AIRCRAFT HEALTH MONITORING

The True Value of Aircraft Health Monitoring and Data Management

14 September 2017
Agenda

Market Trends
MRO Forecast
New Technology Aircraft
Benefits for the Airline
Market Trends
Airlines are achieving historically high return on invested capital (ROIC) levels – there’s an evident correlation with changes in fuel costs.

Fuel Price and Global Airline Return On Invested Capital

Source: IATA, ICF Analysis
The global airline industry achieved record profitability over the past years, driven by low fuel prices and greater cost control.

Global Airline Profitability, 1997-2017F

$USD (Billions)

Source: IATA, ICF Analysis
Latin America has seen modest but stable profit margins over the past decade.

Global Airline EBIT Margin by Region

Source: IATA, ICF Analysis
Commercial aircraft OEM production backlog remains at historical highs...

**Commercial Aircraft OEM Production Backlog**

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<td>Backlog /% Active Fleet</td>
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Source: CAPA, ICF Analysis
... and more stable fuel costs have slowed aircraft retirements

**Potential Impact:**

- Reduced part-out feed stock for surplus market
- Mature aircraft being placed with new operators
- Increase in airframe and engine MRO spend on older airframes
- Improved new parts sales
- Higher used part values/pricing

![Commercial Annual Aircraft Retirements](chart)

*Source: CAPA, Airline Monitor, ICF analysis*
The outlook for Latin America’s aviation industry is starting to brighten as economies recover ……

**Aviation Outlook:**

- Economic growth remains weak, driven by uncertainty and geopolitical events
- Three LCC carriers have launched this year, bringing total LCCs to over 10
- Additional LCCs have been announced
- High taxes on air travel and airport duties hinder market growth
- Infrastructure constraints

Source: ICF Analysis
…and carriers are beginning to reverse losses and earn profits

Source: IATA, Company Filings & ICF analysis
MRO Market
The current commercial air transport fleet consists of ~28,000 aircraft; ~2,000 are located in Latin America.

2016 Global Commercial Air Transport Fleet

By Aircraft Type:
- 28,000 Aircraft
- Narrowbody Jet: 54%
- Widebody Jet: 19%
- Turboprop: 14%
- Regional Jet: 13%

By Global Region:
- 28,000 Aircraft
- Latin America: 8%
- Europe: 25%
- Asia Pacific: 28%
- North America: 30%
- Middle East: 5%
- Africa: 5%

Source: ICF, CAPA 2016
The combination of strong air travel demand and the need to replace ageing aircraft will drive fleet growth at a healthy 3.2% p.a.

10-Year Global Air Transport Fleet Growth

Source: ICF, CAPA 2016
2016 commercial air transport MRO demand is $67.6B; Latin America has ~5% of the market

2016 Global MRO Demand

By MRO Segment

- Airframe: 40%
- Line: 22%
- Components: 17%
- Engines: 14%
- Modifications: 8%

By Global Region

- Europe: 26%
- North America: 27%
- Asia Pacific: 30%
- Middle East: 8%
- Latin America: 5%
- Africa: 4%

Source: ICF, CAPA 2016, Constant 2016$
The global MRO market is expected to grow by 4.1% per annum to over $100B by 2026

10-Year Global MRO Demand Growth

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<th>$ USD (Billions)</th>
<th>2016</th>
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Source: ICF, CAPA 2016
Note: Constant 2016$
Over the next decade, Latin America will see ~$2.7B increase in MRO spend

Difference in MRO Spend, 2026 vs. 2016 –By Global Region

<table>
<thead>
<tr>
<th>Region</th>
<th>Difference in MRO Spend, 2026 vs. 2016 (Billions)</th>
<th>Percent Change</th>
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<tbody>
<tr>
<td>Asia Pacific (excl China)</td>
<td>$8.0</td>
<td>65%</td>
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<td>China</td>
<td>$6.6</td>
<td>83%</td>
</tr>
<tr>
<td>Middle East</td>
<td>$5.5</td>
<td>101%</td>
</tr>
<tr>
<td>North America</td>
<td>$3.5</td>
<td>19%</td>
</tr>
<tr>
<td>Latin America</td>
<td>$2.7</td>
<td>71%</td>
</tr>
<tr>
<td>Western Europe</td>
<td>$2.7</td>
<td>18%</td>
</tr>
<tr>
<td>Eastern Europe (incl CIS)</td>
<td>$2.3</td>
<td>76%</td>
</tr>
<tr>
<td>Africa</td>
<td>$1.7</td>
<td>71%</td>
</tr>
</tbody>
</table>

Source: ICF, CAPA 2016, Constant 2016$
2016 MRO market in Latin America is ~$3.8B; Top 5 operator groups contribute over 50% of the MRO spend

Source: ICF, CAPA 2016, Constant 2016$
New Technology Aircraft
When Lindbergh flew from Long Island to Paris Le Bourget in 1927, it was a long flight – 33.5 hrs.

With no IFE, ACARS or … lavatory!
The “new technology” fleet is set to grow significantly

10-Year Fleet Forecast by Aircraft Generation

Old: First flight <1990s, e.g. A300/A310 / 747-1/2/3 / BAe146
Mature: First flight >1990s, e.g. 737CL / 737NG / A330/340 / 777 / E-Jet
New: First flight > 2005; e.g. 787 / A350 / A380 / CSeries / E-Jet E2
Source: ICF
Airlines need to understand how best to realize value from the terabytes of data generated by new technology aircraft.

**Stakeholder Battle:**
Who will control and gain the most from the operating data IP?

- Operators
- Lessors
- OEMs
- MRO Suppliers

Source: ICF Research
Today, AHM is being used by airlines and OEMs for reliability analysis & updating maintenance programs

**Evolution of Aircraft Maintenance Approach**

- Aircraft health monitoring
- Predictive maintenance
- Inventory optimization

**Leading to…**
- Improved aircraft availability
- Cost control

Source: ICF
As AHM becomes a critical service, non-OEM players need to develop capabilities to retain competitiveness...

- Aircraft Health Monitoring has been around in various forms since 1970
- Rolls-Royce was the first OEM to provide extensive services as part of its TotalCare program
- Large MROs have also started to integrate the product in their services offerings

Rolls-Royce starts its TotalCare program introducing extensive health monitoring services

AFI KLM and LHT launch health management and prognostic products

Boeing launches AHM as part of Boeing Edge

Airbus launches AiRTHM in 2012

Source: ICF
There are a number of structural trends affecting the maintenance data and health management market.

Key Trends:

- Increased OEM Aftermarket Focus
- E-enabled Aircraft
- Advancement in Analytics
- Large Volumes of Data Processing

Source: ICF
True benefits for the airline
Airlines can extract the highest value when operator not only predicts the issues but can allocate resources in an optimal way

<table>
<thead>
<tr>
<th>Capability</th>
<th>Goal</th>
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<tbody>
<tr>
<td>Prescriptive</td>
<td>Optimizing the MRO operation</td>
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<tr>
<td>Prognostics</td>
<td>Fault</td>
</tr>
<tr>
<td>Diagnostics</td>
<td>Troubleshooting</td>
</tr>
<tr>
<td>Storage and Basic Processing</td>
<td>Fault Identification</td>
</tr>
</tbody>
</table>

- **When can we schedule the repair in the most economic way?**
- **When will a part fail?**
- **Why did the part fail? What do we need to fix?**
- **What systems failed? What is the reliability of a system?**
For airlines, improved technical dispatch reliability and fewer NFFs are the key benefits of AHM

ICF sees 4 main categories of benefits for airlines:

- **Technical Dispatch Reliability**: Increased dispatch reliability

- **No Fault Founds**: Reduction in unnecessary removal of functional components
  - Airlines can optimize inventory by strategically distributing parts among maintenance centers and holding the right number of parts
  - Improved monitoring can reduce time spent on finding faults

- **Inventory**: Spare parts held by airlines/MROs

- **Labor Productivity**: Increased labor productivity

Source: ICF Analysis
THANK YOU

For questions regarding this presentation, please contact:

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ICF provides aircraft operators, manufacturers, financiers, lessors, and owners, maintainers, airports, and related businesses with world-class advisory, implementation, and improvement management consulting services.
ICF guides manufacturers, airlines, independent MROs, suppliers, and the financial community through every step of the aerospace and MRO supply chain to realize value and deliver strategies that drive growth. We understand and focus on the key aspects of the industry, and have the proprietary tools necessary for successful operations. Below, we briefly describe our core aerospace & MRO services and proprietary supporting products.

AEROSPACE AND MRO PRODUCTS
ICF’s suite of proprietary aerospace & MRO tools, models, and databases helps stakeholders navigate key business challenges to their advantage.

Aerospace and MRO

Strategy Development
Leveraging years of aerospace and MRO advisory experience as well as proprietary market intelligence, ICF delivers data-driven, objective insight to underpin sustainable strategies.

Transaction Support
For clients’ investment decisions, ICF combines global thought leadership in aerospace and MRO supply chain with accurate market intelligence, operations expertise, and unparalleled industry contacts.

Operations and Supply Chain
ICF’s proven tools and methodologies offer improved performance and cost reduction across manufacturing, operations, and all phases of make-buy supply chain planning and execution.

MRO Best Practices and Benchmarks
Comprehensive, proprietary databases on processes, costs, and organization.

Fleet & MRO Forecasts
Proprietary, independent forecasts for commercial and business aviation, industrial gas turbine, and military markets.

Value Database
Production value breakdown by component category and raw material content across the aerospace supply chain.

ICF focuses on key aspects of the industry that drive value in both revenue growth and cost control.

MRO Business Improvement
For airlines, OEMs, and independent MROs, ICF has deep experience in comprehensive operational and financial diagnostics based on extensive proprietary benchmarks, followed by results-oriented improvement programs.