Public Workshop on Optimising the Use of the Radio Spectrum by the Public Sector in the EU

Applications and Technologies

John Burns, Aegis Systems Ltd

1st April 2008

Scope of Presentation

- Overview of Public Sector spectrum use by sector
  - Aeronautical, Maritime, Defence, Others
- Technology Evolution in the Public Sector
- Focus on radar technologies and applications
- Future requirements for public sector spectrum use
- Opportunities for sharing and spectrum release

Main Radio Spectrum Applications by Sector and Application

	Aeronautical	Maritime	Road / Rail	Defence	Public safety	Meteorology
Voice comms						
Data comms						
Video comms						
Ground Radars						
Airborne Radars						
Ship Radars						
Navigation Aids						
Satellite						
Point–point links						

Extensive spectrum use (>100 MHz below 1 GHz or >200 MHz above 1 GHz)

Some spectrum use

Biggest users of PS spectrum are Radars and Military Communications

wik CONSULT

ÆGIS systems limited

IDATE

plum

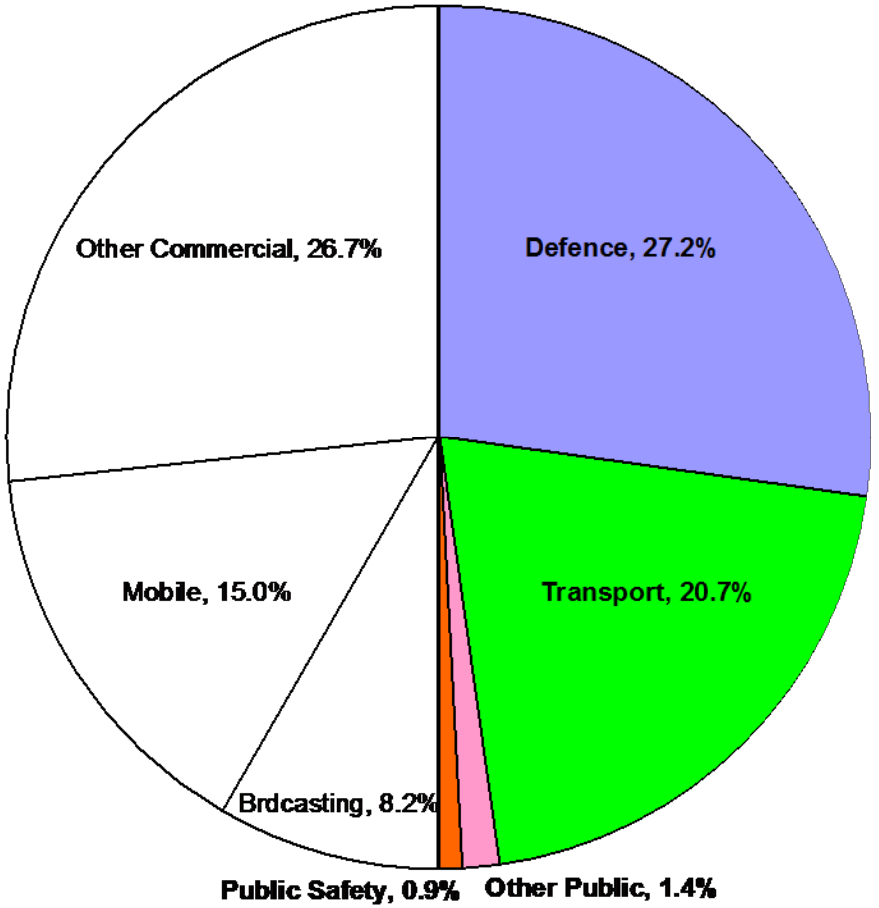
Comparison of Spectrum Use (typical EU country)

Spectrum Use by Sector

108 MHz – 6 GHz

Notes:

1. To avoid double counting we have assumed that all spectrum used by the civil aviation and maritime sectors is classed under the Transport sector, even where this spectrum is also used by the Defence sector
2. Where spectrum is widely used for commercial applications but is also used by the Defence sector (e.g. the 5 GHz WLAN bands), this has been classified as commercial.



wik CONSULT AEGIS systems limited IDATE plum

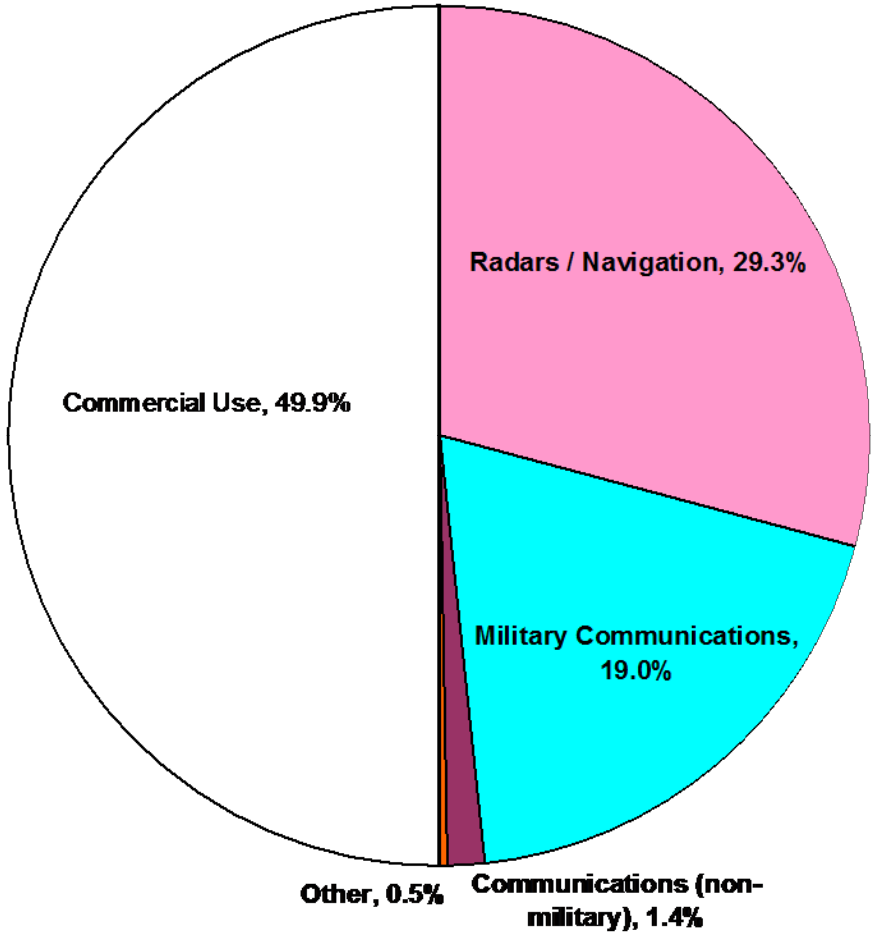
Comparison of Spectrum Use (typical EU country)

Spectrum Use by Application

108 MHz – 6 GHz

Note:

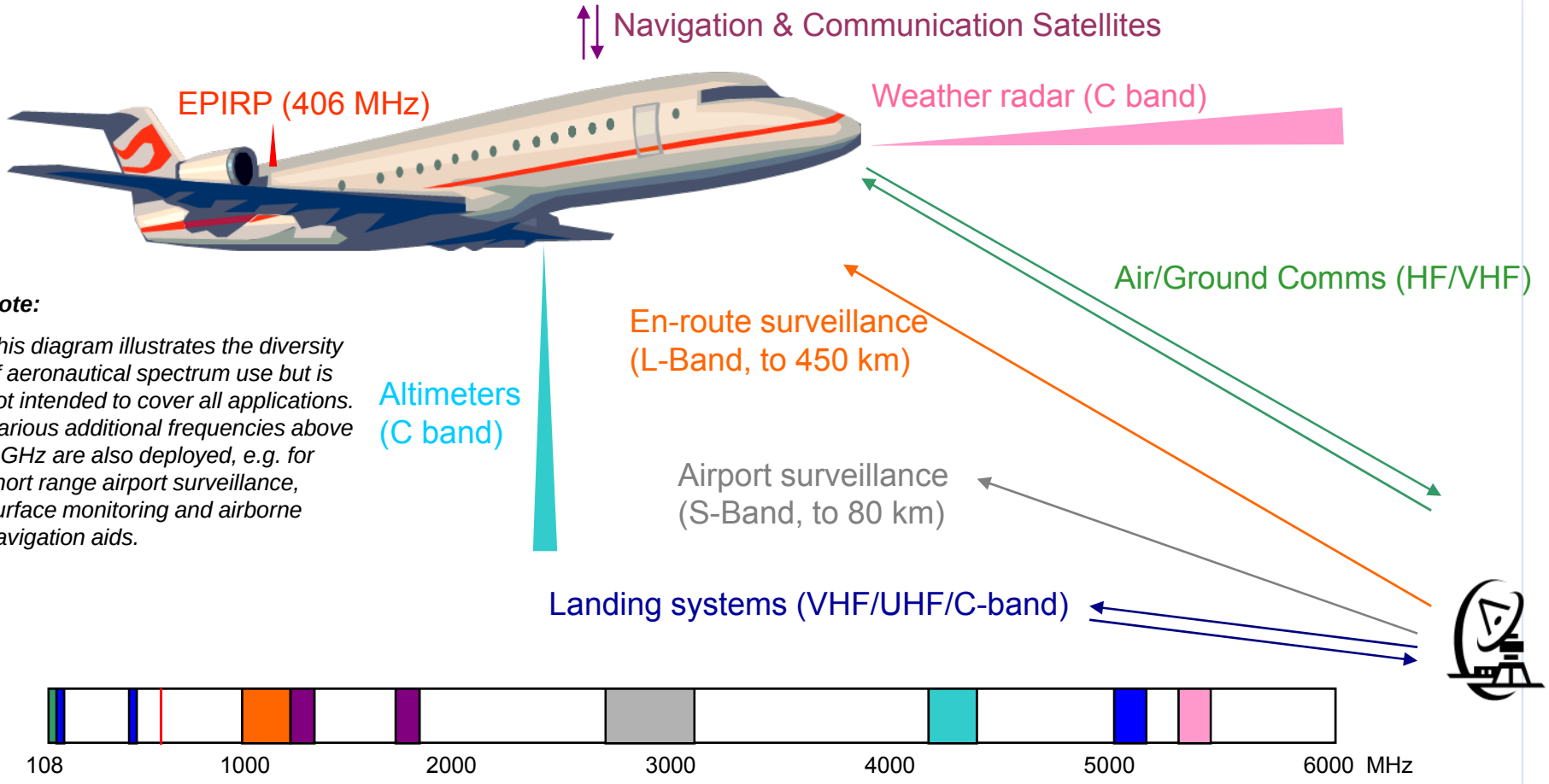
Where spectrum is widely used for commercial applications but is also used by radars (e.g. the 5 GHz WLAN bands), this has been classified as commercial.



Aeronautical and Maritime Spectrum Planning

- Largely managed by ICAO / Eurocontrol and IMO
- ICAO / Eurocontrol specify performance requirements and in some cases technical standards for aeronautical communications and navigation
  - e.g. mandating of narrower bandwidth (8.33 kHz) communications channels above 24,000 ft
- Frequency Bands generally harmonised globally
- Safety of Life at Sea (SOLAS) regulations specify distress frequencies and carriage requirements for communications and radar equipment
  - e.g. all merchant ships above 3,000 tonnes must carry S-band and X-band radar

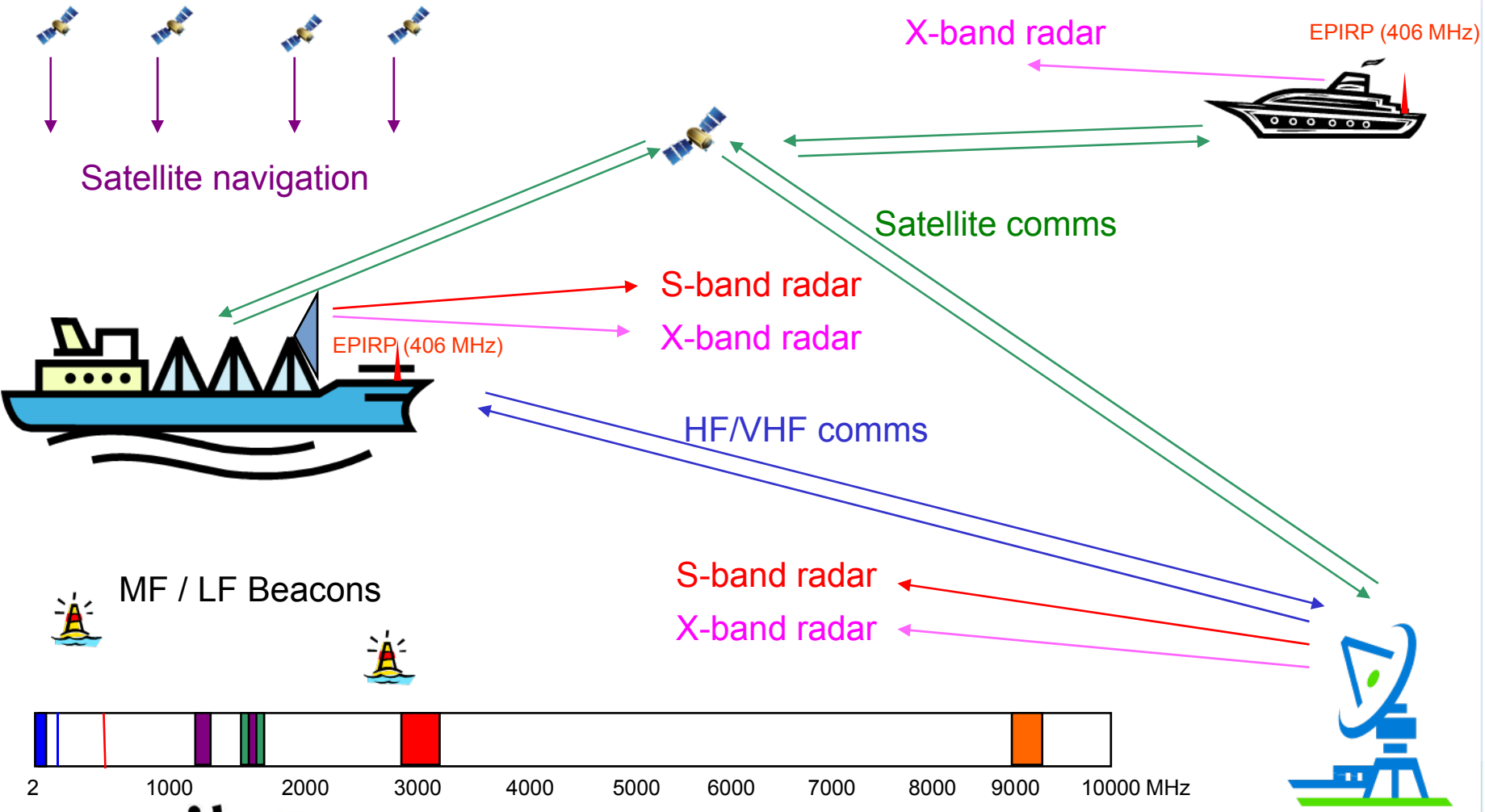
Aeronautical Communication & Navigation Systems



Note:

This diagram illustrates the diversity of aeronautical spectrum use but is not intended to cover all applications. Various additional frequencies above 6 GHz are also deployed, e.g. for short range airport surveillance, surface monitoring and airborne navigation aids.

Maritime Spectrum Use: An Overview



wik CONSULT

AEGIS systems limited

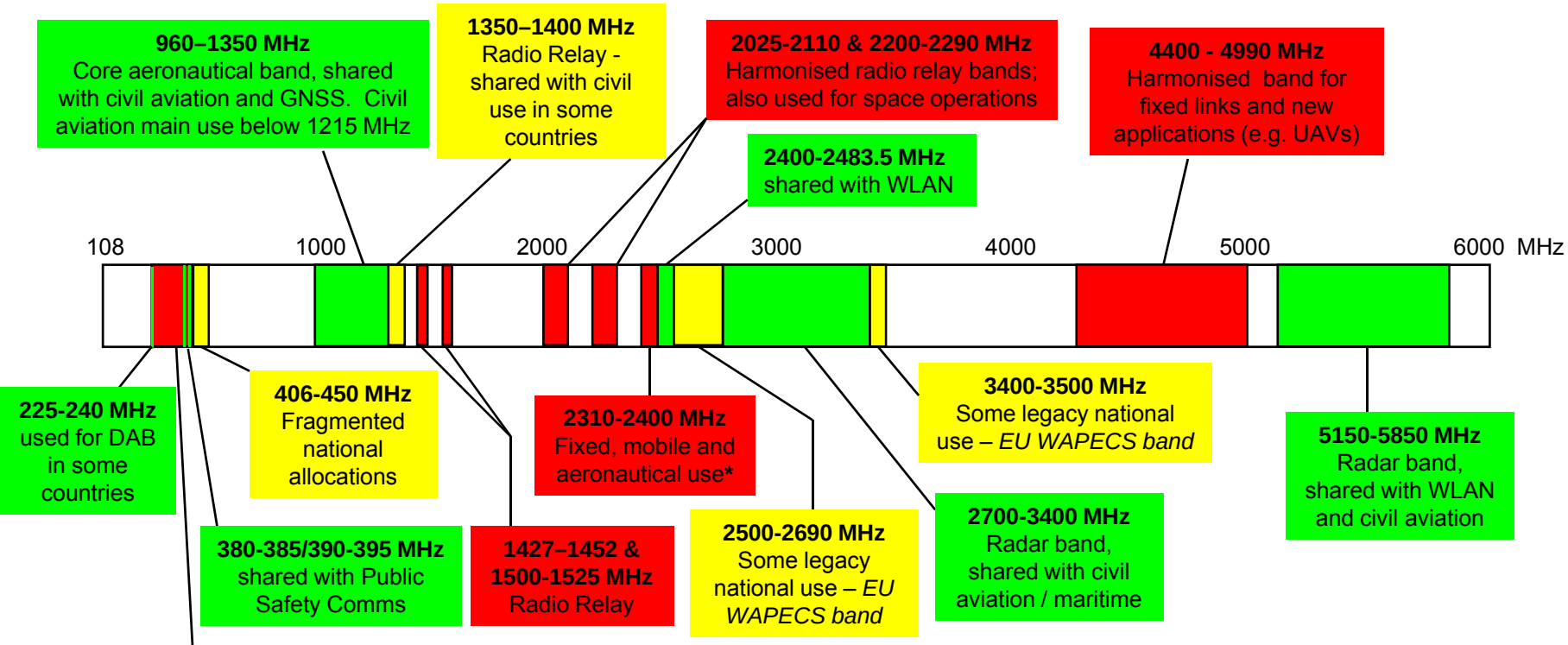
IDATE

plum

Military Spectrum Planning

- Largely planned at international level
  - NATO plays a key role, in liaison with civil spectrum managers and non-NATO EU countries
  - Legacy of former Warsaw Pact allocations in some countries
  - Extensive sharing, especially aeronautical and maritime apps
- Most spectrum harmonised to varying extent, but still significant variation in some bands
- Small, fragmented allocations at national level can constrain re-farming options
- Some IMT / WAPECS bands still used by military in some countries
  - e.g. 2500-2690 MHz, 3400-3500 MHz

Military Spectrum Use: An Overview



*Note: the 2310-2400 MHz band has been identified by ITU as a candidate band for future IMT (3G/4G mobile) systems but no such use is currently planned in Europe

Key:

- Exclusive, harmonised bands (1,055 MHz)
- Shared, harmonised bands (1,895.5 MHz)
- Main non- harmonised bands (386 MHz)

wik CONSULT

ÆGIS systems limited

IDATE

plum

Other Public Sector applications

- Public Safety
  - Mainly voice and narrow band data but growing interest in broadband (e.g. video links)
  - Legacy analogue services migrating to harmonised digital trunked radio band (380 – 400 MHz)
- Rail and Road Transport
  - Voice / data comms, signalling, collision avoidance radars
- Meteorology
  - Weather radars, satellites and other meteorological aids
- Scientific Research (e.g. Radio Astronomy)
  - Some globally harmonised bands, others only used in certain countries
- Relatively small users of spectrum overall

Technology Evolution in the Public Sector

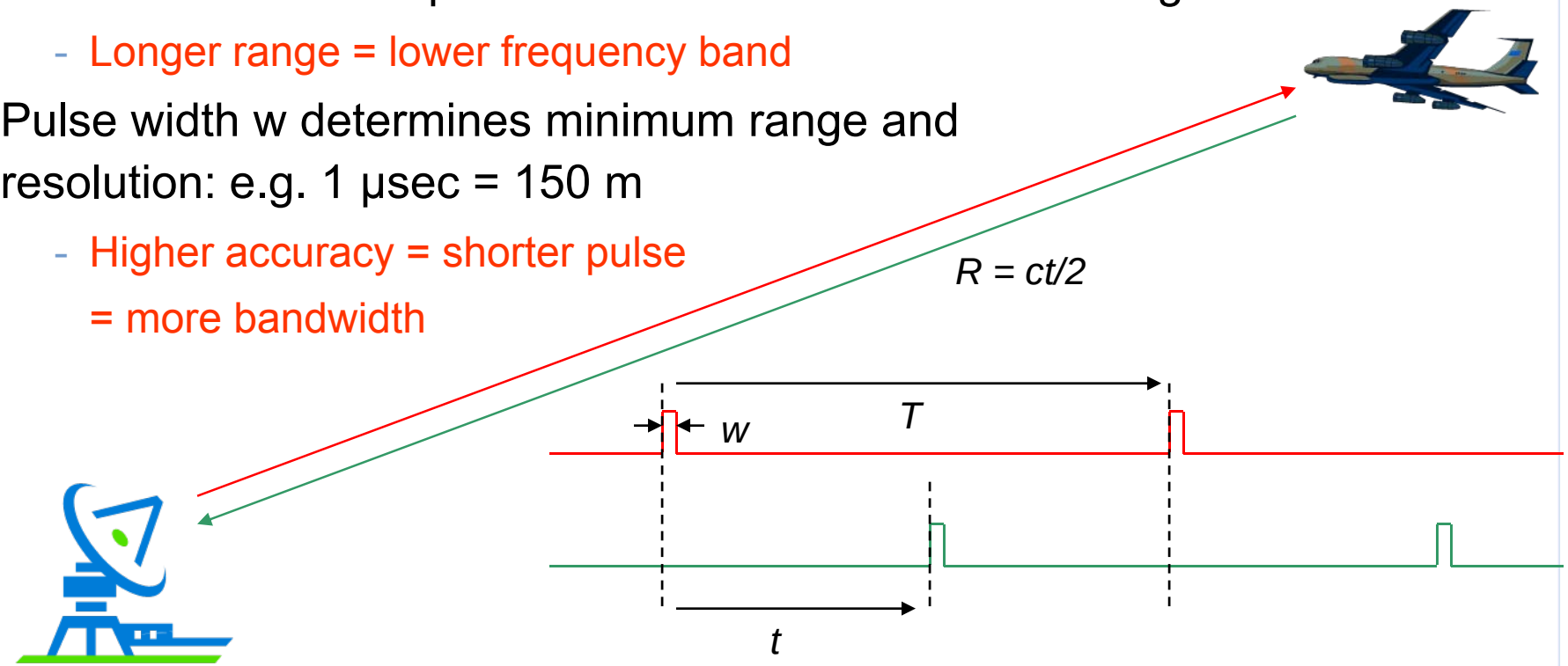
- Technology evolves more slowly than *some parts* of the commercial sector but comparable to others
- Typical upgrade cycle 15 – 25 years
  - Comparable to broadcast transmission or telecoms backbone networks in the commercial sector
- Limiting factors include:
  - Low market volumes
  - High unit costs
  - Demanding performance requirements
  - Need for global interoperability (e.g. aircraft / ships)
  - Tendency for professional equipment to be re-used by private users (e.g. general aviation, leisure craft)
  - Lack of incentive to upgrade

A brief introduction to radar systems

- Primary Radar relies on passive reflections from the target
  - Needs very high transmit powers and very sensitive receivers
  - Large interference potential – requires large geographic and/or frequency separation
  - System is self-contained (no remote terminals or transponders)
- Secondary Radar relies on a transponder mounted on the target to send a return signal
  - Much lower transmit powers and higher link budget
  - Greater scope for signal processing
  - Relies on compatible transponders on all target craft (may be tens or hundreds of thousands in use)
- Primary radar requires more spectrum but more scope for improvement (as numbers involved are smaller)

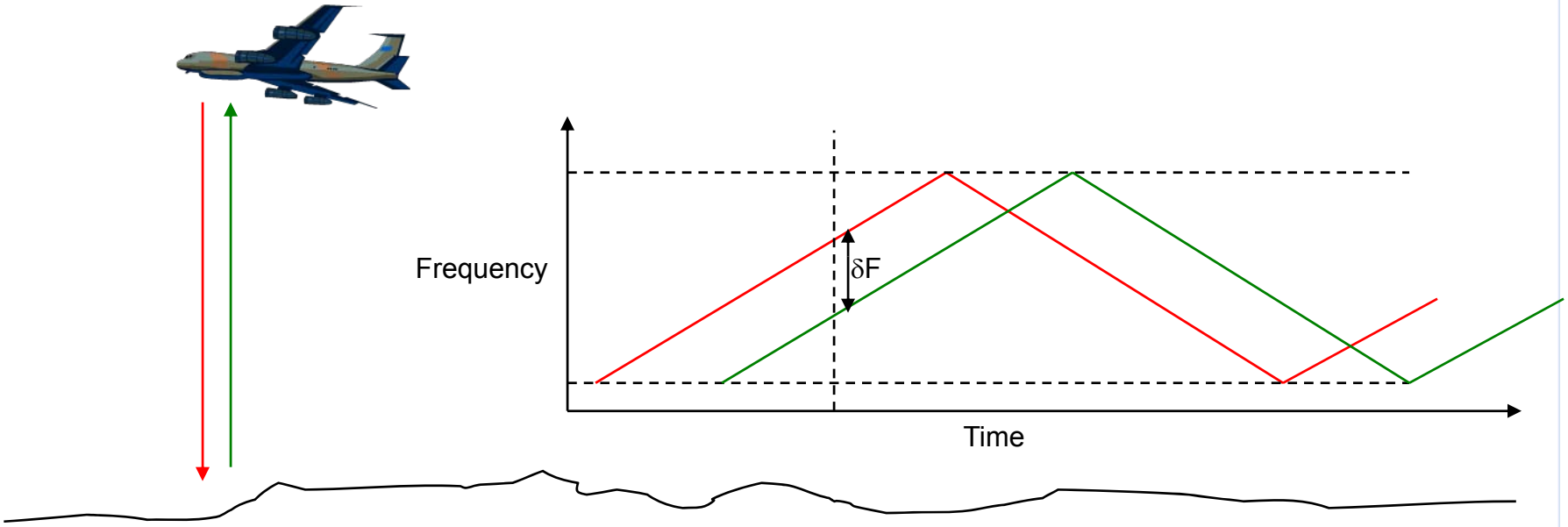
Radar Technologies (1): Pulsed Radars

- Determine position by measuring time delay in reflected signal
- Pulse interval T and path loss determines maximum range
  - Longer range = lower frequency band
- Pulse width w determines minimum range and resolution: e.g. 1 µsec = 150 m
  - Higher accuracy = shorter pulse = more bandwidth



Radar Technologies (2): FMCW Radars

- Determine position by measuring frequency difference between transmitted and received signal
- Need sufficient bandwidth to achieve range and resolution objectives (current systems around 100 MHz)



Comparison of Radar Technologies

- Pulsed Radars
  - Higher Transmit Power, more sensitive receivers (since not transmitting simultaneously)
  - Hence ideal for long range surveillance applications
  - Need large geographic and/or frequency separation to avoid interference between radars
- FMCW Radars
  - No minimum range constraint
  - Better range resolution (depending on bandwidth)
  - Ideal for short range applications (e.g. low altitude altimeters)
- CW Radars
  - Used to measure speed using Doppler Effect

Principal Radar Frequency Bands

- Different Bands used for Different Applications:
  - L-band (960 – 1215 MHz): Secondary radar systems 
  - L-band (1215 – 1365 MHz): Long range surveillance (to 450 km) 
  - S-band (2700 – 3400 MHz): Mid-range Surveillance (to 80 km) 
  - C-band: (4200 – 4400 MHz): Altimeters 
  - C-band (5350 – 5470 MHz): Wind Shear Detection 
  - X-band (9000 – 9500 MHz): Surveillance 
  - X-band (9345 – 9375 MHz): Storm Cloud Detection 
  - X-band (9300 – 9500 MHz): Ground Movement Radar 
  - Ka-band: (13.25 – 13.4 GHz): Airborne Doppler Radar 
  - Ka-band (15.3 – 15.7 GHz): Ground Movement Radar 

 Ground / Shore based  Airborne  Ship borne

Controlling Radar Emissions

- Radar emissions largely defined by range / resolution requirements
- Typical Operational Bandwidths (Primary Radar, -20 dB):
  - L-band: 4 - 16 MHz
  - S-band: 2 – 20 MHz
- But out-of-band emissions extend well beyond these limits:
  - Can result in “overspill” into adjacent bands
  - But bigger issue is required frequency separation for other radars (due to highly sensitive receivers)
  - New tighter out-of-band limits have been developed by CEPT
  - Recent solid state radars significantly improve out-of-band performance
  - But many existing radars still use older valve technology

Benefit of reduced out of band emissions

- Work undertaken for Ofcom in the UK suggests up to **63% reduction** in required frequency separation between two S-band radars at 45 km distance if latest solid state technology used to replace existing TWTA based radars*
- Average reduction anticipated to be about half this (**32%**)
- Suggests ability to "pack" more radars into existing frequency bands without compromising performance
- Longer term possibility to re-plan the bands and maybe reduce overall bandwidth
- But this would require all existing TWTA / magnetron radars to be upgraded

* see "Study into Spectrally Efficient Radar Systems in the L and S Bands - Short Report for Ofcom Spectral Efficiency Scheme 2004 – 2005, by BAe Systems, July 2006

Future Requirements for Public Sector Spectrum

- Additional Aeronautical Mobile Spectrum
  - Includes new telemetry and security applications
  - Seeking to accommodate within aeronautical navigation bands
  - Allocations amended at WRC-07 to permit communications in radionavigation bands
- Spectrum for Unmanned Aircraft Systems
  - ITU-R Studies planned for WRC-11
  - Possibly seeking additional allocations
- Public Protection and Disaster Relief
  - 5150 – 5250 MHz identified by CEPT as a preferred band for broadband systems
- Road and Rail Transport
  - Intelligent Transport Systems, Road Pricing, Collision Avoidance
  - Rail needs mostly met by GSM-R

Spectrum Demand Trends in the Military

- Demand growing for wideband data links and airborne telemetry systems
- Future combat systems increasingly reliant on mobile broadband tactical communications with resilient wide area coverage – implies large, contiguous RF bandwidth
- Increased deployment of unmanned vehicles (ground and airborne) driving demand for wireless telemetry
- Demand growth can be offset to some extent by deployment of new technologies
  - e.g. software defined radio allows systems to operate across wide range of existing bands and air interfaces, adapting to local availability

Spectrum Sharing

- Spectrum can be shared between Public Sector users…
  - Many radar bands are shared between civil (especially aeronautical and maritime) and military uses
  - Ground based aeronautical radars and Shore based marine radars can co-exist
- …or between Public and Commercial users
  - Geographic sharing has taken place in TV broadcast and GSM bands
  - Dynamic Frequency Sharing between radars and WLANs at 5 GHz
- Some public sector systems have evolved to serve both sectors
  - e.g. GPS, Inmarsat

Future sharing and spectrum release opportunities

- Greater use of Smart Radio technologies could enhance ability to share spectrum
  - Many military systems are designed for “hostile” RF environments hence should be able to co-exist with commercial uses
- Some applications could migrate to higher, less congested bands
  - e.g. line-of-sight communication links
- Future requirement for some existing allocations is uncertain
  - e.g. ILS / MLS likely to be replaced by satellite systems enabling re-farming to support demand growth for new applications
- Pre-emptive access to spectrum could cater for unpredictable emergency requirements
  - But need to be sure spectrum available when needed

Summary

- Radars and Military Communications account for bulk of public sector spectrum use
- Demand for aeronautical communications is growing but should mostly be met in existing aeronautical bands
- Growing demand for spectrum to support unmanned aircraft
- Demand growth can be addressed by (for example):
  - Upgrading technology to improve spectrum efficiency (e.g. in primary radar bands)
  - Greater sharing of spectrum both within the public sector and between public / commercial users
  - Migrating line-of-sight applications to higher bands
  - Use of Software Defined Radio to provide more flexibility in choice of spectrum