Spectrum Management in the Acquisition of Equipment

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Overview

- Spectrum Management is becoming more Challenging as:
  - Military and Civil Users Compete for Scarce resource
  - New Communications, Sensor and EW systems come into Service
  - Bandwidth requirements increase

- This paper:
  - Outlines the problems, some of the causes and gives some examples
  - Describes work being undertaken in the UK to help address these problems in the equipment acquisition process
  - Draws some conclusions and makes some recommendations

This paper can only scratch the surface this vast subject

Aim

- The main aims of this paper are:
  - To outline the problem
  - To describe three studies conducted as part of MODs research programme
    - Spectrum Requirements Analysis
    - Benefits Analysis
    - Spectrum Congestion Guidance
  - And to present the conclusions and recommendations
- But this problem is international so it is also intended
  - To provoke international dialogue
  - Raise awareness of the problems we all face

EM Spectrum is an International Resource

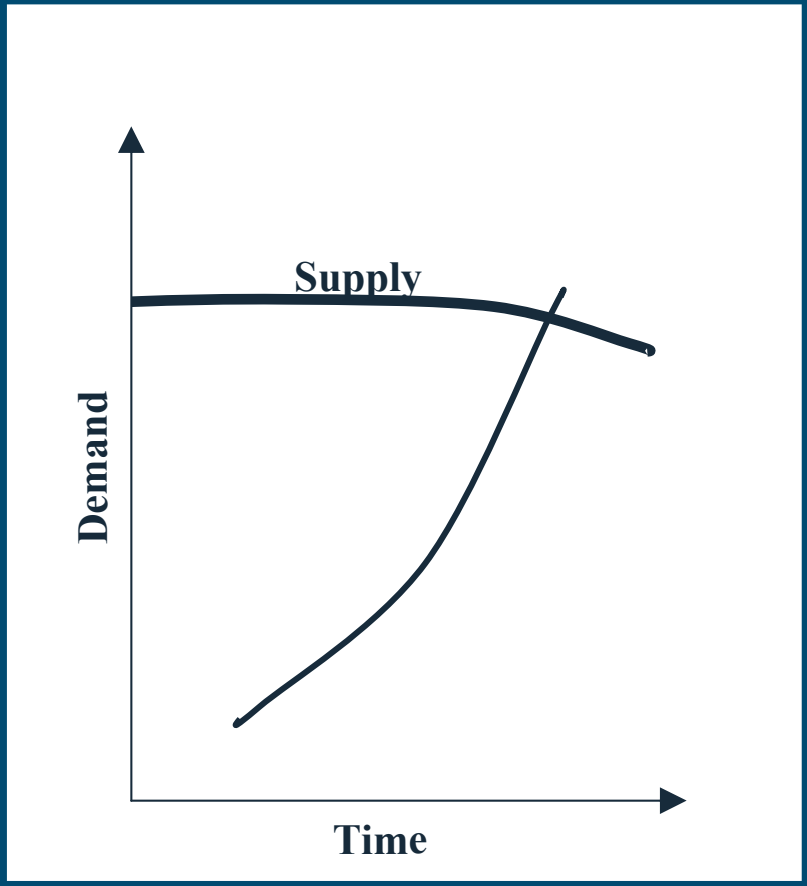
Background

- Historically spectrum has been viewed as an almost infinite resource (in a military context)
- Military acquisition programmes have assumed availability, an assumption now invalid
- Problem exacerbated by nations selling spectrum to commercial users previously viewed as military bands
- Military spectrum demands increasing rapidly to meet:
  - NCW/NEC Needs for agility, increased operational Tempo, improved situational awareness and synchronised operations
  - ISTAR ambitions for persistence, improved sensor performance, time sensitive targeting and challenging Imagery based RoEs

The problems will only get worse

Spectrum Congestion - Today's Problem

- Supply and Demand:
  - Reducing Supply
  - Increasing Demand
  - = Congestion
- We need to:
  - Manage Demand
- By improving:
  - System design
  - System of Systems Design
  - Incentives and policies to encourage appropriate design



We Need to do Something Now

Technical Factors

- System Issues
  - RF (Physical Layer)
    - Power, frequency, Modulation scheme, directionality, multiplexing
  - Networking
    - Routing, prioritisation,QoS, cogestion control, topologies
  - Application
    - Appropriate and efficient data generation, data compression

- System of System Issues
  - Spectrum Management
    - National and International
  - Security functions
    - allowing efficient topologies
  - Interoperability between systems
    - Allowing efficient topologies, flexibility
  - Spectrum Situational Awareness
  - Freedom of spectrum manoeuvre
  - Adoption of common technology policy

The Solutions Cross Many Domains

Example 1- 225-400MHz

- Attractive Features of this band are
  - Potential to carry high datarate traffic (>1MB/s)
  - Useful for LOS traffic using omni directional antennas
  - Technology is relatively cheap
  - Wavelength is short enough that directional antennas are manageably sized
  - Provides SATCOM with affordable Ground terminals and other unique characteristics
- The users include
  - Military Air Radio (Fixed frequency and Hopping)
  - Battlespace Trunk Radio
  - High(er) datarate overlays for Combat Net Radio
  - High datarate Point to Point systems
  - UAV C2 and Datalinks
  - Loitering Munition C2 and datalinks

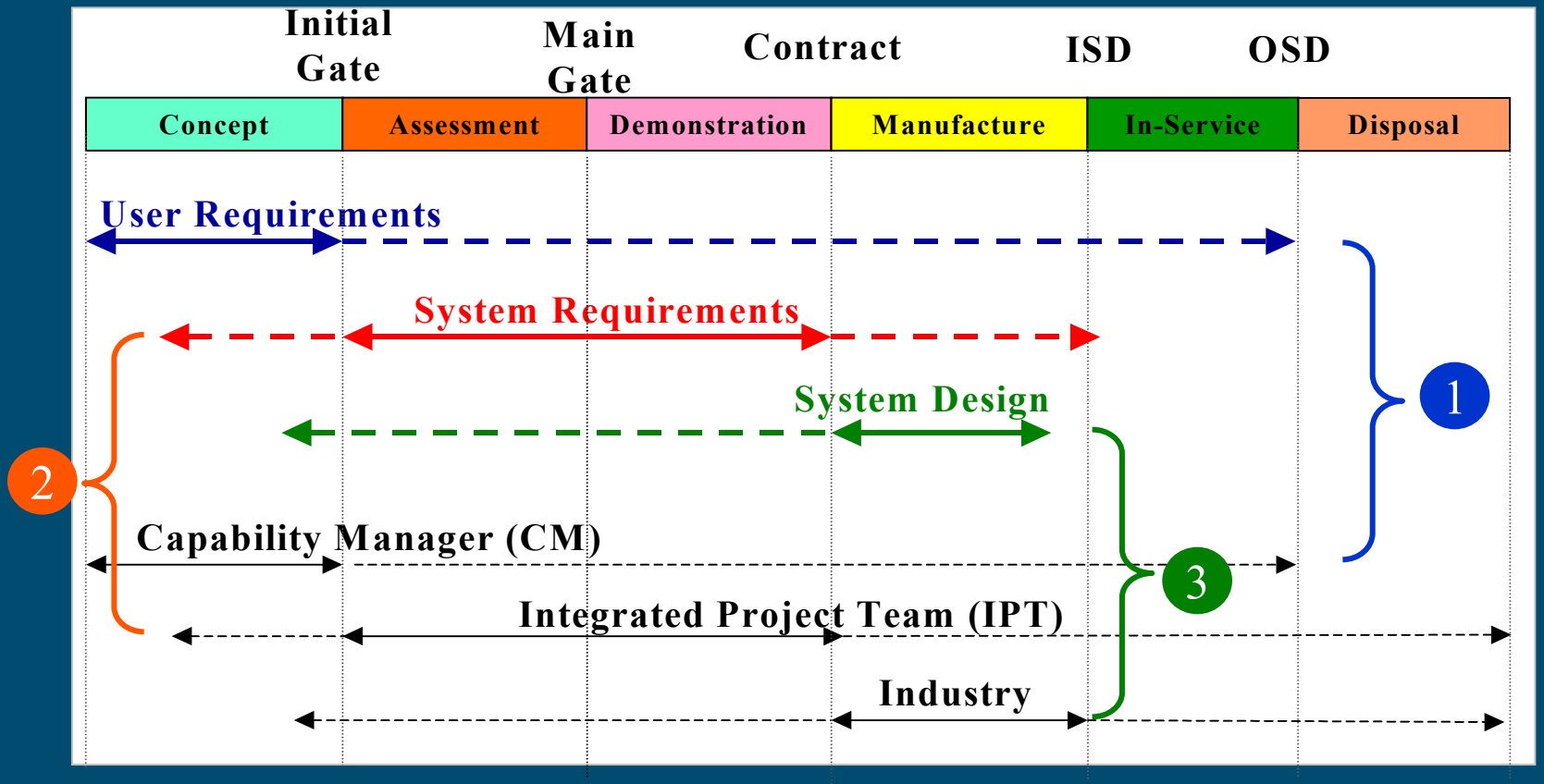
Very congested especially for Coalition Ops

Ex 2 - CDL and TCDL in Ku Band

- Used predominately for Air to Ground imagery
- Datarates - from 10.7 - 274 MB/s with High Occupied bandwidth
- As currently in service allows 6 Channels in Ku Band for 10.7 MB/s (and 5 in X Band)
- In sufficient contiguous Bandwidth in the UK for 1 channel at 274MB/s
- If used with relay for range extension the channel capacity is halved
- Total capacity very limited
- We may lose some of our X-band allocation at the next IRC in 2007 increasing Ku demand
- Many platforms currently being procured using this technology
- Very attractive for ISTAR if all factors not considered

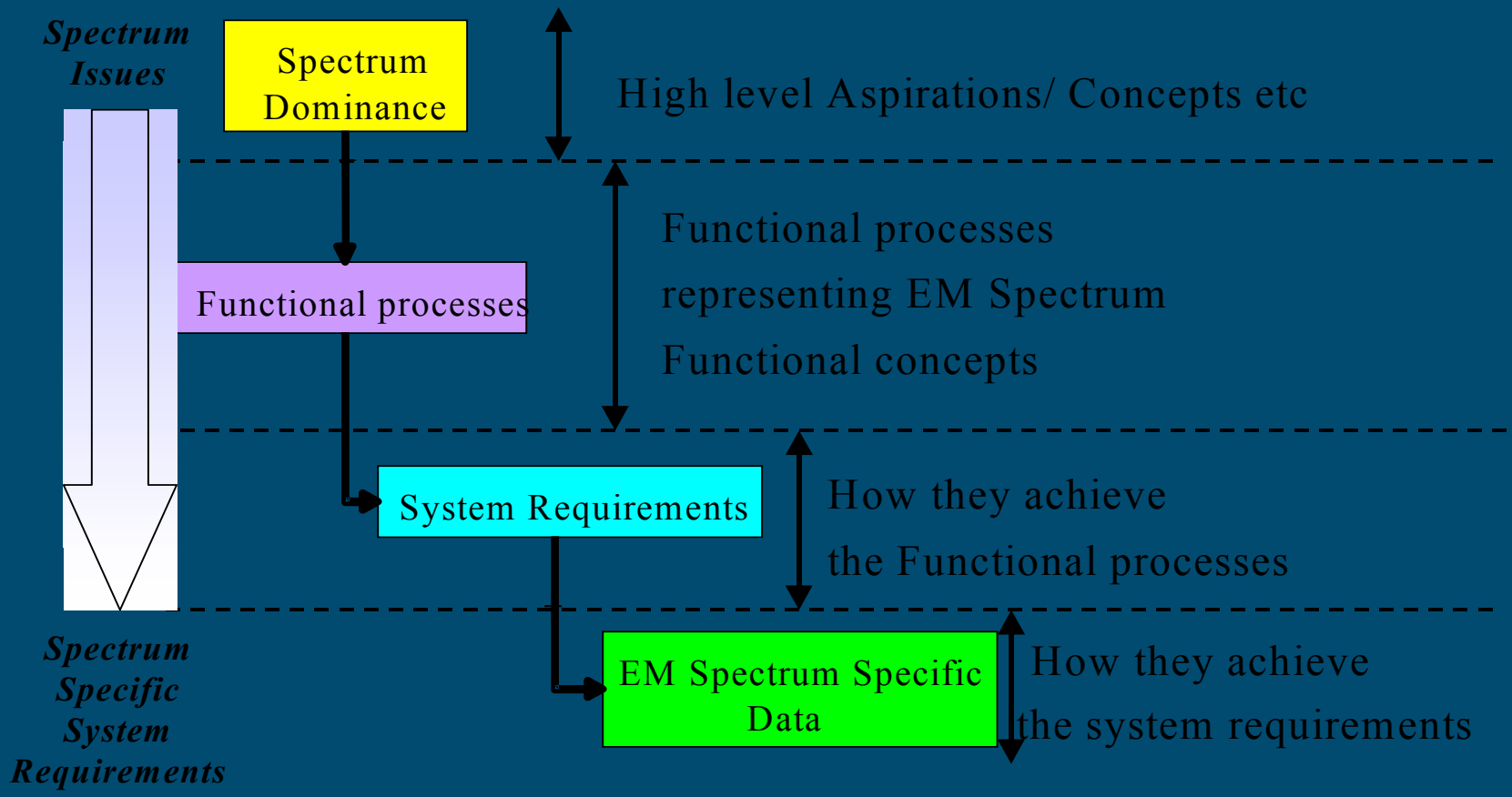
Indicates the need to consider *all* the implications when intoducing new platforms with pervasive spectrum need

The CADMID Cycle



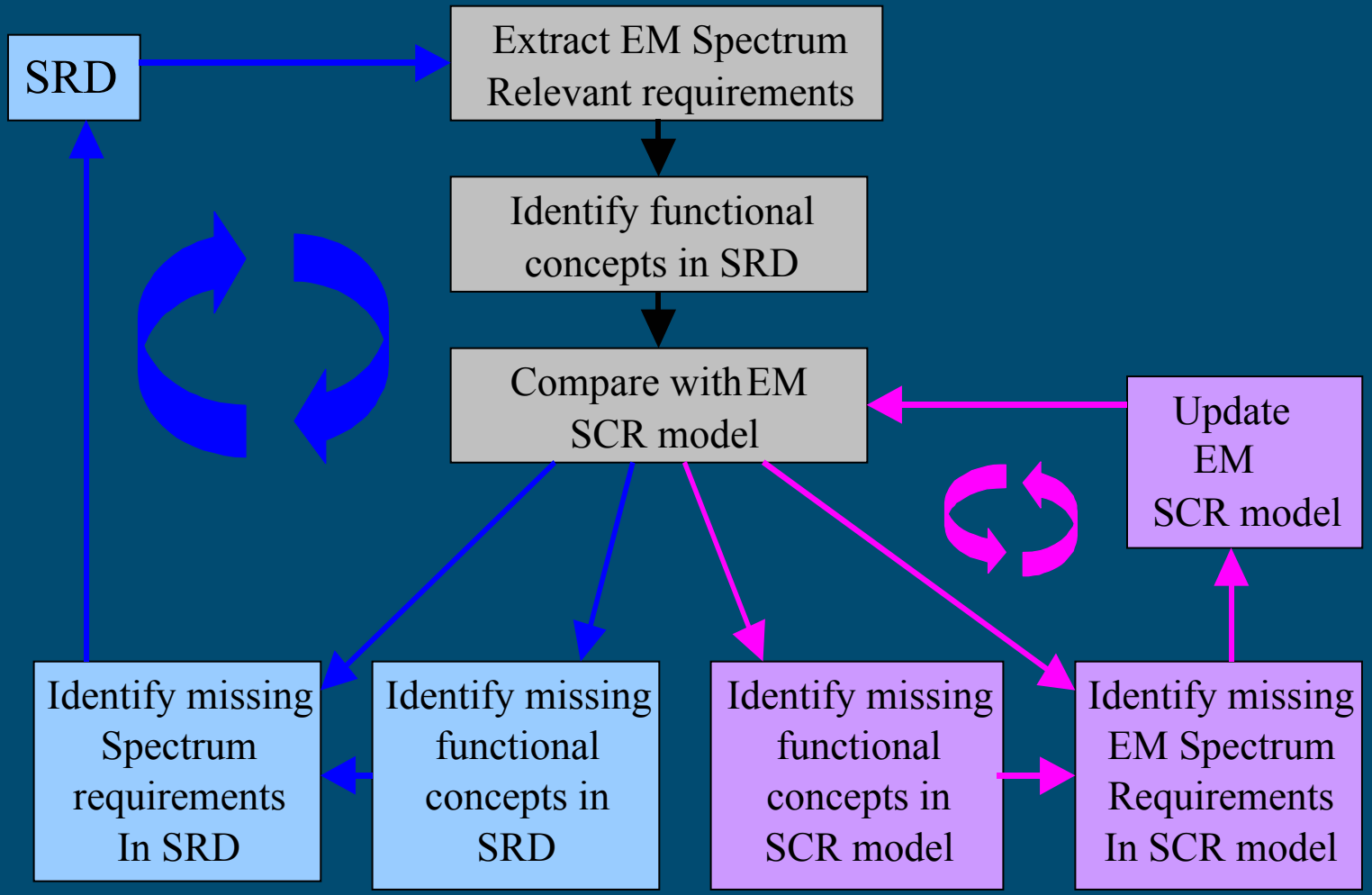
Note the linkages between 1 - CM and User reqs, 2 - IPT and System reqs and 3 - Industry and design

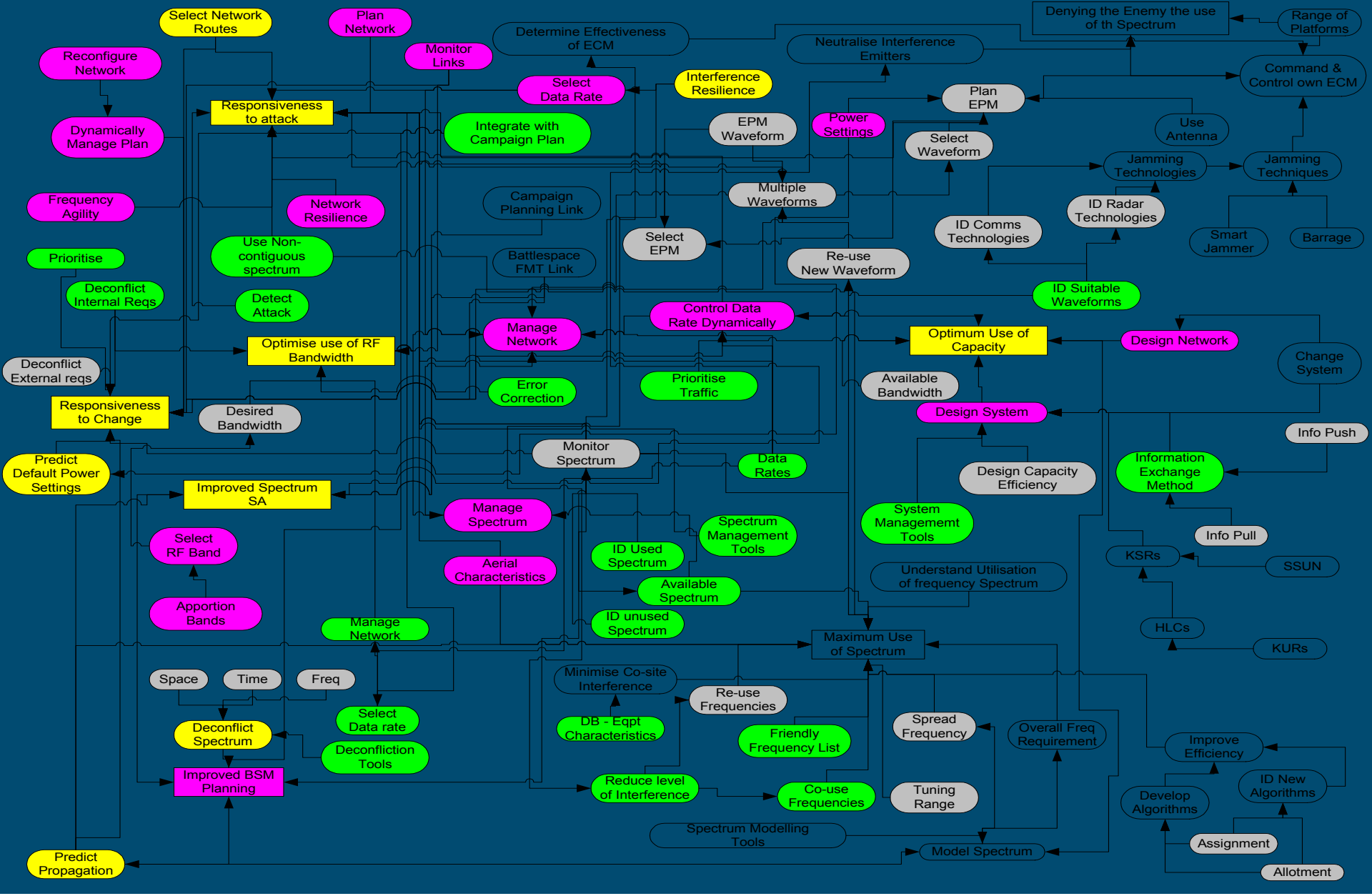
The SCR Model concept



Spectrum Capability Requirement Model entities can be processes, resources or concepts.

Requirements Analysis Process




Select Network Routes
Plan Network
Monitor Links
Determine Effectiveness of ECM
Denying the Enemy the use of th Spectrum
Range of Platforms
Reconfigure Network
Neutralise Interference Emitters
Command & Control own ECM
Select Data Rate
Interference Resilience
Plan EPM
Responsiveness to attack
Integrate with Campaign Plan
EPM Waveform
Power Settings
Use Antenna
Dynamically Manage Plan
Select Waveform
Jamming Technologies
Jamming Techniques
Campaign Planning Link
Multiple Waveforms
Frequency Agility
Network Resilience
ID Radar Technologies
ID Comms Technologies
Smart Jammer
Barrage
Select EPM
Use Non-contiguous spectrum
Battlespace FMT Link
Re-use New Waveform
Prioritise
ID Suitable Waveforms
Deconflict Internal Reqs
Detect Attack
Control Data Rate Dynamically
Manage Network
Optimum Use of Capacity
Design Network
Optimise use of RF Bandwidth
Change System
Deconflict External reqs
Error Correction
Prioritise Traffic
Available Bandwidth
Responsiveness to Change
Desired Bandwidth
Design System
Info Push
Monitor Spectrum
Predict Default Power Settings
Data Rates
Information Exchange Method
Design Capacity Efficiency
Improved Spectrum SA
Manage Spectrum
System Managemt Tools
Spectrum Management Tools
Info Pull
Select RF Band
ID Used Spectrum
KSRs
SSUN
Aerial Characteristics
Understand Utilisation of frequency Spectrum
Available Spectrum
Apportion Bands
ID unused Spectrum
HLCs
Manage Network
Maximum Use of Spectrum
KURs
Space
Time
Freq
Minimise Co-site Interference
Re-use Frequencies
Select Data rate
DB - Eqpt Characteristics
Spread Frequency
Overall Freq Requirement
Deconflict Spectrum
Friendly Frequency List
Improve Efficiency
Deconfliction Tools
Improved BSM Planning
Reduce level of Interference
Co-use Frequencies
Tuning Range
ID New Algorithms
Develop Algorithms
Spectrum Modelling Tools
Assignment
Predict Propagation
Model Spectrum
Allotment

Benefits analysis

What is benefits analysis….

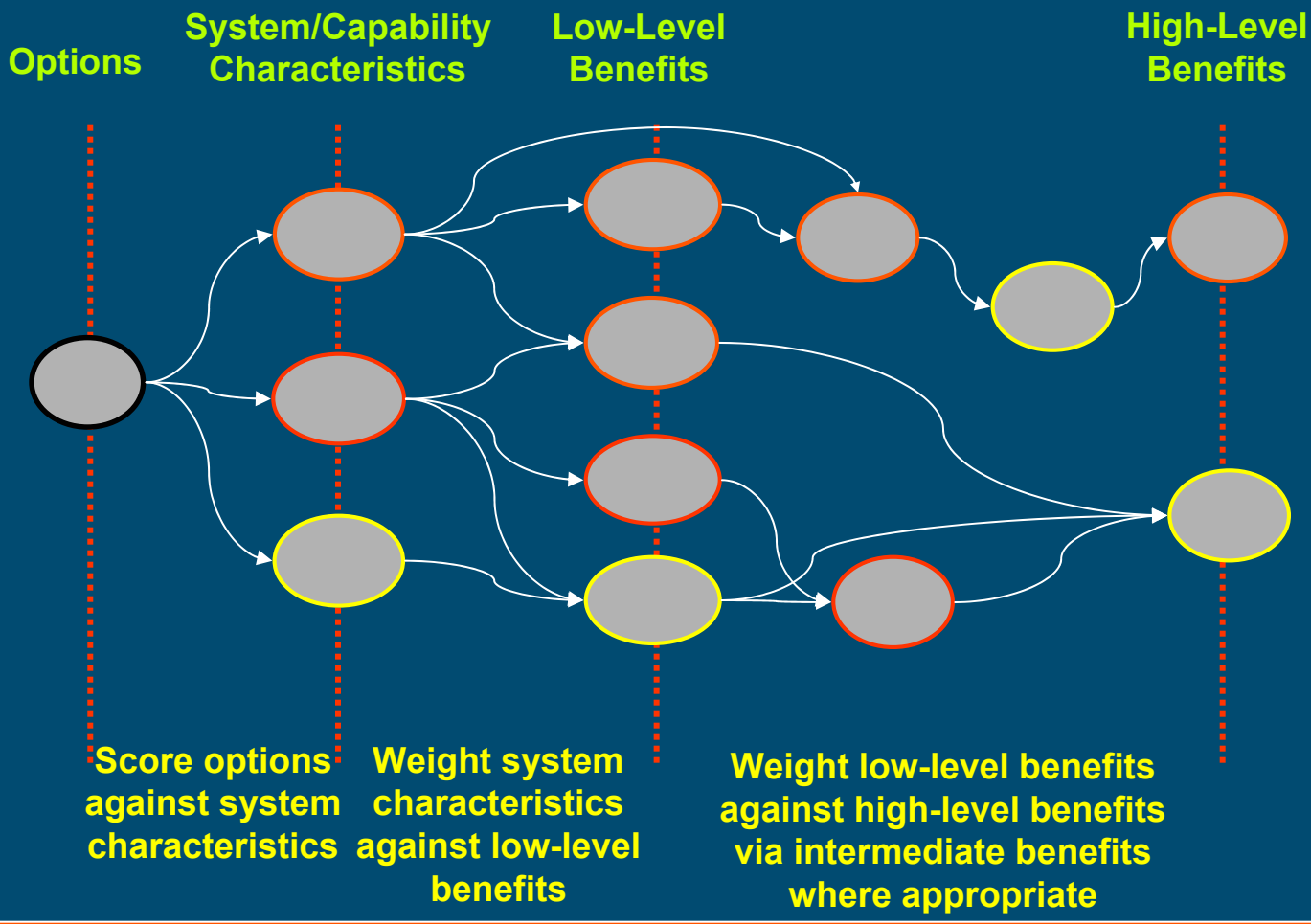
- a soft analysis method
- developed to establish the relationships between low level measures of performance and high level measures of effectiveness
- can be used to assess the comparative effectiveness between alternative system options

In this study….

- it effectively structures knowledge about pertinent spectrum issues
- an option scoring assessment provides comparative Figures of Merit for acquisition options that utilise and consume spectrum

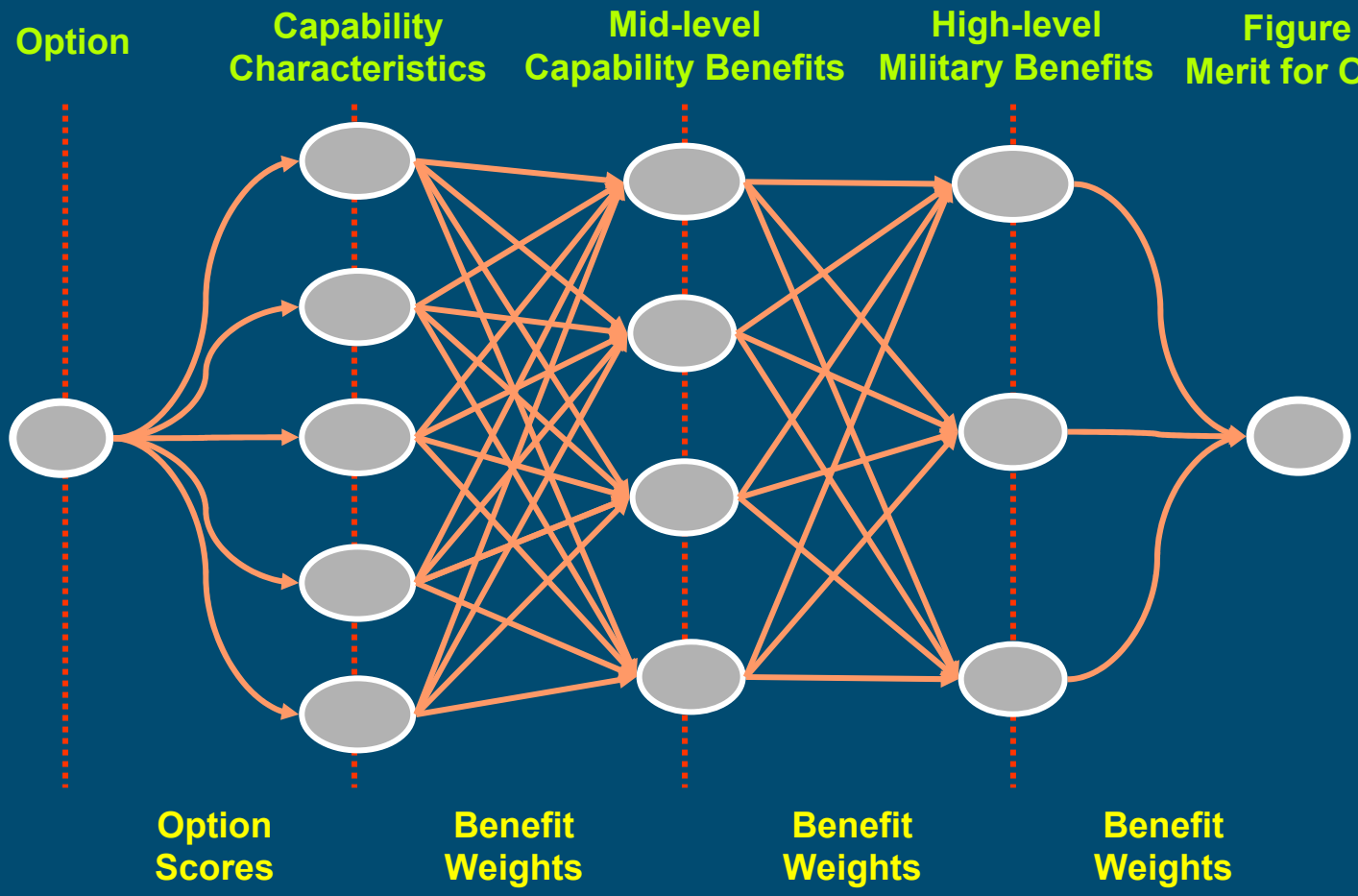
Benefits modelling can be used for knowledge structuring and option assessment.

Generic benefits map



Benefits maps can represent complex benefits relationships.

Simplified benefits model



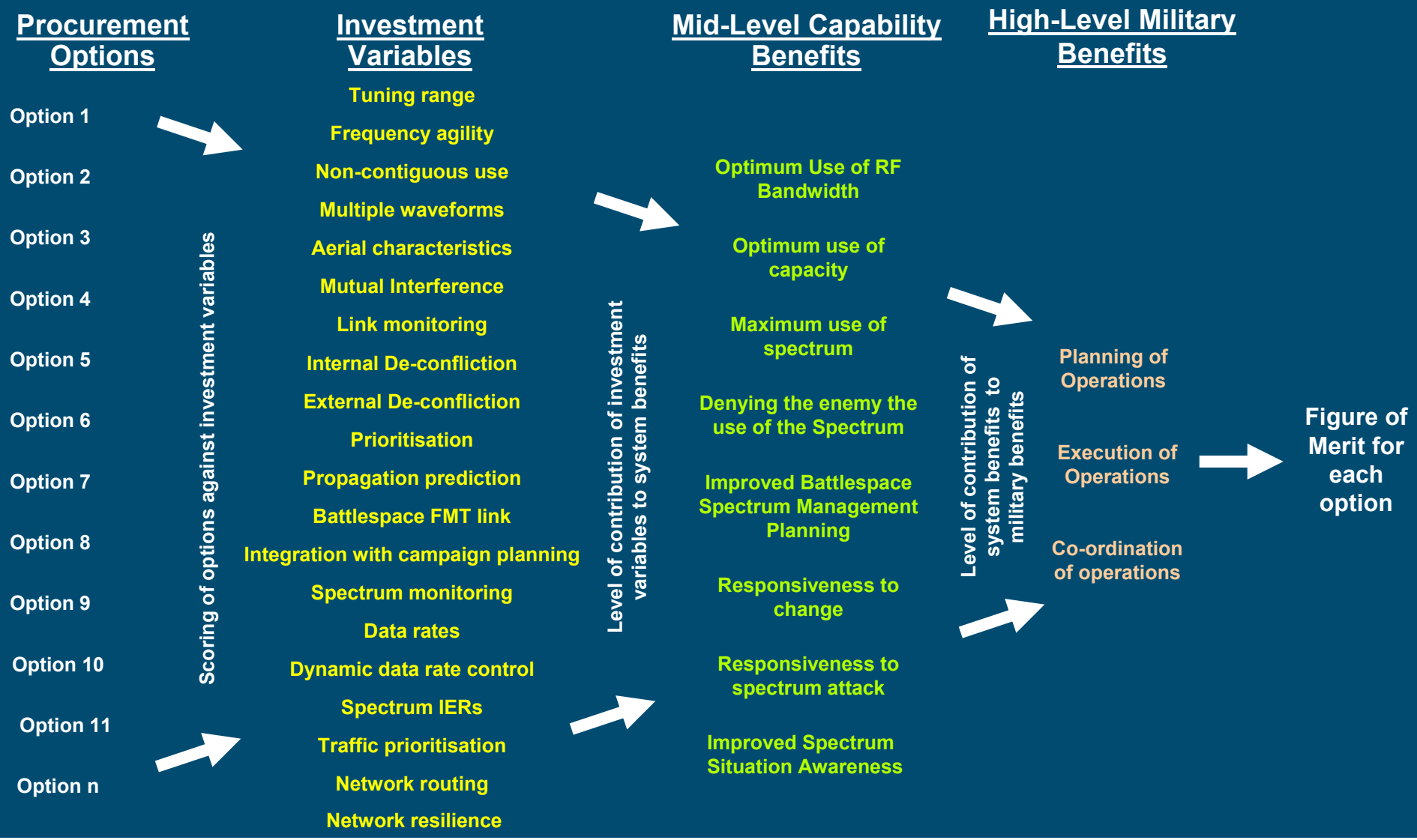
Benefits maps, if appropriate, can be simplified into a hierarchical structure.

Benefits analysis process

- Problem structuring
- knowledge elicitation
- development of an outline benefits model
- development of scoring scales and metrics
- assessment to weight and score the model
- post-assessment analysis

The Delphi technique of assessment can be used with benefits modelling.

Current benefits model - ‘optimum spectrum usage’



Exploitation

- greater awareness of pertinent issues
- knowledge structuring
- balance of investment assessments
- capability gap analysis
- requirements definition
- risk analysis

Benefits modelling has the potential to be exploited in many ways.

Investment Variables

- emitters / receivers

Tuning range

Do the systems within the option support the ability to tune across bands?

Frequency agility

Does the option support ability to automatically change frequency in particular conditions (such as frequency hopping)?

Non-contiguous use of the spectrum

Do the systems within the option support the use of isolated sections of bandwidth?

Multiple waveforms

Do the systems within the option have the ability to support different waveforms? (Single (2)/Multiple waveforms(4))

Aerial characteristics

Does the option offer improved aerial characteristics? (omni-directional automatically score 0)

Mutual Interference

Does the option have the ability to resist mutual interference?

Link Monitoring

Can the receivers be used in a multi-role capability i.e. do they have the ability to monitor desired signals/detect interference?

- frequency management

Internal De-confliction

Does the option support the ability to re-use assigned/allotted frequency in space and time?

External De-confliction

Does the option support de-confliction of assignment with other systems in time and geography?

Prioritisation

Does the option have the ability to support prioritisation and re-prioritisation within spectrum management?

Propagation Prediction

Does the option have the ability to predict the propagation for particular desired links?

Battlespace frequency management tools linkage

Linkage between the full set of frequency management planning tools

Integration with campaign planning

Linkage between frequency planning tools and campaign planning

Spectrum monitoring

The ability of the management function to identify available spectrum.

- networking

Data rates

Does the option provide the ability to support a range of different data rates?

Dynamic data rate control

Does the option support the ability to dynamically control the data rate (automatic capability)?

Spectrum IERS

Do the options minimise the spectrum related data rate exchange requirements?

Traffic prioritisation

Do the systems within the option support traffic prioritisation?

Network routing

Does the option support a network solution or just a link? (This will impact on the ability to re-route traffic)

Network resilience

Do the systems within the option support network resilience? i.e the ability of integrated systems to withstand data error without affecting waveform.

Mid-level Capability Benefits

Optimum use of bandwidth

Delivery of the maximum data rate for the assigned/allotted bandwidth. Major contributing system characteristics: correct network management selection of data rates and waveforms and dynamic data rate control. Secondary factors: link monitoring, internal deconfliction and efficient use of error correction.

Optimum use of capacity

Reducing data load on the system using appropriate techniques. Major contributing system characteristics: spectrum modelling, network design, system design, traffic prioritisation, bandwidth availability and dynamic data rate control.

Maximum use of spectrum

The ability to make effective and efficient use of all available spectrum. Major contributing system characteristics: spectrum modelling algorithms for assignment and allotment, battlespace spectrum monitoring, accurate database of equipment characteristics and accurate friendly frequency use tables. Other secondary factors include tuning range, non-contiguous use, aerial characteristics and propagation prediction.

Denying the enemy the use of the spectrum

To deny the enemy's effective use of the EMS through the use of electromagnetic energy, whilst maintaining own forces' freedom of use of the EMS. The ability to neutralise emitters interfering with own forces of the spectrum.

Improved Battlespace Spectrum Management planning

Planning efficient and effective management of the spectrum within the battlespace through the production of a BSM plan(s) which reduces the potential for friendly interference. Major contributing system characteristics: having spectrum awareness and propagation prediction. Secondary factors include integration with campaign planning and spectrum monitoring.

Responsiveness to change

Responsiveness to changing priorities, ORBAT, flow of battle etc. This includes dynamically managing the plan once in action, including the re-configuration of networks. Major contributing system characteristics: external deconfliction and battlespace FMT link. Other secondary factors include multiple waveforms, link monitoring, internal deconfliction, prioritisation,integration with campaign planning, data rates, dynamic data control, tuning range, propagation prediction, spectrum monitoring and network routing.

Responsiveness to spectrum attack

Ability to detect and respond to attack/interference caused by battlespace tempo/advancing forces. Contributing system characteristics: frequency agility, non-contiguous use, multiple waveforms, aerial characteristics, data rates, dynamic data control, network resilience, spectrum monitoring and network routing.

Improved Spectrum Situation Awareness

Awareness of friendly and hostile use of spectrum in the battlespace. Major contributing system characteristics: battlespace FMT link and spectrum monitoring. Contributing system characteristics: propagation and campaign planning link.

Interim scoring scale

-4 = provides SIGNIFICANTLY LESS capability than existing systems

-2 = provides LESS capability than existing systems

0 = provides SAME capability than existing systems

+2 = provides MORE capability than existing systems

+4 = provides SIGNIFICANTLY MORE capability than existing systems

Interim weighting scale

0 = No improvement of spectrum usage

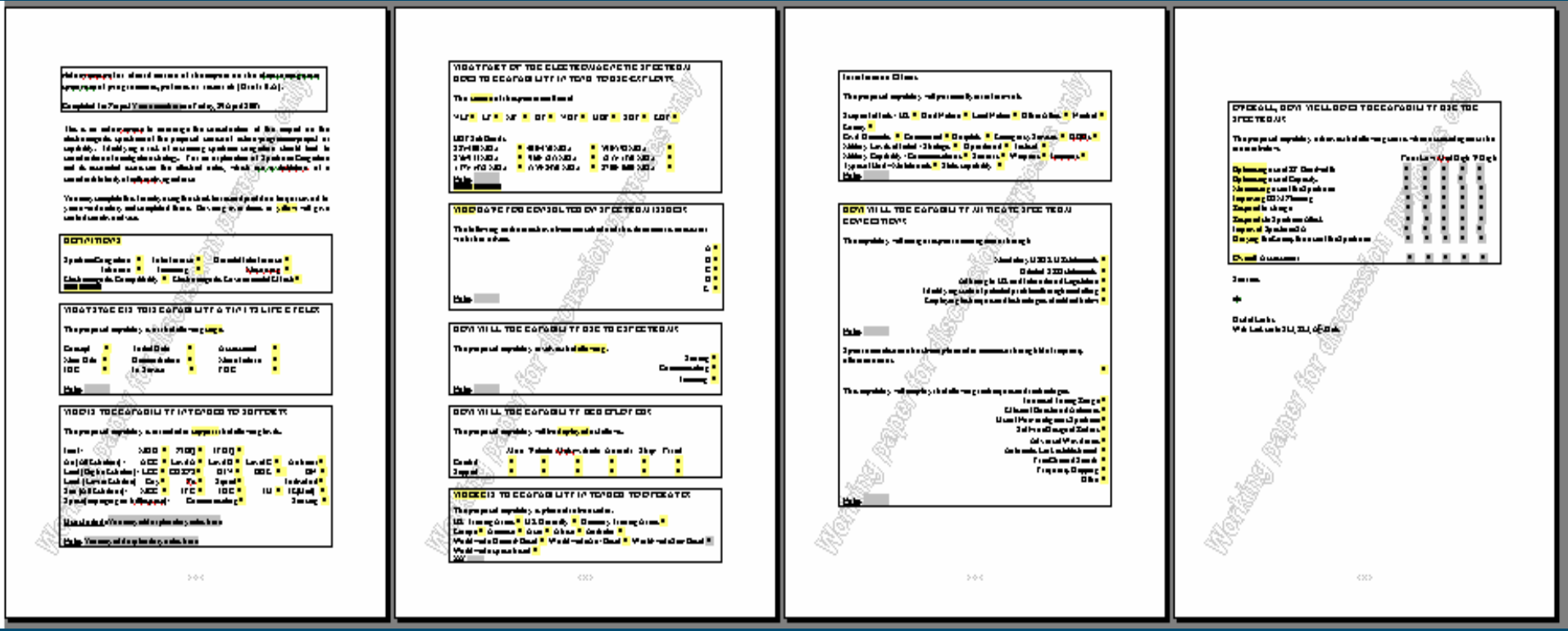
2= Little improvement of spectrum usage

4= Modest improvement of spectrum usage

6= Significant improvement of spectrum usage

8= Total improvement of spectrum usage

Congestion Advice



This is the Spectrum Questionnaire.
It doesn't look too hard to fill in does it?

Conclusions

- Battlespace systems are making ever more demand on this limited resource
- The nature of military operations in the future dictate that spectrum management will be more complex and international
- Early discussion with all parties and analysis of spectrum needs will contribute to awareness
- During the system procurement process benefits analysis is a valuable tool
- Spectrum Functional requirements can be modelled with suitable tools
- Soft analysis processes compliment traditional hard analysis in supporting acquisition decisions
- All analysis processes demand data capture so increase awareness in the stakeholder communities

Recommendations

- EM spectrum requirements should be addressed as early as possible in the procurement cycle
- Current EM demand together with the physical constraints should be used to derive spectrum requirements of potential new systems
- Further refinement of the of the analysis method should take place with an international partner based on a coalition operation use case
- The data capture questionnaire should be sent to all stakeholders and the data used to construct a spectrum usage knowledge base (ideally internationally)
- Raise awareness of spectrum issues amongst those not traditionally concerned with RF layers of systems
- Continue to refine the analysis techniques and introduce them into the acquisition cycle
- The application of the analysis techniques described in this paper should be considered by international bodies responsible for EM spectrum allocation and management

Questions?

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