2008 Technical Maturity Conference

Technology Transition on the C-17 Aircraft

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Technology Development

- Technology development done at various places:
  - Government labs (e.g. – Air Force Research Laboratory)
  - Aircraft manufacturer labs (e.g. – Boeing Phantom Works)
  - Independent labs
  - Universities
- Special interests drive technology development:
  - Better performance (higher, faster, lighter, etc.)
  - Lower cost (manufacturing and operating)
  - Higher reliability
  - Longer life
  - Etc.

Technology Transition Challenges

- Technology must "buy" its way onto the system
  - New materials, manufacturing methods, etc. need to be competitive with current products
  - Technology should offer a benefit to the customer (higher performance, less weight, reduced maintenance, higher reliability, etc.)
- Aircraft manufacturers want multiple, reliable, and low cost sources for production and sustainment
  - Risks must be taken by the manufacturers and operators to adopt unique materials, new technology, etc.
  - Technology must be manufacturable, producible, repairable, available, etc.

Technology Application

- Finding an appropriate *application* of new technology is just as important as developing and certifying the technology
  - Good technologies applied poorly will not be successful
  - Material and product form selection for structures is critical
- New structural / material technologies have historically been applied initially to tertiary or secondary structures
  - Gathering in-service performance is highly desirable
  - Primary structure applications may follow if field experience is favorable
- New applications should have minimal impact to the customer

What to Transition

- Plenty of screening and readiness assessment tools are available
- All tools try to answer the following questions:
  - How much will this save?
  - When will it be ready for production?
  - What are the risks?
  - Is this the best option?
  - How to prioritize?

What "sieve" do we pass potential technologies through to answer these questions?

Transition Tools

- Technology Transition Tools:
  - Technology/Manufacturing Readiness Levels (TRLs/MRLs)
  - Technology/Manufacturing Readiness Assessments (TRAs/MRAs)
- TRLs provide a common standard for:
  - Assessing the ***performance maturity*** of a technology and plans for its future maturation
  - Understanding the level of ***performance risk*** in trying to transition the technology into a weapon system application
- MRLs are a common language and standard for:
  - Assessing the ***manufacturing maturity*** of a technology or product and plans for its future maturation
  - Understanding the level of ***manufacturing risk*** in trying to produce a weapon system or transition the technology into a weapon system application

Systems Engineering Approach

1. Who is your customer(s)? How are you involving them in the program?
2. What are customers specific/comprehensive requirements? What must you achieve to make the program viable? (Exit Criteria)
3. How will you demonstrate you have met the requirements?
4. What are the technology options to respond to the requirements and what is the best approach? Why?
5. What are the risks to developing the selected technology?
6. How will you structure your program to meet requirements (Exit Criteria) and account for risk? Have you coordinated all key aspects with your customer?
7. What is the business case for transitioning this technology. Are you collecting the needed info. What is your transition strategy? Do your business/transition plans have customer approval?

Andy's 6 "Magic" Questions

- How much does this technology improve performance?
- Is there a Strategic Need for this?
- Is it applicable to other areas?
- When will it REALLY be ready for use?
- When can I REALLY get it "on the jet?"
- What is the TOTAL cost/benefit?

Notional Cost Benefit Matrix

	Factory		Field	
	COST	SAVINGS	COST	SAVINGS
Contractor Lab	X			
Government Lab	X			
Program Office / Customer			X	X
Supplier	X			
Manufacturer (OEM)	X	X		
Total	X	X	X	X

“The Question”

- A laboratory has developed a new technology…
  - Readiness tools have been used to the maximum extent:
    - Technology is mature – TRL=7
    - Manufacturers are ready – MRL=7/8
- Designers have found a great application…
- The technology is cheaper to build in the factory…
- The customer wants the technology…
- So…

Why can’t we just build it and put it on the airplane???

“The Standoff”

Technology Development and Maturity

Technology Transition

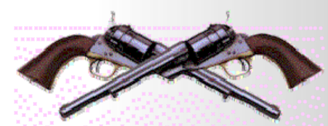
Technology Implementation and Certification

Laboratories

Program Offices

TRL=7

TRL=8



A “standoff” exists between the laboratories and the program offices in order to move from TRL=7 to TRL=8

Implementation and Certification

Technology Implementation and Certification

Program Offices

Implementation – the non-recurring engineering to get it on the jet

Certification – the tasks required to ensure that it is airworthy

Technology Implementation

- Implementation of technology requires a non-recurring investment to “get it on the airplane”
- Non-recurring effort can be large:
  - Drawing changes (paper and electronic)
  - Model updates (finite element, thermal, etc.)
  - Material, processing, and fabrication specifications
  - Updates to technical and maintenance manuals
  - Manufacturing tooling
  - Shop floor training

Understanding non-recurring cost investment is critical

Airworthiness Certification

- Airworthiness Certification
  - A repeatable process implemented to verify that a specific air vehicle system can be, or has been, safely maintained and operated within its described flight envelope.
- USAF and USN use MIL-HDBK-516 "Airworthiness Certification Criteria"
  - Describes the certification process and provides criteria to assess the degree of airworthiness
  - Covers all airframe, aircraft systems, avionics, etc.
  - Tailored by weapon system
- FAA use the Federal Aviation Regulations (FARs)
  - Parts 21 through 49 for aircraft

Certification Impacts

- Cost and schedule impacts for certification need to be understood
  - Communications with certification agency are mandatory to determine requirements
  - Need to understand specific requirements: documentation, build records, material certifications, etc.
  - Additional analysis, testing, qualifications, etc. may be required by the certification agency to prove airworthiness

Understanding the certification requirements is key to successful technology transitions

C-17 Technology Transition and Projects

- Address technology transition process
- Provide examples of successful and not so successful airframe technology projects on the Boeing C-17 Globemaster III aircraft
- Show customer needs and the impacts of the non-recurring and certification effort

C-17 Technology Planning Process

Capability Focus Areas

Precise Delivery
Survivability
Efficient Operations
Reduce Life Cycle Cost

Capability Roadmaps

STRATEGIC CAPABILITY NEED	PRODUCTS / SERVICES: 2006-2008	PRODUCTS / SERVICES: 2009 & BEYOND
PRECISE DELIVERY	Precision Airdrop	Autonomous Landing Operations
SURVIVABILITY	Improved Crew Armor; Advanced Situational Awareness; Defensive Systems	Counter Measures; ASACM Integration; Oxygen Sensors
EFFICIENT OPERATIONS	Airborne Networking; Lab Modernization	Database Management System; Airborne Aircraft Carrier; LRU Obsolescence; Civil Aviation Rqmts.
REDUCE LIFE CYCLE COST	Material Improvements	CBM+/ ISHM/; FCC Diagnostics; Smart Sensors; Smart Actuators
EFFICIENT SUSTAINMENT (under construction)		UID / RFID; ITEMs; JTAV; AIT; PMAs; FDA; Others

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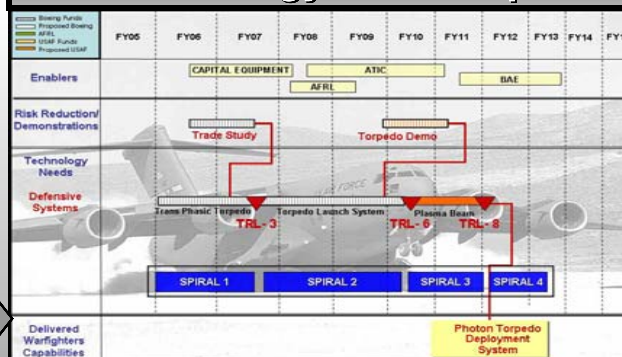
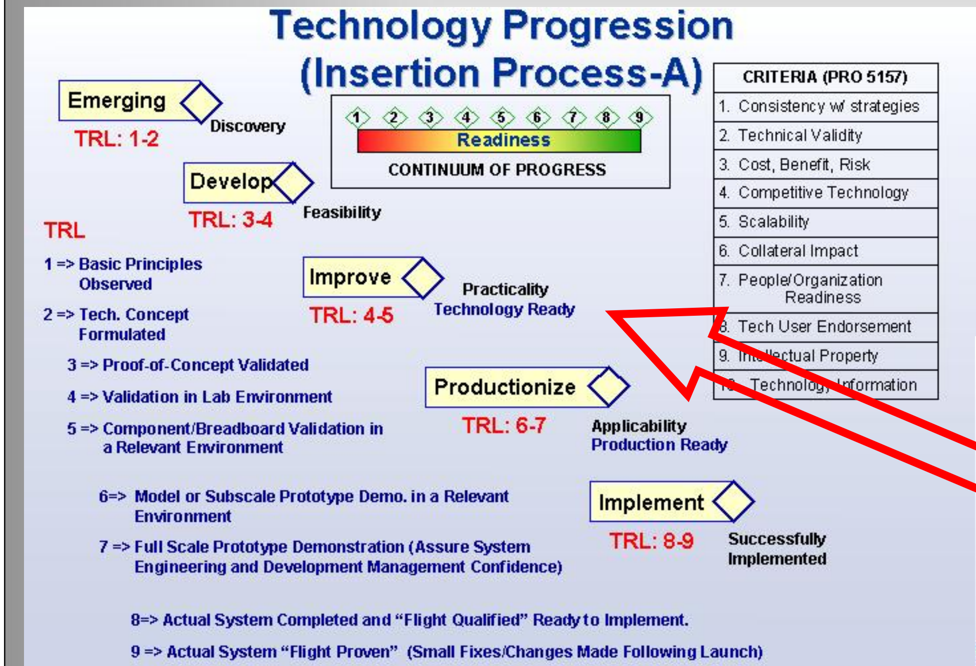
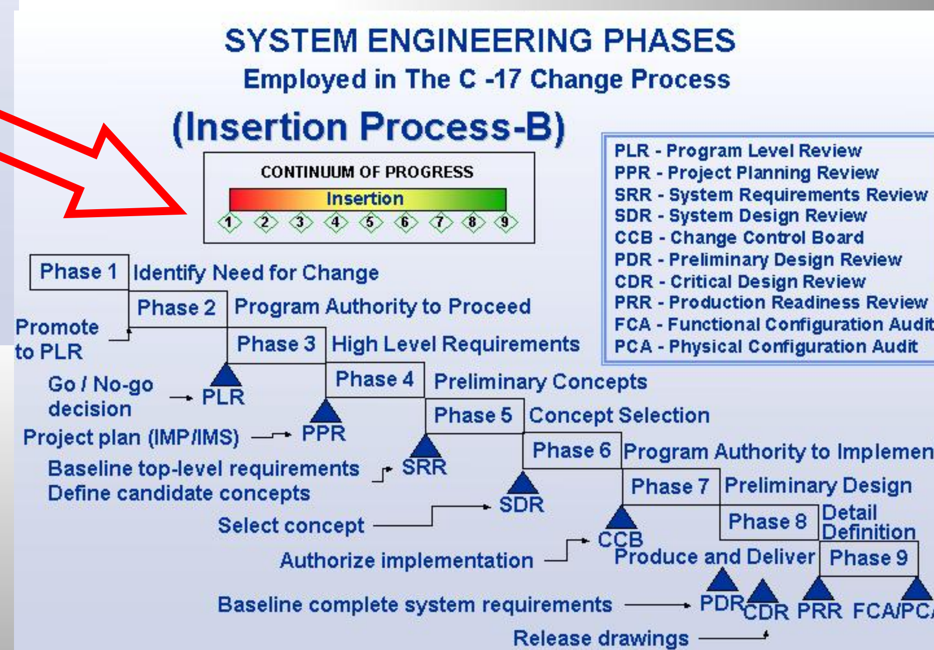
Technology Roadmaps



Closing the Gap Between Dev. & Prod.



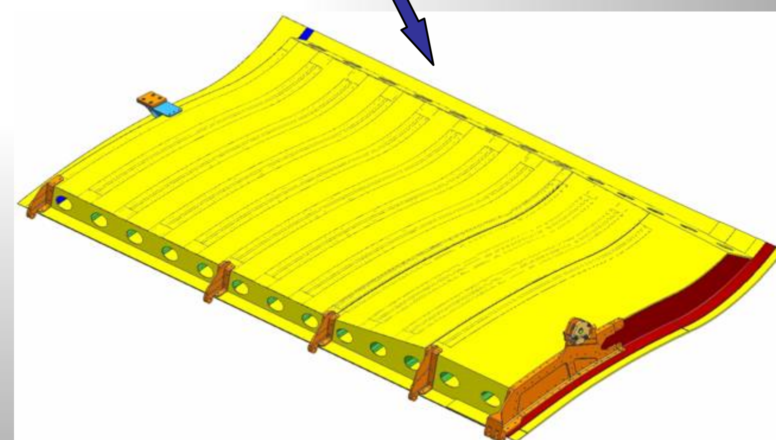
Production



Development

Success: SRI MLG Doors

- Stitched/Resin Infused (S/RI) Composite Main Landing Gear (MLG) Doors
  - Resolved production issues with door loft and preload
  - Customer benefit – higher resistance to runway debris
  - Weight neutral
  - Non-recurring costs significant - covered by multiple parties
  - Secondary structure
  - Certification by analysis and similarity

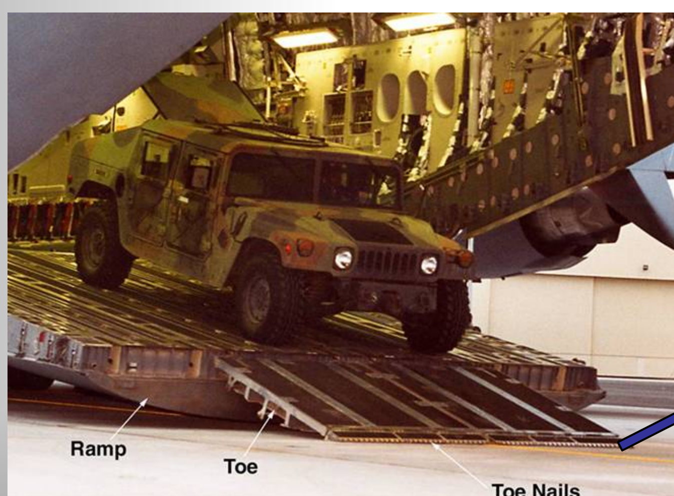


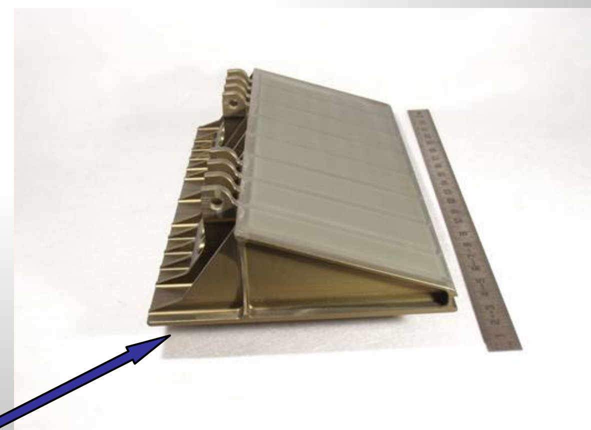
Success: Monolithic Frames

- Monolithic Machined Aluminum Fuselage Bulkheads and Frames
  - Reduced manufacturing cost, part inventory, and assembly labor
  - Reduced weight
  - No impacts to customer
  - Primary structure – certification effort significant
  - All non-recurring costs including certification covered by recurring production savings

Success: FSW Ramp Toe Nails

- Friction Stir Welded (FSW) Titanium Ramp Toe Nails
  - Reduced production and spares costs
  - Saved weight
  - Non-recurring costs covered by recurring production savings
  - Certification costs minimized by application to tertiary structure





Success: Cast Pylon Nose Cap

- Cast Titanium Pylon Nosecap
  - Thin walled titanium casting replaced complex built-up structure
  - Original design costly to manufacture
  - No impact to customer
  - Non-recurring costs covered by recurring savings
  - Certification costs small - secondary structure

Success: Nacelle Strakes

- Foam Core Nacelle Strake
  - Construction changed from honeycomb to foam core
  - Saved material and machining costs
  - No impacts to customer
  - Tertiary structure - non-recurring and certification costs small

Limited Success: ARALL Cargo Door

- Aramid Reinforced Aluminum Laminate (ARALL) Door Skin
  - Original design - used on cargo door skins for first 40 aircraft
  - Raw material and manufacturing costs were high - complex joining required due to limited panel widths
  - Replaced with sheet aluminum for cost savings
  - No customer impacts
  - Secondary structure
  - Non-recurring and certification costs covered by recurring production savings

Limited Success: Al Li Fuselage Parts

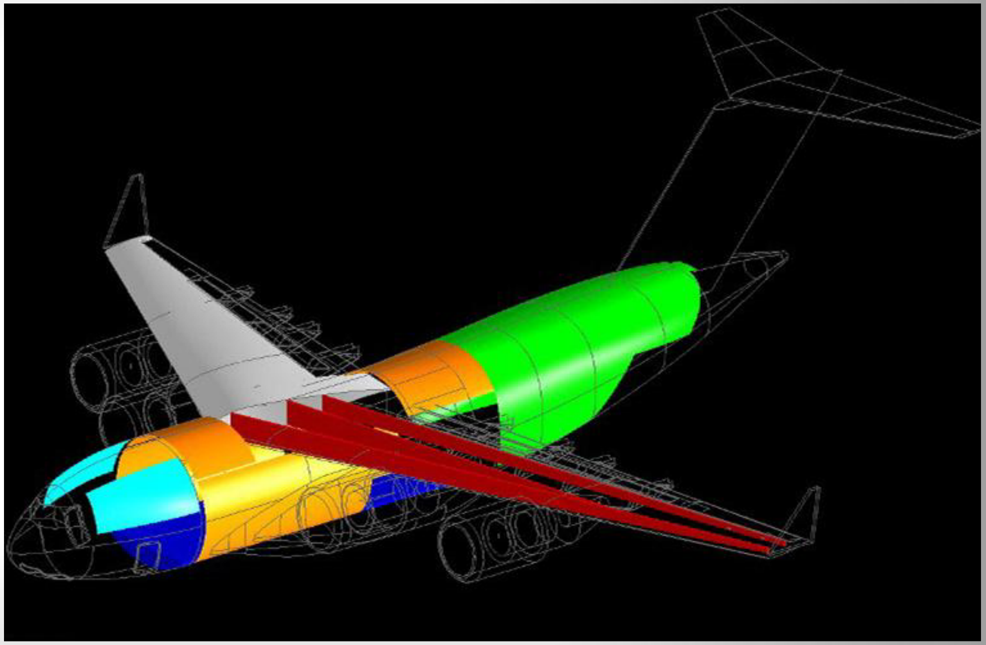
- Aluminum Lithium Cargo Floor and Fuselage Stringers
  - Difficulties with manufacturability (warpage and machining) and toxicity issues (chips and dust)
  - Changed to aluminum alloy for cost savings
  - Manufacturing challenges outweighed weight savings
  - Primary structure
  - Non-recurring and certification costs covered by recurring production savings

Limited Success: LAM Pylon Skins

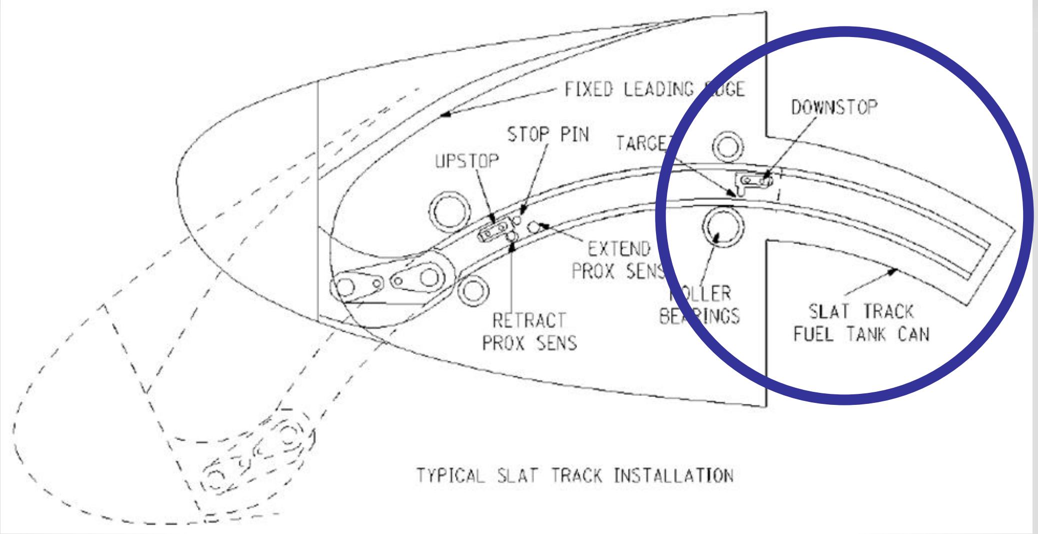
- Laser Additive Manufacturing (LAM) Engine Pylon Sidewalls
  - Saved material and machining costs
  - Vendor decided to drop production for business reasons - built only 5 shipsets
  - Primary structure – large certification effort
  - Non-recurring and certification costs were to be amortized over production run

Unsuccessful: Machined Spars

- Machined Front and Rear Wing Spars
  - Spar caps integral to web in lieu of mechanically fastened caps – machine from thick aluminum plate
  - Non-recurring costs likely paid by production savings
  - Certification costs prohibitive – materials testing plus full scale static and durability tests of wing would have likely been required



Unsuccessful: Slat Track Cans



- Slat Track Can
  - Design change to save material and assembly costs
  - Impact to user – required separate spares and technical data
  - Minimal non-recurring cost
  - Secondary structure - certification by analysis and similarity

Conclusions and Recommendations

- Foster communication between technology developers and technology implementers
- Search for appropriate applications of technology
- Understand customer requirements and constraints
- Don’t rely 100% on technology readiness tools
- Understand requirements of the certification agency
- Develop realistic cost estimates for non-recurring and certification efforts
- Technology has a higher probability of transitioning early in a program so that non-recurring costs can be amortized over the production run