The Challenge of New Materials In the Aerospace Industry

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Boeing Almost 100 Years of Innovation





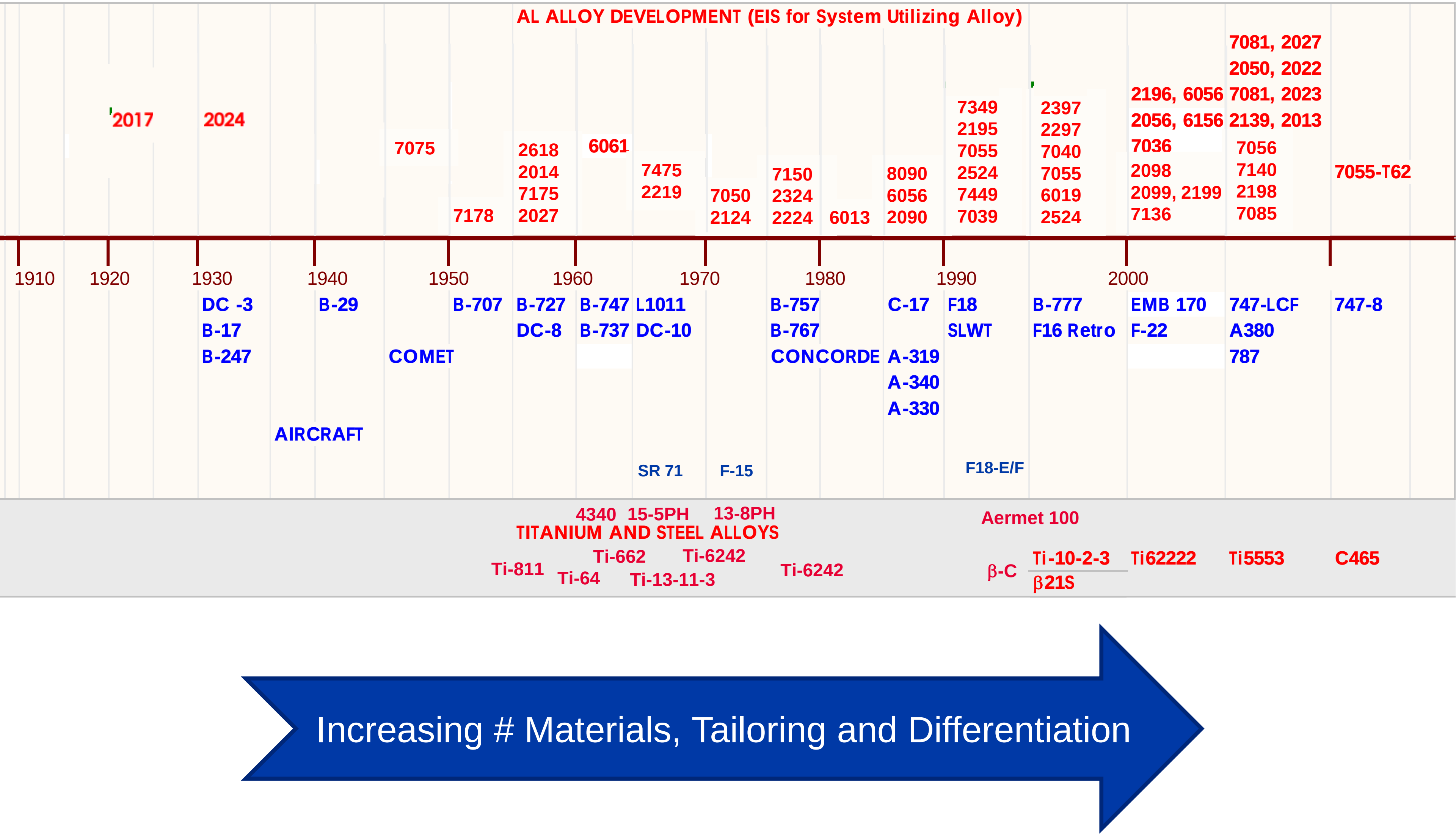




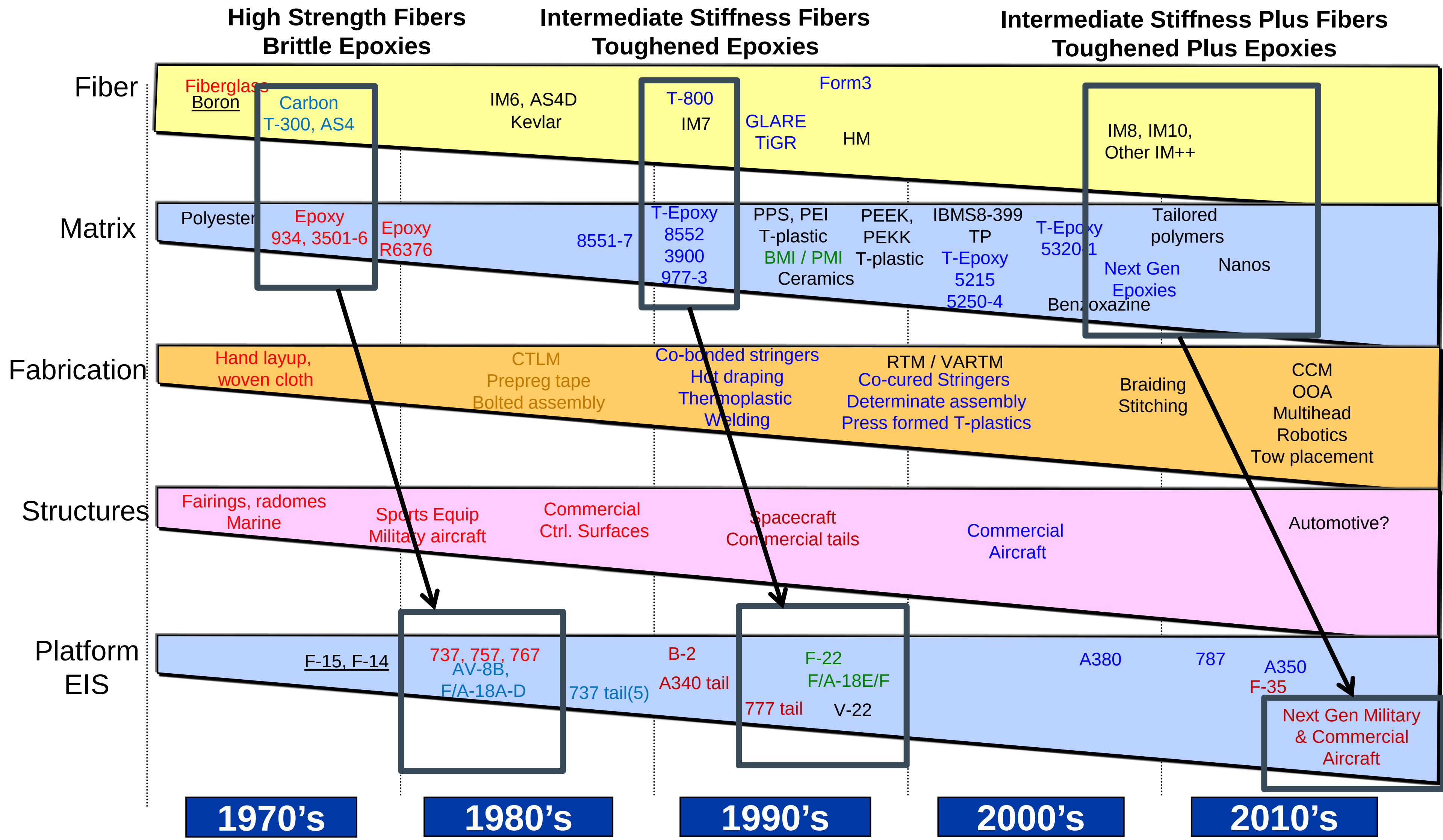



Year	Model	Innovation
1916	B&W - Model 1	Boeing's first airplane - spruce construction
1928	Model 80	America's first airliner specifically for passenger comfort
1932	P26 Peashooter	Fastest air cooled pursuit fighter in the world
1935	TBD Devastator	First all metal monoplane torpedo bomber
1935	B17	Multi-engine long range bomber
1938	314 Clipper	3500 mile range - Transatlantic Flight
1939	B29	Long range pressurized bomber
1941	P51 Mustang	First fighter to fly Britain to Berlin and back
1949	B47	First swept wing multi-engine bomber
1956	KC-135	Strategic Air Command aerial tanker
1957 - 58	707 & DC-8	Swept wing jet transport
1958	F4 Phanton	Jet fighter - 16 speed, altitude and time to climb records
1959	X-15	Rocket powered airplane - 354,000ft and 4,104mph
1961	CH47	Two rotor heavy lift
1960's	Mercury & Gemni	Manned Spacecraft
1969	747	Largest airliner built
1969	Apollo & Lunar Landed	Manned spaceflight to the moon
1970 - 1980	F15 & F18	Air superiority and multi-role fighter
1978	AV8	Fixed wing vertical take off aircraft
1981	Space Shuttle	Space access with return flight
1982	B1B	Swing wing supersonic bomber
1982 - 1984	757 - 767	Narrow and Wide Body with nearly identical cockpits
1986	V22 Osprey	Tilt rotor aircraft
1993	B2	All composite stealth long range bomber
1995	C17 Globemaster	Heavy lift and short field capability
1995	777	Wide body with composite empennage - 100% digital definition
1998	Space Station	International space station assembled in space
2009	787	First mostly composite airliner

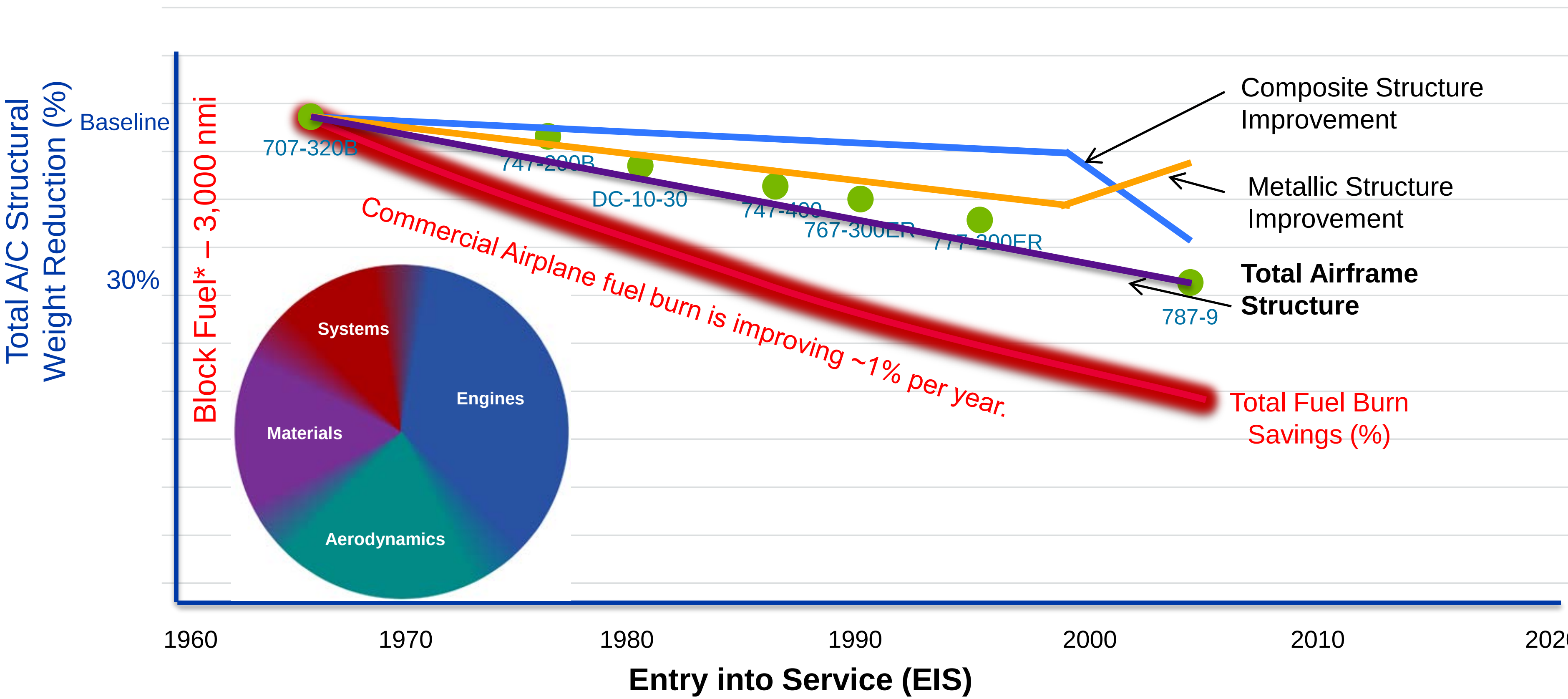
Airframe Metallic Materials Evolution



Composite Materials Have Enabled Next Generation of Military and Commercial Aircraft



Commercial Transport Performance Improvement
Materials Contribution



Materials Improvements Pace Airplane Performance Improvements

*Block Fuel = gals/seat over 3,000 miles

E Kaduce, 2012, The Boeing Company, based on publically-available data

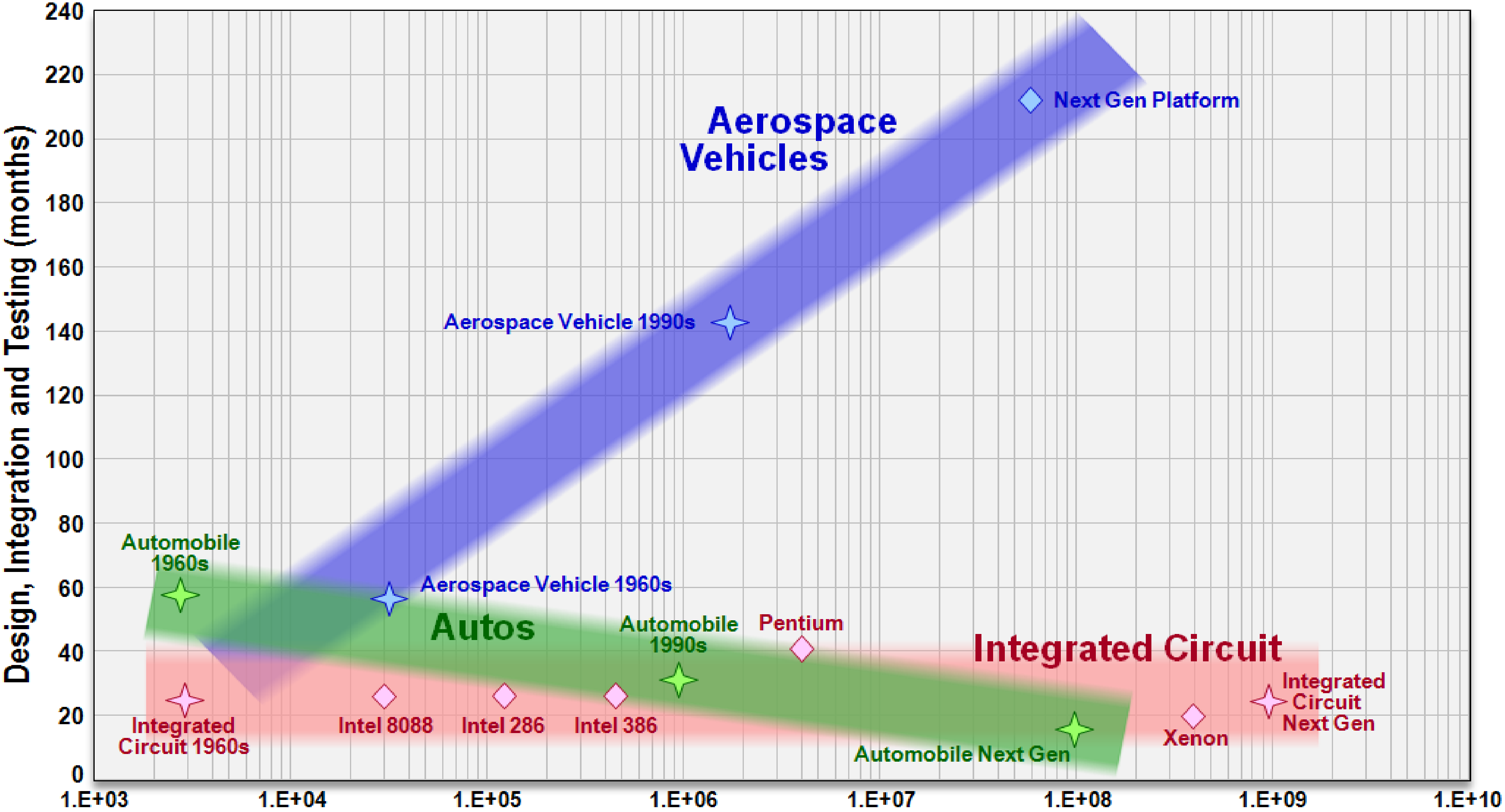
A Conclusion
Materials Are A Critical Enabler

History Says………..

- **Demand for improved aircraft performance will continue**
- **Properties of existing materials will improve**
- **New materials will be discovered**
- **Optimization capability will improve**
- **More materials will be used**

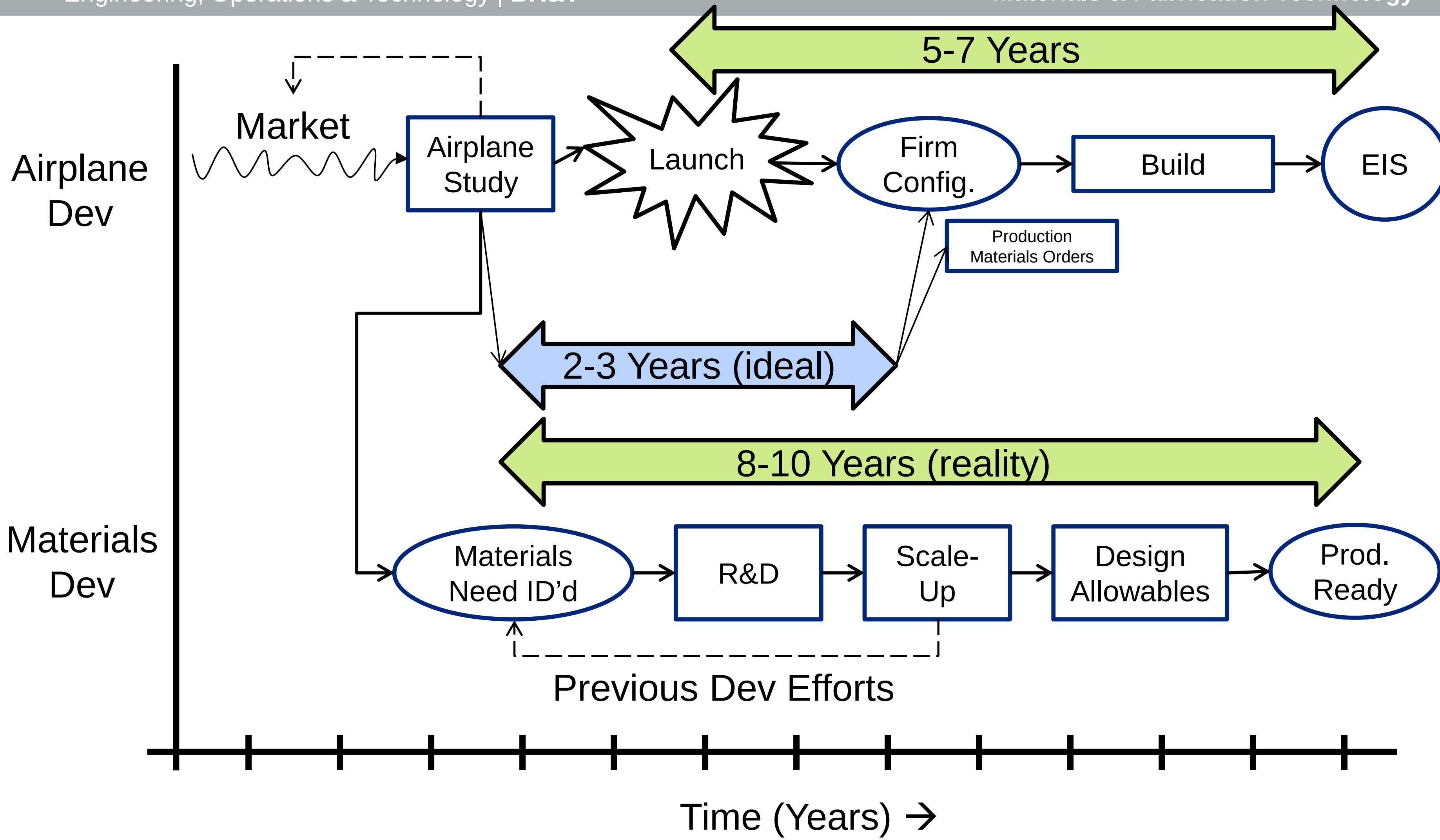
- **But ……….**
  - **Development costs climb**
  - **Development schedules increase**

Development Trends in Different Industries



Development Time Is Increasing At Unsustainable Rate

Airplane Development vs. Material Development



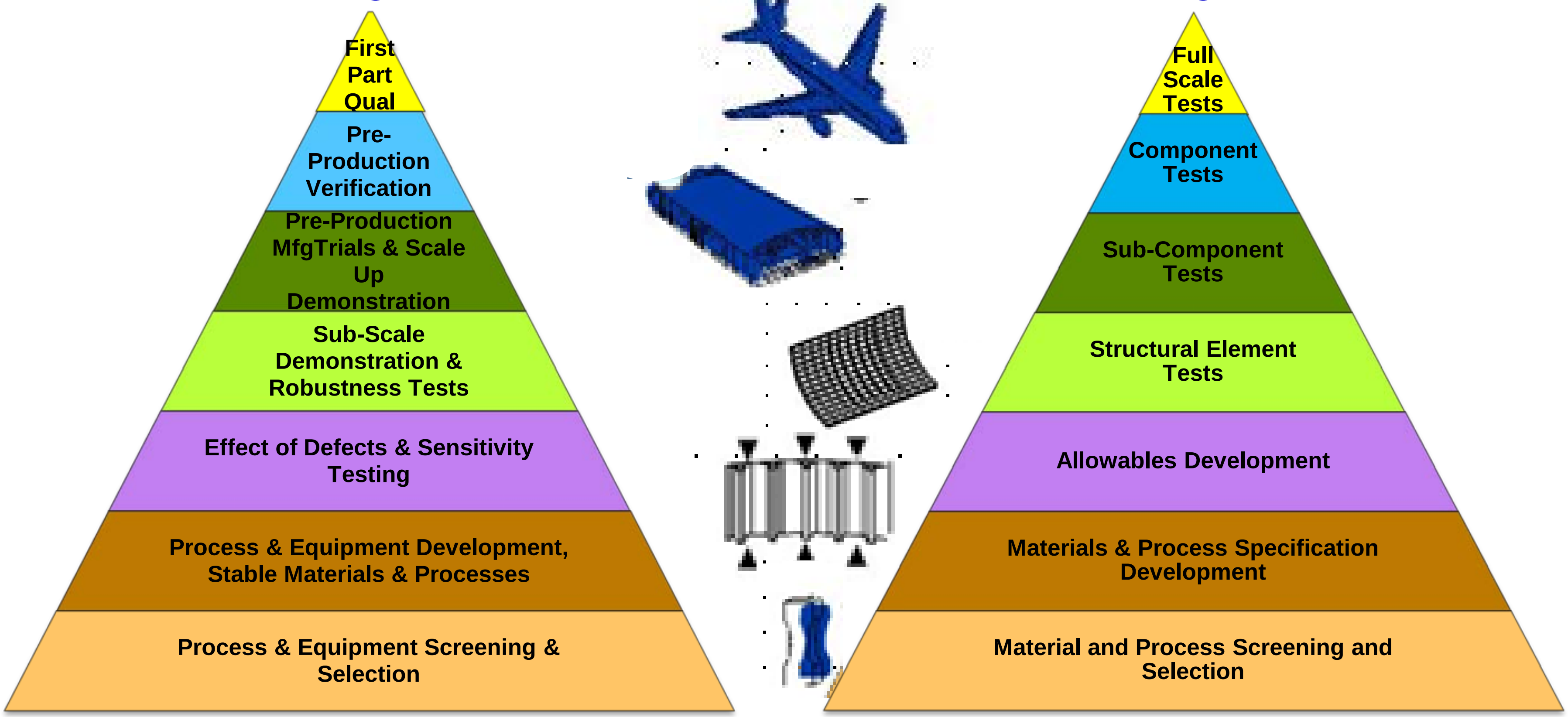
Materials Data Required for Airframe Design

Physical Properties	Static Mech. Properties	Durability and Damage Tolerance Properties	Environmental Effects	Producibility	Certification
Density	Tensile Strength	Fatigue Strength	Temperature Humidity	Castability	Material Specs
Thermal Expansion	Compressive Strength	Notch Sensitivity	Chemical Resistance	Formability	Process Specs
Heat Capacity	Shear Strength	Crack Growth	Wear	Deformation Characteristics	Approved Supplier List
Thermal Conductivity	Bearing Strength	Toughness	Corrosion Resistance	Weldability	Repair Methods
Poisson's Ratio		Special Design Factors	Oxidation Resistance	Machinability	Safety
Tensile, Compression, Shear and Bulk Modulus				Assembly	MSDS
				Chemical Processing	
				Inspection Methods	

Building Block Approach

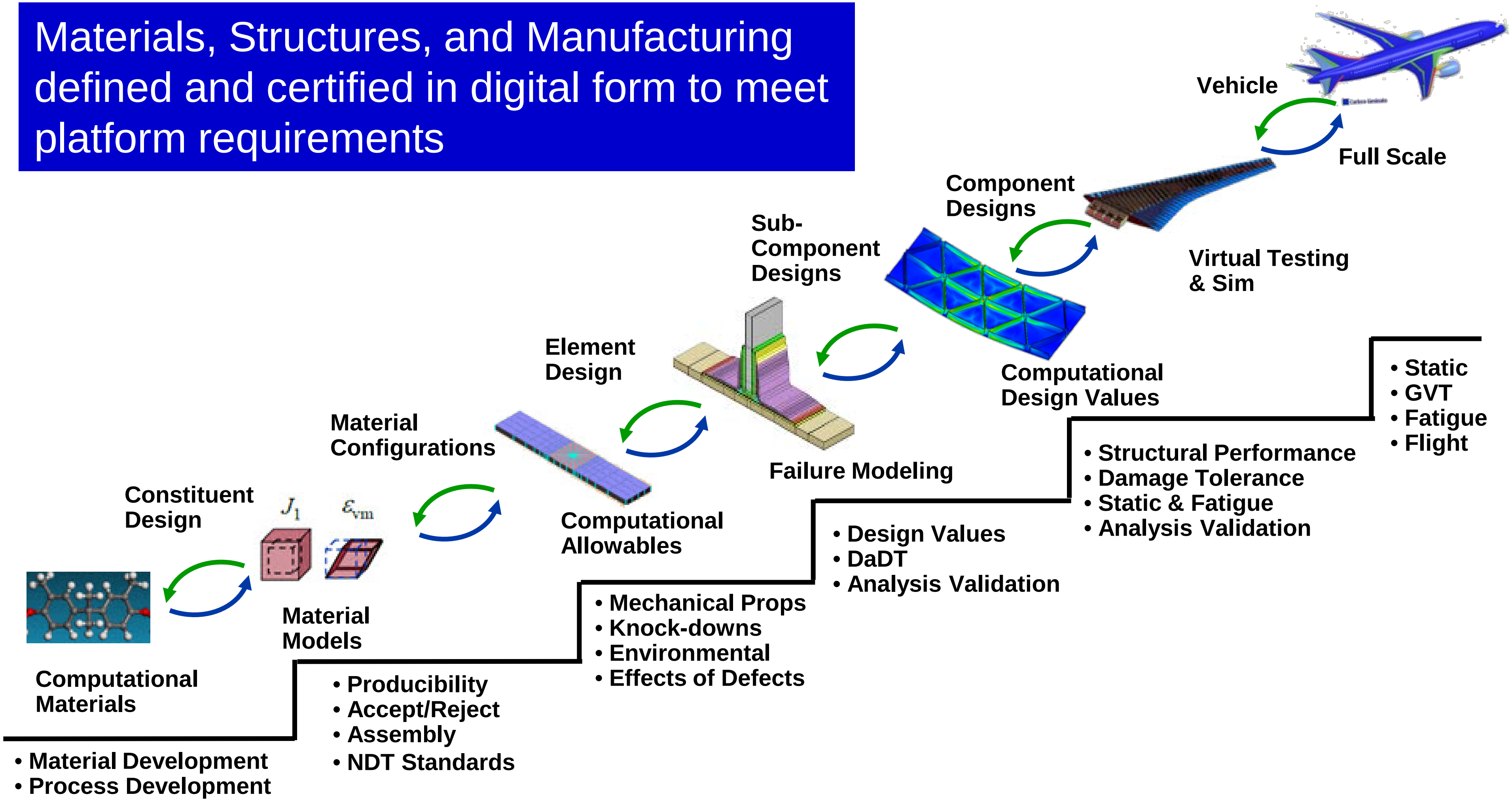
Manufacturing Qualification Building Blocks

Structures Certification Building Blocks



Future: Material Performance to Certification

Materials, Structures, and Manufacturing defined and certified in digital form to meet platform requirements



Future: Material Performance to Qualification

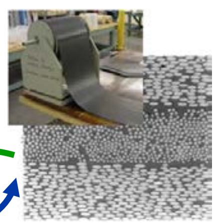
Materials, Structures, and Manufacturing defined and qualified in digital form to meet platform requirements

Constituent Design

Computational Materials

- Material Development
- Process Development

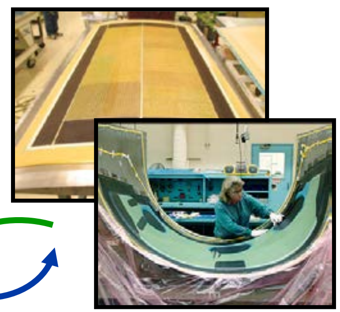
Material System & Forms



Material Models

- Mat'l & Process Capability
- Initial Accept & Reject Criteria

Process Development



Processing and Quality Simulation

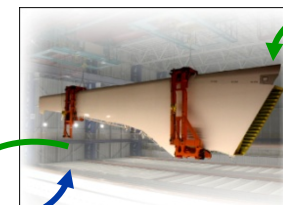
- Producibility
- Inspection Standards
- Quality & Effects of Defects
- Process Tolerances

Scale Up

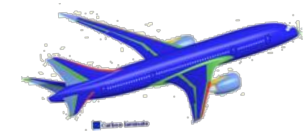
Process and Manufacturing Simulation for **Quality Aspects** of **Full Size Parts**

- Manufacturing Scale up
- Full size fabricated elements
- Effects of Defects
- Expanded Mfg Limits

Assembly



Vehicle



Tolerances & Assembly Simulation

- Production System

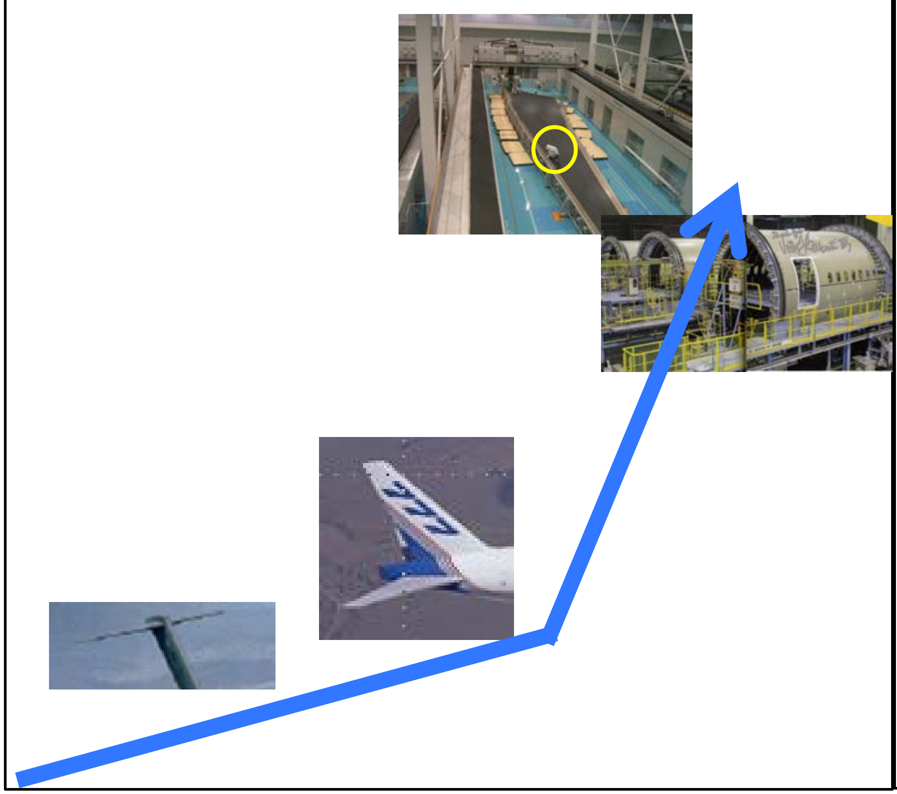
Aerospace Composites- Rate and Volume Trend

Platform	Percent Composites	Total Wt (lbs)	Approx Composite Wt (lbs)	Approx Delivery Rate	Wt (lbs/Month)	# Delivered	Total Wt Composites Delivered (lbs)
C-17	8%	277,000	22,714	1.5		218	4,951,652
B-2	High					20	
F-18 c/d	10%	24,700	2,470			1,450	3,581,500
777	10%	300,000	30,000	7	210,000	1066	31,980,000
F-22	20%	31,700	6,340	6		339	2,149,260
F-18 e/f	18%	30,500	5,490	4	21,960	500	2,745,000
V-22	43%	33,140	14,250	1	14,250	160	2,280,000
787	50%	250,000	125,000	5	625,000	130	16,250,000
Total					871,210		63,934,360

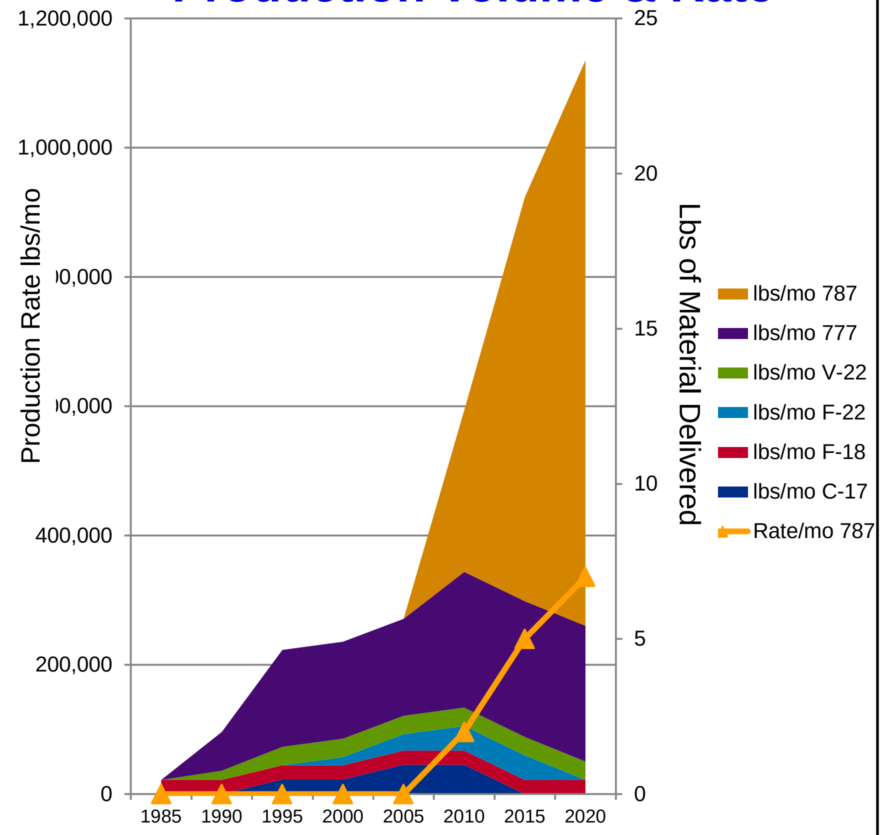
- **Boeing Has Fielded More than 63 Million Pounds of Composite Structure**
- **Boeing Will Field Nearly 10 Million Additional Pounds Every Year**

Industrialization of Aerospace Grade Composites

Detail Component Size



Production Volume & Rate



Structural Integration Coupled with Production Volume and Rate Increases Will Drive a Tipping Point in Manufacturing Cost

Parting Thoughts

- **Optimization will continue to increase number of materials**
- **Materials improvements are vital to aircraft performance improvements**
- **Discovery is only a small part of materials development**
- **Computational materials & manufacturing tools will speed decision making**
- **New material development must have:**
  - **Reduced qualification and certification costs & schedule**
  - **Concurrent scale-up and quality in manufacturing**