

Complex Systems (Systems of Systems) Technology and What's Next!

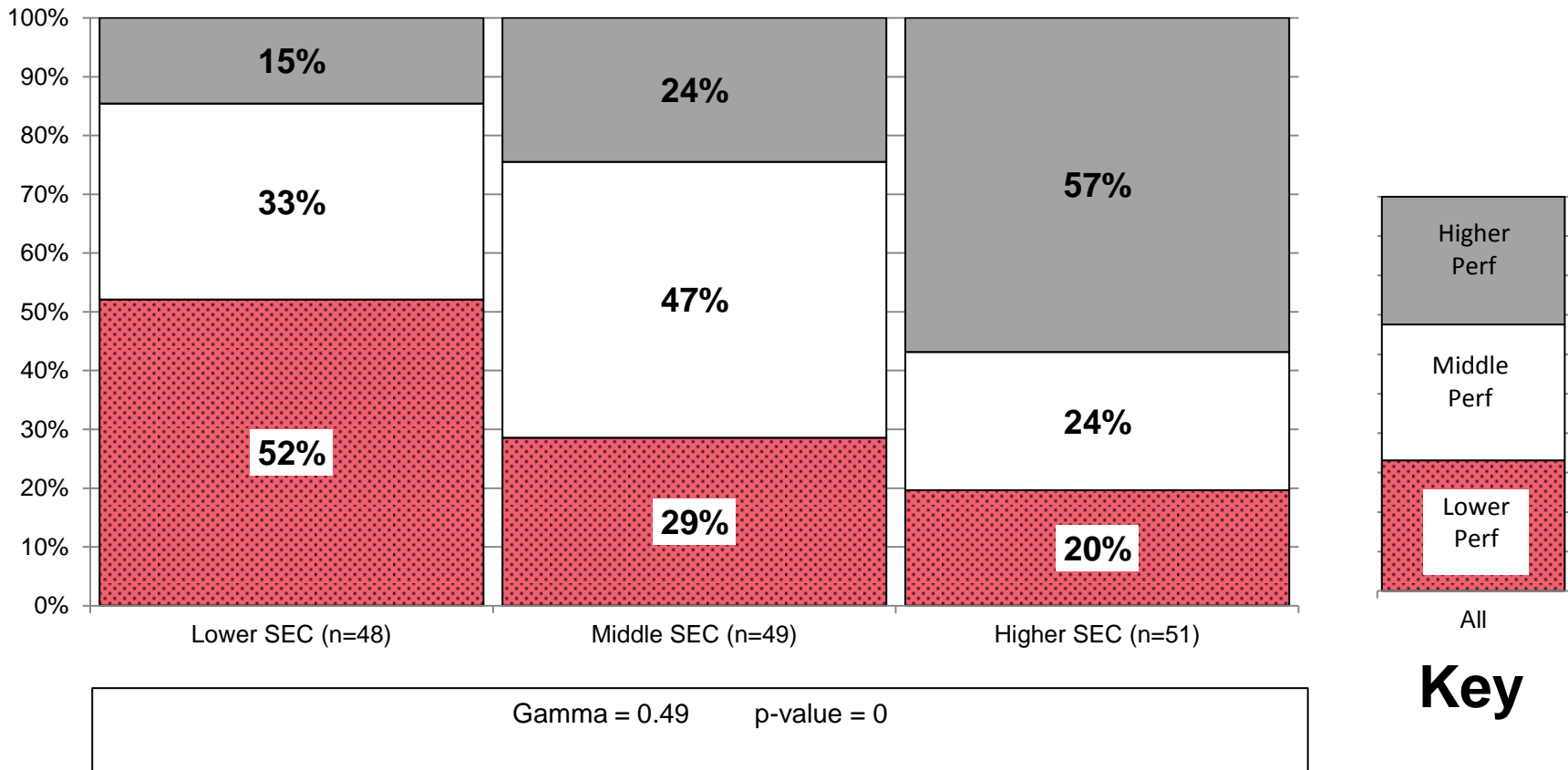
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Chief Technology Officer
Date: June 2014



Objectives

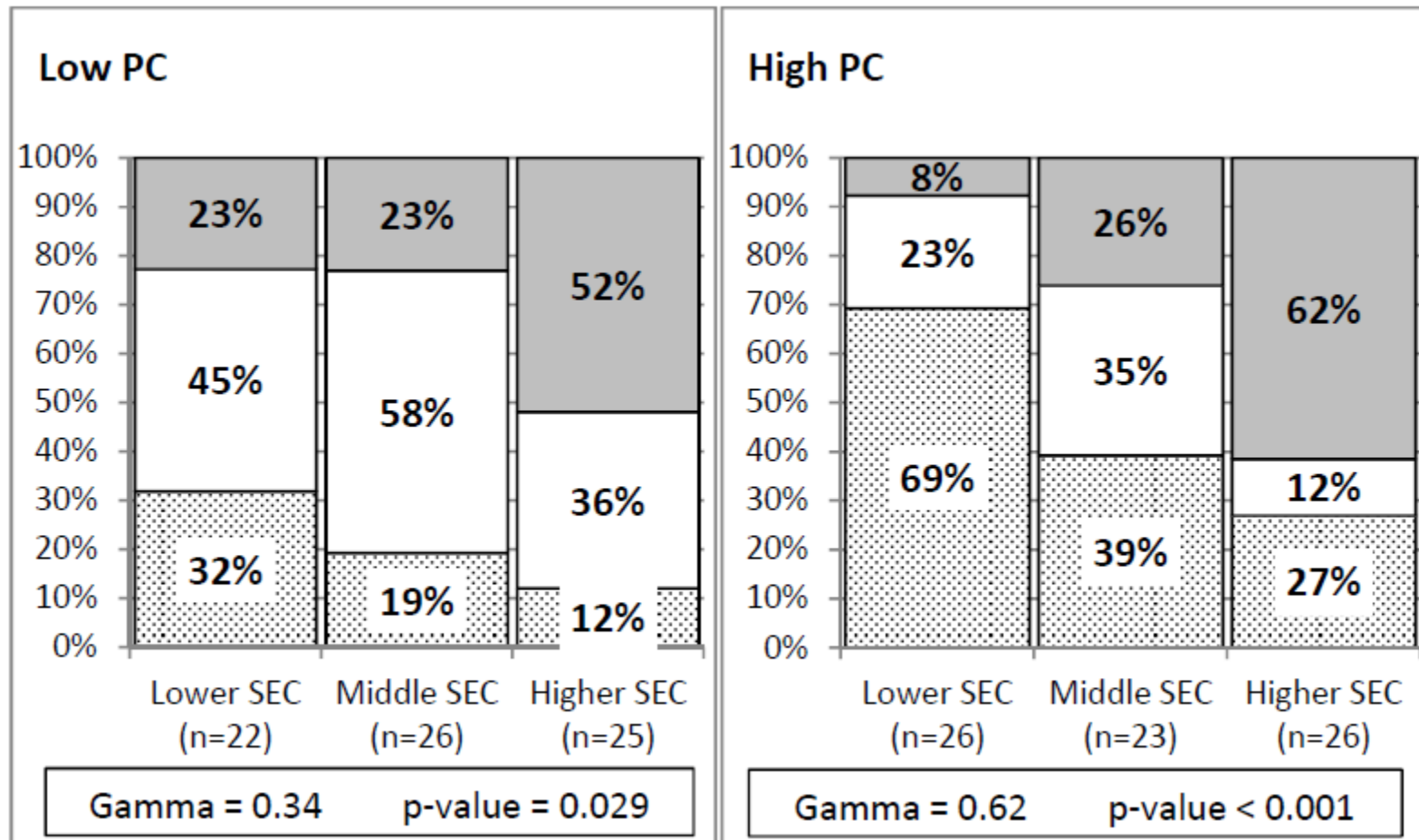
- Project Performance link with Systems Engineering Capability (SEC)
- Complexity: A Perspective
- Look at Strategies to manage complexity
- The Mission Systems Integrator (MSI) as a solution
- The Role of Statistical Techniques
- The Dilemma of Statistics
- Cost Reduction through Test Optimisation
- Technology Update
- What's Next

Linking Performance with Systems Engineering Capability(SEC)



There is an unambiguous correlation between performance and SEC

Effect of Project Complexity



SEI / NDIA Study_2012

PC = Project Challenge

As complexity increases, so does the effectiveness of higher SEC

Index of Complexity – A Guide

	<u>Type of System</u>	<u>Index</u>	<u>Comments</u>
	Class A	< 5	Simple Systems
System being designed →	Class B	< 10⁶	Human designed S/W, H/W
	Class C	> 10⁹	Single Human Being
	Class D	> 10¹¹	Human Social System
	Class E	> 10¹¹	Ecologies with Humans
Team doing the design →	Class F	> 10¹³	Sociotechnical Systems

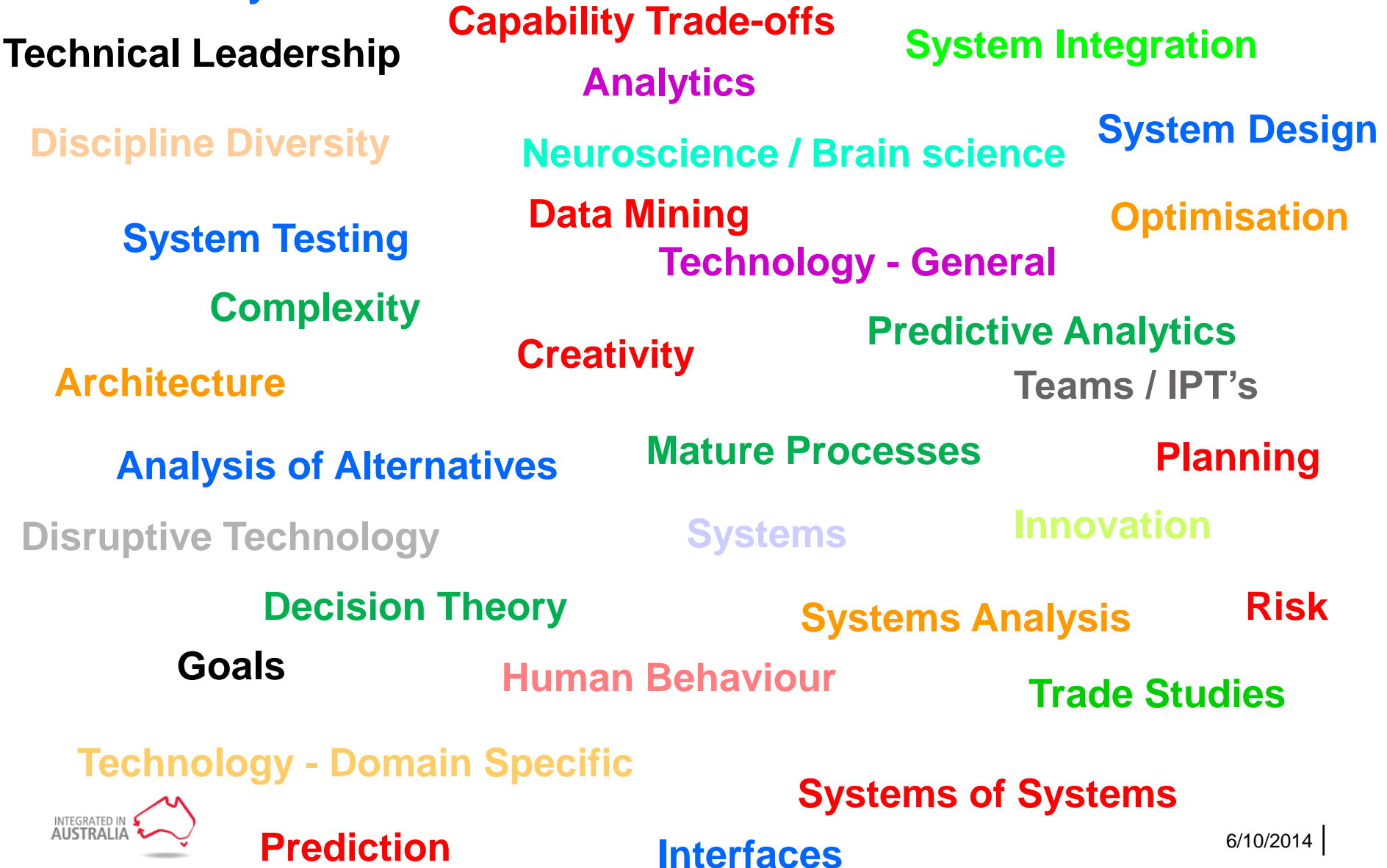
(Kline, 1995)

Collins Submarine



The Landscape for Engineering – Always changing!

Uncertainty



Hornet Training Simulator



Systems: Some definitions

■ Definition

- A **System of Systems (SoS)** is defined as a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities. [DoD, 2004(1)].

Example:

A shipboard air defense system consisting of one or more sensors, a weapon system, a launcher system, and a control system. The ANZAC and Hobart Class Destroyer Project Combat Systems are SoS's.

A **family of systems (FoS)** is defined as a set of systems that provide similar capabilities through different approaches to achieve similar or complementary effects . [DoD, 2004(1)].

Note: A family of systems lacks the synergy of a system of systems. The family of systems does not acquire qualitatively new properties as a result of the grouping.

The key discriminator here is 'Integration'

MSI - Some Background

- **The Mission System Integrator (MSI) role has evolved over the last decade to enable organisations to manage the development and execution of large and complex programs.**
- In the past, terms, such as Prime System Integrator (PSI) and Lead System Integrator (LSI), have been used however, the focus here was on cost management as well as the management of subordinate contractors.
- The PSI and LSI have traditionally been the platform provider, based on the fact that they were the platform provider and not on whether or not they possessed the prerequisite skills and capabilities.
- **The Mission System performs the ‘Mission’ and is more than the Combat System.**
- In the case of modern systems the MSI is not normally the platform provider, as this imposes a further constraint.
- The true MSI provides best value to the customer, by making the most appropriate selection of capability from the available pool of products and services, to meet the Users needs.

Harold E Holt: Submarine VLF Communications



Dealing with the Complexity of SoS

The MSI Role Defined: Within Raytheon Australia, the Mission System Integrator undertakes the following activities:

- Specifies the Mission and Support System requirements;
- Undertakes Capability Trade-offs, using techniques, such as, Cost As an Independent Variable (CAIV) analysis and the Operational Analysis skill set.

– Architects the systems and defines the Integration Strategy;

- In conjunction with the customer, selects the appropriate technology;
- In conjunction with the customer, through the use of Trade Studies and Make/ Buy/ Reuse processes, selects Subsystems, Products and Components;

– Integrates the System/ Subsystems, Products and Components;

- Verifies System Requirements at all levels;
- Supports validation of the system against the Users requirements;
- Maintains, Mission and Support Systems;
- Sustains, Mission and Support Systems;
- Provides evolutionary and technology upgrades through Life of Type (LOT);
- Disposes of the system.

Defining the 'Mission' in MSI

- For example, a 'Mission' for a destroyer to provide 'defence' of a task force in transit, would involve many elements of the ship, including;
 - Navigation System
 - Communications System
 - Weapons System
 - Combat System (Tactical + Weapon)
 - Underwater Weapons System
 - Radar (Primary and Secondary) System
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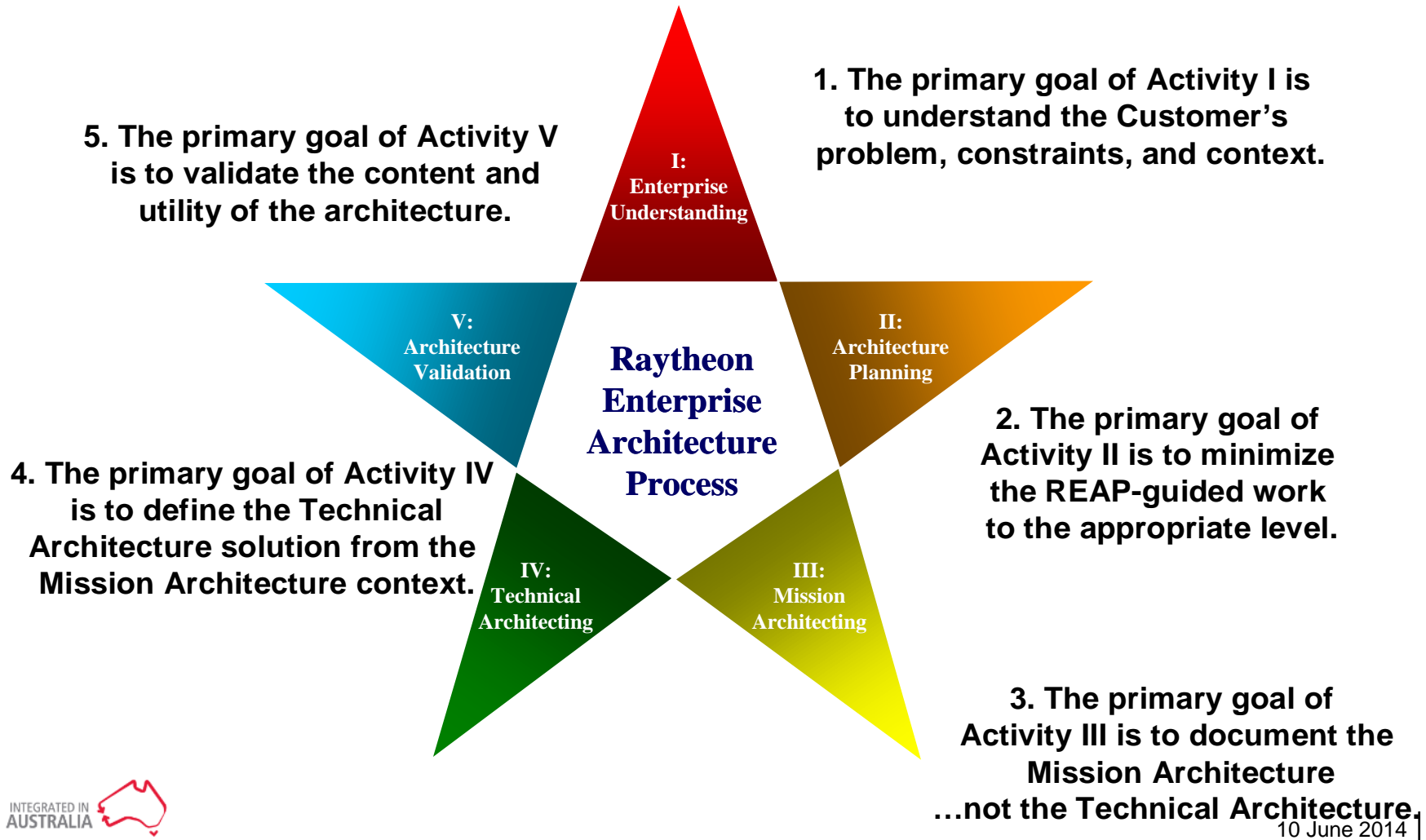
The Mission System is more than the 'traditional' Combat System

Air Traffic Management:ADATS



It is all about Architecture

Architecture Process - REAP



Being Misled by Integration

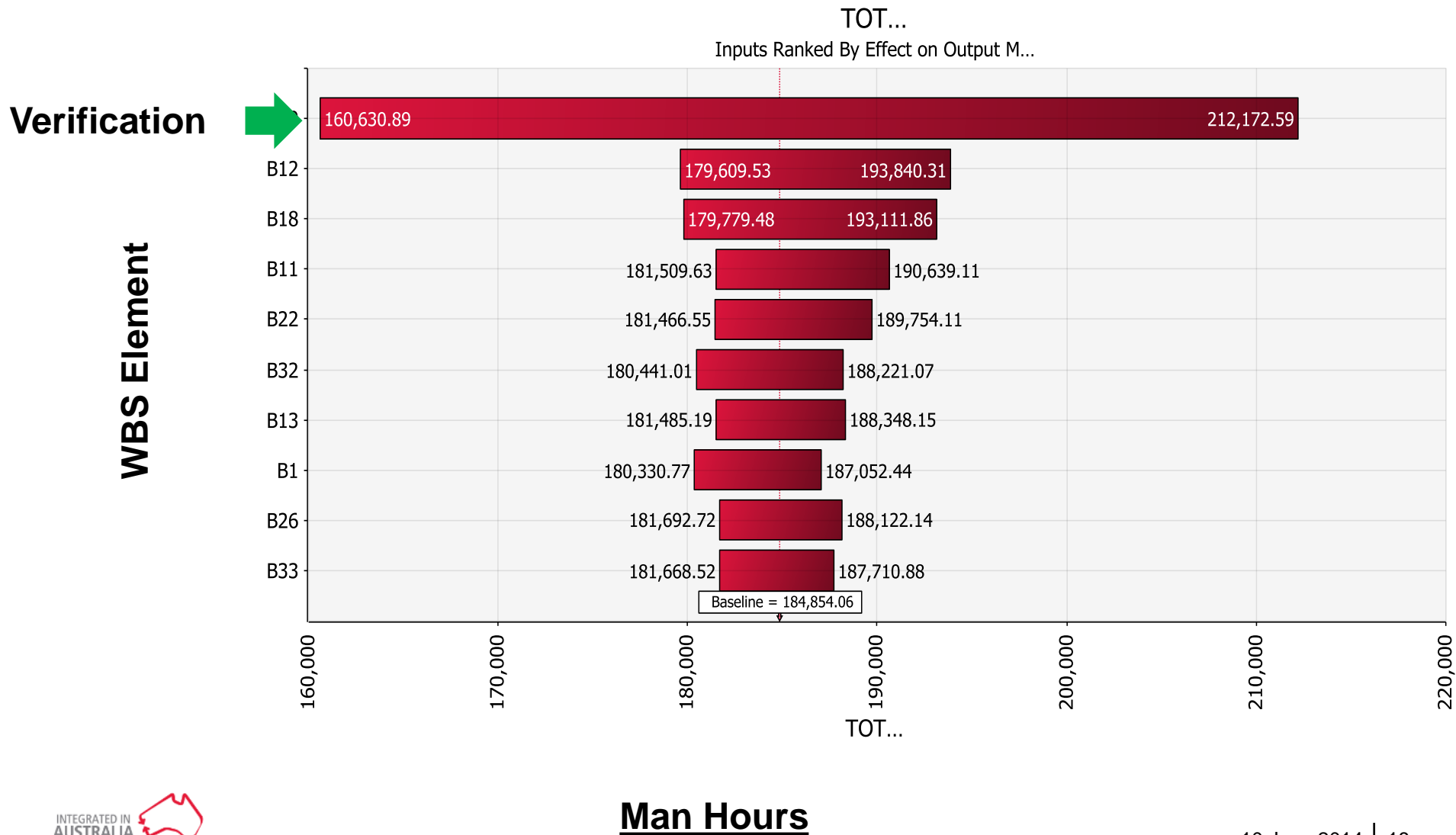
1. Architecture and Integration go together from the start.
2. Systems Integration is an issue but not the root cause of Project problems.
- 3. Integration problems are usually an outcome of poor project performance in many areas. For example, Architecture and Requirements.**
4. Problems can no longer be hidden or ignored once the program reaches the System Integration phase.
5. People still confuse testing with Integration.
6. Testing follows Integration

**Problems become evident when systems are integrated;
However, Systems Integration is not the root cause of these problems.**

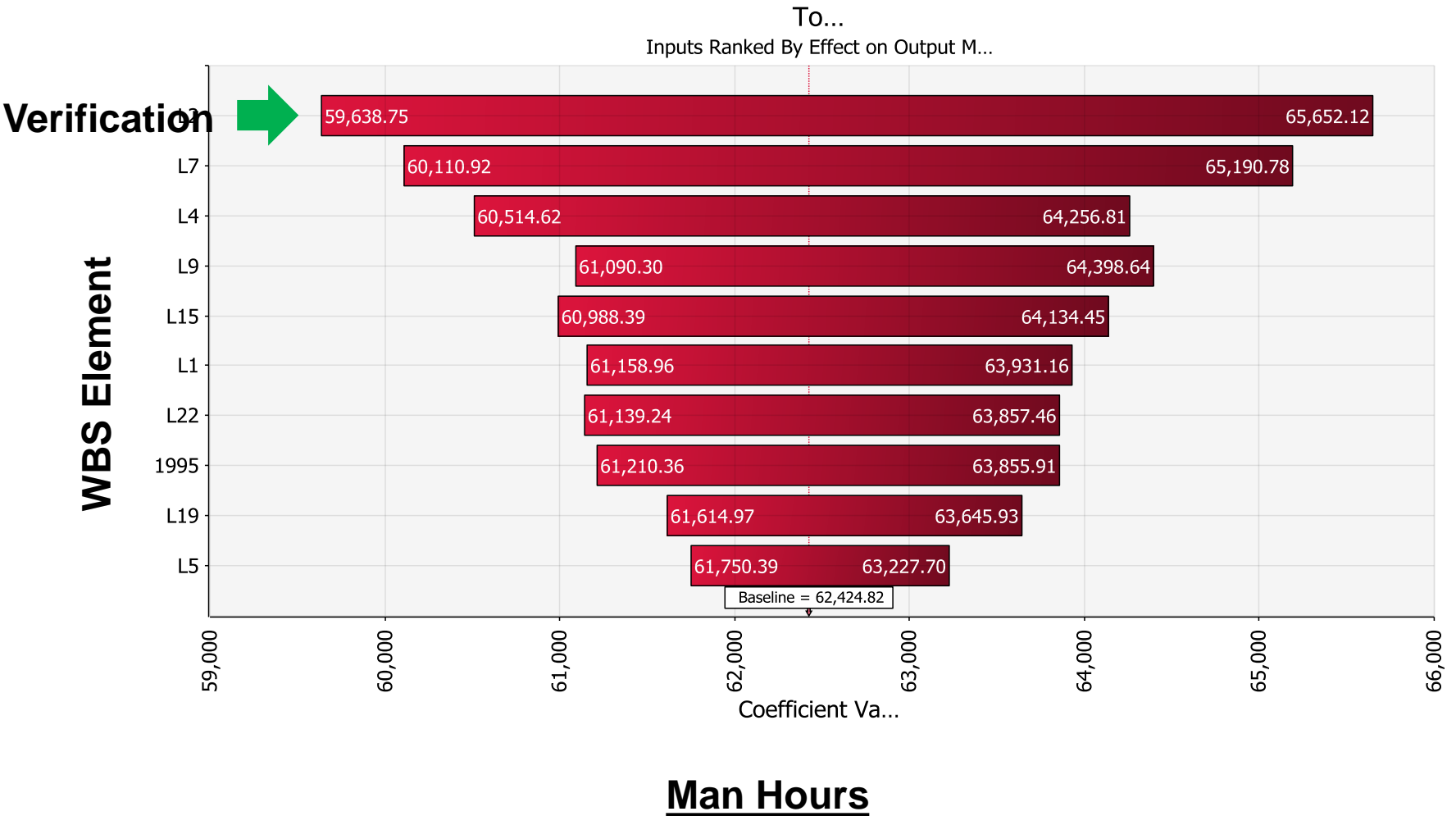
Hobart Class Destroyer



Verification is a Cost Driver – Example Project 1



Verification is a Cost Driver – Example Project 2



Optimisation

- Some candidate areas:
 - Monte Carlo Simulation to validate performance
 - Assess Kill probabilities, without firing missiles
 - Assess Overall System Capabilities; how many missile systems?
 - Evaluate scenario based performance; Functional Threads, life cycle costs
 - Conduct interactive, What If analysis
 - Statistical techniques to provide Active Element Array Thinning – Phased Array Radars.
 - Three Point estimates to provide confidence levels of cost estimate
 - Monte Carlo analysis to evaluate schedule confidence.
 - **Test Optimisation to provide test coverage and reduce level of testing.**

Statistical Techniques can reduce: design cost, Integration Cost and Testing Cost...

The Dilemma of Statistics

- **People are probability blind: Fooled by Randomness: Taleb**
 - It does not come naturally; it is not part of our DNA.
 - People mistake intuition for sound judgment based on data.
- **Systems 1 and Systems 2 thinking: Kahneman**
 - We genuinely think we understand when we do not.
 - Being pre-conditioned (anchored) and not knowing.
 - We are not rational but think we are.
- **We are blinded by effects and biases: Dobelli**
 - We accept things as fact rather than challenge: Bernoulli
 - People are not trained to make judgments or decisions and make reliable predictions.

We are limited by being human and are not self aware when it comes to Probability.

Electronic Warfare Training System



Test Optimisation to reduce Costs

- Statistically based Test Optimisation can dramatically reduce the amount of testing required to verify performance.
- Statistically based techniques provide the added advantage of providing Test Coverage.
- **However, the results are generally counter-intuitive; Less Testing more coverage!**
- Additionally such approaches requires customer buy in to not test every requirement.
- **Typical Test reduction is in the order of 35%**

People need to understand statistical techniques to see the benefits!

RMI-2 – Bell Helicopters in Nowra

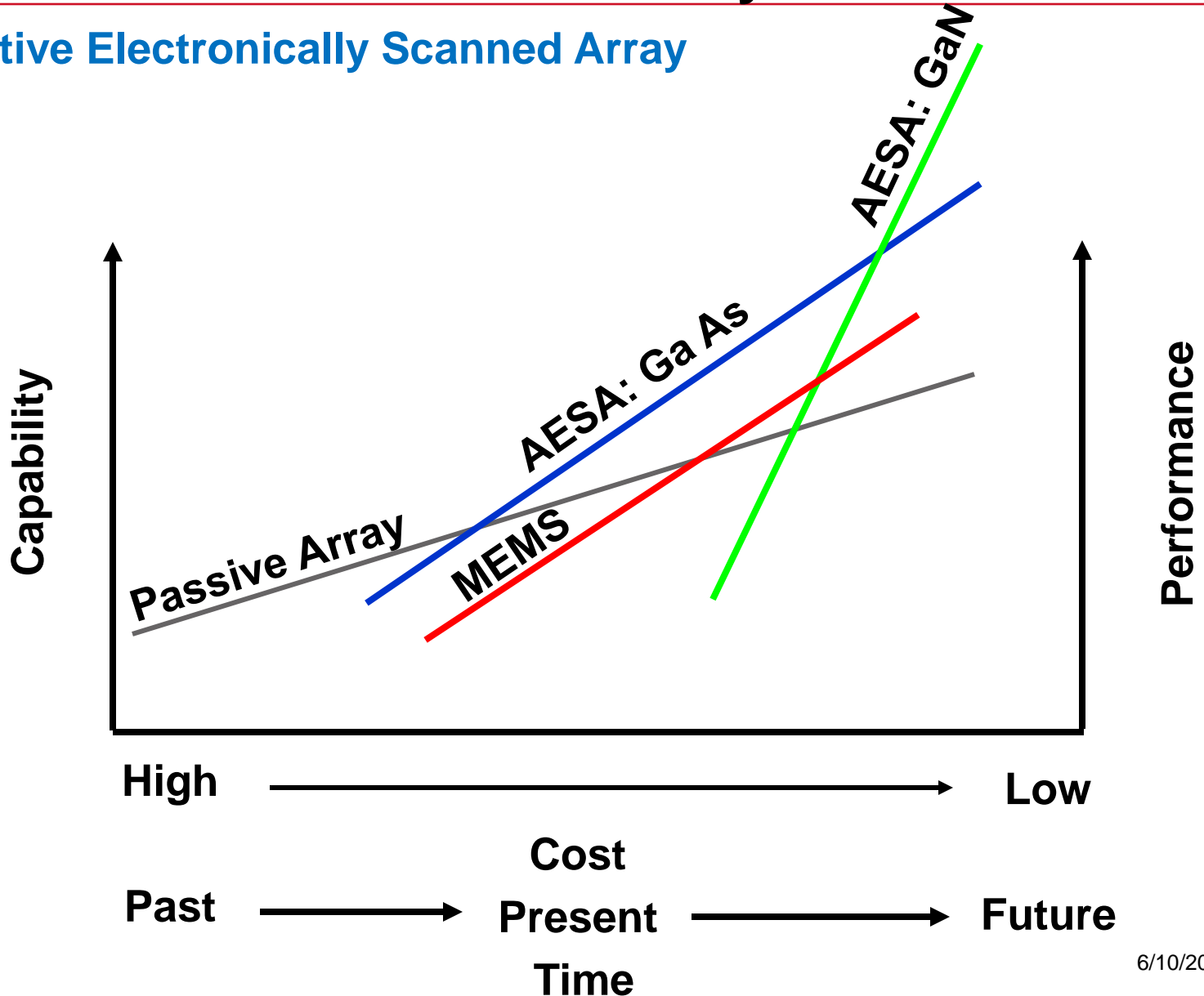


Technology Update

How Technology can make a difference!

Trade-Offs – Radar: Phased Arrays

AESA: Active Electronically Scanned Array



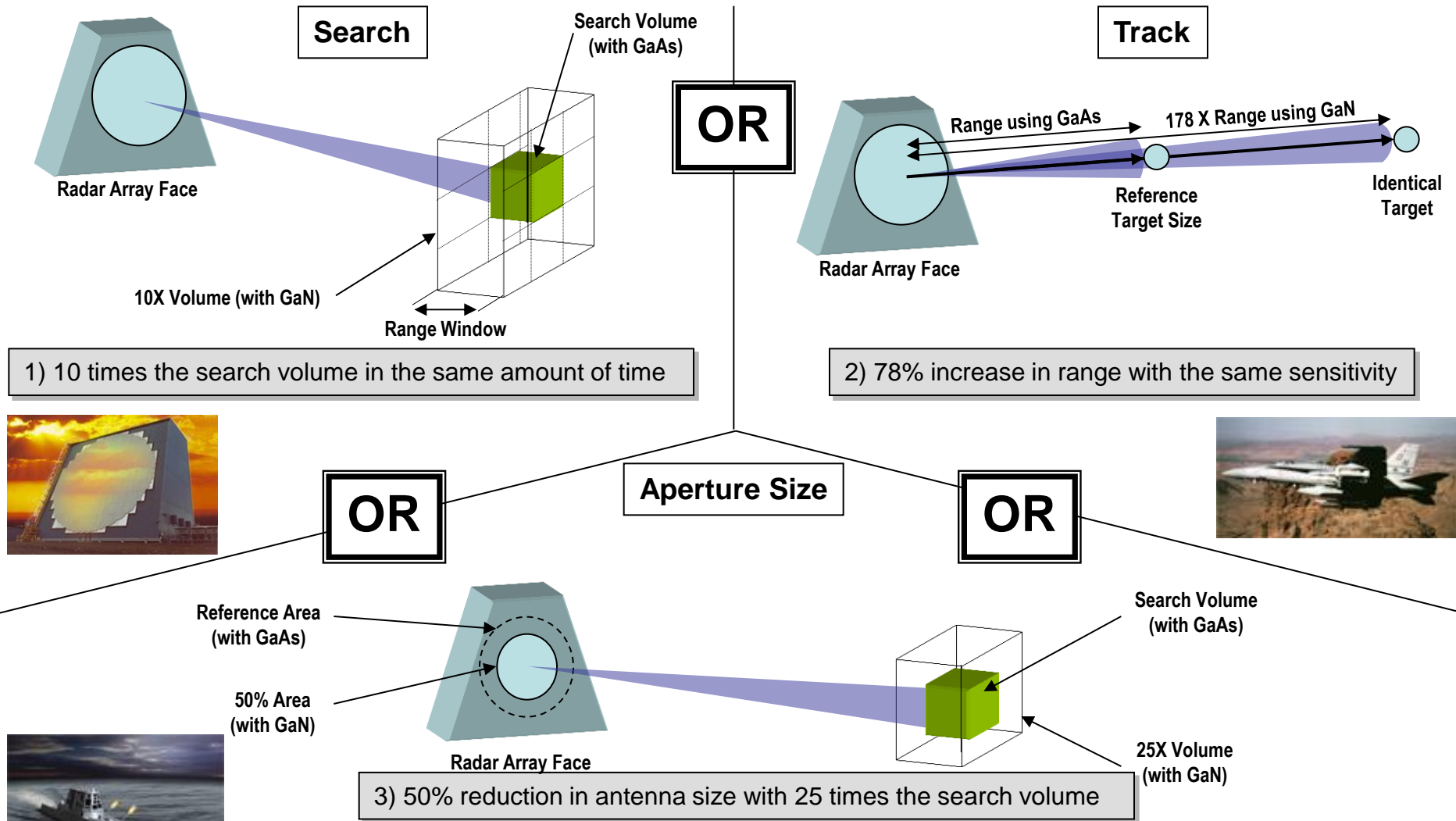
GaN versus GaAs

<u>Parameter</u>	<u>GaAs</u>	<u>GaN</u>
Output power density	0.5–1.5 W/mm	5–7 W/mm
Operating voltage	5–24 V	28–48 V
Breakdown voltage	15–48V	>100V
Maximum current	~ 0.5 A/mm	~1.2 A/mm
Thermal conductivity	47	~390 (SiC)* (W/m-K)

* GaN on silicon carbide substrate

Demonstrated GaAs and GaN microwave performance and thermal conductivity showing superior GaN results.

Why Is GaN Important?



Huge Trade Space has been provided through Technology

What's Next?

- Data Mining
- Analytics
- Predictive Analytics
- Biological Systems: Low Power, algorithms; self organising systems
- Cyberwarfare
- Networked Forces: Intra and Inter
- Information Assurance: Proofing of Systems
- Unmanned Platforms; Sea, Air, Land: micro and macro
- Merging of commercial and military systems
- Laser weapons replacing missiles
- Co-operative networking for Co-operative engagement
- Change in Acquisition Philosophy?

“In the year 2054, the entire defense budget will purchase just one aircraft. The aircraft will have to be shared by the Air Force and Navy 3½ days per week except for leap year, when it will be made available to the Marines for the extra day.”

Norman Augustine - Aircraft Industry Executive

Questions?