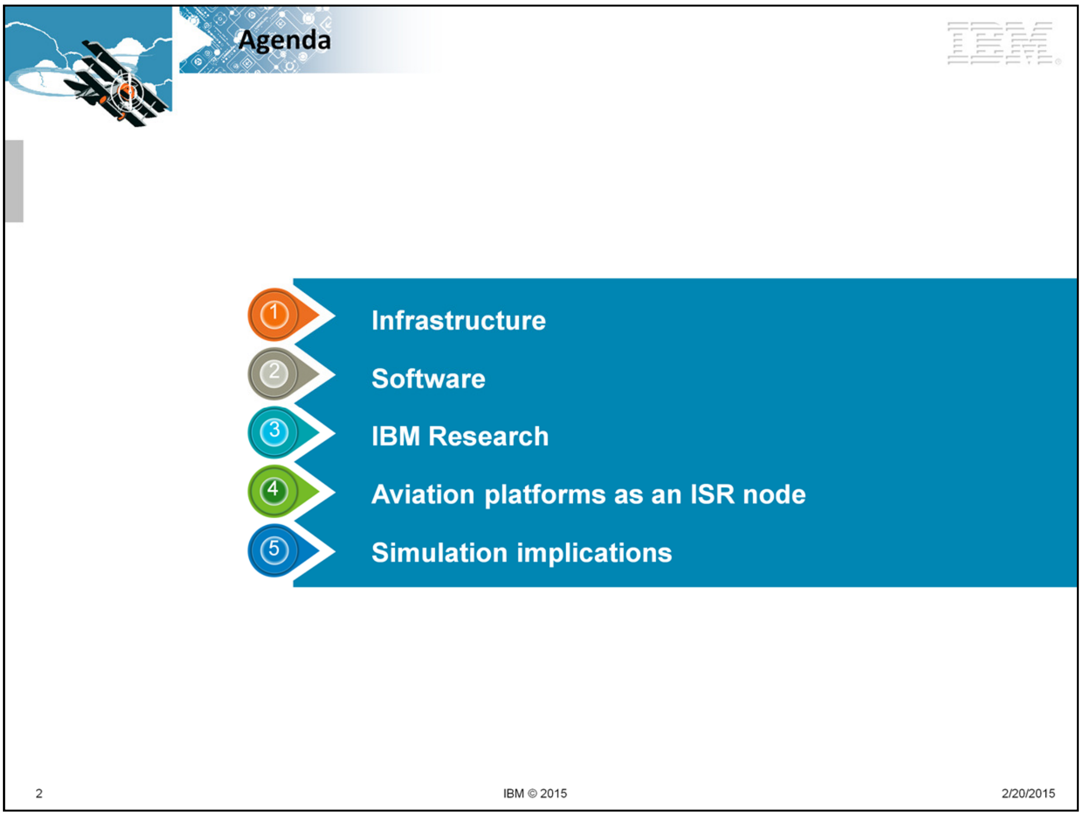
Here is a recent holiday snap showing a pilot's worst nightmare.

This is at Dublin International airport and you can see the wingtip of our plane just to the left of the firefighter, embedded in the tail of the other plane that our pilot didn't quite manage to miss while taxying prior to takeoff…

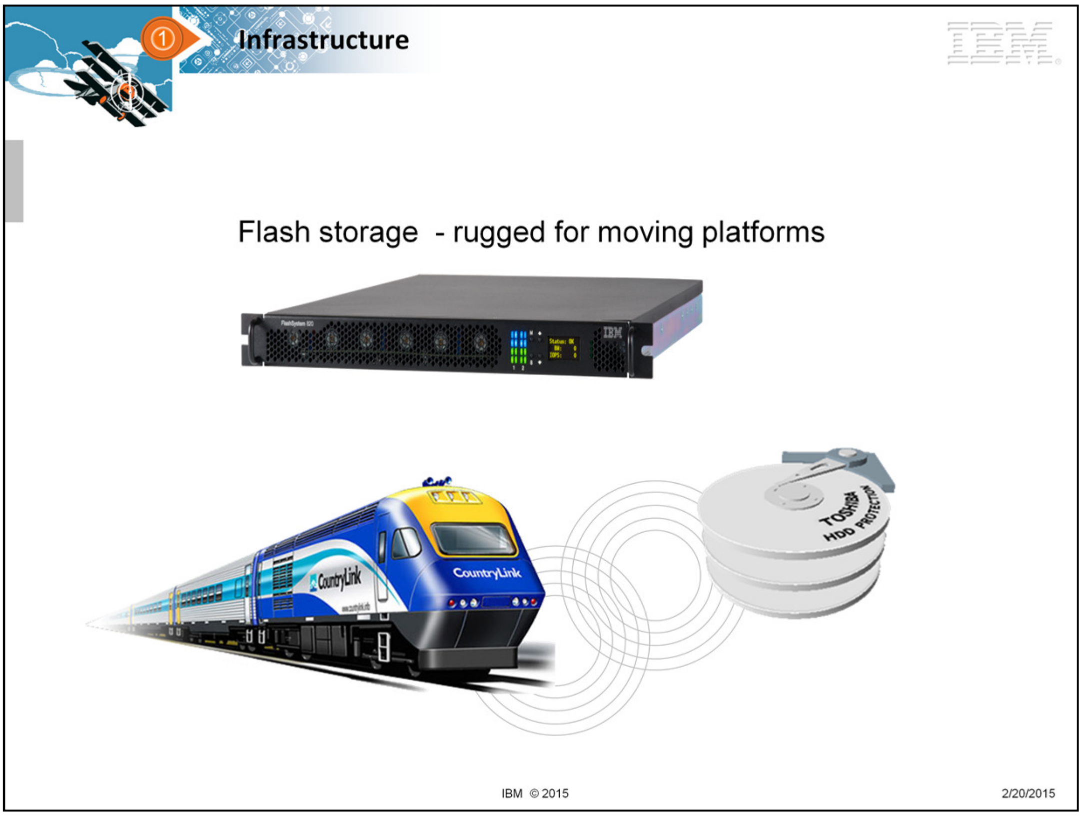
We took this shot as we were being evacuated from the aircraft to endure a five hour delay before getting to our destination.

Some days just don't go according to plan …



This is a necessarily brief overview of the key technology trends that I have seen potentially affecting the upcoming aerospace programs for Australian Defence.

We will look at trends in Infrastructure, Software; several items from IBM Research, then considerations with aviation platforms becoming a node in the interconnected ISR network and finally some of the implications for the simulation area.



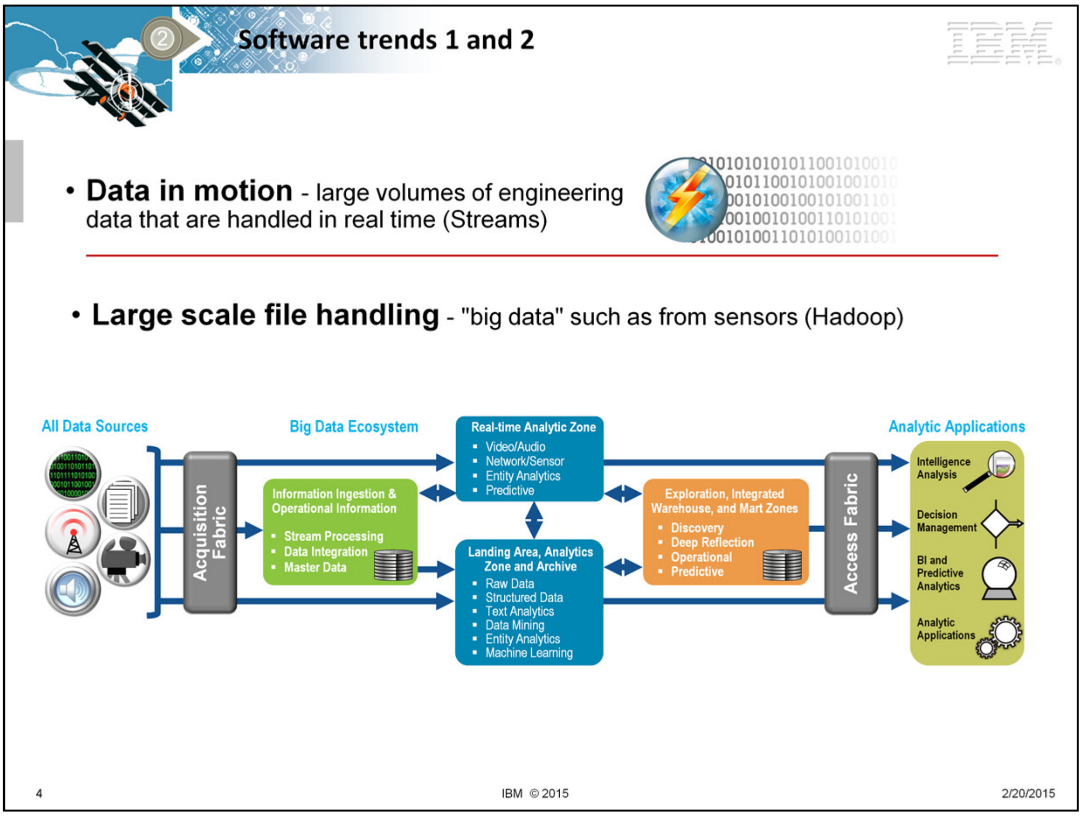
Flash storage

As a moving platform sometimes subject to violent weather and combat manoeuvres, aircraft are not a gentle platform for IT equipment. You may have heard of the introduction of solid state storage with no moving parts. Your iPad or tablet may be an example of that. Apart from its inherent reliability, another benefit of flash storage is the performance density; the space and power required to support a given I/O rate is much less than the equivalent for spinning disk storage. At large scale, the price point for premium quality flash storage has now come down to where it is practical for all aerospace applications.

There are also power consumption and thermal efficiency benefits to solid-state storage which in turn leads to density and packaging benefits, of particular value to deployed platforms where the cost/TB of the technology is but a very small element of the cost of the platform on which it is deployed.

I travel to Canberra occasionally by train. Working away on my laptop I would be surprised by the slow running of various applications. I finally realised what was happening – the vibration of the train on the tracks was being transmitted through to the laptop and the protective mechanism on the hard disk drive was parking the heads until the vibration settled down, leading to these strange delays in application performance. How much more vibration prone are todays aviation platforms.

I am confident in predicting that is “no more need for spinning disks”, which will be replaced by solid state flash storage in all future aerospace platforms.



The explosion of digital data being generated by sensors of all descriptions has presented a fundamental challenge to the IT industry. How to efficiently handle huge amounts of data? This problem space has colloquially become known as “big data”. So here are three key software trends around ‘big data’:

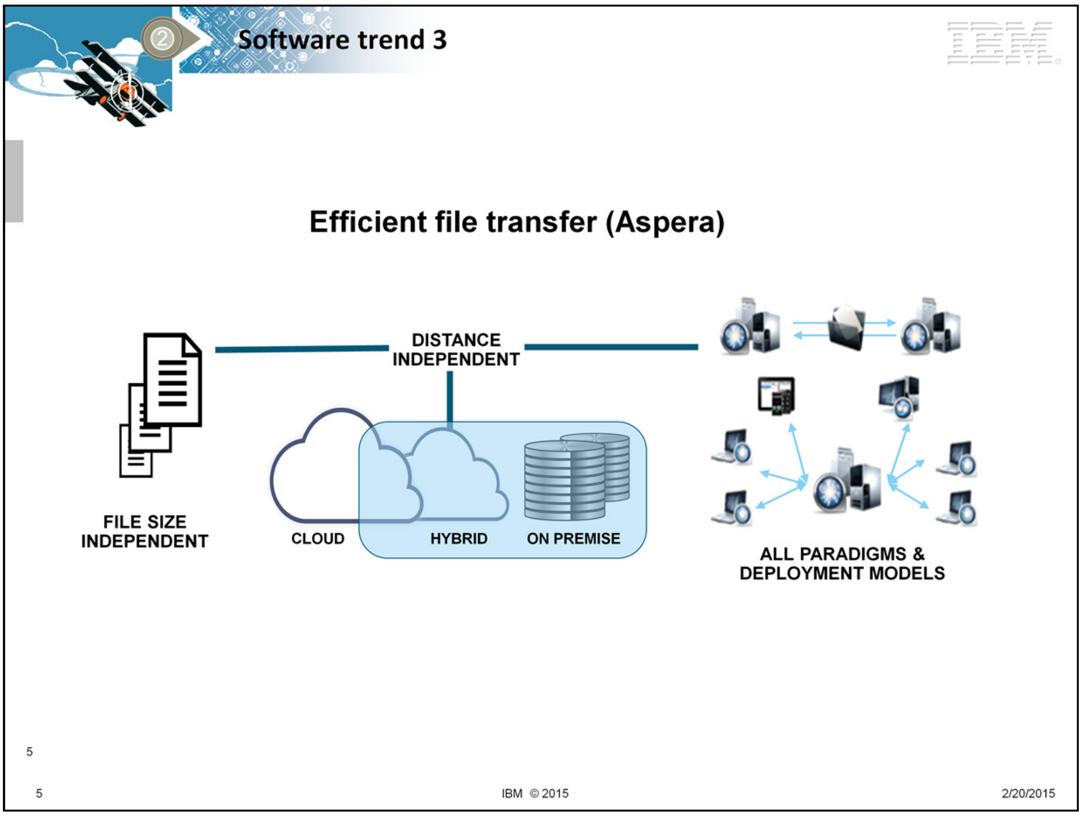
Trend #1 - Data in Motion

Engineering sensors are now generating large volumes of data to be handled in real time. There is neither the time nor capability to store this flood of data. Specialised techniques are used for handling this “streaming” data which do not involve the persistent storage of that data. The stream of data flows from one computer to the next with real time processing as required. For example, there may be a stream of sensor data about the engine which is used for real-time alerting and engineering management, gradually reducing to a trickle of data supporting periodic reporting requirements. There may also be analytics in the stream to alert the operators to something of interest, such as a military vehicle against a desert landscape, a vessel in the ocean or the voice imprint of a suspected terrorist .

Trend #2 - Hadoop

One of the inherent challenges in big data is how to describe it. As IT practitioners we are used to the discipline of describing data (i.e. the data model) before we load a database. The concepts of big data reverse that notion. The data is created first and later we can describe what it is we are seeing. To realistically process the huge volumes of data, it cannot be done sequentially, so the problem is broken down into small parallel pieces for processing in reasonable timeframes. The approach underlying ‘Hadoop’ will be utilised in the ISR domain to handle large volumes of sensor data. The sensor data can be collected first and then described later with parallel processing to make sense of it all.

In fact, both approaches will be used as appropriate. The <u>stream</u> of video data from a UAV can be analysed in real-time with alerts triggered when objects of interest are recognised in the data stream. Post action analysis on collections of sensor data can be defined later with parallel processing in a <u>Hadoop</u> cluster to make sense of it all.



Trend no 3 - Efficient File Transfer

There is growing demand for the ability to move large files around the aerospace domain, typically between sensors and other platforms or command structures, including analytical capabilities back in Australia.

Networks have over recent times trended toward IP (Internet Protocol) networks. While network speeds are increasing, latency (or the 'round trip' time) is a consequence of the speed of light and the nature of IP itself means that latency becomes a barrier to the efficient and effective exploitation of bandwidth.

The TCP (Transmission Control Protocol) layer above IP is a very chatty connection-oriented protocol. It is reliable but not well suited to the rapid transfer of large amounts of data.

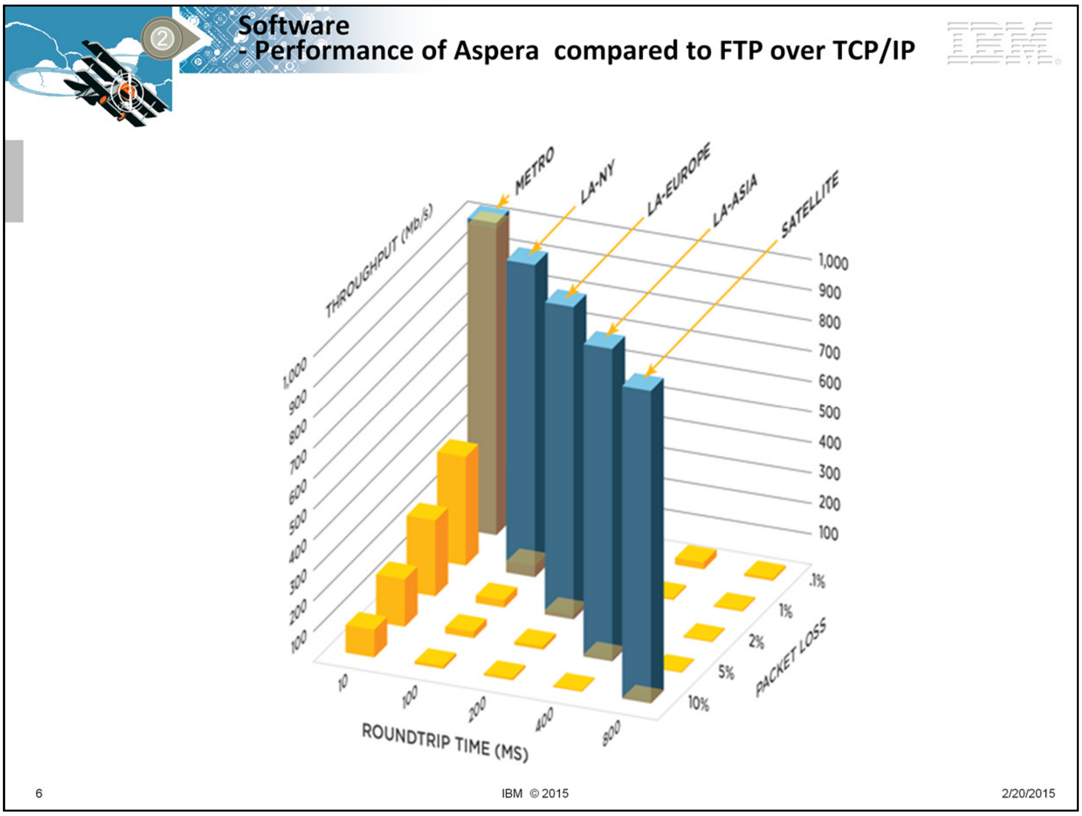
A new protocol layer above IP called FASP can replace TCP and allows for the highly efficient transfer of data utilising almost all the available bandwidth.

IBM has recently acquired Aspera which is the company commercialising this technology.

By way of a layman's illustration:

Imagine that I am throwing virtual balls into the audience here; each time you catch one give me the thumbs up signal so I can throw the next one. You can see how this can introduce significant delays, particularly over satellite links. We experience this delay when watching live news broadcasts from a foreign correspondent somewhere in the world via a satellite link; there can be a noticeable pause in the conversation – questions 1 2 3 answer etc.

Now suppose we number our virtual balls from 1 to 100 and just throw them rapidly to you in the audience; when you drop one, just tell me the number of the missed ball and I'll retransmit it. Because the balls are numbered, you can be sure that you have collected all the data payloads without the individual and chatty transmission-control-protocol overheads.



Trend no 3 - Efficient File Transfer

Distance degrades conditions on all networks

- Latency (or Round Trip Times) increase
- Packet losses increase
- Fast networks just as prone to degradation

TCP performance degrades with distance

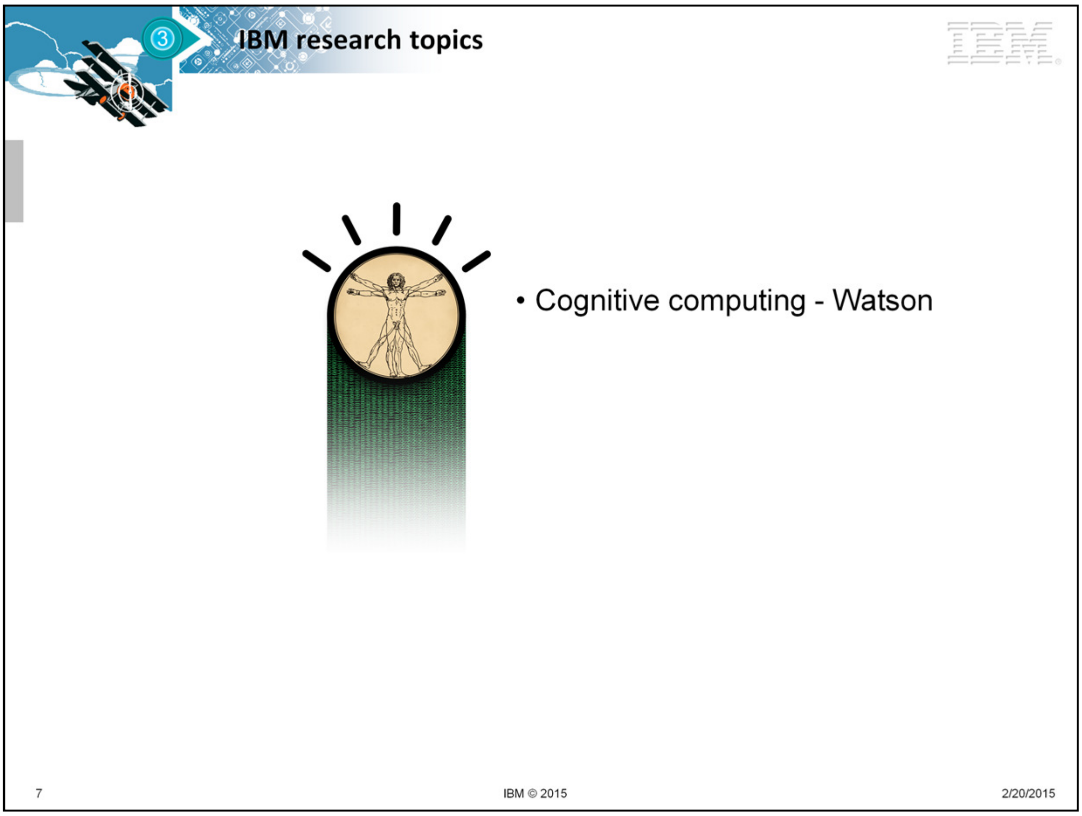
- Throughput bottleneck becomes more severe with increased latency and packet loss

TCP does not scale with bandwidth

- TCP designed for low bandwidth
- Adding more bandwidth does not improve throughput

Resulting in

- Transfers up to thousands of times faster than FTP
- Precise and predictable transfer times
- Extreme scalability (concurrency and throughput)



IBM spends around $6B per annum on research and development and three topics relevant to the Air Force of the future include:

Topic 1 - Cognitive Computing

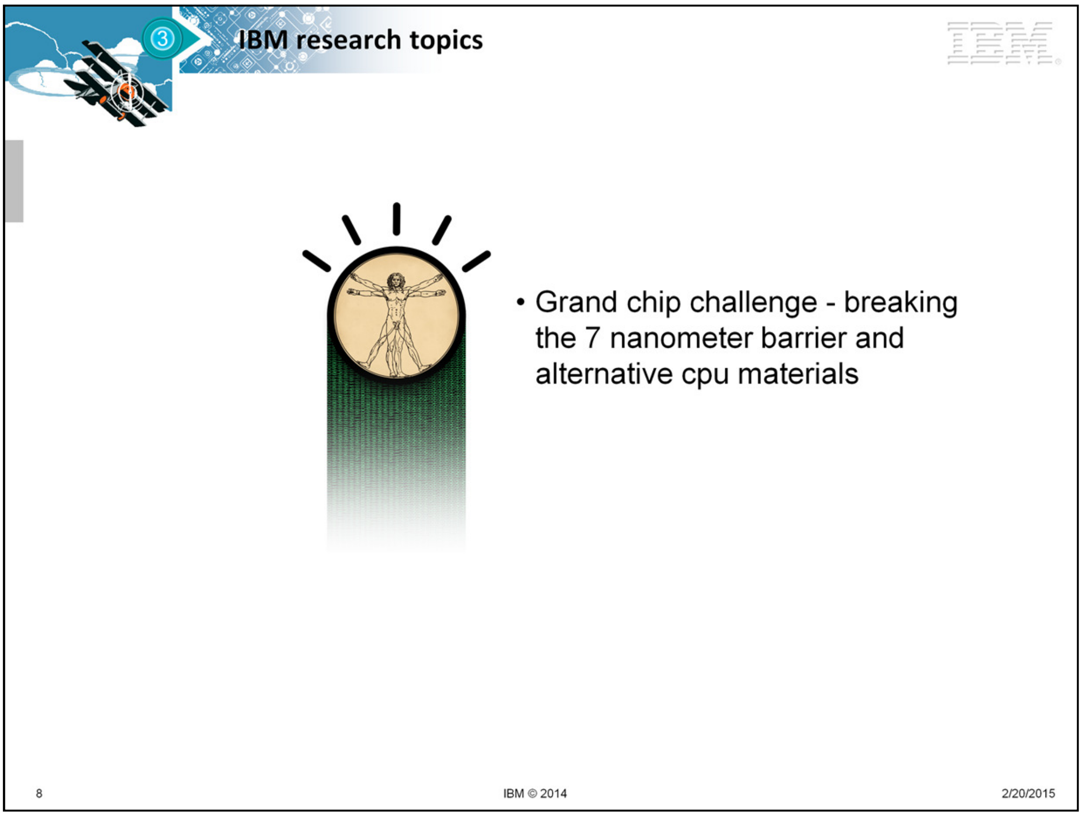
You may have heard of our “Watson” supercomputer that won Jeopardy in 2011 against the two grand masters of the game; Ken Jennings, unbeaten in 74 appearances on the show and Brad Rutter with the biggest prize pot of $3.25 million. That capability has now been stood up with a $1B investment into a cognitive computing division. We can think of cognitive computing as that halfway point between a machine that calculates the answers according to fixed rules with unvarying outcomes (2+2 always equals 4) and a human which can address complex situations that are characterised by ambiguity and uncertainty.

You may recognise this in the Iron Man movie Series as the interactive computer assistant called J.A.R.V.I.S (which actually stands for ‘Just A Rather Very Intelligent System’). It is expected that the role of cognitive computing will be to act as a decision support system helping humans make better decisions on the best available data.

Applying cognitive computing to aerospace systems might cover areas such as:

- Answers to maintenance type questions based on available symptom data from real-time sensors (the F-35 is heading in this direction with its ALIS logistics capability)
- Health informatics based on an individual’s personal medical records.

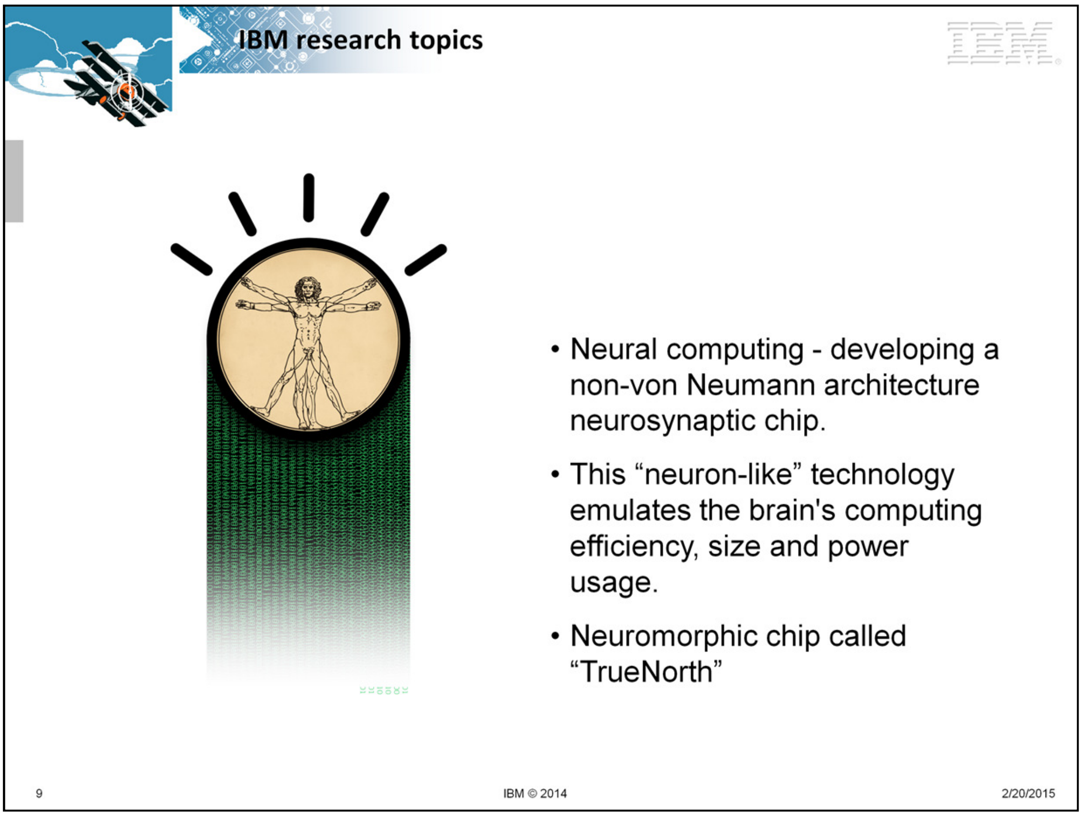
- Strategy and tactics support drawn from the library of available data about the capability and behaviours of potential enemy forces.



Topic 2 - Grand Chip Challenge

Over decades, the overall processing power of computers has generally doubled every two years. You may recognise this observation as Moore’s law. These increases were initially achieved by a combination of increases in the number of transistors on the chip and an increase in their operating frequency. Recently the number of cores has increased to maintain that same momentum. That is to say, the direction for compute power is shifting from faster processors to packaging more processors or ‘cores’ together so more performance is coming from parallelism rather than speed. This is a consequence of the physical challenge of increasing density to the point where the size of the silicon atom is becoming an issue.

So now, finally in 2015 we are reaching the limits of what is possible under the laws of physics; the current difficulty is breaking the seven nanometre barrier (i.e. seven billionths of a metre). Consequently there is research into alternative cpu materials, so we may see a non-silicon chip coming with new performance characteristics.



Topic 3 - Neural Computing

Of course the ultimate goal is to make a computer which “thinks” like a human. We have made progress developing “neuron-like” technology which emulates the brain’s computing efficiency, size and power usage.

What is a cognitive chip? The latest SyNAPSE chip called “TrueNorth”, introduced on August 7, 2014, has the potential to transform mobility by spurring innovation around an entirely new class of applications with sensory capabilities at incredibly low power levels. This is enabled by a revolutionary new technology design inspired by the human brain. IBM built a new chip with a brain-inspired computer architecture powered by an unprecedented 1 million neurons and 256 million synapses. It is the largest chip IBM has ever built at 5.4 billion transistors, and has an on-chip network of 4,096 neurosynaptic cores. Yet, it only consumes 70mW during real-time operation — orders of magnitude less energy than traditional chips. As part of a complete cognitive hardware and software ecosystem, this technology opens new computing frontiers for distributed sensor and supercomputing applications.

Imagine the competitive advantage to the air force utilising a supercomputer the size of a postage stamp, light like a feather, and low power like a hearing aid with cognitive abilities like the human mind!

Our general approach is that the architecture will support machine learning, and could be deployed in a distributed or centralised structure.

Initial research is focussed on the imaging domain. An example use case could be distributed image recognition where recognition/event detection happens on site rather than streaming data back over a network to a central processing system.

IBM Research (including the Australian Lab here in Melbourne) is working on further use cases for the technology and we are seeking collaboration partners who would be interested in applying the technology.

In summary, the TrueNorth chip;

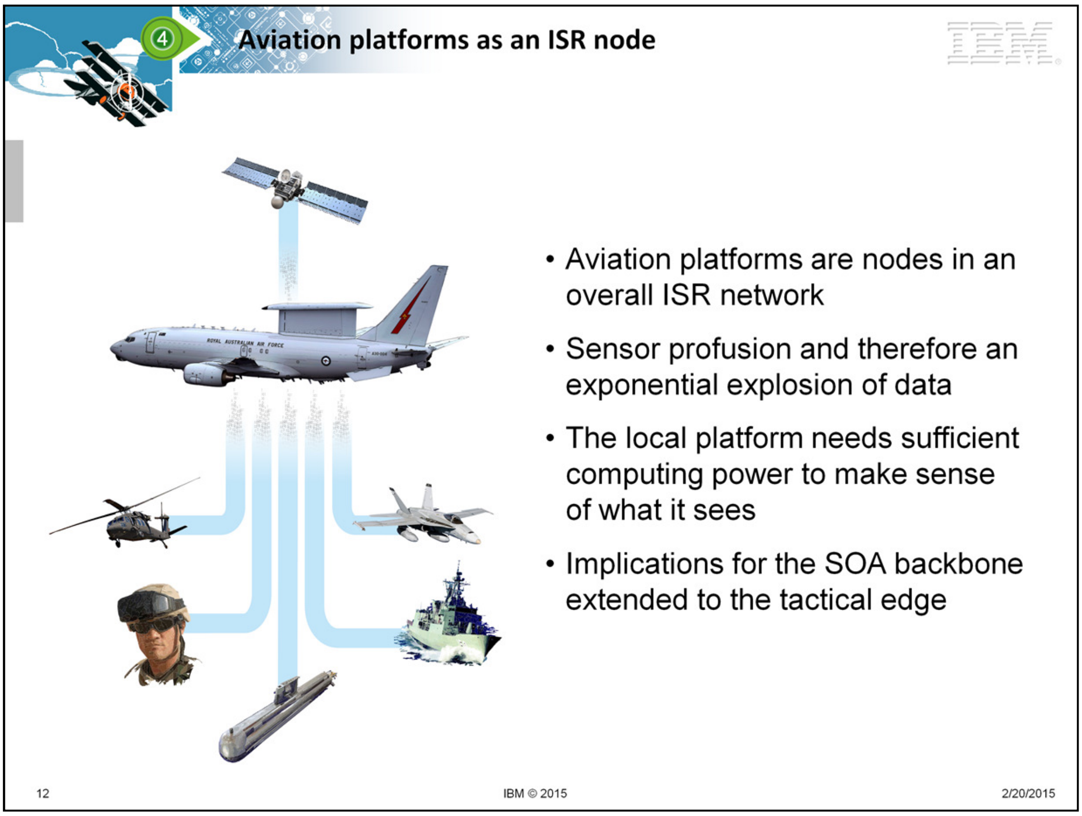
- Has the potential to push event processing to the "edge" of the network and thus reduce the exposure to network interruptions and EW.
- Has the potential to drive a lot more machine learning and intelligence into the defence systems at a much lower compute/power budget.

③ Some observations relating to the "ISR problem space"

- There is a growing profusion of sensor data
- The efficiency of moving data across networks is improving
- It is becoming practical to move the data to the analyst, reversing the historical trend of taking the analyst closer to the data and potentially in harms way

Expected trends in the "ISR problem space"

- In the near term – we will move the data back from the front line to the analyst who will be in a safer location.
- In the longer term – we will move a "cognitive computing assistant" out to tactical edge.



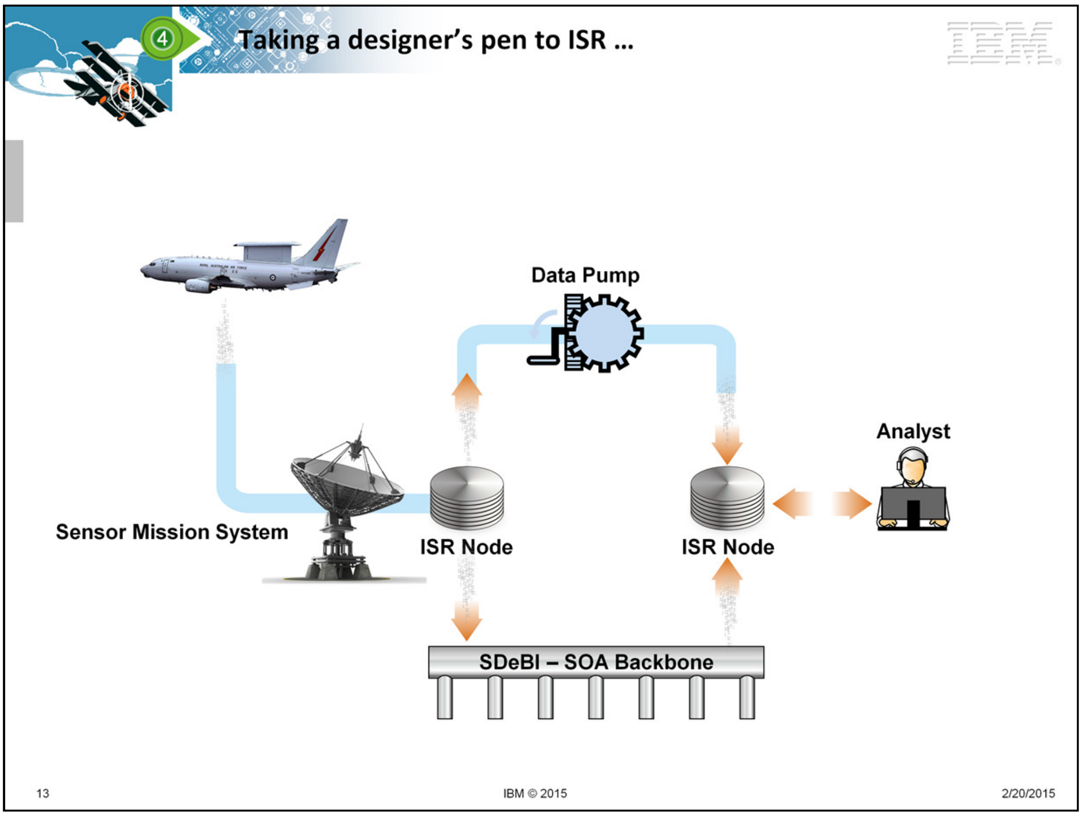
Aviation platforms are nodes in an overall ISR network.

How much computing power is enough? A guiding principle here is that the local platform needs sufficient computing power to make sense of what it sees. It cannot necessarily afford to send off data to be processed, particularly in a restricted communications environment. Perhaps that is less important for a UAV and I'm not sure quite how to express this principle: something like; "manned aerospace platforms need sufficient computing power to make tactical sense of what they see, for the protection of the platform and the people on board".

We will advertise the presence of interesting data, not move the 'big data' itself. That is 'meta data', or data about data, will move around the network and only the requested files will be moved.

Data movements across the backbone will be organised into queues reflecting their relative priority for delivery.

Particularly after networks are restored when there has been a communications blackout; possibly due to a change in the operating posture, the relative priority will need to be dynamically re-evaluated to avoid flooding networks with irrelevant data transfers that prevent urgent messages from getting through to their destinations.



Here is a freehand approach to designing the ISR system.

Firstly a few design principles:

Sensor Mission System

- This is generally a ground station, responsible for collecting the raw sensor data and performing any initial processing
- Standards in this area are still being developed, noting that there is a Sensor Open Systems Architecture coming down the pipeline
- The Sensor Mission System advertises the presence of the various ISR files to its nearest ISR node, but does not transfer any files until requested.
- The Sensor Mission System is responsible for local backup of all raw and processed data files from the sensor system
- On request from an ISR node, sends the requested file to the nearest ISR node for subsequent distribution

The ISR Node

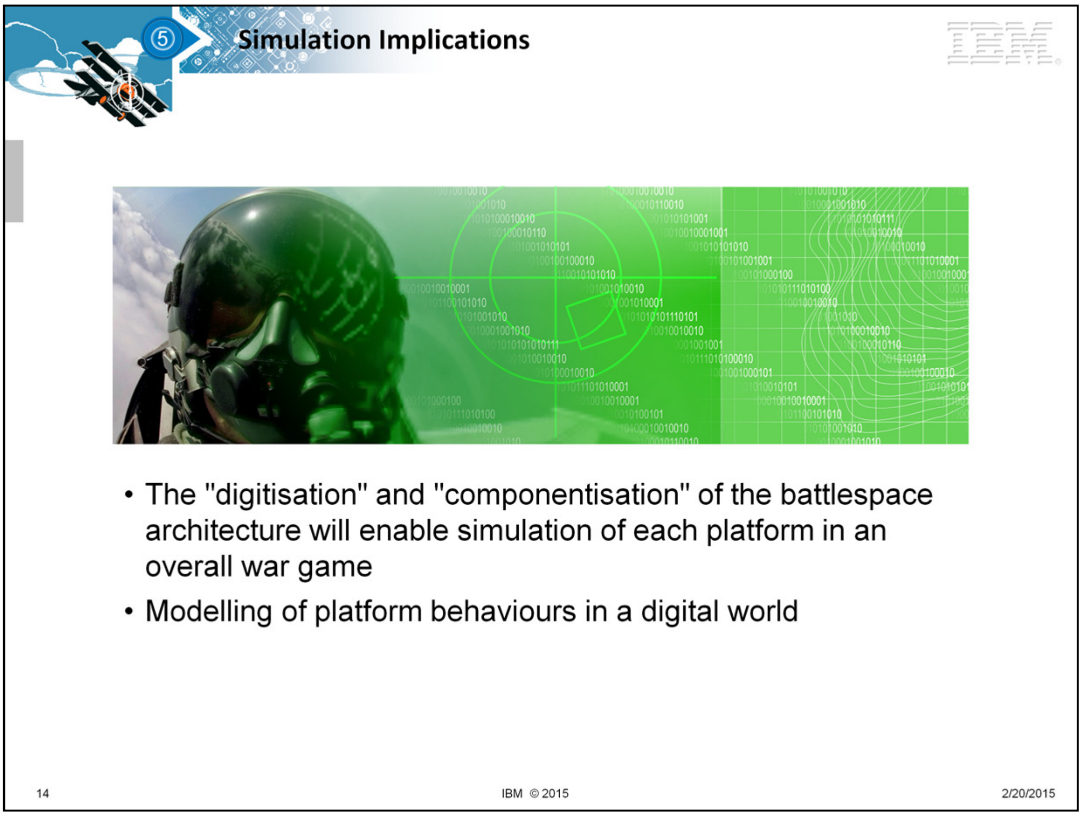
- Receives summary or 'metadata' about the various sensor files
- Metadata announcements are broadcast via the SOA backbone (SDeBI) where they are built up as an ISR index at each ISR node.
- Actions a request for a data file by passing the request to the correct Sensor

Mission System

- Using the Data Pump or high speed file transfer system, it will transfer files to the closest ISR node to the requestor where it is cached for a configurable period of time

Analyst

- Analysts search their nearest ISR index and request files as appropriate
- Retrieve the files when notified from their nearest ISR node (this request may be satisfied from a local cache at the nearest ISR node, so that data is moved only once)
- Performs local intelligence processing and aggregation on the data in their usual intel cycle and publishes the results



Finally let's consider the implications of some of these changes for the simulation of aviation capabilities.

Progress has been made in Defence simulations which are combining live action with simulators for other military units. Indeed, future exercise and war gaming strategy will be able to mix and match real military forces with simulated units as required. We're reaching the point where the granularity of features in the simulated world are approaching those of the real world – that will create the opportunity for simulation environments which blend the "real" and "virtual", so that simulation of manoeuvring around an airport could use the real geospatial data of the actual airport – creating a much more realistic environment.

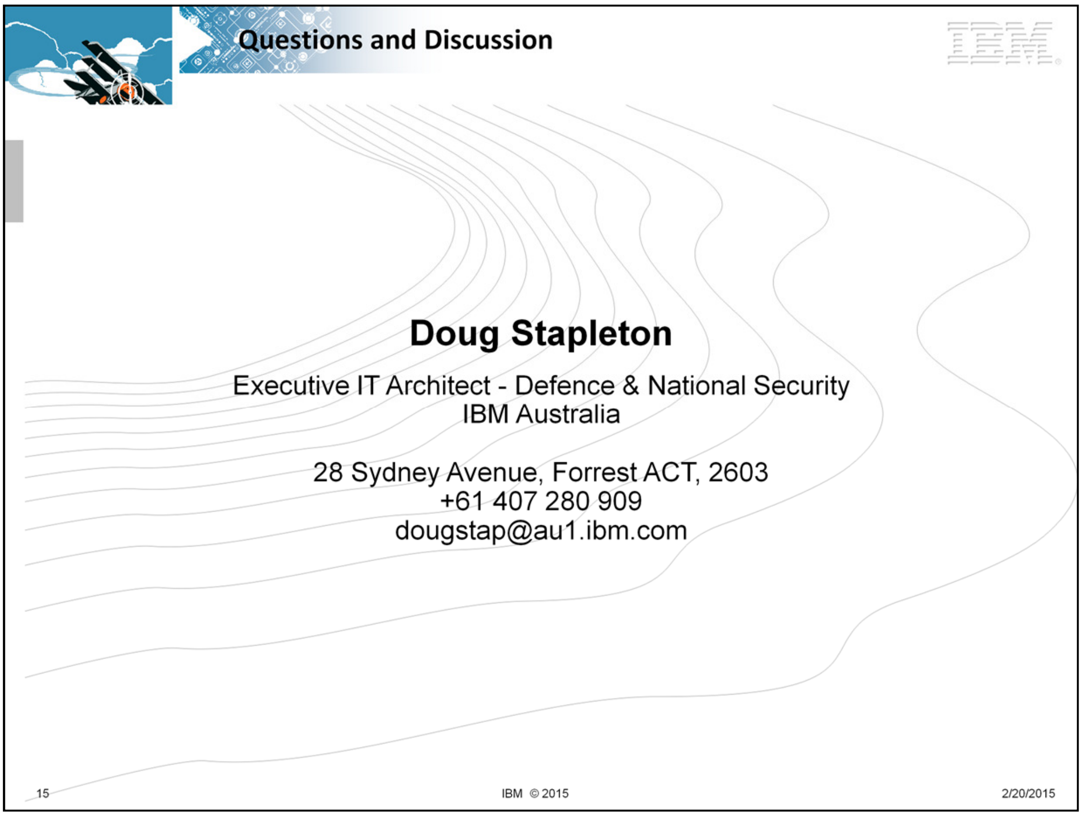
As components on platforms become increasingly digitised, we can see the trend towards a virtual input at each level as the components are aggregated to allow for simulated input into systems.

Must the behaviour of a platform be stimulated only by a real threat? Must there be a real incoming missile before the radar system can detect, track and respond to a threat. That issue is already being dealt with for on board training systems which can simulate incoming threats for crew training.

All of this will lead to an interesting need for interlocks which prevent the firing of physical weapons against virtual threats.

We have in the past thought of simulation in the training context and therefore kept live and virtual separate. However in the future of live, virtual and constructive simulation, we need rigor and discipline around recognising virtual events in a real world.

One simple example is of a building lockdown where staff and guests scrambled under tables when told of a terrorist event. One gentleman, unaware that it was a training exercise because it hadn't been announced, then went into cardiac arrest thinking he was under a real terrorist threat!



This has necessarily been a brief overview. Please let me know if you would like to have a conversation about any of these points.