7 December 2015

Foreign Affairs, Defence and Trade Committee
Joint Strike Fighter Inquiry
Department of the Senate
PO Box 6100
Parliament House
Canberra ACT 2600

Dear Chairman and Committee Members,

THE PLANNED ACQUISITION OF THE F-35 JOINT STRIKE FIGHTER

Please find attached my submission to this Inquiry.

Terms-of-Reference matters covered by this submission include:

- The future air defence needs that the aircraft is intended to fulfil;
- The performance of the aircraft in testing;
- Potential alternatives to the Joint Strike Fighter; and
- Other related matters.

I would be pleased to appear before the Committee and answer any questions the members might have.

Yours sincerely,

Chris Mills, AM, MSc, BSc
Wing Commander (Retd)

Attachment: JSF Inquiry Submission

Transmitted by the Committee Upload Facility

THE PLANNED ACQUISITION OF THE F-35 JOINT STRIKE FIGHTER

Einstein's Razor:
Everything should be made as simple as possible, but not simpler.

Australia's Strategic Requirements Define the ADF's Capabilities

The last credible Australian Defence White paper was *Defence 2000, Our Future Defence Force,* which cogently stated:

Air Combat

> 8.37 Air combat is the most important single capability for the Defence of Australia, because control of the air over our territory and maritime approaches is critical to all other types of operation in the Defence of Australia.

Capability Goal

> 8.39 The Government believes that Australia must have the ability to protect itself from air attack, and control our air approaches to ensure that we can operate effectively against any hostile forces approaching Australia. The Government's aim is to maintain the air combat capability at a level at least comparable qualitatively to any in the region, and with a sufficient margin of superiority to provide an acceptable likelihood of success in combat. These forces should be large enough to provide a high level of confidence that we could defeat any credible air attack on Australia and our approaches, and capable enough to provide options to deploy an air-combat capability to support a regional coalition. They will also have the capability to provide air-defence and support for deployed ground and maritime forces in our immediate region.

Major Challenges

> 8.41 … The air combat capabilities of a number of defence forces throughout the region have grown steadily in recent years, and are expected to continue to do so.

The strategic imperatives and assessments made in this White Paper are as appropriate today as when published 15 years ago. The only change required to bring this document up to date would be to observe that regional air forces now have air combat capabilities equal to, or superior,

to the RAAF, and that new capabilities are being introduced that exacerbates Australia's sovereign risk from loss of air superiority.

The Royal Australian Air Force Surrenders Regional Air Superiority to the Royal Malaysian Air Force – RMAF Butterworth 1975

History informs us that we have been deficient in maintaining superior air combat capabilities in the past. The bombing of Darwin on 19 February 1942 exposed a RAAF woefully ill-equipped and unprepared. In Korea, the RAAF's obsolete P-51 Mustangs and outclassed Gloucester Meteors saw them relegated to the ground attack role due to the presence of the superior MiG-15. There was no thought of deploying the Mirage over North Vietnam where the highly effective North Vietnam Integrated Air Defence System could bring SAMs, AAA and advanced MiGs to the fight. The USAF and USN struggled with high air combat losses and at the end of the war the USAF had one Ace, where the NVAF had 15.

My personal experience of loss of air superiority occurred in 1975. I was flying an air combat mission in a Mirage near Butterworth, Malaya at the moment this happened. The RMAF had re-equipped 12 Squadron with the F-5E Tiger, and invited RAAF's 3 Squadron to a four versus four (mock) air combat engagement. Our lead was the Squadron's Operations Officer, and I was his wingman. As we merged, it quickly became apparent that we were inferior: the F-5E could out-turn and the Mirage, they had much more modern air-to-air missiles and a better gunsight. We could out-climb and out-run them, advantages useful for escaping, but not for killing the enemy. The F-5E had a very small cross-section, and was difficult to spot on radar or visually.

I was the only person in that fight to record an F-5E kill, and while I would like to say it was because I was a superior pilot in a superior aircraft, it was not true. I was 'spat out' of the intensive turning fight and managed to record gun-camera film on the RMAF Section Leader as he was concentrating on 'hosing' my Leader from a range of 300 metres.

One of the fallacies of air combat is that a good pilot will compensate for a bad aircraft. In this case, my Flight Lead had about 2,000 hours on type and was considered to be one of our Mirage 'Aces'. The RMAF pilots had about 50 hours on type.

Another fallacy is that we will receive adequate 'warning time' to respond to the introduction of a new air combat aircraft in the region. The F-5E was produced at a high rate, and the RMAF completed their conversions in the USA in 12 weeks. Their aircraft were loaded as '6-Packs' on a C-5A

Galaxy and delivered to RMAF Butterworth. Assembly and testing took about an hour; a test flight was flown by a USAF delivery pilot, the aircraft was then inducted into the RMAF. On one such test flight, I was horrified to see a high-G pitch into the circuit produce a 180 degree turn at about half the turn radius of a Mirage. Some 15 weeks after conversion training started, the RMAF was soundly defeating the RAAF in air combat.

The lesson from history is that there must be continuous vigilance to maintain the RAAF's air superiority. In our region Indonesia, India, Malaysia, Vietnam and China have advanced versions of the Sukhoi Su-27 and Su-30. China has signed a contract for 24 very lethal Sukhoi Su-35S and Indonesia has announced it will purchase 16 Su-35S to replace its ageing fleet of F-5Es:

https://www.flightglobal.com/news/articles/indonesia-moves-closer-to-su-35-buy-416440/

Worse news is that the even more lethal Sukhoi T-50 is in advanced state of development, as is the Chengdu J-20 and Shenyang J-31.

What is the USAF's Assessment of the Air Combat Capabilities of the JSF?

In an interview with the Commander of the USAF Air Combat Command, currently the Service with the most powerful air combat capability on earth, General Michael Hostage said on 3 February 2014:

> *'If I do not keep that F-22 fleet viable, the F-35 fleet frankly will be irrelevant.* ***The F-35 is not built as an air superiority platform****. It needs the F-22.'*

The interview can be accessed here:

Defense News Interview with General Hostage

It does not take the mind of Einstein to realise that if an Air Force does not possess an aircraft with the air combat capabilities of the F-22A Raptor, then in future warfare, that Air Force will be 'irrelevant'. Thus: Q: Does the RAAF have F-22As? A: No. Q: Will RAAF F-35As be 'irrelevant' in future air combat engagements? A: Yes.

There is an comprehensive compilation of many assessments of the capabilities and manifold deficiencies of the F-35 JSF here:

https://www.defenseindustrydaily.com/the-f-35s-air-to-air-capability-controversy-05089/

Using Simulation to Assess the Air Combat Capabilities of the JSF

Simulations have long been used to assess the capabilities of an aircraft, often before it has been built and tested. In the case of the F22A Raptor, three cutting-edge simulators, two at Lockheed Martin and one at USAF's Edwards Air Force Base, were used to test the efficacy of designs, and the combat-effectiveness of the Raptor against all known threats. The simulations were extended to include probable and possible future threats. This type of critical operations analysis reduces the threat of fielding a weapon that is defeated on the first day of the war.

I have specialised in using simulations as a decision support tool since my 1976 posting to the Defence Science and Technology Organisation as an Operations Research Analyst. My USAF Institute of Technology thesis was a large FORTRAN simulation, for which I was awarded the Thesis Prize.

I re-joined the RAAF in 1997, and was posted to the position of Deputy Director for Air Control in Capability Development Division after the intended incumbent was killed in a hang gliding accident. In that position, my old adversary, the RMAF had equipped their MiG-29s with the new Russian R-77 AA-12 'Adder' and my recommendation was a substantial upgrade to the F/A-18 Hornet's air-to-air capabilities to redress the resulting deficiency in the RAAF's air combat capability. This recommendation was accepted and became the Hornet Upgrade Program.

This experience, and knowledge of my DTSO Operation Research work, led to an invitation to assist the Director of Explosive Ordnance to provide assistance with the simulation of future air combat in our region. The work used unclassified data and simulation suites, but the results are classified, and cannot be included in this submission. My colleague, Mr Michael Price, has previously reported to a Parliamentary Committee that he compared the results of these unclassified simulations with highly classified simulations, and found an insignificant difference. He was awarded a 'Commander's Commendation' by the Chief Executive of the Capability Development Executive, General David Hurley for his contribution. None of the higher Defence Committees questioned the veracity of his work when it was presented to them.

Mr Price and I left the employ of the Department of Defence, and in July 2006 formed a company 'Representative Simulations' (REPSIM Pty Ltd) to provide simulations of future air combat, again using unclassified data and an improved version of the simulation suite – developed in part by the Australian Department of Defence – now named 'H3MilSim'. We were

successful in selling our product overseas, but confidentiality agreements restrain us from revealing the results.

As a marketing exercise, we compiled simulations for the Inter-Service / Industry Training, Simulation, and Education Conference (I/ITSEC) 2010, the largest conference if its kind in the world:

http://www.iitsec.org/Pages/default.aspx

We presented future (2018) air combat engagements over the East China Sea, based on the Scenario used by RAND Corporation for their presentation: *Air Combat – Past, Present and Future*, delivered at Pacific Vision 2008. This was a prescient decision, as China has only recently purchased 24 Sukhoi Su-35S, now operational with the Russian Air Force.

The videos were posted on You Tube and can be found by a search using the key 'Computerharpoon'. The scenarios include 24 Su-35S versus 24 USAF F-22A, F-35As. The video of the engagements can be accessed here:

F-35A versus Su-35S (USAF View)

Su-35S versus F-35A (Chinese View)

Assessing the result of Monte Carlo (probabilistic) simulations requires the accumulation of several runs. In this case, the 24 F-35A versus 24 Su-35S scenario was run 10 times.

The accepted metric of relative air combat capability is the 'Loss-Exchange-Rate' (LER) where combat losses are counted, and those of the side with the least losses are reduced to the number 1, and the other as a decimal number. In this case of 10 runs of F-35A versus Su-35S the losses were: 205 F-35A and 87 Su-35S. As a LER this becomes:

F-35A versus Su-35S LER = 2.36:1

To avoid misunderstanding, this means that **2.36 JSFs were lost for each Su-35S killed.**

As a comparison, the same scenario flying the F-22A Raptor is:

F-22A versus Su-35S LER = 1:2.14.

Given China's purchase of the Su-35S and Indonesia's intending purchase of Su-35S, these results are of grave concern for an Australian JSF fleet.

Put simply, the F-35 Joint STRIKE Fighter, '***not built as an air superiority platform'*** to quote the USAF's Air Combat Capability Commander, is performing as designed and expected. When it engages a purpose-designed, lethal air combat aircraft, the simulations assess that it is soundly defeated. This is a credible evaluation.

I reported these results in detail as Submission 11 to the Joint Standing Committee on Foreign Affairs and Trade's Review of the Defence Annual Report 2010-2011. The response from Lockheed Martin was predictable – they could not let these assessments go unchallenged for the simple reason that if a Fourth Generation Sukhoi Su-35S could soundly defeat the JSF with a Unit Price more than double that of the Sukhoi, then the JSF program would be dead in a heat-beat. Appearing before a Parliamentary Committee provides protection via Parliamentary Privilege and the only risk to Lockheed Martin was being found guilty of Misleading Parliament – and it has been a very long time since that has happened.

The Lockheed Martin Project Manager Mr Tom Burbage and Mr Gary Liberson presented to the Committee on 20 March 2012. Mr Liberson was introduced by Mr Burbage as follows:

> *Gary Liberson, has 22 years of experience as an operations analyst and research engineer with McDonnell Douglas, the RAND Corporation, and Lockheed Martin Aeronautics. He has extensive experience with combat analysis, methodologies and analysis techniques. He is considered an expert in Brawler, Thunder, Suppressor, SeaFan and PacWar constructive simulation tools. His areas of expertise include combat aircraft systems and tactics as well as advanced threat analysis.*

Lockheed Martin Presentation 20 March 2012

During the questioning, Mr Liberson made this claim:

> *Our current assessment that we speak of is: greater than six to one relative loss exchange ratio* ***against*** *in four versus eight engagement scenarios—four blue at 35s versus eight advanced red threats in the 2015 to 2020 time frame. (sic)*

He refused to reveal what threats were assessed, making the extraordinary claim that the threats were 'classified'.

Clearly, an **LER of JSF versus Undeclared Threat of 1:6** is substantially at odds with the REPSIM H3MilSim results of **JSF Versus Su-35S LER of 2.36:1.**

A literal reading of Mr Liberson's testimony including the word '*against*' (my bolding above) could be interpreted as: Six JSFs lost for each Undeclared Aircraft type killed.

If REPSIM's RAND Corporation had been changed to run 24 F-35A versus 48 Su-35S then the **JSF versus Su-35S LER would increase to about 6:1 or greater.**

When REPSIM made assessments of Loss-Exchange-Ratio, the normal practice is to have equal numbers on both sides of the fight. If there is numerical asymmetry, then the Lanchester's Laws come into play:

Lanchester's Laws

Numerical asymmetry generates non-linear changes to the results. Accordingly the 2.36 JSF losses could well increase above 6 JSF losses when the JSF is outnumbered, 2:1

Thus, Mr Liberson's testimony could be plausible, with the receiver of his answer misinterpreting that a Lockheed Martin representative would naturally present the JSF as the superior air superiority platform.

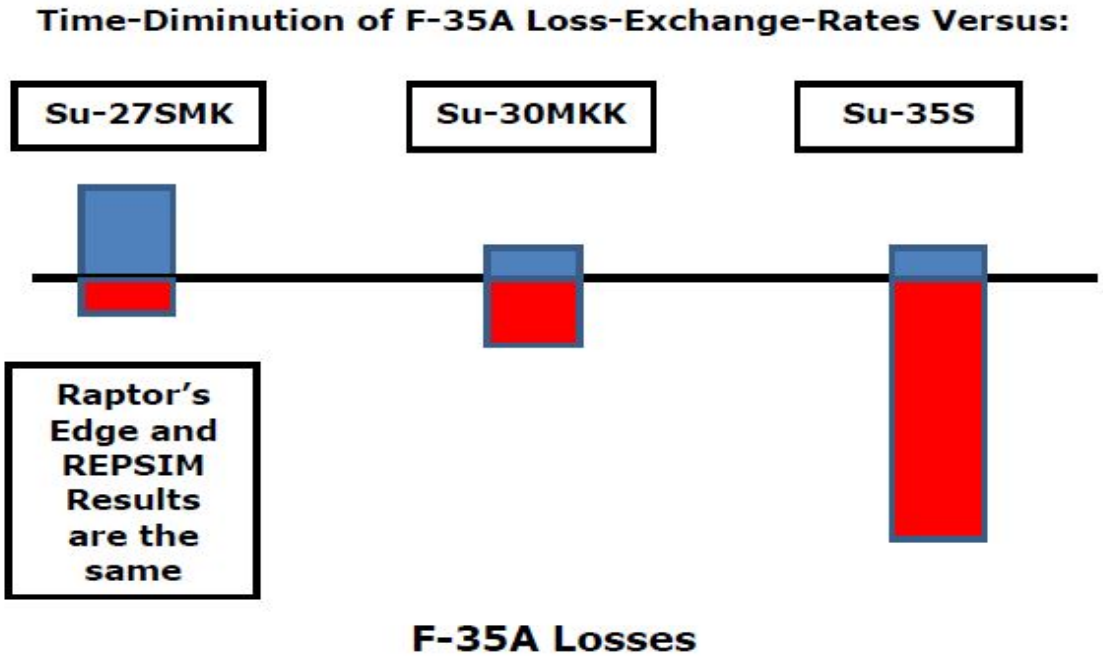
Just before this exchange, the Acting Chair initiated this exchange:

> *ACTING CHAIR: In terms of simulations and so on there was a report in* Aviation Week and Space Technology *called 'Raptor's edge', written by David Fulghum. It said the operational arguments focus on combat effectiveness against top foreign fighter aircraft such as the Russian Su27 and MiG29. Lockheed Martin and USAF analysts put the loss-exchange ratio at 30:1 for the F22,* ***3:1 for the F35*** *and 1:1 or less for the F15, FA18 and F16. Is that Lockheed Martin's view? It says here that that was both analysis by Lockheed Martin analysts and the USAF.*
>
> *Mr Burbage: Time has moved on since 2008 and we know a lot more about this airplane now than we knew then.*

The simulation expert Mr Liberson could have used several USAF Accredited simulations to reach the conclusions revealed in the '*Raptor's Edge*' article, Tac Brawler being a prime candidate. REPSIM Pty Ltd made an A-B Verification of such an engagement, pitting F-35A versus Su-

27SK, producing a LER of 2.7:1, remarkably close to the 3:1 advantage reported by the *Aviation Week* article.

Logically, if the F-35A capability is the same and the competition becomes more lethal, then the Loss-Exchange-Rate must deteriorate. This subject is covered in detail in my Submission 11; here is the graphic:



There was a specious claim made by Air Commodore Bentley that unless there was access to classified material, a simulation could not be accurate.

The Lockheed Martin team brushed aside the '*inconvenient truth*' of their own earlier work in the combat capability of the F-22 Raptor and the F-35 JSF – probably done by the combat analysis expert Mr Liberson when the company was attempting to protect the F-22A program from termination. They also failed to address Mr Price's advice to the Committee that he had tested the unclassified Harpoon 3 results against those from highly classified simulation, with no significant differences.

The '*Who Is Right?*' simulation imbroglio is a matter of grave concern to Australia, indeed, any Western country operating the JSF as an essential part of its National Defence Force. If the Harpoon 3 / H3MilSim simulations Mr Price and I compiled for the Australian Department of Defence and REPSIM Pty Ltd's International Customers are correct, and this made by Lockheed Martin and the USAF when protecting the F-22A Raptor Program, and the Loss-Exchange-Rates are of the order of 2.36:1 against threats such as the Sukhoi Su-35S, and potentially worse against

more advanced aircraft such as the T-50, J-20 and J-31, **then JSFs will only survive a day or two in battle.** The consequence would be a grave threat to Australia's sovereignty.

Because of the importance of the issue, my colleagues and I searched for additional evidence of the capability of VSIM, especially whether the simulation suite had been independently Verified and Validated. An internet search quickly found a Lockheed Martin presentation 'Modeling and Simulation Applied in the F-35 Program'. The PDF of a presentation on the subject can be found here (and is attached):

Modeling and Simulation in the F-35 Program

This presentation is dated 2011, and Slide 11 is of particular interest, as it claims 'All Models Verified and Validated', and predates the evidence given to the Australian Parliament by Mr Burbage and Mr Liberson.

The matter of Independent Verification and Validation takes a new twist in 2013 and 2014, as a result of an assessment of the JSF program released annually by the Director of Operations Test and Evaluation, Dr Michael Gilmore, an independent statutory office holder appointed by the US Congress. His report is a public document and can be downloaded here:

http://www.dote.osd.mil/pub/reports/FY2014/

Of particular interest is the section on VSim which Mr Liberson appears to be claiming is producing JSF LERs in the 6:1 range and better.

Dr Gilmore differs and declares VSim has failed critical Verification and Validation tests, and therefore cannot be used as an 'Accredited' simulation. As Mr Liberson is making extravagant claims about the air combat capabilities of the JSF, an understanding the reasoning behind the '*Independent Umpire*' assessment is of vital importance when assessing the credibility of witnesses and indeed, the actual combat capability of the JSF. Accordingly, the full content of Dr Gilmore's 2014 report on VSim is reproduced here:

> **Modeling and Simulation**
>
> Verification Simulation (VSim) (My boldings below.)
>
> · At the beginning of CY14, the program planned to accredit the VSim for use in Block 2B contract compliance verification by the end of the year. However, lack of progress on the Verification and Validation (V&V) process, and to a lesser extent the VSim development process, caused the program to charter an independent review of VSim. **This review eventually led to cancellation of the contract verification portion of Block 2B VSim planned usage.** For similar reasons, after the Block 2B OUE re-scoping effort began, the JSF Operational Test Team determined that VSim would likely not support planned Block 2B operational testing in 2015 and reduced the requirements for the simulation's intended uses to support only tactics development and other activities that directly contribute to the fielding of Block 2B capabilities.
>
> · About one-third of the validation evidence for Block 2B VSim was reviewed by the developmental and operational test stakeholders before the contractual use of VSim for Block 2B was cancelled. This review confirmed that additional time was needed before VSim V&V could potentially meet expectations. Collaborative replanning of Block 2B activities is not complete, **but V&V reviews to support operational testing needs are now planned for early 2015, with accreditation of VSim for tactics development and other uses expected in October 2015.**

· Exercising the V&V process for Block 2B VSim is critical to reducing risk for its use in Block 3F IOT&E. **Rigorous validation will identify gaps in VSim performance, including threat modeling**, in time to create the appropriate fixes for Block 3F. Creation of test and V&V procedures as well as V&V reports and accreditation documentation will provide a significantly better understanding of VSim status by the end of 2015.

· Rigorous validation depends on good source data, and the contractor and Program Office improved efforts to ensure VSim needs are met in the Block 3F flight test plan. Those plans are not finalized, but will certainly result in deficits as the enterprise-wide need for flight tests exceeds available resources. Success in validating Block 3F VSim will depend on bridging this gap with acceptable data sources.

· The contractor has increased resources on VSim V&V teams, and the quality of the V&V products is increasing. **However, the rate of completing validation points** (a comparison of VSim model performance to aircraft hardware performance under similar test conditions using data from flight test, avionics test bed, or labs), **has been much slower than planned. This makes completing the validation reports, which analyze the points with respect to intended use, at risk to support even the reduced accreditation requirements for Block 2B.** Additional resources may be required to complete the significant task of validating the complex federation of models in VSim in time for Block 3F IOT&E.

· Although the VSim validation process has improved, DOT&E has continued to highlight shortfalls in the test resources needed to gather key elements of data required for validation of the VSim for IOT&E, **in particular for electronic warfare performance in the presence of advanced threats. These shortfalls are a function of limitations in the test assets currently available to represent threat systems.** DOT&E has made formal recommendations to address the shortfalls and is pursuing solutions to make the assets available in time to prepare for IOT&E in a realistic threat environment.

· Limiting VSim Block 2B validation, and use, to tactics development and evaluation will help the program progress towards V&V of Block 3F. Block 3F use of VSim for IOT&E is not optional; it is required for an adequate IOT&E.

In summary, VSim has not passed essential Verification and Validation tests, and therefore, cannot be used in tasks such as establishing Loss-Exchange-Rates.

Potential Alternatives to the Joint Strike Fighter

The foregoing has been presented as this sequential logical argument:

1. Australia's strategic imperative is to maintain sovereignty, and to do that it needs to retain control of the air '*with a sufficient margin of superiority to provide an acceptable likelihood of success in combat'*.

2. Australia has failed to maintain, or has lost, air superiority in the past and the consequences have had grave effects on the Nation;

3. General Michael Hostage USAF Commander of Air Combat Command, said on 3 February 2014: '*If I do not keep that F-22 fleet viable, **the F-35 fleet frankly will be irrelevant**. The F-35 is not built as an air superiority platform. It needs the F-22'*.

4. Simulations of the type commended by the Head, Capability Development Executive, General David Hurley, indicate that the '*not built as an air superiority platform*' JSF will be soundly defeated by lethal air combat capability aircraft like the Su-35S, now entering our region; simulations offered by Lockheed Martin as 'proof' of the air combat capability have been shown to lack credibility as the VSim used has failed essential verification and validation tests.

5. The F-22A Raptor, designed as an Air Dominance weapon system, has the capability to defeat these threats, an assessment supported by REPSIM's air combat capability modelling.

Looking at the foregoing logic chain, Blind Freddie would assess that the answer to providing Australia, and several other countries in the Western World, with a superior future air combat capability is to bring the F-22A Raptor '*Air Dominance Fighter*' back in production.

To those who say: 'it can't be done', my answer is that USAF has kept all the production tooling with capacity for several hundred new aircraft to be built. There is a new, underutilised production line at the JSF production facility at Lockheed Martin's Fort Worth factory.

To those who say it will be too expensive, my answer is that the Unit Price of the last-produced F-22A was $US153 million – substantially less than the cost of the JSF. With a substantial production run to meet the Western World's needs, and the R&D costs 'sunk' and written off, that cost will fall. There will, of course, be some set-up costs for parts manufacturers, but many will have retained tooling and production skills.

There is another factor to consider – operational obsolescence. An air combat fighter can expect to have a safe '*flying life'* of about 35 years, but an '*air superiority life*' of 15 to 20 years at best. As an example of emerging threats, the Sukhoi T-50 has been specifically designed to challenge the F-22A. The air combat capabilities of the Chengdu J-20 and the Shenyang J-31 are at present unclear, but we can be confident that the Chinese also have the F-22A in their sights. To remain competitive, the Western world needs to commit to the '*Next Generation Fighter'*. The air-combat deficient '*not designed for air superiority*' JSF design has no possibility of fulfilling that requirement.

With the F-22 back in production, the USA, assisted by the Western World, needs to start on developing the Next Generation Fighter which could be the 'F-22E'. (Using the experience that the F-15A, a superlative air combat aircraft with an unblemished air combat record (its Loss-Exchange-Ratio cannot be calculated as it has not lost a single aircraft in combat,) became the powerful two-seat F-15E 'Strike Eagle').

If the Western World replaced the JSF with an improved Raptor, perhaps designated the F-22C, and developed a 'stretched' two-place F-22E as a follow-on, the production numbers might look like this:

Country	**F-22C**	**NGF F-22E**
USA	80	260
Australia	30	30
Canada	30	30
Japan	60	60
Korea	40	40
Israel	60	60
NATO	120	120
Totals:	**420**	**600**

At a production rate of 100 per year, building this world-dominance fleet would require 4.2 years for the F-22A and a further 6 years for the F-22E.

The 'Raptorization' of the Western World confers considerable operating cost advantages as the remaining life on 'legacy' fleets such as the F/A-

18E/F/G, A-10, F-16, F-15 etc. can be flown out, maximising the return on past investments. These legacy aircraft would take on specific tasks for which they are well suited, examples being anti-shipping strike, ground attack and close-air-support.

The 'NATO' suggestion, while not of particular concern to Australia, is that some 4 squadrons of 30 F-22C Raptors would be established and operated with air and ground crews drawn from NATO members and with Command exercised by NATO. Independent European countries might still choose to operate their own '*second-tier'* combat aircraft such as the F-16, Typhoon, Tornado, Raphael and Gripen.

The Joint Strike Fighter, while operationally crippled with design defects that cannot be re-designed out, nonetheless has some advances in materials and systems that could, and should, be incorporated into the development of the F-22C & E. The table above suggests that the numbers are sufficient to support a production line for many years.

Finally, the Western World needs an improvement to the AIM-120 AMRAAM air-to-air Beyond-Visual-Range missile. The MBDA Meteor, now entering operational service, would be a sound candidate for development and world-wide deployment on the F-22C and F-22E.

Chris Mills, AM, MSc, BSc
Wing Commander (Retd)
7 December 2015

Attachment:

Modeling and Simulation Applied in the F-35 Program, Lockheed Martin, 2011

Modeling and Simulation Applied in the F-35 Program

Barry Evans

Lockheed Martin Aeronautics

Barry Evans

Chief Engineer and Senior Fellow
Simulation and Systems Integration Labs

Lockheed Martin Aeronautics Company

- Chief Engineer and Senior Fellow – Technical Direction and General Oversight for Simulation and Systems Integration Labs Across Lockheed Martin Aeronautics Programs
- Two Years as Acting Director for F-35 Labs to Lead Major Re-plan, Reduce Costs, and Overcome Technical Challenges
- Program Re-plan Lead and Integration Mgr. for C-5 RERP Air Vehicle
- Functional Mgt., Including: Mgr., Sr. Mgr., and Acting Director, Electronic Systems and S/W (Marietta)
- Lead Architect for Common Suite of Laboratory Architecture, Software, Hardware, Standards, Processes, and Paradigms Deployed Across Program Domains, Including F-35, F-22, C-5, C-130, C-27, P-3, S-3, CRAD, and IRAD
- System Architect and/or Project Manager for Numerous Simulation and Systems Integration Labs
- Simulation Design and Development
  - Operating Systems, Simulation Executives, I/O, S/W Tools, Data Collection etc.
  - Modeling: Air Vehicle, Mission Systems, Environment, Tactical Combat, OFP Re-hosts, etc.
  - Feel Systems, OTW Visual Systems, Displays, Motion System, Audio Systems, Cockpits, etc.
  - H-I-L Stimulation, Test Benches, Custom Board-Level H/W, Buss Systems, etc.
- BSEET, Southern Polytechnic State University; Course Work in Flight Dynamics, Kansas State Univ.

Introduction

- The Lockheed Martin Aeronautics Company Develops State-of-the-Art Aircraft, Aircraft Systems, Weapon Systems, and Ground Support Systems, (Collectively Referred to as Air Systems)
- Current Air System Platforms Include:
  - F-35 Joint Strike Fighter
  - F-22 Raptor
  - F-16
  - C-130J
  - C-5M
  - C-27J Avionics
  - P-3 Upgrades
  - F-2 and T-50 Sustainment

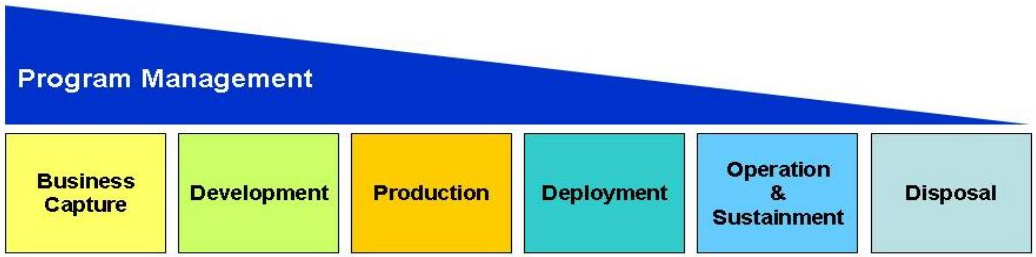




- Modeling and Simulation Play Critical Roles Throughout the Life Cycle of Air System Products
- As the Newest, Large-Scale System Development Program, The F-35 JSF Program Maximizes Leverage of Modeling and Simulation to:
  - Optimize Systems Development and Test
  - Minimize Cost and Risk
  - Improve Visibility and Quality
- This Presentation Specifically Highlights Modeling and Simulation Utilized in the Simulation and Systems Integration Laboratories on the JSF Program

Modeling and Simulation Application

- **The JSF Program Utilizes Real-time Man-In-The-Loop (MITL) and Hardware-In-The-Loop (HITL) Simulation & Systems Integration Laboratories to Support all Phases of Air System Development and Sustainment**
  - **Research and Development (R&D)**
  - **Theater-level Analysis**
  - **Concept Exploration**
  - **Business Development**
  - **System Trade Studies**
  - **Requirements Development**
  - **Design Evaluation**
  - **Developmental Testing**
  - **Integration Testing**
  - **Verification and Validation (V&V)**
  - **Operational Test and Evaluation (OT&E)**
  - **Training/Familiarization**
  - **Sustainment**



Modeling and Simulation Role in Systems Engineering

Concept Exploration & Prototyping

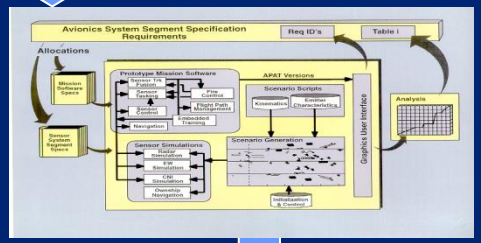
Mission Needs

- Net Centric, Force-On-Force
- Air System Performance
- Business Development

Define Requirements

- Analysis
- Definition
- Requirements Trades
- Customer Decisions
- Understanding/Clarification

Design & Development



- Evaluation
- Design Trade Studies
- Capability Assessment
- Development Support
- Customer Visibility

Integration

- H/W & S/W Integration
- DT, Subsys Integ, Sys Integ
- Prove the System Works as Designed

Lab Test

Verification & Validation

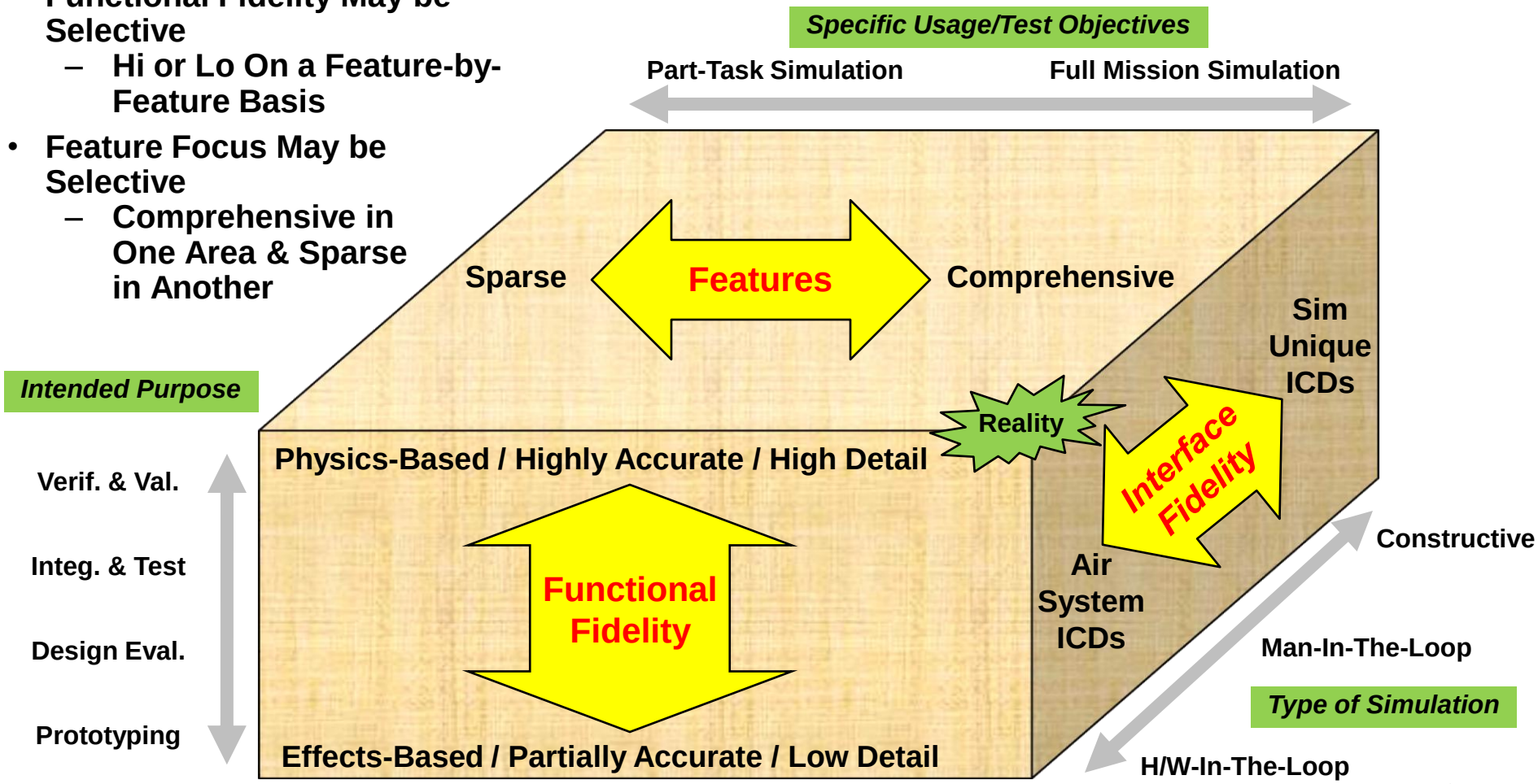
- Requirements Verification
- Mission Effectiveness
- Integrated System Performance
- Operational Test & Evaluation

- *Facilitates Intelligent, Informed, and Optimized Decisions*

- *Improves Technical Content, Cost, Schedule, Quality, Risk, Visibility, and Confidence*

General Model Fidelity Considerations

- Simulation Fidelity Requirements are Based on:
  - Intended Purpose for the Simulation
  - Sensitivity of Usage/Test Objectives to Specific Model Features and Performance
  - Interface Requirements (MITL, HITL, Other Sims, etc.)
- Functional Fidelity May be Selective
  - Hi or Lo On a Feature-by-Feature Basis
- Feature Focus May be Selective
  - Comprehensive in One Area & Sparse in Another



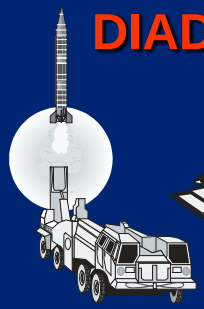
Man-In-The-Loop Simulation

F-35 MITL Simulations

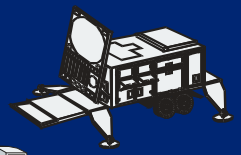
- **Virtual Cockpit (VC)**
  - PVI Development
  - Desktop and Cockpit Based PVI and PVI Stimuli
  - Low Fidelity, Own-ship Focused
- **Development Simulation (DSIM)**
  - Air System Requirements, Design, and OCA
  - Multiple F-35s, MICS, Threats, Weapons, etc.
  - Medium Fidelity, Full Battle Environment
- **Vehicle Integration Facility Simulator (VIF)**
  - Handling Qualities, Flight Controls
  - Single F-35, Vehicle Systems, U&S
  - High Fidelity, Own-ship Focused

- **Verification Simulation (VSIM)**
  - Contract Spec Verification, Mission Effectiveness, Performance Assessment, Flight Test Rehearsal
  - Multiple F-35s, MICS, Threats, Weapons, OFP Re-host, etc.
  - High Fidelity, Full Battle Environment
- **Air Combat Simulation (ACS)**
  - Operational Test & Evaluation, Contract Spec Verification, Mission Effectiveness, Performance Assessment
  - Multiple F-35s, Hi Fi MICS, Hi Fi OTW, Threats, Weapons, OFP Re-host, etc.
  - High Fidelity, Full Battle Environment

Primary ACS/VSim Elements



DIADS / RTSAM / CGF



AWACS

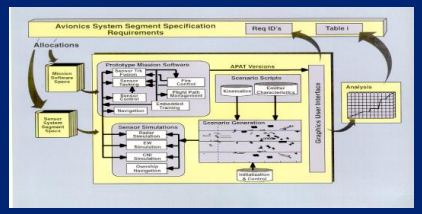
4 High Fidelity Cockpits

Pilot Briefing Rooms
- Playback
- Analysis

Control Room

8 Threat and Friendly Aircraft Control Stations

Viewing Room Video Wall

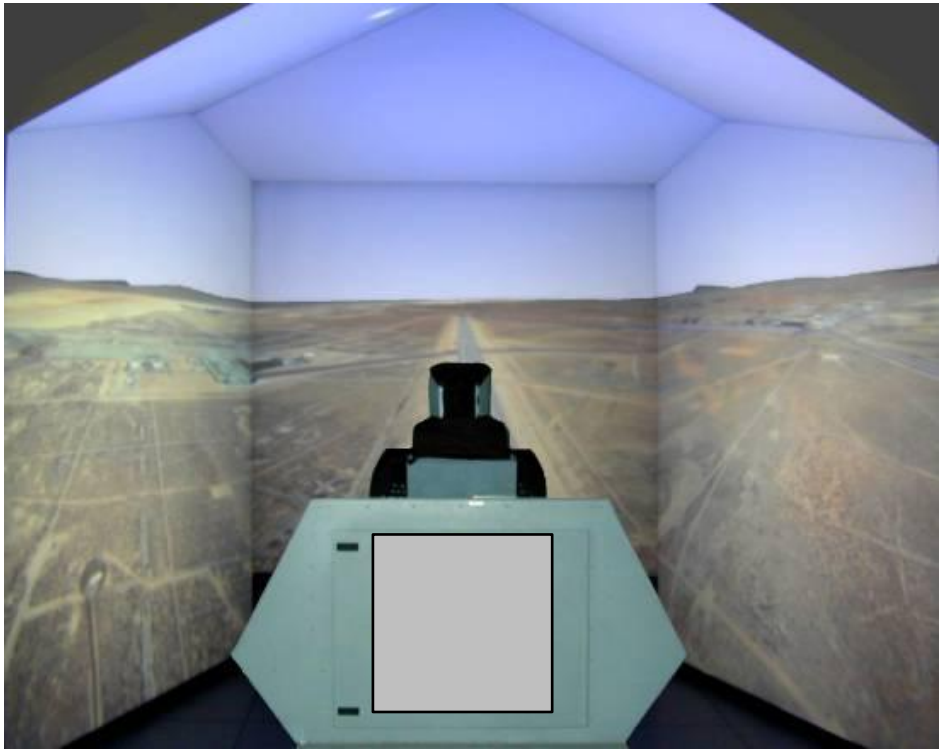


High Fidelity, Validated Models of Own-ship, Threats, Friendlies, Environ., Weapons, Grnd Entities, Networks, etc.

WASP Dome and MICS Visual Systems

WASP Dome Visuals

- 19 Projectors ea.
- Barco 908s and 808s Going to Rockwell Collins 2015s
- 1600 x 1200 Going to 2048 x 1536
- IGs: Q3D IDX 4000s



MICS Dome Visuals

- 4 Projectors ea.
- Barco Sim6s Going to Sim7s
- 1600 x 1200 Going to 2048 x 1536
- IGs: PCs & Mantis

VSIM F-35 Own-ship Simulation

All Models Verified and Validated

Handling Qualities Level Models For Airframe, Flight Control Systems and Propulsion System

Mission Systems Integrated Core Processor (ICP) Re-hosted OFPs

Comm/Nav and Datalink Models

Simulator HMDS

Vendor-Supplied High Fidelity Sensor Models

Simulated Malfunctions

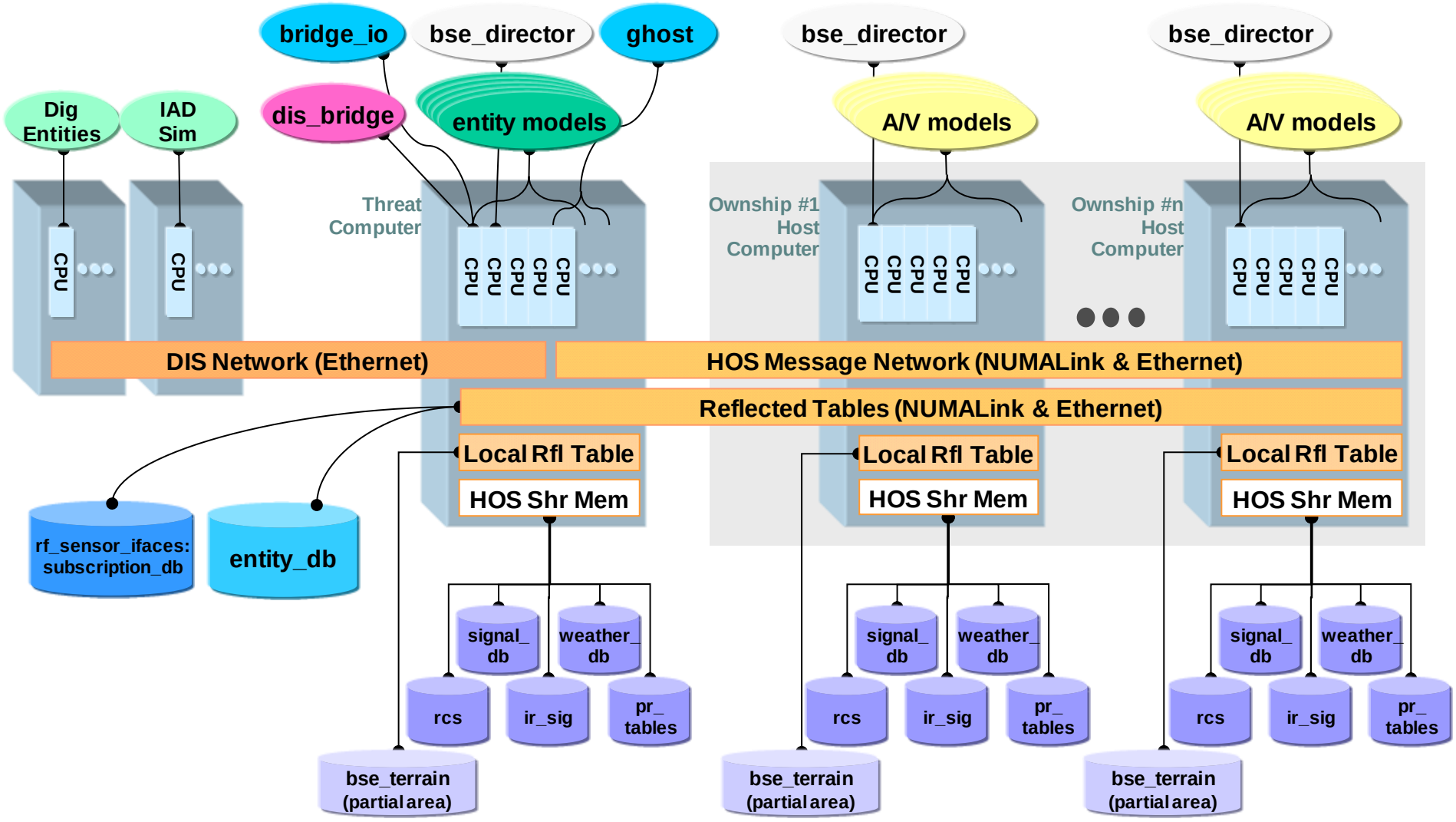
High Fidelity Weapons Models

Realistic Signature Models (All Three Variants)

Stores and Expendable Models

Mission Systems Panoramic Cockpit Display (PCD) and PVI via Computer Re-hosted OFPs

Battle Space Environment Simulation
Top Level System Architecture



Systems Integration Labs

Vehicle Systems Simulators

VIF Motion Base Simulator

VIF Cockpit w/SEOS Visuals

VIF Fixed Base Simulator

M&S Used to Develop and Test:

- Vehicle Systems Design
- Handling Qualities
- Flight Control Laws
- Vehicle Systems OFP
- Man-Machine Integration

VIF Motion Base Control Room

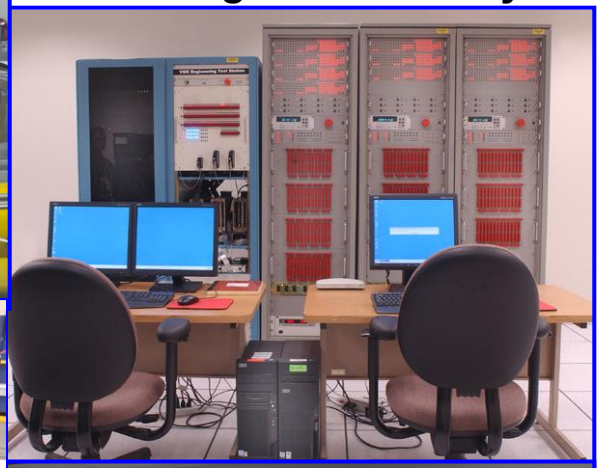
VIF Fixed Base Control Room

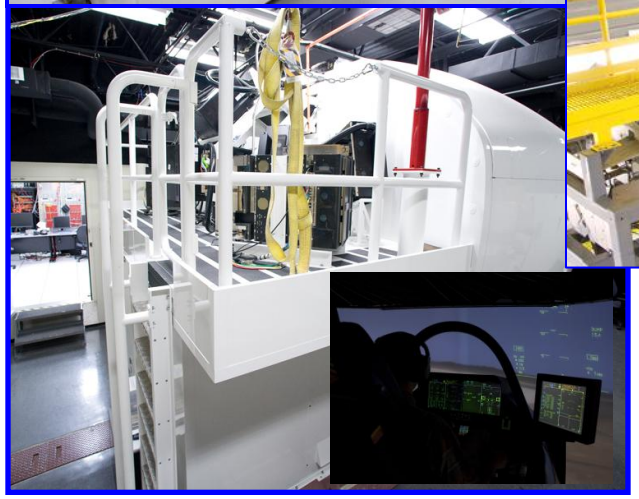
Vehicle Systems Integration Lab

Control Surface H/W and Dynamic Loads

Electrical Power Lab

Utilities & Subsystems Integration Facility





Hydraulics Integration Facility

M&S Used to Integrate and V&V:

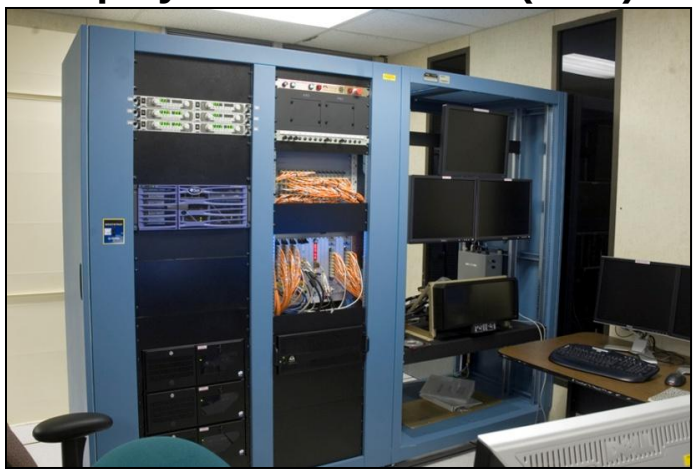
- Vehicle Management Computer
- Flight Controls
- Propulsion Systems
- Utilities and Subsystems
- Hydraulics and Electrical Power
- Overall Vehicle Systems

Pilot In the Loop Cockpit/Visual

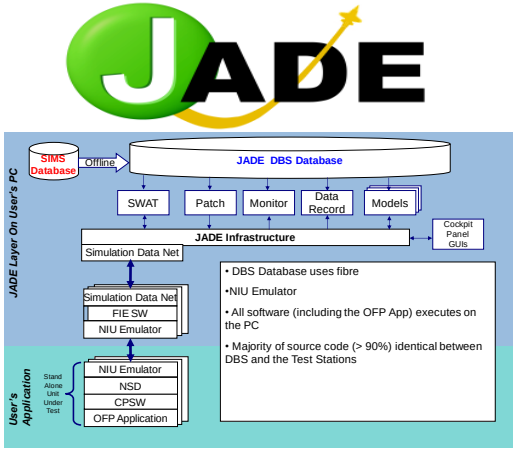
Propulsion System FADECs

Mission Systems Domain Development & Integration Labs

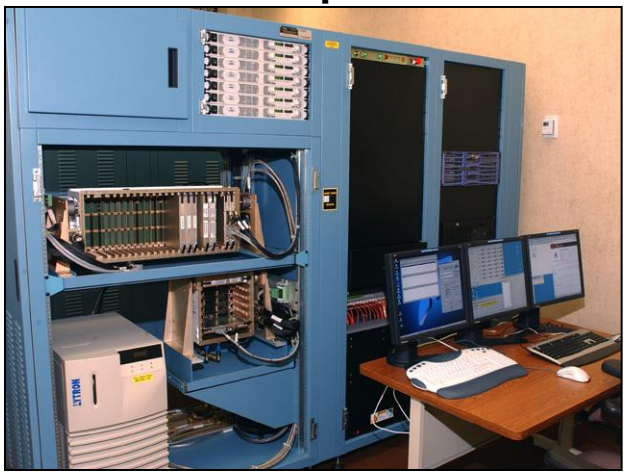
Display Domain Station (DDS)



JSF Avionics Development Environment



ICP O/S Development Station

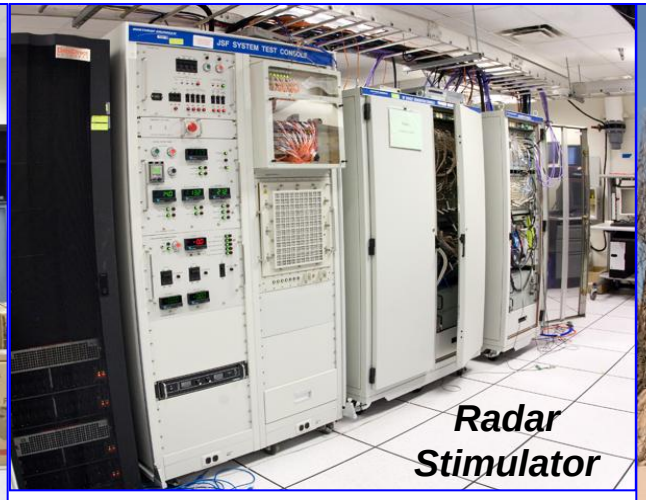


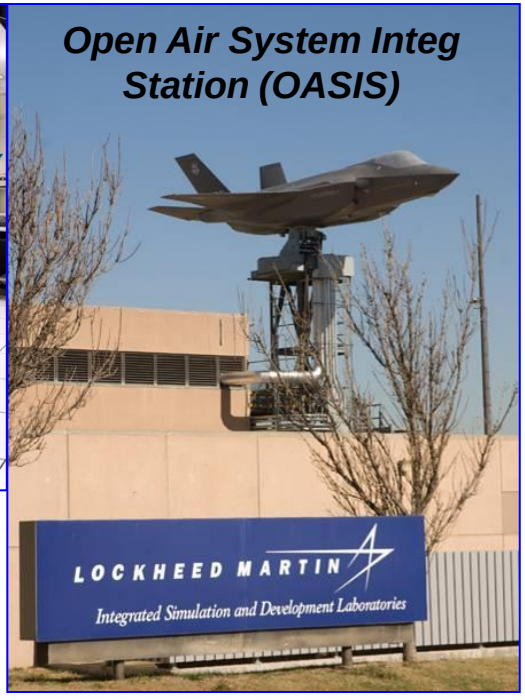
Simulation-Based System Integration Station (SimSIS)

M&S Used to Develop, Integ, & Test:

- Integrated Common Processor (ICP)
- Mission Systems OFP
- Display Management Computer (DMC)
- Display Software
- MS and VS S/W Integration

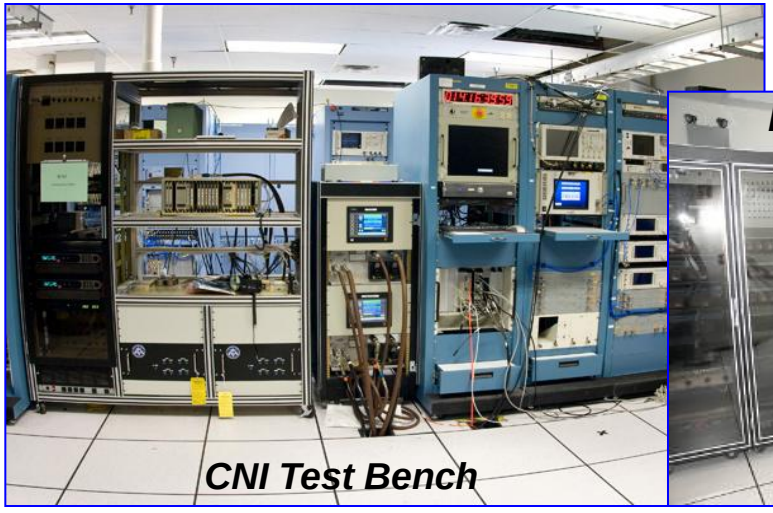
Mission Systems Integration Lab

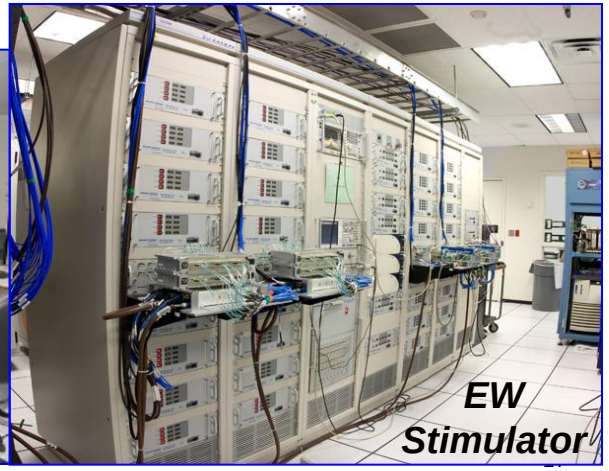




M&S Used to Integrate and V&V:

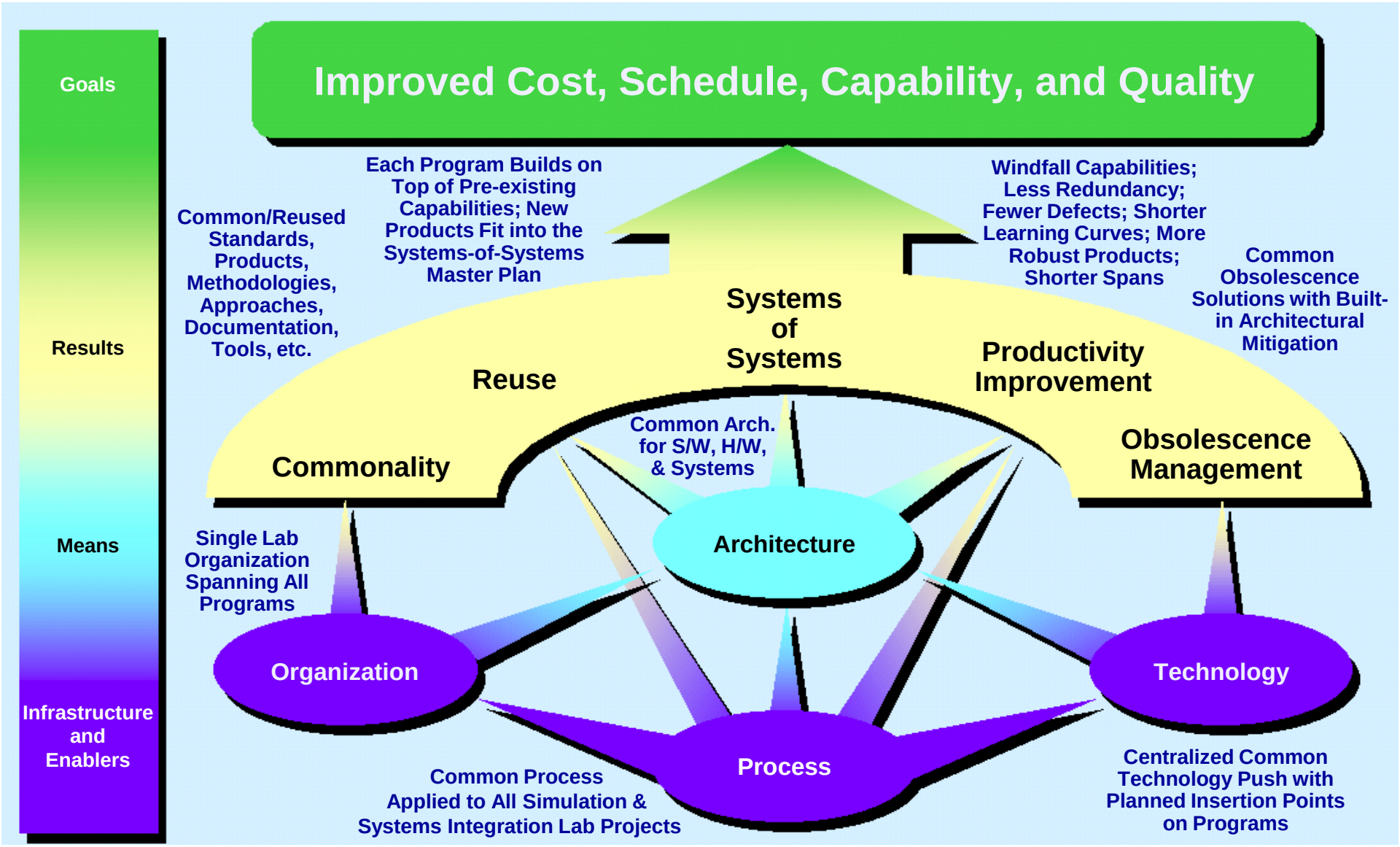
- Integrated Common Processor (ICP)
- Mission Systems OFP
- Sensor Hardware
- Sensor Processing
- Fire Control & Stores





Simulation Laboratories Approach for Leveraging Commonality and Reuse

Laboratory Vision for Commonality and Reuse



Some Specific Commonality & Reuse Initiatives

- Processes and Methodologies
- Technical Standards
- Development Environment & Tools
- Common Operating Real-time Environment (CORE)
- Battle Space Environment (BSE)
- Multiple Specific Model Reuse Plans
- Two Distinct, but Compatible Standardized Model Suites
  - One for High Fidelity
  - One for Lo/Med Fidelity
- Computer Systems Architecture
- CGI Systems
- Multi-Spectral Databases
- Central Boot and Storage Systems (CBASS)
- Network Architecture and Topology
- Audio/Video Data Recording and Analysis

Lockheed Martin Aeronautics Simulation: Approaching Reality