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- Market Analysis of Commercial Turbofan Engine Industry
- Supply Chain Analysis of Commercial Turbofan Engine Industry
- Technology Trend and Future of Commercial Turbofan Engine Industry
- Growth Opportunities and Emerging Trends
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Executive Summary

- Commercial aero turbofan engine on new airframe deliveries totaled 1,862 units in 2011. Turboprop engine deliveries realized 1% CAGR during the 2006-2011 time frame. Engine market was US $16.7 billion in 2006 and reached $21.2 billion with CAGR of 5% during 2006-2011.
- CFM International is the leading turbofan engine manufacturer in the narrow body aircraft market, capturing 62% market share of the active fleet. GE dominates in wide body aircraft with 48% share.
- Major drivers of this industry include growth in air traffic, environmental regulation, the need for economization to enhance airline profitability/competitiveness, and the replacement of aging fleet.
- Commercial aero turbofan engine on new airframe deliveries in terms of units is expected to growth with CAGR of 5% during the 2012-2017 time frame.
- Some of the emerging trends in aero engine market include: (1) use of second-generation biofuels, (2) lower maintenance cost, and (3) design & development of fuel-efficient and light weight aero engines.
- Titanium, nickel, and steels are the dominating materials in aero engine design – with an increasing interest in composites.
- Aero engines to be qualified and released during the forecast period include the CFM LeapX and the PW1000G Geared Turbofan. The manufacturers of these engine cite the following advantages: (1) Enhanced fuel efficiency over current market offering, (2) Reduced emission of NOx and CO₂ (3) Lighter weight
- China Commercial aircraft COMAC C919 will be launch with CFM LeapX engine but in future China has plan to manufacture engines for the airframe domestically.
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Creating the Equation for Growth

Lucintel
Global Commercial Aero Turbofan Engine Market Overview

- An aircraft engine is the primary component of the propulsion system for an aircraft that generates mechanical and in-flight electrical power.

- This market is dominated by three major manufacturers: GE Aviation (a subsidiary of General Electric, based in Evendale, Ohio, US); Pratt & Whitney, (a subsidiary of United Technologies Corporation, based in Hartford, Connecticut, US); and Rolls-Royce (Derby, UK).

- The industry is also characterized by consortiums: International Aero Engine (Pratt & Whitney, Rolls-Royce, and MTU); CFM International (GE and Sncma); and Engine Alliance (GE and Pratt & Whitney).

- Revenue-sharing partnerships play an important role in how the industry operates. Several suppliers are involved in this type of relationship with engine OEMs, including Volvo Aero, IHI, KHI, MHI, and Avio SPA.

- The Trent 1000 and GEnx are the newest engines in the fleet, soon to be followed by the CFM Leap-X and PW1000G Geared Turbofan.
## Commercial Turbofan Engine OEMs on Wide Body Aircraft (Engines with Thrust Range of 60-90 K Lbs.)

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<td>B747</td>
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Creating the Equation for Growth
# Commercial Turbofan Engine OEMs on Narrow Body Aircraft (Engines with Thrust Range of 20-40 K Lbs.)

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<td>A 320 Neo</td>
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<td>B737</td>
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<td>B757</td>
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<tr>
<td>B737 Neo</td>
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<tr>
<td>Comac C919</td>
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</tbody>
</table>
Portfolio of Commercial Turbofan Engines for Wide & Narrow Body Aircraft

Engine Manufacturers

- CFM Engines
- GE Engines
- RR Engines
- PW Engines
- JV: GE & PW
- CFM Engines
- JV: PW, MTU & Japanese Aero engine

Creating the Equation for Growth
The activities are primarily located in the US.

Pratt & Whitney: • Aircraft engine manufacturing activities are primarily located in the US. • It serve more than 500 customers that operate large commercial engines in 136 countries.

GE: • JV of GE Aviation and Aviation Industry Corporation of China to develop the new generation of commercial integrated avionics systems with an immediate priority on supporting development of China’s first narrow-body passenger jet (COMAC 919). • Increase its presence in China, with nearly 2,000 GE and CFM56 engines now in service. An additional 1,000 GE and CFM engines are on order.

Rolls-Royce: Business expansion in South America, the Middle East, and Asia through securing orders for development of an enhanced Trent XWB engine (with 97,000 lbs of thrust, for the enhanced Airbus A350-1000).

Note
• CFM International is a joint venture between GE Aviation, a division of US-based General Electric and Snecma, a division of Safran of France, with manufacturing of engines in their respective facilities.
• IAE International Aero Engines AG is a joint venture between Pratt & Whitney of the United States and MTU Aero Engines of Germany, with manufacturing of engines in their respective facilities.
• Engine Alliance, a 50/50 joint venture between General Electric and Pratt & Whitney, with manufacturing facilities mentioned above.

Creating the Equation for Growth

Key Insights

- Global commercial aero engine shipments totaled 1,744 units in 2006 and grew at a CAGR of 1%, reaching 1,862 in 2011
  - CFM International and IAE are the major players driving the market.
- The industry realized revenues of $16.7 billion in 2006, growing to $21.2 billion by 2011, at a CAGR of 5%
  - Engines for narrow body aircraft made up 81% of the market on a volume basis, and led industry growth with a CAGR of 20%.
- Commercial aero engine market is expected to reach $29.9 billion by 2017 with a CAGR of 6% from 2012-2017
  - CFM and PW are expected to be the dominant engine manufacturers for next-generation narrow body aircraft.
Global Commercial Turbofan Engine Market by Manufacturer: 2006-2017

Key Insights

• Highly consolidated industry, with top 3 major players controlling 85% of the total market

• The market is dominated by CFM, accounting for 62% of the market in 2011, followed by IAE.

• CFM International, a 50-50 joint venture between Snecma and GE, manufactures the CFM56, one of the most fuel-efficient aero-engines in the market.

  – New CFM engines reduce NO\textsubscript{X} emission by 25%, and are powering several aircraft, including A319, A320, A321. and B737.

  – With its new Geared Turbo Fan engine, PW share is expected to grow at the expense of IAE and, to a smaller extent, CFM.

Creating the Equation for Growth
CFM dominates narrow body turbofan engine fleet with 62% market share
GE dominates wide body turbofan engine fleet with 48% market share in 2011

<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>PW</th>
<th>GE</th>
<th>RR</th>
<th>CFM</th>
<th>IAE</th>
<th>EA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Narrow Body</td>
<td>☀</td>
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<tr>
<td>Wide Body</td>
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</tr>
</tbody>
</table>

Range
- 76%-100%
- 51%-75%
- 26%-50%
- 6%-25%
- 0%-5%

World Aircraft Active Fleet Market Share by Engine Manufacturer 2011

Narrow Body Active Fleet
Total Fleet in 2011: 11,576
- PW: 16.5%
- GE: 62.0%
- RR: 6.0%
- IAE: 15.5%

Wide Body Active Fleet
Total Fleet in 2011: 4,317
- PW: 47.9%
- GE: 26.6%
- RR: 20.1%
- IAE: 5.2%

Creating the Equation for Growth
Top 6 Airlines: Turbofan Engine Inventory by Age and Manufacturer

Creating the Equation for Growth
Material Composition in Turbofan Engines

- Titanium, nickel and steels are the dominating materials in aero engine design – with increasing interest in composites.
- Industry-wide requirements for enhanced fuel efficiency is driving the need for lightweight engines.
- Environmental regulators are requiring reductions in both noise and carbon emissions.
- Fans made of woven carbon fibers rather than titanium have been demonstrated to enhance fuel efficiency by up to 15%.
- Sophisticated airfoil design, advanced nickel-based super alloys, and thermal barrier coatings have allowed for hotter, more complete combustor burn, thus reducing carbon emissions and affording designers greater thrust options.
China Aero Engine Industry

- Chinese players will bring major changes to aerospace industry dynamics in the coming years by launching its new commercial aircraft and engine in international market.
- The country's aerospace industry is developing under the Chinese government's five year plan with the following goals:
  - Development of COMAC C919 narrow body aircraft
  - Initially C919 will be launch with CFM LEAP X engine
  - Longer term engine for C919 to be manufactured domestically
  - Five year plan clearly states the development of civil aircraft and engine, engines in pipeline by China aero engine manufacturers are
    - CJ-1000A
    - CJ-1000AX
    - CJ-1000B ER
- MTU Aero Engines of Germany and the Chinese engine manufacturer AVIC Commercial Aircraft Engine Co. Ltd. (ACAE) have signed an agreement on key terms for a possible cooperation on the future CJ1000 engine.
Upcoming China Aero Engines

CJ-1000A
- Launching Year: 2016
- Application: C919 Basic
- Specific Fuel Consumption: 0.53 kg/(kgf.h)

CJ-1000AX
- Launching Year: 2022
- Take-off Thrust: ~12800 kgf
- Specific Fuel Consumption: ~0.53 kg/(kgf.h)

CJ-1000B ER
- Launching Year: 2026
- Take-off Thrust: ~13400 kgf
- Specific Fuel Consumption 0.52 kg/(kgf.h)

China Jet CJ-1000A is the domestic engine designed and built for C919 150-seater commercial aircraft
- Initially C919 will be launched with CFM LeapX engine
- In the longer term, the C919 will be powered by a domestically produced engine
- Certified and into-production by 2020
- Demonstrator engine to be produced by 2016
- Take-off thrust: ~14000 kgf
- SPF: ~0.52 kg/kgf.h
- Bypass Ratio: >9
- OPR: ~40
- HPC Pressure Ratio: ~20

The CJ-1000 Engine Family

Creating the Equation for Growth
Drivers and Challenges of Commercial Turbofan Engine Market

**Drivers**

- **Increasing Traffic Forecast**
  - Traffic growth on the existing route network where it is more efficient to add capacity than frequency
  - Some 1,300 very large aircraft to meet passenger demand are required in future years; increasing population; urbanization and increasing world disposable income is leading to demand for new aircraft

- **Demand for Light Aircraft and Low-Cost Carriers**
  - Soaring fuel prices has pushed the demand & need for lighter aircrafts among airliners to leverage their shrinking bottom-lines
  - Continued growth of LCCs, especially in Asia

- **Retro-fitting of New Engines in Existing Aircraft**
  - Retro-fitting of new engines in aircraft-Leap X in A320neo family of aircraft
  - Leap-1B in B737 Max

- **Fuel-Efficient Engines**
  - Manufacturing fuel-efficient engines that can emit less CO$_2$ and NOX

**Challenges**

- **Increase in Prices**
  - Increase in material pricing such as the price of titanium
  - Cost of fuel also affects the engine market

- **Tough Regulations and Certification Process**
  - Stringent certification process discourages market entry
  - Market requirement for 20% improvement in operating economies to launch next-generation narrow body

- **Meeting Technological Changes and other Challenges**
  - Technological changes taking place over time
  - Capacity issues, difficulties in hiring skilled and less expensive labor
  - Challenges in adding production facilities are major constraints for engine manufacturers
## Factors Shaping the Outlook for the Commercial Turbofan Engine Market

### Usage of Composites, Ceramics & Super Alloys

**Advanced Material** usage such as increase in use of composites, ceramics, and super alloys in aeroengines. These materials offer several key advantages in engine design:

- Lower maintenance cost
- Lower weight
- Ability to integrate structures
- Better hi-temperature performance
- Improve fuel efficiency
- Satisfy safety standards

### Increasing Use of Biofuels & Green Aero Engines

More efficient "Green Aero Engines" are now a market imperative. Factors that facilitate green aero engines:

- Emerging regulatory requirement to reduce greenhouse gas emissions
- **Biofuels** are the primary means of reducing the carbon footprints, key advantages of biofuels are:
  - Improves efficiency
  - Reduces emission from aviation
  - Reduce dependence on fossil fuels

### Increasing Air Traffic, Market Liberation & Developing Infrastructure

All these are pushing global aerospace engine market toward growth:

- Traffic growth on the existing route network where it is more efficient to add capacity than frequency
- Increasing population; urbanization & increasing world disposable income is leading to demand for new aircraft
- Increase in new airline networks due to turning global cities & new routes are leading to new aircraft procurement

### Prognostics and Diagnostics & Escalating PMA Parts

Growing use of **Prognostics & Diagnostics** have become a core element of engine OEM value proposition:

- New generation aircraft designs feature heavy use of prognostics, diagnostics, and health monitoring systems

**Escalating PMA** parts trends beneficially affecting commercial aerospace suppliers:

- Rising PMA parts could reshape the MRO market
- PMA parts currently 2% to 3% of total parts consumption by value

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Supply Chain: Global Commercial Turbofan Engine Market

Raw Material Suppliers
- Hexcel
- Alcoa
- Hadco
- RMI Titanium
- VSMPO
- ASM
- Allegheny Technologies
- Compos Flex, Inc.
- Others

Aero engine Component (Tier I & II) Suppliers
- Precision Castparts
- Alcoa Howmet
- Blades Technology Intl.
- Carmel Forge
- Aerospace Industrial Development Corp.
- Xian Aero Engine
- Turbocam International
- Twigg Corporation
- Barnes Aero
- SIFCO Industries
- Avio S.p.A.
- IHI
- KHI
- MHI
- Volvo Aero
- Others

Engine Manufacturer
- Rolls Royce
- Pratt & Whitney
- General Electric
- CFM International
- IAE
- Engine Alliance
- Others

Customers
- Delta Airlines
- American Airlines
- China Southern Airlines
- Air China
- United Airlines
- Boeing
- Airbus
- Others

Creating the Equation for Growth
Global Commercial Turbofan Engine Manufacturing Decision Process

Role of Airline (End User) Role of Airframe OEMs

- Parameters
- Specifications
- Lifecycle Needs

Decision Process

- Type of material selection

Process Driver

Influencer

Follower

Product Design & Development

Material Selection

Prototyping & Testing

• Testing
• Gap Analysis
• Improve as needed

Commercial Aero engine

Role of Airline (End User)

Role of Airframe OEMs

Role of Aero engine OEMs

Key Insights

- In life cycle of engines, the engine OEMs are responsible for the following activities:
  - Marketing & Design: Preliminary design studies & market studies, definition of engine with new technology concepts
  - Development Stage: Program launch, engine design, manufacture of first development parts & assembly of development engines
  - Production and Distribution: Parts sent to assembly shop, engine assembly, start of full engine & flight tests
  - Sales and Support: Marketing, sales, and contract negotiations (vendors and customer support)
  - Maintenance, Repair, and Overhaul (MRO): Troubleshooting, repair or restoration, re-assembly, test & reinstallation
  - Spare parts: Forecast customer needs, component delivery, customer-oriented service

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Technology Roadmap of Turbofan Engines

Creating the Equation for Growth
<table>
<thead>
<tr>
<th>PW4000</th>
<th>GP7000</th>
<th>CFM 56</th>
<th>Trent 1000</th>
<th>GenX Engine</th>
</tr>
</thead>
</table>
| • Fan tip diameter of 100 inches  
• Take-off thrust: 64,000 - 68,000 lbs.  
• Bypass ratio: 5:1  
• Overall pressure ratio: 32  
• Fan pressure ratio: 1.75  
• Four-stage low pressure compressor (LPC) and a four-stage low pressure turbine (LPT) | • Two-spool high-bypass turbofan engine  
• Single annular combustor  
• Two-stage high pressure turbine, boltless architecture, single crystal blades, split blade cooling and thermal barrier coatings, axial flow; six-stage low-pressure axial flow  
• Overall pressure ratio: 43.9 | • Double-annular combustor. Instead of having just one combustion zone [Reduced nitrogen oxides (NOx) and carbon dioxide (CO$_2$)]  
• Nine-stage high pressure compressor  
• Single-stage fan, and most variants have a three-stage booster on the low-pressure shaft, with four stages in the 5B and 5C variants | • Trent 1000 is three-shaft high bypass ratio (11-10.8:1) turbofan engine  
• Trent 1000 has OPR of 52  
• Single stage LP, eight-stage IP, six-stage HP compressor  
• Single-stage HP turbine, single-stage IP turbine, six-stage LP turbine | • Successor to CF6  
• Major Applications: Boeing 747-8  
Boeing 787 Dreamliner  
• Composite fan blades with titanium leading edges  
• Fan bypass ratio of 19:2, which also helps reduce noise  
• Titanium aluminide stage 6 and 7 low pressure turbine blade |

Creating the Equation for Growth
Future Technology: CFM LeapX Engine Vs PW1000G Engine

CFM LEAP-X

- Compressor: Axial flow, 1-stage geared fan, 2-3 stage LP, 8 stage HP
- Single-stage fan, 3-stage low pressure compressor, 10-stage high pressure compressor
- 3-D woven RTM technology for 18-blade composite fan
- 15% better fuel efficiency
- 50% Lower NOx emission
- 75% reduce reduction of noise foot print
- Maximum thrust: 18,000-35,000 lbf., ca. 25,000-30,000lbf. for C919
- Overall pressure ratio: 40:1
- Bypass ratio: 10:1
- Applications: A320neo, B737 Max, C919
- Reduced weight, fuel burn and noise
- Better maintenance cost

PW1000G

- Compressor: Axial, 1-stage LP, 3-stage LP
- Turbine: Axial, 2-stage HP, 3-stage LP
- Maximum thrust: 14,000–23,000 lbf (62–100 kN)
- By pass ratio: 12:1
- Applications: A320neo, Bombardier CSeries, Mitsubishi Regional Jet, Irkut MS-21
- Talon X combuster is a third-generation combuster that reduces NOx emission by 50% to CAEP/6 standards
## Comparison: CFM LeapX and PW1000G

<table>
<thead>
<tr>
<th>Parameters</th>
<th>CFM LeapX</th>
<th>PW1000G (GTF)</th>
<th>Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Fan section</strong></td>
<td>18 blade composite fan</td>
<td>18 blade bi-metallic fan</td>
<td>• <strong>LeapX</strong>: Foreign-object damage (FOD) reduction technology, lower maintenance cost ↑</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• <strong>GTF</strong>: Translating sleeve, lower maintenance cost ↑</td>
</tr>
<tr>
<td><strong>Gearbox</strong></td>
<td>No gearbox</td>
<td>Yes</td>
<td>• <strong>LeapX</strong>: No Maintenance ↑</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• <strong>GTF</strong>: Maintenance cost for gearbox ↓</td>
</tr>
<tr>
<td><strong>Low pressure compressor</strong></td>
<td>3 stage LPC</td>
<td>3 stage LPC</td>
<td>• <strong>LeapX</strong>: Moderate maintenance cost ↑</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• <strong>GTF</strong>: Moderate maintenance cost ↑</td>
</tr>
<tr>
<td><strong>High pressure compressor</strong></td>
<td>10 stages</td>
<td>8 stages</td>
<td>• <strong>LeapX</strong>: More airfoils than GTF ↓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• <strong>GTF</strong>: one-third fewer airfoils than the LEAP ↑</td>
</tr>
<tr>
<td><strong>Combustor</strong></td>
<td>TAPS combustor</td>
<td>Third-generation Talon combustor</td>
<td>• <strong>LeapX</strong>: New Technology ↑</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• <strong>GTF</strong>: New Technology ↑</td>
</tr>
<tr>
<td><strong>Low pressure turbine</strong></td>
<td>4 to 7 stages (application dependant)</td>
<td>3 stages</td>
<td>• <strong>LeapX</strong>: 7 stages ↓</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• <strong>GTF</strong>: Two-thirds fewer airfoils for GTF than LEAP ↑</td>
</tr>
<tr>
<td><strong>High pressure turbine</strong></td>
<td>2 stages</td>
<td>2 stages</td>
<td>• <strong>LeapX</strong>: Minimize fuel burn ↑</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• <strong>GTF</strong>: Low maintenance ↑</td>
</tr>
</tbody>
</table>

Creating the Equation for Growth
Large investments have already been made in Europe and the US through R&D programs and collaborations to reduce the negative environmental effects of aircraft use.

ICAO, under the CAEP process, has undertaken an effort to establish medium and long-term environmental goals relating to three types of technologies – noise, NOx, and fuel burn:

- **Medium Term Goal (2016):** CAEP/6 levels – 45%, ±2.5% (of CAEP/6) at an overall pressure ratio of 30
- **Long Term Goal (2026):** CAEP/6 levels – 60%, ±5% (of CAEP/6) at an overall pressure ratio of 30

The Advisory Council of Aeronautical Research in Europe (ACARE) identified the research needs for the aeronautics industry for 2020. The engine has to contribute to the overall ACARE targets with a 20% reduction in CO₂ emissions per passenger-kilometer, 10 dB noise reduction per certification point and a 80% reduction in NOx emissions.

Source: NEWAC
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Growth Opportunity of Commercial Turbofan Engine Market

Key Insights

• In 2017, the global aero engine market is expected to approach 2,500 units with a CAGR of 5% for 2012-2017

• The global aero engine market is poised for robust growth with the following opportunities:
  • New material development, which will drive the aero engine market in coming years
  • New future technologies such as woven resin transfer molding technique, driving weight reduction
  • Next-generation narrow body aircraft with upgraded engines are expected to drive the market in coming years
  • CFM engines are forecast to drive the aero engine market with over 1,500 units in 2017

* Bubble size indicates 2017 aero engine market size.
Emerging Trends in Global Commercial Turbofan Engine Market

- **Fuel-efficient and light weight aero engines**
  - The CFM International LEAP-X is a high-bypass turbofan engine
  - Use of composites on fan blades and other components could reduce the weight of engine to 1,000 pounds

- **Less CO₂ and NOx emitting engines**
  - The PurePower PW1000G series engines use an advanced gear system allowing the engine’s fan to operate at a different speed than the low-pressure compressor & turbine
  - This engines will have 50% reduction in NOx & 50% reduction in engine noise

- **Retro-fitting of new engines**
  - Airbus is working on offering a new engine for the A320 known as the New Engine Option (NEO)
  - The new engine will burn 16% less fuel and will have 20% lower maintenance cost

- **Use of second- generation biofuels**
  - Air transport’s contribution to climate change represents 2% of man-made CO₂ emissions and this could reach 3% by 2050, according to the Intergovernmental Panel on Climate Change (IPC). Thus, introduction of biofuel will drive the future aero engine market
  - The GenX engines offers 30% reduction in the maintenance cost
  - Some of the GE engines predict elapsed time between inherent failures of a system during operation

**Creating the Equation for Growth**

Emerging Trends in Aero Engine Market
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• About Lucintel
Lucintel is the leading global management consulting and market research firm.

Lucintel creates the equation for growth and is committed to actionable results that deliver significant value and long-term growth to its clients.

Lucintel has been creating measurable value for more than 14 years and for thousands of clients in 70+ countries worldwide.

**Market Reports**

- Aerospace
- Transportation
- Marine
- Construction
- Renewable Energy
- Recreational
- Composite Materials

**Consulting**

- Growth and Strategic Consulting
- Benchmarking
- Opportunity Screening
- Partner Search and Evaluation
- Due Diligence and M&A
- Market Entry Strategy

*Creating the Equation for Growth*
Lucintel has an extensive toolkit to address key strategic questions for increasing your company’s profitability and market presence

Key Questions

- Is market space/opportunity of current product offerings sufficiently robust?
- Markets are focus for many: how can my company profitably differentiate?
- Based on our core skills, where should we focus?
- Should we build or buy? Is build even an option?
- What game changer actions exist and/or is a more incremental approach best?
- What is the order sequence of market entry segments/products?
Clients Around the World Value Lucintel’s Services

Creating the Equation for Growth
Reach Lucintel

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