquisition, and reconnaissance
CIE	Capability Integration Evaluation
COALWNW	Coalition Wideband Networking Waveform
COE	Common Operating Environment
CR	Cognitive Radio
CRS	Cognitive Radio Systems
CS	Capability Set
CSCHR	Consolidated Single-Channel Handheld Radio
CTRW	Coalition Tactical Radio Waveform
DGA	Délégation Générale à l'Armement
EBM	Enterprise Business Model
EDA	European Defense Agency
ESSOR	European Secure SOftware defined Radio
FY	Fiscal Year
GMR	Ground Mobile Radio
GOTS	Government off-the-shelf
GPR	Government Purpose Rights
GTRS	Gemensamt Taktiskt RadioSystem
HDR	High Data Rate
HMS	Handheld Manpack
ICT	Information and communication technology
ISTAR	Intelligence, surveillance, target acquisition, and reconnaissance
JPEO	Joint Program Executive Office
JTNC	Joint Tactical Networking Center
JTRS	Joint Tactical Radio System
LBT	Light Battle Tank
LFD	Landing Force Digitalizzata
LOS	Line Of Sight
LRIP	Low Rate Initial Product
LTE	Long Term Evolution
LTE	Long Term Evolution
LTE-A	Long Term Evolution – Advanced
MANET	Mobile Ad-Hoc Network
MBT	Main Battle Tank
MNVR	Mid-Tier Networking Vehicular Radio
MOTS	Military Off-the-shelf
NB	Narrow Band
NBWF	Narrow Band Waveform
NCO	Network Centric Operations
NEC	Network Enabled Capacities
NED	Network Enterprise Domain
NIE	Network Integration Evaluation
NLOS	Non Line Of Sight
OCCAR	Organisation Conjointe de Coopération en matière d'ARmement
OE	Operating Environment
OFDM	Orthogonal frequency-division multiplexing
OFDMA	Orthogonal Frequency-Division Multiple Access
PMP	Point to Multi-Point
PR	Press Release
PTF	Platform
PtP	Point to Point
QFY	Quarter Fiscal Year
RCIED	Radio Controlled Improvised Explosive Device
SATCOM	Satellite Communications
SCA	Software Communication Architecture
SDR	Software Defined Radio
SRW	Soldier Radio Waveform
SVFuA	Streitkräftegemeinsamen Verbundfähigen Funkgeräteausstattung
SwISS	Software In-Service Support
TDRS	Tactical Data Radio System
TICN	Tactical Information Communication Network
WF	Waveform
WNW	Wideband Networking Waveform