ELECTROMAGNETIC SPECTRUM DOMINANCE

AN AUTONOMOUS AND EFFICIENT SPECTRUM MANAGEMENT SYSTEM

SDR'11 – WInnComm
Washington DC Nov. 29 – Dec. 02, 2011

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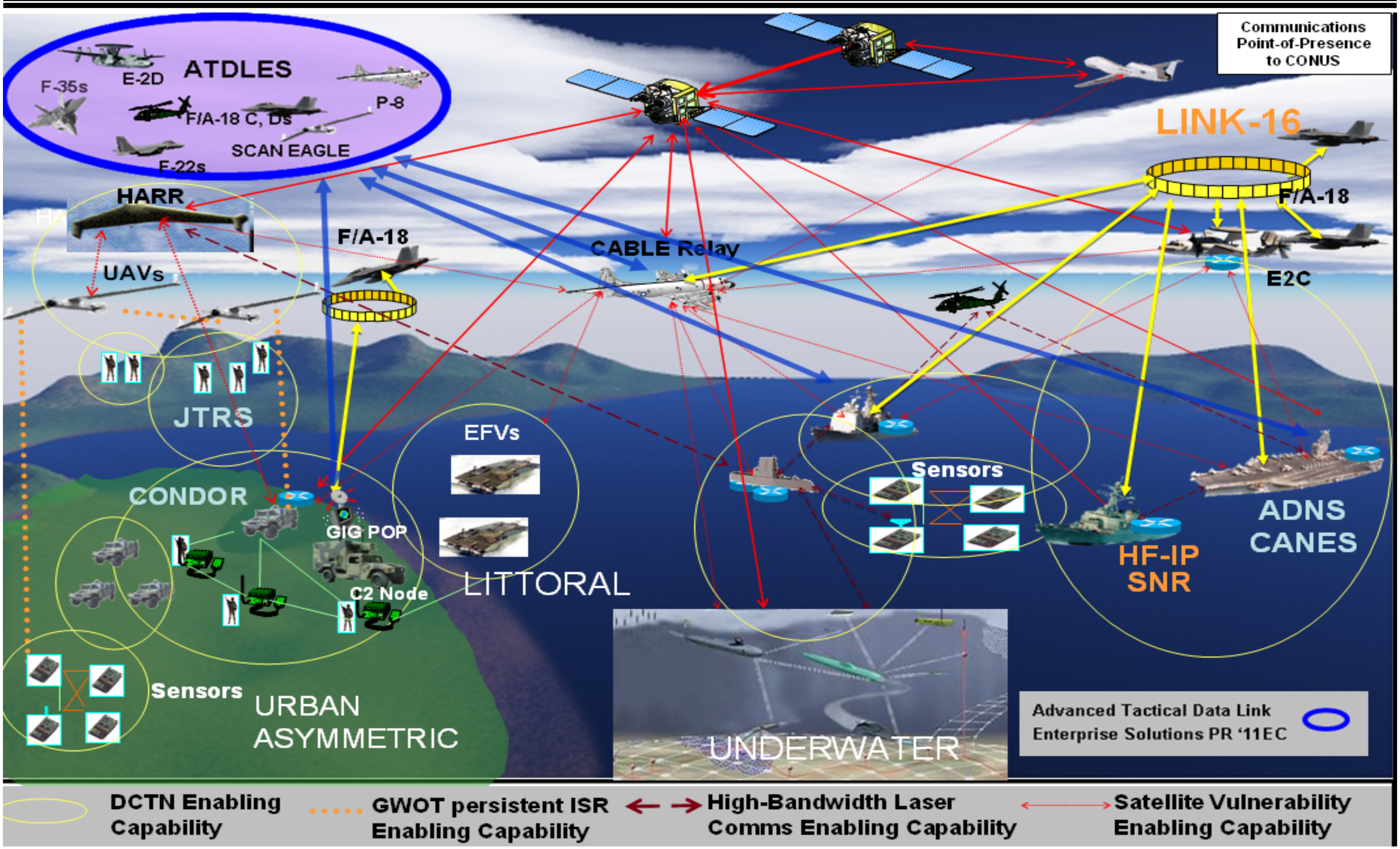
Tactical Communications



Electromagnetic Spectrum & Military Operation

- Military Spectrum Dependent Systems (SDS):
  - Communications systems
  - Radars
  - Sensors
  - EW
  - Weapons systems
  - Munitions
  - Geo-location
  - Logistics
  - Etc…

- Access to required spectrum as needed is key to success in Military Operation

- Spectrum dominance assures access to required spectrum

- Spectrum Dominance => Success in Military Operation

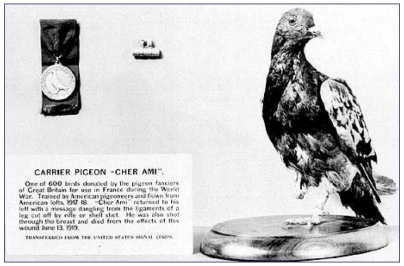
Spectrum Management History

Key Dates in Spectrum Management History[1]

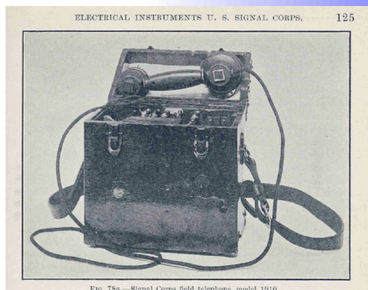
- **1912 -- U.S. Radio Act of 1912**. Commercial radio licenses issued by the Department of Commerce. In the 1920s, Secretary Hoover discovered that the authority was like a driver's license: any qualified person could get one.
- **1922 -- Interdepartment Radio Advisory Committee.** Under presidential authority, Federal Government agencies determine allocations for naval and other Federal spectrum use.
- **1927 -- Radio Act of 1927.** Establishment of independent commission, Federal Radio Commission, with power to grant exclusive radio station licenses to limited number of applicants.
- **1934 -- Communications Act of 1934.** Provisions of Radio Act incorporated with little change as Title III of new act. Federal government stations remain exempt under section 305.
- **1962 -- All-Channel Receiver Act.** Required televisions to receive UHF as well as VHF signals.
- **1992 -- World Administrative Radio Conference.** Another of a long line of conferences under the auspices of the U.N.'s International Telecommunication Union, this conference among other things considered common location for what was to become known as "3G" services.
- **1993 -- Omnibus Budget Reconciliation Act.** Authorized FCC to use competitive bidding (auctions) to choose licensees, and ordered identification and transfer of 200 MHZ from government use to FCC jurisdiction.
- **1996 -- Telecommunications Act of 1996.** Set stage for licensing of digital television channels to incumbent broadcasters and essentially precluded an open auction. Granted broadcasters flexibility to use their spectrum for non-broadcast services. Other miscellaneous provisions regarding wireless services.
- **1997 -- Balanced Budget Act of 1997.** Required transfer of additional 20 MHZ of spectrum below 3 GHz from Federal Government use to FCC for reallocation; set 2006 as the year broadcasters had to give up their analog channels, with a big if; and set deadlines for auctions of specified frequency bands.

[1] http://www.ntia.doc.gov/legacy/opadhome/spectrumhistory.htm

Historical Perspective - Communications during WWI



Cher Ami on display at the Smithsonian Institution



Field Telephone

WWI Messenger Dog

signal lamp, semaphore and heliograph

WWI Bicycle and Motorcycle Messenger

Royal Air Force flare gun

AVAILABLE TECHNOLOGY

- Electronic Communications were limited to telephone and telegraph
  - Maintaining wired communications difficult
  - Wireless telegraph prone to interception
- Signal lamps, semaphores, signal flares and heliographs depended on field conditions
- Pigeons, dogs and people relied on to deliver messages

RESULT

- Absent, Poor or unreliable communications
- Examples
  - Battle of Tannenberg
  - Battle of Marne

Historical Perspective - Electronics Explosion WWII

Radio Set SCR-536, the smallest Signal Corps transmitter/receiver of World War II.

SCR-300 Backpack Walkie-Talkie Radio.

U.S. Navy. Radar on USS Yorktown April 1945.
Here are seen a full complement of radar.
1) mark 12, 40cm fire-directions sets with their mark 22 3cm elevation-only height finders.
2) the 10cm SG surface search;
3) the flying bedspring of the 1.5m SK with IFF antenna on top;
4) another SG and the YE aircraft homing antenna (not a radar);
5) an SM, a 10cm radar with parabolic reflector mounted on a stabilized platform used for fighter control.

AVAILABLE TECHNOLOGY

- Extensive use of wireless communications and additional modulations
- Radar saw broad application
- Electronic counter measures appeared
- Long-range navigation (loran) developed

RESULT

- Enabled rapid coordinated military actions
- Examples
  - German blitzkrieg
  - Allied Normandy landing

Evolution of Satellite Communications

YEAR	MILESTONE
1957	First man-made Earth satellite launched by the former Soviet Union.
1958	First US satellite launched. First voice communication established via satellite.
1960	First communication satellite (passive) launched into space.
1962	First active communication satellite launched.
1964	First satellite launched into the geostationary orbit. INTELSAT founded.
1965	First satellite launched into the geostationary orbit for commercial use.
1972	First domestic satellite system operational (Canada). INTERSPUTNIK founded
1975	First successful direct broadcast experiment (one year duration; USA-India).
1979	International mobile satellite organization (Inmarsat) established
1981	First reusable launch vehicle flight (American Space Shuttle)
1982	International maritime communications made operational
1984	First direct-to-home broadcast system operational (Japan)
1987	Successful trials of land mobile communications (Inmarsat)
1989/90	Global mobile communication service extended to land mobile and aeronautical use (Inmarsat)
1990/92	•Several organizations/companies propose the use of non-geostationary satellite system for mobile communications. •Plans for provision of service to hand-held telephones by the year 2000 announced by several organizations/companies. •Continuing growth of VSATs in diverse regions of the world. **•WRC allocates new frequencies for mobile satellite communication.** •Continuing growth of direct broadcast in Asia and Europe.
1995	•Largest single-year worldwide growth in the numbers of VSATs. **•Spectrum allocation for non-geostationary satellite system** •First successful test of low data rate commercial low Earth orbit satellite system (ORBCOM)
1997	•Launch of first batch of low earth orbit satellites for provision of voice services to hand-held terminals (Iridium) •Voice communication services to desk-top telephone sized mobile terminal launched (Inmarsat). •Paging service to pocket-sized terminals launched (Inmarsat). •Several broadband FSS personal communication system proposed (Iridium)
1998	Introduction of hand-held services via low Earth orbit constellation.
1990/2000	Introduction of direct sound broadcasting system.
2000/2005	•Introduction of broadband personal communications. **•Ka band system proliferate.** •A number of low and medium orbit constellation system operational.

Evolution of GPS

YEAR	GPS MILESTONE
1957	Sputnik launched
1960	The first navigation satellite TRANSIT IB is launched.
1972	USAF conducted development flights with experimental navigational receivers of the form that could be used with a satellite based navigational system
1978	After an initial launch failure, the first of the Block I development satellites is launched.
1983	US Air Force signs a $1.2 billion for the production build, Block II satellites.
1985	On 9th October, the last of the Block I satellites is launched.
1989	First production, Block II GPS satellite launched
1990	Navstar GPS becomes operational.
1994	24th Block II is satellite launched
1995	In April, Full Operational Capability status of the system is reached signifying availability of the Precise Positioning Service, PPS.
1998	United States Vice President Al Gore announced plans to upgrade GPS with two new civilian signals to provide enhanced accuracy.

Growing Demand in DoD Spectrum Usages

• Virtually every military modern equipment/system depending in some way on RF spectrum

• Demand on RF spectrum for military operation is growing; and growing fast

• The concept of network-centric warfare and the wider use of unmanned vehicles are making militaries equally dependent on the availability of wideband wireless

Navy Unmanned Aerial Systems[1]

1: OPNAV N2/N6F4S, JTEN 20th April 2011

Growing Demand in Civilian Spectrum Usages

Future spectrum demand[1]:

- Today: ~3 billion wireless devices in a density of ~10 – 100 devices/km^2
- 2025: ~100 billion wireless devices in a density of ~1000 – 10000 devices/km^2

1: Future Directions in Cognitive Radio Network Research, NSF workshop report, June 2009

Regulatory Challenge to Traditional DoD Spectrum Access

- FCC's National Broadband Plan, sent to Congress in March 2010, recommends 500 MHz available for broadband in 10 years, including 300 MHz in 5 years.

- In June 2010, Presidential Memorandum directed NTIA to collaborate with FCC to make available 500 MHz over 10 years for broadband.
  - Projected uses: Smart phones, wireless broadband for laptops, machine-to-machine communication, health care initiatives.

Although the specific issue is National – This is a global phenomenon
Always with an adverse impact on DoD operations.

Operational Challenges to Traditional DoD Spectrum Access

- Deconflicting Blue Force Communications and CREW
- Implementing "mobile WLANs" at the edge
- Reduction in radar exclusive spectrum bands globally
- Increased UAS/ISR bandwidth requirements for data distribution
- Saturated RF environment
  - Shortage of datalink spectrum
- Security of Dynamic/Reactive Spectrum Access systems
- Situational Awareness of All Spectrum Usage (COP)

FACTS & ACTIONS

Facts:

- RF spectrum is a finite resource
- Warfighter's reliance on RF spectrum dependent systems will continue to grow. Access to required RF spectrum/bandwidth is key to success of military operations
- DoD has lost and will lose more access to valuable spectrum:
  - 1992 to 2002: Lost access to over 400 MHz spectrum in US and abroad
  - 2010 Presidential Memorandum: Reallocate 500 MHz from DoD/ Federal for commercial broadband
- Current battlefield spectrum planning and execution cannot match the warfighter's current and future needs

Actions:

DoD must develop an Automation of Integrated Electromagnetic Spectrum Resource Management to effectively and efficiently use of the finite spectrum resource to achieve Spectrum Dominance

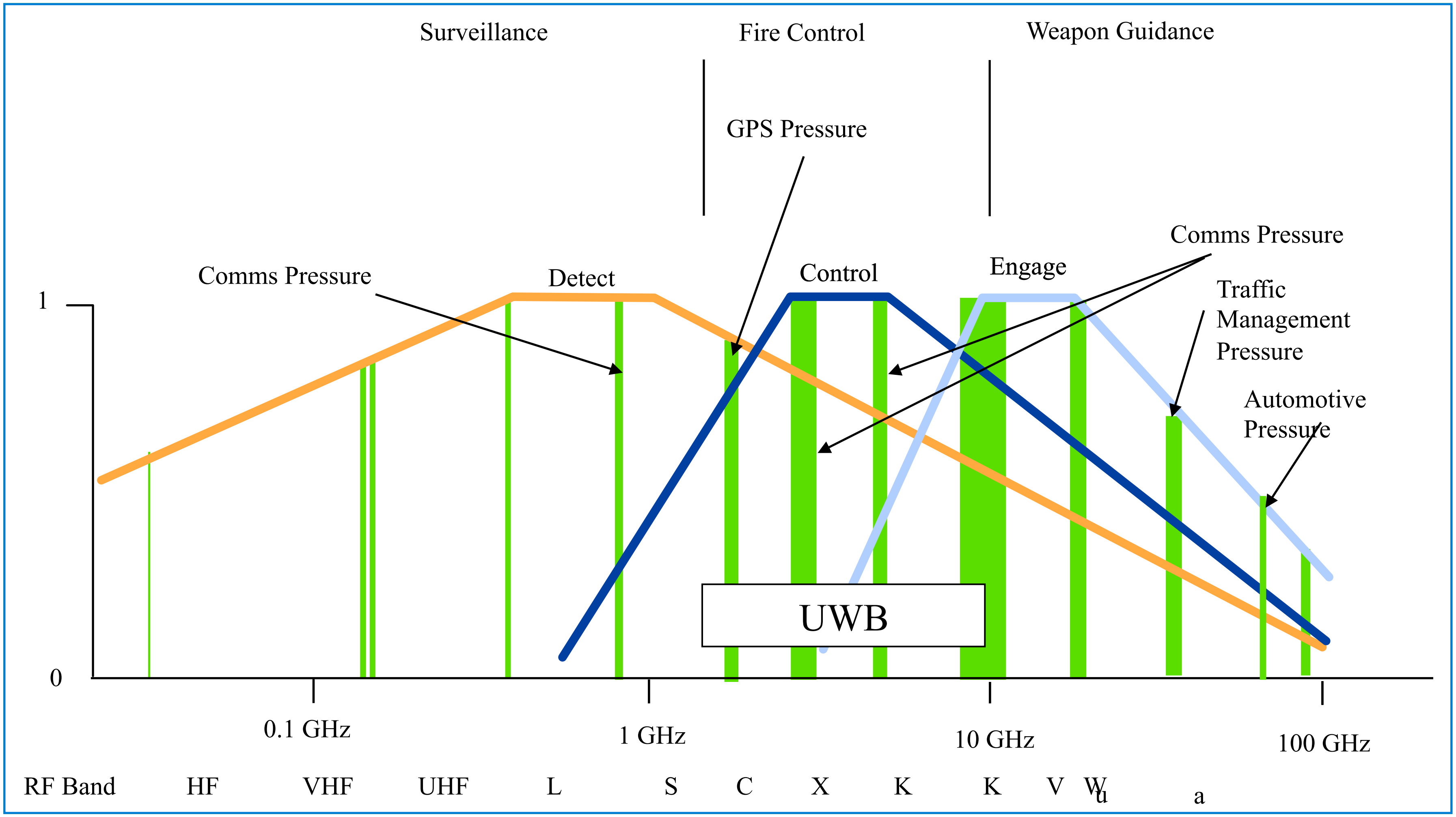
Spectrum Dominance and Challenges

- Spectrum Dominance is the ability to enter a foreign controlled space and **in REALTIME** assert control over how the Electromagnetic Spectrum (EMS) is utilized

- Operational Challenges: De-conflict between the spectrum users – civilians, friendly forces, and adversarial forces across platforms, services and geo-boundaries

- Research/development areas:
  - Spectrum situation awareness
  - Integrated spectrum management
  - Spectrum dependent system (SDS)
  - Security - IA

Pressures On Radar Bands



GREEN BARS ARE RADAR ALLOCATIONS

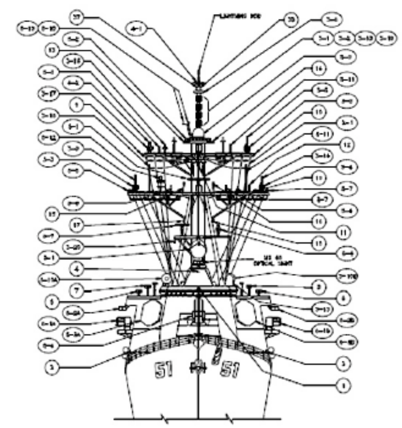
Source: www.ntia.doc.gov

Surface Environments

- Environments: Terrestrial, maritime, and low altitude aerial layer

- Typical conflicts:
  - Remote Control Improvised Explosive Device (RCIED): Need of continuous spectral awareness of the adversary's use of the spectrum with the ability to rapidly deny access when detected

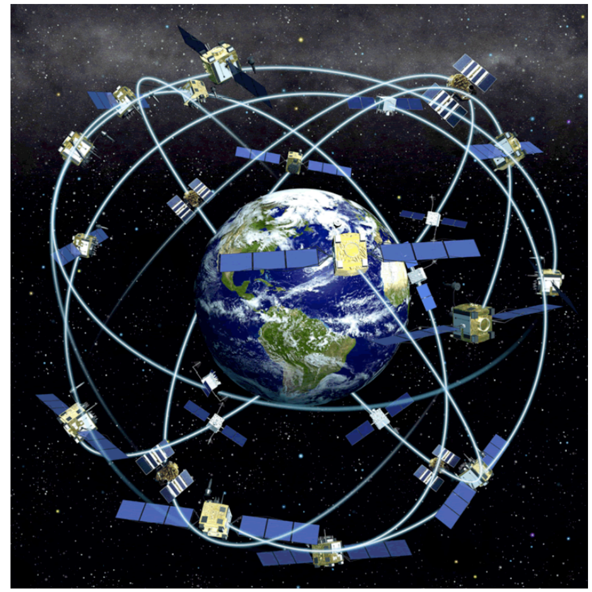
  - Ship top side: extremely dense multi-mission electromagnetic platforms. Conflicts arise in the use of the EMS are not currently adjudicated and automated at a platform level to assure highest-level priority missions access to the spectrum



Topside antenna clutter on surface combatants

Space Environment

- Satellite communications:
  - Currently are conducted within RF spectrum
  - Continue to be the most compelling communications environment
- Current limits of satellite communications:
  - There is no integrated processing power to fully support autonomy and decentralized control
  - Bandwidth allocations are statically sized with over-apportionment being wasted
  - Spectrum limited: MILSATCOM satellites are spectrum-limited:
    - Retain the current allocated spectrum
    - Develop alternative technologies to allow increase the utility of available spectrum in the future



- GPS, Navigation and Timing
- DoD SATCOM provider:
  - Approximately 80% of DoD SATCOM capacity requirements are provided via Commercial SATCOM systems[1]

1: *Spectrum Dominance: S&T Challenge for Space Domain*, Dr. R. Scott Erwin, AFRL/RV Kirtland AFB, NM

Military Operations Require Bandwidth

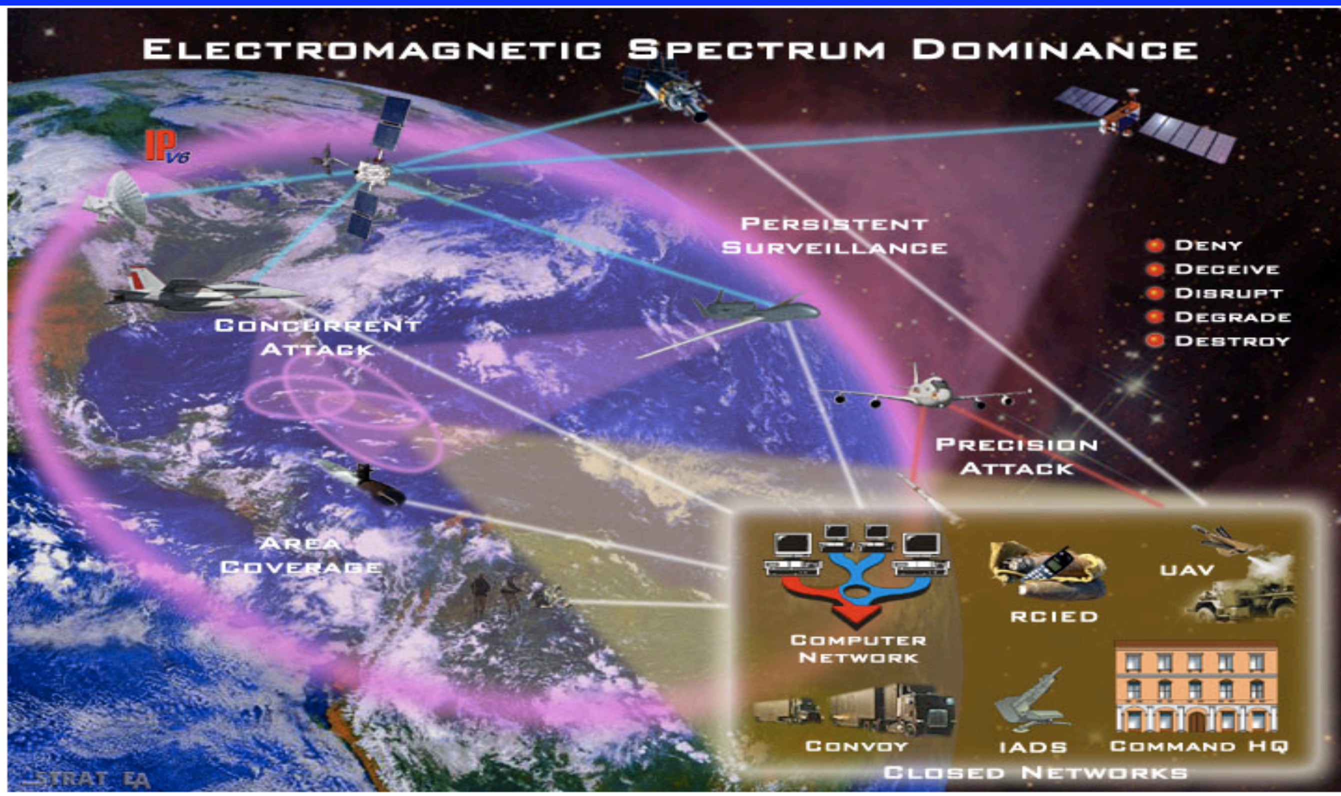
- ***Operation Desert Storm*[1]**
  - Satellites were the most important factor in extending communications to the Persian Gulf
  - Defense Satellite Communications System provided 75 percent (68 Mbps)
  - NATO furnished an additional 5 percent
  - 20 percent from leased commercial systems
- ***Operation Allied Force*[1]**
  - Kosovo air operations required more than twice the bandwidth used to support all the forces in Operation Desert Storm
  - Extensively used video teleconferencing and videotaped Predator operations
- ***Operation Enduring Freedom*[1]**
  - Global strike task force concept of "reach-back"
  - Integrated architecture of C2 and ISR capabilities

[1] Lt Col Kurt A. Klausner, "Command and Control of Air and Space Forces Requires Significant Attention to Bandwidth," *Air and Space Power Journal* ***16, no. 4 (Winter 2002): 72.***

Operational concepts and systems (such as GSTF and UAV) have been developed with the assumption that adequate bandwidth will be available.

Program Objective

To develop a real-time autonomous electromagnetic spectrum management system to exploit, deny, deceive, disrupt, degrade, and/or destroy the adversary's ability to use the EMS while preserving the use of the EMS at the time and place of our choosing

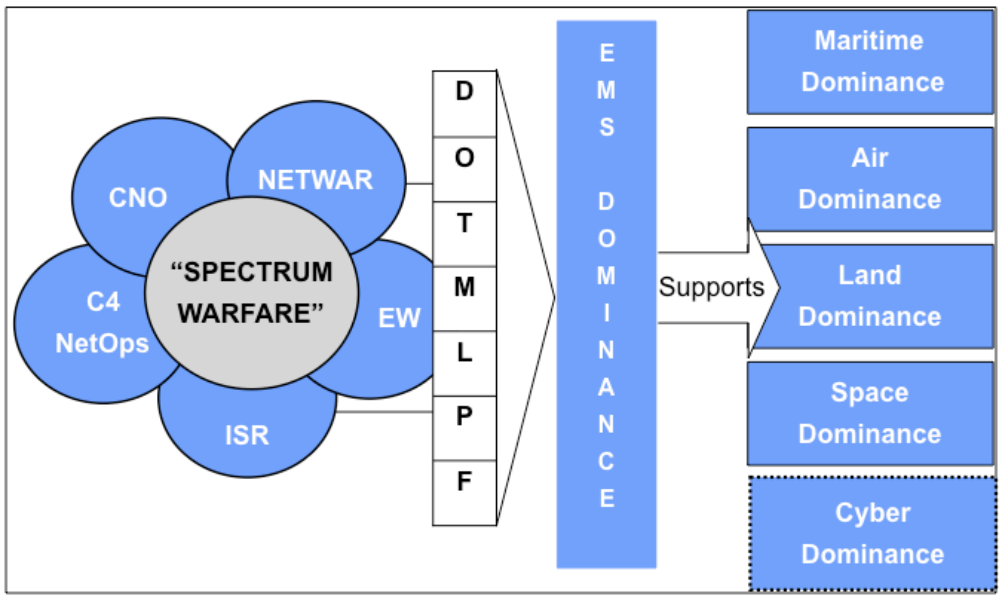


USS TRATCOM vision of EMS as enabler(*)

(*): *EMS Dominance*, CDR Bob Hoffer, USN USS TRATCOM J861, 11 May 2006

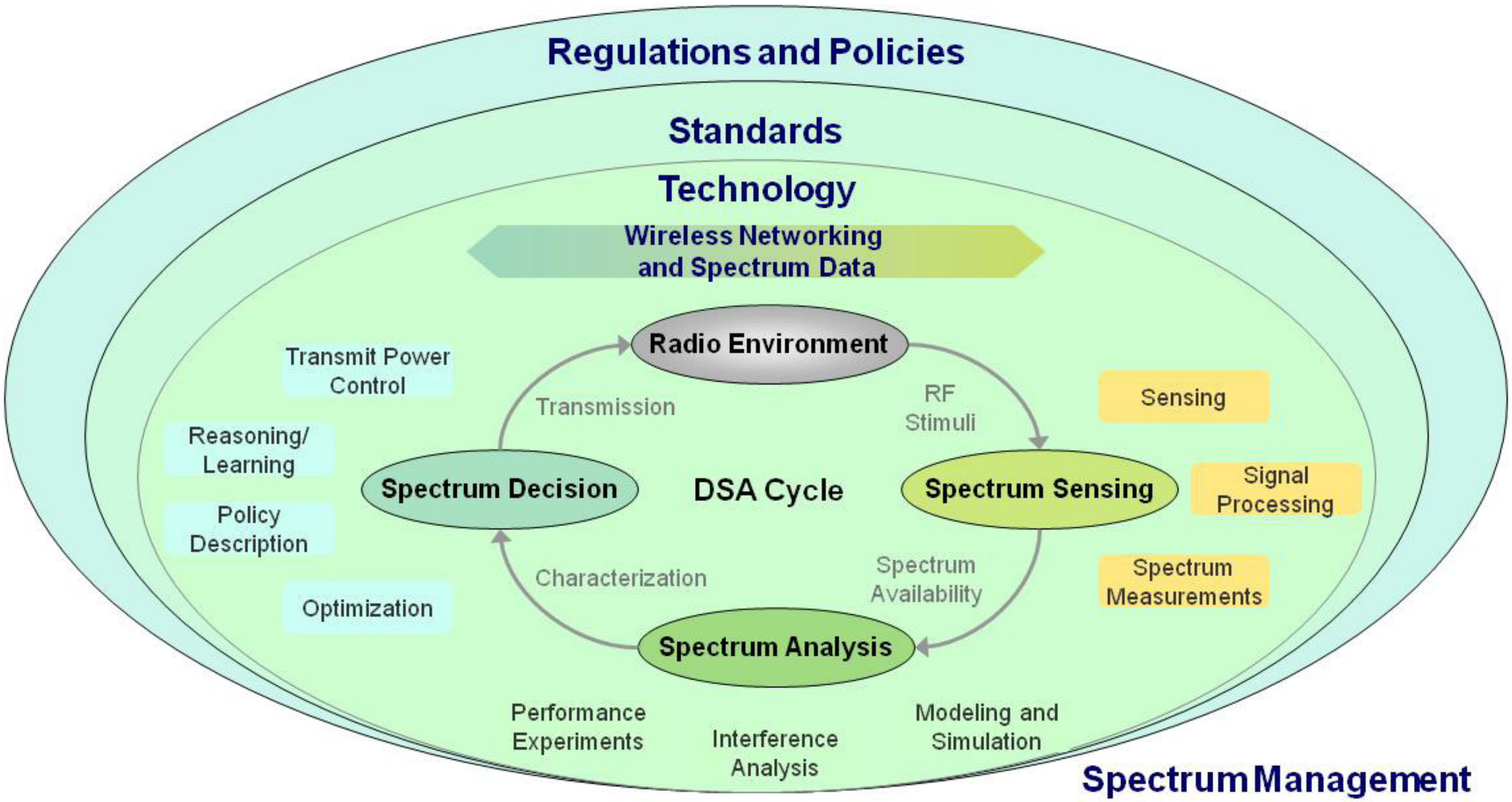
Architecture

- Fractionated Architecture: Supports a hierarchy that allows for distribution of authority across the multiplicity of domains



Coordinated approach of spectral management to achieve mission objective [Doctrine, Organization, Training, Materiel, Leadership and education, Personnel and Facilities (DOTMLPF)]

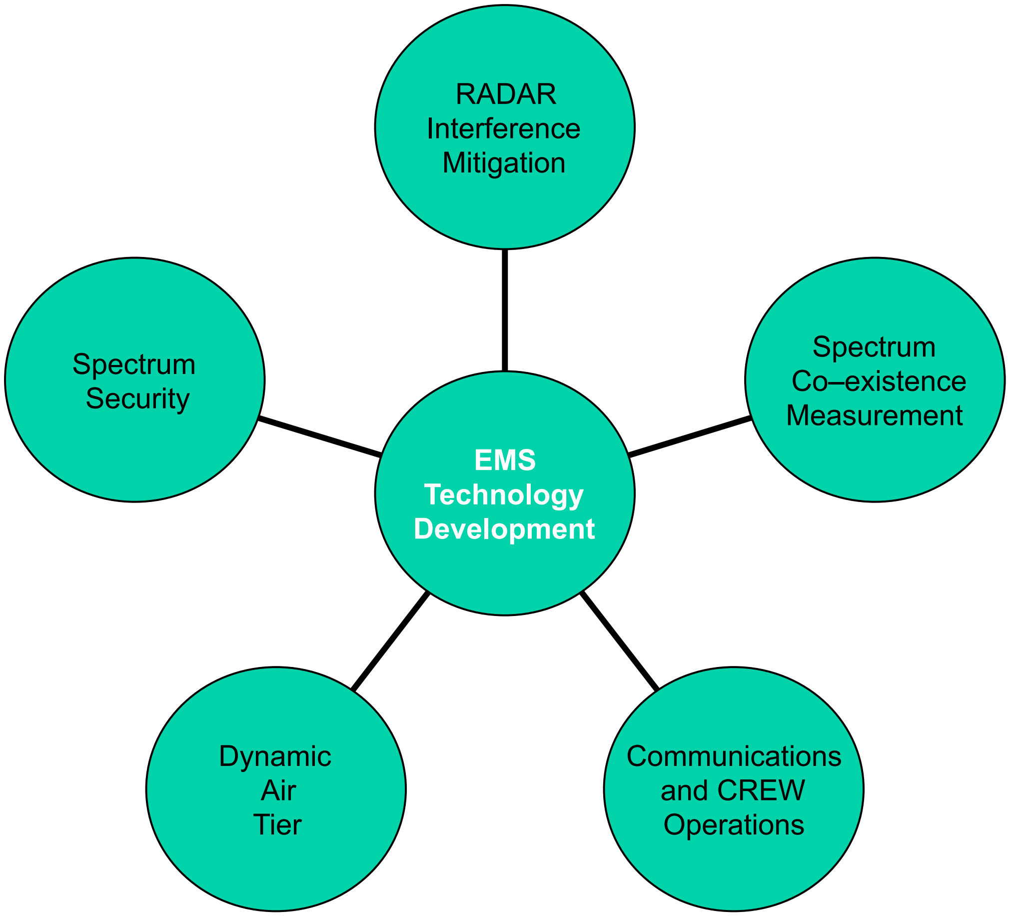
Spectrum Management Domain: Functionality and Relationships



FOUO DRAFT WORKING PAPERS

Electromagnetic Spectrum Technology Convergence

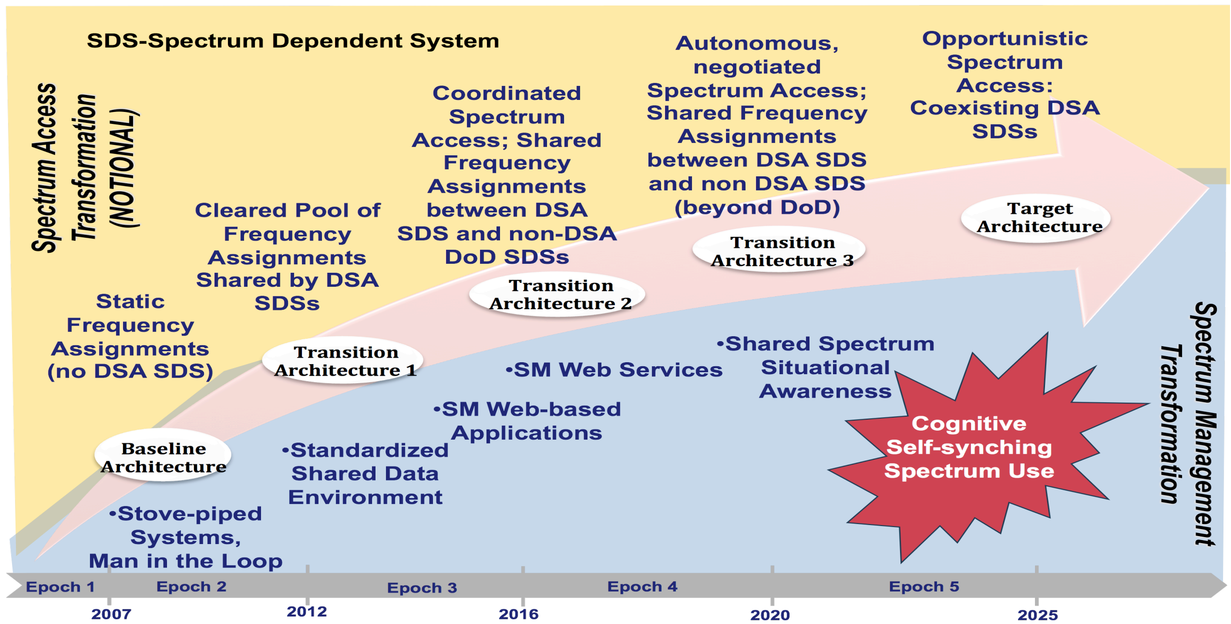
- Perform analysis pertinent to prioritization of spectrum bands and metrics for spectrum technology efforts
- Coherent spectrum technology research
  - Prototype and experiment with DoD and commercial spectrum sharing approaches
- Plan spectrum coexistence joint test range
  - Develop co-existence methods that ensure DoD access to spectrum bands across military systems (e.g. communications, ISR, and EW) and domains (land, sea, air)
- Analyze impact of proposals from industry



Spectrum Management Technical Thrusts

- Abstraction of policy rule:
  - Policy rule sets across heterogeneous SDS platforms
- Real-time coordination and distribution of spectrum awareness and policy updates:
  - The architecture elements, the protocols, sensitivities, and mechanism for distribution/updates must be developed
- Reasoner optimization:
  - The priority of spectral policy distribution/updates must be established and integrated with the network QoS levels
- Common emission protocols and guidelines for across mission interoperability:
  - Communications waveforms need additional features to exert spectrum dominance in an uncontrolled electromagnetic environment
- Dynamic priority allocation

Technical Thrusts



(*)

- CR/DSA technologies: Efficiently and effectively use limited spectrum resource; e.g. XG, WNaN, MAINGATE, and EXPLR-xF
  - Spectrum policy for DSA
  - Fast, secure rendezvous protocols
  - Interference resilience/tolerance
  - Adaptive co-existence
  - Policy reasoning and autonomous adaptation
  - Certification and qualification for Cognitive Radios

(*): *DSO's DoD Spectrum Management and Spectrum Access Transformation*

Technical Thrusts

- Adaptive and cognitive antennas:
  - Adaptive antenna, directional antenna, beam forming; e.g. CABLE JCTD and InTop
- Higher frequency and optics:
  - Expand into underutilized higher frequency bands. Combination of RF, microwave and optics for aerial communication links
- Coalition forces:
  - Joint doctrine and information sharing
- Information Assurance:
  - It's always a challenge to provide security for information integrity protection
- Timing and synchronization:
  - All associated adaptive actions are dependent on timing. Needs to ensure timing through associated reference, networking timing distribution or over-the-air timing signals
- Performance and prediction:
  - Analysis and modeling are needed
- Verification and validation:
  - Modeling and simulation to evaluate performance of EMS management algorithms and policies for different scenarios and CONOPs

Futuristic Ideal

- Self organizing technology
  - Providing access as required
  - Sufficient bandwidth
  - For the duration of the requirement
  - Localized geographically
  - Optimized for the type of service

- Result – Multiplier of available spectrum

- Technologies that may lead the way
  - Multi-antenna signal processing
  - Dynamic Spectrum Access
  - Coordinated cooperative access

Summary

- Modern military operations depend heavily on electromagnetic spectrum
- Need a Spectrum Dominance capability to guarantee spectrum access:
  - Real-time automation in control of how electromagnetic spectrum is used across platforms, users' domains and international boundaries
- Concepts, architecture and information exchange requirements are identified
- Explore technology challenges associated with a vision of automation and agility to achieve Spectrum Dominance
- Impacts: Resulting technology will help DoD to achieve Spectrum Dominance which is key to success of Military Operation