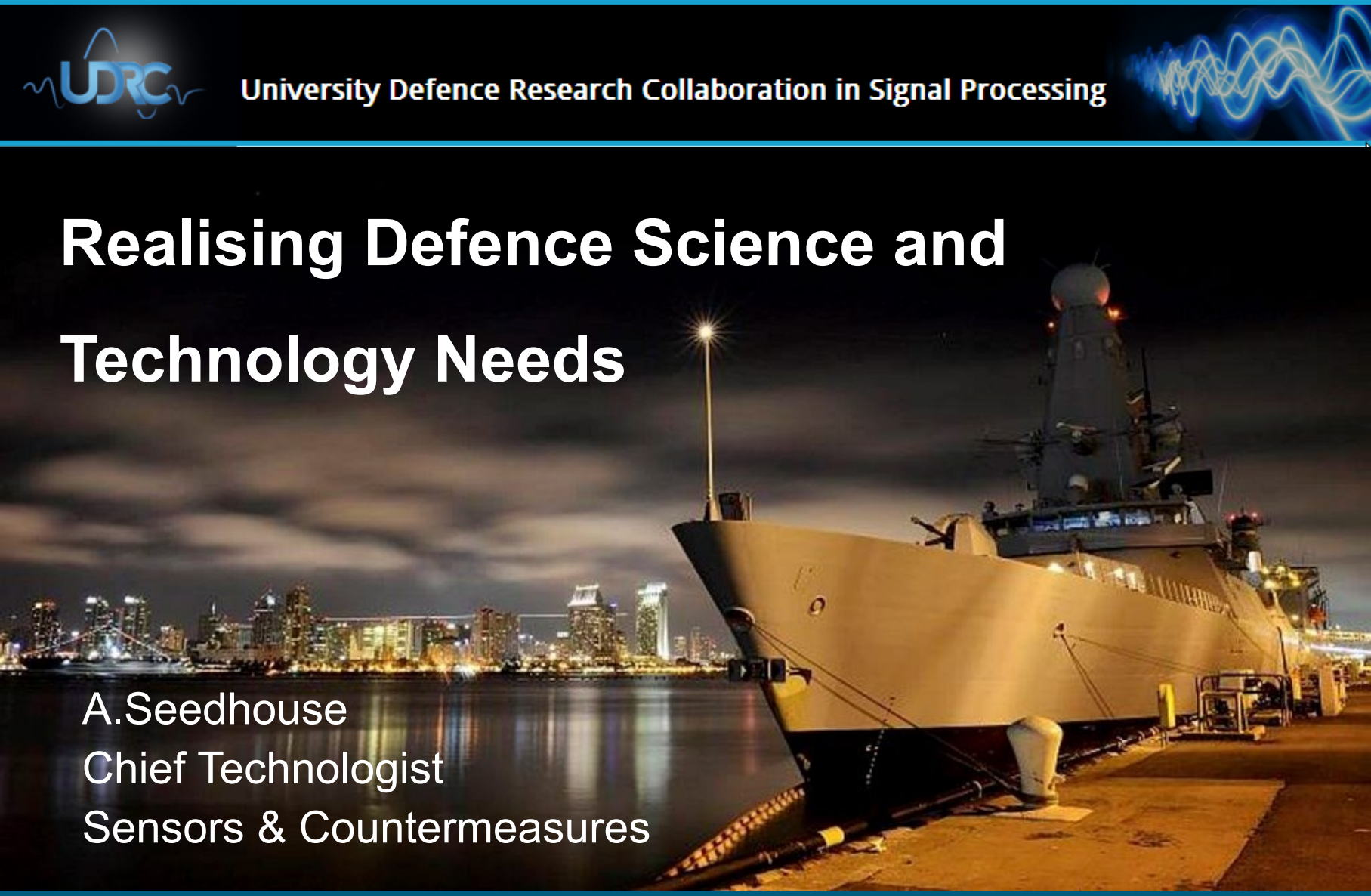
17 December 2013

Realising Defence Science and Technology Needs



A.Seedhouse
Chief Technologist
Sensors & Countermeasures

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MOD priorities

Afghanistan

- To succeed in Afghanistan – the main effort for the MOD. Our armed forces are working to deliver HMG's 'Enduring Aim' and to set the conditions for a political settlement that will underpin sustainable and irreversible security so that the terrorist threat to UK national security from Afghanistan no longer requires the deployment of UK combat forces

Standing Commitments

- To continue to fulfil our standing commitments, including strategic intelligence, the strategic nuclear deterrent, defence against direct threats to the UK and its Overseas Territories (including Chemical, Biological, Radiological and Nuclear (CBRN)), CT and Military Aid to the Civil Authorities

Operations

- To succeed in other operations we are required to undertake by providing a Defence contribution to UK influence, by defending our interests by projecting power strategically and through expeditionary operations, and by providing security for stabilisation and by building capacity overseas to meet the threat from terrorism upstream

Exports

- To promote defence exports consistent with export control criteria, as part of a defence diplomacy programme to strengthen British influence and help support British industry and jobs

Efficiency

- To deliver Defence in the most effective, efficient and sustainable way by meeting benchmarking, efficiency and Government sustainable development targets, building on the Defence Reform Unit's Review.

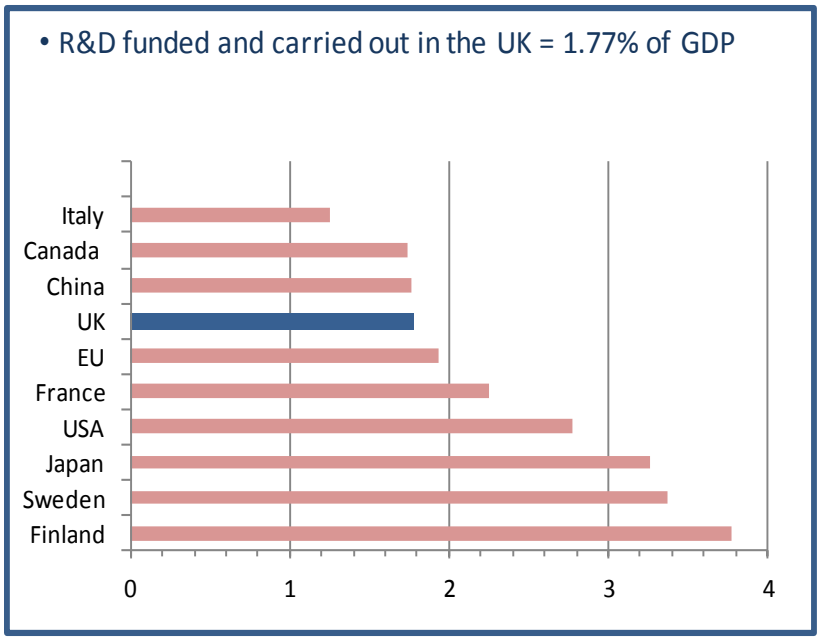
Strategic Context

The changing world

- DCDC's Global Strategic Trends states: "The era out to 2040 will be a time of transition; this is likely to be characterised by instability".
- Ten years ago few would have predicted that in 2013:
  - we would still be in Afghanistan;
  - the Libyan government would have fallen;
  - that the US would be shifting their attention from western Europe and the Middle East to the Pacific ring;
  - we would have seen the world's first significant cyber attack on state-run infrastructure;
  - and that the situation in the Middle East would be unfolding as it has.

The economic challenge

- The Chief of Defence Staff stated that "the single biggest strategic risk facing the UK today is economic rather than military." At £33.8Bn, the UK Defence budget currently represented 2.7% of GDP. The 2012 White Paper, 'National Security through Technology' confirmed intent to sustain S&T investment at a minimum of 1.2% of the overall budget.
- In 2011, the UK's gross domestic expenditure on research and development was £27.4 Bn. Total R&D expenditure in the represented 1.79% of Gross Domestic Product (GDP). Of the £27.4Bn, Defence accounts for just over £2Bn (~7%) of this R&D total expenditure.
- As MOD's science and technology agent, Dstl currently spends over £600M in research and technology development. The largest element of this income is the MOD S&T Research Portfolio which at £400M.



The evolving nature of technological developments

- Fifty years ago major technological developments were primarily driven by the space race and the cold war. Today, almost all technology development derived from current global S&T investment is driven by the consumer market.
- Advanced technology development, once the realm of Government laboratories, is now carried out to a large extent in the civil and commercial sectors. As technology continues to be driven by market needs, exploitation of technology to meet defence and security needs will require an increasing focus and understanding of emerging technologies and their impact.
- E.g. Microsoft R&D investment is nearly 3 times the amount that MOD invests in R&D and more than 10 times the R&D investment made by Dstl

German copyright law

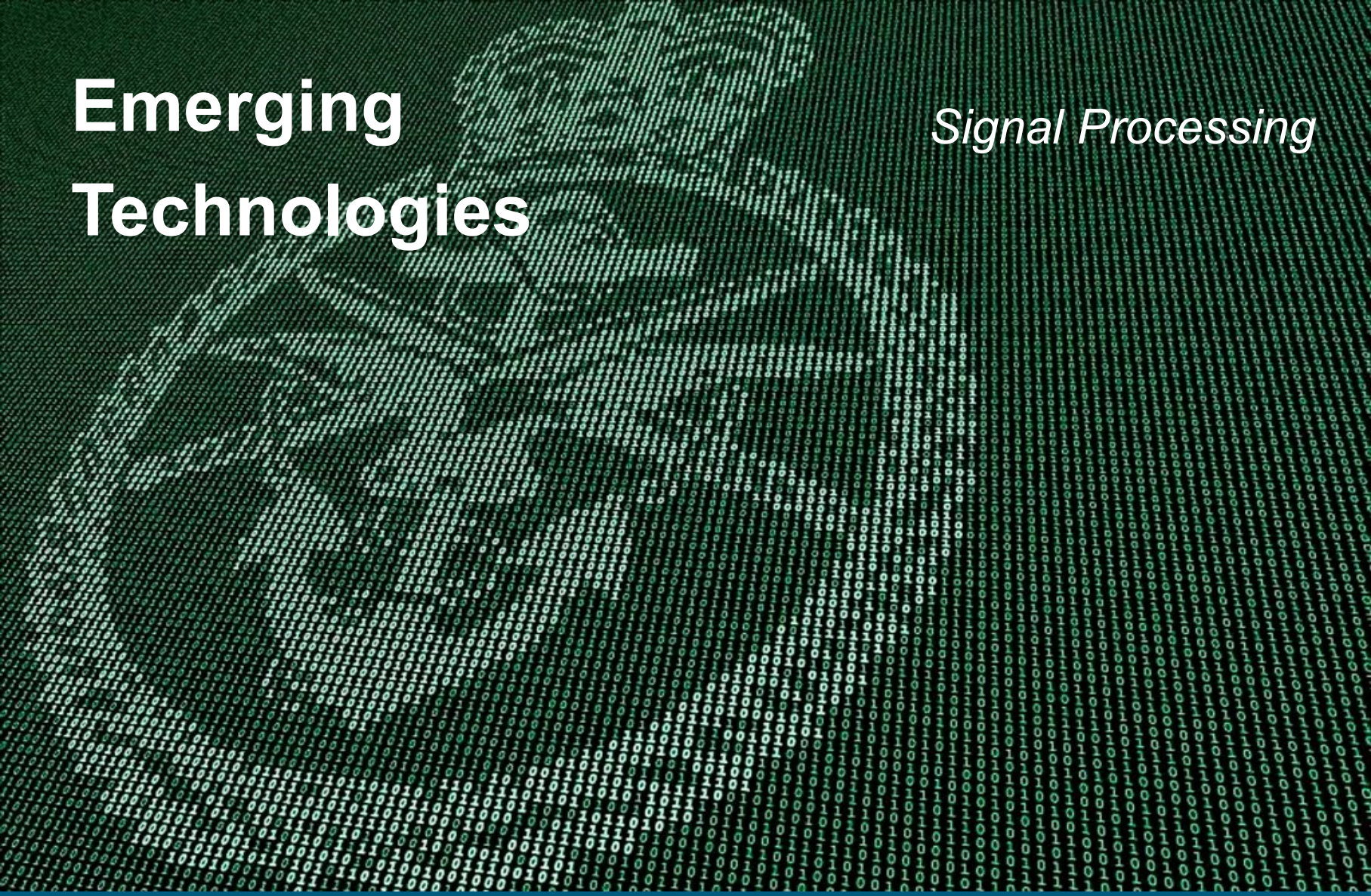
- **Reminder**
- Of the UK R&D Investment £27.4Bn, Defence accounts for just over £2Bn (~7%) of this R&D total expenditure.
- As MOD's science and technology agent, Dstl currently spends over £600M in research and technology development. The largest element of this income is from the MOD S&T Programme, which at £400M accounts for 1.2% of the UK Defence budget (£33.4bn).

Table 2: Top 25 global companies by R&D expenditure

Rank 2010	Company	Sector	Country	R&D (£m)	Growth in R&D over last year (%)	Rank 2009
1	Toyota Motor #	Automobiles & parts	Japan	6,014	-6	1
2	Roche, Switzerland	Pharmaceuticals & biotechnology	Switzerland	5,688	9	4
3	Microsoft#	Software & computer services	USA	5,396	-3	2
4	Volkswagen	Automobiles & parts	Germany	5,144	-2	3
5	Pfizer #	Pharmaceuticals & biotechnology	USA	4,802	-2	6
6	Novartis	Pharmaceuticals & biotechnology	Switzerland	4,581	2	10
7	Nokia	Technology hardware & equipment	Finland	4,440	-6	8
8	Johnson & Johnson #	Pharmaceuticals & biotechnology	USA	4,326	-8	7
9	Sanofi-Aventis	Pharmaceuticals & biotechnology	France	4,060	0	12
10	Samsung Electronics #	Electronic & electrical equipment	South Korea	4,007	8	18
11	Siemens	Electronic & electrical equipment	Germany	3,805	2	20
12	General Motors USA #	Automobiles & parts	USA	3,758	-24	5
13	Honda Motor #	Automobiles & parts	Japan	3,746	-4	11
14	Daimler	Automobiles & parts	Germany	3,700	-6	13
15	GlaxoSmithKline	Pharmaceuticals & biotechnology	UK	3,629	10	21
16	Merck #	Pharmaceuticals & biotechnology	USA	3,619	22	25
17	Intel #	Technology hardware & equipment	USA	3,501	-1	17
18	Panasonic	Leisure goods	Japan	3,445	-7	14
19	Sony #	Leisure goods	Japan	3,308	-4	16
20	Cisco Systems #	Technology hardware & equipment	USA	3,225	1	22
21	Robert Bosch	Automobiles & parts	Germany	3,179	-9	19
22	IBM #	Software & computer services	USA	3,061	-10	15
23	Ford Motor #	Automobiles & parts	USA	3,034	-33	9
24	Nissan Motor #	Automobiles & parts	Japan	3,030	0	23
25	Takeda Pharmaceutical #	Pharmaceuticals & biotechnology	Japan	3,014	64	n/a

Emerging Technologies

Signal Processing



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CBR Defence

- Measuring the effects of a CBR attack or outbreak is likely to come via a network of sensors.
- There is a need for efficient inference and fusion algorithms which account for the specific physics of the incident (e.g. diffusion equation), while accounting for the environmental parameters (e.g. weather, geography) and sensor characteristics.
- Uncertainty in an estimate must also be captured. This is as important, if not more so than, the estimate itself. (Particularly if one is trying to make decisions based on those estimates.)

C4ISR

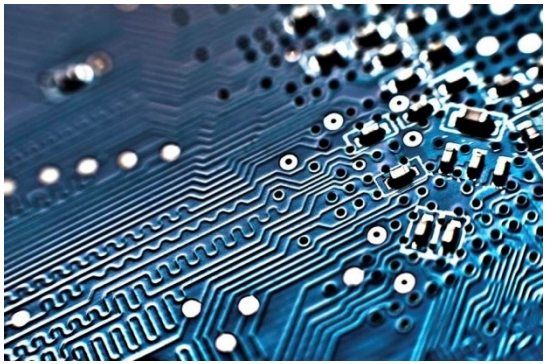
- Multi-target tracking – an NP(nondeterministic polynomial time)-complete problem and so analytical solutions in real time for medium-to-large numbers of targets and targets are unlikely. Robust approximate, timely, traceable solutions required.
- Accountability/traceability/replication: a problem for stochastic algorithms (randomly seeded iterative optimisation).
- Distributed sensor nets, particular where the sensors are heterogeneous will become much more common. Algorithms will be required which account for changing sensor characteristics.
- Distributed fusion. Avoid data incest.
- How do we estimate trust in sensed data?

Counter Terrorism & Security

- Plan detection: Can observations of a mass of individual and group interactions be used to determine adherence to a plan? Analogous to problems which seek to extract a signal from within a mass of other signals.
- What happens if we don't know what the signal looks like?
  - Methods for 'pattern of life' analysis.
  - Anomaly detection.
- Graph theory and derived algorithms provide methods for social network analysis.
- What happens when countermeasures are employed by your adversary? Touches on Game Theory.
- How far can we go to determine intent?

Cyber

- Epitome of the big data problem.
  - Number of DNS (Domain Name System) requests is ~130 billion on Google public DNS, the largest Domain Name System. The total number worldwide is probably well into the trillions.
  - 500 million tweets/day
  - Looking for needle in ~10^4 haystacks
- 2010 National Security Strategy rated cyber attacks as a 'Tier 1' threat to national security.
- Adversaries include:
  - Criminals
  - States
  - Terrorists
  - Disaffected individuals
- So the task is to extract a signal in among noise where S/N is <<1.
- This signal may be amenable to modelling (when you know what you're looking for).
- Or maybe not (i.e. you don't know what the needle looks like).
- Observations may not give you much contrast (you're looking for a needle in a needle-stack).



Human Capability

- Inclusion of ‘soft’, or categorical, data alongside hard, or quantitative, data. Algorithms which combine these forms should allow for decisions which do not unduly prioritise quantitative data.

- How will the human interact with the algorithm?
- Systems will not be fully autonomous in the medium term (and probably not in the long term). However, there is a clear drive to autonomous systems to relieve the operator of difficult, dull, dirty and dangerous work. Our task of developing signal processing methods for defence must include consideration of how the human fits into the system.
- Engineering systems which proceed from advisory to autonomous and do not require a rebuild from the ground up.
- Mission planning – delegate and retain oversight.
- This is all important as there will always be a human decision in the system loop.

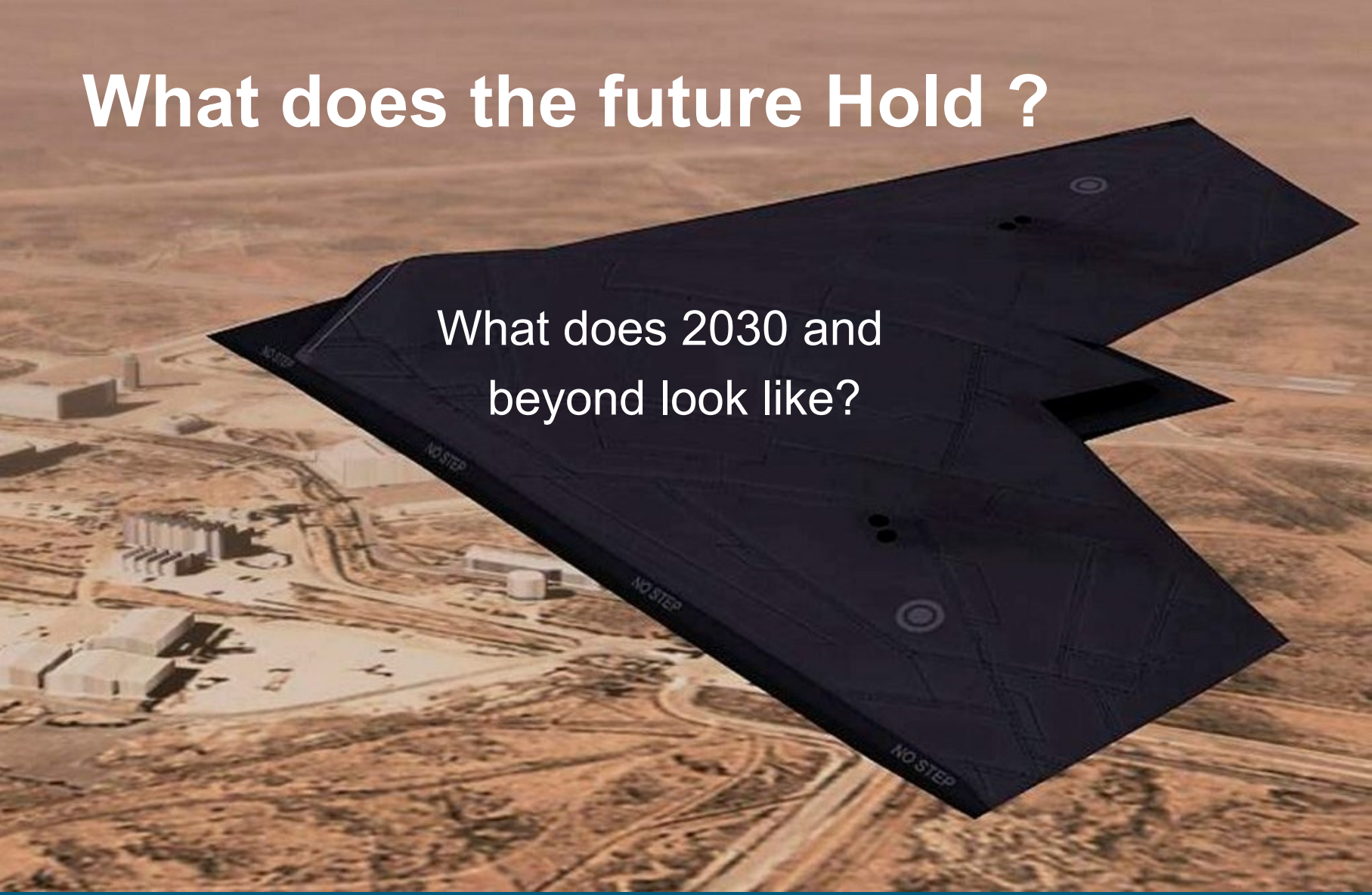
Integrated survivability

- Threat evaluation, automated systems will need:
  - to have sufficient sensing and processing capability to be able assess threats to themselves and their mission.
  - subsequent ‘intelligence’ to decide what action advice to give.
- Robustness
  - Systems must adhere to the mission rules of engagement
  - Which sensors and processing techniques are required (now that a human is not in-situ) to ensure that:
    - System knows the limits of its abilities?
    - System remains tamper free?
    - System is able to decide or advise on the optimal course of action to survive(fly/land, continue/abort)?

Challenges

- Hence the UDRC is driven by challenges to develop technical solutions
- It is Dstl's job to ensure the solutions are applicable to MOD's problems
- And it is Industry's job to adopt the solutions in its products such that MOD can procure them

What does the future Hold ?



Conventional

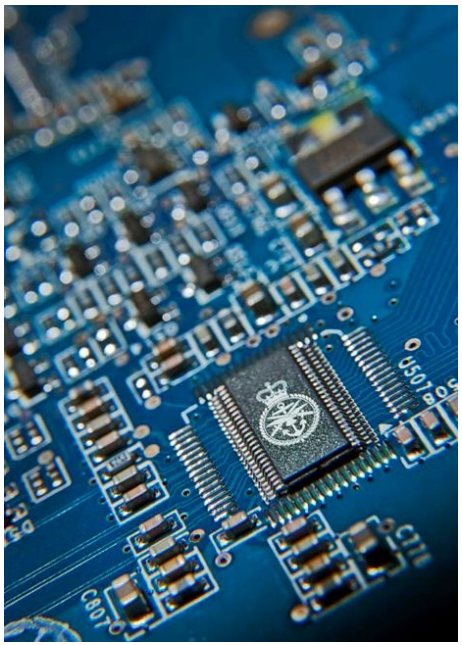
- New equipment that will be in service in 2030

Next Generation

- New concepts that might be developed to follow the current procurements

What is the difference?

- Those systems being bought now are will bear the technology you are familiar with now.
  - PC based 64-bit processing with, performance boosted by FPGAs and GPUs, wired & wireless networks, IP based communications and applications
- The next generation of systems will be dominated by increasing levels of autonomy, this will require:
  - cognitive processing, which in turn will require the next generation of processing hardware.
  - Sensor bandwidths will have increased and so will the communications



MOD Autonomy Policy

- *"Current UK policy is that the operation of weapon systems will always be under human control and that no planned offensive systems are to have the capability to prosecute targets without involving a human. By retaining highly-trained and qualified aircrew at the heart of the decision making process, the UK ensures that the legal requirements governing the use of force during armed conflicts are observed. There are no plans to replace military pilots with fully autonomous systems. In summary, we do not currently have any autonomous weapons systems or plan to have any in the future."*

What will enable this transition

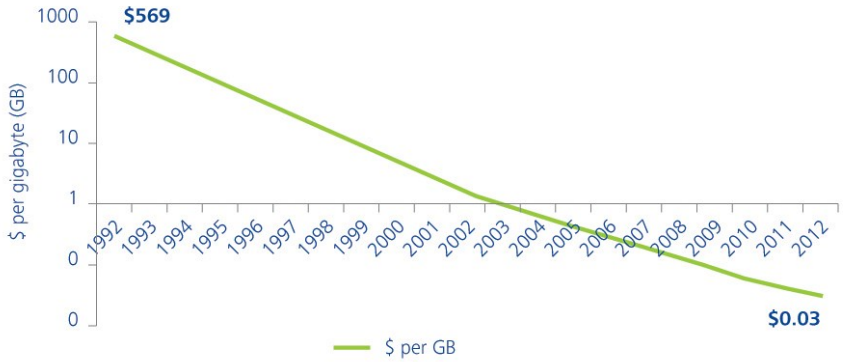
- The access to affordable high performance processing and wireless communications will enable suppliers to deploy processing that will move from logic regime to a cognitive regime
- Enablers: intelligent sensor networks, ubiquitous computing, cloud computing and quantum computing

Figure 1. Computing cost-performance (1992–2012)

Source: Leading technology research vendor

Graphic: Deloitte University Press | DUPress.com

Figure 2. Storage cost-performance (1992–2012)



Source: Leading technology research vendor

Graphic: Deloitte University Press | DUPress.com

Plus a bit of magic

- Yes the processing engineering is improving to amazing levels
- The communications bandwidths add an order of magnitude with each generation
- But we need the Human ingenuity to write the algorithms to give us the advanced & cognitive processing
- That's were you come in !

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What is the context for 2030

(the error bars for these forecasts are off the scale)

2023 – Reverse engineering of human brain - Arthur C. Clarke

2027 – China's GDP exceeds that of United States – Goldman Sachs, Price Waterhouse Coopers

2030 – Robots capable of performing at human level at most manual jobs - Marshall Brain

2032 – India's GDP exceeds that of Japan – National Intelligence Council

2034 – Robots (home automation systems) performing most household tasks - Helen Greiner, Chairman of iRobot

2035 – First completely autonomous robot soldiers in operation – US Department of Defence

2040 - Space-based solar power will be commercially viable

2045 – The Singularity (creation of the first ultra-intelligent machine) occurs – Ray Kurzweil

2050 - Robot "brains" based on computers that execute 100 trillion instructions per second will start rivalling human intelligence

2050 – Computer costing a few hundred pounds will have the capacity of the human mind – Hans Moravec

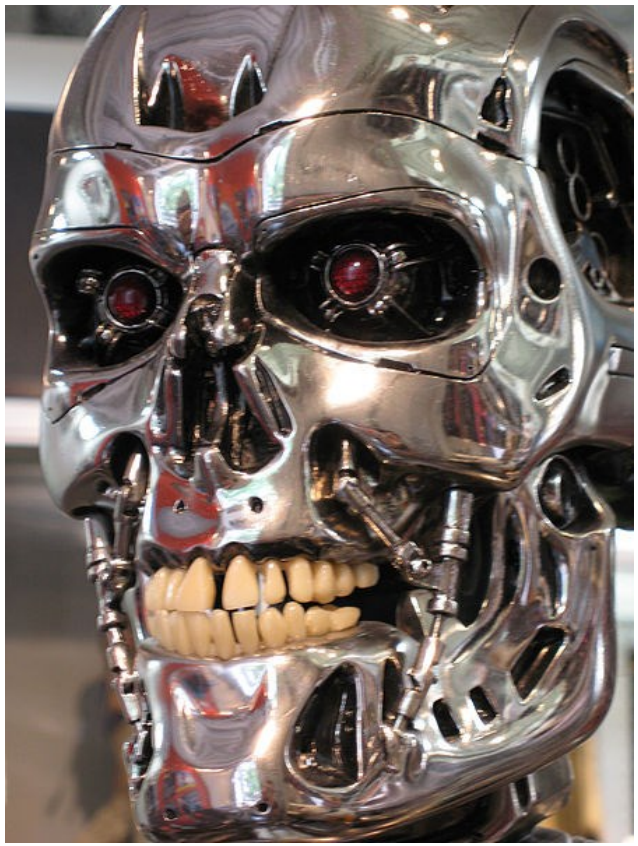
2055 – £750 computer will match the processing power of all human brains on Earth – Ray Kurzweil

Cronos, the humanoid Robot of the Artificial Intelligence laboratory of the university of Zurich

So!

- After 2050, the machines could take over and write the next set of processing solutions; that we do not understand.
- This would be against MOD Policy
- This is beyond my life expectancy
- So, Good luck !

Not an MOD programme !



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