Air Force Materiel Command

Unitized Composite Manufacturing

Impacts on Cost Estimating

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Agenda

- Background
- Efforts to Date
  - Case in Point
  - An Analogy
- What's to Come
  - Example
- Cost Model
  - Application
  - Result
- Conclusion

Background

- **Unitization:** Forming into a single unit by combining parts into a whole – *Oxford Dictionary*
- **Composite:** made up of various parts or elements – *Oxford Dictionary*
- **Composite Material:**

Carbon-Fiber

Plastics

Plywood

Efforts to Date

- **Composites in airframe manufacturing:**

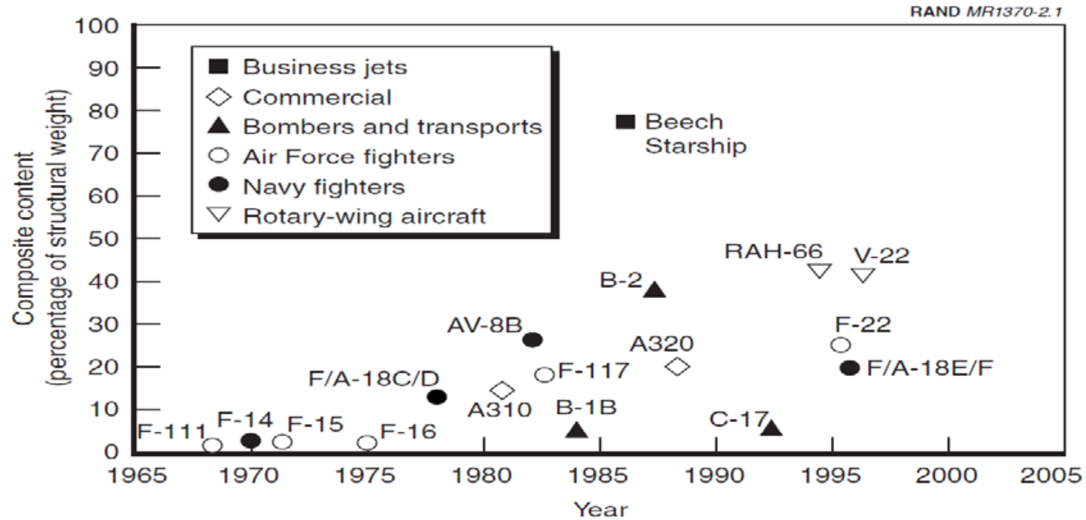
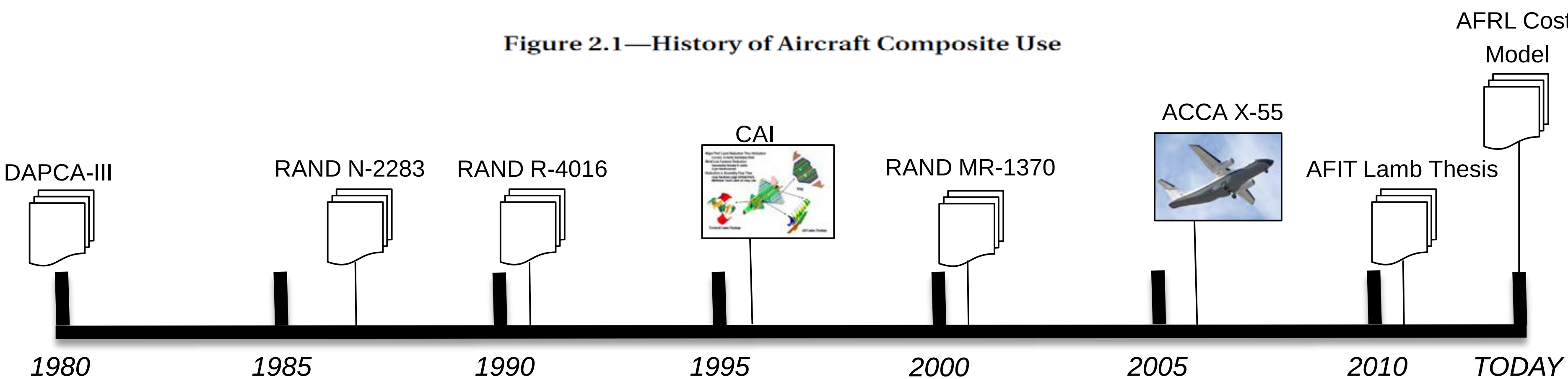


Figure 2.1—History of Aircraft Composite Use



History of Airframe Cost Estimating Models (not all inclusive)

Case in Point

"The use of composites in aircraft manufacturing will mean lighter, less expensive and more durable aircraft that also are easier to maintain. For example, the manufacturing process will require far fewer parts ..."

-Lockheed Martin

90% PART COUNT REDUCTION

An Analogy…

LEGO CREATOR ~ **100 PARTS**

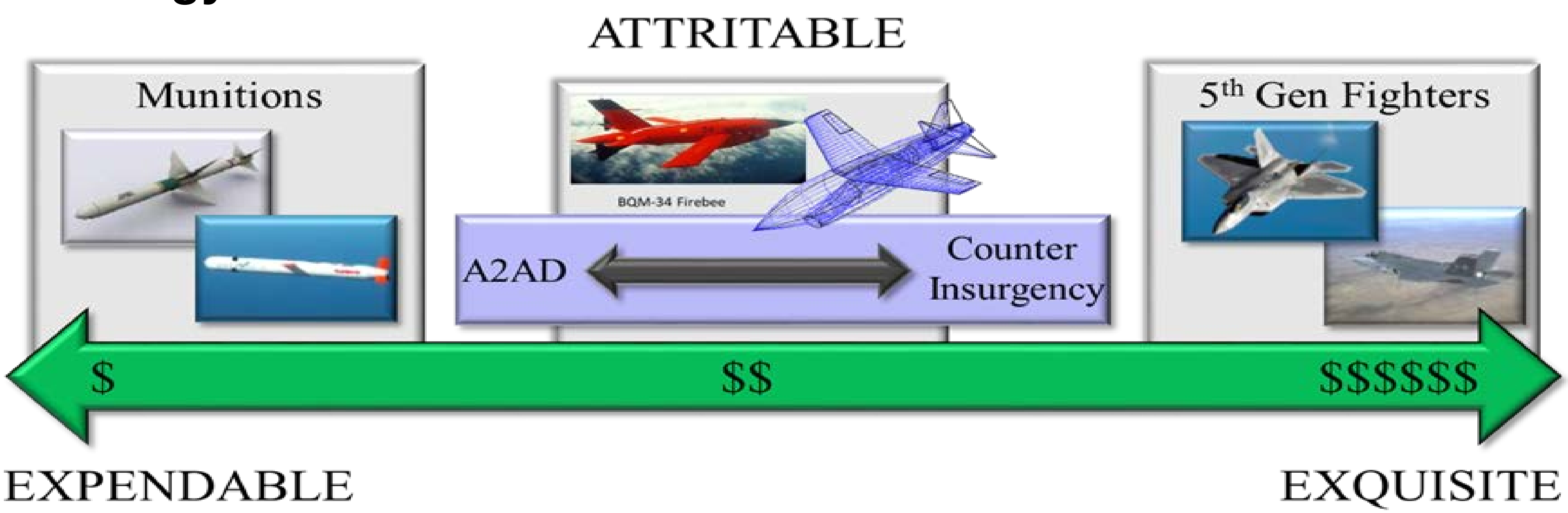
duplo ~ **10 PARTS**

What's to Come

BAA-AFRL-RQKP-2015-0004

Low Cost Attritable Strike Unmanned Aerial System (UAS) Demonstration

This effort will design, develop, assemble, and test a technical baseline for a high speed, long range, low cost, limited life strike Unmanned Aerial System (UAS). The program will also identify key enabling technologies for future low cost attritable aircraft demonstrations, and provide a vehicle for future capability and technology demonstrations.



Example: An Attritable Cost Estimate

BAA-AFRL-RQKP-2015-0004

- **Is it possible to develop, demonstrate, and produce a capable, low cost attritable aircraft with an average unit flyaway cost of less than $3M (excluding mission essential systems) with:**
  - **1,500 Nautical mile mission radius**
    - 500 lb payload
  - **Capable of Mach 0.9 Mach**
  - **Maximum G load limits**
  - **Runway independent take-off**
  - **Internal weapons capability**

Cost Model

Creating a cost model with:

- A relatively high fidelity of detail to assist in preliminary design space exploration
- Ability to use pass through costs (i.e., COTS/MOTS)
- Ability to account for certain manufacturing types
- Known errors and variation in estimate to apply uncertainty and risk analysis

RAND Equations (RAND R-4016)

- RAND starts with an aluminum baseline cost estimate
- Non-recurring cost elements
  - $NRE(hrs) = 0.0168(EW^{.747})(SP^{.800})$
  - $NRT(hrs) = 0.01868(EW^{.810})(SP^{.579})$
  - $DS = 0.0563(EW^{.630})(SP^{1.30})$
  - $FT = 1.54(EW^{.325})(SP^{.823})(NTA^{1.21})$
- Recurring cost elements
  - $RE100(hrs) = 0.000306(EW^{.880})(SP^{1.12})$
  - $RT100(hrs) = 0.00787(EW^{.707})(SP^{.813})$
  - $RML100(hrs) = 0.141(EW^{.820})(SP^{.484})$
  - $RMM100(hrs) = 0.54(EW^{.921})(SP^{.621})$
  - $RQA100(hrs - cargo\ acft) = 0.076(RML100)$
  - $RQA100(hrs - non\ cargo) = 0.133(RML100)$

Weighted Material Cost Factor

Material Complexity Factors	Al	Al-Li	Ti	Steel	Graph-Epoxy	Graph-Bis	Graph-Therm	Percent Attributed to Structure
NRE	1.00	1.00	1.00	1.02	1.14	1.16	1.14	45%
NR Tooling	0.88	0.99	1.26	0.97	1.21	1.29	1.44	87%
Rec Engineering	0.91	0.94	0.97	1.02	1.18	1.21	1.15	42%
Rec Tooling	0.86	0.97	1.26	1.12	1.33	1.44	1.5	82%
Rec Manufacturing	0.82	0.87	1.29	1.05	1.17	1.24	1.27	67%
Rec QA	0.95	1.04	1.18	1.12	1.5	1.52	1.58	69%
Man. Material	0.8	0.9	2.7	0.7	3.8	4.1	4.4	58%

RAND Report MR-1370, 2001, optimistic projection of WMCF for mid-2000's technology

Material Composition	
Aluminum	79%
Al-Lithium	0%
Titanium	2%
Steel	4%
Graphite Epoxy	5%
Graphite BMI	0%
Graphite Thermo	0%
Other Material	10%

NRE=(0.79*1.00+0.02*1.00+0.04*1.02+0.05*1.14+0.10*1.14)*0.45+(1-0.45)=1.0098

NR Tool=(0.79*0.88+0.02*1.26+0.04*0.97+0.05*1.21+0.10*1.21)*0.87+(1-0.87)=0.9484

Rec Eng=(0.79*0.91+0.02*0.97+0.04*1.02+0.05*1.18+0.10*1.18)*0.42+(1-0.42)=0.9816

Rec Tool=(0.79*0.86+0.02*1.26+0.04*1.12+0.05*1.33+0.10*1.33)*0.82+(1-0.82)=0.9581

Rec Mfg=(0.79*0.82+0.02*1.29+0.04*1.05+0.05*1.17+0.10*1.17)*0.67+(1-0.67)=0.9270

Rec QA=(0.79*0.95+0.02*1.18+0.04*1.12+0.05*1.50+0.10*1.50)*0.69+(1-0.69)=1.0303

Mfg Mat=(0.79*0.80+0.02*2.7+0.04*0.7+0.05*3.8+0.10*3.8)*0.58+(1-0.58)=1.1647

Material Mix Methodology

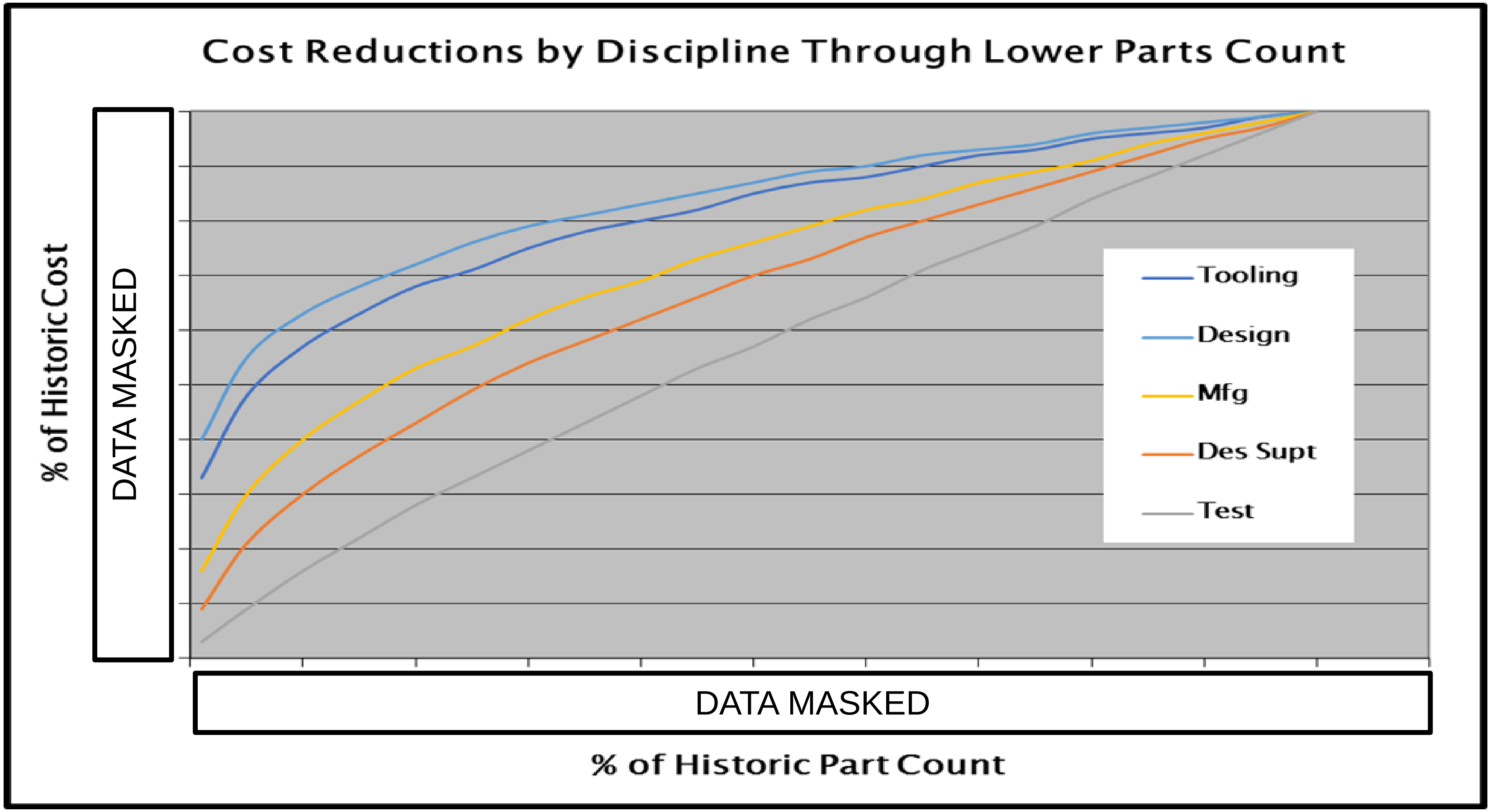
- **Advanced material effects are applied to each cost element**
  - **MWC (j) = SCF(j)*[ΣCF(i,j)*SMM(i)]+[1- SCF(j)]**

Where,

- **MWC(j) = Material weighted cost element j**
- **SCF(j) = Structural cost fraction for cost element j**
- **CF(i,j) = Complexity factor**
- **SMM(i) = Structural material type mix**

- RAND Report R-4016-AF, Advanced Airframe Structural Materials, Primer and Cost Estimating Methodology
- The Effects of Advanced Materials and Manufacturing Processes, Rand MR-1370, Younossi, Kennedy, Graser, 2001

Percentage Degrade



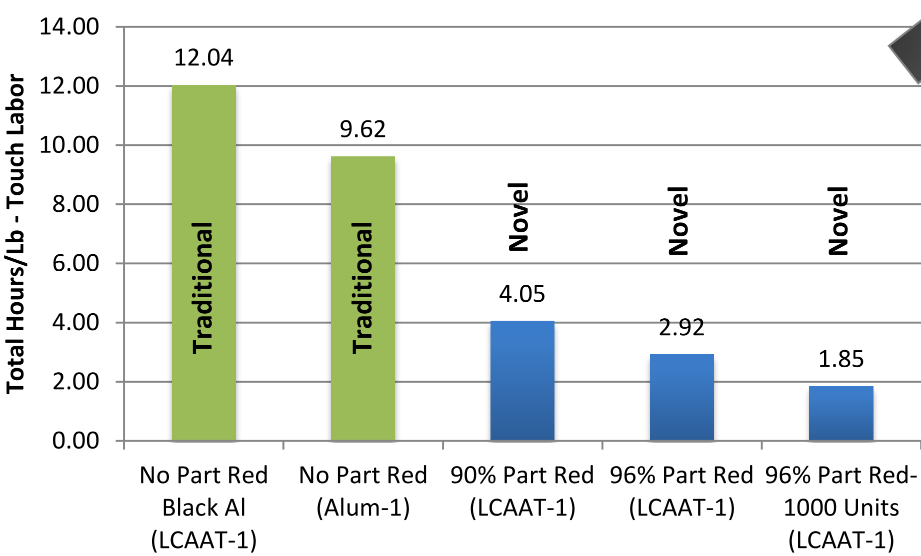
PART COUNT REDUCTIONS PRODUCE COST SAVINGS

Cost Model Results

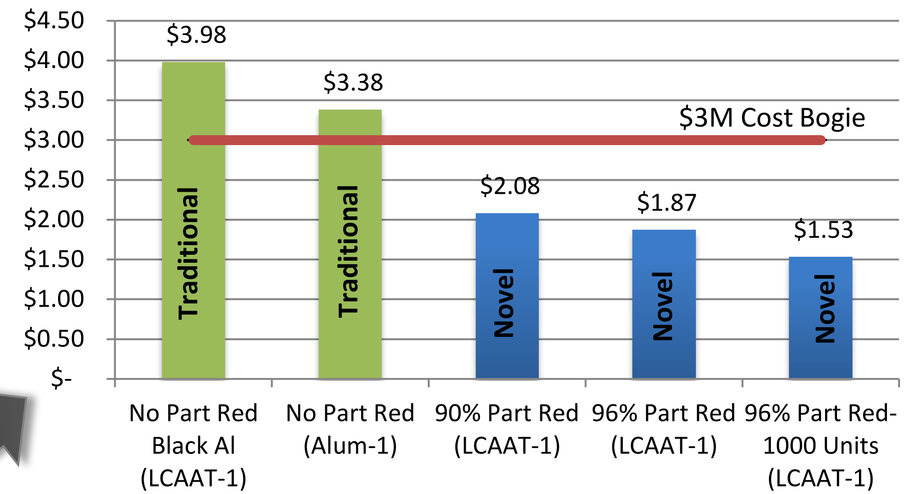
Traditional vs. Novel Mfg: Effects on Touch Labor

With Novel Manufacturing Methods:

- Touch labor per pound is drastically reduced
- Reductions have been realized in Tech Demos and actual manufacturing



Traditional vs. Novel Mfg: Effects on AUFC



- Traditional Manufacturing Methods for Aluminum & “Black Aluminum” do not make the cost goal of $3M.
- “Black Aluminum” replacing aluminum sections with similar small composite material may reduce some weight but the cost have been shown to increase

Conclusion

- **With the high use of composites, novel manufacturing methods hold significant potential**

- **We have cost models to assist us in estimating these reductions to touch labor and cost**

- **While these techniques have been utilized, they are still by in large a new area of research**

Questions?

U.S. AIR FORCE