Driving Growth through Innovation

Military Titanium Demand Trends

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Important Information

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Titanium demand trends in defense – three key points

• Global defense spending is rebounding

• We see strong titanium growth in defense aero structures

• Material and process innovations, such as new alloys for higher temperatures, are key to taking titanium higher
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* expected to 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

Expenditures are driven by geo-political tensions and active conflicts

- **2018 estimated over $1.68T**\(^{(2)}\) in current USD/Fx
- **Global conflicts** are continuing
- Aero and land systems require modernization
- **GDP** and **industrial base** are strengthening

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

<table>
<thead>
<tr>
<th>Year</th>
<th>Expenditure ($B USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>1,672</td>
</tr>
<tr>
<td>2011</td>
<td>1,675</td>
</tr>
<tr>
<td>2012</td>
<td>1,670</td>
</tr>
<tr>
<td>2013</td>
<td>1,645</td>
</tr>
<tr>
<td>2014</td>
<td>1,643</td>
</tr>
<tr>
<td>2015</td>
<td>1,640</td>
</tr>
<tr>
<td>2016</td>
<td>1,649</td>
</tr>
<tr>
<td>2017</td>
<td>1,656</td>
</tr>
<tr>
<td>2018 (est)</td>
<td>1,680</td>
</tr>
</tbody>
</table>

### Global 2017 Defense Expenditures by Region
($B USD\(^{(1)}\))

<table>
<thead>
<tr>
<th>Region</th>
<th>Expenditure ($B USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Americas</td>
<td>710</td>
</tr>
<tr>
<td>Asia &amp; Oceania</td>
<td>415</td>
</tr>
<tr>
<td>Africa</td>
<td>180</td>
</tr>
<tr>
<td>Middle East</td>
<td>52</td>
</tr>
<tr>
<td>Europe</td>
<td>490</td>
</tr>
</tbody>
</table>

\(^{(1)}\) Expressed in constant 2016 USD and exchange rates, excludes DPRK; Source: Stockholm International Peace Research Institute (SIPRI), 2 May 2018

\(^{(2)}\) IHS Markit, Global Defense Budgets, Dec 2017
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**

<table>
<thead>
<tr>
<th></th>
<th>Prior Generation</th>
<th>Current Generation</th>
</tr>
</thead>
<tbody>
<tr>
<td>F-16</td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td>Typhoon</td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td>CH-47</td>
<td>8%</td>
<td></td>
</tr>
<tr>
<td>F-15</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>F-18</td>
<td>12%</td>
<td></td>
</tr>
<tr>
<td>F-35</td>
<td>20%</td>
<td>31%</td>
</tr>
<tr>
<td>V-22</td>
<td></td>
<td>39%</td>
</tr>
<tr>
<td>F-22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Excludes propulsion engines, auxiliary engines and props

**Drivers of demand in defense**

- Ramp-up of 5th gen fighter (F-35)
- Hypersonic weapons and structures; advanced propulsion engines

(1)
Market pressure for cost reduction continues

- **Cost-Down Initiatives** such as Lockheed Martin’s JSF affordability project, Boeing’s Partnering for Success, and Airbus’s SCOPE+ 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 innovations 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™

**180 mm diameter billet**
- After intermediate rolling
- 700mm OD x 100 mm H