Elements and Techniques for Situational Awareness using Networked Passive Sensors

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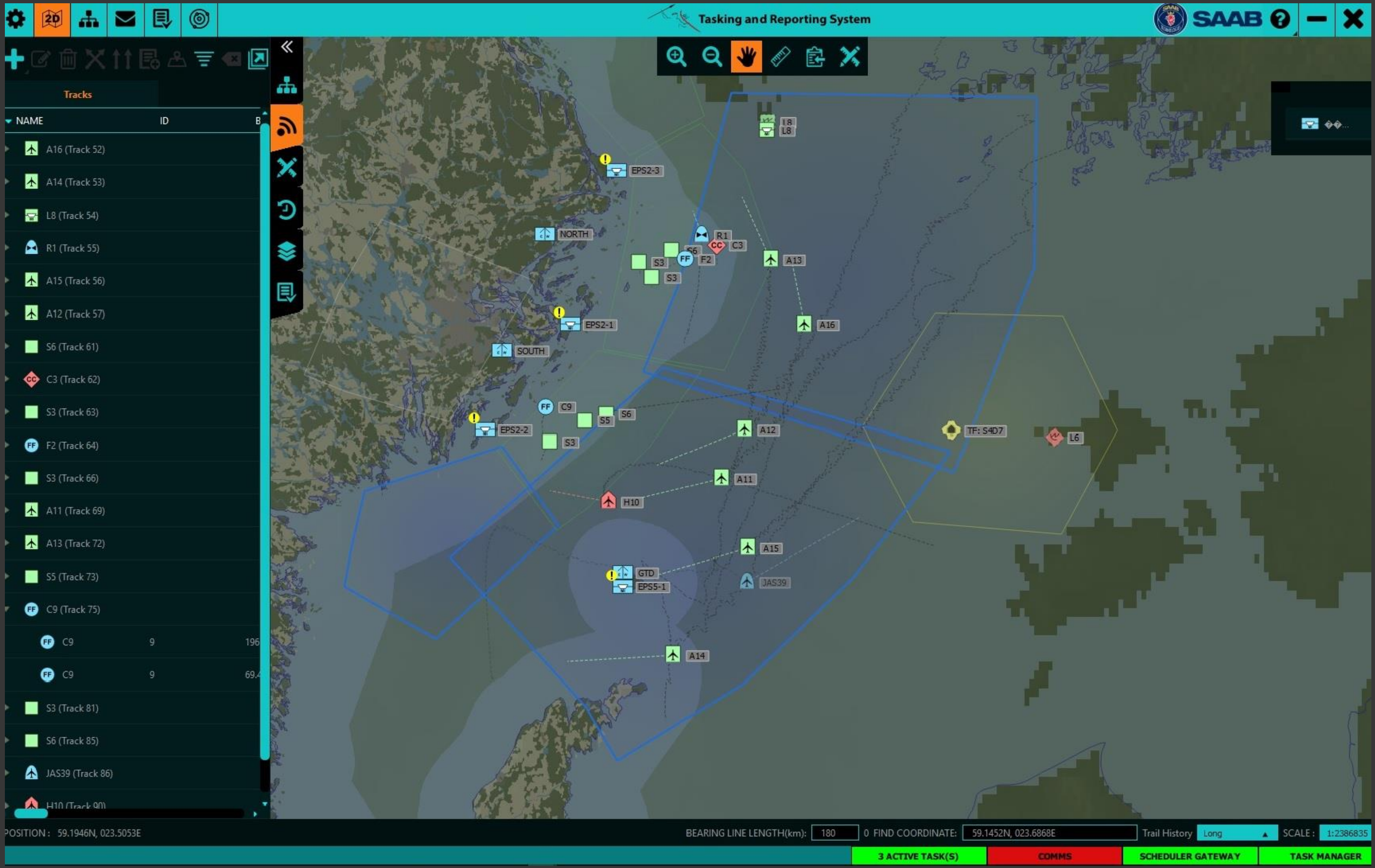
Situational Awareness



Periodic Table – Table of the Eelements

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H Hydrogen 1.01																	2 He Helium 4.00
3 Li Lithium 6.94	4 Be Beryllium 9.01											5 B Boron 10.81	6 C Carbon 12.01	7 N Nitrogen 14.01	8 O Oxygen 16.00	9 F Fluorine 19.00	10 Ne Neon 20.18
11 Na Sodium 22.99	12 Mg Magnesium 24.31											13 Al Aluminum 26.98	14 Si Silicon 28.09	15 P Phosphorus 30.97	16 S Sulfur 32.06	17 Cl Chlorine 35.45	18 Ar Argon 39.95
19 K Potassium 39.10	20 Ca Calcium 40.08	21 Sc Scandium 44.96	22 Ti Titanium 47.88	23 V Vanadium 50.94	24 Cr Chromium 51.99	25 Mn Manganese 54.94	26 Fe Iron 55.85	27 Co Cobalt 58.93	28 Ni Nickel 58.69	29 Cu Copper 63.55	30 Zn Zinc 65.38	31 Ga Gallium 69.72	32 Ge Germanium 72.63	33 As Arsenic 74.92	34 Se Selenium 78.97	35 Br Bromine 79.90	36 Kr Krypton 84.80
37 Rb Rubidium 85.47	38 Sr Strontium 87.62	39 Y Yttrium 88.91	40 Zr Zirconium 91.22	41 Nb Niobium 92.91	42 Mo Molybdenum 95.95	43 Tc Technetium 98.91	44 Ru Ruthenium 101.07	45 Rh Rhodium 102.91	46 Pd Palladium 106.42	47 Ag Silver 107.87	48 Cd Cadmium 112.41	49 In Indium 114.82	50 Sn Tin 118.71	51 Sb Antimony 121.76	52 Te Tellurium 127.6	53 I Iodine 126.90	54 Xe Xenon 131.29
55 Cs Cesium 132.91	56 Ba Barium 137.33	57-71 Lanthanides	72 Hf Hafnium 178.49	73 Ta Tantalum 180.95	74 W Tungsten 183.85	75 Re Rhenium 186.21	76 Os Osmium 190.23	77 Ir Iridium 192.22	78 Pt Platinum 195.08	79 Au Gold 196.97	80 Hg Mercury 200.59	81 Tl Thallium 204.38	82 Pb Lead 207.20	83 Bi Bismuth 208.98	84 Po Polonium [208.98]	85 At Astatine 209.98	86 Rn Radon 222.02
87 Fr Francium 223.02	88 Ra Radium 226.03	89-103 Actinides	104 Rf Rutherfordium [261]	105 Db Dubnium [262]	106 Sg Seaborgium [266]	107 Bh Bohrium [264]	108 Hs Hassium [269]	109 Mt Meitnerium [278]	110 Ds Darmstadtium [281]	111 Rg Roentgenium [280]	112 Cn Copernicium [285]	113 Nh Nihonium [286]	114 Fl Flerovium [289]	115 Mc Moscovium [289]	116 Lv Livermorium [293]	117 Ts Tennessine [294]	118 Og Oganesson [294]

57 La Lanthanum 138.91	58 Ce Cerium 140.12	59 Pr Praseodymium 140.91	60 Nd Neodymium 144.24	61 Pm Promethium 144.91	62 Sm Samarium 150.36	63 Eu Europium 151.96	64 Gd Gadolinium 157.25	65 Tb Terbium 158.93	66 Dy Dysprosium 162.50	67 Ho Holmium 164.93	68 Er Erbium 167.26	69 Tm Thulium 168.93	70 Yb Ytterbium 173.06	71 Lu Lutetium 174.97
89 Ac Actinium 227.03	90 Th Thorium 232.04	91 Pa Protactinium 231.04	92 U Uranium 238.03	93 Np Neptunium 237.05	94 Pu Plutonium 244.06	95 Am Americium 243.06	96 Cm Curium 247.07	97 Bk Berkelium 247.07	98 Cf Californium 251.08	99 Es Einsteinium [254]	100 Fm Fermium 257.10	101 Md Mendelevium 258.10	102 No Nobelium 259.10	103 Lr Lawrencium [262]

- Alkali Metal
- Alkaline Earth
- Transition Metal
- Basic Metal
- Metalloid
- Nonmetal
- Halogen
- Noble Gas
- Lanthanide
- Actinide

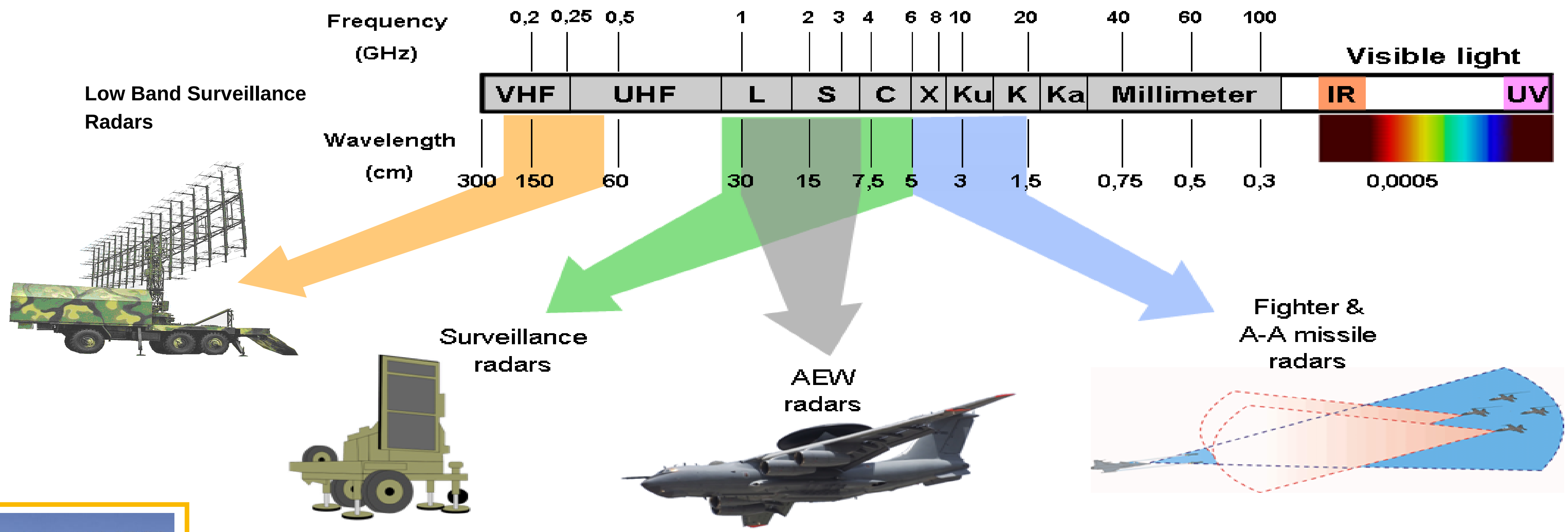
Elements and Techniques…

- The need for situational awareness using networked passive sensors
- Characteristics of sensors
- Creating situational awareness

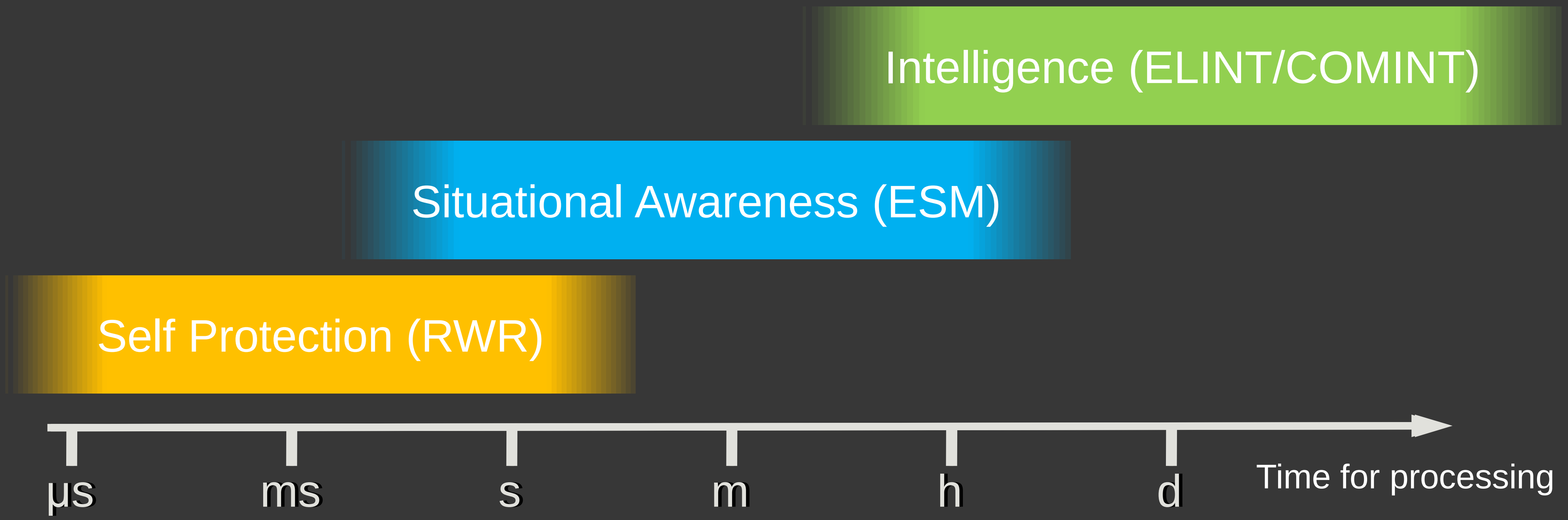
Military Trends and their influence on EW

- Focus shifting (back) from asymmetric operations into traditional combat force
  - Radar threats regaining importance
  - Increasing occurrence of hybrid warfare
- Counter-stealth surveillance radars at low frequency bands such as VHF are in focus
- Anti-Access/Area Denial systems with long ranges are proliferating
- Radar sensors are becoming increasingly agile and are used selectively
- Bi-static radar systems are deployed

Signal and Threat Environment



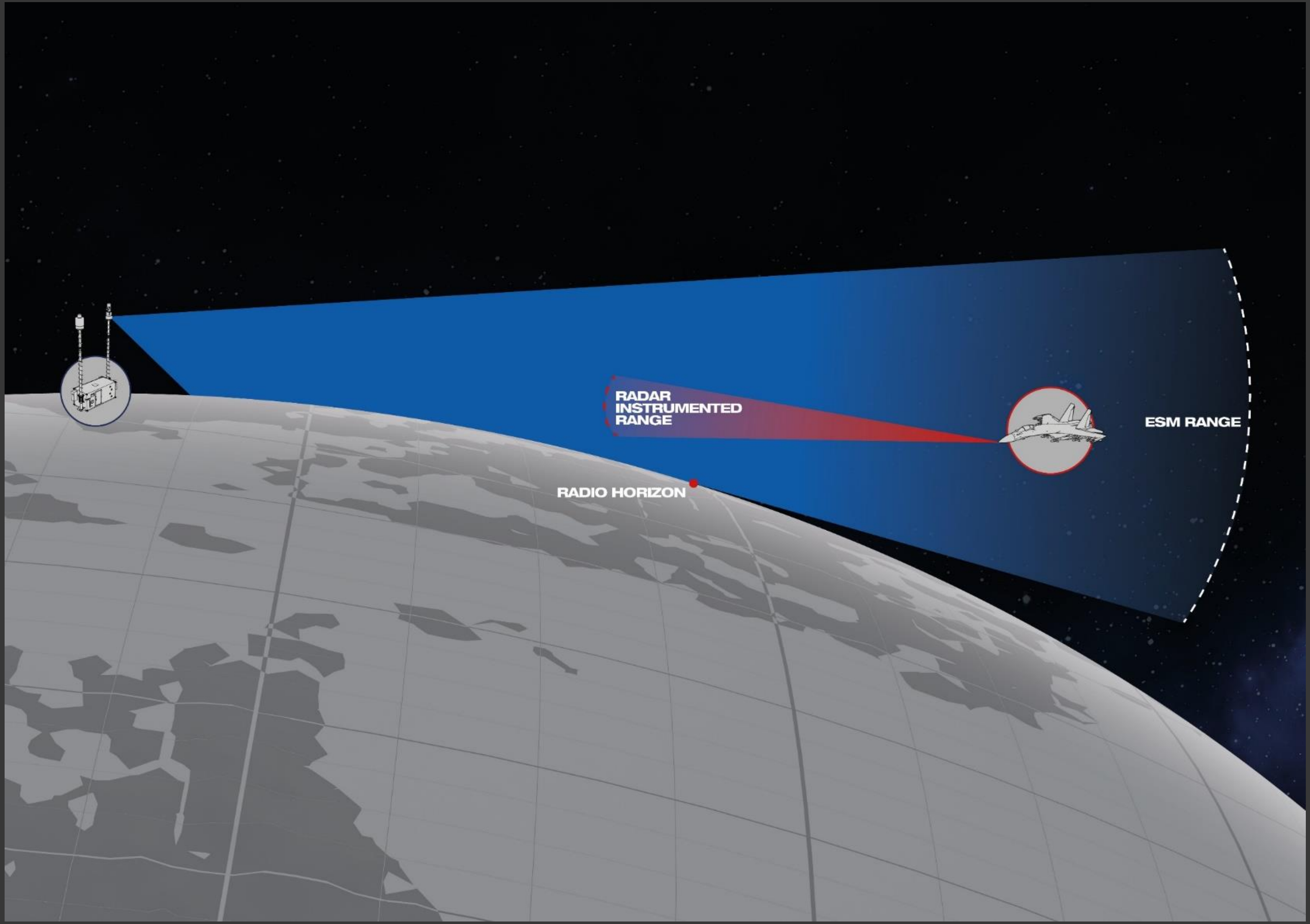
EW Processing Timeline



Priorities between system functions varies with the mission and threat level applicable at a specific point in time but it can be assumed that self-protection is always the highest priority w.r.t. response time

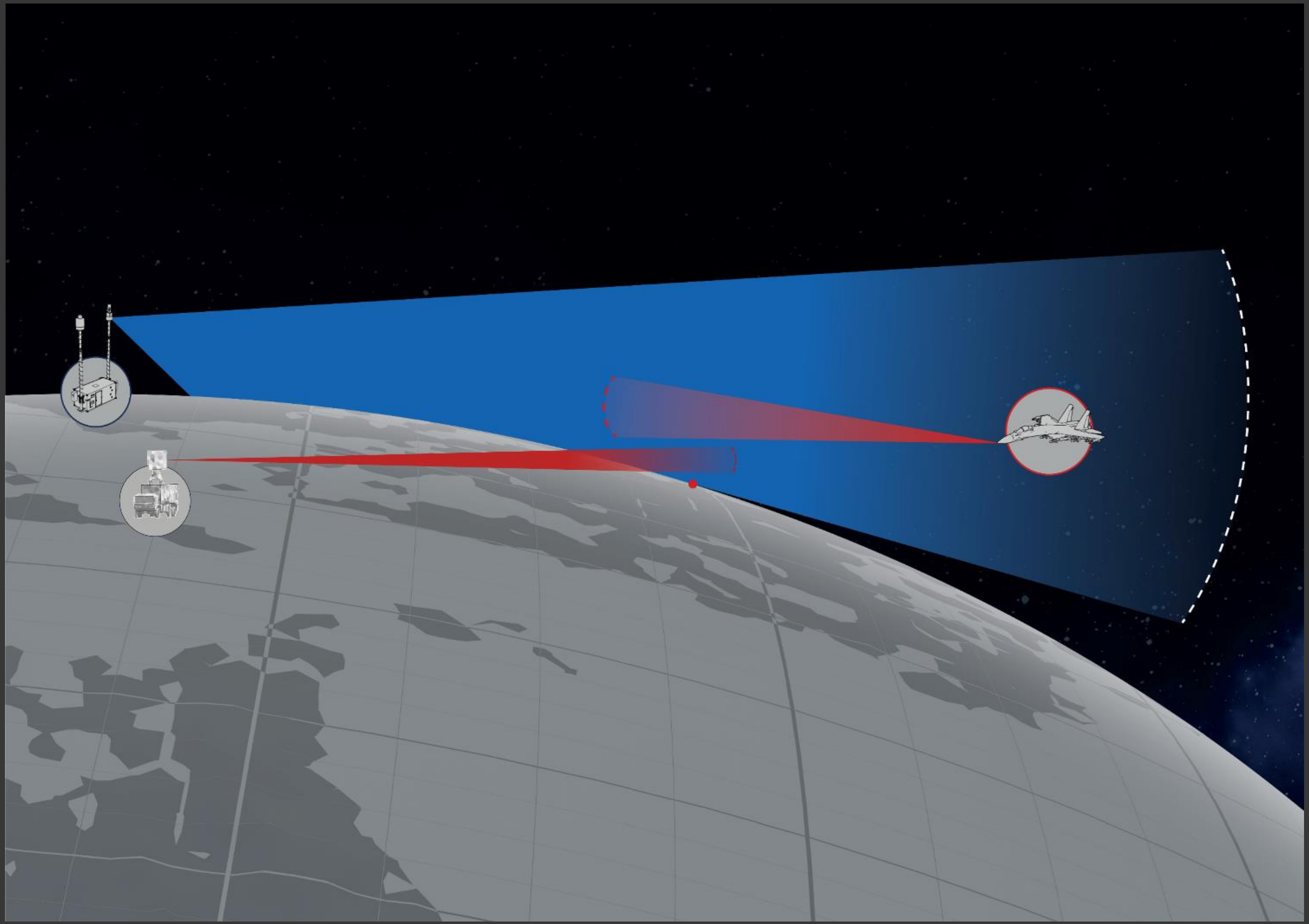
ESM Detection Range Superiority

$$P_{ESM} = \frac{P_{rr}G_{rr}}{4\pi R^2}\frac{G_{ESM}\lambda^2}{4\pi}$$



ESM for GBAD Applications

- ESM detection range
- Radar instrumented range



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Sensor – Functional Requirements

- Wide band RWR high POI system
  - High POI, good sensitivity
  - 360° instantaneous azimuth coverage with DF
  - 2-18(40)GHz
  - LB and HB (warning) extensions possible

- Narrow band ESM high precision system
  - Less demanding POI (cued by high POI system)
  - Very good sensitivity
  - Accurate AoA measurements
  - Selectable sector azimuth coverage
  - Capable of LPI detection and analysis

- For ELINT applications additional sensitivity is needed - can be achieved by adding high gain directional antennas if installation permits.

Probability of Intercept (POI): In the context of EW – detection, warning and then further processing. Consider:

- Frequency
- Space
- Time
- Signal environment!

LPI Radar

- Radar range performance
  - Dependent on total energy transmitted and reflected from a target
- Principles for Low Probability of Intercept (LPI) radar
  - Keep radar signature low by spreading total energy in
    - Time
    - Frequency
    - Space (angle)
    - Diversity
    - Maintain low antenna sidelobes
- LPI detection techniques - improved sensitivity using
    - 2-antenna cross-correlation
    - Using waveform knowledge like FMCW frequency rate

Sensors

ESM sensors

- Automatic detection, de-interleaving
- Emitter classification
- Precision AoA measurements < 1° rms using interferometer antenna arrays

ELINT sensors

- Increased sensitivity
- Ability to measure weak signals
- High gain directional antenna
- Selectivity to supress strong signals

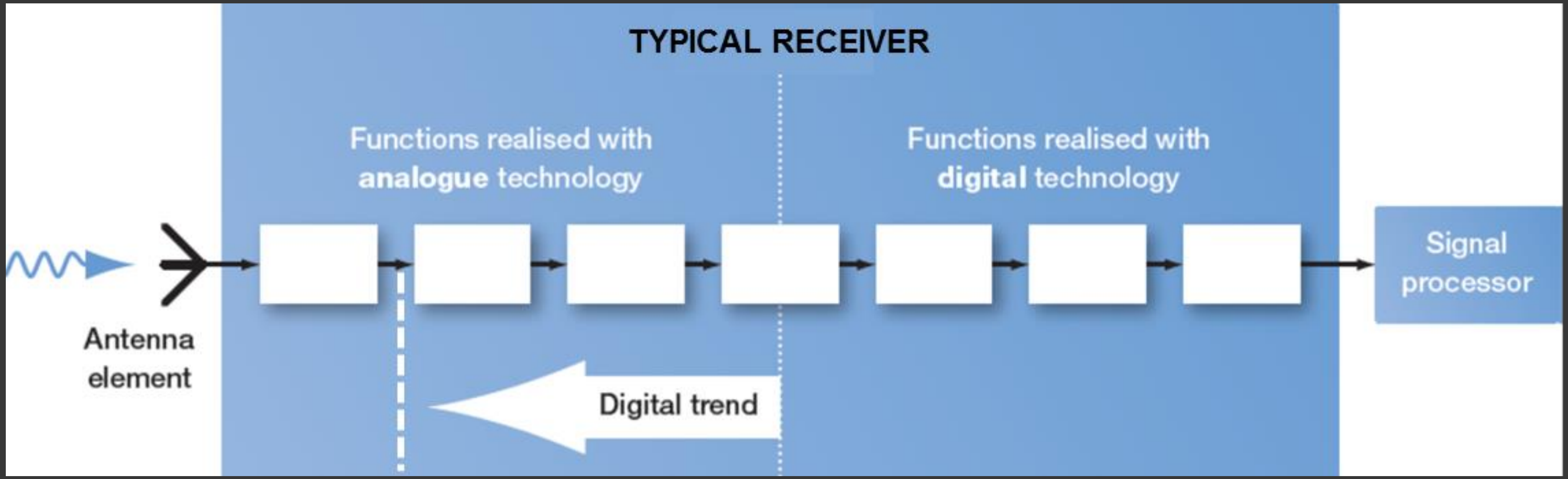
High Precision ESM Sensor

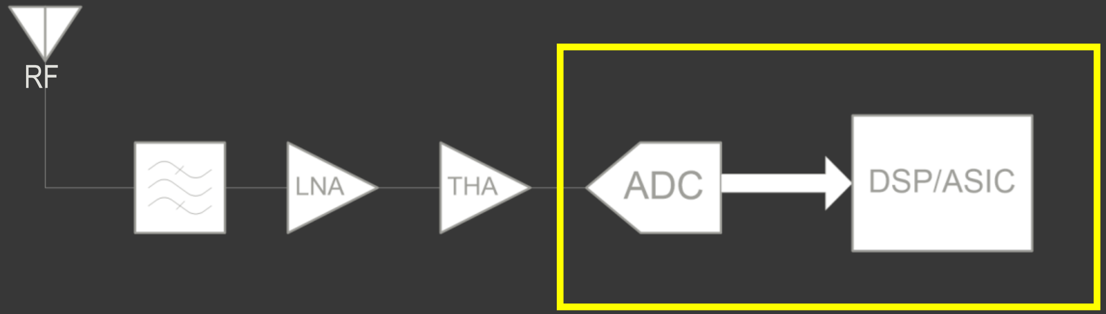
Advanced integrated ESM (C-ESM, R-ESM) sensor

- Frequency coverage 30MHz-18 (40) GHz
- High AoA measurement accuracy < 1° rms
- 30-500MHz using MUSIC algorithm
- 0.5-18GHz linear interferometer panel(s)
- Automatic detection using digital receiver technology and robust identification/ classification algorithms

- Stand-alone or networked ESM operation

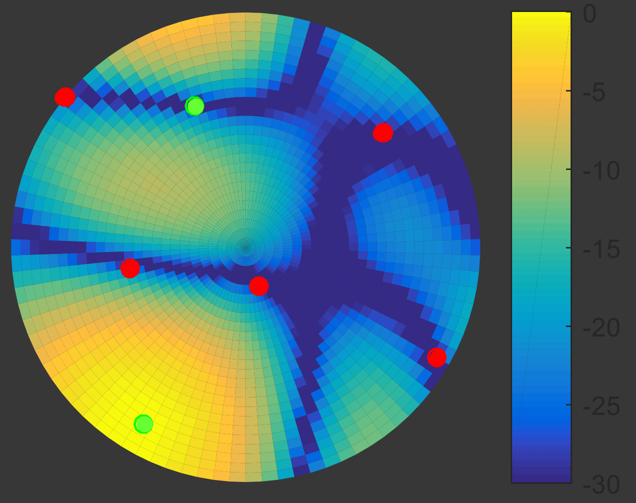
SIGINT Digital Receivers

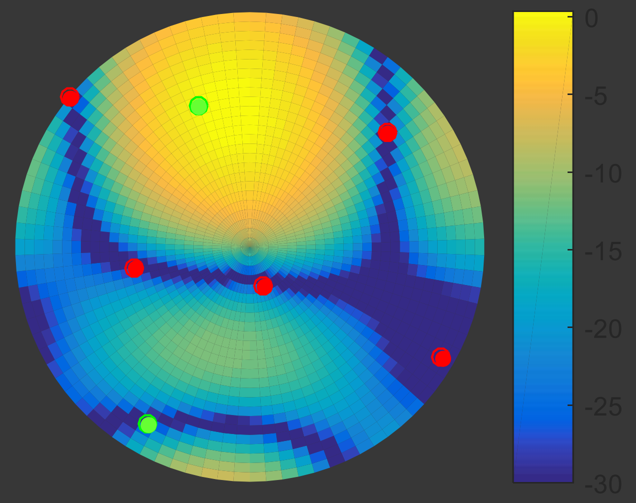




Beamforming for Antenna Arrays

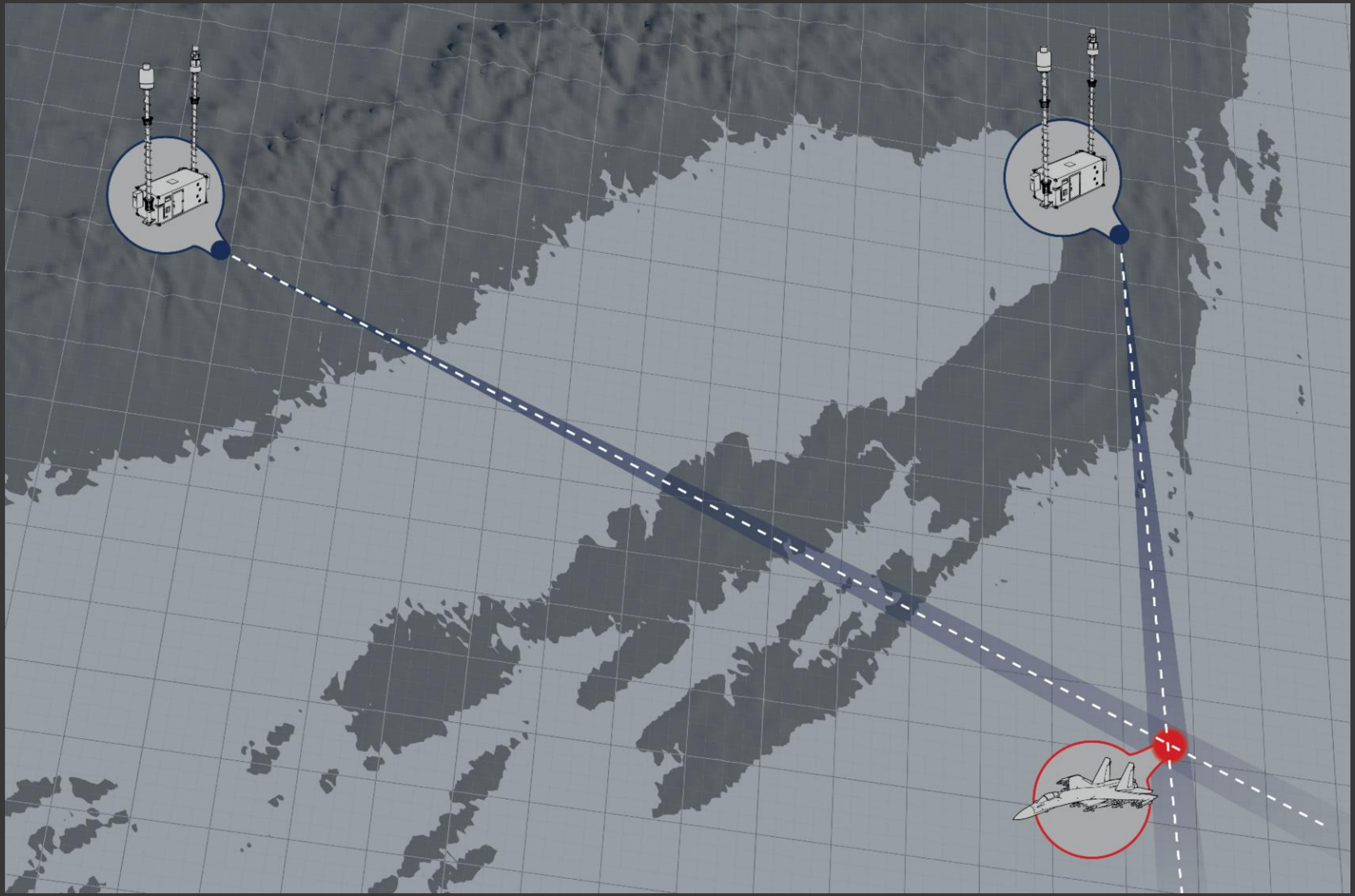
- Creating beams with gain in multiple directions at the same time
- Forming nulls in the direction of strong interfering signals
- Scenario
  - 5 interfering signals in unknown direction (red circles)
  - 2 signals-of-interest (SOI:s) in known directions (green circles)
- Two parallel beams in two different directions
  - Signals from the main beam direction are preserved
  - Interfering signals are suppressed





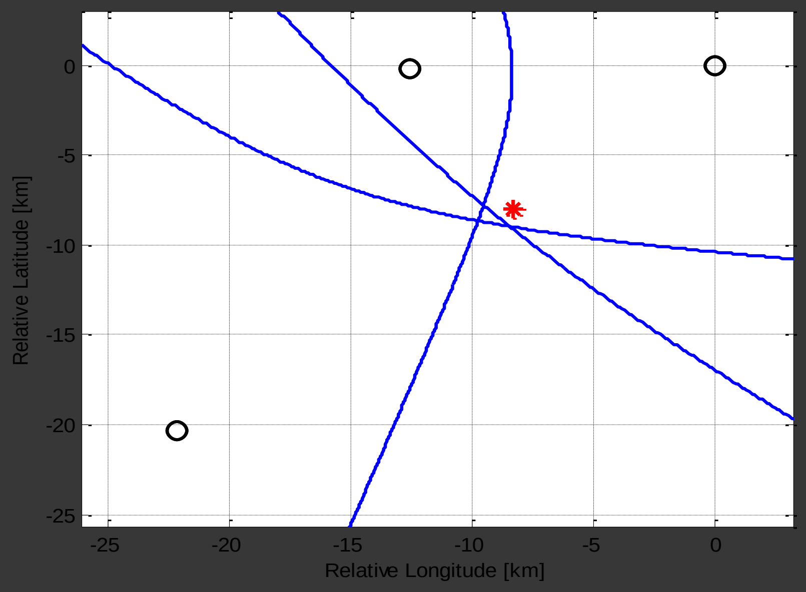
Geo-location using Triangulation

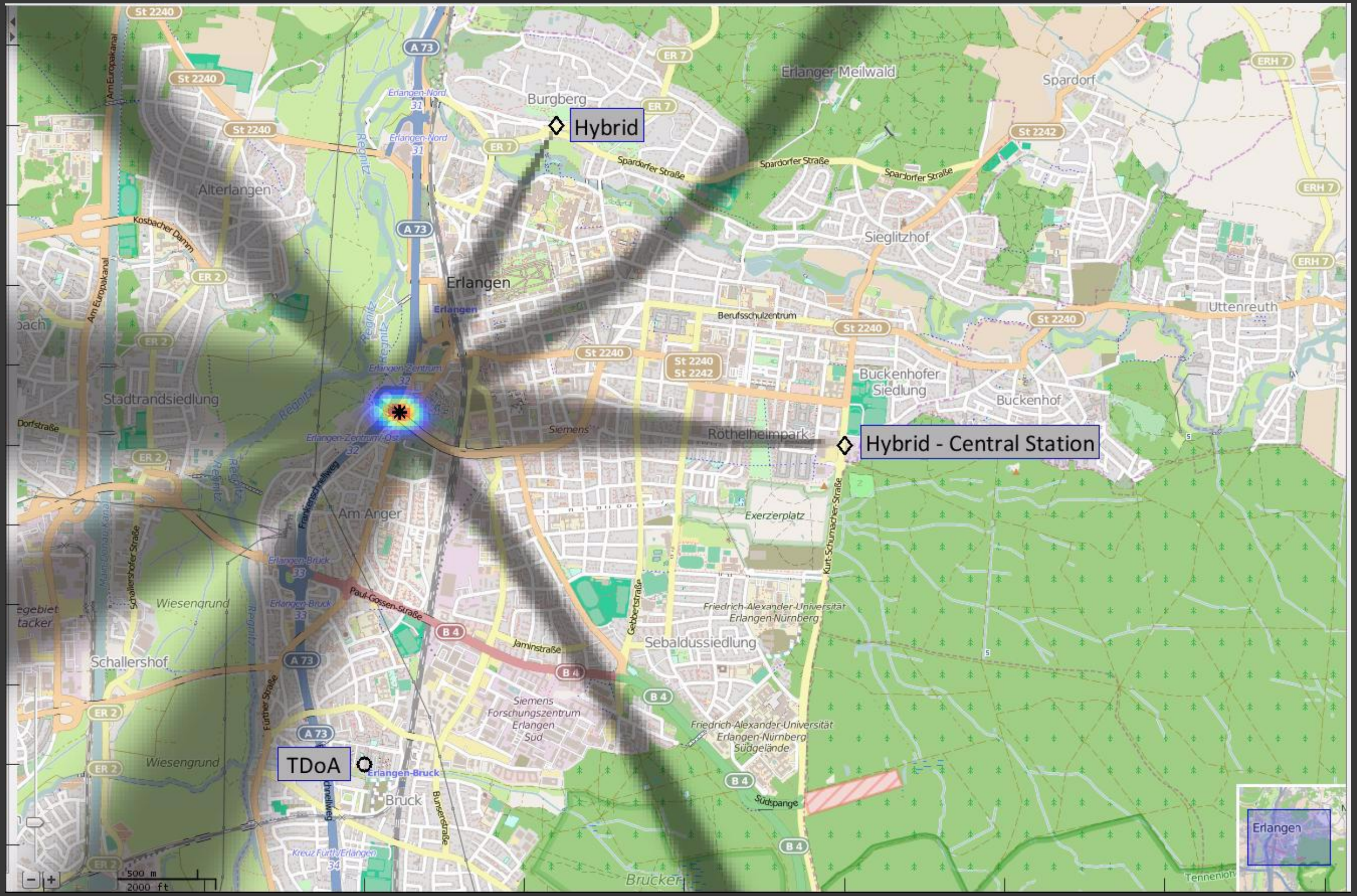
- Sensor performance
- AoA accuracy
- Number of sensors
- Baseline
- Distance to emitter
- Emitter dynamics



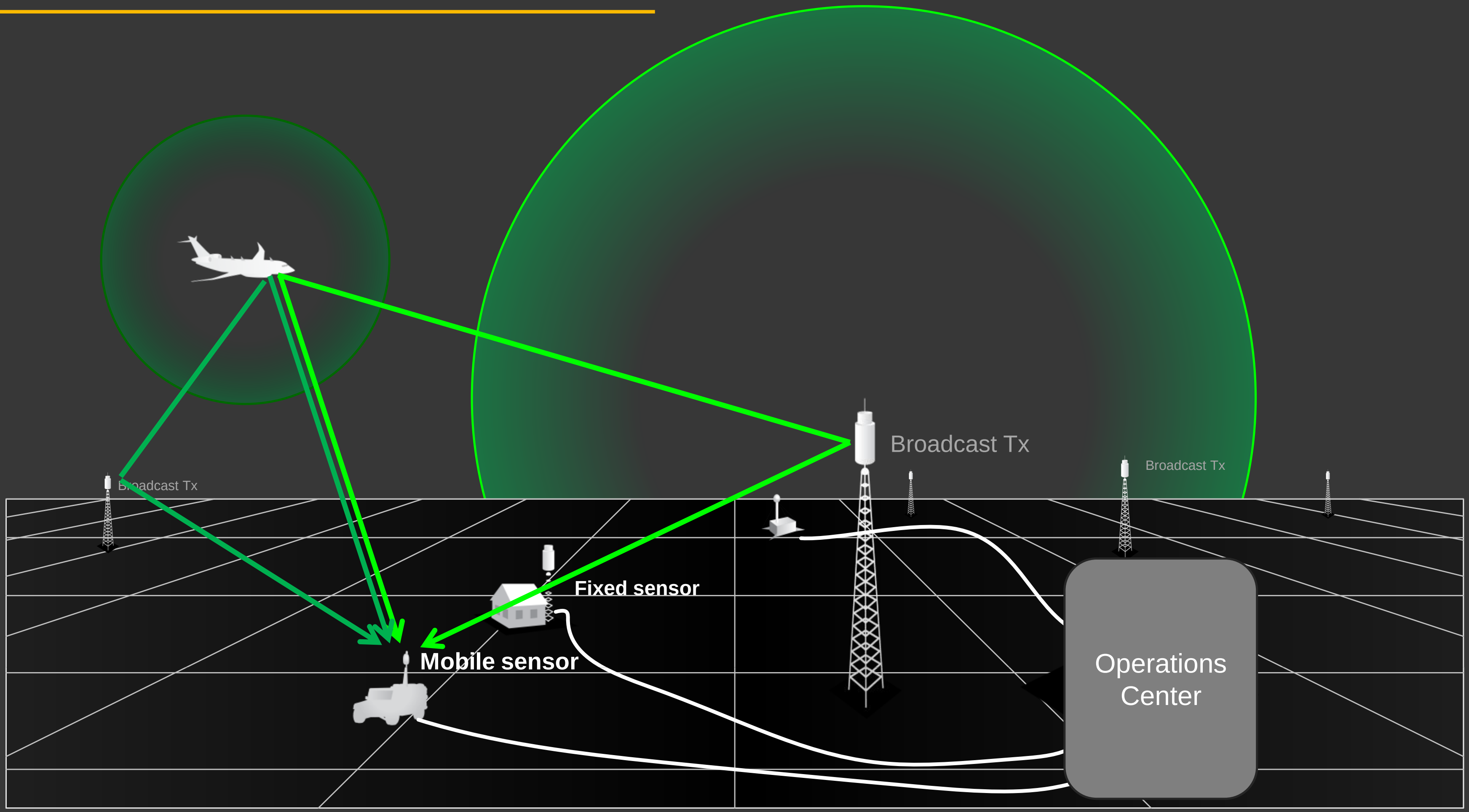
Geo-location using TDOA

- Accurate geo-location
- Single channel receivers
- Geometry dependent

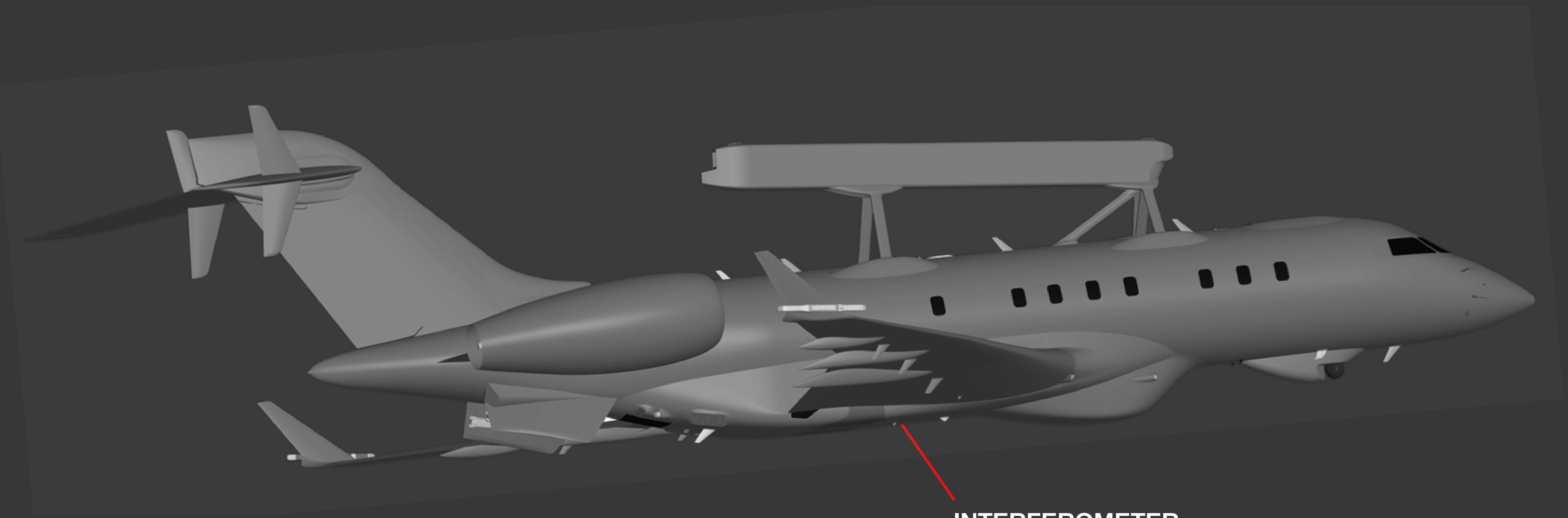




Passive Coherent Location (PCL)

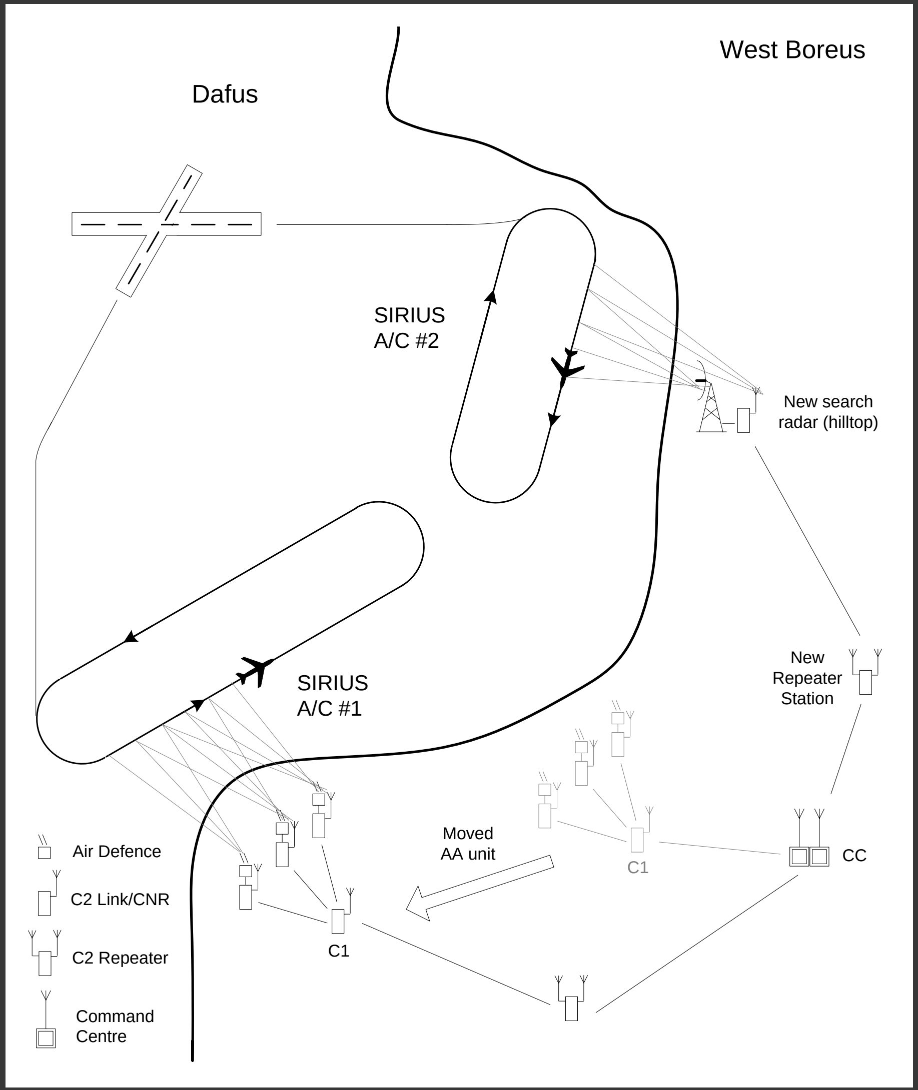


ESM system on GlobalEye



Airborne SIGINT

- Strategic intelligence gathering over longer periods of time
- Regular, planned missions (or ad-hoc)
- Locate and classify existing and new emitters.
- Recording and technical analysis supports threat library updates needed by other EW assets
- Situational awareness for decision makers



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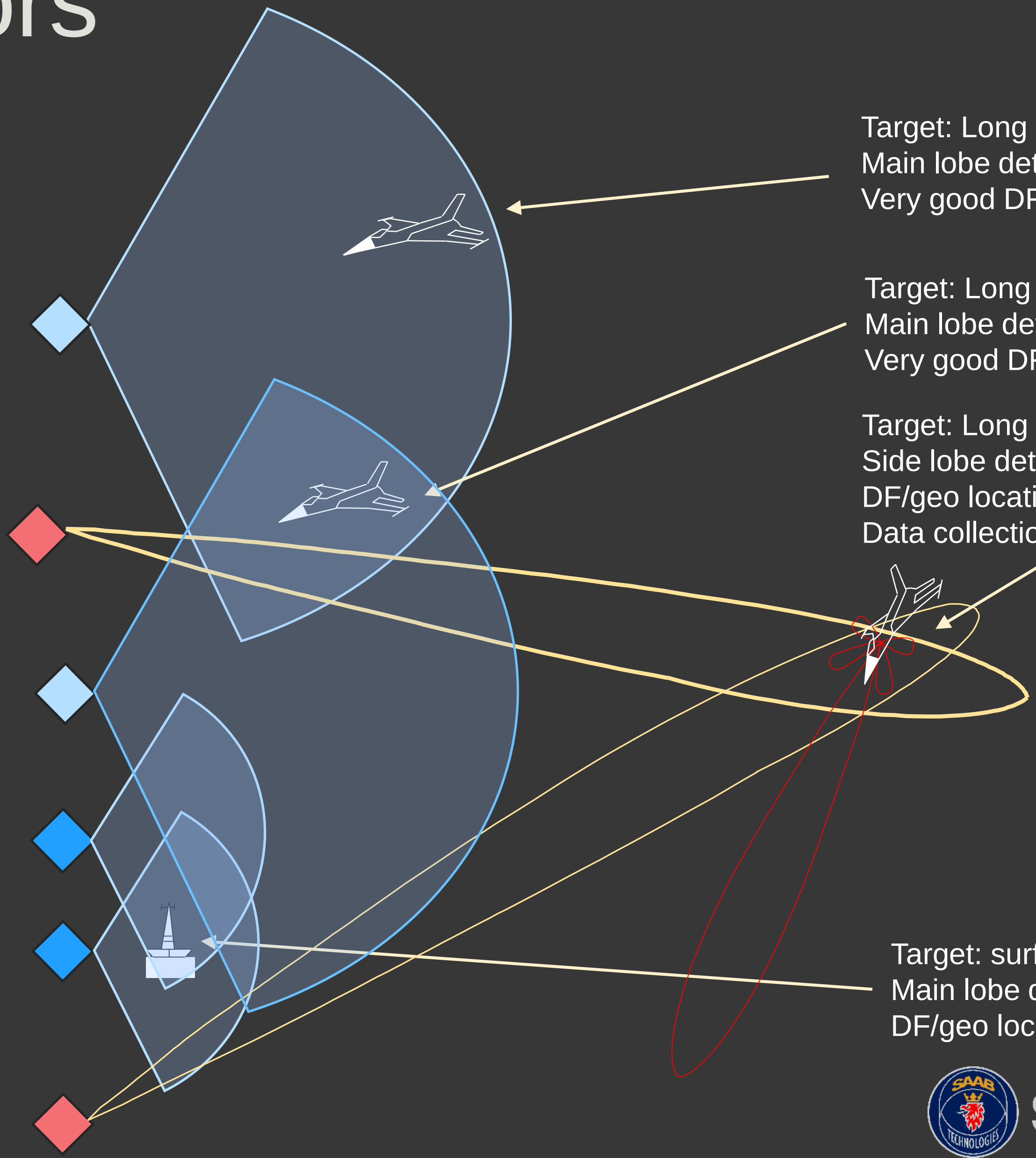
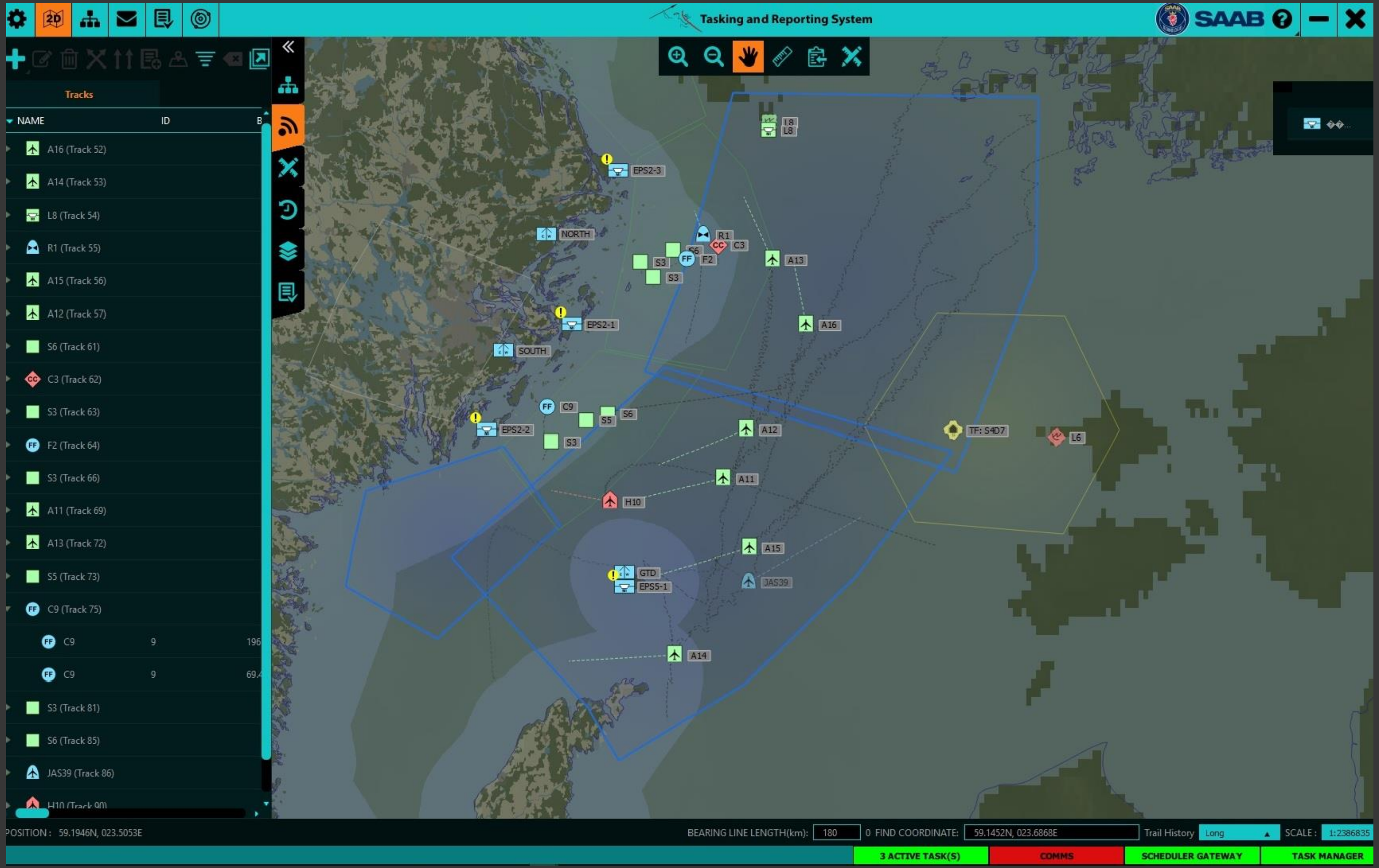
Ground-based Sensors

Sensors with different characteristics, complementing each other



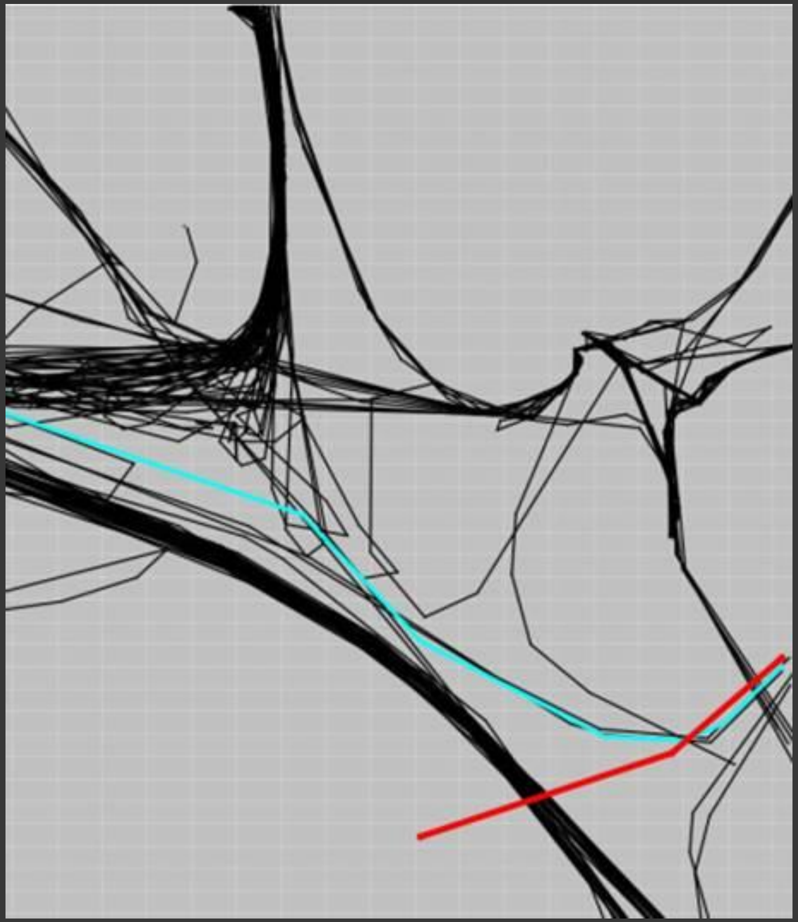
Networked Passive Sensors

- Planning
- Sensor tasks
- Search programs
- Reporting incl. AoA , geo-location
- Data from multiple co-op erative sensors
- Data fusion using TDFE in the background
- Map view with consolidated situational awareness view



Anomaly Detection

- Automatic detection in normal or predicted behaviour
- Raise an alarm to trigger further investigation
- Can use machine learning



Elements and Techniques for….

Rep								Map
Pn	Ts					TDFE	AnD	Fil
Tria	TDoA	PCL	t	Nw	Sec	ADS-B	AIS	IFF
LoS	Frq	S	Sc	AoA	Gla	Ptim	POI	LPI

Changing signal environment (Se)

Silent Power

Thank you