Driving Growth through Innovation

Commercial & Military Titanium Demand Trends

Jeremy Halford, President, Arconic Engineered Structures

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Important Information

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The aerospace industry has transitioned...

<table>
<thead>
<tr>
<th>From the Era of Design</th>
<th>To the Era of Delivery</th>
</tr>
</thead>
<tbody>
<tr>
<td>The past decade <strong>focused on development and introduction of new designs</strong> and technology</td>
<td>A limited number of new starts</td>
</tr>
<tr>
<td>Resulting in <strong>unprecedented number of recently or soon-to-be introduced models</strong> by decade’s end</td>
<td><strong>Today’s focus: Transitioning to new airframe and engine platforms</strong></td>
</tr>
<tr>
<td>✓ A320neo ✓ A330neo ✓ A350 XWB ✓ 777X, 737 MAX ✓ 787 Dreamliner ✓ C Series</td>
<td>✓ C919 ✓ MS-21 ✓ E175/195 ✓ MRJ</td>
</tr>
</tbody>
</table>

**Materials and process innovations are key, such as Arconic’s 3D printing capabilities, shown here:**

![Arconic 3D printing capabilities](image)
Air traffic demand to double over the next 15 years

- Travel demand projected to far outpace GDP growth
- 100 million first-time flyers added every year from within the Asia-Pacific region alone

1) In trillions of Revenue Passenger Kilometers; Source: Airbus 2016 Global Market Forecast
Industry outlook is bolstered by airlines’ performance

Source: IATA, December 2017
Industry forecasts need for 41,000+ new aircraft over next 20 years

- Single Aisles: 29,530
- Widebodies: 9,130
- Regional Jets: 2,370

Results in a 2035 fleet of 46,950 aircraft – approximately 2X what it is today

Dollar value pegged at $6.1 trillion

Source: Boeing 2017 Commercial Market Outlook
Nearer-term outlook buttressed by decade+ of strong orders

The enormous wave of net orders post financial crisis were the product of three drivers:

- High jet fuel prices
- Low interest rates
- New, more fuel-efficient aircraft designs

Has resulted in a combined backlog of more than 13,000 aircraft – roughly 9X worth of deliveries at current rates

Source: Airline Monitor, June 2017; Airbus and Boeing websites
Aerospace materials growth – titanium fastest growing metal

- Overall, raw material demand growth measured in volume (lbs) will be lower than aircraft unit growth due to:
  - Lower buy-to-fly ratios
  - Greater use of composites

- Titanium is growing in conjunction with composites due to the materials’ compatible properties

- Titanium* will grow the fastest among metals with CAGR of 4.0%

*equivalent to a titanium market worth ~$4B per year today.

Source: AeroDynamic Advisory, April 2017
Global defense spending is rebounding

As geo-political tensions and active conflicts increase

- Continuing **global conflicts**
- **Aging aircraft** and systems
- Strengthening GDP and industrial base

**Global Defense and Security Expenditures ($B USD\(^{(1)}\))**

<table>
<thead>
<tr>
<th>Year</th>
<th>Expenditures</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>1,740</td>
</tr>
<tr>
<td>2013</td>
<td>1,719</td>
</tr>
<tr>
<td>2014</td>
<td>1,707</td>
</tr>
<tr>
<td>2015</td>
<td>1,736</td>
</tr>
<tr>
<td>2016</td>
<td>1,768</td>
</tr>
<tr>
<td>2017 (est)</td>
<td>1,822</td>
</tr>
</tbody>
</table>

**Global 2017 Expenditures ($B USD\(^{(1)}\))**

- Americas: 710
- Asia & Oceania: 390
- Africa: 180
- Middle East: 52
- Europe: 490

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(1) Expressed in constant 2012 USD and exchange rates
Source: Stockholm International Peace Research Institute (SIPRI)
Acceleration of new platforms and extension of legacy platforms

Airframes
- Continued use of **legacy aircraft**
- Additional production of current generation systems
- Acceleration of **new programs**

Advanced Engines
- Growing demand for engines with improved **performance and efficiency** for legacy and new platforms

Source: IHSGlobal (Janes), Teal Group, Forecast International
Strong titanium growth in defense aerostructures

Estimated Titanium Content, by Weight, in Aerostructures (1)

<table>
<thead>
<tr>
<th>Prior Generation</th>
<th>Current Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-16</td>
<td></td>
</tr>
<tr>
<td>Typhoon</td>
<td></td>
</tr>
<tr>
<td>CH-47</td>
<td></td>
</tr>
<tr>
<td>F-15</td>
<td></td>
</tr>
<tr>
<td>F-18</td>
<td></td>
</tr>
<tr>
<td>F-35</td>
<td>20%</td>
</tr>
<tr>
<td>V-22</td>
<td>31%</td>
</tr>
<tr>
<td>F-22</td>
<td>39%</td>
</tr>
</tbody>
</table>

Drivers of demand in defense

- Ramp-up of 5th gen fighter (F-35)
  - <14%

- Hypersonic weapons and structures; advanced propulsion engines

(1) Excludes propulsion engines, auxiliary engines and props
Market pressure for cost reduction continues

- **Cost-Down Initiatives** such as Boeing’s Partnering for Success, Airbus’s SCOPE+ and Lockheed Martin’s JSF affordability project continue and also have been adopted by other aerospace and defense OEMs.

- **Sourcing Geography** continues to tilt toward local contributions; increasing amounts of sourcing from low-cost / emerging countries.

- **Procurement Practices:** Supplier consolidation and material / contractual aggregation
Product and process innovation are helping drive titanium growth

**Optimized Structures**
- JSF titanium bulkhead
- Single-piece forging
- Forms “backbone” of aircraft
- Simplified assembly
- Weight and cost savings

**High Temperature Alloys**
- Weight saving vs. Nickel 625
- Options for sheet, plate, billet
- Superior post thermal exposure properties
- Suitable for forming, heat treating, forging, welding

**Additive Manufacturing**

**Direct 3D Printing**
- Reduced material input
- Enables part consolidation
- Speeds time to market
- Arconic/Airbus announce 3D printing 1st – installation of titanium bracket on series production commercial aircraft

**Hybrid Ampliforge™ Technology**
- Reduced material input
- Nearer-net forgings
- Fewer forging operations
- CRA with Airbus for large-scale titanium parts made with HDR technologies and Ampliforge™