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Background

- This presentation addresses some relevant technologies, research programs, products and weapon systems for 2012/3

- The annual international AOC Symposium and Convention (held in Phoenix in Sept 2012) remains one of the most important inputs into modern threats and EW’s future

- This presentation is further based on multiple open literature sources, the most prevalent are:
  - Journal of Electronic Defence
  - Jane’s C4ISR & Mission Systems
  - Jane’s Weapons Systems
  - Jane’s Defence Weekly
  - DARPA publications
  - Military & Aerospace Electronics
  - C4ISR
Introductory Statements

- Traditionally EW has been reactive – which mean we are already behind, because the enemy is dictating the conditions – as is typical in the Irregular warfare arena.
- Irregular warfare scenarios are not going to go away and the enemy is not standing still from a technological point of view.
- The threat landscape is rapidly evolving. We have an eroding confidence in our understanding of the environment.
- Global access to COTS, Software Defined systems and networking technologies are continually changing the EW landscape.
- Dominance of the EMS however, remains essential.
- The main issue we are facing is the evolving of technology - EW has to evolve with technology, especially the communications and networking technology.
- The lexicon for EW needs to adapt to the future of electromagnetic spectrum (EMS) warfare.
Operational and Acquisition Statements

Operations

- Precision-guided munitions and unmanned aerial vehicles have emerged as the centrepieces of air warfare.
- Military operations are almost invariably going to be conducted by international alliances. This international collaboration brings with it a host of issues and opportunities that must be considered.
- There is a dramatic trend away from scripted plans and operational orders to a fluid, nonlinear, and adaptive battlespace.
- The individual warfighter’s technology expectations in terms of capability, ease of use and upgrades are becoming set by the commercial market, not by the defence industry.

Acquisition

- Acquisition programs (not big capital) must be shorter than 18 months:
  - Use spiral processes in development and OT&E; given the rapidly changing threat environment, to ensure suitability and effectiveness – design a little, develop a little, test a little
  - Continuous close interaction between the military, defence institutes & industry
- It is not necessary the best technology that wins, but rather the technology that address the user’s requirement the best.
EW (EM Warfare) and Cyber Warfare

- **Electronic Warfare** - military action involving the use of electromagnetic and directed energy to control the electromagnetic spectrum or to attack the adversary

- **Cyber Warfare** involves crippling adversaries through information systems and the Internet

Electronic warfare and cyberspace operations are complementary and have potentially synergistic effects

- Example: Use EA system to deliver malicious code into cyberspace via a wireless connection - “EW - delivered computer network attack“

- The convergence of EW and Cyber brings with it new opportunities and challenges

- Modern networked systems (EW and threat) bring additional capabilities to the table, but are vulnerable to cyber-attack, because they are predominantly software defined

- We have to use the EMS and Cyber in order to monitor and achieve the desired military effects on the modern battlefield
Cognitive EW

- **Cognitive** - Autonomously Anticipate, Find, Fix, Track, Target, Engage and Assess Anything, Anytime, Anywhere (A2F2T2EA4)

Software Defined vs. Cognitive

- **Software Defined** make limited decisions based on pre-programmed capabilities
- **Cognitive** abilities can reconfigure itself not just with pre-programmed waveforms, but with waveforms created on the fly, using cognitive (reasoning) abilities to make multiple, simultaneous advanced decisions about a bewildering array of questions in real or near real-time

Current Reality

- Today's EW systems rely on libraries of known emitter (radar, communications, Electro-optical, etc.) waveforms and countermeasures
- Emitters using new (unknown) waveforms and other techniques cannot be effectively addressed without recording them, going back into the lab, analysing, developing algorithms and countermeasures, and getting them back into the field
- This is too slow and place military forces at a major disadvantage

Current Requirement

- Is for open-software architectures to allow insertion, modification, and removal of software modules with minimal impact on the rest of the system in a plug-and-play approach to allow for cognitive capabilities – given Software Definable hardware

Biggest challenge – Resistance to change
DARPA Cognitive EW Programs

- **Adaptive Radar Countermeasures (ARC)**
  - Development of new processing techniques and algorithms that can counter adaptive radar threats by assessing its behaviour in real-time, autonomously generating countermeasures, and evaluating their effects, while providing feedback to a weapon system’s operator.

- **Behavioural Learning for Adaptive Electronic Warfare (BLADE)**
  - To counter adaptive wireless communications [DSA (Dynamic Spectrum Allocation) and AESA] and IED threats in tactical environments, in "tactically relevant timescales”
  - The biggest problem is that of the time lag between unknown threat identification, countermeasures development and deployment.

- **Communications in Extreme RF Spectrum Conditions (COMMEX)**
  - Development of the adaptability and flexibility needed to allow communications systems to function successfully through interference suppression.
EM Battle Management (EMBM)

- Up to recently spectrum management was done through the use of (Joint) Allocated/Restricted Frequency Lists – but this concept has outlived its usefulness
- Requirement - The ability to Dynamically Monitor, Assess, Plan, Integrate and Direct EW operations within the EM Operational Environment in order to achieve Strategic, Operational and Tactical EMS Control throughout all phases of conflict in all Domains
- This is the Electromagnetic Battle Management (EMBM) concept
- EMS data standardization is a requirement
- EW can no longer operate on a 'need to know' basis, but instead on a 'need to securely share' basis
- Biggest stumbling block - people don’t want to share their data
WE ARE THE CLOUD.

RESISTANCE...

IS

FUTILE.
Communication Technologies

Cognitive Radio
- Utilizing White Spaces - IEEE 802.22 standard – 29 countries
- Dynamic Frequency Allocation provides EP

Mobile Phones
- Five-billion mobile subscriptions in developing countries
- More than 30-billion mobile applications downloaded in 2011
- Main source of communication in the irregular/crime environment
- Increasingly important role in RF-enabled Geo-locational Targeting and social media - Exploit

Long Term Evolution (LTE)
- Currently > 500 million people use LTE from >100 operators in 94 countries
- Prediction that by 2017 half the world population will use LTE
- Self-organizing, self-optimizing, spectrum efficient and resilient (self-healing)
- Currently COMINT is impossible and EA very difficult
- LTE has been stated as the single biggest current EW challenge

5 G
- Samsung - 2020
- 1.056 Gbit/s @ 28 GHz – 2km

Wireless transmission
- 40 Gbits/sec @ 240 GHz – 1 km - seamlessly tied in with fibre
ICT Programs

- DARPA’s Fixed Wireless at a Distance program - mobile communications infrastructure that interconnects military radios, commercial cellular telephone (3G or 4G), Wi-Fi and new MIMO radios

Commercial

- USAF – procured 18,000 iPads for mission planning
- US Army Nett Warrior smartphone program to be fielded in 2013 (security and anti-tamper apps) - Tablets to cumbersome
- Various companies are producing ruggedized hardware
- Employing cloud computing enables secure cell phones to perform tasks by using virtual systems - applications that rely on central services and applications
- Applications:
  - Military and Industry App Stores
  - Virtual Radio App (SCA) – Raytheon radios
- Huge Cost, Training, Time-to-Market savings and operational effective advantages
Antenna Technology

Spray-on Antennas

- ChamTech Operations developed a nanoparticle mix that can be sprayed on any object and make that object act as a high-powered antenna.
- Also extend the range of an existing antenna by a factor of 100:
  - RFID tags readable range extended 1.5 m to 200 m
  - 20 dBm increase for iPhone
Radar Technologies and Programs

- Continued Trends - Multi-Function, Higher Resolution, Agile and Networked AESAs

- New semiconductor materials - Gallium Nitride (GaN) – smaller, higher power – also for EA systems

- USA’s Scalable Millimetre-wave Architectures for Reconfigurable Transceivers (SMART) program - wafer-scale integration of RF and microwave transmit-and-receive modules for radar and communications (44 GHz)

- Europe’s Silicon-based Ultra Compact Cost Effective System (SUCCESS) program - 'system-on-chip' (SoC) radars operating frequencies beyond 100 GHz.

- USAF research program for a Phased Array Antenna for Passive RF Sensing
  - Covert passive radar surveillance capability for ground sites and aircraft
  - Wideband (10:1 bandwidth between 400 MHz and 18 GHz) dual polarized phased array radar antenna technology that will allow for up to 64 independent, simultaneous beams
  - Protection against ARMs
Radar Technologies & Programs …

- Selex Galileo’s Raven ES-05
- Shipboard Electronically Steerable IFF Antennas
  - 64 vertical radiating dipole antenna element pairs arranged in a circle on the ship's mast
  - Redirect within 50 µs to interrogate any target
- Naval Air and missile defence
  - Requirements:
    - Increased radar sensitivity and bandwidth to detect, track and support engagements of advanced missile threats at required ranges
    - Increased sensitivity and decluttering capability for very-low-observable/very-low flying threats in the presence of heavy land, sea and rain clutter
  - Programs (Air and Missile Defence Radar – AMDR):
    - USN Spy-1 upgrade: AMDR suite will consist of a four-face S-band radar (AMDR-S) for volume search, a three-face X-band radar for horizon search
- Omni-directional Weapon Locating (OWL) radar
  - Non-rotating antenna – full instantaneous hemispheric coverage (-20 to +90 °) - US Army Communications Electronics Research, Development and Engineering Centre (CERDEC).

Electronic Protection
- University of Rochester - use the quantum properties of photons to create an imaging system that is very difficult to be fooled by DRFM jamming
ES Technologies & Programs

- SIGINT receiving systems requires greater sensitivity in order to detect energy in low-power radar and communications signals as well as spatially directed (AESA) emissions

- Greater Integration & Increased Functionality for SIGINT Systems
  - Requirement for a combination of COMINT ES and Radar ES (traditional ELINT)
    - Thales (C-130 pod-mounted SIGINT 0.1- to 40-GHz)
    - Plath’s (ICAS) Intelligence Control and Analysis System (up to 40 GHz)

- Chain-of-reporting
  - Rapidly deliver the right intelligence to the right people – continually larger and more diverse groups of users
  - The challenges in the sensors are more or less solved - the problems associated with managing the mass of data being collected are not at all solved at the moment
    - Major requirement is a standard data reporting format that will allow for efficient data fusion and comprehensive analysis
ES Technologies & Programs …

- **DARPA’s Radio Frequency Mapping (RadioMap) program:**
  - RF Situational Awareness - RF mapping technologies and capabilities to chart spectrum usage and congestion in real time at critical locations
  - EW/ISR functions that exploit the RF receivers & transmitters available in theatre

- **IARPA’s High Frequency Geolocation & Characterization (HFGeo) program:**
  - **Requirement**
    - 10x Improvement of geolocation and characterization of High Frequency (HF) Radar & Communications emitters
  - **Approach:**
    - Resolve several angles-of-arrival and polarization states accurately through novel antenna concepts
    - Enhance signal-to-noise ratio and signal detection with multi-dimensional adaptive signal processing
    - Determine the state of the ionosphere accurately (regional/wide area bottom side profile rather than global Total Electron Content (TEC) or local profile)
    - Integrate these technologies into geolocation and source characterization applications
ES Technologies & Programs …

Thales (and DSTL) Vigile DPX ES System
- Fully digital spectrum analysis & signal processing
- Elimination of many expensive microwave components to lower through-life costs
- Allow ships to operate in all maritime theatres against multifunction radars, land-based communications emitters like 3G and 4G mobile phone infrastructure, and complex on-board satellite communications & other interferers, incl. jammers

Aerostats & Airships
- India's DRDO’s COMINT payload for their Akashdeep surveillance aerostat
- Northrop Grumman’s Long Endurance Multi-Intelligence Vehicle (LEMV)
  - Optionally manned
  - On station for up to three weeks
  - Operating altitude of 20,000 ft,
  - Generate 16 kW electrical energy
  - 2,500-lb payload - electro-optical & infrared imagers, video sensors, SAR, SIGINT package & on-board processing of 300 terabytes/hour
COMINT Technologies & Programs

- Use of commercial and civilian communication equipment are on the increase:
  - Require specific receivers
  - Require 'oriented processing' with prior specific knowledge of the signal
- Data processing (previously only signal processing) with intuitive and mission-oriented user interfaces is critical in the dense complex signal environment
- Spread-spectrum technology, digital modulation techniques, proprietary encoding and encryption makes it complicated to extract message content in real-time
- The trend of signals with specialized waveforms as generated by Software Defined Radios and the use of adaptive transmit power ensuring low probability of detection is set to continue
- Trend toward the use of more, and widely-distributed sensors and collection systems (e.g. having basic EW collection sensors carried on virtually every military platform down to the individual soldier or swarming)
- UAS as collection platforms

Close-In Covert Autonomous Disposable Aircraft (CICDA)
Electronic Attack Technologies & Programs

Enhanced Nulka
- ONR
- Repeater replacement with new low cost compact RF payload
- Electronically scanned array transmitter and advanced isolation materials

UAV Based
- Raytheon's Miniature Air Launched Decoy Jammer (MALD-J)
  - Use technologies from UAV AESA surveillance radars for stand-in jamming as well as intelligence gathering
- Communications Electronic Attack with Surveillance and Reconnaissance (CEASAR)
  - Variant of the EA-18G's AN/ALQ-227 system
EA Program - JCREW 3.3

Joint Counter Radio Controlled Improvised Explosive Device Electronic Warfare (JCREW) 3.3 systems requirement:

- Mid-LF to mid-EHF frequency range (LF: 30 – 300 KHz, EHF: 30 – 300 GHz)
- Wide instantaneous bandwidth (100 MHz) with high dynamic range at 10's of kHz resolutions
- Efficiency better than 40%
- >100 Watt for fixed/mounted and >10 Watt for dismounted applications
- Multiple simultaneous coherent jamming waveforms with low-noise in response to detected RF emissions
- Digitally controllable parameters and waveform selection waveform generators (direct digital synthesizers, arbitrary waveform generators and digital RF memory technologies) with nsec waveforms switching speeds
- Intelligent jamming techniques that can defeat sophisticated IED threat devices without disabling the RF/communications network
- Mapping the RF environment (spatial, spectral & functional)
- Direction-finding (better than 35 degrees), geolocation (better than 100m accuracy)
- Support distributed jamming concepts, suggest optimal jammer deployment based on terrain and mission needs - secure wireless link
- Multifunction, scalable open architectures
Next Generation Jammers

- Israel’s Military Optical RF Equipment (MORE)
  - Based on analogue RF-photonic design that renders RF sampling unnecessary
  - Overcomes limited immediate bandwidth, quantisation noise, limited dynamic range and large delays

- USN’s Next Generation Jammer (NGJ)
  - Replacement for the ALQ-99 intended for tactical stand-off jamming missions, SEAD and disruption or denial of modern communications
  - Key performance goals include increased ERP, interoperability, beam steering, broad frequency coverage, advanced coherent jamming techniques, jamming assignment management (precision), thermal management, and minimal size and weight
Directed Energy Weapons

Survey - 36 countries gave a 39% probability of encountering DEW against Vehicles (air, land & sea) during operations

High Power Microwave
- Rheinmetall TM170
- Northrop Grumman Counter Electronics
- USAF Research Lab’s Counter-Electronics High-Powered Microwave Advanced Missile Project (CHAMP)
  - CHAMP missile navigate a pre-programmed flight plan and emit bursts of selective frequency, high-powered microwave energy against numerous targets during a single mission
DEW - HEL

- Avenger
- Rheinmetall (10 kW)
- NavSea’s Laser Weapon System (LaWS) - 50 kW
- Lockheed Martin’s Area Defense Anti-Munition System (ADAM) – 10 kW
Electronic Protection measures:

- GPS Antenna technology
  - Raytheon UK’S Fixed Reception Pattern Antenna (FRPA) GPS antenna makes use of multiple patch antennas
  - NovAtel & QinetiQ’s GPS Controlled Reception Pattern Antenna Arrays (CRPAs) use a 7 element array to mitigate interference by creating nulls in the gain pattern
- GPS Anti-spoofing measures
  - US DoD Selective Availability Anti-Spoofing Module (SAASM) - generic technology using signal encryption to defeat spoofing
- Finding alternatives to GNSSs
  - Enhanced LORAN (E-LORAN)
    - Information conveyed includes the identity of the transmitter, an absolute time, anomalous propagation warnings, signal authentication and differential corrections
    - USA not using
  - Locata’s ground-based GNSS augmentation system
    - Receive-only system
    - Accuracy of 6 cm horizontally and 15 cm vertically at a height of 25,000 feet while travelling 304 knots
    - Duplicates all of GPS satellite’s functions
RF Navigation …

Enhanced GPS Navigation Technology

- **HIGPS**
  - Boeing - augmenting GPS satellites (MEO) with the Iridium satellite (LEO) communications system (Contract placed Oct 2012)
  - Lock on and maintain a GPS signal quickly, even while operating in RF signal-restrictive areas like cities, forests, mountains and canyons, as well as under enemy jamming attempts or amid battlefield RF noise

- **GPS III Satellites**
  - Better accuracy
  - Improved anti-jamming power
  - Adding a new civil signal designed to be interoperable with international global navigation satellite systems
  - First 4 (of 32) satellites under construction

Non-GPS navigation

- **Timing & inertial measurement unit (TIMU)**
  - Highly-accurate master clock and a six-axis inertial measurement unit consisting of three gyroscopes and three accelerometers
Air Defence Technologies and Programs

SEAD

- Advanced Anti-radiation Guided Missile (AARGM) - AGM-88E
  - Supersonic, medium-range
  - GPS and inertial navigation system
  - Active millimeter wave (MMW) radar seeker
  - Digital anti-radiation homing seeker
  - Integrated Broadcast Service Transceiver - missile can receive targeting information from various platforms while it is still on the aircraft, and reports fusing status just prior to impact

- Future - Need for specially dedicated lethal SEAD weaponry?
  - Development in other targeting, data link and networking systems:
    - UAV SIGINT and Data-links
    - Stealth platforms with ES systems
    - Precision guided stand-off munitions (AGM-154 JDAM)
SEAD Lessons from Libya

- Non-traditional Integrated Air Defence (IADS) requires non-traditional analysis!
  - Effective SEAD planning must incorporate "civilian" capabilities (such as air traffic control radar and modern communication devices) into the targeting plan
  - If one fails to discern how the C3 nodes are linked, one will fail to fully suppress the IADS
  - Due to a Common Operating Picture (COP), tactical SAMs need not to turn on their radars to gain situational awareness, which significantly complicates the ability of ISR assets to find, fix and track non-cooperative targets
  - The longer the war continued, the more difficult it became to effectively conduct Joint SEAD

- Tactical reality requires the doctrinal flexibility to modify J-SEAD to fully prosecute IADS

- Actions that will prevent re-identifying these lessons:
  - Incorporate realistic, modern IADS into training scenarios for regular training
  - Don’t deceive yourselves by assuming that tomorrow's threat IADS will look anything like past IADS
  - Frequently re-evaluate the status quo
Anti-Ship Missile Technologies & Programs

Russia Seekers for Yakhont
- Dual-channel active/passive RF homing head employing wideband coherent monopulse processing in active mode

China
- CM-400AKG
  - High altitude after launch terminates with high-speed dive at Mach 4+
  - Range 250 km
  - Active radar seeker and an imaging infrared seeker with target-recognition
  - Pre-programmed with digital imagery for fixed sites precision attacks
- C701AR, C-704 & C-705
  - Intermediate range (140 km)
  - Digital autopilot & 35-GHz mmW radar seeker

Joint Naval Strike Missile (NSM)
- Reduced FOV IIR seekers (mid- and far-IR)
- Advanced Automatic Target Recognition (littoral & blue water)
- GPS & Stealth
Anti-Ship Missile Technologies & Programs …

- **Light Weight Brahmos**
  - Air-launched, lightweight, 292 km range – 2015

- **Anti-Ship Ballistic Missile (ASBM)**
  - China's Dongfeng-21D
    - Range 1500 km+
    - Manoeuvrable warhead & homing seekers (active radar (mmW?) & passive RF)

- **MBDA’s CVS 401 Perseus multirole naval strike weapon**
  - Mach 3 & 300 km range powered by a continuous detonation wave engine
  - Dual-mode sensor package – AESA radar with a laser radar (LADAR)
  - Stealth
  - The payload includes two guided effectors plus the main warhead for a dispersed lethal effect on large or multi-element targets
Air-Launched Weapons

Raytheon’s Small Tactical Munition (STM)
- Designed for UAS deployment
- GPS/INS and semi-active laser for guidance
- 13.5-pound, 22-inch long

Raytheon GBU-53/B Small Diameter Bomb
- Engage moving targets in adverse weather conditions
- Millimetre-wave radar, uncooled imaging infrared and semi-active laser as well as datalink
- Autonomously search, acquire and track its target before automatically selecting the optimum aim-point

Boeing Flying Torpedo
- Mark 54 torpedo
- GPS-guided, 30 000 ft
- 2016

BAE Paveway IV PGM
- Penetrating warhead
- New blast/fragmentation charge - reduced collateral damage & bunker-busting
- New proportional navigational guidance
- Future - range extension kit & data link
Testing & Training/Education

- Increased sophistication and integrated/networked EW systems makes testing more complex
- Testing of multifunction systems is not the same as using a multifunction tester to separately test multiple discrete systems!
- We need to educate the warfighters, as well as the leaders, in the utilization and vulnerabilities of the EMS & equipment
- Technology requires an educated (not only trained) workforce
- EW training must be matched to the operational environment - realism as well as accommodating emerging technologies
Summary

- Commercial Communications has established itself as a main C2 medium
- LTE has been stated as the single biggest EW challenge
- Traditional COMINT and ELINT functions have merged
- Platform centric EW has made way for Net centric EW
- The main issue is the evolving of technology - EW has to evolve with technology, especially the communications and networking technology
- The lexicon for EW needs to adapt to the future of electromagnetic spectrum (EMS) warfare
- Future EW systems will have to be Cognitive Systems
- Electronic warfare and cyberspace operations are complementary - We have to use the EMS and Cyber in order to achieve and monitor military effects on the modern battlefield
- EMBM - The ability to Dynamically Monitor, Assess, Plan, Integrate and Direct EW operations within the EM Operational Environment in order to achieve Strategic, Operational and Tactical EMS Control throughout all phase of conflict in all Domains
- Biggest stumbling blocks:
  - People don’t want to share their data
  - Resistance to change
- EW training must be matched to the operational environment - realism as well as accommodating emerging technologies
Technology is Evolving

Any Easy Questions?