FROM THE GROUND UP

How the internet of things will give rise to connected aviation

Contents

Introduction

With this book, we aim to spark an industrywide conversation about how the Internet of Things will reshape aviation.

Obviously, this is a huge topic – one that we at Gogo couldn't tackle alone. That's why we interviewed thought leaders across the aviation and technology fields, gathering insights from a multitude of perspectives and industries.

The contributors come from around the world, representing aircraft operators and Original Equipment Manufacturers (OEM), avionics and supply chain companies, and connectivity and satellite providers within commercial and business aviation. We also interviewed innovators from industries such as Connected Car and Smart Cities who are taking the Internet of Things from hazy concept to concrete reality. These folks met our questions with enthusiastic responses and enlightened us with their initiatives. One theme that quickly emerged was our shared desire to heighten awareness and align our efforts toward a more connected future. Sincere thanks to all of them. Without their input, this book would not have been possible.

The Internet of Things – particularly how it applies to aviation – is often clouded by marketing claims and big ideas without much backbone to support them. But as you'll see in this book, the infrastructure needed to bring smart, connected aircraft to the sky is largely in place today. The challenge before us is to reach a common understanding of what's possible and how we can apply this new technology effectively.

The Internet of Things – which will be referred to as IoT throughout this book – is not a zero-sum game for aviation. What we're seeing is a move toward all-encompassing improvement from which all of us stand to benefit. The collaboration behind this project is a testament to that.

We hope this book sheds light on this transformative technology and ignites a wave of new ideas. But more importantly, we hope this endeavor makes it clear that we won't transform the industry simply by blanketing planes with sensors and connectivity. Only through broad collaboration and alignment of interests will we finally realize the promise of Connected Aviation.

Michael Small
President and CEO
Gogo

Key Contributors

Bob Crandall

Legendary airline veteran with a reputation for straight talk.

Bob Crandall earned his stripes by growing American into the world's largest airline while pioneering a variety of innovative initiatives including the first frequent flyer program, refinements to the hub and spoke system, and quantitative approaches to such problems as ticket pricing, fleet scheduling, and crew tracking. Bob brings a healthy dose of realistic thinking to any aviation-related subject, and to his membership on Gogo's board. Anyone who's met him knows it's best to let Bob speak for himself, which is exactly what he does in the "Bob's Takes" sections appearing throughout this book.

Michael Porter

Authority on how the Internet of Things is transforming business.

Michael Porter is a professor at Harvard Business School, and a leading authority on competition and strategy. He is a thought leader in the emerging role of information technology in transforming products and competition. Together with Jim Heppelmann, their articles "How Smart, Connected Products are Transforming Competition" and "How Smart, Connected Products are Transforming Companies" appeared in the November, 2014 and October, 2015 issues of the *Harvard Business Review*.

Foreword

A new era of competition, sparked by increasingly smart and connected products, is radically reshaping industries and companies.

Once composed solely of mechanical and electrical components, products have become complex systems that combine hardware, sensors, computing power, software, data storage, and connectivity in a myriad of ways. This is having a profound effect on companies and industries, and it is a game changer for competition across virtually all industries. We are seeing this first in manufacturing, but it is rapidly migrating to service industries. Since service industries use products, these new types of products will affect service delivery and service competition as well.

Aviation is no exception. This book highlights how the transformative shift in products and competition will impact aviation. The airplane is becoming a smart, fully connected product, and airlines will face more technological changes and strategic choices over the coming decade than perhaps any time in the industry's history.

The driving force behind this discontinuity in products is information technology (IT). IT has been a major driver of shifts in the economy for more than 50 years. Before the 1960s, products were mechanical and electrical, and activities across the value chain were performed manually through paper processes and human to human communications. The first wave of IT transformation came in the 1960s and '70s as computers and software automated activities within the enterprise. Innovations such as enterprise resource planning (ERP), manufacturing resource planning, and computer aided design (CAD) transformed activities across the value chain. The second wave of IT transformation came in the 1980s and '90s as the internet enabled coordination and integration across the value chain and with outside partners, suppliers, and customers across geographies. Customer relationship management (CRM), supply chain management (SCM), and global manufacturing systems were some of the manifestations.

Now, in 2016, these first two generations of IT have largely played themselves out. We are now entering a third wave of IT-driven transformation, as IT is

Michael Porter

becoming embedded in products themselves. Products are no longer just mechanical and electrical, but packed with IT and connected to the internet. This is happening across all products – in cars, mining machines, watches, water heaters, and in airplanes. Smart, connected products (SCPs) give rise to major new capabilities and new ways for products to create value. The data generated by SCPs is a major new resource, and data analytics is an emerging value driver. But SCPs also change the inside of companies too, triggering the next restructuring of the value chain and organizational structure. This is creating new best practices that every company must assimilate, and a new set of strategic choices.

In aviation, intense competition has historically led industry participants to compete heavily on price, limiting margins and producing an unending search for cost efficiencies. Connected Aviation will drive new major operational efficiencies. However, it also presents the opportunity for industry players to differentiate themselves in new ways. New potential sources of competitive advantage are emerging in flight operations, maintenance, passenger service, and many others. The connected aircraft will significantly improve operational effectiveness through applications such as flight-path tracking and optimization, predictive and preventative aircraft maintenance, and optimization of aircraft systems. Airlines will also be able to differentiate through new types of onboard services to meet the sophisticated needs of business passengers.

Airlines need to begin now to understand how the connected aircraft will transform the competitive landscape, and start down their own path. Connected Aviation is still in the early innings, but no airline, supplier, or business partner in aviation will be unaffected. This book provides an invaluable and insightful look at Connected Aviation, the technological evolution that is underway, the emerging choices, and the organizational changes that airlines and suppliers alike must make to successfully navigate.

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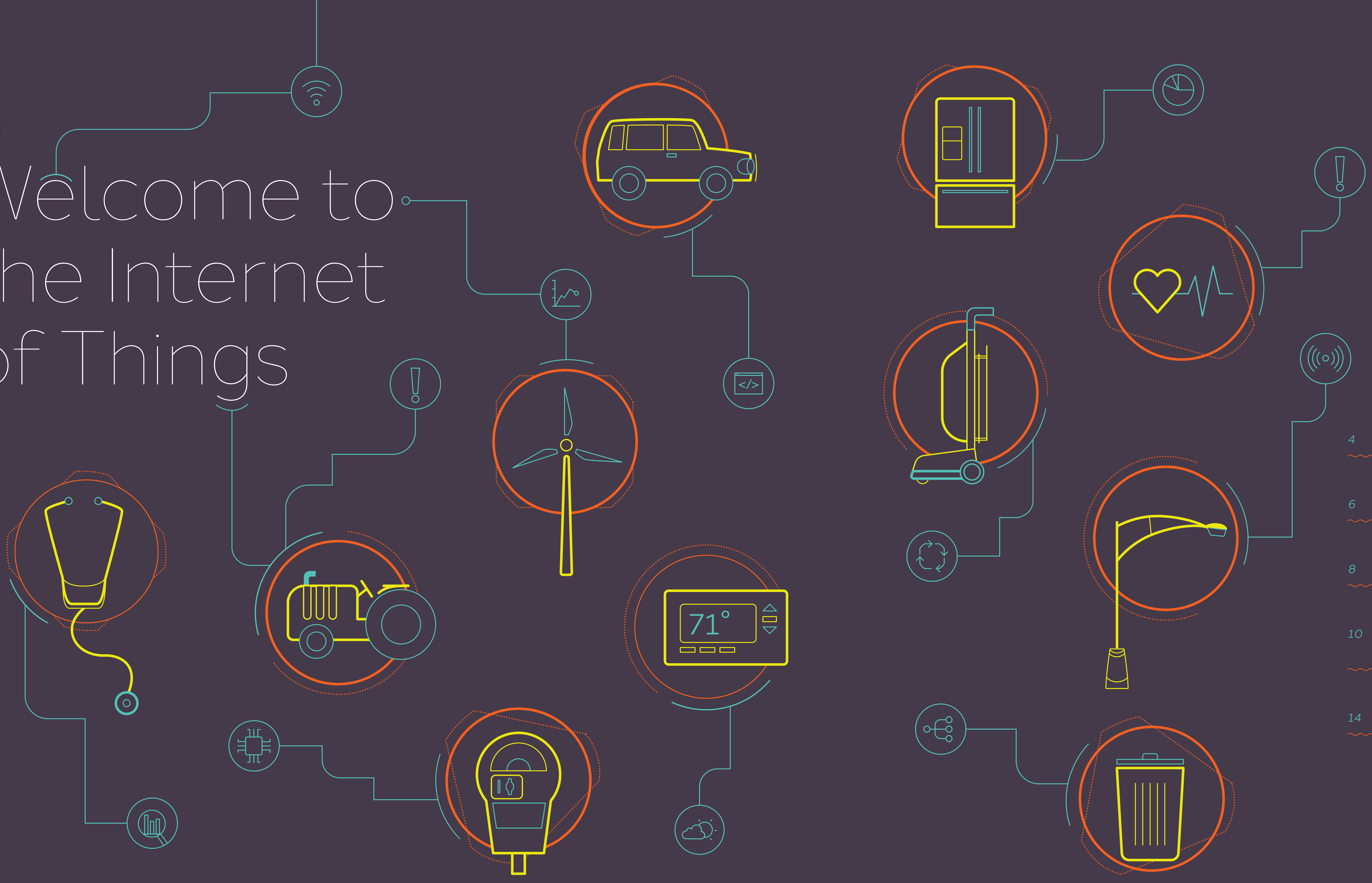
Welcome to the Internet of Things



Anyone catching a flight at Miami International Airport, dodging traffic on the streets of Singapore, tracking a run with a fitness watch, or brewing a cup of coffee with a smart coffeemaker has experienced the IoT. While consumers have come to anticipate new technology and the buzzwords it brings, IoT has become entrenched in pop culture.

Similarly, technology has introduced many new terms like IoT into corporate lexicon. Most Fortune 500 technology firms have now marketed some version of their services or products for IoT. Some IoT companies have even been acquired for billions of dollars without ever listing earnings.[1] It's clear that the "Internet of Things" has become an iconic phrase in the business world as well.

IoT and related technologies such as autonomous vehicles (Connected Car) and wearables, are at the peak of the hype curve in regards to inflated expectations, according to Gartner's "Hype Cycle for Emerging Technologies."[2] IoT surrounds us in our cars, homes, cities, and offices, impacting the way we work and live. But what is it, and why is it so important?

What is the Internet of Things?

“IoT is where objects or devices, like aircraft or avionics, are connected and exchanging data with other systems. It’s where everything effectively becomes a node on a network, and we’re able to sense and monitor the status of those devices.”

Mark D. Miller
Senior Vice President and General Manager
The Weather Company an IBM Business
(formerly WSI Corporation)

“IoT is the seamless integration of the physical and digital worlds through networked sensors and actuators, big data, processes, and people.”

Ben Salama
Global IoT Practice Connected Operations Lead
Accenture Digital - Mobility

“IoT is enabled by the internet and connects the things, the machines, and the devices of the world. It’s about machine to machine. It’s about machine to people. It’s about machine to knowledge, and building a whole knowledge around that space.”

Dave Bartlett
Chief Technology Officer
GE Aviation

“IoT is an expansion of how we connect devices and people to make them smarter and more predictive in the environment around them. It enables things they may want to do even if not physically in that location.”

Michelle Gattuso
VP of Product Operations
Motorola Mobility

Building a definition

Michael Porter from Harvard Business School, describes IoT as the "third wave" of technology evolution within IT – following the shift from manual to automated activities in the 1960s and 1970s (first wave), and combining automation with the internet to integrate these activities in the 1980s and 1990s (second wave). But what is IoT fundamentally? Is it just a marketing gimmick that delivers no real value? Pinning down a specific and broadly accepted answer is challenging, and intensive scrutiny uncovers answers that conflict in some ways. As ThingLogix's Steven Loving ascertains, "The definition of IoT will fluctuate depending on who you ask – it's best to understand the background of who you are asking to appreciate how they view IoT."

IoT has been used synonymously with "Industrial Internet," "Machine to Machine (M2M) networks," the "Internet of Everything," "Array of Things," "smart, connected devices," etc. IoT encompasses all of these and more. Regardless of industry, several key elements emerge when defining IoT.

Cloud-based data processing has enhanced our ability to analyze events and trends. Wirelessly connected devices with embedded sensors are enabling automated data collection and providing real-time access to information. By generating bursts of real-time data and analytics, IoT enhances the value of cloud data. This allows for the analysis and reporting that ultimately drives proactive and predictive insights.

Real-time exchange of data between sensors is critical, and this requires connectivity. According to Porter and PTC's Jim Heppelmann, "Connectivity allows information to be exchanged between the product and its operating environment, its maker, its users, and other products and systems."[3] Further, network communications between products or things and the cloud allow "functions of the product to exist outside the physical device."[4]

Cisco's Howard Charney adds, "Value is really obtained when we connect people and data and

> "Connectivity allows information to be exchanged between the product and its operating environment, its maker, its users, and other products and systems."
>
> **James Heppelmann**
> *President and CEO*
> PTC

things together – it's all connected via process." Real-time connectivity provides access to information that was previously seen only when sensor systems identified significant deterioration in performance. Connectivity enables a shift from reactive, delayed response and low control, to real-time preventive response, situation avoidance, and insightful control.

Taking this idea further, Heppelmann asserts that IoT is about creating, "a feedback and control loop, to understand what's happening on the other end." To PTC, a leader in developing IoT solutions and supporting data services, the value is in optimization and data analysis. Rather than simply collecting masses of data from sensors, the feedback and control loop in essence, closes the loop in process by providing actionable insight and enabling optimization. The term "analytics" is often associated with IoT, but this is merely the process by which IoT delivers its true value: actionable insights.

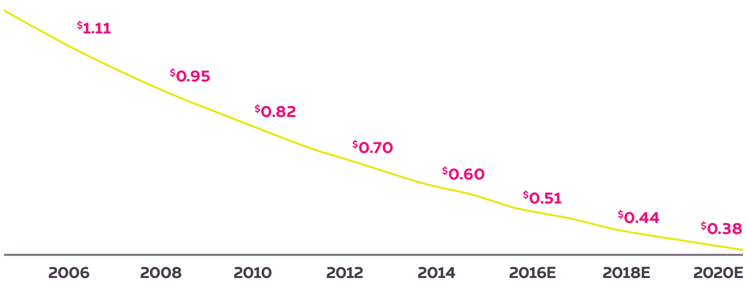
Any complete IoT definition must include sensors, real-time data aggregation and analysis, and actionable insights. Thus, IoT is the framework of sensors virtually connecting the physical world with processes that distribute data securely in order to provide the real-time information that drives actionable insights. Commercially, this means improved performance and optimized operational costs.

IoT is not simply a buzzword, but a market evolution affecting both consumers and businesses. It is an evolution already underway.

Why now?

With IoT at the peak of Gartner's hype cycle, it is important to understand how technology has evolved and contributed to the rise of IoT.[5] Careers and fortunes have been made and lost on bets in advance of new technology, but there is extensive research around the evolution of IoT. Two particular catalysts have contributed to the rise of IoT: the decreasing cost of sensors and the proliferation of personal consumer devices.

AVERAGE SENSOR COST FORECAST

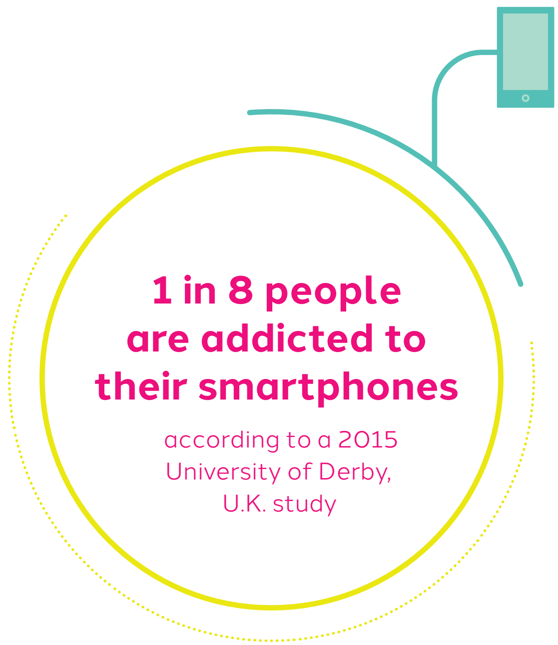


Source: *Business Insider*, "The Internet of Everything: 2015 [Slide Deck]," by John Greenough, BI Intelligence, April 8, 2015. http://www.businessinsider.com/internet-of-everything-2015-bi-2014-12?op=1

Electronic sensors have become cheaper to manufacture recently, leading to their ubiquity.

DECREASING SENSOR COST

In 1965, Gordon Moore predicted that "computing would dramatically increase in power, and decrease in relative cost, at an exponential pace."[6] "Moore's Law is about exponentially moving forward in terms of capability, price, and performance, so we're seeing a greater number of sensors at a lower price point," adds Dave Bartlett from GE. "The average sensor cost fell from $1.30 in 2004 to 70¢ in 2012 – a more-than- 40% decrease."[7] For example, the average selling price (ASP) of accelerometers for automotive applications is expected to decrease from $2.26 in 2014 to $1.85 in 2020.[8] According to BI Intelligence, "The price of sensors that make up IoT will keep falling" in the future.[9]



University of Derby, "Smartphones Are Addictive—Reveals First UK Study from The University of Derby," March 3, 2015.

http://www.derby.ac.uk/newsevents/news/archive/news-archive/smartphones-are-addictive--reveals-first-uk-study-from-the-university-of-derby.php

PROLIFERATION OF CONSUMER DEVICES

Decreasing technology costs have also made personal devices such as smartphones and tablets affordable for the mass consumer market. Sales of the Apple iPhone, for example, have gone from 1.39 million in 2007, to 231.22 million in 2015.[10] Forrester forecasted that by the end of 2015, 42% of the global population would own a smartphone.[11] By 2019, the International Data Corporation expects the smart connected device market to be "77.8% smartphones, 11.6% PCs, and 10.7% tablets."[12]

Studies also show that consumers are developing emotional attachments to their smart devices, further spurring this rapid adoption. The preference for smart personal devices and the ubiquity of wireless connections have led to a demand for constant connectivity. As Air Canada's Lise Fournel observes, "Our customers are now connected all the time. It's a continuum of their lifestyle. They are even walking while looking at their phones."

Consumers are clearly engaging with technology in ways they never have before. Rapid adoption and reliance on smart, connected devices has made it easier to push new technology, setting the stage for IoT. Moreover, the adoption of consumer devices has led to their use in industrial applications. Referred to as commercial off-the-shelf (COTS) technology, the use of these devices and software is motivated by the desire to reduce operational costs.

Decreasing sensor costs and the rapid device adoption on both consumer and industrial fronts have brought IoT to fruition, and its impact will only grow stronger.

IoT's impact on industry

Consumer IoT products, such as the Fitbit wearable or Nest Learning Thermostat, garner attention because they are real objects with results that can be physically experienced. They offer tangible benefits, such as improving health, saving money, or increasing comfort. However, IoT offers even greater value in industrial applications. The impact of optimizing air conditioning in a factory or office is far greater than in a home. IoT also offers more touch points in industrial environments due to the volume of systems that can be integrated and the number of devices in use.

PUTTING IOT TO WORK

According to Porter, two key IoT benefits are operational effectiveness and strategic differentiation, which can have implications for all parts of the business value chain, from product development, to marketing and sales, to service and support.

Operational effectiveness

To achieve operational effectiveness, one of the key value drivers is the reduction of product and service costs. A recent study by Machina Research and Xively by LogMeIn shows that 44.4% of companies cited reducing operational expenses as a main reason to deploy IoT.[13] As an example, ATM industry leader Diebold began utilizing smart, connected products to conduct remote diagnostics and issue resolution across its network of 5,000 ATMs. Results showed a "17% increase in remote issue resolution, a 15% reduction in equipment downtime, and average downtime responses shortened to less than 30 minutes."[14]

Cities also offer prime examples. In Barcelona, IoT is improving the efficiency of waste management. By embedding sensors in garbage cans, capacity – rather than fixed collection schedules – determines waste collection frequency. With IoT initiatives such as this, Barcelona is projected to save more than

$4.1 billion in the next decade.[15] On another front, “The City of Chicago recently saw a 20% savings on its rat control efforts due to utilizing predictive analysis of where nests were expected to be built,” explains Brenna Berman from Chicago’s Department of Innovation and Technology (DoIT).

Cisco suggests that by equipping street lights with motion sensors and connecting them to the network, cities can dim lights to save energy, which can reduce costs by 70%.[16] These results all drive cost reduction, thereby improving operational efficiency.

Strategic differentiation

According to Heppelmann’s IoT value roadmap, two key value drivers are differentiating product and service offerings and enabling new revenue streams. This is further validated by a recent study of companies that have deployed IoT solutions by Machina Research and Xively by LogMeIn. The two main reasons for deploying IoT were to better compete with rival products and services (64.6%) and to expand revenue opportunities (56.8%).[17] Caterpillar offers an example of revenue expansion through IoT. By partnering with Uptake, a data analytics startup, Caterpillar has already seen an increase of more than $1.1 billion in annual revenue from various software and newly developed data products.[18]

How the Internet of Things drives value in an organization

OPERATIONAL EFFECTIVENESS

Optimize Operational Performance

Combine real-time data from assets, enterprise systems, and people to increase operational efficiency of equipment, plants, and logistics.

Improve Risk Management

Improve ability to proactively identify and mitigate financial, safety, environmental, and regulatory compliance risk.

Reduce Product and Service Costs

Implement proactive service, limit warranty costs and risks, and optimize service and product development processes.

STRATEGIC DIFFERENTIATION

Improve Customer Experience

Make products smarter, easier to update, and more personalized to improve customer experience and value.

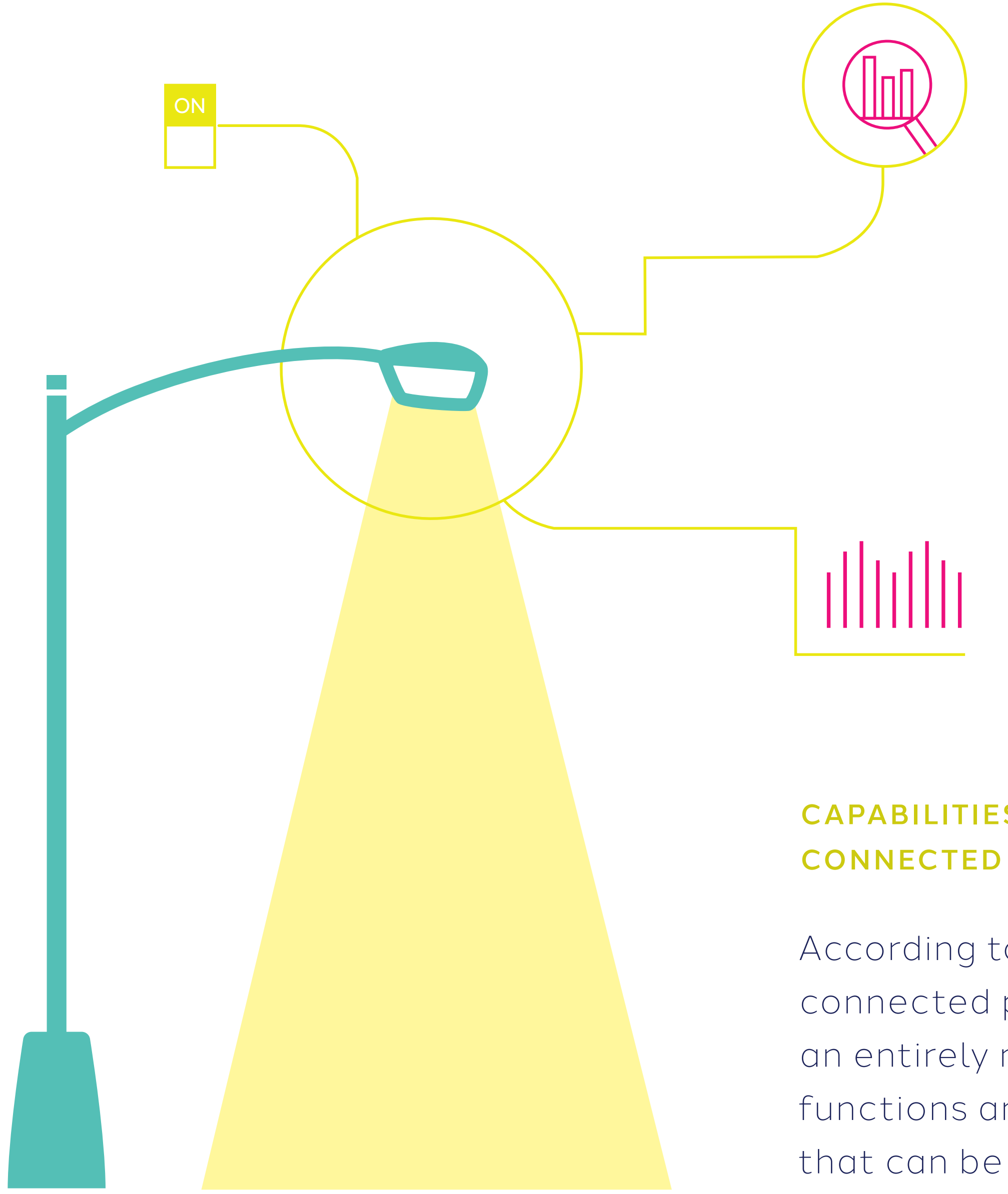
Differentiate Product and Service Offering

Quickly deliver compelling, differentiated products and services that meet or anticipate customer demands.

Enable New Revenue Streams

Maximize revenue opportunities and value capture from new services or new business models.

Source: PTC, “The IoT Value Roadmap,” 2015.



CAPABILITIES OF SMART, CONNECTED PRODUCTS

According to Porter, smart, connected products "enable an entirely new set of product functions and capabilities" that can be grouped into four phases: monitoring, control, optimization, and autonomy.[19] The four phases build upon one another: Once a product enters the control phase, it inherently has the ability to monitor.

STEP 1 MONITORING

The observation of device operation, or monitoring, is the foundational capability of any smart, connected product. Monitoring does not require significant change in the product; it simply adds a recording and/or reporting mechanism.

Home automation systems do exactly this, allowing homeowners on holiday to know the lights are off or the boiler is running at an idle state. Utility companies have realized benefits from self-reporting meters, which eliminate the need for employees to visit homes to collect information.

Industrially, a factory using devices that report current status (even a simple on or off) has a means of validating assumptions about performance. To a company, the value of monitoring can have a positive return relative to cost.

STEP 2 CONTROL

Embedding software in devices or the cloud to allow remote control is the next capability. This can be as simple as diagnostics that validate the data being collected, or it can extend much further. Many home security system and thermostat manufacturers have added control capabilities to their devices, which consumers can manage remotely – a convenience that provides value.

On the industrial side, controls are typically found in manufacturing plant safety systems. Rather than simply monitoring valves, a control system can allow technicians to remotely trigger reactions to environmental changes. Such remote operation of systems is not uncommon, but more advanced layers are not yet ubiquitous. Huge potential exists to expand this capability and reap the benefits of IoT.

STEP 3 OPTIMIZATION

Optimization becomes possible when a smart, connected product can analyze data collected from monitoring, and can be controlled remotely. This phase depends on the user's ability to analyze the data and make recommendations that improve operation.

A prime consumer example is the Nest Learning Thermostat, which automatically sets home temperature based on historical understanding of user preferences combined with contextual awareness of the current environment. This optimization results in a more comfortable environment for the homeowner, while also offering potential cost savings.

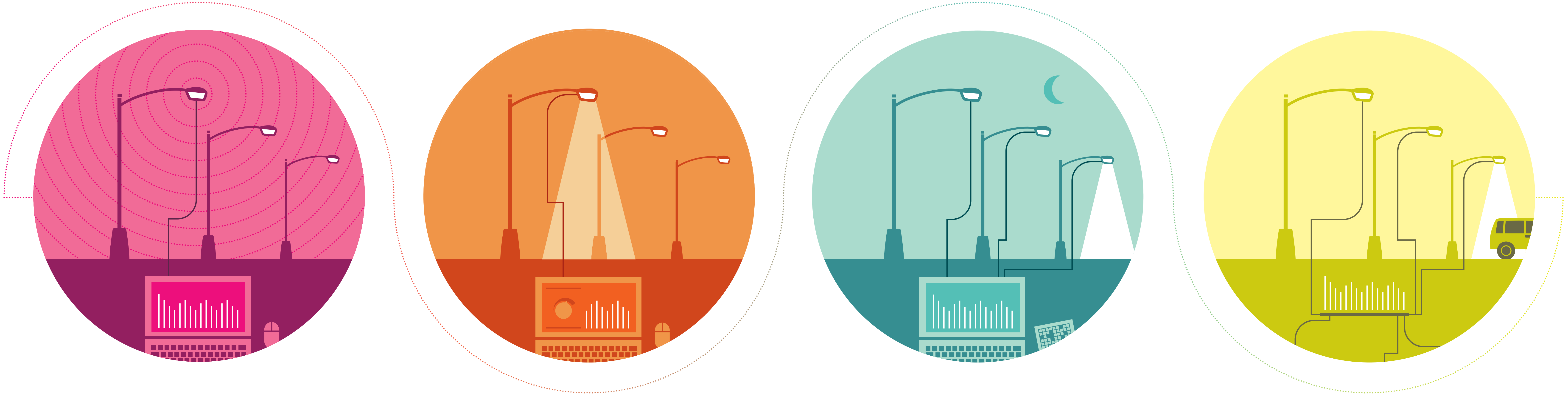
Commercially, optimization can be seen in agricultural applications. Soil monitors can track moisture and nutrient levels, triggering sprinklers or fertilizer applications to exact demand levels. This reduces waste and run-off, while producing a more robust crop.

A product intelligent enough to learn patterns and evolve was once the realm of science fiction. Modern computing has made this idea commonplace.

STEP 4 AUTONOMY

At the apex of smart, connected product capabilities is autonomy, which provides maximal return on investment. Progression to this stage is not yet widely in place.

The Roomba vacuum is a consumer example of autonomy, as the device continually monitors its environment and modifies operation to deliver optimal results without user input. Another example is the self-driving car. While there are currently cars with self-driving features on the road, BI Intelligence estimates there will be 10 million autonomous cars on the road by 2020.[20] McKinsey Global Institute ▸



STEP 1
MONITORING

Monitoring systems can be as simple as detecting bulb failure and creating a maintenance report based on that data. More advanced implementations include motion sensors to track pedestrian or vehicle traffic, environmental sensors for air quality and emissions measurement, and video sensors to monitor road conditions. Each of these can trigger a response to the appropriate public service department.

STEP 2
CONTROL

Embedded or cloud-based software allows for remote management of the connected hardware. Lighting levels can be altered from the operations center, allowing city officials to dim lights to save electricity, or increase brightness in emergency situations.

STEP 3
OPTIMIZATION

Monitoring and control applications combine with software algorithms and data mining to allow the network of streetlights to perform more efficiently. Predictive failure diagnostics become more specific and accurate, thereby reducing costs. Similarly, total light output can be managed by local photovoltaic sensors, allowing the lamp to slowly increase its output as the sky darkens. This saves energy and extends the life of the system.

STEP 4
AUTONOMY

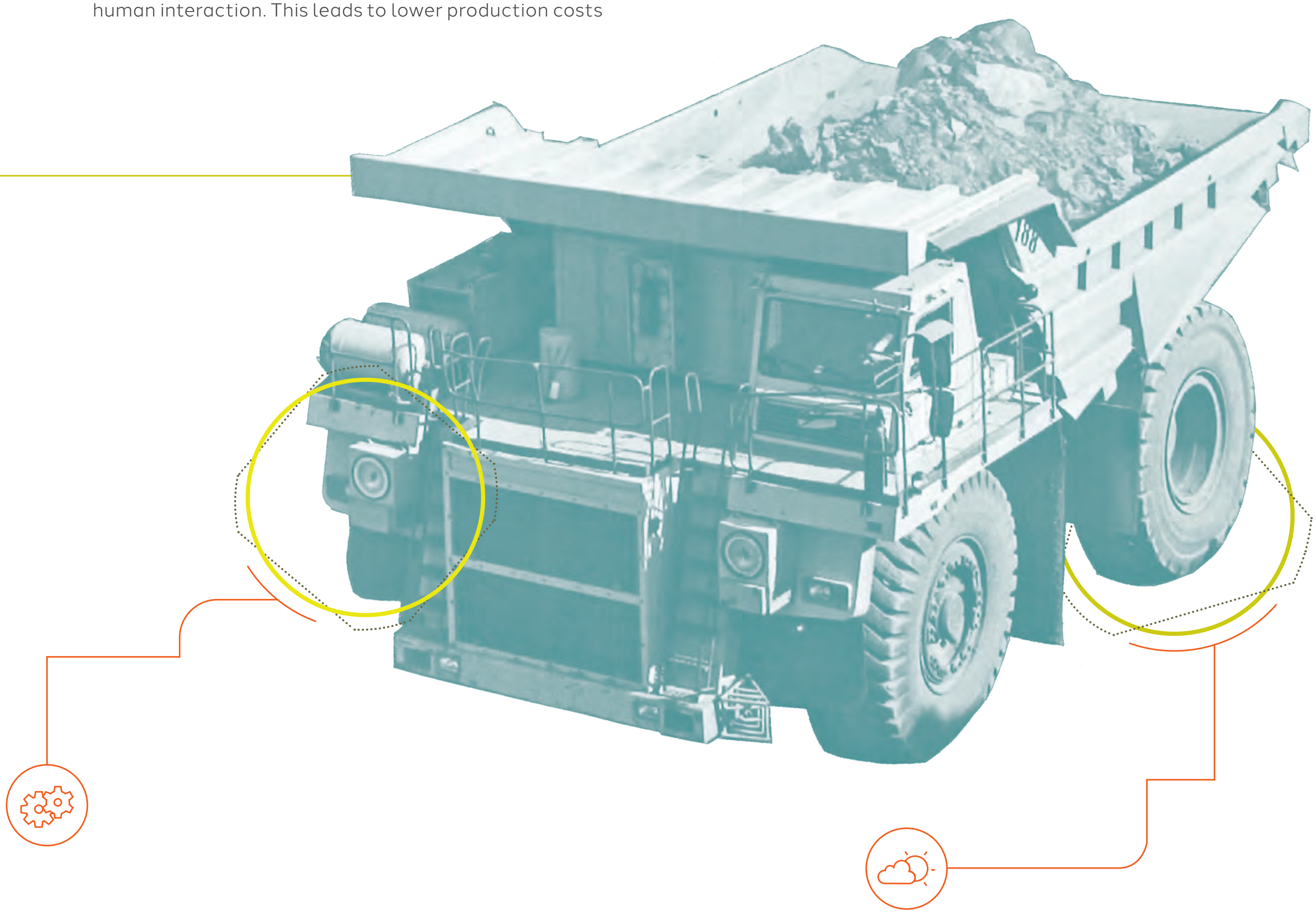
Combining the prior phases with automation algorithms creates an environment where the system can now control itself. Lights can brighten or dim based on the presence of pedestrian or vehicle traffic, providing a safe travel path while reducing total consumption and costs. A light sensing an impending failure state may dim its output to prolong the functional lifespan while signaling to neighboring fixtures a need to increase output, maintaining the overall volume of light in an area.

Based on: Harvard Business Review, "How Smart, Connected Products Are Transforming Competition," by Michael E. Porter and James E. Heppelmann, November 2014.

estimates this technology could lead to a near-90% reduction in vehicle crashes in the U.S.[21]

Manufacturing production lines offer an industrial example: Autonomy enables them to adjust output rates based on observed conditions. General Motors and Harley-Davidson have systems that automatically adjust the processes of paint shops in their factories. Humidity and temperature sensors trigger changes to ventilation and paint flow, ensuring a consistent coat of paint without human interaction. This leads to lower production costs and ultimately higher customer satisfaction. Rio Tinto, an Australian mining company, uses autonomous trucks and rail systems in some of its mining facilities, allowing for safer and more efficient movement of goods across sites.

Autonomy may not be attainable in all industries as user tolerance, market forces, and regulations may limit adoption. But when realized, the benefits of autonomy become obvious.



"We don't need new technology. What we need is innovation that makes it practical and easy to use."

Michael Simon
Chairman of LogMeIn and Founder of Xively by LogMeIn

Looking forward

IoT may still be in its infancy, but the McKinsey Global Institute sees a market as large as $11 trillion annually in just a decade.[22] And while the projected number of connected things in the future varies by study, the common denominator is that IoT is upon us, and it has real potential.

While consumer-facing products such as the Nest Learning Thermostat or Roomba vacuum cleaner receive the majority of media attention, consumer IoT value is expected to account for about half of the expected industrial IoT value. McKinsey expects the ratio to be near 2:1, with industrial and manufacturing processes leading the market in value generation.[23] Reaching this target will require significant improvements in the volume of real-time data processing – a key component of the IoT value proposition. According to McKinsey, only 1% of available data is currently utilized, mainly for anomaly detection and control.[24] For example, a modern offshore oil rig may have more than 30,000 sensors, but less than 1% of the data collected is used to drive decisions.[25] This translates to huge potential as more data is employed for optimization and prediction, which provide the greatest value.

Time will further define IoT and the value it delivers. As IoT technology matures, it is expected to progress through Gartner's hype cycle. Employing IoT without understanding the value drivers will likely lead some companies to invest in areas that do return value, leading IoT to Gartner's "Trough of Disillusionment," where the technology fails to provide the expected value. However, each IoT implementation or "focused experimentation" will help draw the value line and establish areas where IoT is most effective, progressing to Gartner's "Slope of Enlightenment."[26] Ultimately, Gartner expects IoT to go from market buzz to achieving mainstream adoption, where "real-world benefits of the technology are demonstrated and accepted," in five to ten years, when it finally reaches the "Plateau of Productivity."[27]

IOT on the rise

Various projections show that by 2020, the number of connected things will have grown exponentially

25 BILLION
BY 2020

According to Gartner, approximately 3.9 billion connected things were in use in 2014 and this figure is expected to rise to 25 billion by 2020.

Source: Gartner, Consider All Cost Elements When Planning for an Internet of Things Initiative, Federica Troni, 01 July 2015

30 BILLION
CONNECTED THINGS

IDC predicts that by 2020, there will be a projected 30 billion connected "things" and a revenue opportunity of $1.7 trillion for the ecosystem.

Source: IDC, "Worldwide Internet of Things Forecast," 2015-2020, May 2015

34 BILLION
CONNECTED DEVICES

BI intelligence projects an increase of devices connected to the internet — from 10 billion in 2015 to 34 billion by 2020 — representing a 28% five-year compound annual growth rate (CAGR).

Source: BI Intelligence, "The Internet of Things 2015: Examining How The IoT Will Affect The World," November 2015

50 BILLION
THINGS CONNECTED

Cisco estimates more than 5 billion people will be connected, not to mention 50 billion things.

Source: World Economic Forum, "Are you ready for the Internet of everything?," by John Chambers, January 15, 2014. https://agenda.weforum.org/2014/01/are-you-ready-for-the-internet-of-everything/

BOB'S TAKE

It is clear that we can now communicate much more easily and rapidly than was true five years ago,

and equally clear that we will do far better five years hence. As devices proliferate, and their interaction produces more and more data, individual operators and the industry will begin to produce better and more inclusive performance standards than have previously been possible. During the next several years, the industry will need to come to grips with how much of the new capability will be invested in collective improvement, and how much will be used to create competitive differentiation. It should be a fascinating time.

Endnotes

1. M&A International Inc., "Technology Report—The Internet of Things: On the Internet, Nobody Knows You're a [Nest] Thermostat," June 2014. http://www.mergers.net/sites/default/files/MAI.Technology.Report_June2014_0.pdf

2. Gartner Press Release, "Gartner's 2015 Hype Cycle for Emerging Technologies Identifies the Computing Innovations That Organizations Should Monitor," August 18, 2015. http://www.gartner.com/newsroom/id/3114217

3. *Harvard Business Review*, "How Smart, Connected Products Are Transforming Companies," by Michael E. Porter and James E. Heppelmann, October 2015.

4. *Harvard Business Review*, "How Smart, Connected Products Are Transforming Companies," by Michael E. Porter and James E. Heppelmann, October 2015.

5. Gartner Press Release, "Gartner's 2015 Hype Cycle for Emerging Technologies Identifies the Computing Innovations That Organizations Should Monitor," August 18, 2015. http://www.gartner.com/newsroom/id/3114217

6. Intel, "50 Years of Moore's Law, Fueling Innovation We Love and Depend On." http://www.intel.com/content/www/us/en/silicon-innovations/moores-law-technology.html

7. *Business Insider*, "The Internet of Everything: 2015 [Slide Deck]," by John Greenough, BI Intelligence, April 8, 2015. http://www.businessinsider.com/internet-of-everything-2015-bi-2014-12?op=1

8. Yole Développement, Status of the MEMS Industry report, May 2015.

9. *Business Insider*, "The Internet of Everything: 2015 [Slide Deck]," by John Greenough, BI Intelligence, April 8, 2015. http://www.businessinsider.com/internet-of-everything-2015-bi-2014-12?op=1

10. Statista, "Unit sales of the Apple iPhone worldwide from 2007 to 2015 (in millions)," 2015. http://www.statista.com/graphic/1/276306/global-apple-iphone-sales-since-fiscal-year-2007.jpg

11. Forrester, "Mobile Leaders Will Break Away from Laggards in 2015," by Thomas Husson, November 11, 2014. http://blogs.forrester.com/thomas_husson/14-11-11-mobile_leaders_will_break_away_from_laggards_in_2015

12. IDC Press Release, "As Tablets Slow and PCs Face Ongoing Challenges, Smartphones Grab an Ever-Larger Share of the Smart Connected Device Market Through 2019, According to IDC," March 20, 2015. http://www.idc.com/getdoc.jsp?containerId=prUS25500515

13. Machina/LogMeIn, "Lessons Learned from Early Adopters of the IoT: A Global Study of Connected Businesses," November 2015.

14. PTC, "Diebold Customer Success Story— IoT-Enabled Services," 2015. http://www.ptc.com/internet-of-things/customer-success/diebold

15. Bloomberg Business, "Barcelona's Smart Trash Cans Pave Way for Mobile Future," by Amy Thomson, February 23, 2014. http://www.bloomberg.com/news/articles/2014-02-23/barcelona-s-smart-trash-cans-pave-way-for-mobile-future

16. *International Business Times*, "CES 2014 Keynote Recap: Yahoo, Cisco, Sony and Other Announcements So Far," by Abigail Elise, January 9, 2014. http://www.ibtimes.com/ces-2014-keynote-recap-yahoo-cisco-sony-other-announcements-so-far-1533274

17. Machina/LogMeIn, "Lessons Learned from Early Adopters of the IoT: A Global Study of Connected Businesses," November 2015.

18. Fortune, "The Race to the Internet of Things," by Michal Lev-Ram, March 5, 2015. http://fortune.com/2015/03/05/the-race-to-the-internet-of-things/

19. *Harvard Business Review*, "How Smart, Connected Products Are Transforming Competition," by Michael E. Porter and James E. Heppelmann, November 2014.

20. Business Insider, "10 Million Self-Driving Cars Will be on the Road by 2020," by John Greenough, BI Intelligence, July 29, 2015. http://www.businessinsider.com/report-10-million-self-driving-cars-will-be-on-the-road-by-2020-2015-5-6

21. McKinsey & Company, "Ten Ways Autonomous Driving Could Redefine the Automotive World," by Michele Bertoncello and Dominik Wee, June 2015. http://www.mckinsey.com/insights/automotive_and_assembly/ten_ways_autonomous_driving_could_redefine_the_automotive_world

22. McKinsey & Company, "The Internet of Things: Mapping the Value Beyond the Hype," June 2015.

23. McKinsey & Company, "The Internet of Things: Mapping the Value Beyond the Hype," June 2015.

24. McKinsey & Company, "The Internet of Things: Mapping the Value Beyond the Hype," June 2015.

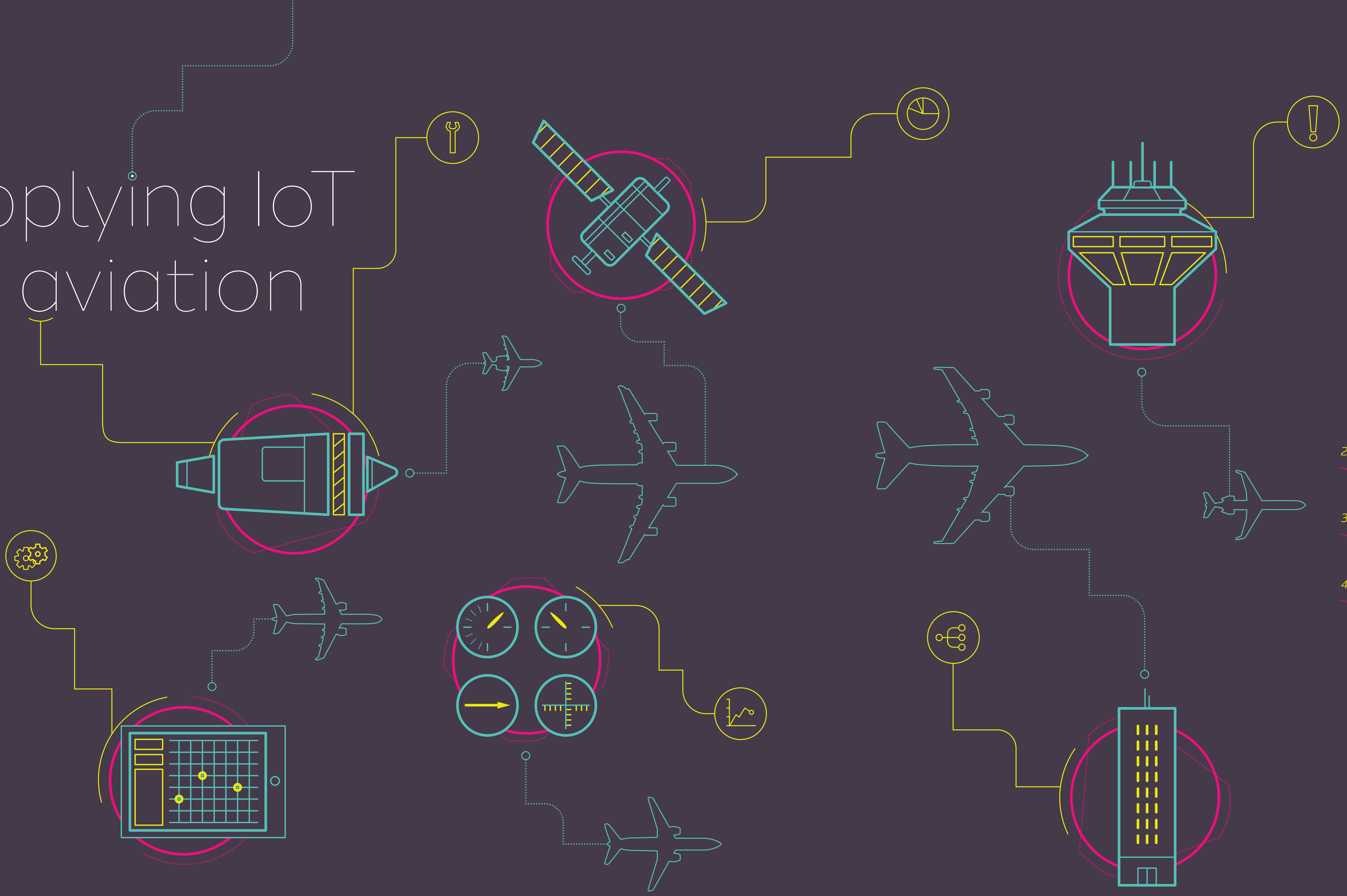
25. McKinsey & Company, "The Internet of Things: Mapping the Value Beyond the Hype," June 2015.

26. Gartner Press Release, "Gartner Highlights Key Emerging Technologies in 2005 Hype Cycle," August 23, 2005. http://www.gartner.com/newsroom/id/492175

27. Gartner, "Hype Cycle for the Internet of Things 2015," by Alfonso Velosa, W. Roy Schulte, Benoit J. Lheureux, July 21, 2015.

2

Applying IoT to aviation



The aviation industry presents a unique and substantial opportunity to leverage IoT with capabilities that have already been built into aircraft, such as sensors, transceivers, and wireless networks. Advances in connectivity and technology have carried the industry from a pre-digital state to eEnablement to Connected Aircraft, and with the application of IoT, to Connected Aviation. Ubiquitous connectivity combined with data analytics will drive the value proposition for Connected Aviation, providing significant advantages for operators. Nearly every facet of the air travel experience, from passengers to aircraft to operators, and even airspace management, will be touched in some way by these connected systems.

Aviation's technology evolution

Aviation operations have evolved dramatically in recent years with the adoption of consumer electronics and the emergence of low-cost, ubiquitous connectivity. But to understand how the industry has reached the point of aircraft as edge device, it helps to review the industry's progress.

PRE-DIGITAL REVOLUTION

Data connectivity is not a recent innovation in commercial aviation with Aircraft Communications and Reporting Services (ACARS) having been developed in the late 1970s to support automated time-reporting of significant flight events. The adoption of ACARS by operators to deliver aircraft Out, Off, On, In (OOOI) messages leveraged the ground network investment by major suppliers SITA and ARINC, and provided immediate Return on Investment (ROI). Yet OOOI messages would not have been possible without previous efforts to install standardized data bus infrastructure (ARINC 429) on aircraft, which connected sensors to an onboard management computer. Utilizing basic, but effective onboard processing, avionics developers provided a groundbreaking application of multiple technologies to deliver significant value to operators.

Over time, ACARS was expanded to include many other message types including air traffic control and the transmission of flight plan data. John Craig from Boeing explains, "The original intent of ACARS was timekeeping. If you look at what it's being used for now, it's everything from getting maintenance data from airplanes to crew communication with the ground." Nevertheless, ACARS can relay only 2.4 kilobits/second, a data throughput last experienced in the early 1990s. This "skinny pipe" creates a situation where only the smallest and most critical pieces of real-time data can be effectively exchanged. While providing near-universal coverage, ACARS is insufficient in terms of capacity.

But it remains heavily used by most operators today. As a communications protocol, it provides the industry with a robust, highly-resilient option for messaging, including the delivery of safety-critical and air traffic control (ATC) messages to and from aircraft. While ACARS is not broadband connectivity, it was invented to support early aircraft connectivity needs with real-time data exchange. When considering the architecture requirements for IoT, it is interesting to note that with ACARS, the aviation industry created the underlying elements for Connected Aviation decades ago.

eENABLEMENT

A lack of connectivity did not limit operators from investing in technology improvements for operations. eEnablement started to gain traction in the aviation industry in the early 2000s, thereby ending the pre-digital era. With the rise of consumer laptop technology, operators observed groundbreaking changes for enterprise systems in other industries. These COTS computing technologies helped to lay the foundation of the digital world. Flight operation teams at many operators sought to exploit this technology. The Electronic Flight Bag (EFB) was a product of these efforts, as laptops were considered a better host for information such as performance (take-off and landing), document libraries, and charts compared to the traditional paper-based flight bag. Carry-on EFBs became a permanent fixture on the flight deck, to be consulted only during non-critical phases of flight. Soon thereafter, American Airlines gained fleet-wide approval for tablet usage during all phases of flight. Starting with laptops and simple applications, the aviation industry accepted the application of COTS devices as part of their eEnablement initiatives.

THE CONNECTED AIRCRAFT

In the late 2000s, operators began introducing tablets into the flight deck and cabin. Compared to laptops, tablets called for more Internet Protocol (IP) connectivity. This new demand drove the need for standards and governance, eventually pushing the industry beyond eEnablement and into the Connected Aircraft phase.

THE RISE OF IP CONNECTIVITY

Connecting sensors to an IP system was not possible prior to 2004, as the technology and regulatory framework for connectivity systems had not yet matured. Nevertheless, the introduction of Connexion by Boeing for passenger connectivity marked a major shift in how connectivity between an aircraft and the internet could be realized. Connexion by Boeing introduced IP as the default standard for communication, which allowed isolated systems to be connected more easily than legacy protocols could permit. By driving commercial standards, IP maximized the value of eEnablement when integrating new devices, sensors, and data – especially for airframe and OEM vendors developing systems to integrate into the aircraft environment. This shift away from closed protocols allowed the aviation industry to benefit from the development of sensors and other technology from various industries.

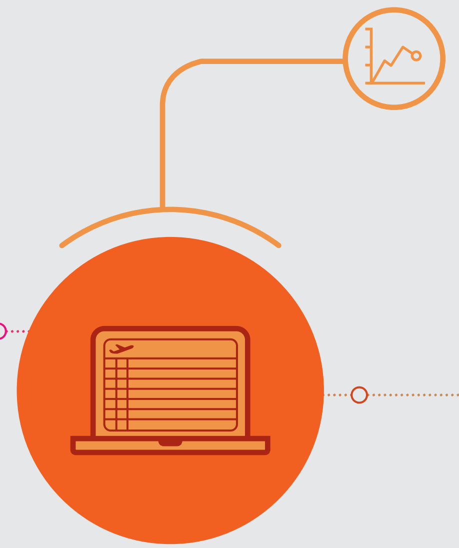
Connexion by Boeing had agreements with more than ten operators, and completed its first run with Lufthansa in 2004, but it failed to reach critical mass. Boeing discontinued the service in 2006. Consumer technology had not yet simplified wireless networking for widespread use, and battery technology was not sufficient for hours of travel. Bandwidth was also expensive, making it difficult to justify the business case.

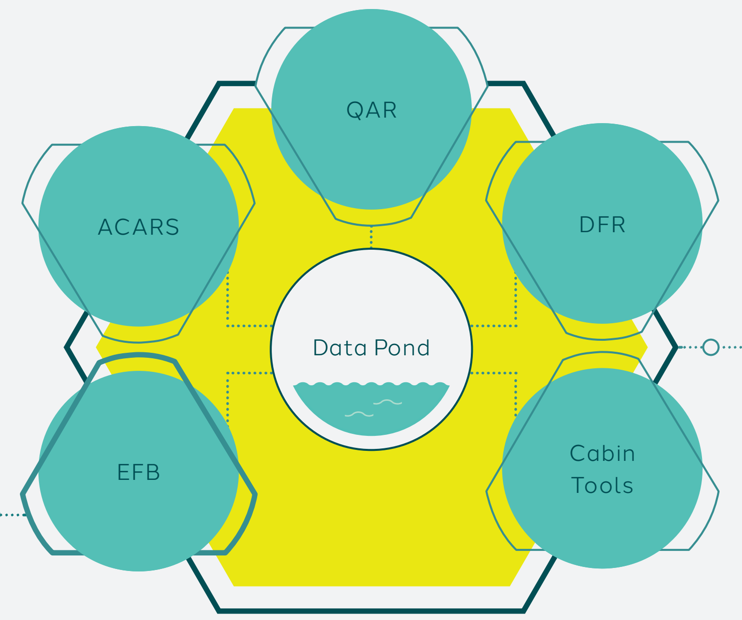
In 2007, ARINC introduced GateFusion, a wireless gatelink system, which was one of the first applications of IP connectivity for operational use. GateFusion enables aircraft to “dock at airport gates to downlink aircraft diagnostic and operational data, and simultaneously uplink data to the aircraft’s on-board computers, electronic flight bags, and inflight entertainment systems,” and it is still in use today.[1]

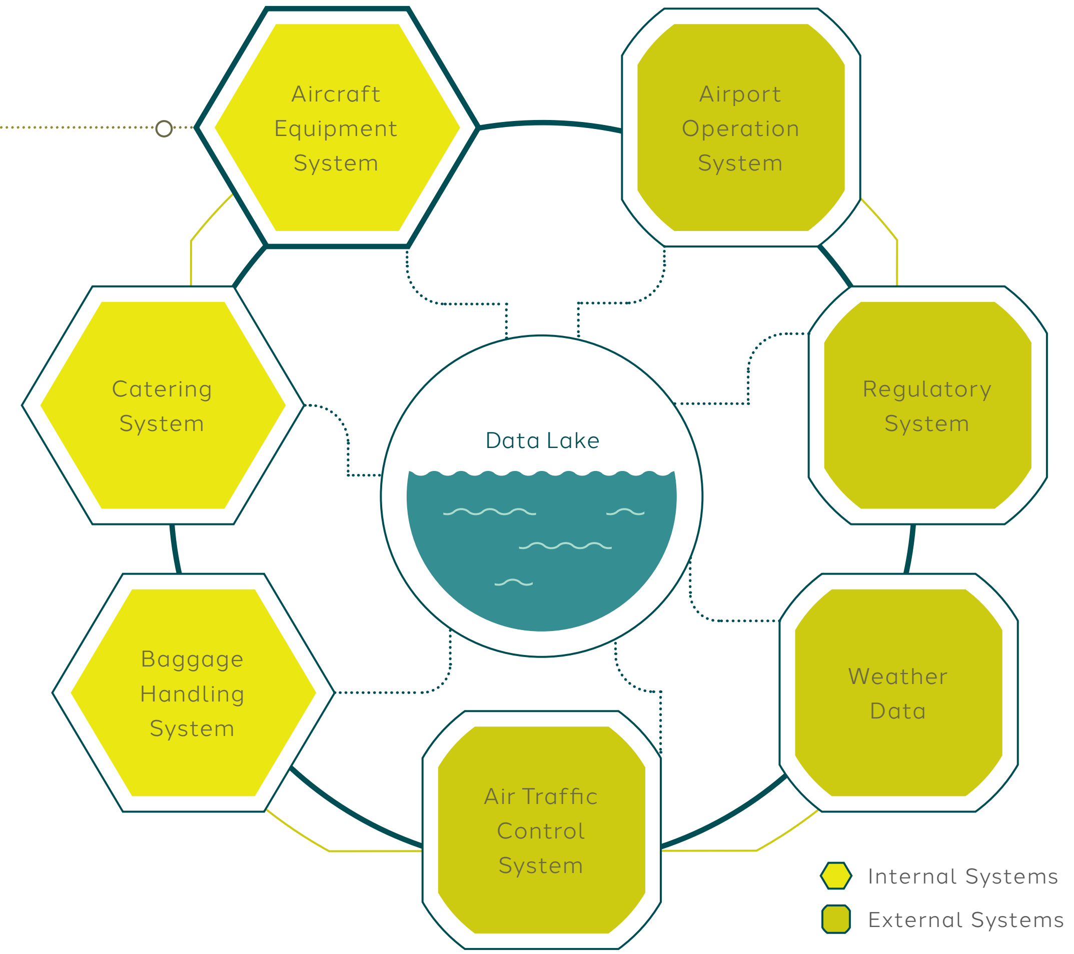
DEFINING CONNECTED AIRCRAFT

Connected Aircraft can be defined as the adoption of technology that uses IP data networks on aircraft to connect to ground systems via broadband. The Connected Aircraft approach views the aircraft as an equipment system with multiple components such as EFBs, ACARS, and Quick Access Recorder (QARs). Some Connected Aircraft definitions cover passenger connectivity, but these are growing to include operations.

Evolution of the flight bag







FLIGHT BAG

Product

For more than six decades, the flight bag remained virtually unchanged. On every flight, everywhere in the world, pilots carried bulky printed collections of manuals, maps, and other critical data – each weighing between 35-40 pounds.

Based off of: *Harvard Business Review*, "How Smart, Connected Products Are Transforming Competition," by Michael E. Porter and James E. Heppelmann, November 2014.

ELECTRONIC FLIGHT BAG

Smart product

When pilots began using laptops to access their essential charts and manuals, the flight bag became a smart product: the Electronic Flight Bag.

The EFB was significantly lighter and easier to manage. Updating devices with the most up-to-date content is far easier than tracking down pilots to verify content in a binder. And while the fuel savings from shedding a 40-pound flight bag may be small on a single flight, the savings scale quickly across fleets.

CONNECTED EFB

Smart, connected product

IP connectivity took the EFB from Smart to Connected as the industry evolved from eEnablement to the Connected Aircraft phase. Operators began to apply inflight connectivity to the EFB allowing for real-time bidirectional data flow.

From 2014, EFB Wi-Fi connectivity while on the flight deck has increased 100% according to the AirInsight 2015 Annual EFB Research Project.

Source: AirInsight, 2015 EFB Research Project

AIRCRAFT EQUIPMENT SYSTEM

Product system

Moving from eEnablement to the Connected Aircraft phase requires more than connectivity. The EFB will become one piece in a larger aircraft equipment system. In this system, multiple components such as the Digital Flight Data Acquisition Unit, Quick Access Recorder, or Aircraft Communications Addressing & Reporting System are able to follow data policies to consolidate and selectively share information into a data pond, enabling better human and automated decision-making. Even with automated data collection, much of the control and optimization are still managed manually. However, data is no longer analyzed in isolation. Instead the scale of systems is leveraged to capture information and implement decisions fleet-wide. EFB is at this stage today on some aircraft, but it is far from universal.

AVIATION MANAGEMENT SYSTEM

System of systems

Aviation Management System is the convergence of multiple Aircraft Equipment Systems with other internal systems and external systems. In this evolutionary ecosystem, value is created from real-time and historical data analytics driving actionable results. Combining multiple data ponds into a homogenized repository, a data lake can provide accessibility to and from aircraft systems. Within this data lake, the EFB is one tiny component of a larger interconnected ecosystem. Integration with endless possibilities: This is where Connected Aviation proves its value.

PRE-DIGITAL

eENABLEMENT
2000s

CONNECTED AIRCRAFT
2016

IOT AVIATION / CONNECTED AVIATION
~2021


SIDESTICK PRIORITY
CSTR
WPT
NDB
ARPT
VOR1
WX
TERR
TRAF
VOR2
SWITCHING
ATT HDG
AIR DATA
FMS

Industry definitions of Connected Aircraft

"Connected Aircraft provides IoT capability for passengers, crew, and aircraft components."

Mohammed Amin Abdulmajeed
VP Hajj & Umrah Product & Services
Saudia Airlines

"We look at the Connected Aircraft as two work streams: One, is a customer work stream that focuses on improving the customer's experience on the aircraft. The other is the operational work stream."

Vikram Baskaran
Managing Director – ITS Airline Operations Systems
Alaska Airlines

"Connected Aircraft is a new term that came from the passenger cabin. As it has expanded, we're now starting to see the usage of the same links for operational aspects like EFB."

John Craig
Chief Engineer of Cabin & Network Systems
Boeing

"It's really an integrated information-management system that combines applications, connectivity, and avionic solutions. It provides actionable information to and from the aircraft in real-time to improve safety and aircraft operations."

Mike DiGeorge
VP of Commercial Aviation & Networks Services
Rockwell Collins

A CLOSER LOOK AT CONNECTED AIRCRAFT

CONNECTED EFB

Connected Aircraft took the paperless flight bag and connected it, eliminating the weight and complexity of managing paper manuals. With connectivity, flight bag information can be updated in real-time with bidirectional data traffic. For Shane White at Delta Air Lines, the challenge was “managing 7.5 million pages of charts and technical documentation to be printed and distributed annually.” Today that challenge is ensuring that the hardware is operating properly and that the necessary connectivity is in place. Darrell Haskin from Delta adds, “We’ve moved out of a ‘nice-to-have’ environment into an operationally critical environment – another piece of equipment that has to be in place and working. This has been a huge paradigm shift.”

REAL-TIME CREDIT CARD PROCESSING

Without connectivity, credit card transactions are stored during flight and finalized when the aircraft reaches its destination. With connectivity, cabin crews are able to run real-time verification in the air. This minimizes fraud risk, which is especially important for luxury operators offering extensive duty-free shopping on board. Valour Consultancy estimates universal real-time credit card verification could potentially equate to around $90 million in recoverable onboard duty-free sales on an annual basis.[2]

CONNECTED LOGBOOKS

Multiple logbooks (for the cabin, for aircraft maintenance, etc.) on board every aircraft can benefit greatly from Connected Aircraft capabilities. With conventional cabin logbooks, crews manage maintenance requests through manual reports; faults are documented and delivered to maintenance when the aircraft lands or at the end of the duty day. “It can take some operators a day or two to get all paper tech log data entered into a maintenance tracking system,” adds Mark McCausland from Ultramain. The actual repair workflow cannot begin until the cabin or maintenance log entry is realized, which significantly extends the total time from report to resolution.

Accumulations of data

Data can be collected from an aircraft or devices and aggregated to generate insights. The ebb and flow of data within these reservoirs has been likened to bodies of water, with names that reflect the relative size of each collection.

Conventional logbooks can be difficult to read once submitted. With a guided, digital workflow to manage data entry, the data becomes more reliable across the myriad flight and cabin crews working at any given operator. Connected logbooks improve root-cause fault analysis and allow operators to be more proactive.

In order to fix a problem within a gate turn or overnight cycle, information needs to reach maintenance within a certain timeframe. Otherwise, the aircraft either continues to fly with a broken component or it is delayed, leading to disruptions in the system schedule and extensions of the flight crew duty day. Electronic logbooks with real-time connectivity can automatically relay information and initiate repair workflows.

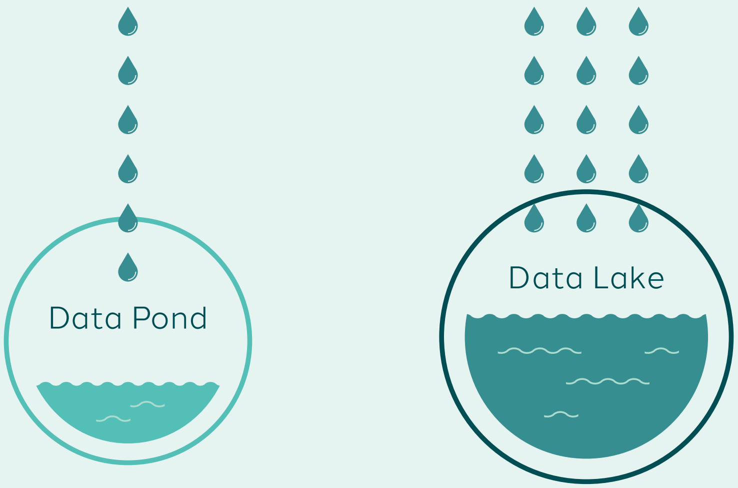
While these Connected Aircraft examples show progress, sensor integration is not yet being leveraged. This telling gap describes the next step in the evolution to Connected Aviation, where aircraft systems integrate not only with each other, but also with non-operator systems on the ground.

CONNECTED AVIATION

Investment in new technology and the resulting data generated is mostly sub-fleet-centric today. Virtually none of this generated data is transmitted off the plane in real-time (this applies to newer Boeing 787s and Airbus 350s, legacy Boeing 777s and Airbus 330s alike). There has been an effort to expand the scope of real-time data transmission, but this effort will be limited until the industry recognizes Connected Aviation's value proposition.

DEFINING CONNECTED AVIATION

There is an opportunity for the industry to define Connected Aviation and how it fits into the IoT framework. Connected Aviation means different things to different industry stakeholders. As with Connected Aircraft, some operators may focus wholly on passenger entertainment and productivity. But the larger IoT marketplace demonstrates that such an approach is limiting and will ultimately restrict the ways in which an operator can adopt technology.



Collection of data sets relevant to a single system enabling specific analytics based on contextual system data rules that can also be integrated and scaled.

Collection of a wide variety of data sets relevant to multiple systems (or businesses) “in one place and enabling multi-talented analytics based on big data approaches that easily scale” and can be integrated.[3]

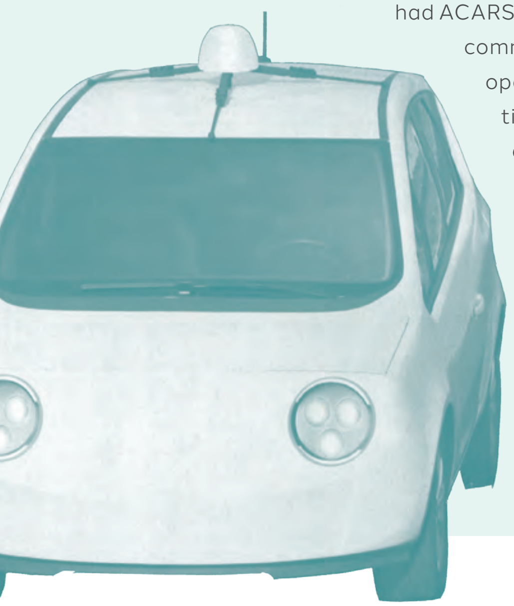
Put simply, Connected Aviation is the application of IoT to the aviation industry. Within the larger aviation management system, it manifests as a system of systems, in which all facets are interconnected and sharing data when appropriate. To achieve this system-of-systems ideal, Connected Aviation requires an IP network complete with servers and routing capacity in addition to the data bus infrastructure on the aircraft. The system must have the capacity to provide data-pond capabilities on the aircraft, and a secure connection to the data lake on the ground. Connected Aviation also calls for collaboration among multiple parties who require access to data, processing, and storage on the aircraft. This will be the culmination of aviation’s IoT efforts, though the industry is only beginning to explore this functionality today. As Gogo’s Andrew Kemmetmueller says, “Connected Aviation is the IoT value created by combining the known benefits of eEnablement with the dramatic opportunities of onboard IP networks, and the integration of sensors and aircraft systems.”

Connected Aviation represents a revolutionary leap in operator technology. Kyle Gill from NetJets describes the contrast he sees between current operations and what is possible with Connected Aviation. “There are still some airplanes that have floppy disks to update the Flight Management System (FMS) database. We spend a lot of money on ACARS messaging, but there’s an iPad in the cockpit with email and text messages.” The breadth of Connected Aviation’s ecosystem is difficult to overstate. The widespread sharing of data, capabilities, and networking will forge new relationships, while increasing potential ROI throughout the industry. As contributors to this book have confirmed, aviation can achieve this only through integrated, cooperative innovation.

COMPARING CONNECTED AVIATION

In the Connected Home and Connected Car industries, connectivity on the ground is inexpensive and ubiquitous, but it is still underutilized. As Cisco's Barry Einsig highlights, "There's almost as many automobiles as there are cell phones in the United States. These are huge, expensive assets that are under-connected. The connectivity that does exist is generally proprietary and unusable by many systems." The growth of Connected Home and Connected Car is dependent on the cost and capabilities of new sensors, which need to overcome certain size, cost, and capability hurdles before providing ROI.

By comparison, aviation has had sensors installed on aircraft for decades to support safety monitoring, but the industry is only recently investing in persistent, IP-based connectivity on those aircraft. Air Canada's Lise Fournel says, "In aviation, we have had ACARS air-to-ground communication in operation for a long time. However, cars and homes may become more sophisticated before aircraft, because the adoption cycle for airlines has been very long."



AT THE TIPPING POINT

IoT is at the peak of the hype curve in regards to inflated expectations, according to Gartner's "Hype Cycle for Emerging Technologies."[4] Just like IoT applications of Connected Home and Connected Car, contributors generally see Connected Aviation at the cusp of a massive impact, which will ultimately change prevailing paradigms in each of these industries. Experts agree that there are several catalysts pushing it toward the tipping point.

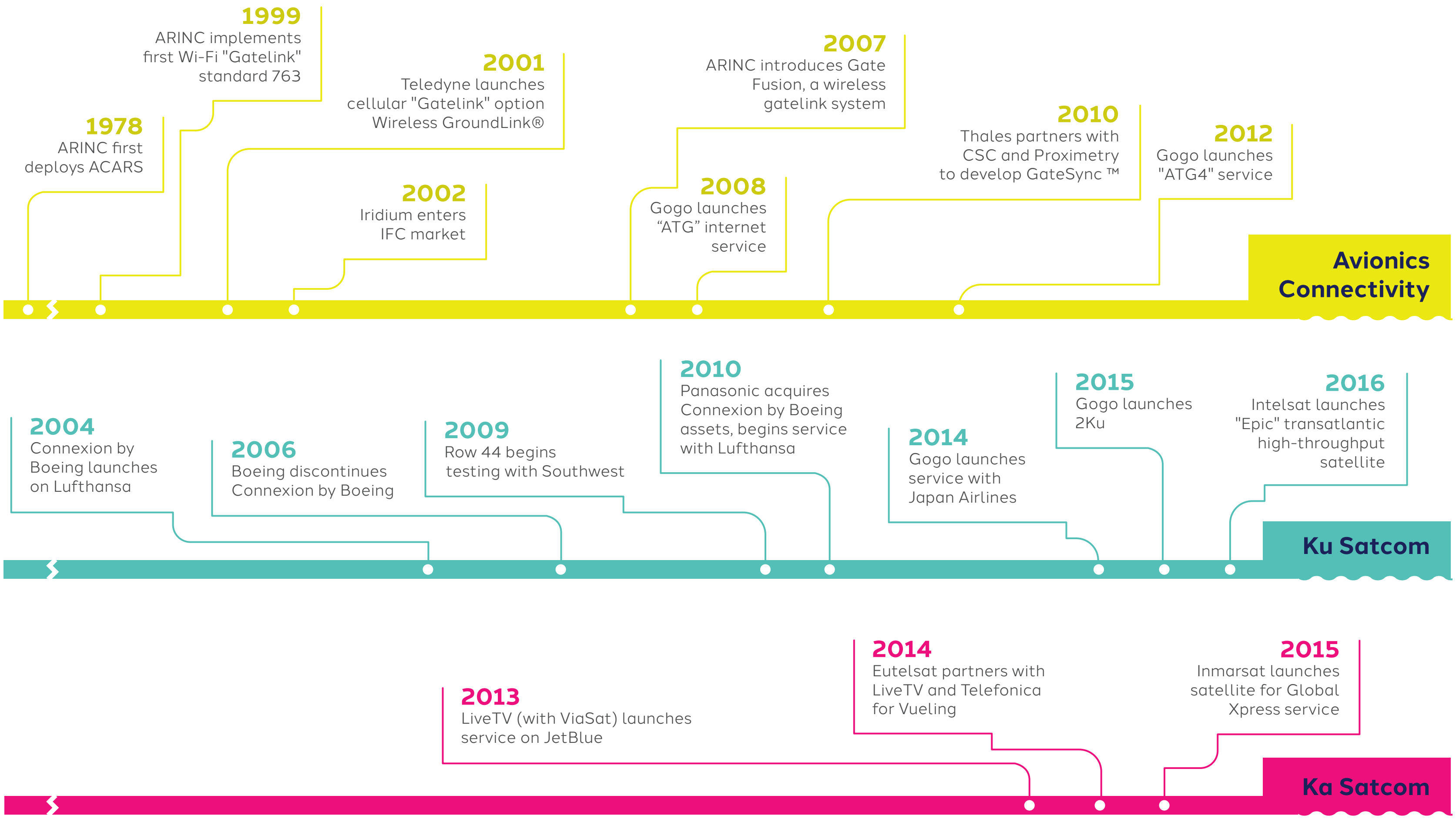
INCREASING CONNECTIVITY

Connexion by Boeing was an important step in establishing IP as the communication standard and spurring further development of aviation connectivity. Unfortunately, the commercial aviation slowdown due to the events of September 11, 2001, was a blow to the connectivity market's viability. But in the following five years, several advances in technology renewed interest in connectivity. For passengers, lithium-ion technology essentially doubled laptop battery life, allowing for roughly four hours of continuous use. Smartphones and tablets changed how people accessed the internet, driving demand even onboard aircraft. Operators began to adopt these same consumer electronic devices, furthering the need for IP connectivity. In this developing ecosystem, several providers picked up where Connexion by Boeing left off.

These providers have since managed to generate substantial and sustained growth in IP connectivity. Global Eagle Entertainment, Gogo, Panasonic, Thales/LiveTV, and ViaSat have advanced capacity and coverage beyond what Connexion by Boeing offered. "We now have the kinds of pipes and speeds we need to connect aircraft," says Carl Esposito from Honeywell. The continued investment in coverage and capacity by these suppliers reflects the industry's demand for connected solutions and services.

Decades of progress

Inflight connectivity milestones



SOURCES:

ARINC Industry Activities, http://www.aviation-ia.com

Boeing, "Boeing to Discontinue Connexion by Boeing Service," August 17, 2006. http://boeing.mediaroom.com/2006-08-17-Boeing-to-Discontinue-Connexion-by-Boeing-Service

Flight Global, "ARINC Launches Common-Use Wireless Gatelink System," by David Learmount, June 14, 2007. https://www.flightglobal.com/news/articles/arinc-launches-common-use-wireless-gatelink-system-214660/

The Global Link by ARINC, "Chairman's Perspective—Changing Aviation All Over Again," Fall 2003. http://www.arinc.com/publications/The-Global-Link_45_Fall-2013/HTML/files/assets/common/downloads/The-Global-Link_Fall-2013_45.pdf

Gogo LLC, "The Anatomy of Inflight Connectivity", 2014.

Gogo, "2014 Retrospective – A Year of Major Milestones for Gogo," December 29, 2014 http://concourse.gogoair.com/technology/2014-retrospective-year-major-milestones-gogo

Gogo, "Gogo Unveils its Game Changing 2KU In-Flight Connectivity Technology," November 12, 2015 http://concourse.gogoair.com/inside-gogo/gogo-unveils-its-game-changing-2ku-in-flight-connectivity-technology

Inmarsat, "Inmarsat Global Xpress is the First High-Speed Broadband Network to Span the World," 2016. http://www.inmarsat.com/service/global-xpress/

Runway Girl Network, "Better Inflight Wifi over North Atlantic is Months Away: Intelsat CEO," by Mary Kirby, January 29, 2016. https://www.runwaygirlnetwork.com/2016/01/29/better-inflight-wifi-over-north-atlantic-is-months-away-intelsat-ceo/

Skift, "A Brief History of In-flight Entertainment form Projectors to iPads," by Samantha Shankman, January 9, 2014. http://skift.com/2014/01/09/a-brief-history-of-in-flight-entertainment-from-projectors-to-ipads/

Teledyne Technologies, "Teledyne Controls Announces Successful Launch of Wireless GroundLink™," September 5, 2001. http://www.teledyne.com/news/groundlink.asp

Thales, "Thales Secures GateSync Partnership," July 21, 2010. https://www.thalesgroup.com/en/content/thales-secures-gatesync-partnership-0.

Valour Consultancy, "The Future of Aeronautical Connectivity Report," October 2014.

Vueling News, "Vueling Will be the First European Company to Offer Connectivity at 20Mbps," April 8, 2014. http://vuelingnews.com/2014/04/09/vueling-will-be-the-first-european-company-to-offer-connectivity-at-20mbps/?lang=en

> "Without the next step of integrating systems on the ground and on board, we will continue to have basic connectivity, which I am afraid will phase out."

Mohammed Amin Abdulmajeed
VP Hajj & Umrah Product & Services
Saudia Airlines

The combination of pervasive IP connectivity, properly equipped aircraft (with sensors and local networking), and decreasing connectivity costs, has helped operators reach profitable IoT business cases, thereby setting the stage for Connected Aviation. With progress on these three fronts, operators have increased installations of inflight connectivity systems. According to BI Intelligence, the top four providers of inflight connectivity (Global Eagle Entertainment, Gogo, Panasonic, and Thales/LiveTV) have connected 3,340 out of a potential 5,500 commercial aircraft in North America in the addressable market.[5] While connectivity is aggressively moving forward, adoption varies as many operators around the world work toward basic passenger connectivity. Yet for the last three years, the AirInsight EFB Research Project has shown that respondents believe the business case for connectivity should be prioritized for flight operations (81%) over passenger connectivity (19%).[6] These results demonstrate an essential shift toward Connected Aviation: connectivity is central to creating value versus a perk for passengers.

The stringent regulatory and safety standards associated with aircraft installations, combined with the variety of aircraft types, have delayed the adoption of connectivity. Despite these hurdles, installations are on the rise and operators recognize the value in the coming change. Some operators are investing now, evolving through the growing pains as early adopters, while others are waiting to see what happens. Regardless, the industry is changing. "Without the next step of integrating systems on the ground and on board, we will continue to have basic connectivity, which will eventually phase out," shares Mohammed Amin Abdulmajeed from Saudia Airlines. While there has been significant progress, much work remains before ubiquitous connectivity enables Connected Aviation.

Connectivity enabling the edge

Connectivity is central to IoT. It is the glue that binds all the sensors and devices in a system together. Connectivity drives opportunities by providing pathways to transfer data in real-time and enabling predictive capabilities. Regardless of industry, IoT is not complete without a comprehensive connectivity strategy that identifies how data freshness and value will be addressed. "Connectivity is a requirement to enable IoT to properly interface with ground systems," adds Craig.

Appreciating the necessity for real-time connectivity requires a better understanding of the aircraft's place within the IoT network. As operators and the supply chain begin to adopt a system-of-systems approach, the network takes a cloud form, with the data lake and key application functions at the center. Given their mobility and geographic distance from core system components, aircraft are at the extreme reaches of this cloud. Networking experts refer to these outermost elements as "edge devices." Edge devices connect an internal local area network (LAN) to an external wide area network (WAN) over the internet, and provide interconnectivity and traffic flow between various networks, rather than being hosted on a centralized cloud. The aviation technology stack, based on a model

Aviation technology stack

SYSTEM OF SYSTEMS (CLOUD)

Smart Systems Applications

Cloud-based applications managing the monitoring, control, optimization, and autonomous operation of system functions

Systems Data Database (Data Lake)

Collection of data sets relevant to multiple systems aggregated through normalization and management of real-time and historical systems data

Systems Application Platform

Application development environment enabling the creation of smart, connected system applications using data access and run-time tools

Rules/Analytics Engine for Systems

Rules, business logic, and data-analysis capabilities that populate systems-based algorithms to reveal new insights

DATA PRIVACY & SECURITY

Capabilities allowing management of user access, user identity, and data privacy while also securing cloud connectivity for products and systems

EXTERNAL INFORMATION SOURCES

Supplementary Information from external sources (weather, airspace traffic, etc.) to enhance product or system capabilities

Broadband connectivity/ external wide area network (WAN)

AIRCRAFT EQUIPMENT SYSTEM

EDGE COMPUTING

Network boundary operating close to a product communicating with the product system via LAN

Rules/Analytics Engine for Products

Rules, business logic, and data-analysis capabilities that populate product-based algorithms to reveal new insights

Product Data Database (Data Pond)

Collection of data sets relevant to a single system aggregated through normalization and management of real-time and historical product data

Smart Product Applications

Cloud-based applications managing the monitoring, control, and automated operation of product functions

In-cabin local area network (LAN)

PRODUCT

Software

OS, UI, onboard app, and software-controlling components

Hardware

Sensors, processors, and electrical and mechanical components

INTEGRATION WITH BUSINESS SYSTEMS

Tools enabling the integration of product and system data and analytics with core enterprise business systems such as ERP and CRM

Based off of: *Harvard Business Review*, "How Smart, Connected Products Are Transforming Competition," by Michael E. Porter and James E. Heppelmann, November 2014.

developed by PTC's Jim Heppelmann and Harvard's Michael Porter, shows how the WAN and LAN connect aircraft and systems, underscoring the critical nature of connectivity.

Each aircraft can be seen as an edge device, with connectivity serving as the aircraft's link to the larger network. ThingLogix's, Steven Loving envisions the aircraft as "an edge device with a lot of sensors where data is being captured and stored." This data is not limited to edge devices, as aircraft share data cooperatively with other network nodes. United Airlines recently suggested that its goal with inflight connectivity was to turn each aircraft into a "node on the network," driving tighter integration to improve passenger experience and operations.[7] Bob Smith from Honeywell Aerospace offers a similar view. "Moving down the technology stack, the idea of getting to the connected edge – the gateway – is what we're focusing on with our central maintenance computers and our communications management functionality." Due to the mobility of the industry and remoteness of connected devices, aviation is heavily skewed toward emphasizing the edge as a critical part of the network.

Other industries have somewhat flattened the network cloud to bring the edges closer to the center, either by extreme broadband capacity or by adopting a decentralized approach. In the early 2000s, the telecom industry built the edge into its architecture because of capacity limitations and restricted interconnections between providers. This yielded cost efficiencies, increased speeds, and reduced latency. Although telecommunications firms have largely overcome their capacity problems, the adoption of smartphones and tablets has led to enormous growth in data consumption over the past decade. To keep pace, edge computing remains essential, and telecommunications firms continue to invest in it.

Last year, the launch of Nokia's Liquid Applications was called "a kick-starter for the Mobile Edge Computing (MEC) movement."[8] Nokia Networks brought together the European Telecommunications Standards Institute (ETSI) Industry Specification Group (ISG) dedicated to MEC with Vodafone, IBM, Intel, NTT Docomo, and Huawei supporting the initiative. As Nokia's Marc Rouanne describes, "The MEC initiative ... will create an open, multi-vendor environment at the most lucrative point within the mobile network, driving differentiated services, new applications, and ultimately new revenues. It also builds on our view of fundamentally changing the telecom industry through increasing our collaboration with different players and partners."[9]

NEXT-GENERATION AIRCRAFT

New aircraft are becoming more advanced and are generating previously-unheard-of data from thousands of sensors. The advanced data collection capabilities of the Boeing 787 engine, auxiliary power unit, central maintenance computer, and other components, generate a massive half a terabyte of data per flight.[10] The aircraft also hosts a massive computing network, and much of the aircraft is managed by an onboard server cluster and advanced software. Compared to the Boeing 787, the Airbus 350 will generate more than double the amount of data.[11] "They're really flying data centers," asserts Mike DiGeorge from Rockwell Collins. These advanced aircraft not only produce more data, they also allow for easier system integration.

SUSTAINED DECREASE IN FUEL COSTS

The dramatic fuel price increase in 2008 and 2009, forced operators to evaluate technology at unprecedented levels in order to reduce costs. The recent decrease in fuel costs has not prompted operators to revert to their conservative approach to technology, but instead has opened investment in new systems, which operators expect to drive long-term savings and efficiencies.

> “We are at that tipping point right now.”

Dave Bartlett
Chief Technology Officer
GE Aviation

EVOLVING IT PROGRAMS

Over the past decade, operators have been gradually adopting more traditional corporate IT programs. This can be seen in the advances of e-commerce, mobile applications, and workplace programs at many operators. Although technology adoption has often been slowed by a long implementation cycle due to aviation’s safety considerations, the growing influence of IT has shortened this cycle in several areas. IT departments have evolved to manage inexpensive, portable, and highly functional tablets and smartphones. According to the AirInsight EFB Research Project, the number of operators planning to issue tablets to cabin crews has increased more than 60% since 2013.[12] These devices have found their way into the hands of flight and cabin crews and are best utilized when connected.

Connected Aviation is at the tipping point, but the precise timeframe is unclear. Most contributors estimated that Connected Aviation will arrive in the next five to ten years. Fournel expects to complete the initial steps at Air Canada by the end of the decade to prepare its fleet for the Connected Aviation ecosystem. Esposito observes that to date, most aircraft have been “islands of information,” without much planning for interconnectedness. Industry history shows that once the adoption of new technology begins, pervasiveness is only a matter of time. Examples such as winglets, EFB, and even passenger connectivity show a rapid adoption curve once early adopters demonstrate value. Dave Bartlett from GE asserts, “We are at that tipping point right now. The interest we’re seeing in the aviation industry is all the way from customers, to suppliers, to airframers, to airlines, and to the major industrial equipment providers.”

Data as the currency of IoT

On the verge of Connected Aviation, operators are recognizing how big data is a key element of IoT in other industries. Data is the “currency of IoT,” says Michael Simon from Xively by LogMeIn. In fact, 84% of companies surveyed predict that big data will shift the competitive landscape within the next year according to GE and Accenture research.[13] This research also shows that the top reasons executives leverage analytics are to increase profitability and to gain a competitive advantage.

Data is not new in aviation. ACARS, the Flight Operations Quality Assurance Program (FOQA), and ARINC 429/717 data busses have been collecting and communicating on a limited basis for decades. Yet barriers such as infrequent data collection, union concerns of data use, and the limited capabilities of current operator applications, prevent maximizing data value. Traditionally, data has been used retroactively – particularly during incident evaluations. With the exception of passenger data, it is seldom applied proactively to inform ongoing operations.

Realizing potential efficiencies and value requires massive amounts of data from disparate collections of sensors and devices to be synthesized in a coherent solution. Connected Aviation requires going beyond applying data to revenue and inventory management (as has often been the case) and expanding the applications to every aspect of operations.

DEFINING BIG DATA

According to Gartner, “Big data is high-volume, high-velocity and/or high-variety information assets that demand cost-effective, innovative forms of information processing that enable enhanced insight, decision making, and process automation.”[14] Each of those elements deserves a closer look.

HIGH VOLUME

The volume of data that operators will face in the future is daunting. “When you’re talking about data from health monitoring systems, live performance information, or telemetric flight data, the volume is overwhelmingly huge,” comments Simon. Next-generation engines from GE, such as the GENx, collect over 5,000 data points per second, exponentially increasing both volume and opportunity.[15] As previously discussed, new aircraft such as the Boeing 787 and Airbus 350 are generating incredible amounts of data volume from thousands of sensors. Terabytes are new to an industry that still measures data in kilobytes in many aircraft systems. To put this volume into perspective, a connected car can generate 25 gigabytes of data per hour.[16] One terabyte is equal to 1,024 gigabytes. The volume of data an aircraft can generate is massive compared to other industries, and it will only continue to grow.

HIGH VELOCITY

Data velocity refers to various bursts in intensity of real-time data streams. IP connectivity, coupled with enhanced network capabilities on aircraft, has delivered not only the capacity to collect data, but also the ability to process and distribute it in real-time, which enables predictive capabilities. While not all data is critical enough to demand real-time distribution, the opportunity has prompted operators to reconsider how they manage data altogether.

Next generation engines can collect over

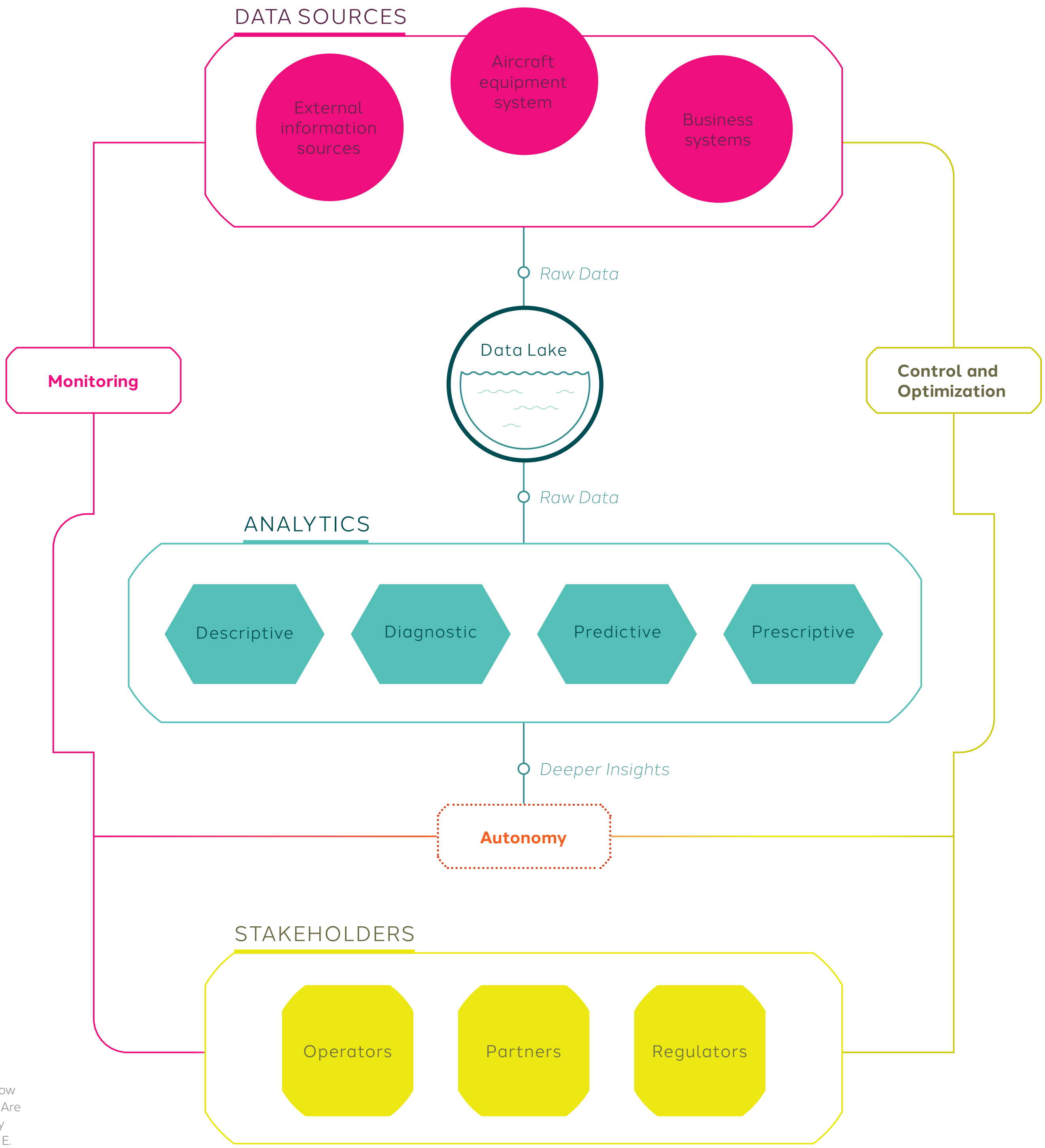
5,000

points of data per second[15]

HIGH VARIETY

Data will arrive from multiple input streams and potentially in proprietary formats. With Connected Aviation, this means information will arrive from individual aircraft or even from a carrier’s entire fleet. It will also mean processing large amounts of data in different formats from third-party sources, including other operators.

Driving value with data



Based off of: Creating New Value with Data model from *Harvard Business Review*, "How Smart, Connected Products Are Transforming Companies," by Michael E. Porter and James E. Heppelmann, October 2015.

PUTTING ANALYTICS TO WORK

"We are currently data rich, but information poor," says Simon. It isn't data or collections of databases, but rather the analytics conducted on top of this data that is driving the value proposition for the industry. "To simply have a collection of data is meaningless. Meaning is only derived when data is analyzed to interpret the patterns within," notes Scott Robinson of Farmlink. Heppelmann and Porter agree: "While individual sensor readings are valuable, companies often can unearth powerful insights by identifying patterns in thousands of readings from many products over time." Data not only drives better insight into why something happened, but can also be used to predict future behavior of systems and people. "The beauty of IoT and the deployment of sensors is the ability to further expand our knowledge with analytics," adds Brenna Berman from the city of Chicago's DoIT.

The driving value with data model, based on Heppelmann and Porter's work, shows how data can help create new value in the aviation industry. Basic insights can be derived directly from monitoring data sources like aircraft equipment systems, business systems, or other external information sources. Data from these sources can also be combined in a centralized data lake, where big data analytics can provide deeper insights for industry stakeholders. Insights require stakeholder control or optimization until the system has the intelligence data to run autonomously.

According to Gartner, "Big data analytics builds further upon the traditional analytics, but its value comes from using advanced analytics to extract valuable insight from the data."[17] As Gartner notes, "There are three critical differences between traditional and big data analytics:

> *Big data analytics can handle variety, velocity, and volume. Variety means that data can come in various formats, ranging from sensor data to video images to unstructured text. Big data analytics is also designed to handle massive volumes of data and the high speed in which the data is produced and changing.*
>
> *Big data analytics is not exclusive to real-time analysis. Rather, big data analytics can cater to varying requirements for speed of analysis, ranging from real-time monitoring of asset performance for immediate notification to pattern analysis of years of sales data for detailed customer segmentation.*
>
> *Many of the big data analytics techniques are revolutionary because they do not require the user to know what question to ask. Rather, the analytics solution mines the data, finds patterns, and uncovers relationships unknown to the user."*[18]

Gartner defines the big data analytic capabilities as the following:

DESCRIPTIVE ANALYTICS

"Descriptive analytics spans the tools that provide historical insights into a supply chain's performance, answering the question: 'What happened?' Dashboards, historical reports, data discovery, online analytical processing (OLAP), and ad hoc queries are examples of descriptive analytics capabilities."[19]

DIAGNOSTIC ANALYTICS

"Diagnostic analytics can help the user understand why an event occurred. Diagnostic capabilities span root cause analysis, data visualization, and clustering. As the company becomes more mature, its analytics emphasis shifts to forward-looking and actionable capabilities."[20]

PREDICTIVE ANALYTICS

"Predictive analytics uses causal forecasting, pattern-based analytics, statistical analytics, and simulation to offer the user an understanding of likely future events."[21]

PRESCRIPTIVE ANALYTICS

"Prescriptive analytics relies on optimization, heuristics, rule engines, and artificial intelligence to build on the remaining capabilities and offer the user an actionable recommendation to exploit or mitigate a future event."[22]

Other industries have illustrated the value of big data in their operations. The Big Data and Analytics Survey 2015 showed that the number of organizations that either deployed or implemented data-driven projects increased by 125% over the last year.[23] Operators and the aviation supply chain have observed this new opportunity with interest. Combining the existing capabilities of aircraft with connectivity and new data-processing applications, the industry can

125% INCREASE

IN THE NUMBER OF ORGANIZATIONS THAT EITHER DEPLOYED OR IMPLEMENTED DATA-DRIVEN PROJECTS[23]

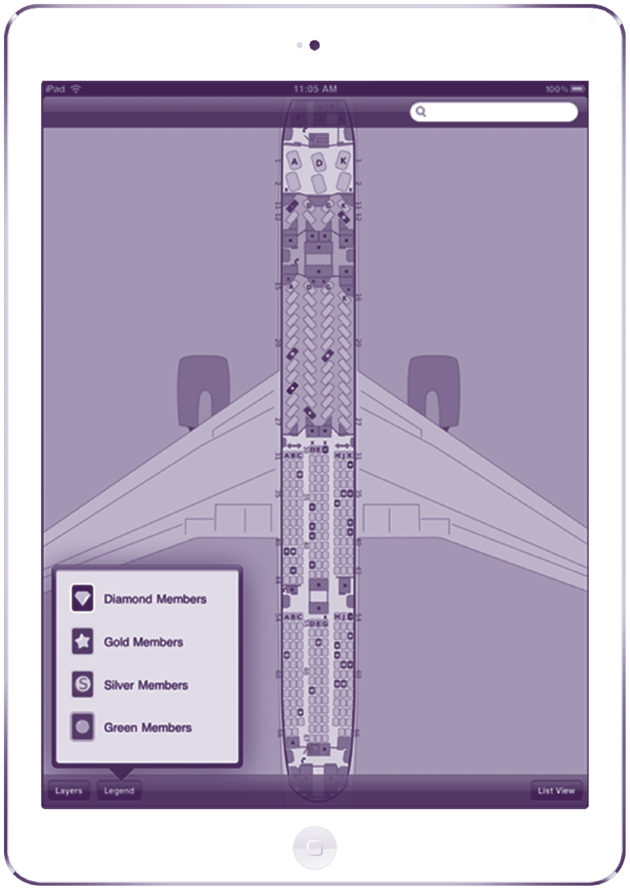
move toward a financial return. As examples, Southwest Airlines is leveraging speech analytics to improve customer interactions, while Delta Air Lines is sharing information with their “Track My Bag” feature on the Delta app for passengers. “The industry challenge will be to translate data into information,” adds Esposito.

There are many data-related questions the industry will need to answer as it evolves into Connected Aviation. If the market parallels the approach found in other industries, data ownership, data access, data sharing, and data hosting will all become integral, strategic elements, which will be addressed in Part 3.

However these elements are addressed, big data will revolutionize operations across the aviation industry. “The newness of the IoT is how it brings together data and analytics technologies to derive insights and make timely decisions based on fact,” concludes John Schmidt from Accenture.

Building the value proposition

As connectivity and big data begin to reach critical thresholds, the emphasis begins to shift to the benefits, and where maximum value can be achieved. Connected Aviation is a technological evolution that can be applied to nearly every facet of aviation: The supply chain will gain the opportunity to improve products and services; passengers will enjoy an improved flight experience and potentially see reduced fares; and, most importantly, operators will achieve greater efficiency across the board, reducing expenses within inflight services, flight operations, maintenance, and aircraft systems.



Courtesy of Ultramain

INFLIGHT SERVICES

For many operators, inflight services have been the early adopter of integrated connectivity and applications. Since IP connectivity has been adopted primarily as a passenger service, the inflight department has essentially “owned” the bandwidth, making it natural for them to leverage it for their own benefit. Basic applications such as real-time credit card processing are in place at many operators, but only recently have inflight services begun to explore the opportunities of big data and integrated applications.

CABIN LOGBOOK

With the evolution to Connected Aviation, the capabilities of the basic connected cabin logbook have expanded. With more sensors in the cabin, there is opportunity for more automated reporting. With sensors placed within seats, for example, a broken seat can automatically be entered into the logbook. Cabin crews would simply review the entry for approval instead of logging the report manually.

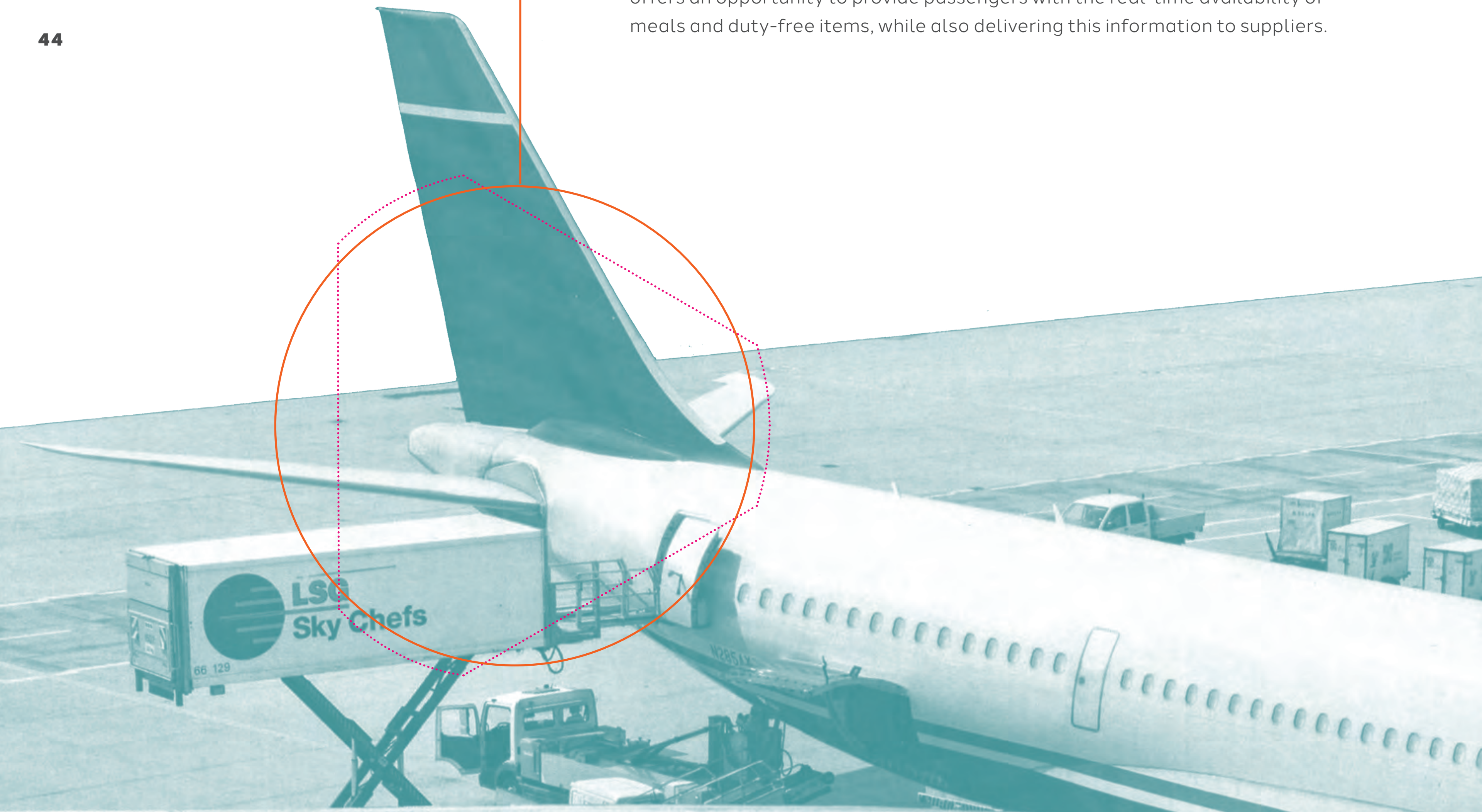
There are many opportunities to integrate the cabin logbook with flight operations, maintenance, and airport technology programs. As data is generated, suppliers are able to mine for recurring issues, which can improve their ability to respond and predict.

> "If it isn't flying, it's not making money."

Carl Esposito
Vice President of Strategy, Marketing and Product Management
Honeywell

CATERING AND DUTY-FREE

For inflight sales, managing catering and duty-free inventory is an opportunity to exchange data with suppliers to better manage passenger expectations. With catering, today's operators must balance potential revenue, waste, and cost. While many operators manage sales digitally, information beyond available inventory is not tracked. An operator may not know whether a particular meal barely sells out each flight, or that dozens more passengers have to settle for an alternative. Similarly, for duty-free items, inventory tracking can be improved by collecting more data about transactions while in flight. Adding sensors to carts offers an opportunity to provide passengers with the real-time availability of meals and duty-free items, while also delivering this information to suppliers.



MORE PERSONALIZED SERVICE

Connected Aviation is an opportunity for deeper levels of personalized service. Operators will be able to recognize not merely when they're unable to meet a passenger's request, but also if they've failed the same passenger in other ways. Repeated failures to satisfy frequent flyers can be damaging, and mitigating them is part of the Connected Aviation value proposition. For example, Delta Air Lines has deployed more than 22,000 mobile devices to inflight crew members. "We're working on providing our crew members with more personalized information for our customers. Even though we have 170 million passengers a year, the flight attendant knows you and your history and can provide customized services," explains Darrell Haskin from Delta Air Lines.

Beyond a specific operator's accumulation of passenger data, there is an opportunity to collect substantially more data through a system-of-systems of approach. Knowing that a passenger had a disruption on a connecting flight with another operator, their preferred hotel or rental car chain, or food and beverage preferences are all helpful in predicting passenger response, ultimately opening the door for more personalized service.

FLIGHT OPERATIONS

Fuel and labor are major cost drivers, and operators continuously seek to improve their financial returns. As Esposito says, "If it isn't flying, it's not making money. Opportunities to pull data from the aircraft generate valuable insights in real-time, which help operations." Improving aircraft routing, decreasing fuel consumption, and reducing ground-turn times will increase margins. Although operators have clear interest in this area, many are still in the research phase of such Connected Aviation initiatives.

WEATHER

Weather forecasts today are typically based on data that is 6 to 24 hours old. In the Connected Aviation world, weather forecasting will update more frequently and will incorporate data from multiple aircraft operating on the proposed route.

By integrating data from multiple sources, Connected Aviation will allow aircraft to see further beyond the horizon than any onboard system today, enabling more strategic decision-making. “Pilots would love to have a complete weather picture and see the same information that dispatchers have on the ground,” says Mark Miller from The Weather Company.

Connected Radar

An aircraft at cruising altitude has a forward radar range of around 300 nautical miles, which translates to around 30 minutes of flight time to the far edge of the radar zone. “The radar displays the information to the pilot, then the information is just thrown away,” explains Esposito. Honeywell has combined a weather application with shared radar data across multiple aircraft. By connecting aircraft along similar routes and aggregating radar views, the overall area visible to any one aircraft expands significantly. “By crowd sourcing, the view will be unlimited. It’s a different perspective of the weather – much richer and longer range,” adds Esposito. Combining this capability with additional time management and air traffic flow systems allows pilots and controllers to make strategic decisions earlier; this is especially important over oceans, where radar coverage is

currently lacking. All this leads to a safer, more comfortable passenger experience and lower total costs through more efficient routing.

Connected Turbulence

Turbulence lends itself well to the Connected Aviation application of big data. “There are costs associated with turbulence, whether it be injuries, unnecessary maintenance inspections, or less-than-efficient flight routes,” says Miller. The current process calls for pilots to self-report severe turbulence incidents, which by regulation demands a physical inspection of the aircraft upon landing. Everything about this process is manual and subjective, and the data is limited to the affected aircraft.

With WSI’s Total Turbulence, Miller says, “We’re able to fundamentally solve that problem by constantly monitoring an aircraft, detecting when it is subject to a turbulence event, immediately reporting that to the ground, monitoring all the other aircraft in the area, and then notifying any other aircraft that may be impacted.” With this program, information is now standardized and automated, and there is an opportunity to leverage data with crowd sourcing. “Aircraft are now acting as mobile turbulence sensors and feeding more and more data into the system,” he adds.

8,000
HOURS OF FLIGHT TIME

$131
MILLION SAVED

Saved by Metron in its first year

AIR TRAFFIC CONTROL (ATC) /AIRSPACE OPTIMIZATION

Airspace congestion is a growing issue in North America and Europe, and regulatory authorities in both regions have announced aggressive technology programs to relieve it with automation. Asia and certain oceanic airspaces have similar issues and stand to benefit. For operators, congested air space leads to delays, lost productivity, and additional operating costs, which translate to a demand for solutions. Next-generation aircraft control systems are expected to help dramatically on this front, and have already shown initial success in Australia.

Operators have historically competed for the same landing slots and air traffic clearance. From the perspective of a single operator, gaining priority over these resources may seem like the most efficient approach, but optimal efficiency comes from "amalgamating all that remote data and managing traffic flow across the industry," according to Virgin Australia's Stu McGraw. While there is still competition for resources, it is also possible to share more information between carriers, allowing them to optimize based on a combination of shared and internal knowledge.

The Metron Air Traffic Flow Management system (now a component of Airbus ProSky), is the "industry's first Collaborative Decision Making (CDM) platform for optimizing system-wide traffic flow."[24] It allows all participating parties to seamlessly share aircraft position, flight plan, and airport congestion data to better optimize aircraft positioning en route. It automates many of the decisions regarding aircraft sequencing and flow based on a rules engine, operator inputs, and various traffic management initiatives to reduce flight delays and flight hold times. The Metron system "fuses advanced science and mathematics with unparalleled subject-matter expertise to turn groundbreaking ATM research concepts into next-generation operational capabilities."[25]

According to McGraw, "In the first year of operation in Australia, Metron saved more than 8,000 hours of airborne flight time, translating into savings in excess of $131 million." The system operates most effectively with maximum data inputs in as near real-time as possible. With this capability, Connected Aviation will aid in refining and redesigning airspace to better meet the density needs of operators.

Courtesy of NASA

TAP software on a tablet-based EFB

ADVANCED FLIGHT OPTIMIZATION

NASA's Traffic Aware Strategic Aircrew Requests (TASAR) concept is an example of the advanced flight optimization possibilities with Connected Aviation. Currently, pilots follow a flight plan that is filed and approved by ATC before takeoff. Once in flight, Traffic Aware Planner (TAP) software combines data inputs from the aircraft with information from the ground to provide pilots with improved routing recommendations. If pilots accept the recommendations, they request the route change from ATC. TAP "takes into account what a pilot normally doesn't have information for: traffic, the latest wind data, weather data, and turbulence data," and can redefine the optimal flight path.[26] NASA's Mark Ballin adds, "TASAR is a first step in the use of sophisticated onboard planning algorithms to manage an aircraft's flight. It can serve as a platform for many additional inflight replanning functions, which will involve increasingly capable machine intelligence. These airborne planning systems will need to negotiate with ground-based systems of the airlines and the air navigation service providers. NASA is working on the airborne and ground-based elements of such traffic management systems, and Connected Aviation will be critical to their success."NASA is currently working with Alaska Airlines and Virgin America to trial the software.

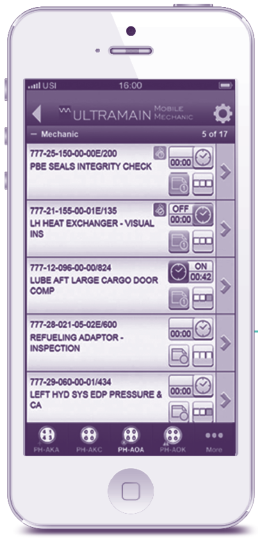
FLIGHT KIT REMOVAL BY THE NUMBERS

As an impactful Connected Aircraft initiative, the efficiencies gained through EFB begin to paint a picture of Connected Aviation's vast potential.

"On average each flight kit on a Delta jet weighs 38 pounds (2-4 flight kits per airplane). That was 7.5 million sheets of paper, or 900 trees per year we were going through. With potential fuel savings, we have 766 aircraft and it was going to be 1.2 million gallons of fuel per year. That's a 26 million pound carbon footprint, about the equivalent of taking 2,300 passenger cars off the road.

We'll realize an annual fuel savings of $13 million per year."

Shane White
Technical Pilot
Delta Air Lines



Courtesy of Ultramain

MANAGING MAINTENANCE AND AIRCRAFT SYSTEMS

In many ways, maintenance organizations stand to gain the most value from big data and Connected Aviation. Collecting data from a growing number of sensors on the aircraft means potentially identifying issues earlier and saving money. Preventing an uncontained engine failure can save an operator millions of dollars. "Connected Aviation will help us understand in advance where the maintenance issues are, which can save us a lot of money. It helps us decide where we will allocate resources," says Fournel.

Aviation has developed sophisticated models for identifying certain outcomes based on specific systems data. The increase in sensors and data will improve these models over time. With maintenance applications located directly on the aircraft, processing data, and providing analytics to the ground, teams have access to information much earlier in the maintenance cycle. Having a technician and parts ready when an aircraft lands creates huge efficiencies, limiting – if not eliminating – costly maintenance delays.

AIRCRAFT MAINTENANCE LOGBOOK

As noted previously with the cabin logbook, Connected Aviation moves beyond the concept of electronic, real-time logbook solutions. There is the potential for hybrid reporting, which combines data from onboard sensors with pilots' electronic logbooks. Instead of guiding pilots through the process of correctly identifying the broken part and fault code, connected sensors can create the logbook entry automatically, complete with all the diagnostic data. The pilot simply acknowledges the automated entry and inputs any additional details. This method can improve data reliability, duplication errors, and consistency, while simultaneously reducing workload. For example, after replacing a part, engineers are occasionally unable to update this information in the system successfully. When the system still indicates a need, teams at the next stop may replace the part again. Such "no-fault found" part replacements, as described by Ultramain's Mark McCausland, "can cost airlines millions of dollars a year."

128
HOURS

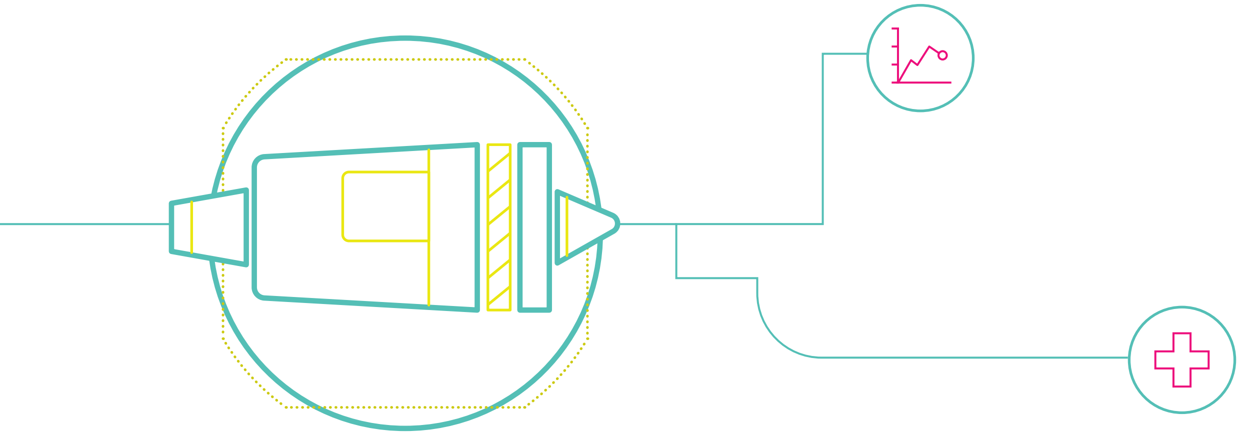
Estimated worker time saved by SHM systems on Embraer E-190 jets [30]

AIRCRAFT HEALTH MONITORING (AHM)

To help reduce operating costs and mobilize maintenance crews, airframers like Boeing, Airbus and Embraer offer AHM services for operators to monitor systems while the aircraft is in flight. In 2006, Embraer launched AHEAD (Aircraft Health Analysis and Diagnosis), which they describe as "a modern, automated system that enables airlines to continuously monitor the health of an aircraft while it is in flight, through the automatic transmission of warning messages from the aircraft systems to a ground base."[27] Since then, AHEAD has been further developed to facilitate decision making during line maintenance activities, including real-time transmission of alert and maintenance messages, advanced filters for improved fault analysis and trend identification, and personalized reports that support failure analysis.

Boeing's AHM system is in service with "58 airlines worldwide, on board more than 2,000 airplanes and standard on the Boeing 787."[28] With Boeing's system, data from onboard systems and engines are sent in real-time to ground operations. The data can be accessed via Boeing's secure portal, allowing issues to be communicated easily.

AHM continues to evolve with the introduction of structural health monitoring (SHM) systems. SHM is an alternative to manual inspections of hard-to-access areas of the aircraft, and it is gaining traction. Boeing recently outfitted seven Delta Air Lines 737s with Comparative Vacuum Monitoring (CVM) sensors for crack detection. Airbus is also progressing its SHM development with "structural and flight testing monitoring" and "in-service 'hot spot' monitoring."[29] Embraer has also taken steps to outfit its E-190 regional jets with SHM sensors, estimating "reduced time for inspections by 128 worker hours."[30]



ENGINE HEALTH MONITORING (EHM) AND OPTIMIZATION

Engines appear to have a head start over other aircraft systems due to their high costs and potentially catastrophic risks associated with failure. Not only do the engines on new aircraft like the Boeing 787 and Airbus 350 include new sensors, they are also delivering new ways to collect sensor data earlier to reduce the costs of unscheduled maintenance, unnecessary inspections, and trouble-shooting. Engine manufacturers including GE, Rolls Royce, Snecma, Honeywell, and others have all launched EHM programs and added software teams to support Connected Aviation initiatives.

Aircraft engines are the most expensive and most sensitive aircraft components, requiring maintenance at multiple points throughout their lifecycles. Regularly cleaning engines allows them to operate more efficiently, but taking aircraft out of service means downtime. Striking the correct balance of when to perform the maintenance based on operating efficiency, aircraft routing, and other factors is a complex process. Until now, this process has mostly consisted of scheduled maintenance at operating-hour intervals. As the onboard sensors become better and more connected, manufacturers and operators can identify the optimal inflight longevity points for maintenance.

Not only does this allow for savings and more efficient operations, it also leads to a longer total lifespan of the engine. Optimizing cleaning cycles reduces overall wear, extending the usable run time before an overhaul is required. One of the keys to this is real-time data. Bartlett is focused on getting "not only data about that engine and how many hours it's been running, but everything else you know about where it's been operating, how it's been operating, and the environment it's been operating in." Compiling all of this data in real-time enables the necessary precision to realize savings and efficiency.

This level of maintenance monitoring applies to other aircraft components as well. Auxiliary Power Units (APUs) are essentially small engines, so the benefits that apply to the main engines can apply here as well. Similar to how GE monitors its engines in the field, Honeywell is also monitoring and connecting the APUs found on most aircraft today. The goal is to offer "predictive trend monitoring and provide that as a service as part of the tracking data," adds Bob Smith from Honeywell.

HARNESSING THE POTENTIAL

From inflight operations to maintenance, the potential for improvements enabled by Connected Aviation is vast. Unlocking the benefits goes beyond getting data from a single aircraft; it means aggregating and synthesizing data from entire systems to gain actionable insights that drive the bottom line. Only with a true IoT approach can the aviation industry fully leverage big data analytics. Increased fuel efficiency, reduced maintenance costs, and an improved inflight experience are all on the table, but getting to that point will require better collection and sharing of data. Vikram Baskaran from Alaska Airlines highlights, "There is already real-time collaboration going on, but adding a data element to that and sending it to pilots can absolutely enhance options and take efficient flying even further."

BOB'S TAKE

Airlines invest enormous amounts of energy and money into minimizing aircraft out-of-service time.

Avoiding downtime means building systems to more accurately forecast failure, and other systems to expedite repair when failure does occur. These efforts will become more sophisticated and successful as IoT becomes more inclusive, and more data becomes available. Increased reliability is likely to be one of Connected Aviation's greatest successes.

Endnotes

1. *Flight Global*, “ARINC Launches Common-Use Wireless Gatelink System,” by David Learmount, June 14, 2007. https://www.flightglobal.com/news/articles/arinc-launches-common-use-wireless-gatelink-system-214660/

2. Valour Consultancy, “The Future of Aeronautical Connectivity Report,” October 2014.

3. TechTarget, “Navigate Data Lakes to Manage Big Data,” by Mike Matchett, June 2015. http://searchstorage.techtarget.com/opinion/Navigate-data-lakes-to-manage-big-data

4. Gartner Press Release, “Gartner’s 2015 Hype Cycle for Emerging Technologies Identifies the Computing Innovations That Organizations Should Monitor,” August 18, 2015. http://www.gartner.com/newsroom/id/3114217

5. BI Intelligence, “The Internet of Things 2015: Examining How The IoT Will Affect The World,” November 2015.

6. AirInsight, 2015 Annual EFB Research Project.

7. *Runway Girl Network*, “United is on Bleeding Edge of Integrating Multiple Wi-Fi Products,” by Seth Miller, September 25, 2015. https://www.runwaygirlnetwork.com/2014/09/25/united-is-on-bleeding-edge-of-integrating-multiple-wi-fi-products/

8. Telecoms.com, “Industry Giants Form Mobile Edge Open Networking Group,” by Tom Skinner, October 17, 2014. http://telecoms.com/295312/industry-giants-form-mobile-edge-open-networking-group/

9. Telecoms.com, “Industry Giants Form Mobile Edge Open Networking Group,” by Tom Skinner, October 17, 2014. http://telecoms.com/295312/industry-giants-form-mobile-edge-open-networking-group/

10. *ComputerWorld UK*, “Boeing 787s to Create Half a Terabyte of Data per Flight, says Virgin Atlantic,” by Matthew Finnegan, March 6, 2013. http://www.computerworlduk.com/news/data/boeing-787s-create-half-terabyte-of-data-per-flight-says-virgin-atlantic-3433595/

11. *Data Science Central*, “That’s Data Science: Airbus Puts 10,000 Sensors in Every Single Wing!” by Bernard Marr, April 9, 2015. http://www.datasciencecentral.com/profiles/blogs/that-s-data-science-airbus-puts-10-000-sensors-in-every-single

12. AirInsight, 2015 Annual EFB Research Project.

13. Accenture, “Moving Toward the Future of the Industrial Internet,” 2015. https://www.accenture.com/t20150523T033740__w__/us-en/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Dualpub_9/Accenture-Industrial-Internet-Competitive-Landscape-Industries-Infographic.pdf

14. Gartner Glossary, Big Data. http://www.gartner.com/it-glossary/?s=high-velocity+

15. *Runway Girl Network*, “The Internet of Things Coming Soon to an Airline Near You,” by Ben Kepes, March 14, 2015. https://www.runwaygirlnetwork.com/2015/03/14/the-internet-of-things-coming-soon-to-an-airline-near-you/

16. Green Car Congress, “Sensor fusion, machine learning, and “big data” featuring in Ford R&D for advanced driver assistance,” December 22, 2012. http://www.greencarcongress.com/2012/12/ford-20121222.html

17. Gartner, How to Derive Value From Big Data in Transportation, Bart De Muynck, 25 June 2015.

18. Gartner, How to Derive Value From Big Data in Transportation, Bart De Muynck, 25 June 2015.

19. Gartner, How to Derive Value From Big Data in Transportation, Bart De Muynck, 25 June 2015.

20. Gartner, How to Derive Value From Big Data in Transportation, Bart De Muynck, 25 June 2015.

21. Gartner, How to Derive Value From Big Data in Transportation, Bart De Muynck, 25 June 2015.

22. Gartner, How to Derive Value From Big Data in Transportation, Bart De Muynck, 25 June 2015.

23. IDG Enterprise, "Big Data and Analytics Survey 2015," by IDG Enterprise Marketing, March 9, 2015. http://www.idgenterprise.com/resource/research/2015-big-data-and-analytics-survey/

24. Metron Aviation, "Airservices Australia Improving Performance with Metron Harmony Air Traffic Flow Management System," June 25, 2012. https://www.metronaviation.com/project/airservices-australia-improving-performance-with-metron-harmony-air-traffic-flow-management-system/

25. Metron Aviation, "Airservices Australia Improving Performance with Metron Harmony Air Traffic Flow Management System," June 25, 2012. https://www.metronaviation.com/project/airservices-australia-improving-performance-with-metron-harmony-air-traffic-flow-management-system/

26. Tech Briefs, "David Wing, Air Traffic Management Researcher, Langley Research Center, Hampton VA," January 1, 2014. http://www.techbriefs.com/component/content/article/ntb/features/whos-who/19008

27. Embraer Press Release, "Embraer Launches New Version of the Ahead Software," June 4, 2007. http://www.embraer.com/en-US/ImprensaEventos/Press-releases/noticias/Pages/EMBRAER-LANCA-NOVA-VERSAO-DO-SOFTWARE-AHEAD.aspx

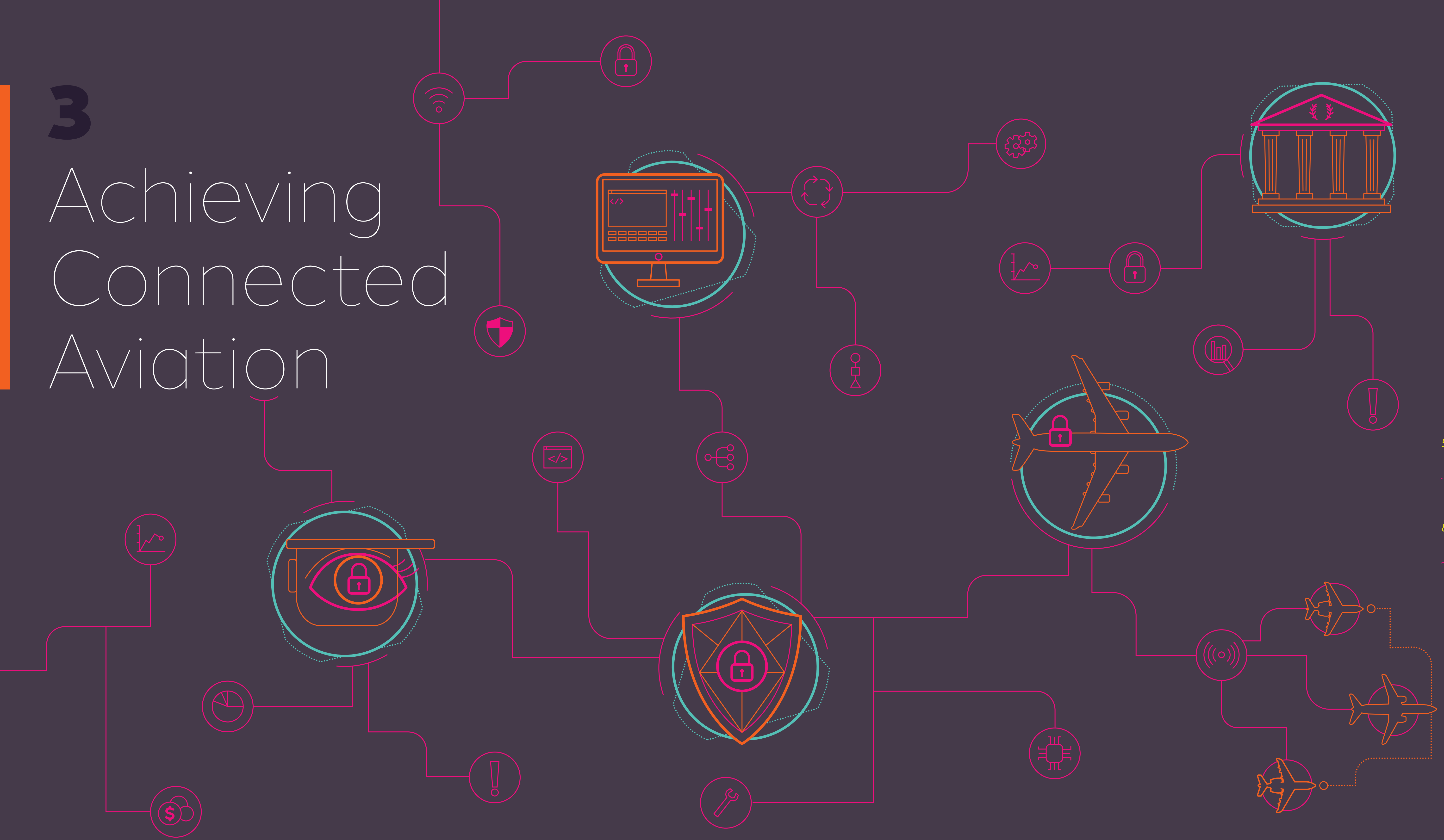
28. Boeing, "Airplane Health Management: Monitoring the Airplane in Flight," July 30, 2013. http://www.boeing.com/features/2013/07/bca-airplane-health-mgmt-07-30-13.page

29. Composites World, "Structural Health Monitoring: Decades of Demonstrations Build Confidence in Local SHM," by Ginger Gardiner, July 31, 2015. http://www.compositesworld.com/articles/structural-health-monitoring-decades-of-demonstrations-build-confidence-in-local-shm

30. *Aviation Week*, "Embraer Continues Second-Generation E-Jet Development," by Guy Norris, February 4, 2013. http://aviationweek.com/awin-featured-story/embraer-continues-second-generation-e-jet-development

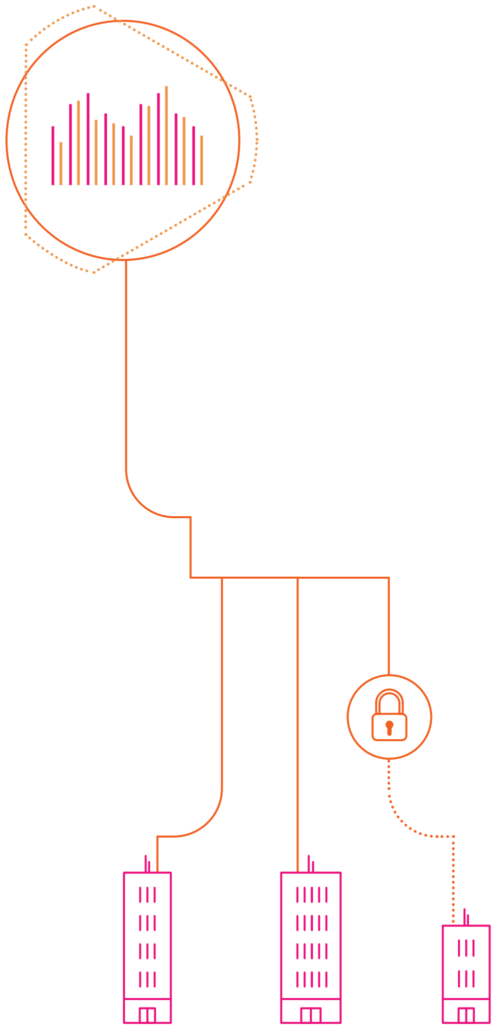
3

Achieving Connected Aviation



The evolution toward Connected Aviation promises tremendous operational and economic opportunity, but the technical challenges are significant. When analyzing how big data and connectivity will impact aviation, hurdles such as data privacy and security, regulations, and standards must be considered. Organizational challenges such as managing structure, internal processes, and costs must be addressed as well. Left unaddressed, these factors can remain a significant impediment to the success of Connected Aviation, but as other industries have shown, they can be overcome.

Tackling data privacy and security



Data privacy and security concerns are paramount with Connected Aviation. Big data, whether from aircraft components, passengers, or metadata, must be handled with sensitivity. There are questions around data ownership, data privacy management, and data security that the industry must address.

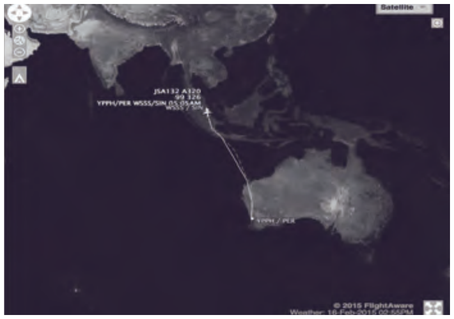
DATA PRIVACY AND SHARING

Privacy concerns are significant because so many stakeholders are part of the aviation supply chain. This is not simply an aviation issue; it is one being addressed in other industries. In fact, privacy was raised as an inhibitor to IoT adoption by nearly half of companies surveyed by Gartner.[1] The question of data privacy hinges on whether to adopt an open, shared, or closed, proprietary approach.

The consensus from operators is that they own the data, regardless of the system, and it should be treated as proprietary. In other words, it is rare for data to be freely shared with others in the supply chain, regardless of interest or intent.

Data has historically been a source of competitive advantage in the aviation industry. In early days, possessing charts with optimal routes was one such advantage. More recently, flight planning and aircraft configuration software offers a similarly perceived advantage. But with Connected Aviation and big data, ownership could lead to multiple claims to the same data. In some cases, ownership claims from within the supply chain may prove stronger than those of the operator. Looking at leased aircraft, power-by-the-hour, and other shared-risk asset structures reveals the complex nature of data ownership, as there is a vested interest in the non-operator having equal access to some data.

Data ownership is different than data access. Instead of focusing on who owns the data, the more pertinent question may be: "How can the industry successfully establish a plan to manage data privacy and share permissions?" In many ways, this is similar to how libraries operate. Just as patrons who are granted permission to join a library are able to check out books, partners in the aviation world could access data. Authors retain ownership of information, while the library acts as the repository that manages information transfers. Such hub sharing allows members to access more information than they could individually.



Courtesy of FlightAware

OPEN SOURCE FLIGHT TRACKING

FlightAware

Aviation supplier FlightAware offers a prime example of successful open data. For tracking business and commercial aircraft, FlightAware has built an extensive surveillance network that includes Automatic Dependent Surveillance - Broadcast (ADS-B), government air traffic control, and private datalink sources, as well as a self-developed, open-source ground station that can be installed in a home or garage. Daniel Baker of FlightAware, explains, "We have over 5,000 open-source flight trackers deployed all around the world in over 100 countries. It may be just a fun hobby for enthusiasts, but it's also backhauling all the data to us over the internet" improving overall flight-tracking capabilities.

"Privacy is always a concern in the absence of proven value."

Navin Ganeshan
Chief Product Officer
Zubie

Industries outside aviation see the potential value from open data sharing. Motorola's Michelle Gattuso believes, "The more openness that you can create, the better the entire ecosystem will be." Bryan Biniak from Nokia Growth Partners (formerly from Microsoft) adds, "There is both a business and a consumer expectation toward openness, accordingly companies like Microsoft are embracing open, cross-platform collaboration." The City of Chicago has hundreds of thousands of sensors measuring vehicle and pedestrian traffic flow and environmental data, with a formal policy of open, public access. More than 500 data sets are currently available, and the number is growing. "One of the real drivers of why many cities like Chicago build in open-source is so we can share with other cities and learn," says Brenna Berman of Chicago's DoIT.

In aviation, safety may be an obstacle to open data. However, the value to the industry – and even to the operator – is greater when more data is shared and combined. Many trends and valuable insights can be achieved only by analyzing large amounts of data. An aircraft component supplier will see value in collecting performance data to refine products for future-generation production and upgrades. For an operator, interest in operational data focuses on planning for staffing, spare parts, maintenance cycles, and fleet utilization. Each of these benefits are in line with cost centers seeking optimization, which comes with more and better data. While smaller operators may be more likely to share and gain access to a larger data pool, larger operators may benefit from these insights.

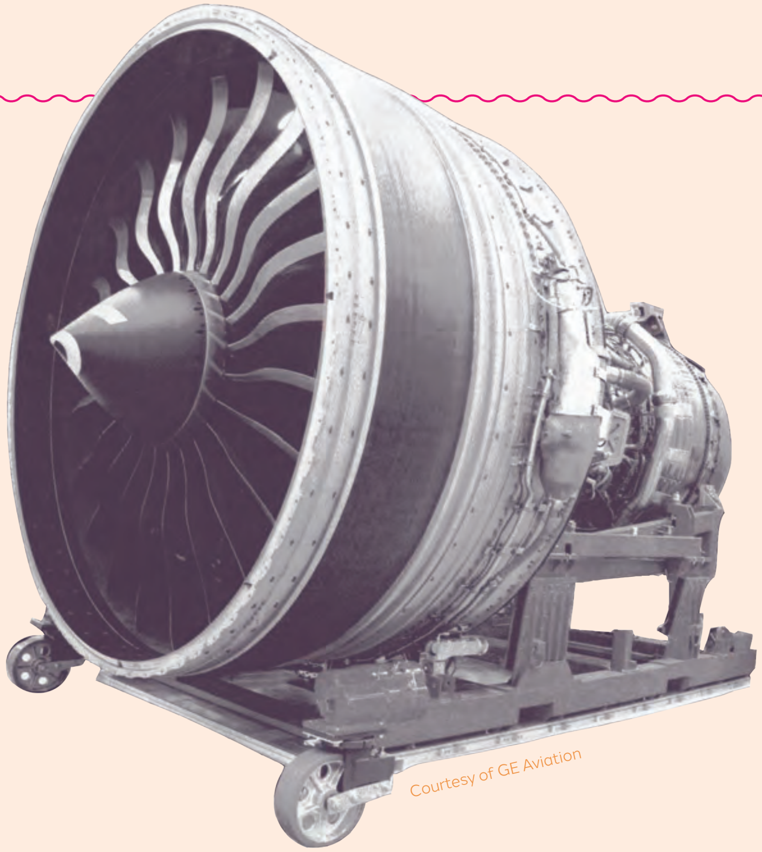
Determining the balance of shared versus proprietary data approaches will have repercussions across the Connected Aviation landscape. Other industries have demonstrated the value of selective data sharing. This is the case with education, healthcare (within the confines of patient confidentiality), and even in competitive industries, such as banking. Within the automotive industry, Omar Rahman of Here describes how an open location platform does not necessarily mean all data is freely shared with all stakeholders. "Some data will belong to a specific OEM and will not be shared with other OEMs, while there's other data that will be commonly shared." To accomplish the optimal results of Connected Aviation, the industry must come together to determine what data is valuable for the greater ecosystem and what data should remain proprietary. As Don DeLoach of Infobright adds, "In order to really leverage data, companies are going to have to deploy it against a certain architecture that allows for it to be leveraged in the right place by the right people for the right reasons."

There are certain competitive implications to data sharing, but finding the balance between shared and proprietary data is where efficiencies can be found. It will be necessary to respect traditional data ownership, while also pushing new boundaries in data sharing, which may create concern and delays from industry stakeholders. In particular, there is often commentary around the need to respect privacy, hence the need to keep data proprietary. "Privacy is always a concern in the absence of proven value," notes Navin Ganeshan from Zubie. ThingLogix's Steven Loving adds, "Suppliers will need to show a strong value proposition as to why operators should engage in data analysis."

BOB'S TAKE

These are enormously interesting issues that will drive discussion for many years to come.

Years ago, in the early days of reservations systems, we grappled with the question of who owned and who could use flight information. While those questions are now settled, the proliferation of systems gathering more and more data will raise new ownership and use issues, many of which will bear on the industry's ability to optimize operations via data sharing. Although these questions seem less pressing than immediate operational concerns, they are important, and deserve careful thought.



Courtesy of GE Aviation

WHO OWNS THE DATA?

GE Engines

An aircraft outfitted with GE's newest engines generates a terabyte of data for analysis in just one day,[2] but who owns this data, and who should have access?

GE is interested in collecting the data from its engines. Near-real-time performance metrics will guide development of next-generation engines. That same data will also be used to further optimize predictive maintenance forecasts and to tune engine software. As a result, every engine flying will perform better, and every operator will benefit from reduced failure frequencies and maintenance costs.

Aircraft manufacturers such as Boeing and Airbus want access to this data because it will provide essential details on aerodynamic efficiency and other factors that airframe manufacturers are constantly fine-tuning. Understanding when an engine is optimally efficient under certain circumstances means designing the aircraft for those conditions and further increasing overall aircraft efficiency.

Operators see the data's value for planning maintenance cycles and to ensure aircraft and engine manufacturers are delivering the promised operational performance.

PASSENGER PRIVACY

With connectivity, more passenger details can be shared with cabin crews in real-time. The benefit of increased data sharing is improved personal service, such as offering birthday wishes or knowing how they take their coffee. In the future, flight crews may even be able to monitor passenger health with information from sensors in the seats or as reported by personal devices and wearables.

However, there is a privacy concern with building passenger profiles and data mining. The line may become further blurred if those profiles use data shared between companies or other non-aviation sources. In some cases, these profiles already exist and are shared among companies. For example, an operator and a hotel company may collaborate to produce more detailed passenger profiles and target specific offers to those customers. Most travelers appreciate the benefits of such information sharing, but there are limits to what is comfortable.

There are even greater concerns once regional differences come into play. The capacity to share consumer data in European countries is far more limited (culturally and legally) than in the United States. The overarching European Data Directive addresses the processing of personal data and requires companies to comply with a broad set of principles relating to data quality. In the United States, the approach is more fragmented, where a patchwork of laws covers different categories of data. With these differences, companies must navigate a complex system in which compliance standards vary by jurisdiction.

As personal privacy expectations evolve with Connected Car and Connected Home, the privacy expectations for air travel will likely become more lax as well. While the challenges of sharing passenger data need to be addressed, the privacy and sharing of operational data is most critical to the value proposition of Connected Aviation.

BOB'S TAKE

As Connected Aviation evolves, we must be absolutely sure that no part of any system can ever be used or misused so as to endanger the aircraft.

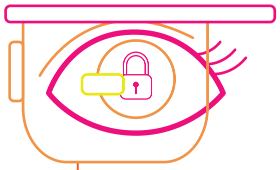
That's a tough challenge and, inevitably, the need for extraordinary caution will prevent some applications and delay others. The bottom line is clear: The security of an aircraft in flight must never be compromised.

CYBER SECURITY

"Before we can fully exploit the potential and power of an open, cross-platform, pervasive network of things, security issues need to be addressed," says Nokia Growth Partner's Bryan Biniak (formerly from Microsoft). Cyber security and data protection remain the greatest hindrance when it comes to deploying an IoT-related project, according to a recent study by Machina Research and Xively by LogMeIn.[3] Gartner reports similar results in its research.[4] The adoption of big data and consumer technology means that cyber security is now becoming more important for aviation.

The merging of aviation technology into the mainstream drives the need for heightened awareness of cyber security developments in other industries. A record 79% of survey respondents from the 2015 US State of Cybercrime Survey said they detected a security incident in the past 12 months, and the concern around cyber security threats have increased 17%.[5] Given the vast amount of sensors and data that must be managed with IoT, the risk of cyber attacks and breaches is apparent. Bruno Fromont from Intelsat observes, "The more sensors, the more communication paths you have, the more interplay among the vast amounts of data. This is going to exacerbate the security issues we may have."

Over the last few years, cyber incidents have made headlines (Sony Pictures, Target, and Anthem to name a few). "Cyber incidents affect us in many parts of our lives, both from a personal privacy perspective from our credit cards to our health



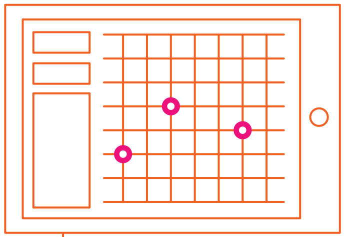
79%

DETECTED A SECURITY INCIDENT IN THE PAST 12 MONTHS[5]

records," points out A-ISAC's Faye Francy. "There is an interconnectedness that has brought us closer together as a community, but there's increased risk with being interconnected."

Within the automotive industry, compromised automobiles make headlines. While lives may be put at risk, isolated incidents are unlikely to have the same impact as such incidents would in aviation, where the safety of many more passengers stands to be compromised.

Discussion of cyber security is not new in aviation; the idea of an unauthorized third party accessing avionics data or other critical systems has driven system architecture for years. Nevertheless, examples from 2015 alone have illustrated the threat of cyber attacks to the aviation industry. Last year, it came to light that American's AAdvantage and United's MileagePlus loyalty programs were breached, allowing illegitimate miles transactions.[6] Chris Roberts, a security researcher, claimed to hack



38%

INCREASE IN ADOPTING CYBER-SECURITY PLANS FOR EFBs

over the last two years[7]

a United Airlines aircraft's inflight entertainment system. The news generated headlines, but little in the form of demonstrable vulnerabilities in operator systems. Similarly, LOT Polish Airlines recently had to ground 10 flights in the face of an attack on computer systems in its Warsaw hub. That incident did not impact aircraft in flight, but it did invite scrutiny upon the security of the networks operators rely on. Francy says, "We are using an infrastructure designed many years ago, when security risks were not as significant as they are today." It is a situation that leaves the industry vulnerable to a variety of attack pathways. While many incidents affect only consumer-facing aspects of the flying experience, other scenarios may have broader implications. Learning from these breaches should help create stronger infrastructure and security practices in tandem with developing Connected Aviation.

The Connected Aviation architecture necessitates open communications lines – an inherent security risk – but cyber security has always been a race between competing interests. Threats are always coming from new and different angles. "Cyber security is a journey, not a destination," says PTC's Jim Heppelmann. "No data center is ever fully secure, because the bad guys are always inventing new ways to get into it, and you always have to be mitigating those new ways." Ongoing monitoring and training are a must for system users. "Users of a system need to be aware and vigilant for any particular blip or abnormality that they might see in the operation. If the data that they get in their flight plan doesn't seem right to them, they need to be trained to check and double check and validate or verify that it is actual, real data," adds Gogo's Andrew Kemmetmueller. Monitoring the overall system to make sure such changes come only from the authorized sources is a critical step. If training and monitoring are adopted by crews, breaches can be identified earlier to minimize the impact.

People have become conditioned to cyber-attacks as part of life. Despite security breaches in retail, consumers still shop at affected stores while the companies try to reassure them that their data is safe. Even with cyber security risk, the aviation industry is moving forward with Connected Aviation.

"The tolerance for error on a plane is as low as any industry you're going to find, and standards to prevent security issues or to maintain maximum cyber security will rise dramatically as the applications become more relevant to flight operations," notes Gogo's Michael Small.

Building out infrastructure and standards to support the industry needs has worked many times in the past, and there is no reason to doubt it here. Francy believes, "We've got to work toward resiliency. We have to be in a position that when there is an issue, there's still a way to get back up and keep going." The growth of cyber security and empowered cyber security teams has enabled a 38% increase in adopting cyber-security plans for EFBs over the last two years, according to operators.[7] "People used to use hardware that was designed for something else, but as we move forward there is now special hardware and software all being designed for specific environments. That is where security is going, and I think specifically designed solutions will solve these problems," concludes Arconics' Niall O'Sullivan.

"With threat factors common across all domains and infrastructures, you need to build architectures and solutions that account for everything in the product portfolio. An agile approach allows you to mitigate threats, regardless of where they come from."

Barry Einsig
Global Transportation Executive
Cisco Systems

SECURING THE NETWORK

One of the integral facets of Connected Aviation cyber security is how to secure the data network. Navin Ganeshan outlines some of the key questions Zubie asks in their approach to cyber security. “We look at how you secure data at rest and data in motion. Data at rest involves data that exists within the device, as well as data uploaded to the cloud. How do we secure our cloud infrastructure, and restrict access to it? Then when we transfer data between systems, how do we re-encrypt?” Within aviation, the approach to address these challenges varies widely.

Some advocate a wholly isolated network – an approach similar to an air gap – to ensure that intruders are blocked from accessing the data. By placing communications on separate networks, the security of each data stream is improved. Each aircraft “domain” would be completely isolated from the other domains. Designs for the Boeing 787 included isolated networks conforming to industry guidance for separation of domains. These domains have protections between them to allow managed traffic between them. During the certification of the Boeing 787, the FAA issued a Special Condition for the aircraft, requiring that Boeing prevent all “inadvertent or malicious changes to, and all adverse impacts upon, all systems, networks, hardware, software, and data” in the Aircraft Control Domain (ACD) and in the Aircraft Information Service Domain (AISD) from all points within the Passenger Information and Entertainment Services Domain (PIESD).[8] This rule resulted in the aircraft demonstrating appropriate isolation between all the networks on board. FAA Special Conditions similar to the ones on Boeing 787 are now in place for other aircraft, such as the Airbus 350, with linefit eEnabled systems. In all cases, connectivity providers have adapted installations to provide key protections for operational data, segmented from any passenger-facing elements.

Others believe that different radio frequencies should be used for operational and monitoring data, adding an even greater level of separation. Allocating dedicated spectrum for on-board communications could provide increased security for data traffic. The costs and benefits of each approach are hard to reconcile given uncertainty surrounding regulatory issues covering these advances.

REGULATIONS AND STANDARDS

Regulators play an integral role in aviation and will continue to do so within Connected Aviation.

A prime area for regulatory involvement is managing the certification phase of Connected Aviation. Essentially, regulators will need to work with airframe manufacturers and suppliers to ensure that aircraft, when delivered to operators, meet the standards defined by the regulator. While the most expected standards for Connected Aviation will revolve around data privacy and security, connectivity elements such as installation will also require standards. Regulation also requires managing the operational phase, where there is greater risk for compromised data. When an operator wishes to add functionality to the aircraft, the regulator is often involved in reviewing the new items against approved processes to determine compliance with standards. International operations deepen this complexity, potentially resulting in multiple obligations from different countries that the operator must satisfy for approval.

KEY PLAYERS

The International Civil Aviation Organization (ICAO) and the International Air Transport Association (IATA) are two key players in the promotion of air transport safety, and they will be involved in supporting the industry's advance toward Connected Aviation.

ICAO

Created to help mitigate international aviation issues and standardize requirements between nations, the ICAO is a regulatory body formed by charter as part of the United Nations. It coordinates efforts with national regulatory bodies to achieve a coherent global strategy that allows aircraft to fly internationally without violating regulations.

ICAO has already taken tangential action on big data and Connected Aviation by requiring operators to have a flight-following capability. In the wake of Malaysian Airlines Flight 370's disappearance on March 8, 2014, it appeared that the industry was finally ready to move forward with aircraft tracking, including an uncharacteristically aggressive implementation schedule based on an ICAO mandate. ICAO's aircraft tracking mandate is set to be adopted by national civil aviation authorities. However, implementation has been delayed, and the future is uncertain. This also delays any benefits operators might garner from working together to reduce costs and ease the impact on operations. Radio spectrum was finally allocated on a global basis, but reporting requirements have not been formally adopted, nor have the necessary details surrounding who will control the data or where it will be stored.

In the face of delays, many operators are talking about aircraft tracking efforts and some are even moving forward with their own. Qatar Airways has built its own set of protocols and standards with positional

BOB'S TAKE

What's the hold up?

We need applications that tell us where the airplane is at all times. Lost aircraft are an absurdity. The industry needs to get it together. This should not be an issue in this day and age. It's 2016. We can't afford to wait around for this.

"IATA will have a key role to play with establishing standards for Connected Aviation."

Mohammed Amin Abdulmajeed
VP Hajj & Umrah Product & Services
Saudia Airlines

tracking and reporting requirements. But the uncertainty about standards makes it harder for more operators to move forward with their own efforts. Those that do invest could face additional costs if their system does not comply with the final mandate.

Aircraft tracking is just one example, but ICAO is expected to play an increasing regulatory role in data management for aviation over time.

IATA

In 1945, 57 airlines came together to form IATA. Global standards, partnerships and collaboration were the driving force behind the creation of IATA - elements that are just as important today as they were seven decades ago. IATA works closely with ICAO and its members on many issues related to aviation, with safety its number one priority. In Flight Safety, technology has an important role. Saudia Airlines' Mohammed Amin Abdulmajeed states, "IATA did an excellent job with electronic ticketing in setting certain standards that operators were able to apply and interconnect with each other. They will have a key role to play with establishing standards [for Connected Aviation]."

The IATA Operational Safety Audit (IOSA) is an internationally recognized and accepted evaluation system designed to assess the operational management and control systems of an airline. All IATA members are IOSA registered and must remain registered to maintain IATA membership. Incorporating various Connected Aviation checks into aviation industry audits may be one way the industry might work with regulators to add mutually agreeable checks to the process and improve security and safety.

Regulations, Standards, and Security

A-ISAC

Aviation Information Sharing and Analysis Center

A-ISAC is a membership organization focused on sharing information about potential threats and mitigation in a global effort to protect aviation businesses, operations, and services. A-ISAC enhances the ability "to prepare for threats, vulnerabilities, and incidents so that aviation sector firms can best manage their business risks" from reservation to destination.[9]

A-ISAC is a member of the National Council of ISACs, the collective of official threat sharing information groups. ISACs were established in 1998 to protect the critical infrastructure of the United States by bringing together public and private sectors to share information about threats and vulnerabilities.

CAAC

Civil Aviation Administration of China

With its early beginnings as an operator, CAAC is responsible for national civil aviation affairs and is authorized by the Civil Aviation law of the People's Republic of China to "enforce the unified supervision and regulation on the civil aviation activities of the whole country, and in accordance with laws and State Council's decisions, to issue regulations and decisions concerning civil aviation activities within its jurisdiction." [10]

FAA

Federal Aviation Administration

The FAA is the national aviation authority of the United States. It has authority to regulate and oversee all aspects of American civil aviation. Its mission is "to provide the safest, most efficient aerospace system in the world."[11]

ICAO

International Civil Aviation Organization

Established in 1944, ICAO is a United Nations special agency tasked with driving consensus on international civil aviation Standards and Recommended Practices (SARPs) and policies "in support of a safe, efficient, secure, economically sustainable, and environmentally responsible civil aviation sector" with its Member States.[12] These SARPs and policies are used by Member States to ensure that their local civil aviation operations and regulations conform to global standards.

IATA

International Air Transport Association

IATA is the trade association for the world's airlines, representing some 260 airlines or 83% of total air traffic. IATA's vision is "to be the force for value creation and innovation driving a safe, secure, and profitable air transport industry that sustainably connects and enriches our world."[13]

EASA

European Aeronautical Safety Agency

Established in 2002, EASA is the European Union Authority for aviation safety. Its mission is "to promote the highest common standards of safety and environmental protection in civil aviation."[14] EASA oversees "the strategy and safety management, the certification of aviation products and the oversight of approved organizations and EU Member States."[15]

Transport Canada

Transport Canada is responsible for promoting the safety, security, and environmental soundness of transportation systems. Specifically for air safety, Transport Canada is responsible for "inspecting aircraft to make sure they are safe to fly; setting standards for testing and licensing pilots; and testing crewmembers on emergency response procedures."[16]

WORKING WITH REGULATORS

Regulators are working on frameworks that will facilitate necessary security parameters and architecture. "Today, already 85 Member States are working on regulations addressing cyber threats," notes IATA's Pascal Buchner. They work with airframe manufacturers and integrated systems suppliers to ensure operators are secure and able to take advantage of new technology. The Boeing 787 and Airbus 350 programs have redefined the scope of interest in regulators for onboard technology, with Bombardier and Embraer closely following with their own programs. Major component providers, such as GE and Honeywell, are seeing increased attention from regulators and a desire for standardizations to take advantage of big data. Integrators, such as Rockwell Collins and Gogo, are working closely with regulators to develop standards for open communications platforms that deliver data to and from the aircraft, regardless of geography. Ultimately, even air traffic control is moving toward big data standards to improve safety and efficiency.

While there has been regulatory progress, experience has led many operators to believe that regulators are problematically slow when it comes to providing the necessary guidance and oversight to build standards. For example, the AirInsight EFB Research Project revealed that approvals were cited as the biggest challenge when launching an EFB program, and respondents "typically addressed these (challenges) to the government authorities tasked with approving the airline for use of an EFB."[17] Virgin Australia's Stu McGraw explains, "The industry is evolving rapidly, but regulators are not keeping pace. This potentially results in a situation where either nothing gets done or poor decisions are made." To address this challenge, McGraw suggests that regulators must change their approach. "To make sure that the right part of the network is secure, regulators must stay abreast of the technology and stay abreast of the security protocols themselves." Regulators are an integral part of the system, but will be forced to adapt in response to new technology.

For Connected Aviation to succeed, suppliers and operators alike must partner with regulators to help drive standards. Some industry leaders see promise in a concerted effort between the industry and regulators to deliver the necessary infrastructure operators and manufacturers demand. The partnership extends the relationship beyond traditional boundaries into new areas of common interest. Airframe manufacturers can benefit tremendously from regulators in areas of cyber security and monitoring. GE Aviation's David Bartlett sees the participation of regulators as key to the success of Connected Aviation. "Regulators are in place to ensure we bring everyone home safely and ensure other players in the industry do it, too." Collaborating with regulators and involving them early in the process are central to Bartlett's vision for success. "Let's start working with them today to find processes for sharing information more dynamically." Samuel Lacarta Chavarrias from Vueling adds, "If avionics providers, aircraft manufacturers, and connectivity providers all work together to set up the standards, I would hope that we can improve some of the avionics and operational systems without security risk."

> "It's the job of everybody in the industry to improve the safety, operational benefits, and the environmental benefits of the aircraft."

Aviation has been insular in addressing technology for much of its existence. Industry veterans describe the unique environment of flying aircraft and cite it as reason for pursuing a path different from other industries. But the adoption of COTS hardware during the eEnablement phase began a shift toward commonality with other industries, and the installation of IP connectivity on aircraft makes for inevitable parallels. It may be time for the aviation industry to also look outside the industry for guidance on tackling IoT regulations. Buchner adds "There will be great benefits for the aviation industry to follow the standards developed in other industries, such as banking, telecom, automotive."

There is clear consensus within the industry that all stakeholders should be involved. "It's the job of everybody in the industry to continue to improve the safety and operational benefits, [as well as] the environmental benefits of operating the aircraft," concludes Carl Esposito from Honeywell. Finding the commonality, at least with regards to safety-related items, is an essential aspect of Connected Aviation. How the industry makes this shift is not clear and can present both opportunity and obstruction.

Carl Esposito
Vice President of Strategy, Marketing and Product Management
Honeywell Aviation

ESTABLISHING STANDARDS

As demonstrated in other industries, defining standards can often be more difficult than implementing technology. Reaching a Connected Aviation core design that drives commonality with enough flexibility to maintain reasonable data security and privacy requires cooperation from all stakeholders including operators, suppliers, and regulators. While this cooperation is not inherent in the highly competitive aviation industry, the adoption of standards is essential. Boeing's John Craig explains, "At Boeing, standards are very important to use. Driving a standard at an industry level that includes production and retrofit are essential." Connected Aviation will likely drive a number of opportunities for the industry to adopt common development practices and policies including:

- *Data formatting*
- *Application program interfaces (APIs)*
- *Cyber security standards*
- *Communication protocols*
- *Requirements for availability, latency, and redundancy*
- *Data policies*
- *Network segregation*

"Standards are needed for airlines to avoid having to go back and build applications that require integration," concludes Abdulmajeed.

DATA POLICY

Data policies build upon the principles of regulatory policies and business logic that "defend and establish public access of information, often defining standards and service level agreements for information quality, disclosure, and publishing."[18]

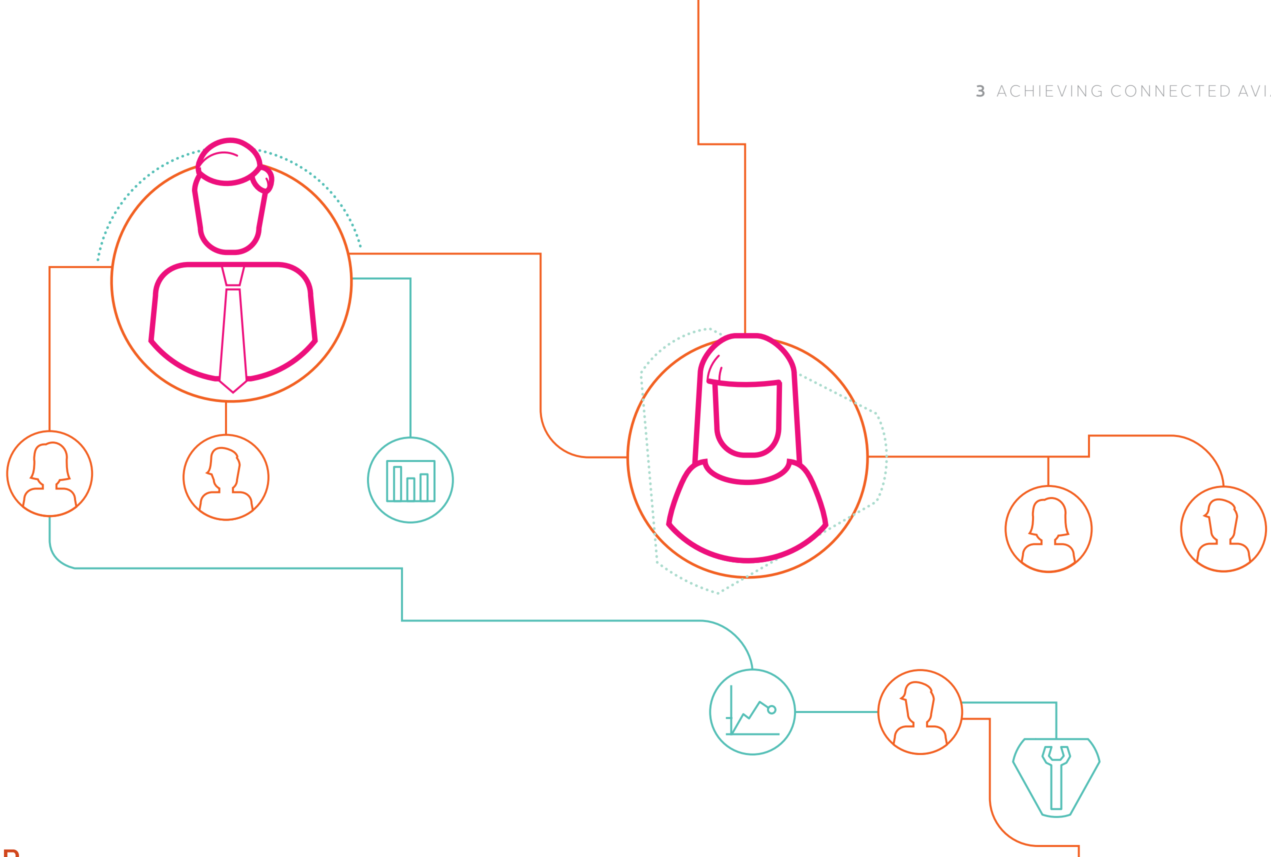
STANDARDS EMPOWERING PASSENGER BOOKING SYSTEMS

The need for coordination is not unprecedented in aviation, as passenger booking systems demonstrate. A generation ago, the industry witnessed innovation in the automation of reservation systems – the platform that remains at the core of passenger bookings today. Each major operator set out to build its own solution. Over time, the benefits of maintaining bespoke systems lost ground to the costs associated with ongoing development. Eventually, the competing systems coalesced to what is a common Passenger Name Record (PNR) format with specific data and structures that can be shared across systems. However, visibility of PNRs across networks was not considered during the initial design. The computerized systems were significantly better than the paper records used prior, but without common PNR standards they were far less powerful. Only when those standards were adopted, was the true value and flexibility of the system realized.

Transforming organizations and workflow

The industry agrees that implementation will not be easy. In addition to the challenges discussed, operators will need to reexamine their organizations when adopting the complex structure of Connected Aviation. Operators will have to implement a new organizational structure and internal process before leveraging technology and realizing its value. As Rockwell Collins' Mike DiGeorge observes, "You can have all the technology, but in order to drive the benefit of Connected Aviation, it really is going to come down to changing the way you do business."

Corporate culture will need to evolve. Operators will need the right leadership, structure, and people, while also employing the right approach to connectivity, legacy systems, external collaboration, and internal adoption. Poor management of these elements poses significant risk for operators, and most operators have not yet assessed their own organizations to ensure the right culture is in place.



THE RIGHT LEADERSHIP

One of the biggest challenges is determining who owns Connected Aviation efforts within operator organizations. Connected Aviation will touch all functional departments. The leader of any Connected Aviation initiative, according to DiGeorge, should be "someone within the organization who is really going to sponsor it and take ownership, because it cuts across so many disciplines within the airline – flight operations, engineering, maintenance, etc. You need somebody to drive it."

It is necessary that the effort be consolidated, rather than splitting it across the groups, leaving a clear, accountable owner. This leader should not represent a specific department but rather sit atop organizational silos to avoid conflicts of interest and bring departments together. IoT requires an executive sponsor to champion the initiative. DoIT's Brenna Berman credits Mayor Rahm Emanuel for making IoT a priority for the City of Chicago. "Mayor Emanuel had a really strong transparency and service delivery improvement agenda as part of his campaign. He brought data awareness to his executive teams and his administration." GE offers another example of executive sponsorship, with CEO Jeff Immelt championing its vision for the industrial IoT. He famously embraced the impact of IoT by declaring, "If you went to bed last night as an industrial company, you're going to wake up today as a software and analytics company."[19]

Operators may need to look beyond their organization for an external executive sponsor. Bartlett suggests this approach may be necessary because Connected Aviation is so transformative it "literally needs to be driven with a new perspective to really get the maximum benefit," and finding that perspective in current ranks may prove difficult. According to Delta's Shane White, when Delta was looking to keep ideas and technology fresh, they hired a candidate outside the aviation industry. Delta also hired at the vice president level, "so that we have a visionary in the high levels of leadership," adds White.

> "A benefit from being a low-cost and flat organization is having a more agile operation."

Samuel Lacarta Chavarrias
Chief Information Officer
Vueling

THE RIGHT STRUCTURE

While the right leadership is critical, the supporting organizational structure must be aligned. Similar to most corporations, operators traditionally function in siloed environments with departments seldom interacting with each other. Engineering and cabin crews, or customer service and flight operations don't often work together, nor do they collaborate on businesses cases. Functional departments often have their own goals and cost centers, which may conflict, leading to interdepartmental friction. Abdulmajeed observes, "Departments within airlines working in silos can be dangerous, because you may end up with many applications that only satisfy a specific department as they are not really talking to each other." Despite attempts to change, the fact remains that operators typically organize in traditional, isolated business units.

To fully embrace Connected Aviation, operators will need to become flatter organizationally to support a common IoT agenda. Samuel Lacarta Chavarrias from Vueling emphasizes, "A benefit from being a low-cost and flat organization is having a more agile operation." At the heart of IoT is interconnectedness, which must be reflected structurally. Internal collaboration and cross-functional efforts will be necessary for the greater good. Alaska Airlines has already set the foundation for an open, sharing culture. "Alaska is a very collaborative company, so the culture lends itself to support a program like Connected Aviation, where you're going to need separate entities coming together – the company culture absolutely complements taking this forward," says Vikram Baskaran. "Maintenance and engineering are ultimately responsible for installation and getting everything to work in a seamless fashion. They are a key part of the mix and they are fully engaged and collaborating with my IT group, all the way to top leadership."

BOB'S TAKE

While organizational structuring is important, much of the talk is superficial.

In the end, a successful organization is one whose senior leaders are flexible, creative, aggressive, and imaginative. Get the leadership right, and the way in which the organization is structured really doesn't matter.

THE RIGHT PEOPLE

Beyond collaborative leadership and structure, operators need to attract a deliberate mix of people to fill new roles in support of Connected Aviation. The history of isolated workgroups and unwillingness to trust other legacy groups leaves operators ripe for change, with the potential to gain even more than what other industries have seen. Still, obtaining the right talent to drive IoT strategy and systems remains a major inhibitor to IoT adoption.[20] Operators should think creatively as they review talent needs for Connected Aviation. As Virgin Australia's Stu McGraw claims, "I think one of the best moves we made in the last couple of years is employing a hacker. He's one of our best guys."

IT AT THE FOREFRONT

Beyond their traditional role, IT teams will need to collaborate with other departments to integrate new smart, connected products with all aspects of their organizations. Collaborative, multi-disciplined IT teams are integral to the successful implementation of Connected Aviation initiatives. According to PTC's Jim Heppelmann and Harvard's Michael Porter, this need for deep collaboration "may lead to embedded IT teams in R&D or product design teams with IT representation."[21] NetJets is already seeing returns on its efforts in collaborating with IT in design discussions. "Five years ago, I would not have brought IT to an aircraft meeting. Now, IT is with me. Eventually, you're going to see more and more of that convergence," explains Kyle Gill. "The actual development work is probably going to be done by IT, but it's going to be consulted in every direction by maintenance, flight operations, and so on," he asserts. Embraer also recognizes the importance of IT, evident in their goal "to ensure that 50% of the company's tech projects are born within the company's IT department. With this target in mind, the team works with users in order to identify and understand issues, design solutions, and implement them."[22] ▸

Connected Aviation will require more robust IT teams – both in size and skill set. For example, an emerging IT specialization is the enterprise architect (EA), which bridges IT with business groups to ensure system architecture can support business strategy. A recent study in Australia showed that 60% of IT decision makers expect more or different IT skills will be required to handle IoT initiatives, and 70% also believe the current IT workforce is ill-equipped.[23] This skills shortage is a barrier to the adoption of IoT technologies and will need to be addressed across the aviation industry.

To reduce the burden on IT, operators should consider shadow IT, broadly defined as "applications and solutions built within an organization of which the IT department is either unaware or has not officially sanctioned."[24] Shadow IT empowers employees to keep projects moving forward without getting held up by internal IT processes. Examples already in use include Slack, a group messaging tool, Dropbox for file sharing, and Evernote for note-taking. EFB technology offers an aviation example of shadow IT. As the AirInsight EFB Research Project reveals, "It appears that the primary people doing the EFB software updates are not in IT." This task is more often managed by Flight Operations and Pilots.[25] Further, once EFBs are implemented, "IT seems to pay the most attention to cyber security, but Flight Ops play an almost equally important role."[26] While there are security risks, "shadow IT reaps a corporate bounty in lower IT costs, increased flexibility, speedier task completion, and a lot less hassle from IT."[27] With Connected Aviation, IT resources will be in demand; operators should consider shadow IT as a way to "bridge this gap by managing it."[28]

DATA TEAMS

Operators will also need to acquire skills and establish organizations that can leverage big data. "Big data 101 was ingrained in our culture, because you can make better-educated decisions faster with more data," says Michelle Gattuso from Motorola Mobility. This is likely to be the largest area of demand in Connected Aviation, and the most difficult resource to acquire. Some companies have started hiring data scientists, a role hailed as the "sexiest

> "Several years ago, the term data scientist didn't exist. Now, data science is a big deal."

Scott Robinson
President
FarmLink

job of the 21st century" in the *Harvard Business Review*.[29] "Several years ago, the term data scientist didn't exist. Now, data science is a big deal. More industries are seeing the value that data science brings, and there is a shortage of data scientists available to meet that demand," explains Scott Robinson from FarmLink. A data scientist requires not only "strong mathematical, analytical, and problem-solving skills," but also business acumen and creative thinking, coupled with "excellent written and communications skills" to report findings.[30] A data scientist understands not only how to analyze the meaningful patterns within the data, but also how to derive value-added business insights.

In the article "How Smart, Connected Products Are Transforming Companies," Heppelmann and Porter conclude, "To get the most out of the new data resources, many companies are creating dedicated data groups that consolidate data collection, aggregation, and analytics, and are responsible for making data and insights available across functions and business units."[31]

Data groups or data management teams can help operators better manage big data. One such example is British Airways' "Know Me" customer personalization program, which the *The Wall Street Journal* hailed as "one of the most advanced data programs in the industry."[32] Research firm Gartner predicts that 25% of organizations will have a Chief Data Officer (CDO) by 2017, with that figure rising to 50 percent in heavily regulated industries such as banking and insurance.[33]

CHIEF DATA OFFICERS

At the helm of the data organization and part of the executive team, the CDO role has been gaining traction since the early 2000s – a testament to the growing importance and value of big data. While the role varies by company and is still evolving, the CDO sits alongside the CIO. According to Gartner, "The CDO is a senior executive who bears responsibility for the firm's enterprise-wide data and information strategy, governance, control, policy development, and effective exploitation."[34] Industry leaders such as Ford, Charles Schwab, Capital One, Crossmark, and Ameritrade have hired CDOs.

Courtesy of Intelsat

THE RIGHT APPROACH

To reach optimal value in Connected Aviation, it is fundamental to apply a multifaceted approach that aligns connectivity with operator needs, integrates legacy systems, collaborates externally, and drives internal stakeholder adoption.

ALIGNING CONNECTIVITY WITH OPERATOR NEEDS

With such an emphasis on connectivity, implementing an approach that can leverage IoT is critical. Historically, connectivity service providers have not developed with a complete ecosystem in mind, but rather focused on passenger internet services. Three factors define the specific needs of Connected Aviation: coverage, capacity, and capability. These "3 Cs" account for the majority of requirements in defining a connectivity program, accounting for both passenger and operational use of the network. Not every aircraft in a fleet requires the same support, which is why there are instances of operators choosing multiple providers to meet a variety of needs.

Coverage

Coverage is almost universally accepted as the primary requirement for a Connected Aviation program. Operators need to determine not only if their needs are local, regional, or global, but also where the majority of coverage is required. Coverage needs will dictate whether an operator can leverage an ATG network or requires satellite connectivity. An operator with global needs, but flying primarily in Europe, will likely require different services than an operator in South America that flies only on that continent, with routes crossing the equator. Lise Fournel from Air Canada, highlights the coverage challenge. "If the aircraft is going really north (above 65 degrees), there may not be connectivity there, depending on the part of the world, like Canada for example. If you go too far from the border, there's not much connectivity." However, advances are being made to provide better coverage. For example, Intelsat's next-generation platform – Intelsat EpicNG – and their partnership with OneWeb will be interopoerable with Intelsat's fleet of approximately 50 satellites, extending Intelsat's global coverage to include polar regions. Michael Small from Gogo adds, "Gogo 2Ku leverages next-generation spot-beam satellites to provide unprecedented coverage with enhanced equatorial coverage, while delivering unparalleled performance." Coverage is a constantly shifting requirement for operators, but it will be critical to supporting Connected Aviation over time.

An additional component of coverage is phase of flight. Operators today are faced with several opportunities to connect aircraft to various networks while on the ground, and a growing list of options when the aircraft is in flight. Determining coverage requirements across fleets can be extremely complex and may require multiple providers to deliver the optimal solution for any given operator. Such complexity has led operators to move toward Aircraft Interface Device (AID) programs that can support multimodal network routing and store-and-forward capabilities.

Capacity

A key element in every operator's mind is capacity, often described as the "speed" of the network. Although speed can be a misnomer, networks are regularly evaluated on how fast they send and receive data. Particularly for passenger connectivity, competing providers are promoting ever-increasing capacity as both a source of passenger satisfaction and lower costs. Operators have leveraged extremely limited capacity for decades to support their operations. As all IP connections are exponentially larger than legacy options, the importance of capacity is often lessened in their evaluations.

For Connected Aviation however, capacity is important not only in off-aircraft connections, but also in evaluating the requirements of on-aircraft components and elements of the ground network used for various applications. On the aircraft, there is a need to configure the local, wireless, and physical networks for the hundreds of new devices and sensors required to meet the growing needs of different user groups. Off-aircraft bandwidth can be a potential bottleneck in Connected Aviation if demand for data to or from the aircraft exceeds supply. This is a primary focus of the supply chain, and operators are expected to have reasonable capacity to meet the requirements of new installations for years to come. Finally, the capacity of the network on the ground can often be a hidden constrictor of data services, depending on how the network provider is connected to the end users, internet servers, and other data sources.

Gill explains the importance of capacity for NetJets. "We fly to a lot of different places, but there's generally coverage in the places that we fly. I'm more worried about speed, because our customers are looking for an at-home type experience. They forget that they're in an airplane going 400 miles per hour at 41,000 feet."

Capability

Perhaps the most overlooked aspect of Connected Aviation is capability. Networks are only as good as their performance, and identifying the operator's need for reliability will dictate several aspects of its Connected Aviation strategy. Service Level Agreements (SLA) that address reliability, response, and repair will become significantly more important for IP network installations as operators shift IoT traffic to the system. Service providers will likely differentiate on their ability to provide customers with performance that exceeds their needs, along with sufficient coverage and capacity.

Capability can be a considerable cost driver for the operator and therefore tends to receive focus when developing Connected Aviation requirements. Operational teams have become very good at identifying their preferred level of support. One important element, for example, is how an operator will use the network for various applications. Will there be a need to prioritize some applications? How will operators separate passenger and operational data? As Bruno Fromont of Intelsat suggests, "Managing the quality of service, the security, and the SLA for different types of business is extremely important."

"Our customers are looking for an at-home type experience. They forget that they're in an airplane going 400 miles per hour at 41,000 feet."

Kyle Gill
Director, Aircraft Configuration
NetJets

EVOLVING AVIONICS COMMUNICATION PROTOCOLS

Today, most aircraft data is commonly formatted in accordance with aviation industry standards ARINC 429 and 717 protocols. These data formats were originally implemented in the late 1970s, with airframe manufacturers implementing them by the early 1980s. Although dated in comparison with today's data standards, ARINC 429 and 717 provide highly reliable data transfer on thousands of aircraft and represent the mainstay in on-board communication protocols.

As expected with legacy data protocols, capacity and speed are fundamental limitations, but other complications exist including limited quantity of data parameters and regulatory barriers associated with connecting modern airborne IT networks with aircraft avionics. The latter has largely been solved by hardware partitions, such as those functions described as "Interface Protection Devices," although adoption is limited to date.

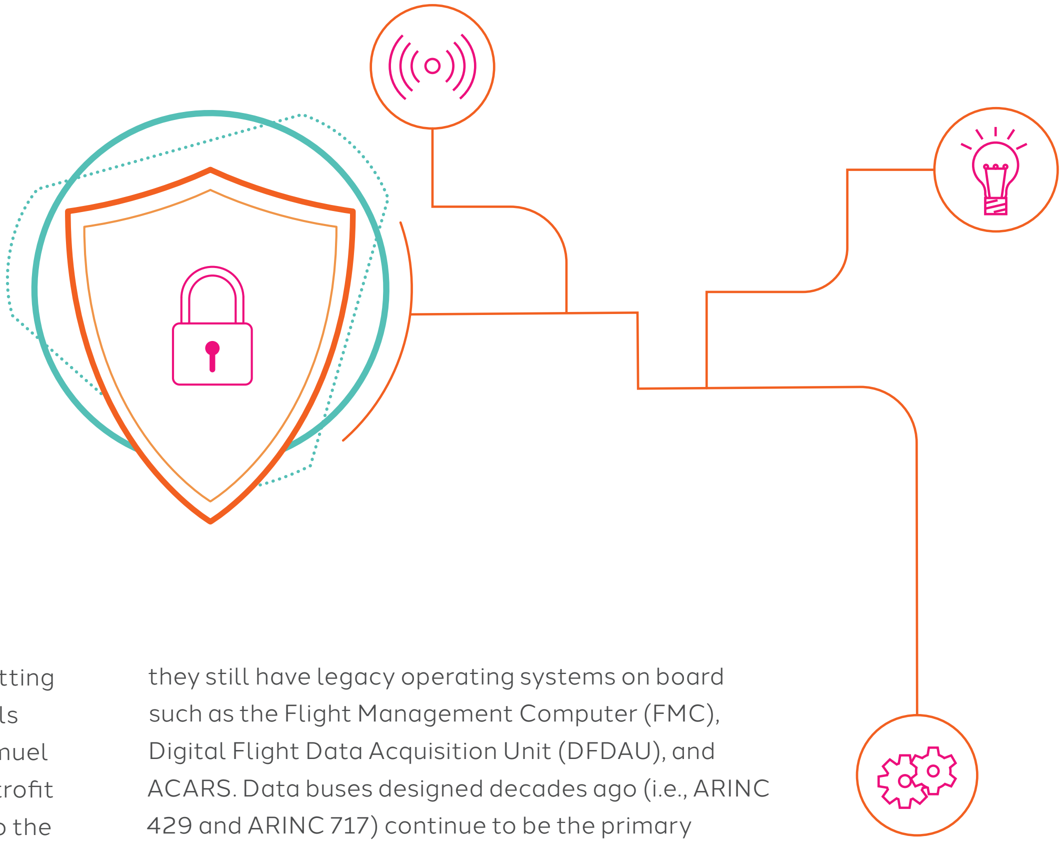
New commercial aircraft, such as the Airbus 350 and Boeing 787, implement a new aircraft data protocol, described as deterministic ethernet, or Avionics Full-Duplex Switched Ethernet (AFDX) on Airbus aircraft. Deterministic ethernet is related to ethernet commonly found in consumer electronics, but it addresses fundamental limitations associated with ARINC 429 and 717. Compared to traditional ARINC 429 and 717 implementations, deterministic ethernet implementations are also lighter in weight.

Aircraft equipped with deterministic ethernet are truly data rich and fit into Connected Aircraft and Connected Aviation ecosystems, as they satisfy the large quantities and frequencies of data required by modern data mining systems to provide meaningful insights.

Although capability is currently the least-developed area in supply chain support, it is also the area that will have the biggest impact on the performance for end users. Maturation of the connectivity industry shows a parallel to other industries, in that providers are trending toward the focused support of their customers' operational performance requirements as a key aspect of service.

LEGACY LIMITATIONS

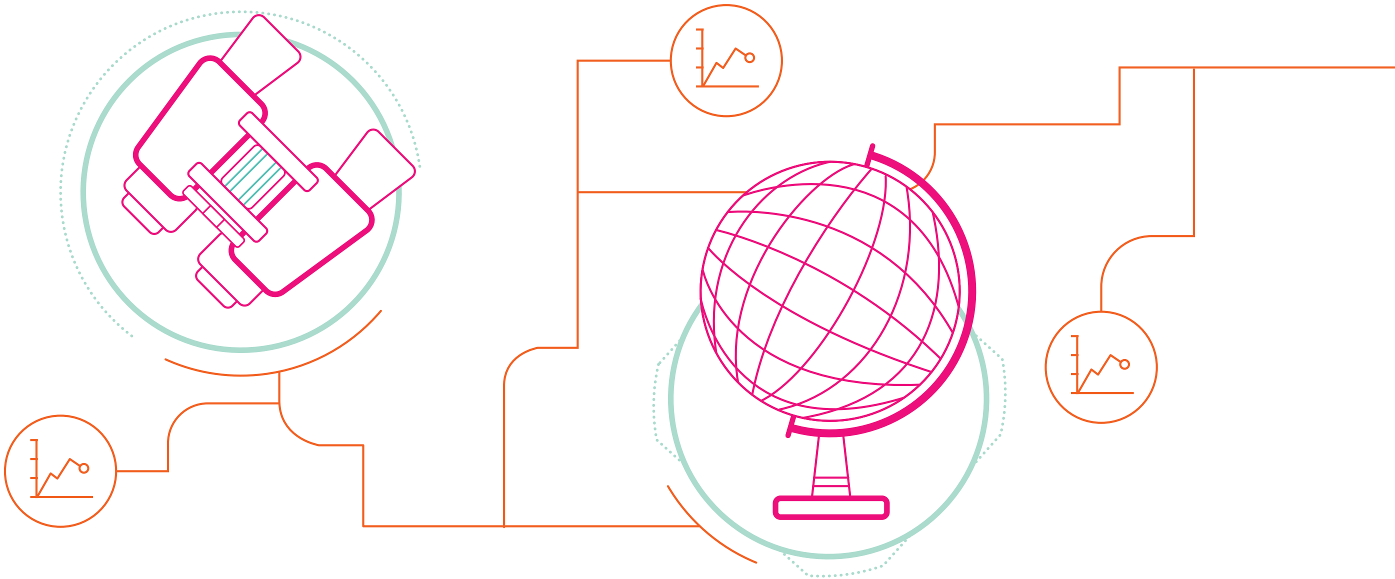
The complexity of integrating IoT initiatives with existing systems and software is a primary concern for 38% of the respondents in a recent study by Machina Research and Xively by LogMeIn.[35] To achieve the interoperability required for Connected Aviation, operators must manage two distinct limitations: older aircraft models and legacy operating systems. Integrating IoT solutions with legacy systems may require short-term implementation costs, but these are necessary to migrate to full optimization, where the maximum benefits of Connected Aviation will be realized.



Aircraft life span is long, which makes retrofitting a unique challenge. Various ownership models further complicate matters. As Vueling's Samuel Lacarta Chavarrias highlights, "When you retrofit an aircraft that you don't own and return it to the lessor after a couple years, it's very difficult to justify a return on investment." Some operators choose to implement only portable solutions on older aircraft. EFB solutions, for example, are showing up even on older aircraft because they can be implemented with COTS devices. Integrating these mobile EFBs with older aircraft still requires additional hardware (typically an onboard server or AID) to connect to the communications infrastructure on board, such as IP broadband or ACARS systems. This may bring operators into the Connected Aircraft realm, but stops short of Connected Aviation, where sensor data is shared on and off the aircraft in real time.

For newer aircraft designed with expectations of sharing data, such as the Boeing 787 or Airbus 350, there are relatively fewer integration challenges, but they still have legacy operating systems on board such as the Flight Management Computer (FMC), Digital Flight Data Acquisition Unit (DFDAU), and ACARS. Data buses designed decades ago (i.e., ARINC 429 and ARINC 717) continue to be the primary networks for sensor data in many aircraft operating today. Many onboard communications protocols are proprietary closed systems, while IoT is based on communicating via IP traffic. Installing additional hardware on aircraft to convert information from legacy formats to modern options requires revisiting the cost and regulatory aspects of integration. "Legacy systems really require a different type of management," stresses GE's Dave Bartlett.

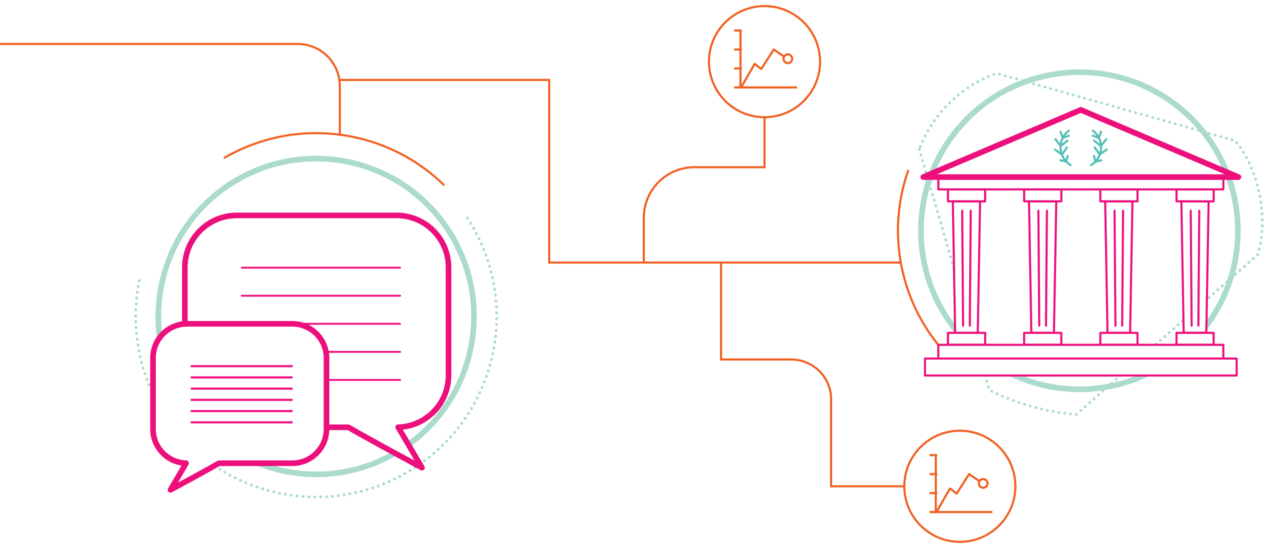
The greatest value is achieved with IoT solutions across an operator's fleet, not just on a few aircraft. Mark McCausland of Ultramain, shares an example. "Replacing a paper logbook with an electronic logbook across all fleet types in your airline changes everything." It increases operational efficiencies with greater cost savings, and reduces the carbon footprint.



EXTERNAL COLLABORATION

Not only do functional departments within operators tend to operate in silos, operators themselves tend to do things in isolation. This may be for competitive reasons, but operators also have different priorities, budget constraints, and limited resources. As with data sharing, it will be vital for operators to collaborate with each other and other industry stakeholders. A commercial example of such collaboration is the purchase of Nokia's Here by three competing German auto manufacturers: AUDI AG, BMW Group, and Daimler AG. On their own, they would be "at risk of losing control of information systems inside the car that are vital to self-driving cars and future automotive safety systems."[36] Here's Omar Rahman observes, "There was an industry need in automotive for an alternative to Apple or Google. That is why automotive OEMs are now turning to Here for a mapping content solution, as well as a platform providing a two-way connection with connected cars, both in terms of delivering data as well as getting data from the car."

For aviation, GE's Dave Bartlett states, "We have to realize as an industry, that there is more value to be gained and less risk in working together than there is working within closed doors." There are early examples of aviation industry collaboration with operator alliances such as Star Alliance, oneworld, and Sky Team. Niall O'Sullivan from Arconics cites a more recent example. "The EFB Users Forum is about users coming together and swapping stories, good and bad. We all share, we all learn. And that's good, honest, open collaboration." To achieve Connected Aviation, the industry will need to collaborate beyond traditional alliances with groups like the EFB Forum. GOL's Paulo Miranda predicts, "As more airlines become connected, the focus will shift to become more collaborative, and airlines will work within alliances or with partner airlines to realize potential synergies."



Aviation standards and cyber security will also require industry collaboration. "You cannot control cyber security within the boundary of your organization. Cyber security needs to be addressed through global partnerships" asserts Pascal Buchner from IATA. Fromont adds, "Being aware of the other technologies and having an ongoing conversation about the security, the changes, and the upgrades will need to happen throughout the supply chain." A-ISAC is a way operators can stay on top of cyber issues by extending security cooperation across organizational lines; this will be critical to realizing the level of security the aviation industry demands.

Operators may also need to collaborate with startups, which Barry Einsig from Cisco describes as key players in the IoT industry. While startups can afford to experiment and shift gears quickly, they may not be equipped to support the scale of Connected Aviation. Einsig recommends a hybrid solution of startups "working with big industrial players that have the ability to scale." The ability to scale production and leverage partner relationships will be essential as companies move to the Connected Aircraft ecosystem.

Learning from other industries will help aviation reduce the adoption curve. Ben Salama at Accenture Digital-Mobility explains, "Connected Cars are probably the most advanced in terms of IoT adoption, and the most relevant to aviation due to long product development cycles, heavy regulation with geographic disparities, and high value assets." Buchner also envisions aviation working with other industries. "Collaboration will have to happen between smart cities, smart government, and smart business. Aviation will lead in some areas and follow in others. We have to participate in all forms of collaboration." The rise of cross-industry IoT alliances such as Thread Group, AllSeen Alliance, and Open Interconnect support this idea.

> "The real challenge with cyber security is not only how quickly you can identify vulnerability, but how quickly you respond."

Navin Ganeshan
Chief Product Officer
Zubie

DRIVING INTERNAL STAKEHOLDER ADOPTION

Connected Aviation will transform operators, but the aviation industry has a reputation for being slow to embrace change. "Technology tends to outpace how aviation paces itself from a market perspective – how they roll out new items, new technology. Aviation is very safe. They have a deep safety culture, which leads them to move slowly. That's a good thing," acknowledges A-ISAC's Faye Francy. To achieve Connected Aviation, the industry will need to embrace change and keep pace with technology, all while maintaining safety. Popular models such as Lewin's Change Management Model or Kotter's 8 Step Change Mode, will help drive internal adoption and offer best practices that operators can implement to increase the likelihood of success.

Planning

A sound plan for adopting Connected Aviation initiatives must clearly illustrate the benefits and the steps for implementation, as stakeholders need to understand the why, the why now, and the how. Salama says, "A strategy must be put into place no matter the size or length of an IoT project."

Planning is more than presenting the initial implementation concept to get stakeholder buy-in. "Data ownership, business model, use cases, as well as regulatory, security, and ongoing management issues, must be addressed right at the start," comments Zubie's Navin Ganeshan. This should also include an IT disaster-recovery plan, he notes. "The real challenge with cyber security is not only how quickly you can identify vulnerability, but how quickly you respond and recover." A proactive plan will drive swift response to a breach, which can reduce damage and even save lives. Accounting for such scenarios is likely to give internal stakeholders confidence.

Internal Communication

Communication and documentation provide transparency while reducing uncertainty and managing expectations. This goes beyond sharing the vision and plan for a Connected Aviation initiative; it requires continually sharing information. It should be approached as an ongoing dialogue – sharing progress against plans, while also addressing questions and concerns. "By planning, recording, and reporting activity clearly, it will be easier to see how successful an IoT implementation might be, and how it can add value to your business in the long term," says Salama. Communication can also prepare stakeholders for what's coming. Stu McGraw from Virgin Australia adds, "As an industry, we need to make sure that we lay the platform and manage the expectations. It's so easy to mess these things up and make a negative impression, but if we do it correctly and get positive buy-in, we can demonstrate some really tangible efficiency." Clear and consistent communication throughout a Connected Aviation initiative will manage stakeholder expectations and help drive adoption.

Proving Value

Connected Aviation initiatives should not be tackled all at once, but approached on a manageable project-by-project basis. Organizational transformation "will be evolutionary, not revolutionary, and old and new structures will often need to operate in parallel," observes Heppelmann and Porter.[37] It will take time to get the building blocks for Connected Aviation in place. Adopting short-term goals within the framework of a long-term plan makes short-term wins tangible, as emphasized in the Lewin and Kotter models.

When the City of Chicago began its IoT initiative, it had a list of more than 30 projects. Berman was able to showcase early wins by strategically selecting projects. "We have very strong selection criteria with levers that we can turn on and off so that we know very clearly where the risk is and how to manage for it,"

THE EVOLVING FARMING INDUSTRY

FarmLink is an AgTech startup helping drive the agriculture revolution by employing data science to make modern agriculture more successful. As FarmLink's Scott Robinson explains, "We are transforming agriculture from anecdotal gut instinct around land to something much more scientific."

Yet when trying to transform conventional farming practices, the company faced an adoption barrier in a historically fragmented industry. As Robinson observes, "People do not change unless something forces them to. The trick is taking a technology that will revolutionize farming, and helping people understand how it actually works to get them on board." FarmLink overcame this challenge with data to prove value. "We do a lot of complex mathematics and statistical analysis to give people actionable answers."

BOB'S TAKE

You've got to do the numbers.

As these pages explain, doing the numbers on Connected Aviation projects is likely to be exceedingly complex, as there are many inputs and alternatives to be considered. Nonetheless, careful screening will separate projects whose benefits exceed costs from those that look more attractive than they are.

Complexity is one of the attractions of the industry, and dealing with the new challenges of Connected Aviation will add another dimension of interest to the management challenge.

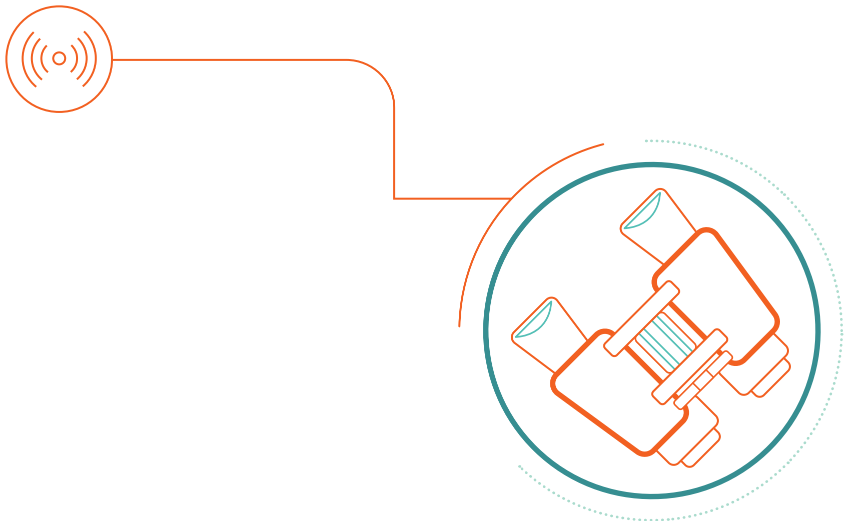
she explains. Salama agrees, adding, "By running proof of concept experiments, enterprises can see how the IoT can bring value to their company, and can start to build business cases."

COST CONSIDERATIONS

Because Connected Aviation requires significant time and resource investment, the challenge for each operator will be how to manage costs as it moves forward. As with virtually all technology evolution cycles, Connected Aviation will follow a similar cost pattern. Costs – particularly related to connectivity – are sensitive to volume, and greater adoption leads to lower prices. While the costs of aircraft connectivity are decreasing, they remain significant. Communication between aircraft and ground systems is not free, even when aircraft are on the ground. Moving data across satellite links is even more expensive. Evolving network and data security also comes at a cost. Operators should begin by implementing programs that leverage maximum value with limited connectivity and then adopt new services as costs decrease.

There are also costs associated with the administration and management of big data. Whoever bears these expenses will likely want to see remuneration, particularly when others are granted access for collaborative efforts. There will not only be upgrade costs to legacy systems, but a loss of revenue when the aircraft is out of service during the upgrade. Security, organizational structure, and external collaboration are major investments, as well. "Cost is a big factor in making some of these decisions, so operators prioritize their investments. For some operators it may be a bigger priority than others," notes Vikram Baskaran from Alaska Airlines.

Early technology adopters are often less sensitive to higher costs, or are more willing to accept such costs as part of a non-standard business case, but the vast majority of the market will wait until their business cases can be met before pushing ahead. The impact of the costs associated with Connected Aviation will drive deeper sharing between organizations over time. Lise Fournel from Air Canada adds, "Implementation costs will be a challenge. We've got to be careful as



to what exactly we take on, because I don't think we're at the right price level right now. Stakeholders see the potential, but they're not willing to invest just yet."

Each operator must consider the cost/benefit ratio of connectivity for each of its subfleets. Operating disparate fleets is an expensive proposition, but depending on fleet refresh plans, the cost to connect a single aircraft and the potential value of having all aircraft connected may make the investment worthwhile. "The model has to be profitable in terms of revenue, brand awareness, or customer satisfaction. You have to do your return investment calculation, and it's obviously different for short haul and long haul carriers," says Vueling's Samuel Lacarta Chavarrias. McGraw adds, "ROI in a silo is very difficult to make a good business case. I think the business case becomes logical and valid once you look at four or five different areas of the business." For Baskaran, this investment in technology is a strategic move, one which requires "striking the balance between finding the right value and investing in the right things while keeping costs low."

HURDLES DOWN THE STRETCH

There may be an abundance of industry and organizational obstacles to achieving Connected Aviation, but identifying them is the first step toward conquering them.

Evolving into an organization primed to manage data is iterative. Operational integration is attainable, but it begins with building the core infrastructure, managing the various work groups, and fostering an environment of cooperation – internally, within the aviation industry, and beyond. These initial efforts can be seen today in operators large and small. As Carlos Domingo from du concludes, "All new technologies have risks, and some people will not embrace them because of the fear of new things, but these short-term challenges will eventually be overcome."

Endnotes

1. Gartner, "Mass Adoption of the Internet of Things Will Create New Opportunities and Challenges for Enterprises," by Jim Tully, February 27, 2015.

2. *Fast Company*, "Behind GE's Vision for the Industrial Internet of Things," by Jon Gertner, July/August 2014. http://www.fastcompany.com/3031272/can-jeff-immelt-really-make-the-world-1-better

3. Machina/LogMeIn, "Lessons Learned from Early Adopters of the IoT: A Global Study of Connected Businesses," November 2015.

4. Gartner, "Mass Adoption of the Internet of Things Will Create New Opportunities and Challenges for Enterprises," by Jim Tully, February 27, 2015.

5. PWC, "US Cybersecurity: Progress Stalled, Key findings from the 2015 State of Cybercrime Survey," July 2015. http://www.pwc.com/us/en/increasing-it-effectiveness/publications/assets/2015-us-cybercrime-survey.pdf

6. *The Dallas Morning News*, "Cyberthieves Steal Miles from American, United Customers," by David Koenig, January 12, 2015. http://www.dallasnews.com/business/airline-industry/20150112-american-united-airlines-targets-of-attempt-to-steal-customers-miles.ece

7. AirInsight, 2015 EFB Research Project.

8. Department of Transportation, Federal Register, Volume 73, Number 1, January 2, 2008. https://www.gpo.gov/fdsys/pkg/FR-2008-01-02/html/E7-25467.htm

9. Aviation ISAC
http://www.a-isac.com/

10. General Administration of Civil Aviation
http://www.gov.cn/english/2005-10/22/content_81677.htm

11. Federal Aviation Administration
http://www.faa.gov/

12. International Civil Aviation Organization
http://www.icao.int/about-icao

13. International Air Transport Association
http://www.iata.org/about

14. European Aviation Safety Agency
https://easa.europa.eu/the-agency

15. European Aviation Safety Agency
https://easa.europa.eu/the-agency

16. Transport Canada
https://www.tc.gc.ca/eng/aboutus-whatwedo.htm

17. AirInsight, 2015 EFB Research Project.

18. Sunlight Foundation, Open Data Policy Guidelines, Version 3, March 2014
http://sunlightfoundation.com/opendataguidelines/

19. CIO, "GE Says Industrial Internet is Here," by Thor Olavsrud, October 9, 2014. http://www.cio.com/article/2824542/internet/ge-says-industrial-internet-is-here.html

20. Gartner, "Mass Adoption of the Internet of Things Will Create New Opportunities and Challenges for Enterprises," by Jim Tully, February 27, 2015.

21. *Harvard Business Review*, "How Smart, Connected Products are Transforming Companies," by Michael Porter and James E. Heppelmann, October 2015.

22. CIO (Spanish edition), "Embraer Wants IT Immersed in the organization," November 10, 2015. "CIO da Embraer quer IT "imerso" na organização" http://www.cio.pt/2015/11/10/cio-da-embraer-quer-it-imerso-na-organizacao/

23. Solarwinds, "IoT Report 2015: Business at the Speed of IT," July 14, 2015. http://www.solarwinds.com/assets/surveys/iot-report-2015-business-at-the-speed-of-it

24. *TechCrunch*, "It's Time to Embrace, Not Fear, Shadow IT," by James Quigley, September 25, 2015. http://techcrunch.com/2015/09/25/its-time-to-embrace-not-fear-shadow-it/

25. AirInsight 2015 EFB Research Project.

26. AirInsight 2015 EFB Research Project.

27. *Forbes*, "Why CIOs Should be Happy About Shadow IT," by Russ Banham, May 4, 2015. http://www.forbes.com/sites/centurylink/2015/05/04/why-cios-should-be-happy-about-shadow-it/

28. *Forbes*, "Why CIOs Should be Happy About Shadow IT," by Russ Banham, May 4, 2015. http://www.forbes.com/sites/centurylink/2015/05/04/why-cios-should-be-happy-about-shadow-it/

29. *Harvard Business Review*, "Data Scientist: The Sexiest Job of the 21st Century," by Thomas H. Davenport and D.J. Patil, October 2012. https://hbr.org/2012/10/data-scientist-the-sexiest-job-of-the-21st-century/

30. Massachusetts Institute of Technology, Data Scientist Position Description, February 9, 2015. https://ist.mit.edu/sites/default/files/about/org/roles/Data_Scientist_Position_Description_v4.pdf

31. *Harvard Business Review*, "How Smart, Connected Products are Transforming Companies," by Michael Porter and James E. Heppelmann, October 2015.

32. British Airways, Customer Analytics http://www.britishairways.com/careers/analysthub/customer_analytics.shtml

33. Gartner Press Release, "Gartner Says CIOs and CDOs Must 'Digitally Remaster' Their Organizations," February 2, 2015. http://www.gartner.com/newsroom/id/2975018

34. Gartner, Smarter With Gartner, "Understanding the Chief Data Officer Role," by Tom McCall, February 18, 2015. http://www.gartner.com/smarterwithgartner/understanding-the-chief-data-officer-role/

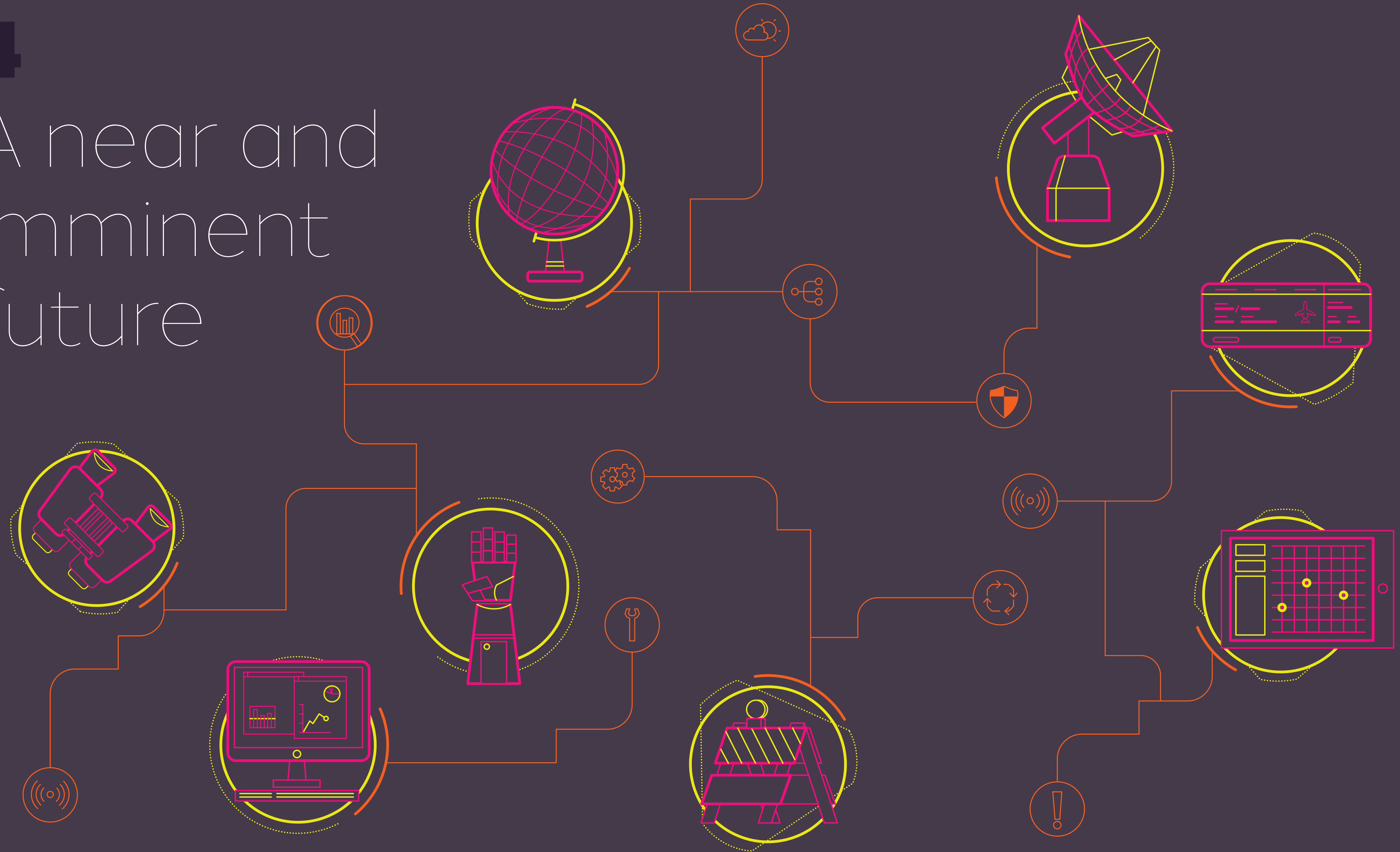
35. Machina/LogMeIn, "Lessons Learned from Early Adopters of the IoT: A Global Study of Connected Businesses," November 2015.

36. *The Wall Street Journal*, "Audi, BMW and Daimler Near Deal to Buy Nokia Mapping Service," by William Boston, July 21, 2015. http://www.wsj.com/articles/german-car-makers-audi-bmw-and-daimler-to-buy-nokia-here-1437493575

37. *Harvard Business Review*, "How Smart, Connected Products are Transforming Companies," by Michael Porter and James E. Heppelmann, October 2015.

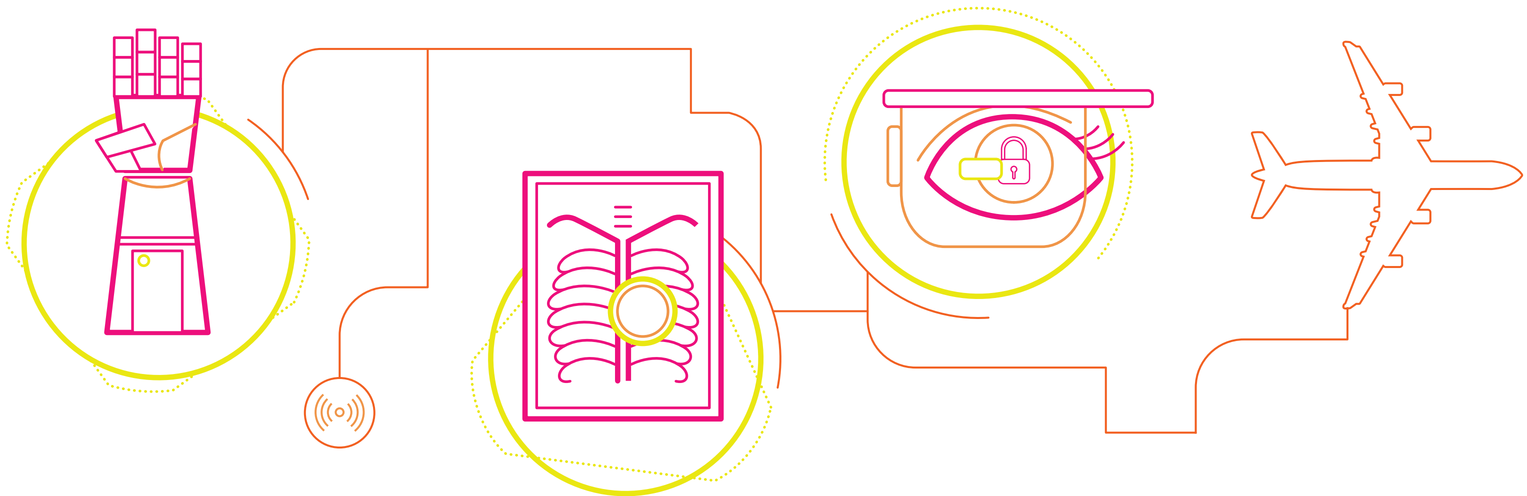
4

A near and imminent future



In Part 1 of this book, we outlined Michael Porter's "waves," which describe the technical evolution leading to the enhanced capabilities and benefits of the IoT. Another useful comparison for examining technology's impact is the Industrial Revolution, which defined economies in the 18th and 19th centuries, and transformed the commercial landscape. There were winners and losers, but most slow-to-change companies were outflanked by new, specialized organizations. The Industrial Revolution affected not just cities and countries – it redefined how the entire world generated products and wealth. The advent of robotics, networking, and advanced computing has been described by many as the second Industrial Revolution. While there are similarities, experts agree that the timetables (i.e. intervals to adapt) were considerably shorter. IoT is now being called the third Industrial Revolution–yet another call for organizations to shift their emphasis and keep pace with new technology. This is the most rapid revolution yet, with companies keen to demonstrate their adaptability in terms of months, not years.

Aviation's relationship with technology has its own process and timetable. Many believe that aviation drove advances in automation during the Second Industrial Revolution by defining new processes and optimizing technology in manufacturing and operation. Aviation can point to the 1960s and 1970s, when leading-edge technology applications put the industry far ahead



of others in terms of adoption. However, as other markets were quick to adapt personal computing (PC) technology and the Internet, aviation remained committed to existing technology on the ground, with safety being the key driver for any new technology implementation.

This approach paid dividends. Globally, commercial and business aviation have emerged as the safest form of transportation. With rare exceptions, aircraft have become one of the safest forms of machine utilization, and passengers are flying in record numbers. But major market depressions in 2002 and 2008 led operators to seek cost savings in every aspect of their business. PC technology and the internet provided easy and effective opportunities to reduce costs compared to existing proprietary systems.

As aviation gravitated toward COTS technology, it wasn't clear that this was just the tip of the iceberg. The sudden emergence of new operators that could make the business case for cost-savings measures through better technology only heightened the sense of urgency. Operators making initial investments in EFB laptops, for example, could not foresee the arrival of the tablet. As flight crews were adapting to laptop technology, tablets were already being introduced into other departments such as inflight, maintenance, and airport operations. When operators finally transitioned to IP, it created a vast demand for IT resources. Meanwhile, innovations and applications had propagated at a rate that outpaced operator capacity for adoption.

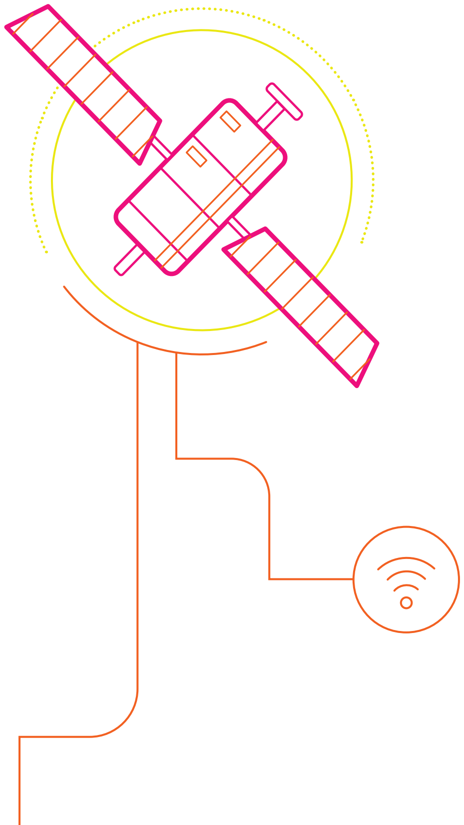
For such reasons, the industry is in the infancy of Connected Aviation. Indeed, most operators are in the phase of "eEnablement" or "Connected Aircraft," but Connected Aviation is inevitable, and we will witness its arrival over the next five years.

“You’re going to see antennas and communication devices that are much smaller, much more flexible, and easier to install.”

Bruno Fromont
Senior VP, Strategy and Asset Management
Intelsat

CONNECTIVITY WILL BECOME UBIQUITOUS

IP connectivity remains the lynchpin for Connected Aviation and demands significant investment from the industry. Research shows an increasingly rapid rate of installations on new and older aircraft, and this groundswell is driving creative concepts for how operators can exploit value. As aviation continues to embrace COTS technology and close the gap with other industries in terms of technology adoption, connectivity will become a requirement for virtually every initiative. Connectivity goals typically involve adding capacity and coverage while reducing costs. Since most of aviation’s IP connectivity services are satellite-based (which translates to long lead-times for adding capacity), predicting future capacity, coverage, and costs is fairly straightforward. In fact, many predict that the growth in allocated bandwidth for aviation is already “reserved,” and the industry will face constraints as it transitions to Connected Aviation. Meanwhile, the challenge of providing sufficient bandwidth to passengers remains, particularly while dedicating a portion of



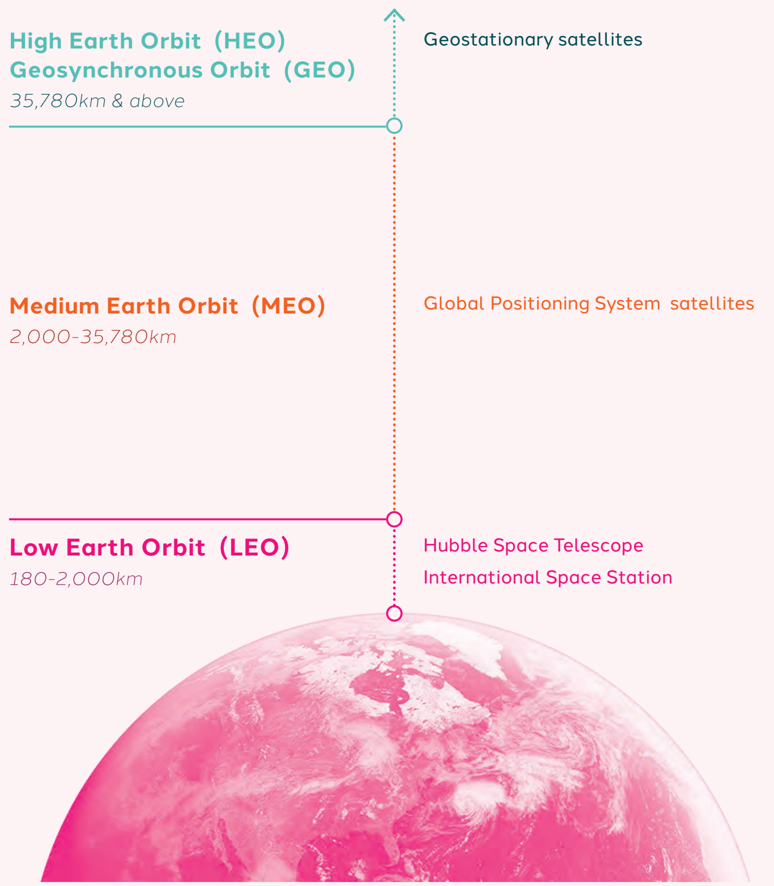
that bandwidth to operational needs. For certain, aviation's thirst for connectivity will grow, even as passengers and operations consume an ever-increasing amount of data.

Satellite operators are working to launch more and better systems into orbit, but on-aircraft hardware is where some of the most significant development is yet to come. Creating systems that are smaller, lighter, and more capable is essential. This will likely mean switching seamlessly between multiple communications technologies in a package that can be installed with minimal aircraft downtime. "Then the single most important problem to solve for the satellite industry is making the terminal seamless. You're going to see antennas and communication devices that are much smaller, much more flexible, and easier to install. In other words, completely steered electronically," anticipates Bruno Fromont from Intelsat.

Next-generation antenna systems are already in use today, but future iterations will be even more efficient and powerful. Some operators have already benefitted from connecting hundreds of aircraft, but eventually the industry overall will reap benefits. For later adopters, there may be delays in outfitting their fleets and in realizing cost savings. Some operators may see an opportunity in deferring, with plans to leapfrog straight to future-generation technologies when they become available.

INNOVATION IN ORBIT

A flurry of recent advancements and proposals highlights the growing demand for global connectivity. High-throughput satellites (HTS) will bring significant capacity gains. Large constellations of LEO satellites could provide more bandwidth. Laser relays from optical satellites could increase throughput by hundredfolds. However it comes about, more bandwidth is certainly on the way.



SOURCES: NASA, "Catalog of Earth Satellite Orbits" by Holli Riebeek, September 4, 2009. http://earthobservatory.nasa.gov/Features/OrbitsCatalog/

TECHNOLOGY WILL EVOLVE

Realizing the goal of Connected Aviation means significant technical and operational changes for the industry. Sensors are inexpensive today, and costs will continue to decrease. They will become even more pervasive, eventually appearing in seats and elsewhere to monitor passenger health and whereabouts on board, rather than monitoring only the aircraft itself. Using technology's evolution over the last five years as a guide, one thing is absolute: five years from now, unanticipated new applications and advancements will have a major impact.

Currently, the industry is just beginning to explore wearable technology, such as smart watches, and how to integrate these devices as tools in a larger ecosystem. While many operators have begun their research, the business case for wearables is not yet universal. Still, many believe wearables will play a significant role in improving aviation operations. For example, easyJet has launched a trial of tech-embedded uniforms, which monitor environmental conditions and repel water to improve safety. Similarly, Japan Airlines has incorporated Google Glass into select maintenance systems to improve accuracy and efficiency. Such considerations will be integral to Connected Aviation.

Technology will impact not only industry operations, but also the way operators engage with passengers. "Digitization is a global term that implies how companies are rethinking their core business – they need to get more intimate with that core business and with customers," states Howard Charney from Cisco. The mobile app, adopted by virtually every major airline and business jet operator, has the opportunity to become a platform where operators can connect with passengers in ways not previously possible. Additionally, operators are beginning to consider location services on the aircraft through beacon technology, which has the potential to drive engagement with passengers.

> "Within a decade, everything on the ground and in the air will be connected, so provided the industry is equipped to analyze and use that data, the IoT will benefit all those adopting it."

John Schmidt
Global Aerospace & Defense Lead
Accenture

THE BIG-DATA GAP WILL CLOSE

Currently there is a gap between Connected Aviation implementations and optimal capabilities that centers on the collection, management, and analytics of big data. There is no doubt that aircraft and operators are major data-generating entities, but most of this data goes unused, or is used minimally to improve operations. "Within a decade, everything on the ground and in the air will be connected and collecting and transferring data. If the industry is equipped to analyze and use that data to help run their businesses, the IoT will benefit all those adopting it," shares John Schmidt from Accenture. Based on the paths of other industries and the early steps taken toward Connected Aviation, it is clear the industry will need to invest in big data.

Because of aviation's traditionally competitive nature, integrating big data industrywide presents one of the greatest challenges. Suppliers are concerned that data shared too early in the market cycle could provide their competitors with valuable information, and adversely impact their market share and positioning. Clearly, leveraging big data will require working together to share data.

Ultimately, experts agree that there will be optimization only when the industry has accepted a reasonable amount of standardization and data sharing. Aviation has been strong with regards to industry standards, but the dawn of Connected Aviation has revealed a desire by operators to leverage data for competitive advantage. This is a short-term opportunity that could equally be exploited to align with early adopters and develop standards, but only if companies are willing to trade a perceived advantage for the prospect of long-term success.

AUTONOMY WILL TAKE TIME

When considering Porter's four phases of smart, connected products, aircraft systems may reach a plateau at the optimization phase. While autonomy is at the pinnacle of Porter's model, strict governance over safety and security within aviation may make this phase unrealistic for the foreseeable future. Pilotless commercial aircraft may be technically feasible, but this seems unlikely due to regulator concerns around cyber security and passenger acceptance. However, applications such as NASA's TASAR program leverage some elements of autonomy to achieve complete optimization through absorbing data, applying analytics, and making recommendations based on the results.

CORPORATE CULTURES WILL CHANGE

Operators are not new to the concept of change. As ThingLogix's Steven Loving explains, "The real challenge for a company is to understand their competitive landscape, as well as their current DNA, and then translate that DNA to a new connected market." Twenty years ago, the internet radically transformed the ticket purchase process, and the rise of the low-cost airline internationally has been closely connected to technology and innovation ever since. Operators that struggled to adapt to the new channel saw reduced market share, increased costs, or were forced out of the market entirely. Changing culture, particularly one that is trained to focus on safety and security, can be extraordinarily difficult. Regardless, aviation has demonstrated adaptability in the past, and it is expected that another shift is imminent.

How companies evolve organizationally will be crucial to success. "Most companies have separated engineering from IT, and they're going to have to find a way to blend them back together," advises PTC's Jim Heppelmann. "The things we are making right now are half physical, engineered products, and half information-technology products. We have that expertise in two different departments, but now it has to come together in a single product." Work on the Boeing 787 and Airbus 350 programs, at the manufacturer level and during the transition into service at the operator level, reflects a transformative shift in structure for successful technology implementation. "Because of the shift in talent that takes place, there will be cultural implications," adds Omar an of Here.

"The real challenge for a company is to understand their competitive landscape, understand their current DNA, and then translate that DNA to a new connected market."

Steven Loving
Client Partner
ThingLogix

Connected Aviation technology is not only a new investment, but a new model for operating technology.

TECHNOLOGY ADOPTION WILL ACCELERATE

With operational technology programs, it is difficult for the aviation industry to match the adoption speed of most commercial IT departments, especially given that some recent operator investments will not realize their optimal business case. Unfortunately, the pace of innovation renders many legacy systems outdated prior to their planned phase-out timeline. Heppelmann calls such a concept “cannibalization,” as the business unit is forced to invest in new technology before optimizing the current version. It is a danger in any industry, but as aviation merges with mainstream innovation, the speed of development will likely outpace operator capability to invest. This delay will eventually lead to leapfrogging to stay current with mainstream industry standards; alternatively, operators face the very expensive proposition of once again deviating from common approaches and maintaining proprietary systems.

Business cases often drive technology investment decisions. ROI is a key phrase when securing funding, and operator finance teams have become adept at tracking the optimal indicators for introducing technology. However, several experts warn that the traditional business case model may be obsolete. Connected Aviation technology is not only a new investment, but a new model for operating technology. Heppelmann adds that many industries are finding that the “new way” does not work well with traditional business models.

Large investments in technology allowed operators such as Ryanair and Southwest to bypass traditional ticketing channels (and the associated costs) and sell directly to passengers. Those operators who quickly adopted the new technology – regardless of their ROI in ticketing agency channels – were able to maintain much of their market share in the face of new competitive threats. Operators slow to adapt incurred much larger costs when finally making the switch; they also suffered diminished market share due to the rise of the low-cost carriers operating on their routes. The adoption of IoT technologies will be similar – in fact, it has already begun. According to Ultramain's Mark McCausland, the push for Connected Aviation is coming from everywhere. "The airlines are pushing for it. Some operators are more involved and on the leading edge than others, but the push is coming from the maintenance side. It is coming from the flight operations side. It is coming from the OEM. It is coming from the special device manufacturers of various components on the airplane. And it is coming from companies like ours, providing software in very specific areas."

Accelerating innovation will make or break some aviation companies over the next five years. Early adopters may see a competitive advantage, while those slower to adjust may become encumbered by their inefficiencies. The impact is expected to be larger than that of previous technology waves, which means adopting Connected Aviation practices is quickly becoming essential for market survival.

BOB'S TAKE

As the world grows more complex, understanding the scope and impact of new developments becomes more and more important.

Each operator needs to pay careful attention to the performance of competitors and the potential of new capabilities. Agility, comprehension, and creativity will be ever more important.

POTENTIAL ROADBLOCKS

If not managed appropriately, the multiple internal and external factors discussed in this book can limit the success of Connected Aviation efforts. Internally, the inability to create the right organizational structure and processes could prove disastrous. For instance, failure to properly define the goals or scope of a project may doom it before the first purchase order is signed. Operators must build the proper mindset within the organization to ensure that each successive step receives the necessary buy-in from affected parties. Operators must also prioritize managing the costs of their Connected Aviation investments.

Externally, a catastrophic event, whether tied to Connected Aviation or not, could derail efforts for years – or even permanently, as was the fate of Connexion by Boeing in the wake of the events of September 11, 2001. Similarly, many operators are seeing sustained profits for the first time in many years, largely due to lower fuel costs; should those costs spike, the funding for Connected Aviation efforts may vanish despite the valuable efficiencies it brings. Finally, regulatory cycles must be endured. The use of COTS hardware and software helps to shorten this timeframe – bringing better systems onto aircraft faster – but requires refreshing technology more frequently.

CLEAR SKIES AHEAD

Barring some unforeseen largescale event, Connected Aviation appears to be inevitable. Manufacturers such as Boeing and Honeywell are making big investments in this area, and operators consistently refer to it as the future. Contributors to this book spoke of the culmination of technology and market penetration within the next five years, when the industry will begin to reap the benefits of Connected Aviation. Five years may sound like a long time, but in aviation terms this is moving at an extremely rapid pace – one that follows the exponential path of Moore's Law and the way consumer technology has impacted the industry. Evolutionary timeframes are getting dramatically shorter with each cycle. Development of IoT in other industries has shown operators and the supply chain endless possibilities for capturing untapped value. By learning from these examples, aviation can likewise succeed.

Efficiencies stand to be gained at nearly every level of operation, which will affect passenger comfort as well. Actionable insights delivered in real-time will yield improvements across the board. The cost reductions achievable with Connected Aviation are too tempting to ignore, and with the current capital available to many operators, internal barriers are surmountable.

Connected Aviation is the future of the industry. Operators will share a resource pool with other industries and big data heavyweights like Google and IBM. Monitoring technology evolution and making difficult investment decisions will be the task of key decision-makers across the industry. What comes next is not a topic for future generations. By 2021, the industry will likely be relishing its Connected Aviation investments and operating on a platform that delivers results. By 2026, the term "Connected Aviation" will no longer be necessary; it will have become the standard for everyone involved in aviation technology. But between now and then, getting Connected Aviation right is imperative to staying relevant for the long haul.

Contributors

accenturedigital

Ben Salama

Global IoT Practice
Connected Operations Lead,
Accenture Digital - Mobility

Ben Salama leads Connected Operations within the Accenture Digital global IoT practice, utilizing nearly 30 years of experience as a business leader in the systems integration, software products, and high-tech and financial services industries. Aiming to bring the value of the Industrial Internet to Accenture's clients worldwide, he strives to enable them to benefit from productivity improvements, as well as create new services and realize new revenue opportunities.

Previously, Ben led Accenture Digital's Go-to-Market team for the United Kingdom and Ireland, as well as leading the mobility sales and consulting team for UKI, with an objective to embed mobility into every aspect of our clients' business as they transitioned to become "connected enterprises."

Prior to joining Accenture in 2011, Ben was an SVP at Teleca, a global system integrator specializing in mobile projects where he led their European business. He has extensive international experience having lived and worked in the US and, more recently, in Asia where he established sales and consulting operations in China, Taiwan, and Korea providing mobile projects to the high-tech industry.

John Schmidt

Global Aerospace & Defense Lead

John Schmidt is the global Aerospace and Defense lead at Accenture. In this capacity, John directs a team of experienced industry professionals who design and deliver transformational solutions for the commercial aerospace, defense, and space exploration sectors. Under his direction, the practice has grown three times the industry average and has worked with nine of the industry's top 10 performers.

Throughout his career, John has worked with many industry leaders, helping them define strategy, drive operational business improvement, accelerate profitable growth, and increase shareholder value. John has worked with the largest OEMs and many Tier 1 suppliers, such as providers of aircraft avionics, engines, controls, and defense communications products. He is known for his ability to lead large teams and work in complex global business environments to deliver programs that result in substantive cost reductions, increased business capabilities, and improved organizational effectiveness.

With deep experience in the aerospace and defense industry, John's knowledge is complemented by his work in other industries, such as consumer electronics, industrial products, and health sciences. John is a member of the Aerospace Industry Association's Board of Governors, and is a frequent industry speaker on industry trends, the digital disruption in aerospace, and the extended supply chain topics.

Lise Fournel

Senior Vice President and CIO

An Air Canada employee for more than 30 years, Lise Fournel joined the airline in 1979, in the Operational Research Department. She became Manager, Customer Relations, Computer and Systems Services Branch in 1983, and over the next 10 years, held several positions as Director and Senior Director in areas such as Strategic and Tactical Planning, and Pricing and Revenue Management. Lise became Vice President, Information Technology and Chief Information Officer, then Senior Vice President Commercial in June 1999. In January 2000, Lise was appointed Executive Vice President, Commercial, and in September 2001 was named to the position of President, Destina, an Air Canada subsidiary, responsible for all e-Commerce initiatives. In 2003, Lise was appointed Senior Vice President, e-Commerce and Chief Information Officer. In 2013, Lise's title was changed to Senior Vice President & Chief Information Officer.

Lise attended l'Université de Montréal, where she earned a Master's Degree in Mathematics (Statistics) and completed graduate studies in Administration at the École des Hautes Études Commerciales in Montréal. Lise is a member of the Technology Committee on the Board of l'Université de Montréal and a member of the Board of the Ontario Teachers' Pension Plan. Lise is a former Board Member, Université de Montréal, Tourisme Montréal, CIREM and Musée Pointe-à-Callière. Lise has been active with the Canadian Muscular Dystrophy Association and the Canadian Cancer Society.

Virkam Baskaran

Managing Director – ITS Airline Operations Systems

Virkam Baskaran is Managing Director of Airline Operations Systems in Alaska Airlines' Information and Technology Services organization. He is responsible for all IT applications used by Alaska and Horizon Airlines operating divisions, including Flight Operations, Inflight, Maintenance & Engineering, Station Operations Center, Airport Operations, Cargo and Safety, and leads multiple large technology programs in Crew Management, Station Operations, and Employee Mobility areas.

Vikram spent 14 years at United Airlines, where he led a range of programs including airport customer self-service, mobile tools for customer service agents, irregular operations, resource management, crew planning, supply chain management, and operational metrics.

He holds a Masters degree in Industrial Engineering from the University of South Florida, and a Bachelors degree in Mechanical Engineering from Anna University.

arconics
CONNECTING EVERYONE ONBOARD

Niall O'Sullivan
Chief Executive Officer

Niall O'Sullivan founded Arconics in 2001, embracing the potential of digital to solve problems in the aviation industry. He has since guided the evolution of the company from its initial expertise in airline content management services to providing complete document management, EFB, wireless IFE, and cabin management solutions in key products AeroDocs, CloudStore, and PaxApp. The company has focused on mobile apps for the airline sector since 2010.

Niall studied at the National College of Art and Design, Dublin, and the University of Limerick to qualify as an industrial designer, learning how design, ergonomics, and engineering should work together to provide economical solutions and tangible benefits. Niall has focused on innovation his entire career. Since founding Arconics, he worked closely with Ryanair, providing solutions to the airline as it grew from 50 to 320 aircraft today. Niall stays closely involved in all Arconics product development and user experience design, communicating his vision of the user-driven connected aircraft across the business.

AVIATION ISAC

Faye Francy
Executive Director

Faye Francy is the Executive Director of the Aviation Information Sharing & Analysis Center where she is working to establish a robust global A-ISAC, a non-profit organization based in Annapolis Junction, Maryland. There are seven founding members, including airlines, manufacturers, and suppliers from across the aviation sector that are collaborating to create a framework for analyzing and sharing information regarding physical and cyber security threats across the global community. Faye is responsible for establishing, implementing, and overseeing the organization's mission, goals, policies, and core guiding principles.

Faye is employed by Boeing Commercial Airplanes (BCA) and on loan to the A-ISAC for one year. Previously, she lead BCA's Cyber ONE engineering team, an enterprise-wide Community of Excellence (CoE) group that collaborates across the company and is focused on leveraging the best of Boeing in the cyber domain.

BOEING

John Craig
Chief Engineer – Cabin and Network Systems/Airplane Systems Information Security Protection

John Craig is currently the Chief Engineer of Cabin & Network Systems and the executive responsible for Airplane Systems Information Security Protection at Boeing Commercial Airplanes. In this role, he is responsible for cabin systems, connectivity, onboard networks, cyber security, and airborne software. In addition, John is the chairman of the board of the Aviation Information Sharing and Analysis Center, which was recently formed to encourage the sharing of cyber threat information within the aviation industry. With 30 years of aviation experience, he has held roles in Electrical Subsystems, Engine Systems, Avionics, Cabin Systems, Onboard Networks, and Connectivity Systems.

He is experienced in large-scale systems development, software developmental programs and, as a previous FAA Designated Engineering Representative, holds knowledge of certification programs.

John holds an Electrical Engineering degree from Montana State University.

Howard Charney

Senior Vice President, Office of the Chairman and CEO

Senior Vice President Howard Charney is a member of Cisco's Worldwide Sales organization and contributes to the company's strategy and direction. A dynamic speaker on technology and global change, he advises businesses, governments, and educators around the world on digitization and how to implement critical technologies to improve organizational effectiveness.

For more than 40 years, Howard has overseen the development and proliferation of key technologies that led directly to the global build-out of the internet. In 1980, he co-founded 3Com, the progenitor of ethernet and local area networking. 3Com's breakthrough technologies brought internet access to the desktop. In 1992, he founded Grand Junction Networks, which invented Fast Ethernet and low-cost switching (and transformed the economics of switching). After Grand Junction was acquired by Cisco in 1995, Howard helped grow Cisco's two-tier distribution business to more than $2.4 billion.

A licensed patent attorney, Howard belongs to the State Bar of California and the Federal Bar Association. He sits on the boards of several technology companies, as well as the Board of Trustees of Santa Clara University (SCU) and the advisory board for SCU's Center for Science, Technology, and Society. In 2014, he was awarded the prestigious Santa Clara Law Alumni Special Achievement Award. Howard holds Bachelor's and Master's degrees in Mechanical Engineering from MIT, and MBA and J.D. degrees from SCU.

Barry Einsig

Global Transportation Executive

Barry Einsig is the Global Transportation Executive for Cisco's Internet of Everything Vertical Solutions Group. Barry is the business lead responsible for driving growth strategy, business planning, thought leadership, and solutions designs and validation for all modes of transportation.

Barry has been in the transportation industry for over 15 years, providing wired and wireless IP communication networks, video, security, and life safety systems for transportation and public safety networks. He is an advisor for Singapore's Ministry of Transport for driverless vehicle systems and a board advisor for Prospect Silicon Valley. Barry has also worked with Network Rail, Deutsche Bahn, DFW, Port of Hamburg, SFMTA, Transport for London, BNSF, WMATA, AMTRAK, DART, and PA Turnpike, as well as many others.

Barry is a member of the American Public Transportation Association, the Association of American Railroads Wireless Communications Committee, and the Intelligent Transportation Society of America. Barry is also active in the Transportation Sector Coordinating Council, APTA Security Standards development, and the Committee on Public Safety. He serves as Chair for the Joint Council on Transit Wireless Communications and is Past Chair for the ITSA Transportation Management Forum, the Business Leadership Council, the Public Safety Council, and the Public Transit Council. Finally, Barry is a board member for The Infrastructure Security Partnership.

Barry studied at Juniata College and has written for many industry publications, including *Passenger Transport*, *Mass Transit*, and *Traffic Technology International*. He has presented at international conferences such as IWCE, APCO, ITSA, APTA, and ITS World Congress on topics including security, wireless communications, IP networks, and transportation systems.

Brenna Berman

Chicago Department of Innovation and Technology (DoIT) Commissioner and CIO

Chicago Department of Innovation and Technology (DoIT) Commissioner and CIO Brenna Berman joined the Emanuel administration as Deputy Budget Director focusing on enterprise initiatives and performance management in 2011. The following year, Brenna transitioned to DoIT as 1st Deputy Commissioner to focus on enterprise IT consolidation and operational excellence.

Over the past year at DoIT, Brenna has focused transforming the team at DoIT to align with the Mayor's commitment to an open and data-driven government, building Chicago's open data program into one of the largest in the country, implemented the ground-breaking "WindyGrid" spatial analytics platform into every level of government, integrating advanced analytics and real-time data-driven decision making across the city, and setting a new standard for government IT.

Brenna built a career promoting government innovation. In over 10 years at IBM, she worked closely with government agencies in cities and countries across the world to leverage technology and analytics to improve the services they provide to their residents. Throughout her time at IBM, Brenna also tailored cutting-edge business and data models, from processes to analytic algorithms for large government organizations in order to accelerate their own modernization efforts, providing an incredibly valuable skill set for the work she continues at DoIT.

Brenna earned her bachelor's degree and Masters in Public Policy from the University of Chicago.

Darrell S. Haskin

Director of Flight Crew Systems

Darrell S. Haskin, the Director of Flight Crew Systems at Delta Air Lines, has over 35 years of experience at three US airlines. Darrell began his airline career in operations at SLC, and continued in MEM and MSP. He spent four years in finance and accounting, 12 years in airport operation, and nearly 20 years in IT.

More recently in 2008, Darrell moved back into IT to lead the pilot and flight attendant systems integration. Here, Darrell is also leading the re-write of the legacy crew systems and the implementation of new onboard technology, including the distribution of nearly 20,000 Windows 8 Nokia Lumia 1520 phones, as well as 11,000 Microsoft Surface V2 tablets for Delta's pilots.

Darrell holds an MBA from the University of Memphis' Fogelman College of Business and Economics.

Shane White

Technical Pilot

Shane White is currently a Technical Pilot at Delta Air Lines, flying both the Boeing 757 and 767 in worldwide operations. He works extensively with Delta's internal divisions and external vendors on technology-driven initiatives impacting flight-deck operations, particularly the current and future integration strategies and challenges for Electronic Flight Bag (EFB) hardware, software, and applications.

Prior to becoming a Technical Pilot, Shane worked for Delta for 10 years as a simulator instructor and Proficiency Check Pilot. He also served as a civilian commuter pilot at both Mesa Airlines and Horizon Air.

Shane holds a Bachelor of Science in Aeronautical Studies from the University of North Dakota.

Carlos Domingo

Senior Executive Officer for New Business and Innovation

Carlos Domingo is Senior Executive Officer for New Business and Innovation at du, where he is in charge of all new products and services initiatives, including all digital products and services, smart cities, du TV, and digital channels (du.ae and du mobile app), as well as business intelligence and big data areas.

Carlos was previously Chief of Product and Business Development for Etihad Etisalat (Mobily), where he managed all company product development, digital services, alliances, and partnerships, as well as business intelligence and analytics. Carlos also spent 8 years as CEO of Telefonica R&D and for New Business and Innovation for Telefonica Digital.

Carlos holds a M.Sc. in Computer Science from the Tokyo Institute of Technology, a Ph.D. in Computer Science from the Polytechnic University in Catalonia, and post grad business studies from Stanford's Graduate School of Business. With more than 20 years of experience in the IT and telecommunications world, he developed his early career in Japan and the US as VP of Celartem Technologies and President & CEO of its subsidiary in Seattle after merging Extensis LizardTech and DiamonSoft.

Scott Robinson

President

As FarmLink's President, Scott Robinson is focused on advancing data science solutions to enable public and private sector innovation for agriculture and natural resources. With deep experience in commodities, technology, and analytics, he helps ensure that FarmLink stays focused on its mission to provide stakeholders with advanced analytics in support of modern practices, innovation, and sustainability. He leads a team of managers, data scientists, and business analysts who can help clients solve challenging problems that are impacting food security, the environment, and profitability.

Scott's career has spanned 30 years in financial services and commodities, focusing on growth strategies, acquisitions, data analytics, and technological innovation. Most recently, he was a Senior Partner at Oliver Wyman, a known leader in benchmarking, and was responsible for their North American Corporate Finance and Advisory practice. Scott was also a member of the management team at the Chicago Mercantile Exchange (CME), where he led strategy and acquisitions during a period of growth from $3.5B to more than $8.5B in market capitalization. Before and after working for the CME, he was a Partner and Senior Advisor at McKinsey & Company, serving in various practice groups, including the Business Technology Office. Early in his career, Scott worked for Reuters, Dow Jones/Telerate, and NeXT Computer. Scott received his Bachelor's degree in Economics from San Diego State University.

Daniel Baker

Chief Executive Officer

Daniel Baker is the founder of FlightAware and has served as Chief Executive Officer since 2005. In this role, he directs all of the business units, leads worldwide business development, and drives corporate growth. Originally one of the principal developers of FlightAware, he now enjoys working directly with partners and customers in both industry (airline, cargo, business aviation, etc.) and government (ANSP ATM) to create mutually beneficial relationships that leverage FlightAware's technology and data to provide innovative and efficient solutions in aviation and travel.

Daniel brings years of experience as a driving architect of rapid growth for small to mid-sized businesses from both technology and business, as well as enterprise sales and partnerships with Fortune 500 companies and foreign governments. He has been in the internet services business for over 20 years, and is a published author on the subject of internet protocols. Daniel has served as a consultant for Fortune 500 companies and is a regular speaker at aviation and technology conferences.

Daniel holds an FAA Commercial Pilot certificate and is a passionate photographer, pilot, and worldwide traveler.

David Bartlett

Chief Technology Officer

Dave Bartlett is the Chief Technology Officer for GE Aviation, located in San Ramon. He provides strategic technology leadership and oversight for digital and analytics growth projects across all of Aviation, evaluating new technologies contributing to the technology vision and direction for the business.

Prior to joining GE, Dave served as IBM's Vice President of Smarter Physical Infrastructure and a key spokesperson for IBM's "Smarter Planet." Other roles have included IBM Vice President of Autonomic Computing and Director of IBM's European Software Development.

Dave earned his MBA at the University of North Carolina in Chapel Hill, in addition to two other graduate programs: Masters in Computer Science at the University of Minnesota and Masters in Project Management at George Washington University. Dave is also a biologist with an undergraduate degree in Biology from the State University of New York.

Andrew Kemmetmueller

Vice President of Connected Aircraft Services

Andrew Kemmetmueller is the Vice President of Connected Aircraft Services at Gogo. Prior to joining Gogo, Andrew was the CEO of Allegiant Systems, the leading commercial aviation mobile services company, and the founding partner of AvIntel, the industry's leading operational technology research consultancy. He has over a decade of experience in aviation, following a successful career in technology and telecommunications.

Prior to Allegiant Systems and AvIntel, Andrew was the Director of New Product Development at ARINC, a global leader in aviation communication and system integration services. There, he successfully led the development of several new product offerings to commercial aviation, including EFB, Gatelink, SkyBuy, Opti-Fi, and the Mobile Communications Gateway.

Andrew is a noted industry speaker on eEnablement, cyber security, Gatelink (aircraft connectivity) and cabin crew operations technology. He is also a published author and patent-holder.

Michael Small

President and CEO

Michael Small has served as Gogo's President and Chief Executive Officer, and as a member of its board since 2010. He has more than 30 years of experience in the communications industry.

Prior to joining Gogo, Michael served as the Chief Executive Officer and Director of Centennial Communications Corporation from 1999 until 2009. Prior to Centennial, he served as Executive Vice President and Chief Financial Officer of 360 Degrees Communications, a regional wireless service provider. He also served as President of Lynch Corporation, a diversified acquisition-oriented company with operations in telecommunications, manufacturing, and transportation services.

Michael recently was named an Ernst & Young Entrepreneur of the Year, and CEO of the Year from the Illinois Technology Association. He currently serves as the Vice Chairman of the Brady Campaign & Center and on the board of First Midwest Bancorp. He was previously on the boards of the CTIA and two private equity-backed telecom companies.

He holds a Bachelor's from Colgate University and received his MBA from the University of Chicago's Booth School of Business.

Paulo Miranda

Chief Experience Officer

Paulo Miranda joined GOL in July 2013 and serves as its Chief Experience Officer. Starting his career in 1998 in Revenue Accounting, Customer Service, and Financial Planning at Northwest Airlines in Minnesota, Paulo has 18 years of experience in the airline industry.

In 2009, he relocated to Atlanta, Georgia as part of the Delta Air Lines and Northwest Airlines merger. He held various positions at Delta Air Lines in Finance and Alliances, participating in the negotiation and implementation of key strategy items. These include the Delta-Air France and KLM joint venture, several alliance-related projects on a global scale, as well as equity investments with GOL, Aeromexico, and Virgin Atlantic. In July of 2012, he relocated to Sao Paulo, Brazil to lead Strategy and Alliances for Delta Air Lines in the Latin America and Caribbean region. In July 2013, he accepted the responsibilities for Product, Customer Experience, and High Value Clients at GOL.

Paulo received a Business Administration degree from the Carlson School of Management at the University of Minnesota and is fluent in English, Portuguese, and Spanish.

Maps for Life

Omar Rahman

Vice President; Head of Strategy & Enterprise Products

Omar Rahman is Vice President, Head of Strategy & Enterprise Products, and heads the strategy group and Enterprise products at HERE, a Nokia business. In this capacity, he supports strategy development for overall HERE and product management and execution for the Enterprise business.

Before his career at Nokia, Omar assumed a variety of roles in the strategy, technology, and marketing organizations at NAVTEQ, a company acquired by Nokia in 2008. Prior to that, he was an Associate Principal at McKinsey & Company, where he advised clients on corporate strategy, M&A, marketing, and post-merger management in the financial services and technology industries. He started his career at Procter & Gamble in financial analysis and planning.

Omar is a graduate of the Wharton School at the University of Pennsylvania, where he earned a Master's of Business Administration degree with High Distinction. He has an undergraduate BBA degree from the University of Michigan.

Honeywell

Carl Esposito

Vice President of Strategy, Marketing, and Product Management

Carl Esposito is the vice president of Strategy, Marketing, and Product Management for Honeywell Aerospace, a $15 billion business group of Honeywell International, a Fortune 100 company diversified technology and manufacturing leader. With the broadest aviation portfolio in the industry, Carl leads strategic planning, product marketing, product management, and marketing communications. He is also a patent author, inventor, pilot, and aviation enthusiast.

An industry veteran and member of the Aerospace Leadership Team, Carl leads technology development that addresses global macro trends, including safety, security, energy efficiency, and globalization. In his current role, he drives Honeywell Aerospace strategy, with a portfolio spanning avionics, mechanical, software, and services in the Air Transport & Regional, Business & General Aviation, and Defense & Space business segments.

Carl holds a Bachelor's of Science degree in Electrical Engineering from Rensselaer Polytechnic Institute and earned his Masters of Program Management and Masters of Business Administration degrees from the Keller Graduate School of Management. He is a project management professional and a certified Six Sigma Green Belt. Carl also holds a private pilot's license.

Honeywell

Bob Smith

Vice President & Chief Technology Officer

Bob Smith is Chief Technology Officer and Vice President of Engineering & Technology for Honeywell Aerospace. He is responsible for all engineering development, technology development, and strategy and leads a global community of elite scientists and engineers recognized as one of the most innovative and capable in the industry.

Prior to this role, Bob was Vice President of Advanced Technology. He established long-term technology growth strategies, worked with government organizations to foster technology investments, and managed the multi-year technology programs that are vital to Honeywell's new product developments.

Before joining Honeywell in 2004, Bob served as Executive Director of the Space Shuttle Upgrades Development Program. He was responsible for a $300M business that managed a variety of projects ranging from major modifications that replaced Orbiter's hydraulic power sources and data handling systems to the development of new shuttle tiles and landing systems.

Bob also worked at The Aerospace Corporation, where through a series of positions of increasing responsibility, he became Systems Director of the NASA Programs Office and site manager for Aerospace's Houston operations. In that capacity, he served as the business leader for all of Aerospace's efforts at each of the major NASA centers.

Bob has been a lecturer at UCLA, was the co-principal investigator on a shuttle payload experiment, and has been published in numerous technical journals. He has degrees in Engineering/Applied Mathematics from Texas A&M, Brown University, and MIT. He also has a doctorate from the University of Texas in Aerospace Engineering.

Pascal Buchner

Chief Information Officer

Since 2010, Pascal Buchner has been the Chief Information Officer of the International Air Transport Association. Pascal has almost 23 years of experience heading IT organizations in industries that have been transformed by budding technologies. In the early 1990s, he witnessed how the printing industry was changed by the revolution of digital offset printers. From 1997 to 2002, he facilitated the transition of Universal Music to music downloading. From 2002 to 2009, he led a major transformation project aiming the Rexel group to create added value services, and since 2012, he has lead the IATA innovation network to help airlines benefit from the digital world.

Pascal started his career as a military systems developer and worked for several IT consulting firms in the defense and manufacturing sectors.

Don DeLoach

CEO and President

Don DeLoach is CEO and President of Infobright, provider of a purpose-built platform for storing and analyzing machine data. Under Don's leadership, Infobright has achieved a strong presence in embedded solutions, especially in the networking and telecommunications industry. He has more than 30 years of software industry experience, with demonstrated success building software companies with extensive sales, marketing, and international experience.

Don joined Infobright after serving as CEO of Aleri, the complex event processing company. Prior to Aleri, he served as President and CEO of YOUcentric, a CRM software company, and spent five years in senior roles at Sybase. He has also served as a Director at Broadbeam Corporation and Chairman of the Board at Apropos, Inc. Don currently serves on the Executive Board of the Illinois Technology Association and the Board of the Juvenile Protective Association. He is also co-chairman of the ITA Internet of Things Council.

Bruno Fromont

Senior Vice President, Strategy and Asset Management

Bruno Fromont leads Intelsat's Corporate Strategy and Customer Solutions Development, focusing on network investments, market and business development, yield management, asset management, and spectrum strategy.

Fromont joined Intelsat in 2000 as Program Manager of Ground Systems Engineering. Since then, he has held positions of increasing responsibility, including Vice President of Corporate Strategy. In this role, he was responsible for overseeing Intelsat's strategy and innovation, most notably the business development of the Intelsat EpicNG® program.

Prior to joining Intelsat, Bruno held senior management positions with Aerospatiale and Alcatel Space. He started his career as a researcher in Artificial Intelligence at MIT.

Bruno earned a Master of Science Degree in Computer Science from Supelec Paris, an MSEE from Institut Polytechnique in Grenoble, France, and an Executive Certificate from MIT's Sloan School of Management.

Bryan Biniak

Entrepreneur In Residence
General Manager,
Developer Experience
(formerly at Microsoft)

Bryan Biniak is currently an Entrepreneur In Residence at Nokia Growth Partners, investing in Virtual Reality, Augmented Reality, Connected Vehicle and IOT growth companies. He previously served as General Manager at Microsoft. He served as Global Vice President & General Manager of Nokia's Global Developer, Application Development, and App Store business for its Smartphones, Feature Phones and Tablets.

Bryan has also served as Founder & CEO of Jacked, an interactive television platform company; as Senior Vice President & General Manager of Interactive at American Greetings Corporation; as EVP of Sales & Marketing at Vivendi Universal; as COO of Premium Wireless Services; and as Vice President of Business Development for Harmonix Music Systems – developers of Guitar Hero and Rock Band.

Bryan holds several patents in the areas of Connected Vehicles, Contextual Storefronts and Instant Messaging, and Interactive Television. He earned a BA in International Relations, Business & Economics from Boston University. He serves as the Chairman of the Board of Seven Arrows Elementary School as well as Board Member of the College of Arts & Sciences at Boston University.

Michelle Gattuso

Vice President of Product Operations

Michelle Gattuso has worked with Motorola for over 20 years, holding leadership positions in sales management, product management, and engineering. As Vice President of product operations with North American wireless operators and retailers, including technical sales, support, and program management, Michelle is passionate about technology and simplifying the user experience. She was previously responsible for leading Motorola's smartphone imaging solutions product management team, and is credited with several patents. She graduated with a Bachelor of Science in Electrical Engineering from Iowa State University, and earned her MBA from Chicago's Loyola University.

Mark Ballin

Technical Integration Manager of NASA's Airspace Operations and Safety Program

Mark Ballin is the Technical Integration Manager of NASA's Airspace Operations and Safety Program. As a research engineer at the NASA Langley Research Center, he specializes in research and development of future decentralized air traffic control concepts and their enabling flight deck automation technologies. He is an Associate Fellow of the American Institute of Aeronautics and Astronautics, and an active member of the Institute of Electrical and Electronics Engineers. He is the author of over forty technical publications to date.

NETJETS

Kyle Gill

Director, Aircraft Configuration

Kyle Gill is Director of Aircraft Configuration for NetJets, Inc. He is responsible for leading NetJets' global business functions related to fleet technical configuration and specification.

Kyle came to NetJets in 2002 as a financial analyst. He spent 8 years performing reliability and operational analyses of NetJets' aircraft maintenance functions to improve operating efficiencies and cost. Kyle joined the Global Asset Management department in 2010, where he was heavily involved in the specification, maintenance support, and purchase of up to $17.6 billion worth of new Signature Series aircraft, spanning the Embraer Phenom 300, Cessna Latitude, Challenger 350 and 650, and Global 5000, 6000, 7000, and 8000.

Kyle's current responsibilities include development and deployment of the new AVOD NetJets Entertainment system on the Signature Series fleet, streaming movies and TV wirelessly to passenger devices, and working with the Global Flight Operations and Maintenance departments to ensure fleet compliance with upcoming FAA and EASA mandates.

He graduated from Embry-Riddle Aeronautical University with an undergraduate degree in Avionics Technology and a Master of Business Administration in Aviation.

PTC

James E. Heppelmann

President and CEO

Jim Heppelmann is the President and Chief Executive Officer of PTC, responsible for driving the company's global business strategy and operations. During his leadership tenure, PTC has assembled the industry's most comprehensive technology capabilities that enable companies to create, operate, and service smart, connected products. He also serves on PTC's board of directors.

Honored as 2014 Internet of Things (IoT) CEO of the Year, Jim is seen as a thought leader in the IoT space. He co-authored (with Professor Michael E. Porter) the article "How Smart, Connected Products are Transforming Competition," which appeared in the *Harvard Business Review*. He speaks regularly on the subject, and was recently a featured speaker at the Brookings Institution regarding the role of digitization in America's advanced industries. He has been published and quoted in numerous global business and trade media, including *The Wall Street Journal*, *Forbes*, and *Bloomberg Businessweek*.

Jim is a member of the board of directors at SENSATA, a world leader in automotive and industrial sensors and controls. He serves as a member of the dean's advisory board at the University of Minnesota College of Science & Engineering, and is an executive advisory board member of FIRST (For Inspiration and Recognition of Science and Technology). Jim was recently recognized as one of the "Top 100 CEO Leaders in STEM" by the STEMconnector organization.

Rockwell Collins

Michael DiGeorge

Vice President Commercial Aviation & Networks Services

Mike DiGeorge is Vice President of Commercial Aviation & Networks Services for Rockwell Collins. In this role, he is responsible for overseeing the team that provides network and communications solutions for airlines as well as air traffic service providers.

Mike has more than 25 years of experience in aviation, aerospace, and information technology. He joined ARINC in 1990, and has held a wide range of leadership positions in Business Operations, Finance, Contracts, and Procurement.

Mike's extensive international experience includes executive management assignments based in Singapore, Hong Kong, and London, where he led the Aviation Solutions Business unit for Europe, Middle East, and Africa. Following the acquisition of ARINC by Rockwell Collins in 2013, Mike became the managing director of Rockwell Collins' Information Management Services division for Asia Pacific. Most recently, he served as Vice President of International and Global Airports.

Prior to joining ARINC, Mike held positions with the Institute for Defense Analyses, Martin Marietta, and Litton Industries. He has an MBA from Mount St. Mary's University, and a Bachelor of Science from Syracuse University.

Mohammed Amin Abdulmajeed

Vice President Hajj & Umrah Product & Services

Mohammed Amin Abdulmajeed's 30 years of experience with SAUDIA spans multiple groups within the airline. He has held roles in the Planning & Management of Strategic Commercial Projects (including Passengers Services Systems), Direct & Indirect Sales Channels Management (E-Commerce & Self-Service kiosks, City & Airport Ticketing Offices, Telephone Sales Centers, and Global Distribution Systems), Business and Budget Planning & Development, Loyalty and Client Relationship Management, On-Board and On-Ground Product Development & Management, and Advertising & Promotions management.

Steven H. Loving

Client Partner

Steven Loving is a hands-on leader specializing in Internet connected products and systems (IoT), enterprise software, cloud computing, and data analytics. He is personally involved with multiple large IoT rollouts, globally, and at scale. Steven is actively involved in the IoT community, and founded the IoT Chicago Meet-up group. He is a true evangelist who is passionate about technology and helping clients realize their vision. Steven is an industry speaker to C-level executives, conference track lead, and panel moderator. He has over 25 years of progressive IT experience.

Steven is currently at ThingLogix, an IoT solutions provider that helps companies instrument the physical world with intelligence and intent for profit and sustainability. Previously, he ran the Eastern Region for Arrayent, an IoT platform provider. Steven has also held executive positions at Forsythe Solutions, USinternetworking, Sun Microsystems, and Accenture Consulting.

Mark McCausland

Chief Executive Officer

After graduating from the University of Arizona, Mark McCausland began his aviation career as a certified flight instructor. From there, he became a commercial pilot and FAR 135 check airman, FAA-designated pilot examiner, and then a New Mexico Air National Guard F-16 fighter pilot. Mark currently serves as the president and CEO of Ultramain Systems.

Since the inception of Ultramain, Mark has kept the company focused with ongoing developments aimed at providing safety and productivity enhancing M&E/MRO software to airlines, MROs, and military organizations.

In 2005, Mark successfully oversaw the creation of Ultramain's Onboard Systems (OBS) division, which focuses on the development of innovative electronic logbook software, branded efbTechLogs™. Ultramain Systems has become the industry-leading provider of paperless technical log software and supplies ELB software for The Boeing Company.

Under Mark's leadership, Ultramain has led the aviation industry in providing connected mobile M&E software applications, notching a number of aviation industry firsts along the way.

Mark currently resides in Albuquerque, New Mexico, where Ultramain Systems corporate offices are located.

Stuart McGraw

Product Specialist, Technology

Stuart McGraw has over 25 years of experience in multiple areas of military and commercial aviation. During his career flying all types of aircraft from the DHC-4 Caribou to the Airbus A330, Stuart has seen significant technological changes both on the ground and in the air.

Cutting his teeth as an aircraft technician for a major airline, Stuart soon transferred to a role as a military flight engineer, where he spent the best part of a decade flying humanitarian relief missions around the Pacific islands with the Royal Australian Air Force. Ever the innovator, he worked to update and digitize the operational ground support systems and played a key role in the development of a new air-to-air refuelling capability.

After injury forced him out of military service, he returned to commercial aviation as an operational technology consultant with Virgin Australia. From here, he guided the airlines Electronic Flight Bag program before stepping across to his current commercial technology role, where he helps redefine the on-ground and inflight guest experience.

Stuart is passionate about the considered use of technology in aviation and believes that technology can and should be used to enhance – not replace – human interaction.

Samuel Lacarta Chavarrias

Chief Information Officer

Samuel Lacarta Chavarrias started his career developing software for one of the pioneer e-commerce companies in Spain, and has spent more than 13 years delivering IT solutions for all business areas in the aviation industry, from e-commerce and reservation systems to operations, airports, and air-to-ground communications. Samuel is enthusiastic about using technology as a differentiator to deliver a better product to customers and streamline operations.

Samuel had an active role in the startup of Vueling Airlines, and was a key player in the merger with clickair. He was responsible for setting up many of the mission-critical systems that led to Vueling becoming a €2B revenue company. During these years, Vueling also won several IT awards for innovation, including Best Travel Website and Best Airline Mobile App.

Prior to joining Vueling, Samuel worked for ARINC (now Rockwell-Collins), delivering solutions for many airlines and airports in Europe, including VHF and Satcom communications.

Mark D. Miller

Senior Vice President and GM

Mark Miller joined The Weather Company, an IBM Business (formerly WSI Corporation) in 1998, as a Senior Product Manager for the industry-leading Weather Pro product line, serving the broadcast and cable markets. He has also served as Director of Content and New Media for Intellicast.com, as well as Director of Aviation Products. Since 2008, he has served as The Weather Company's Vice President and General Manager of Aviation and Government Business. In this role, Mark oversees the company's suite of aviation solutions serving global civil, military, commercial, business, and private aviation markets, as well as the Energy & Risk division. Mark also manages The Weather Company's lightning business, and major government programs as the FAA ADS-B, Air Traffic Command Center, and ETMS.

Prior to pursuing his passion for weather at The Weather Company, Mark managed the environmental software division at Trinity Consultants. In this position, he was responsible for the Breeze line of air compliance and hazardous emissions modeling software and meteorological monitoring systems. Prior to joining Trinity, Mark worked as a senior scientist and project manager for Optimetrics, a leading defense contractor specializing in the development of tactical weather decision support systems for military programs.

Mark has a Bachelor of Science degree in Meteorology from Penn State University and a Masters in Engineering Management from the University of Dallas.

Michael Simon

Chairman of LogMeIn and Founder of Xively by LogMeIn

Michael Simon has served as LogMeIn's Chairman and CEO since its founding, and has grown the company from a single access product line serving thousands of users, to a leading provider of essential cloud services used daily by millions worldwide. After co-founding the company with Marton Anka in 2003, Michael pioneered the company's signature freemium business model in 2004, and took LogMeIn public in 2009 - the first of two VC-backed IPOs in Massachusetts, and one of eight nationally during the year.

In addition to leading LogMeIn's day-to-day operations and long-term product and market strategy, Michael serves on the board of HubSpot, as well as the Graduate Studies Advisory Council at Notre Dame.

Prior to LogMeIn, Michael founded Uproar Inc., a publicly-traded provider of online game shows and interactive games that was acquired by Vivendi Universal Games, Inc. in 2001. He holds a B.S. in Electrical Engineering from the University of Notre Dame and an MBA from Washington University - St. Louis, and retains a soft spot for athletic teams that sport an Irish motif.

Navin Ganeshan

Chief Product Officer

Navin Ganeshan is the Chief Product Officer for Zubie, a connected-car company that uses real-time car data and analytics to make driving safer, easier, and less expensive. Zubie has won accolades and awards for its consumer mobile experiences at CES and innovative work in Usage-Based-Insurance (UBI).

Navin's career spans two decades of building technology and products in "Next Big Thing" sectors, such as social and mobile marketing, location-based services, mobile payments, big data, and connected devices. His work as Chief Product Officer at Centrifuge Systems involved big data analytics and pattern recognition for US intelligence agencies.
In several leadership roles at Network Solutions, including Chief of Strategy, Product GM, and Head of Strategic Investments, he helped transform the company from a domain name provider to a marketing powerhouse. His early career included Checkfree, a pioneer in web-based bill payment, and multiple startups disrupting online insurance and video conferencing. He launched his foray into connected devices in 2003, as cofounder in a home automation startup that was recognized as the Best in Category at CES.

Navin is a frequent speaker and writer on IoT, big data, and emerging tech. Lately, he has been spending much of his spare time working on (and playing with) drones.

Acronym glossary

A-ISAC Aviation Information Sharing and Analysis Center
ACARS Aircraft Communications and Reporting Services
ACD Aircraft Control Domain
ADS-B Automatic Dependent Surveillance – Broadcast
AFDX Avionics Full-Duplex Switched Ethernet
AHEAD Aircraft Health Analysis and Diagnosis, by Embraer
AHM Aircraft Health Monitoring
AID Aircraft Interface Device
AISD Airline Information Domain
API Application Program Interfaces
APUs Auxiliary Power Units
ASP Average Selling Price
ATC Air Traffic Control

CAAC Civil Aviation Administration of China
CAD Computer Aided Design
CDM Collaborative Decision Making
CDO Chief Data Officer
COTS Commercial Off-The-Shelf
CRM Customer Relationship Management
CVM Comparative Vacuum Monitoring

DFDAU Digital Flight Data Acquisition Unit
DoIT Chicago's Department of Innovation and Technology

EA Enterprise Architect
EASA European Aeronautical Safety Agency
EFB Electronic Flight Bag
EHM Engine Health Monitoring
ERP Enterprise Resource Planning
ETSI European Telecommunications Standards Institute

FAA Federal Aviation Administration
FMC Flight Management Computer
FMS Flight Management System
FOQA Flight Operations Quality Assurance Program

HTS High-Throughput Satellites

IATA International Air Transport Association
ICAO International Civil Aviation Organization
IOSA IATA Operational Safety Audit
IoT Internet of Things
IP Internet Protocol
ISAC Information Sharing and Analysis Centers
ISG Industry Specification Group
IT Information Technology

LAN Local Area Network

M2M Machine to Machine
MEC Mobile Edge Computing

OEM Original Equipment Manufacturer
OLAP Online Analytical Processing
OOOI Out, Off, On, In

PC Personal Computing
PIESD Passenger Information and Entertainment Domain
PNR Passenger Name Record

QAR Quick Access Recorder

ROI Return on Investment

SARPs Standards and Recommended Practices
SCM Supply Chain Management
SCPs Smart Connected Products
SHM Structural Health Monitoring
SLA Service Level Agreements

TASAR Traffic Aware Strategic Aircrew Requests, by NASA

WAN Wide Area Network

Works cited

Accenture, "Moving Toward the Future of the Industrial Internet," 2015. https://www.accenture.com/t20150523T033740__w__/us-en/_acnmedia/Accenture/Conversion-Assets/DotCom/Documents/Global/PDF/Dualpub_9/Accenture-Industrial-Internet-Competitive-Landscape-Industries-Infographic.pdf

AirInsight, 2015 Annual EFB Research Project.

ARINC Industry Activities, http://www.aviation-ia.com.

Aviation ISAC
http://www.a-isac.com/

Bloomberg Business, "Barcelona's Smart Trash Cans Pave Way for Mobile Future," by Amy Thomson, February 23, 2014. http://www.bloomberg.com/news/articles/2014-02-23/barcelona-s-smart-trash-cans-pave-way-for-mobile-future

Boeing, "Airplane Health Management: Monitoring the Airplane in Flight," July 30, 2013. http://www.boeing.com/features/2013/07/bca-airplane-health-mgmt-07-30-13.page

Boeing, "Boeing to Discontinue Connexion by Boeing Service," August 17, 2006. http://boeing.mediaroom.com/2006-08-17-Boeing-to-Discontinue-Connexion-by-Boeing-Service

British Airways, Customer Analytics
http://www.britishairways.com/careers/analysthub/customer_analytics.shtml

Business Insider, "10 Million Self-Driving Cars Will be on the Road by 2020," by John Greenough, BI Intelligence, July 29, 2015. http://www.businessinsider.com/report-10-million-self-driving-cars-will-be-on-the-road-by-2020-2015-5-6

Business Insider, "The Internet of Everything: 2015 [Slide Deck]," by John Greenough, BI Intelligence, April 8, 2015. http://www.businessinsider.com/internet-of-everything-2015-bi-2014-12

BI Intelligence, "The Internet of Things 2015: Examining How The IoT Will Affect The World," November 2015.

CIO (Spanish edition), "Embraer Wants IT Immersed in the organization," November 10, 2015.

"CIO da Embraer quer IT "imerso" na organização" http://www.cio.pt/2015/11/10/cio-da-embraer-quer-it-imerso-na-organizacao/

CIO, "GE Says Industrial Internet is Here," by Thor Olavsrud, October 9, 2014. http://www.cio.com/article/2824542/internet/ge-says-industrial-internet-is-here.html

Composites World, "Structural Health Monitoring: Decades of Demonstrations Build Confidence in Local SHM," by Ginger Gardiner, July 31, 2015. http://www.compositesworld.com/articles/structural-health-monitoring-decades-of-demonstrations-build-confidence-in-local-shm

ComputerWorld UK, "Boeing 787s to Create Half a Terabyte of Data per Flight, says Virgin Atlantic," by Matthew Finnegan, March 6, 2013. http://www.computerworlduk.com/news/data/boeing-787s-create-half-terabyte-of-data-per-flight-says-virgin-atlantic-3433595/

The Dallas Morning News, "Cyberthieves Steal Miles from American, United Customers," by David Koenig, January 12, 2015. http://www.dallasnews.com/business/airline-industry/20150112-american-united-airlines-targets-of-attempt-to-steal-customers-miles.ece

Data Science Central, "That's Data Science: Airbus Puts 10,000 Sensors in Every Single Wing!" by Bernard Marr, April 9, 2015. http://www.datasciencecentral.com/profiles/blogs/that-s-data-science-airbus-puts-10-000-sensors-in-every-single

Department of Transportation, Federal Register, Volume 73, Number 1, January 2, 2008. https://www.gpo.gov/fdsys/pkg/FR-2008-01-02/html/E7-25467.htm

Embraer Press Release, "Embraer Launches New Version of the Ahead Software," June 4, 2007. http://www.embraer.com/en-US/ImprensaEventos/Press-releases/noticias/Pages/EMBRAER-LANCA-NOVA-VERSAO-DO-SOFTWARE-AHEAD.aspx

European Aviation Safety Agency
https://easa.europa.eu/the-agency

Fast Company, "Behind GE's Vision for the Industrial Internet of Things," by Jon Gertner, July/August 2014. http://www.fastcompany.com/3031272/can-jeff-immelt-really-make-the-world-1-better

Federal Aviation Administration
http://www.faa.gov/

Flight Global, “ARINC Launches Common-Use Wireless Gatelink System,” by David Learmount, June 14, 2007. https://www.flightglobal.com/news/articles/arinc-launches-common-use-wireless-gatelink-system-214660/

Forbes, “Why CIOs Should be Happy About Shadow IT,” by Russ Banham, May 4, 2015. http://www.forbes.com/sites/centurylink/2015/05/04/why-cios-should-be-happy-about-shadow-it/

Forrester, “Mobile Leaders Will Break Away from Laggards in 2015,” by Thomas Husson, November 11, 2014. http://blogs.forrester.com/thomas_husson/14-11-11-mobile_leaders_will_break_away_from_laggards_in_2015

Fortune, “The Race to the Internet of Things,” by Michal Lev-Ram, March 5, 2015. http://fortune.com/2015/03/05/the-race-to-the-internet-of-things/

Gartner, “How to Derive Value From Big Data in Transportation,” Bart De Muynck, 25 June 2015.

Gartner, “Hype Cycle for the Internet of Things 2015,” by Alfonso Velosa, W. Roy Schulte, Benoit J. Lheureux, July 21, 2015.

Gartner, “Mass Adoption of the Internet of Things Will Create New Opportunities and Challenges for Enterprises,” by Jim Tully, February 27, 2015.

Gartner, Smarter With Gartner, “Understanding the Chief Data Officer Role,” by Tom McCall, February 18, 2015. http://www.gartner.com/smarterwithgartner/understanding-the-chief-data-officer-role/

Gartner Glossary, Big Data.
http://www.gartner.com/it-glossary/?s=high-velocity+

Gartner Press Release, “Gartner’s 2015 Hype Cycle for Emerging Technologies Identifies the Computing Innovations That Organizations Should Monitor,” August 18, 2015. http://www.gartner.com/newsroom/id/3114217

Gartner Press Release, “Gartner Highlights Key Emerging Technologies in 2005 Hype Cycle,” August 23, 2005 http://www.gartner.com/newsroom/id/492175

Gartner Press Release, “Gartner Says CIOs and CDOs Must ‘Digitally Remaster’ Their Organizations,” February 2, 2015. http://www.gartner.com/newsroom/id/2975018

Gartner, "Consider All Cost Elements When Planning for an Internet of Things Initiative," Federica Troni, 01 July 2015

General Administration of Civil Aviation
http://www.gov.cn/english/2005-10/22/content_81677.htm

The Global Link by ARINC, “Chairman’s Perspective—Changing Aviation All Over Again,” Fall 2003. http://www.arinc.com/publications/The-Global-Link_45_Fall-2013/HTML/files/assets/common/downloads/The-Global-Link_Fall-2013_45.pdf

Gogo LLC, “The Anatomy of Inflight Connectivity,” 2014.

Gogo, “2014 Retrospective – A Year of Major Milestones for Gogo,” December 29, 2014 http://concourse.gogoair.com/technology/2014-retrospective-year-major-milestones-gogo

Gogo, “Gogo Unveils its Game Changing 2KU In-Flight Connectivity Technology,” November 12, 2015 http://concourse.gogoair.com/inside-gogo/gogo-unveils-its-game-changing-2ku-in-flight-connectivity-technology

Green Car Congress, “Sensor fusion, machine learning, and “big data” featuring in Ford R&D for advanced driver assistance,” December 22, 2012. http://www.greencarcongress.com/2012/12/ford-20121222.html

Harvard Business Review, “Data Scientist: The Sexiest Job of the 21st Century,” by Thomas H. Davenport and D.J. Patil, October 2012. https://hbr.org/2012/10/data-scientist-the-sexiest-job-of-the-21st-century/

Harvard Business Review, “How Smart, Connected Products Are Transforming Companies,” by Michael E. Porter and James E. Heppelmann, October 2015.

Harvard Business Review, “How Smart, Connected Products Are Transforming Competition,” by Michael E. Porter and James E. Heppelmann, November 2014.

IDC Press Release, “As Tablets Slow and PCs Face Ongoing Challenges, Smartphones Grab an Ever-Larger Share of the Smart Connected Device Market Through 2019, According to IDC,” March 20, 2015. http://www.idc.com/getdoc.jsp?containerId=prUS25500515

IDC, “Worldwide Internet of Things Forecast,” 2015-2020, May 2015.

IDG Enterprise, “Big Data and Analytics Survey 2015,” by IDG Enterprise Marketing, March 9, 2015. http://www.idgenterprise.com/resource/research/2015-big-data-and-analytics-survey/

Immarsat, "Immarsat Global Xpress is the First High-Speed Broadband Network to Span the World," 2016. http://www.inmarsat.com/service/global-xpress/

Intel, "50 Years of Moore's Law, Fueling Innovation We Love and Depend On." http://www.intel.com/content/www/us/en/silicon-innovations/moores-law-technology.html

International Air Transport Association
http://www.iata.org/about/Pages/index.aspx

International Business Times, "CES 2014 Keynote Recap: Yahoo, Cisco, Sony and Other Announcements So Far," by Abigail Elise, January 9, 2014. http://www.ibtimes.com/ces-2014-keynote-recap-yahoo-cisco-sony-other-announcements-so-far-1533274

International Civil Aviation Organization
http://www.icao.int/about-icao

Machina/LogMeIn, "Lessons Learned from Early Adopters of the IoT: A Global Study of Connected Businesses," November 2015.

Massachusetts Institute of Technology, Data Scientist Position Description, February 9, 2015. https://ist.mit.edu/sites/default/files/about/org/roles/Data_Scientist_Position_Description_v4.pdf

M&A International Inc., "Technology Report—The Internet of Things: On the Internet, Nobody Knows You're a [Nest] Thermostat," June 2014. http://www.mergers.net/sites/default/files/MAI.Technology.Report_June2014_0.pdf

McKinsey & Company, "Ten Ways Autonomous Driving Could Redefine the Automotive World," by Michele Bertoncello and Dominik Wee, June 2015. http://www.mckinsey.com/insights/automotive_and_assembly/ten_ways_autonomous_driving_could_redefine_the_automotive_world

McKinsey & Company, "The Internet of Things: Mapping the Value Beyond the Hype," June 2015.

Metron Aviation, "Airservices Australia Improving Performance with Metron Harmony Air Traffic Flow Management System," June 25, 2012. https://www.metronaviation.com/project/airservices-australia-improving-performance-with-metron-harmony-air-traffic-flow-management-system/

NASA, "Catalog of Earth Satellite Orbits" by Holli Riebeek, September 4, 2009. http://earthobservatory.nasa.gov/Features/OrbitsCatalog.

PTC, "Diebold Customer Success Story— IoT-Enabled Services," 2015. http://www.ptc.com/internet-of-things/customer-success/diebold

PTC, "The IoT Value Roadmap," 2015.

PWC, "US Cybersecurity: Progress Stalled, Key findings from the 2015 State of Cybercrime Survey," July 2015. http://www.pwc.com/us/en/increasing-it-effectiveness/publications/assets/2015-us-cybercrime-survey.pdf

Runway Girl Network, "Better Inflight Wifi over North Atlantic is Months Away: CEO," by Mary Kirby, January 29, 2016. https://www.runwaygirlnetwork.com/2016/01/29/better-inflight-wifi-over-north-atlantic-is-months-away-intelsat-ceo/

Runway Girl Network, "The Internet of Things Coming Soon to an Airline Near You," by Ben Kepes, March 14, 2015. https://www.runwaygirlnetwork.com/2015/03/14/the-internet-of-things-coming-soon-to-an-airline-near-you/

Runway Girl Network, "United is on Bleeding Edge of Integrating Multiple Wi-Fi Products," by Seth Miller, September 25, 2015. https://www.runwaygirlnetwork.com/2014/09/25/united-is-on-bleeding-edge-of-integrating-multiple-wi-fi-products/

Skift, "A Brief History of In-flight Entertainment form Projectors to iPads," by Samantha Shankman, January 9, 2014. http://skift.com/2014/01/09/a-brief-history-of-in-flight-entertainment-from-projectors-to-ipads/

Solarwinds, "IoT Report 2015: Business at the Speed of IT," July 14, 2015. http://www.solarwinds.com/assets/surveys/iot-report-2015-business-at-the-speed-of-it

Statista, "Unit sales of the Apple iPhone worldwide from 2007 to 2015 (in millions)," 2015. http://www.statista.com/graphic/1/276306/global-apple-iphone-sales-since-fiscal-year-2007.jpg

Sunlight Foundation, Open Data Policy Guidelines, Version 3, March 2014 http://sunlightfoundation.com/opendataguidelines/

Tech Briefs, "David Wing, Air Traffic Management Researcher, Langley Research Center, Hampton VA," January 1, 2014. http://www.techbriefs.com/component/content/article/ntb/features/whos-who/19008

TechCrunch, "It's Time to Embrace, Not Fear, Shadow IT," by James Quigley, September 25, 2015. http://techcrunch.com/2015/09/25/its-time-to-embrace-not-fear-shadow-it/

TechTarget, "Navigate Data Lakes to Manage Big Data," by Mike Matchett, June 2015. http://searchstorage.techtarget.com/opinion/Navigate-data-lakes-to-manage-big-data

Telecoms.com, "Industry Giants Form Mobile Edge Open Networking Group," by Tom Skinner, October 17, 2014. http://telecoms.com/295312/industry-giants-form-mobile-edge-open-networking-group/

Teledyne Technologies, "Teledyne Controls Announces Successful Launch of Wireless GroundLink™," September 5, 2001. http://www.teledyne.com/news/groundlink.asp

Thales, "Thales Secures GateSync Partnership," July 21, 2010. https://www.thalesgroup.com/en/content/thales-secures-gatesync-partnership-0

T-mobile, "Deutsche Telekom and Inmarsat partner to deliver European Aviation Network," September 21, 2015. https://www.telekom.com/media/company/288250

Transport Canada
https://www.tc.gc.ca/eng/aboutus-whatwedo.htm

University of Derby, "Smartphones Are Addictive—Reveals First UK Study from The University of Derby," March 3, 2015. http://www.derby.ac.uk/newsevents/news/archive/news-archive/smartphones-are-addictive--reveals-first-uk-study-from-the-university-of-derby.php

Valour Consultancy, "The Future of Aeronautical Connectivity Report," October 2014.

Vueling News, "Vueling Will be the First European Company to Offer Connectivity at 20Mbps," April 8, 2014. http://vuelingnews.com/2014/04/09/vueling-will-be-the-first-european-company-to-offer-connectivity-at-20mbps

The Wall Street Journal, "Audi, BMW and Daimler Near Deal to Buy Nokia Mapping Service," by William Boston, July 21, 2015. http://www.wsj.com/articles/german-car-makers-audi-bmw-and-daimler-to-buy-nokia-here-1437493575

World Economic Forum, "Are you ready for the Internet of everything?," by John Chambers, January 15, 2014. https://agenda.weforum.org/2014/01/are-you-ready-for-the-internet-of-everything/

Yole Développement, Status of the MEMS Industry report, May 2015.

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