# Accelerated Insertion of Materials – Industrial Perspectives on Polymer Matrix Composites

## Composites at Lake Louise
## Structural Composites Keynote Address


**Gail Hahn, Boeing**
**Phantom Works**
**314-233-1848**
**gail.l.hahn@boeing.com**

# Acknowledgements

**Jointly accomplished by a Boeing Led Team and the U.S. Government under the guidance of the Office of Naval Aviation Systems Technology**

**Work funded by DARPA/DSO and administered by NAST through TIA N00421-01-3-0098 (Feb 01 – Feb 04)**

**With thanks for the support of Dr. Steve Wax and Dr. Leo Christodoulou of DARPA/DSO**

**Also:**
**Gail Hahn (PM), Charley Saff (DPM), & Karl Nelson (DPM) - Boeing Corp.**

**AIM-C Team - Boeing (St. Louis, Seattle, Canoga Park, Philadelphia), Northrop Grumman, Materials Sciences Corporation, Convergent Manufacturing Technologies, Cytec Fiberite, Inc, Massachusetts Institute of Technology, Stanford & NASA (Langley)**

# AIM-C Alignment Tool

***The objective of the AIM-C Program is to provide concepts, an approach, and tools that can accelerate the insertion of composite materials into DoD systems.***

## AIM-C Will Accomplish This Three Ways

**Methodology** - *We will evaluate the historical roadblocks to effective implementation of composites and offer a process or protocol to eliminate these roadblocks and a strategy to expand the use of the systems and processes developed.*

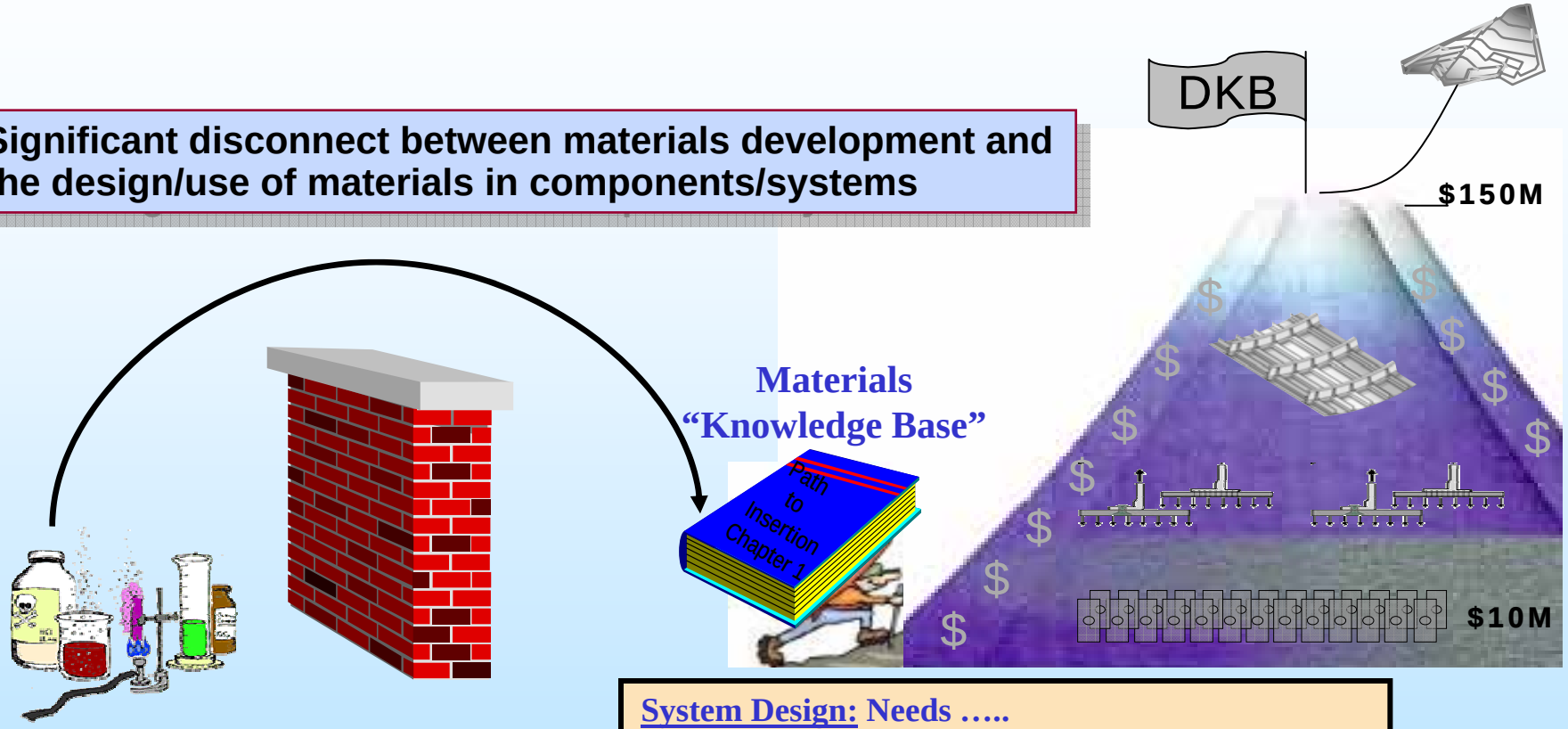
**Product Development** - *We will develop a software tool, resident and accessible through the Internet that will allow rapid evaluation of composite materials for various applications.*

**Demonstration/Validation** - *We will provide a mechanism for acceptance by primary users of the system and validation by those responsible for certification of the applications in which the new materials may be used.*

**Tasks in Phase 1 are directed toward Transition.**

# Technical Motivation

**Significant disconnect between materials development and the design/use of materials in components/systems**




**Materials Development**

- Highly Empirical
- Testing Independent of Use
- Existing Models Unlinked
- No Link to Designer Needs

**System Design:** Needs …..
Materials "Knowledge Base" & Confidence In

- Validation of Critical Properties
- Scale-up of Design and Process(es)
- Manufacture of Parts and Components
- Assessment of Costs
- Predictable Reliability and Life Expectancy

To Establish a Designer Knowledge Base (DKB)
… In a Fixed Insertion Window of Time

# DESIGN TEAM'S NEEDS
## Requirements are Multi-Disciplined

### Structural

- Strength and Stiffness
- Weight
- Service Environment
  - Temperature
  - Moisture
  - Acoustic
  - Chemical
- Fatigue and Corrosion Resistant
- Loads & Allowables
- Certification

### Manufacturing

- Recurring Cost, Cycle Time, and Quality
- Use Common Mfg. Equipment and Tooling
- Process Control
- Inspectable
- Machinable
- Automatable
- Impact on Assembly

### Supportability

- O&S Cost and Readiness
- Damage Tolerance
- Inspectable on Aircraft
- Repairable
- Maintainable
  - Accessibility
  - Depaint/Repaint
  - Reseal
  - Corrosion Removal
- Logistical Impact

### Material & Processes

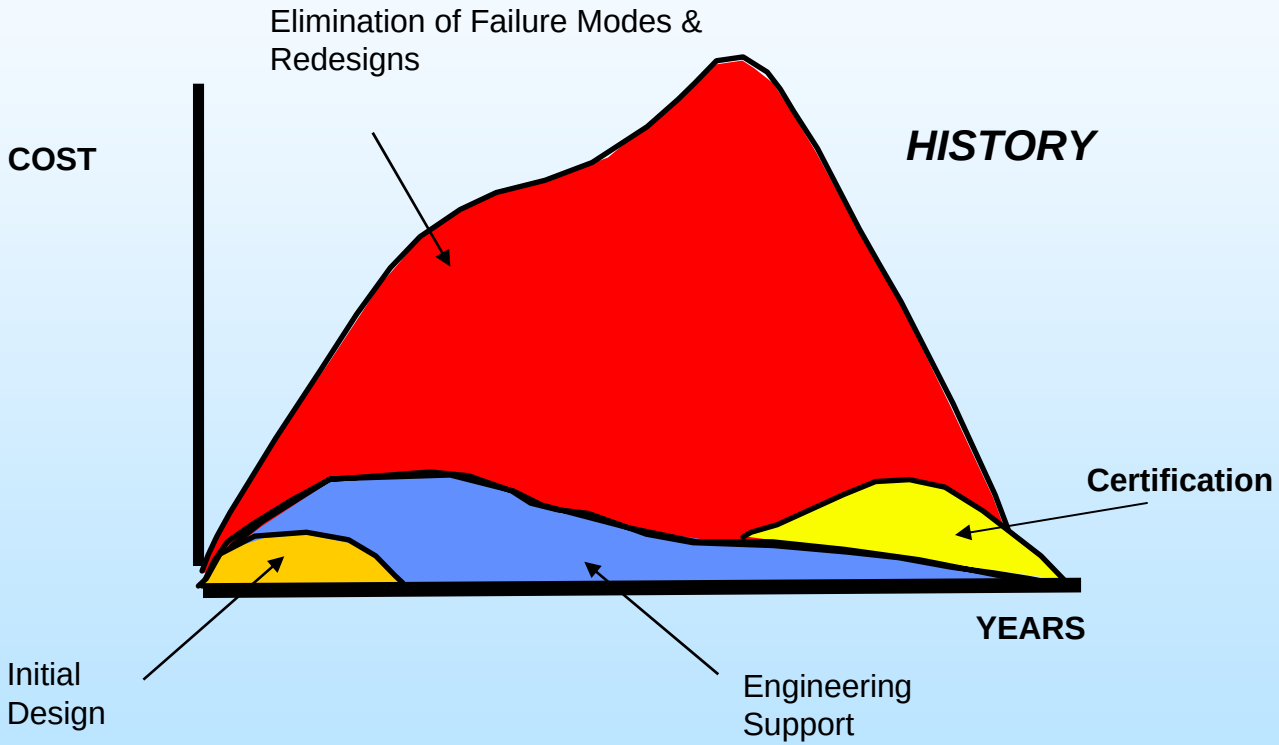
- Development Cost
- Feasible Processing Temperature and Pressure
- Process Limitations
- Safety/Environmental Impact
- Useful Product Forms
- Raw Material Cost
- Availability
- Consistency

### Miscellaneous

- Observables
- EMI/Lightning Strike
- Supplier Base
- Applications History
- Certification Status
  - USN
  - USAF
  - ARMY
  - FAA

# Background: What is the Issue?

**Often, our development time and money is spent on fixing problems because we were not correct with the material, process or design characterization.**



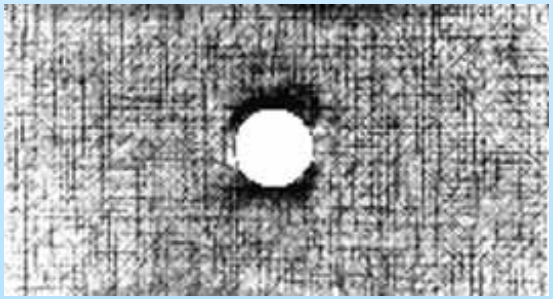

**Development Cycle for a Typical Hardware Insertion**

**Implications of the current scenario:**

**Risk Adversity – Stay with known materials and concepts**

# Among the Top Problems to Accelerated Insertion:

**Scale Up**
**End of Life Properties**
**Part Geometry**
**Unplanned Rework**
**Transition, Support Knowledge**



# What is AIM-C?

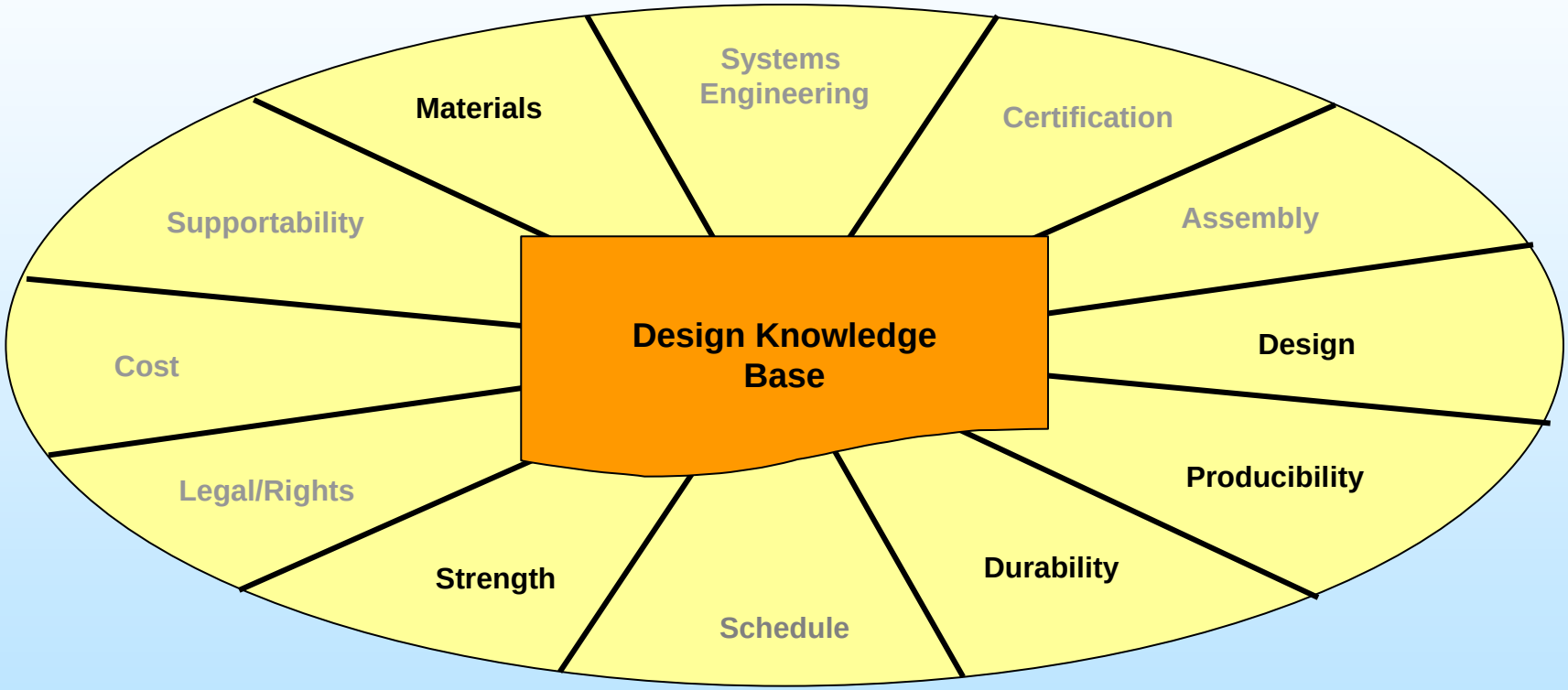
**AIM-C is a methodology for accelerated insertion of materials into defense structures at reduced costs.**

**This methodology develops a design knowledge database that links what is known about a material system to what is needed in order to qualify its application to an application that meets certification requirements**

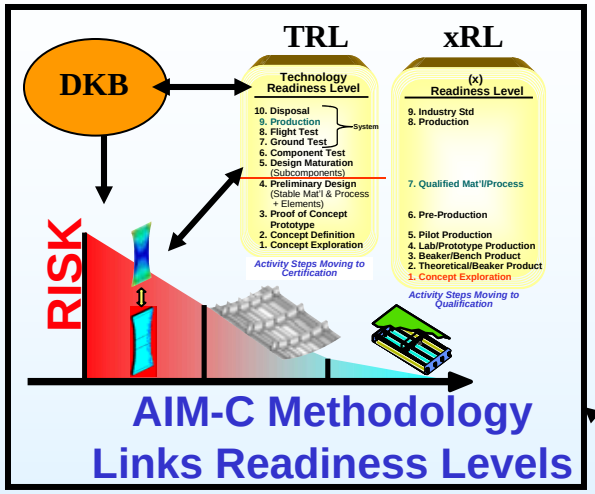
**It allows rapid identification of which applications are too risky and which are not.**

**It uses verified analysis methods, existing test data, and lessons learned from previous experience to minimize the amount of data required to insert new materials into a system with confidence**

# The AIM-C System Uses the Integrated Product Definition Process to Produce the Design Knowledge Base

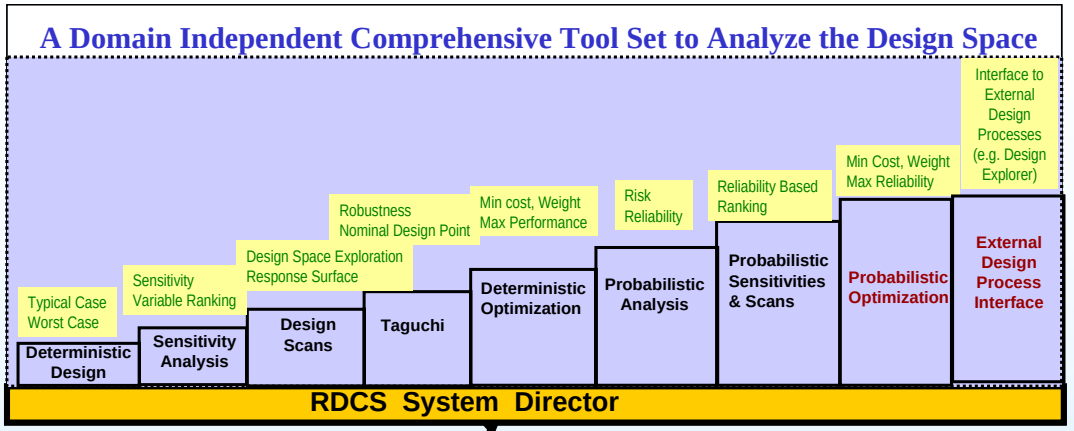



**Each function contributes and receives knowledge**




AIM-C Methodology Links Readiness Levels

## Assessment

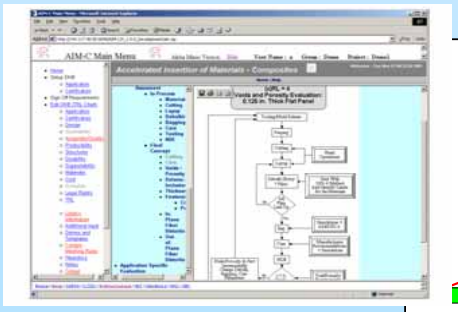


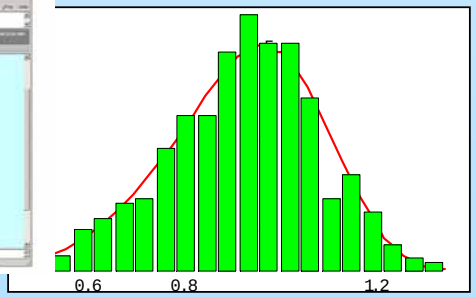

## Computational Tools

# The AIM-C Methodology

## Knowledge Management & Feature Based Studies

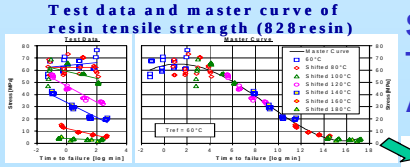
Encoded Heuristics

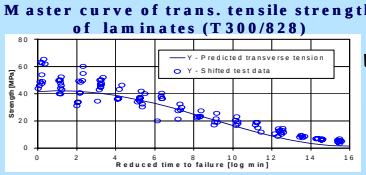




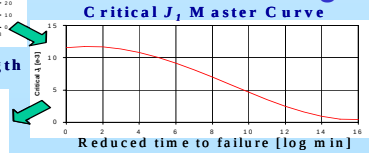

Producibility

## Analysis and Test




Strain Invariant Failure Theory Coupled with Accelerated Testing




BOEING

Approved for Public Release, Distribution Unlimited

AIM Accelerated Insertion of Materials

# Assessment: Thorough Consideration of Each Category

Application
Certification
Materials
Producibility
  Processing/Fabrication
Structures
Durability

Supportability
Design
Intellectual Rights/Legal
Cost
Schedule
Assembly

# Assessment: Technology Readiness Levels

## • Defining all the Questions and Measuring Progress

| TRL | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Application Risk | Very High | High | High - Med | Med - High | Medium | Med - Low | Low | Low - Very Low |
| Application Maturity | | Concept Defintion | Proof of Concept | Preliminary Design | Design Maturation | Component Testing | Ground Test | Flight Test |
| Certification | Certification Requirements Documented | Certification Plan Documented | Certification Plan Approved | Preliminary Design Allowables | Subcomponent Testing | Full Scale Component Testing | Full Scale Airframe Tests | Flight Test |
| Design | Concept Exploration/ Potenital Benefits Predicted | Concept Defintion/ Applications Revised by Lamina Data (Coupons) | Applications Revised by Laminate Data (Coupons)/ Design Closure | Applications Revised by Assy Detail Test Data (Elements)/ Preliminary Design | Applications Revised by Subcompnent Test Data/ Design Maturation | Applications Revised by Component Test Data/ Ground Test Plan | Applications Revised by Airframe Ground Tests/ Flight Test Plan | Production Plan |
| Assembly Concept | Assembly Definition | Assembly Plan | Key Assembly Detail Defintions | Key Assembly Details Tested | Subcomponents Assembled | Components Assembled | Airframe Assembled | Flight Vehicles Assembled |
| Structures Maturity | Preliminary Properties-Characteristics | Initial Properties Verified by Test | Design Properties Developed | Preliminary Design Allowables | B-Basis Design Allowables | A-Basis Design Allowables | | |
| Materials Maturity | Lab-Prototype Materials | Pilot Production Materials | Pre-Production Materials | Production Materials/ Material Specs | | | EMD Material Supplied | LRIP Material Supplied |
| Fabrication Maturity | Unfeatured-Panel Fabrication | Feature Based Generic Small/Subscale Parts Fabricated | Property-Fab Relationships Tested/ Target Application Pilot Production of Generic Full Size Parts | Process Specs/ Effects of Fab Variations Tested/ Elements Fab'd/ Production Representative Parts Fab'd | Subcompnents Fab'd | Full Scale Components Fabricated | EMD Fabrication | Low Rate Initial Production (LRIP) |
| Cost Benefits Maturity | Cost Benefit Elements ID'd & Projected | ROM Cost Benefit Analysis | Cost Benefit Analysis Reflect Size Lessons Learned | Cost Benefit Analysis Reflect Element and Production Representative Part Lessons Learned | Cost Benefit Anlysis Reflect Subcomponent Fab & Assembly Lessons Learned | Cost Benefit Anlysis Reflect Component Fab & Assembly Lessons Learned | Cost Benefit Anlysis Reflect EMD Lessons Learned | Cost Benefit Anlysis Reflect LRIP Lessons Learned |
| Supportability | Repair Items/Areas Identified | Repair Materials & Processes Identified | Repair Materials & Processes Documented | Fab Repairs Identified | Fab Repair Trials/ Subcomponent Repairs | Component Repairs | Production Repairs Identified | Flight Qualified Repairs Documented |
| Intellectual Rights | Concept Documentation | Patent Disclosure Filed | Proprietary Rights Agreements | Data Sharing Rights | Vendor Agreements | Material and Fabrication Contracts | Production Rate Contracts | Vendor Requal Agreements |

**Concept Definition**
- **Application Definition, Loads, Environment**
- **Concept Refinement**

**Concept Definition/Applications Revised By Lamina Data**
- **Design/Geometry Parameter Studies**
- **Heuristics, Simulation, Test**

Assembly Concept
- Effect of Assembly on Performance
- Effects of Defects

Production Materials/Materials Specs
- Material Property Studies

Cost Benefit Elements ID'd And Projected
- Performance Data for Trades

Property-Fab Relationships Tested/ Target Application Pilot Production of Generic full Size Parts
- Effect of cure/tooling on Performance

**Preliminary Properties-Characteristics**
- **Analysis/Test-Generated Design Values**
- **Effects of variability**

**Approved for Public Release, Distribution Unlimited**

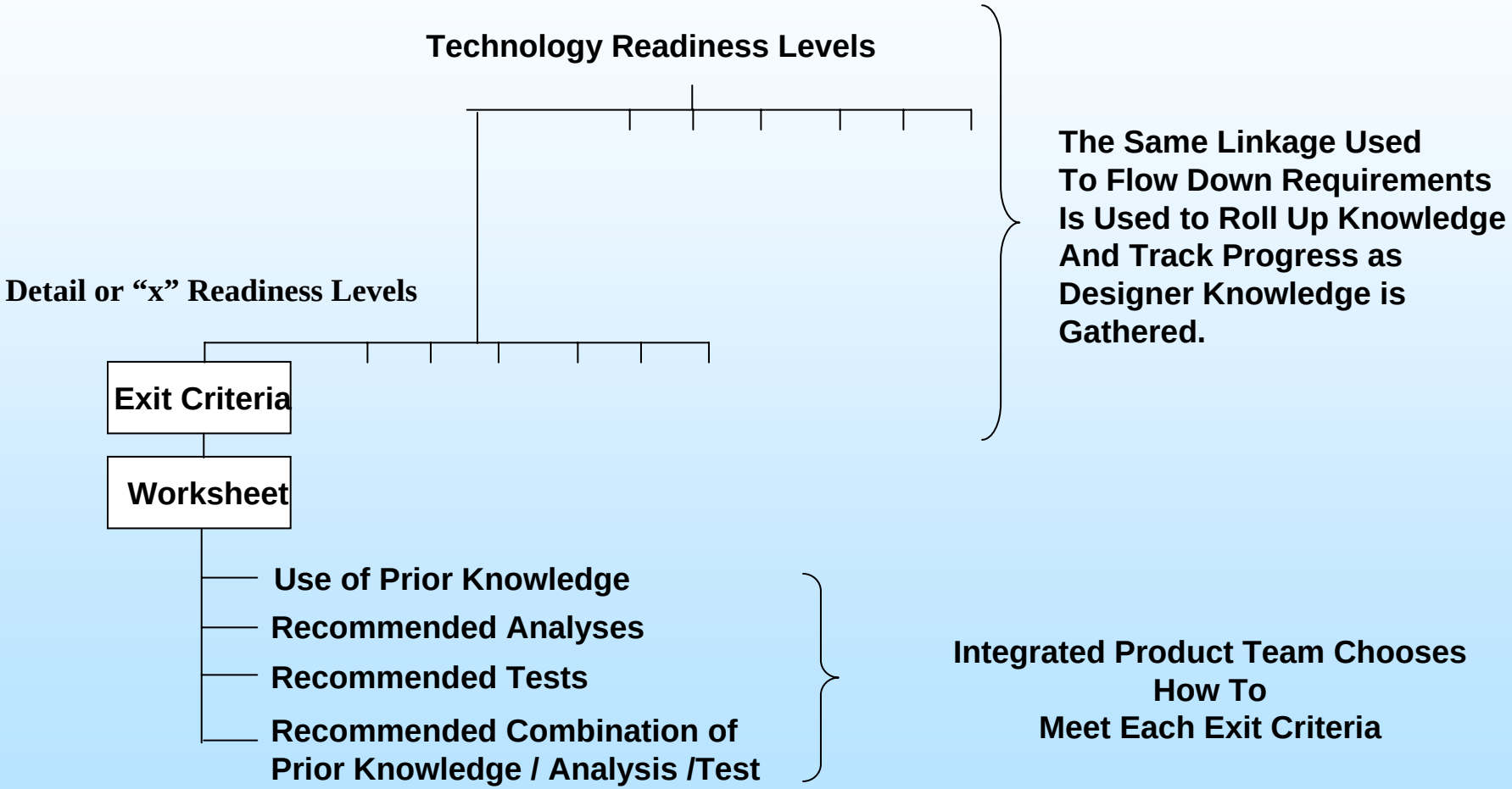
# Assessment: Tracking Conformance

## AIM-C Technology Readiness Summary

| Codes : | YES (done) | NO (not done) | In-Work | Problem | N/A |
|---|---|---|---|---|---|

| TRL | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| Application Risk | Very High | High | High - Med | Med - High | Medium | Med - Low | Low | Low - Very Low | Very Low | Negligible |
| Application Maturity | Concept Exploration | Concept Defintion | Proof of Concept | Preliminary Design | Design Maturation | Component Testing | Ground Test | Flight Test | Production | Recycle or Dispose |
| Certification | Certification Elements Documented | Certification Plan Documented | Certification Plan Approved | Preliminary Design Values | Subcomponent Testing | Full Scale Component Testing | Full Scale Airframe Tests | Flight Test | Production Approval | Disposal Plan Approval |
| Design | Concept Exploration/ Potenital Benefits Predicted | Concept Defintion/ Applications Revised by Lamina Data (Coupons) | Applications Revised by Laminate Data (Coupons)/ Design Closure | Applications Revised by Assy Detail Test Data (Elements)/ Preliminary Design | Applications Revised by Subcompnent Test Data/ Design Maturation | Applications Revised by Component Test Data/ Ground Test Plan | Applications Revised by Airframe Ground Tests/ Flight Test Plan | Production Plan | Production Support | Disposal Support |
| Assembly | Assembly Concept | Assembly Plan Defintion | Key Assembly Detail Defintions | Key Assembly Details Tested | Subcomponents Assembled | Components Assembled | Airframe Assembled | Flight Vehicles Assembled | Production | Disassembly for Disposal |
| Structures Maturity | Preliminary Properties-Characteristics | Initial Properties Verified by Test | Design Properties Developed | Preliminary Design Values | B-Basis Design Allowables | A-Basis Design Allowables | - | - | Flight Tracking/ Production Spport/ Fleet Support | Retirement for Cause |
| Materials Maturity | Lab-Prototype Materials | Pilot Production Materials | Pre-Production Materials | Production Materials/ Material Specs | - | - | EMD Material Supplied | LRIP Material Supplied | Production Material Supplied | Support for Recycle or Disposal Decisions |
| Fabrication Maturity | Unfeatured-Panel Fabrication | Feature Based Generic Small/Subscale Parts Fabricated | Property-Fab Relationships Tested/ Target Application Pilot Production of Generic Full Size Parts | Process Specs/ Effects of Fab Variations Tested/ Elements Fab'd/ Production Representative Parts Fab'd | Subcompnents Fab'd | Full Scale Components Fabricated | EMD Fabrication | Low Rate Initial Production (LRIP) | Production | Recycle or Disposal |
| Cost Benefits Maturity | Cost Benefit Elements ID'd & Projected | ROM Cost Benefit Analysis | Cost Benefit Analysis Reflect Size Lessons Learned | Cost Benefit Analysis Reflect Element and Production Representative Part Lessons Learned | Cost Benefit Anlysis Reflect Subcomponent Fab & Assembly Lessons Learned | Cost Benefit Anlysis Reflect Component Fab & Assembly Lessons Learned | Cost Benefit Anlysis Reflect EMD Lessons Learned | Cost Benefit Anlysis Reflect LRIP Lessons Learned | Cost Benefit Anlysis Reflect Production Lessons Learned | Cost Benefit Anlysis Reflect Disposal Lessons Learned |
| Supportability | Repair Items/Areas Identified | Repair Materials & Processes Identified | Repair Materials & Processes Documented | Fab Repairs Identified | Fab Repair Trials/ Subcomponent Repairs | Component Repairs | Production Repairs Identified | Flight Qualified Reapirs Documented | Repair-Replace Decisions | Support for Recycle or Disposal Decisions |
| Intellectual Rights | Concept Documentation | Patent Disclosure Filed | Proprietary Rights Agreements | Data Sharing Rights | Vendor Agreements | Material and Fabrication Contracts | Production Rate Contracts | Vendor Requal Agreements | Post-Production Agreemtns | Liability Termination Agreements |

# Assessment Becomes a Requirements Flow Down and a Completion Roll Up



# Assessment Summary