Trends in Aerospace Manufacturing

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Vice President of Materials & Manufacturing
Boeing Research & Technology
Airlines will need 38,000 new airplanes valued at $5.6 trillion

Airplane deliveries: 38,050

New airplane deliveries by region

<table>
<thead>
<tr>
<th>Region</th>
<th>Airplanes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asia</td>
<td>14,330</td>
</tr>
<tr>
<td>North America</td>
<td>7,890</td>
</tr>
<tr>
<td>Europe</td>
<td>7,310</td>
</tr>
<tr>
<td>Middle East</td>
<td>3,180</td>
</tr>
<tr>
<td>Latin America</td>
<td>3,020</td>
</tr>
<tr>
<td>Africa</td>
<td>1,170</td>
</tr>
<tr>
<td>C.I.S.</td>
<td>1,150</td>
</tr>
<tr>
<td>World Total</td>
<td>38,050</td>
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</tbody>
</table>
Beyond the 1st Century of Aerospace Manufacturing

Automated Composite Fab
Additive Manufacturing
Robotic Assembly
Industry customers are demanding more for less
Market Challenges – What the Customers Want

- Safe
- Affordable
- Reliable
- Upgradeable
- Flexible
- Performance
- Environmentally responsible
- Available
Challenges & Opportunities Ahead

Design for Manufacturing – Aerospace needs to leverage broader industry

Speed to Market – More capability to customers – quicker

Traveled Risk – Concurrency adds risk of rework

Modularity – Enables Reuse & Customization
Advanced Materials

Top Business Outcomes

- Safe/Environmental/Ergonomic Processes
- Robust First Pass Quality
- High Rate Capability
- Reduced part count
- Optimized Weight AND Cost

Top Advanced Materials Applications

- Metallic Alloys
- Composites
- Sealants/Paints
- Ceramics

Enablers

- High rate processes
- Integrated materials modeling, fabrication processing and properties

Product Performance & Production System Efficiency
Expanding capability for unitized machined components

Advanced modeling/machining technology critical – CMI helping
Automation Innovation

Top Business Outcomes
- Workplace Safety
- Product and Process Quality
- Flexibility / Factory Optimization
- Standardization / Replication

Top Automation Applications
- Drill/Fill
- Paint & Seal
- Composite Fabrication
- Material Movement

Enablers
- Networked Enabled Manufacturing
- In-Process Inspection
- TRL AND MRL

Innovative, Simple, Robust & Cost Effective
Additive Innovation

Top Business Outcomes

• Speed to Market
• Enhance Performance
• Cost Reduction Buy-to-Fly

Top Additive Applications

• Tools
• Interiors
• Structural Parts

Enablers

• Certification
• In-Process Inspection

Since 2002 more than 50,000 flyaway parts!
Titanium Additive/Subtractive Innovation

Complex to complex machining will continue to grow!
Manufacturing Analytics & Digital Threads

Top Business Outcomes

• Reduce Test & Evaluation / Rework 50%
• Affordable Manufacturing
• First Pass Quality
• Improved Factory Safety

Top Applications

• Optimized Factory Flow
• Manufacturing Process Analytics
• Improved Automation Execution
• Robust Process & Material Specs

Enablers

• Analytics
• Advanced Modeling & Simulation
• Industry Standards
• Integrated Digital Factory

Production Simulation

Future Factory Concepts

Highest Impact Cells

On-Time Probability

Integrated Digital Factory

The Complete Picture

Real-Time Predictive Analytics

Process Automation

Computer Vision

Safety Analytics

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Summary

- Market challenges and industry realities are driving changes in the way the aerospace industry designs and builds products
  - Cost
  - Speed to market
  - Performance
  - Environment

- Advances in materials, automation, additive/subtractive manufacturing, and data analytics are leading the changes for the 2nd century of the aerospace industry
BR&T Global Consortia

UK

AFRC

Netherlands

TPRC

Germany

DMRC

USA

CAMT

CALCE

AMATS

MACCCS

Canada

CRN

UAE

SBRC

India

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