INDUSTRY
INSIGHTS

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Quarterly Aviation Briefing

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Best Practices in Aircraft Storage

by **David Louzado, Principal** David.Louzado@icf.com

Many airlines find themselves in a position where one or more aircraft need to be parked up for indeterminate periods of time, due to operational changes, long term maintenance or fleet disposal activity. In this article ICF will cover some the issues related with aircraft storage and how to prevent the rapid deterioration of aircraft and the mitigation of resulting high cost remedial actions.

The main cause of unnecessary expenditure related to non-compliance with storage procedures is not a wilful neglect of the aircraft, but more often the inability to predict the length of storage time and an unwillingness to enter into the perceived high costs of a proper storage programme. Storage requires a significant amount of equipment that many airlines do not keep to hand, such as interior covers, wheel covers, full engine blanks, inhibiting compounds, etc., all of which need to be purchased and delivered in time for the aircraft's entry into storage.

Long periods of inactivity affect aircraft in different ways, hence the manufacturer (OEM) provides a detailed set of procedures to try to address this. These procedures are found in the relevant chapters 10, 49 and 70 of the aircraft maintenance manual (AMM) which covers parking, mooring, storage and return to service for the airframe, APU and engines.

Various OEM's will have their own specific periods of time before storage is required and the frequency of actions but most programmes tend to be in three parts:

1. Entry into storage–where engines are inhibited, interior perishable items are removed and placed into an indoor storage environment and systems are tested.
2. Storage action at 7, 14, 30, 60, 90 180 and 365 day repeat intervals where systems are operated, lubrication and cleaning tasks performed and fuel tanks are treated and tested for contamination.
3. Reactivation - the reversal of the storage actions and operation of the systems and engines in order to return to service, notwithstanding any scheduled maintenance due by calendar controls or lack of flight utilisation.

By far the biggest risk to operation and cost is failure to correctly preserve engines, resulting in FOD, wildlife nests and other internal corrosion issues. It is possible to mitigate preservation by running engines at regular intervals, however, for many types this process cannot continue for indeterminate lengths of time and preservation must then be performed after 60 days, for example. Engine running requires the aircraft to be in a condition for operating the engines and it is here where the best laid intentions of regular engine runs can be unintentionally broken by unforeseen events such as robbery of other airframe systems and an inability to move the aircraft due to physical limitations such as landing gear removals. Once the engine OEM is advised of the fact that correct storage procedures may not have been followed they will issue instructions to return the engine to service, subject to the circumstances provided, which can range from a significant amount of on wing work, such as replacing ancillary parts and flushing fuel and oil systems to the worst case scenario of a shop visit inspection. The reason for shop inspection is normally the risk of bearing corrosion which results from a failure to correctly drain, flush and inhibit the engine and that cannot be determined without disassembly.

Some engine OEM's may issue instructions to perform remedial on-wing maintenance and tests to release the engine to service after inadequate storage on the basis that the affected engines are not flown together on the same aircraft for a period of time, such as a few hundred hours, in order to mitigate any risk of an in-flight shut down causing a catastrophic event. Whilst this may appear easy, and certainly cheaper than a shop visit, the practical implications of having to find an engine not affected by the same issue in a small fleet can be significant and may result in the need to rent a spare engine for up to 1,000 hrs of operations. As long term parking often occurs during transition or fleet replacement, this solution is hard to manage for an airline that may be exiting the type and have no access to spare engines, or indeed the actual aircraft, after its departure from the fleet on a sale or redelivery to a lessor. Most lessors are acutely aware of the need to store aircraft in accordance with the correct procedures so during the redelivery process, any evidence of failure to store in accordance with the AMM could result in the redelivery being delayed and the potential to have to perform additional work at a time when the aircraft is expected to leave the fleet.

In summary, storage and parking requires planning and oversight, despite the random nature of "non-operations" at times. Review the AMM well in advance of any need to enter into a storage programme and order the correct materials. Be aware of the short term and long term requirements and do not allow the aircraft condition to enter into an "uncontrolled" state, as the remedies are far costlier than the storage programme. If there is any failure to comply, speak to the OEM, as they will have a defined set of actions that will help restore the aircraft. Perform periodic audits of stored aircraft to ensure compliance and condition has not deteriorated.

How are Mexican and U.S. carriers taking advantage of the new Mexico-United States Air Service Bilateral?

by **Barbara Mejia, Technical Director** Barbara.Mejia@icf.com

Until July 2016, scheduled passenger non-stop routes between Mexico and the U.S. were limited to a certain number of airlines by city pair. While most city pairs were limited to 3 airlines per country, Mexico City routes were limited to just 2 airlines per country.

In November 2015, a new modernized air transport agreement was reached between the two countries, allowing an unlimited number of carriers by country per city pair. The agreement was implemented in August 2016, and carriers of both countries begun to service to these routes in the last quarter of 2016.

EXHIBIT 1. NUMBER ROUTES WITH MAXIMUM CAP BY NUMBER OF US AND/OR MEXICO CARRIERS PRE- AND POST- NEW BILATERAL AGREEMENT

Number of Routes	Pre- December 2015		Post- December 2016		Post- December 2017	
	Mexico	US	Mexico	US	Mexico	US
Mexico City						
Limit of 2 carriers	8	4	7	3	4	3
More than 2 carriers	–	–	4	–	7	–
Non-Mexico City						
More than 3 carriers	3	13	3	11	3	9
More than 3 carriers	–	–	1	5	–	5

Source: SRS Innovata Published Schedule

Exhibit 1 left, shows that Mexican carriers have been adding routes from Mexico City for Mexico-origin traffic, while U.S. Carriers have increased non-Mexico City related Routes, essentially leisure destinations where the U.S. point of sale is stronger as it can be seen in Exhibit 2.

EXHIBIT 2. NUMBER OF AIRLINES BY ROUTE POST- NEW BILATERAL AGREEMENT

Number of Airlines per Country	Pre- December 2015		Post- December 2016		Post- December 2017	
	Mexico	US	Mexico	US	Mexico	US
Mexico City						
Chicago-Mexico City	2	2	3	1	3	1
Houston-Mexico City	2	2	2	2	3	2
Las Vegas-Mexico City	2	–	3	–	3	–
Los Angeles-Mexico City	2	2	3	2	3	2
Mexico City-Miami	2	1	2	1	3	1
Mexico City-New York	2	2	2	2	3	2
Mexico City-Orlando	2	1	3	1	3	1
Non-Mexico City						
Chicago-Cancun	–	3	–	4	–	4
Cancun-Los Angeles	–	3	1	5	1	5
Cancun-New York	1	3	2	4	1	4
Las Vegas-Monterrey	3	–	4	–	2	–
Los Angeles-Puerto Vallarta	–	3	–	5	–	5
Los Angeles-San Jose del Cabo	–	3	–	5	–	5

Source: SRS Innovata Published Schedule

Aeromexico was already operating the U.S.-Mexico routes which have seen an increase in the number of Mexican carriers. Volaris and Interjet, were the main players in adding the services to their route network.

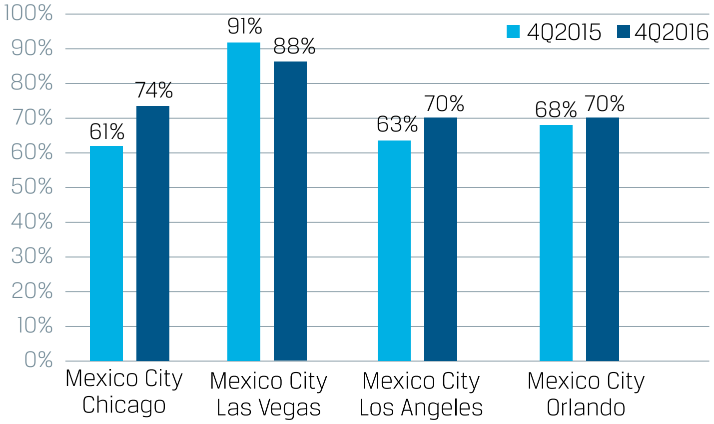
Another route that has shown an increase in airline service is Monterrey-Las Vegas, where Vivaerobus and Magnicharters started to operate after the new agreement- a route already operated by Aeromexico and Interjet.

Outside of Mexico City, full service and low cost carriers have both increased service. For example, American Airlines and Southwest both started operations between Cancun-Los Angeles and Puerto Vallarta-Los Angeles.

Passenger share in the incumbent markets, such as Mexico City to large U.S cities, to have shown an increase in passenger share after the additional services that vary in a range of 2% to 13% as shown in Exhibit 4.

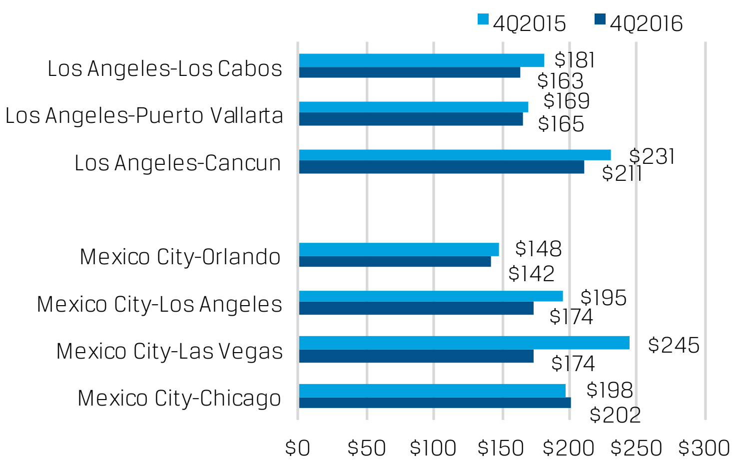
Average Fares have also shown a slight change with the additional air services, with the majority of the routes showing a reduction in average fare in its initial phase, yet the pattern changes by route as shown in Exhibit 4.

EXHIBIT 3. PASSENGER SHARE OF MEXICAN CARRIERS IN THE MEXICO CITY ROUTES WITH AN INCREASE IN NUMBER OF CARRIERS AFTER THE NEW BILATERAL AIR PASSENGER SERVICE AGREEMENT



Source: IATA Pax-IS

EXHIBIT 4. IMPACT IN AVERAGE FARE FOR MEXICO-US ROUTES WITH AN INCREASE IN NUMBER OF CARRIERS WITH THE NEW BILATERAL AIR PASSENGER SERVICE AGREEMENT (INCLUDES ALL SERVICES OPERATED BY US AND MEXICAN CARRIERS)



Source: IATA Pax-IS; Pax-IS data is not fully accurate and includes some estimates

Initially airlines have been conservative, especially U.S. carriers, in adding services to routes that had a cap in number in the US-Mexico market, however, future fleet growth will enable airlines to grow in markets that were limited before the new bilateral air passenger service agreement between US and Mexico. This could have an impact that would benefit the customer with more service choices and lower prices.

777-300ER Aircraft Review

by **Angus Mackay, Principal** Angus.Mackay@icf.com

VALUES AND INDICATIVE LEASE RATES

Boeing 777-300ER Values						
Build year	2007	2009	2001	2013	2015	2017
Currrent Market Value (2017 USD $millions)	81.7	93.9	108.0	124.3	142.9	164.4
Indicative Lease Rates (2017 USD $ thousands/month) (Low > High)	700-800	800-900	900-1,000	1,000-1,100	1,100-1,200	1,200-1,350

This Opinion does not constitute a formal appraisal

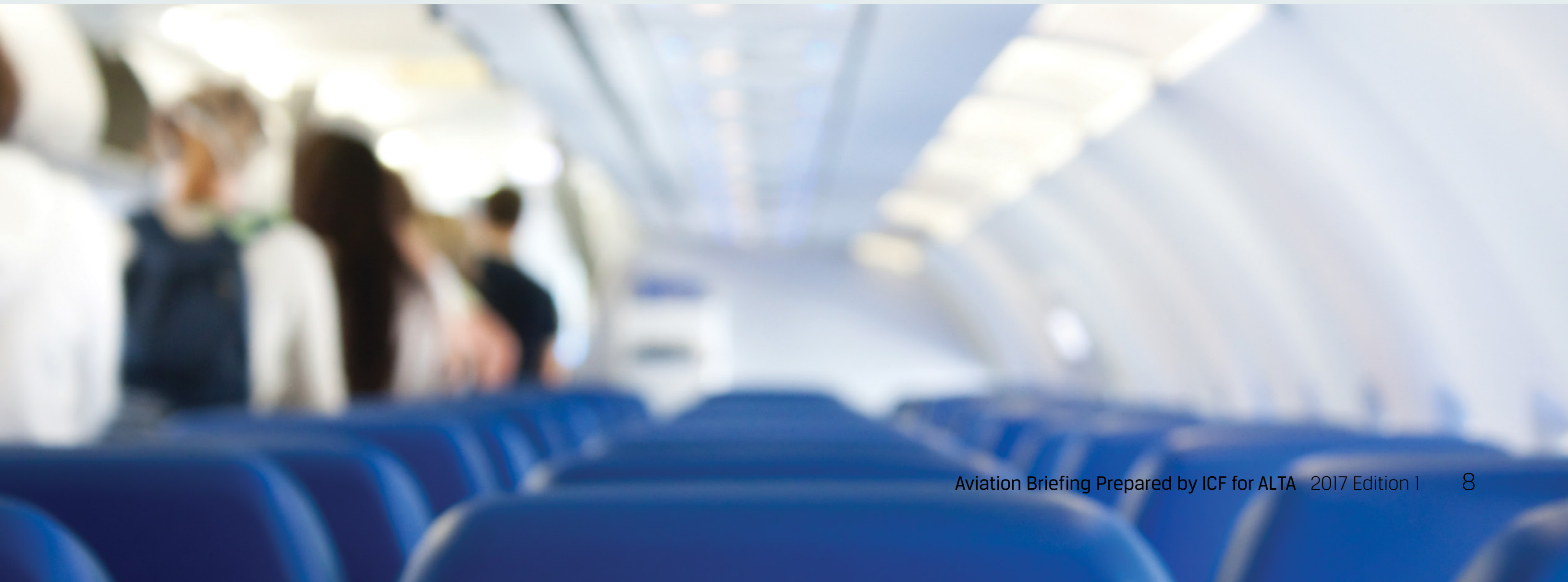
Assumptions:

Engine	GE 90-115BL
MTOW (lbs)	775,000

PRINCIPAL OPERATORS – ACTIVE FLEET AND BACKGROUND

Region	Active Fleet	Order Backlog
Africa	20	0
Asia-Pacific	296	33
Europe	120	8
Latin America & Caribbean	10	0
Middle East	218	39
North America	41	12
Undisclosed	0	6

Source: CAPA Fleet Database – February 2017.



Operator	Active Fleet	Order Backlog
Emirates Airline	129	23
Cathay Pacific	53	0
Air France	43	1
Qatar Airways	34	10
Turkish Airlines	32	1
EVA Air	30	5
Saudia	30	0
Singapore Airlines	27	0
Air China	23	3
All Nippon Airways	22	6

Source: CAPA Fleet Database – February 2017.

Boeing 777-300ER Technical Description

The Boeing 777-300ER aircraft, a member of the highly successful 777 commercial program, is a derivative of the 777-300, and entered service in 2004 with Air France. Seating 386 passengers in a typical three-class configuration – or up to 550 in all-economy, and intended to replace the 747-400, the 777-300ER was designed to operate on dense global routes over a range exceeding 7,800 nm.

The 777 makes extensive use of advanced composite and alloy materials featuring an advanced flight deck and a digital fly-by-wire control system. General Electric is a revenue and risk sharing partner in the Boeing 777-300ER and, with its GE90-115B, is the exclusive engine supplier.

Boeing 777-300ER Market Overview

As of February 2017, there were 705 Boeing 777-300ER model aircraft in commercial operation with 40 operators with only one aircraft parked. Publicly advertised availability of the 777-300ER is six, indicative of a firm current market for the type. The firm order backlog, however, has reduced to 98 aircraft representing less than one year's worth of production at current - 8.3 per month or 100 per year - production rates.

The 777-300ER competes in the 350 to 375 seat, long-haul widebody market segment, with a range exceeding 7,800 nm. This segment, previously dominated by the 747-400, exhibits solid demand as operators, particularly in the buoyant Asia-Pacific region, have increasingly employed large widebody twins which offer compelling operating economics versus four-engined aircraft like the 747-400 and A340-600. A key factor in the success of the 777-300ER to date has been the lack of true competition following the demise of the Boeing 747-400 and the Airbus A340-600.

Over the next several years, the 777-300ER will be challenged from both larger and smaller aircraft. At the lower end, the Airbus A350-1000 will challenge the 777-300ER once deliveries commence in 2017. This aircraft, flying 369 passengers up to 8,000nm, has garnered 206 orders as of February 2017. Boeing's 777-8X will also challenge the 777-300ER from the lower end of the payload spectrum, while the 777-9X will compete from above. Both Boeing products are planned for entry into service in 2020 and could be formidable competitors if they perform as planned.

As market interest in the 777-300ER diminishes, Boeing lacks the skyline to bridge to the 777-X and has announced progressive production cuts from 8.3 to 3.5 aircraft per month in 2018, which represents about two years of production based on the firm order backlog of 98 units. Values and lease rates for the type have declined with general widebody over-supply and is likely to accelerate in the near /medium term with 777-X and A350-1000 EIS. Prospects for a freighter conversion program seem uncertain in current market conditions, and significant redeployment to second-tier carriers may be challenging.

ICF believes the 777-300ER market will continue to soften with further deterioration in values and lease rates in the medium term.

The 777 makes extensive use of advanced composite and alloy materials featuring an advanced flight deck and a digital fly-by-wire control system.

The connected fleet: Further implications of aircraft health monitoring for the aviation supply chain

by **Richard Brown, Principal, and Alexander Diepeveen, Analyst at ICF Aerospace and MRO Advisory**
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It is difficult to avoid a hot topic currently permeating the aviation supply chain. The issues surrounding big data and aircraft health monitoring (AHM), data ownership, access and management are increasingly discussed in industry forums, publications, conferences and boardrooms. Yet, the benefits and challenges for airlines, OEMs, MROs and lessors continue to be debated, as does the role of each player in the AHM market.

The arrival of highly connected aircraft such as the 787, A350XWB and CSeries now allow for the measurement, storage and transmission of more data from aircraft engines, airframes and systems than ever before. The opportunities presented by e-enablement continue apace.

E-enabled aircraft are on approach

The arrival of e-enabled aircraft brought the promise of increased efficiency for airlines. OEMs discussed a new way of operating aircraft – a connected and integrated operation driving increased efficiency for airlines. The greater availability of maintenance and performance data encouraged a step-change towards health monitoring. Until recently, the adoption of aircraft health monitoring services has been slow. Though health monitoring has been available on aircraft engines since the 1990s, the benefits beyond the engine to the aircraft systems are only now gaining traction. The reason for monitoring engines is clear given the potential to maximize time-on-wing and avoid costly AOGs. Yet e-enabled aircraft now provide the ability to monitor key aircraft systems such as avionics and electrical components.

Approximately ~3% of the current fleet is e-enabled and ICF forecasts that approximately 45% of the fleet (over 15,000 aircraft) will be e-enabled by 2025. As the connected fleet grows and service offerings mature to taking advantage of big data, ICF sees operator maintenance increasingly benefitting from advanced analytics. The heart of the debate centers on the form the analytics takes and who performs the analysis.

Enter the MROs

With an increasing amount of data, it is likely that only the very largest operators will develop internal analytical capability. Since the arrival of a new aircraft type provides operators with an opportunity to change their maintenance approach many airlines that have traditionally performed MRO in-house have outsourced much of the MRO on new e-enabled aircraft. There is a variety of suppliers for operators to choose from ranging from the airframe OEMs to integrator MROs and independents willing to offer MRO services often under multi-component cost-perflying-hour contracts. The growing popularity of maintenance contracts covering a broad range of component types provides an opportunity for the maintenance supplier to use data analytics to drive down cost, increase reliability and ultimately improve the profitability of such service offerings. Given the relatively recent arrival of new e-enabled aircraft the advantage in providing aircraft health monitoring systems has typically resided with the aircraft, engine and system OEMs. However, more recently major integrator MROs have also been developing their own offerings. Airbus and Boeing launched their health monitoring service around 2012 and they continue to invest in data analytic capabilities. Rather than develop systems completely in-house, Boeing and Airbus signed agreements with Microsoft and IBM to provide IT infrastructure thereby speeding up the development of analytical capabilities. 2016 saw the large MRO integrators enter the data analytics market. Air France KLM E&M developed "Prognos" and Lufthansa Technik launched "Condition Analytics". The approach taken appears to differ from the OEMs. The OEMs have taken the "Big Data" path by analyzing large sets of data to find nuggets of information. On the other hand, MROs appear to be leveraging their maintenance expertise by focusing on a smaller number of specific, known and frequent reliability/cost issues caused by certain components. Lufthansa Technik offers analytical services to any airline and not just customers of their integrated support programmes.

Though health monitoring has been available on aircraft engines since the 1990s, the benefits beyond the engine to the aircraft systems are only now gaining traction.

Examining the benefits

The potential benefits offered by aircraft health monitoring are varied. ICF expects the majority of savings to come from improvements in dispatch reliability, reductions in inventory and better line-maintenance troubleshooting. With improved reliability comes the potential for reduced provisioning spend- a key source of revenue for component OEMs. The potential is for $3B+ in industry wide savings. In fact, the benefits are only just starting to be understood. To fully achieve the potential benefits that AHM offers operators will need to go beyond just monitoring the aircraft and predicting when parts will fail. Maintenance will need to be further integrated into an airline's operation. If AHM can predict when a part will fail, the airline's scheduling department needs to be able to efficiently utilise this information to minimise disruption to the operation. Information from aircraft health monitoring systems should enable airlines to make better-informed decisions such as whether to cancel or delay a flight or substitute another aircraft instead and of course perform the proactive maintenance. Health monitoring provides airlines with valuable time to make better decisions. Consequently, the industry is moving towards a prescriptive maintenance principle where data analytics works to prescribe maintenance activities based on the best outcome. For prescriptive maintenance to work optimally, OEMs and regulators need to continue to evolve current maintenance practices. Despite all the advances in maintenance computers, real-time condition monitoring and prognostics, MSG-3 is still the underlying process for most maintenance programmes. For instance, even if a system monitors oil levels and pressures during every part of the flight, the maintenance manual may still require a mechanic to visually inspect the oil level. Should such activities be reduced through AHM airlines can reap the benefit of quicker aircraft turnarounds and the reduction of some labour intensive activities.

> The benefits of advanced AHM and the implications for the supply chain are still being quantified and understood. AHM adoption is moving fast and provides real opportunities to reduce maintenance cost and improve aircraft reliability.

Supplier considerations

E-enablement is arriving now. AHM capabilities are advancing and the benefits are being better understood. Suppliers are preparing for the implications that AHM will have on their business. Engine OEMs are well aware of the benefits of increased time-on-wing which drive increased profits given that many of their engines are on $/HR maintenance programmes. System OEMs offering their own maintenance solutions can also drive reliability improvements into their products by better understanding how rotables perform in-flight. AHM offers the chance to reduce frustrating and unnecessary line removal of components.

A challenge for the smaller independent MROs is how to gain access to data given the increasing strength of the OEMs in the aftermarket. Furthermore, there is less opportunity for smaller MROs to justify investment in AHM offerings. Partnership with OEMs or larger integrator MROs may be the realistic approach should they wish to service the newest equipment.

Airframe and system OEMs – well placed to benefit from AHL – need to do a better job of demonstrating the real benefits that AHM heralds to operators. Some airlines see the benefits for MROs and OEMs but are less convinced about the tangible benefits AHM offers them directly. AHM is likely to assist the move to a more OEM-centric MRO market and airlines are aware of this. Furthermore, airlines are keen to avoid AOGs. How can AHM analytics help reduce AOGs and the associated costs these entail?

AHM also allows the airframe OEM to leverage their broad scope of services beyond maintenance thereby supporting their desire to grow revenue from services. It provides OEMs with an opportunity to demonstrate value without turning wrenches.

The benefits and challenges posed by AHM therefore continue to evolve as more e-enabled aircraft enter service. AHM offerings from stakeholders continue to be developed and new partnerships are being established. The benefits of advanced AHM and the implications for the supply chain are still being quantified and understood. AHM adoption is moving fast and provides real opportunities to reduce maintenance cost and improve aircraft reliability. Yet more still needs to be done. For instance, antiquated airline IT systems need to be improved to take advantage of what is being offered and the benefits to the end-user more clearly communicated. It is necessary to further consider how AHM is likely to influence your business and the role you will play as the market evolves. The time to act is now

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ICF International Aviation Expertise

For more than 50 years, ICF International (formerly ICF SH&E) has been serving the air transportation industry. ICF provides trusted aviation and aerospace expertise to airlines, airports, governments, international agencies, manufacturers, and financial institutions.

ICF's core aerospace capabilities include strategy and network planning, forecasting, operations, and logistics; revenue management; asset management and appraisals, supply chain and maintenance management, safety, and security and regulatory compliance; financial due diligence; and privatization, alliances, mergers, acquisitions, and alliances. For airports, ICF is a leader in air service development, demand forecasting, commercial planning, system and economic impact studies, sustainability, ground handling, and cargo operations. In addition to aviation, ICF is a leader in the energy, environment and transportation industries, public safety and defense, health, social programs, and consumer and financial business. This breadth of expertise further enhances the wealth of knowledge and experience available to its aviation clientele.

Committed to providing expert and impartial advice, ICF is both results and value driven. By participating directly in many emerging trends, ICF's aviation consulting group is especially well equipped to assist its clients in adapting to a rapidly changing environment. The firm's staff of nearly 100 professionals dedicated to aviation is based in offices in New York, Boston, Ann Arbor, London, Beijing, Singapore, and Hong Kong. ICF draws from a network of associates worldwide.

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