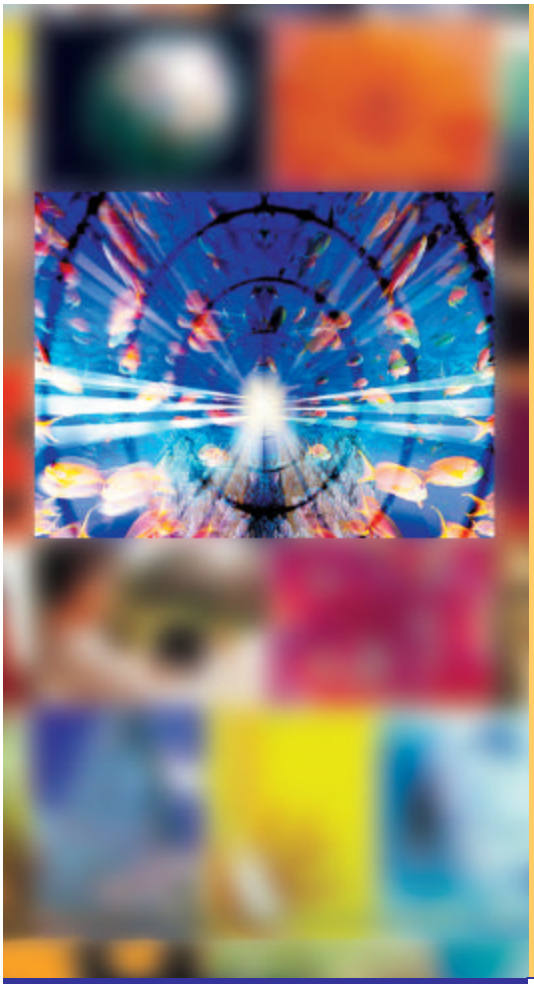
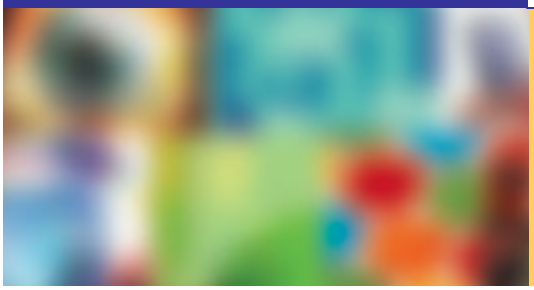


Continental Airlines

Tech Ops Leverages Visual Media to Improve Airline Performance

An IDC Infoimaging Case Study

THE SUBJECT	Continental Airlines is the fifth largest airline in the U.S., with 2001 revenues of $9 billion and more than 40,000 employees worldwide. The core mission of Continental 's Technical Operations division (profiled in this case) is the maintenance and repair of its aircraft. To perform this, Tech Ops relies on a vast body of technical documentation.
THE GOAL	To use technology to improve the flow of information between aviation manufacturers and Continental, and between Continental's engineers and its 3,500 technicians in the field. The ultimate goal was to improve efficiency of maintenance and repair processes, reduce error rates and reduce and/or eliminate document management costs.
THE SOLUTION	The core of Continental's Infoimaging initiative is a Documentum-based content management application—accessed through Continental's intranet—that greatly improves the flexibility, timeliness and overall richness of the technical documentation used by technicians. The use of digital photographs, high-resolution drawings and streaming video within key documents is critical.



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Analyze the Future

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Within Continental's Technical Operations unit, the sweet spot for innovation has centered on improving this flow of information between aviation manufacturers and the airlines, and between the airlines' engineers and its 3,500 technicians in the field.

Business Drivers

Continental's core business driver was to replace its much-maligned process for issuing revisions to its Aircraft Maintenance Manuals. Its key goal was to improve the overall efficiency with which Tech Ops received, processed, and published technical data. Continental sought a shift from paper-intensive, text-based documentation management.

Technology

Beginning in 1999, Continental (with the assistance of a solutions provider) deployed a range of document management and authoring solutions—each targeted to specific needs. Key functions include:

- *General Enhancement through Graphical Illustration*—Involves the expanded use of manipulable high-resolution photos , diagrams , or drawings alongside textual information to increase the accuracy of instructions.
- *Inspection-Related Collaboration*—Involves the use of a digital camera to perform diagnostic analysis.
- *Real-time Instruction*—Involves the use of Java-based streaming video to provide realtime training and tutorials for technicians.
- *Flagging High-Risk Procedures*—Involves the use of digital photos and/or streaming video to provide a priori alerts to technicians when conducting complex or risky procedures.

Benefit Profile

By delivering a richer array of data—especially image-related data—to its technicians, Continental has achieved a higher level of accuracy and a lower error rate for both routine and non-routine maintenance. Continental has also sharply reduced its document management cycle time.

Future

Continental plans to expand the scope of its document management, with an even stronger emphasis on integrating both still photos and digital images.

Eastman Kodak commissioned IDC to identify and analyze examples of Infoimaging at work in the marketplace today. This case study, and others in this series, demonstrates how the convergence of imaging science and information technology is driving growth opportunities for vendors and enabling companies using Infoimaging to improve their mission-critical processes and better serve their customers.

Situation Analysis

Continental Airlines is the fifth largest airline in the U.S., with hubs in New York, Houston, Cleveland and Guam. With 2001 revenues of $9 billion and more than 40,000 employees worldwide, Continental serves more international cities than any other U.S. carrier, offering extensive service throughout the Americas, Europe and Asia. The company serves 15 European cities, seven South American cities, Tel Aviv, Hong Kong and Tokyo. Continental also serves more destinations in Mexico and Central America than any other United States airline. The company serves the western Pacific (including Japan) through its Guam hub.

Of the many strategic and competitive issues affecting the airline industry, few loom larger than the need for carriers to maximize the overall efficiency of their operations. With competition keeping a lid on air fares, airlines are now more dependent than ever on process innovation—and the technology infrastructure that enables it—to deliver bottom-line results. While the airline industry as a whole has been fairly aggressive in deploying technology, much of its activity has thus far been directed toward customer-facing processes (e.g., ticketing and customer service) or employee-based programs (e.g., intranet-based services). In contrast, the airline industry has been relatively slow to deploy technology in the area of Technical Operations—the diverse set of processes through which airlines maintain their aircraft considered the innermost core of its operations.

With a broad mandate to keep the airline's fleet at peak performance, the "Tech Ops" function touches on the most fundamental elements of an airline's business model.

With a broad mandate to keep the airline's fleet at peak performance, the "Tech Ops" function touches on the most fundamental elements of an airline's business model. These range from ensuring passenger safety to maximizing the revenue stream from the airline's key assets—its planes—by keeping them in the air. From a process point of view, Tech Ops relies on the effective management of a vast body of technical documentation related to aircraft maintenance and repair. The most important documentation includes:

- *Aircraft Maintenance Manuals (AMMs)*—Issued by manufacturers such as Boeing, GE, and Pratt and Whitney, AMMs are extremely large documents that provide all information on how to maintain a particular type of airplane, its engines or its subsystem. Primarily text-based, AMMs also include illustrations such as parts drawings or wiring diagrams.
- *Airworthiness Directives (ADs)*—Issued by the Federal Aviation Administration (FAA), ADs alert airlines to potential technical problems on specific aircraft models, and dictates a course of remedial action. Compliance with ADs, which typically involves extensive testing, is mandated by FAA.

- *Service Bulletins (SBs)*—Issued by manufacturers, SBs also alert airlines to potential technical issues; compliance with SBs is at the discretion of the airline.
- *Illustrated Parts Catalog (IPC)*—Issued by manufacturers, provides a more graphical and database-driven view of aircraft maintenance data.
- *Engineering Authorizations (EAs)*—Issued by an airline to its technicians, EAs specify in detail how to perform non-routine maintenance on aircraft and aircraft components (such as work related to service bulletins).

Within Tech Ops, the sweet spot for innovation has centered on improving this flow of information between aviation manufacturers and the airlines, and between the airlines' engineers and its 3,500 technicians in the field. One of the most dramatic improvements of late has been the gradual switch from paper-based documentation to electronic media. The key development that made the shift to digital media possible was the creation of a set of file transfer standards known as Air Transportation Association (ATA)-2100. Through ATA-2100, manufacturers are able to identify discrete elements within a technical document—such as a part number, a heading or a graphic—and label it accordingly. This labeling—or "tagging"—converts what had essentially been a monolithic document into a reusable collection of easily identifiable data.

A Continental Boeing 777 *Source: Continental Airlines, 2002*

For airlines such as Continental, the move to digital documentation has laid the groundwork for significant cost savings and process improvements in the area of Tech Ops. A key enabler of these process improvements is the increased flexibility afforded by digital documents, as well as their ability to accommodate rich media such as high-resolution images and streaming video. The following sections examine how Continental has successfully begun to introduce such functionality into its Tech Ops area.

Continental's Business Drivers

The roots of Continental's digitization strategy extend back to the early 1990s, when Boeing (a key Continental supplier) began making its technical documents available digitally (in SGML format). While Continental's desire to take advantage of Boeing's new approach was a key impetus to its efforts, the company's core business driver was to replace its much-maligned process for issuing revisions to its Aircraft Maintenance Manuals. [Because the process was largely paper-based, it took an average of 3 months to get revised manuals out to technicians in the field.] In the first half of the 1990s, Continental made only modest progress toward digitization, reflecting the relative dearth of off-the-shelf technology products, as well as the high cost of proprietary products on the market at the time.

> "Our goal was to improve the overall efficiency with which Tech Ops' received, processed, and published technical data."
>
> — *John Stelly, Managing Director of Technology, Continental Airlines*

The year 1996 marked an inflection point for Continental's digitization efforts. While the company's intranet infrastructure had reached a critical mass, the focus had also begun to shift from developing better authoring technology to improving the tools available to end-users. According to John Stelly, Continental's Managing Director of Technology, the availability of low-cost, off-the-shelf Web technology made it feasible to provide aircraft maintenance technicians with dynamic, up-to-date, and accurate information. "Our goal was to improve the overall efficiency with which Tech Ops received, processed, and published technical data," says Stelly. "With Web and portal technology, we were able to put technology into the hands of 3,500 technicians—not just the 50 engineers and technical writers using authoring tools."

Understanding the Tech Ops Information Flow

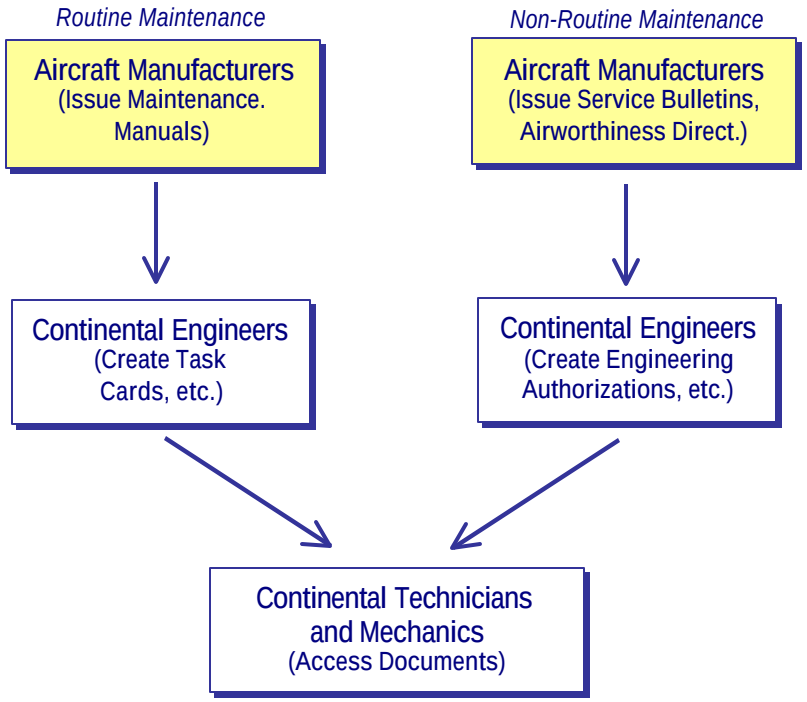
To understand how Continental sought to leverage technology, one must first understand the basic processes by which Tech Ops manages information. At a high level, Continental receives a variety of documents from its manufacturers (the most prominent of which are Boeing, GE, Honeywell, Pratt & Whitney and Rolls-Royce) which provide generic, step-by-step instructions on how to maintain its equipment or how to perform a specific procedure. For documents related to *routine maintenance*, Continental's engineers and technical writers then take these generic source documents and customize them (in accordance with its own Maintenance Plan) into "task cards."

> "Incorporating graphics into task cards and Engineering Authorizations have shown extremely positive results in the field. Our belief is that technologies like imaging enable the Tech Ops group to be more productive, more error-free, and do a better job of maintaining aircraft at peak performance."
>
> — *John Stelly*

Consider an example: while Boeing's manual may specify tasks A, B and C for changing an oil filter, Continental may add a number of tasks that could be conveniently performed at the same time. This newly defined, more inclusive task card would subsume the one specified by the manufacturer.

For documents related to *non-routine maintenance*, such as service bulletins and or airworthiness directives, Continental's engineers again serve as intermediaries between the manufacturers and its technicians in the field. In a hypothetical example, Boeing may notify Continental (and its other airline customers) of a sudden tendency for 737 rudders to turn right. It is the engineer's job to construct a to create an Engineering Authorization to provide detailed instructions on how to perform often-complex inspections, removals and repairs. For documents like Engineering Authorizations, Stelly sees the inclusion of graphical images like drawings, photos and diagrams as a major enhancement to their usability. "Incorporating graphics into task cards and engineering authorizations have shown extremely positive results in the field," notes Stelly. "Our belief is that technologies like imaging enable the Tech Ops group to be more productive, more error-free, and do a better job of maintaining aircraft at peak performance."

Basic Document Flow in Continental's Tech Ops



Source: IDC, Continental

The Need: Smarter, Richer Technical Documents

In 1999, Continental launched a series of initiatives with the broad goal of adding more intelligence and flexibility to its technical document management process. Prior to this, the predominant approach was for manufacturers to send manuals to Continental in paper form, after which they were scanned, converted to PDFs, and then converted to micro-film. Technicians would then typically print out the manuals from a micro-film reader. Similarly, Continental's engineers would write up both task cards and Engineering Authorizations as 100 percent text-based documents. Technicians in the field would then print out the document on a dot-matrix printer. This hard-copy, 100 percent text-based document would then be used to guide technicians as they performed their non-routine maintenance or repair.

But by 1999, Continental saw the emergence innovative technologies as an opportunity to do away with this inflexible, paper-intensive documentation management scheme. Continental contracted with Denver-based Creative Concepts Corp. (CCC), a provider of XML-based content management solutions targeted to the airline industry. The following sections examines the various solutions that CCC developed, and the diverse stream of benefits that they yielded for Continental.

Continental's Implementation: Empowering with Visual Data

A Functional Overview

Beginning in 1999, CCC deployed a range of document management and authoring solutions for Continental—each targeted to the specific needs outlined above. To manage the receipt of maintenance manual information from Continental's manufacturers, CCC deployed its FlightLine™ product, a modular solution built on Documentum's document management product. The basic function of the solution is to take service manual data from manufacturers in SGML format and convert it to an editable, Web-ready database. After receiving the manuals in SGML format, the system then converts the data to XML, breaks the data stream ("bursts") into its component parts, and publishes it on Continental's intranet. Users can access the data with a standard Web browser. FlightLine's biggest strength is its ability to radically streamline the alteration of maintenance manual content—either for the creation of task cards or to incorporate revisions to manuals sent over by the manufacturer. [In the latter case, manual revision processing time was cut from 3 months (see above) to just 14 days.]

To address the creation of Engineering Authorizations, Continental deployed a template-based authoring environment known as the Engineering Information Management system. The system allows

Continental engineers to create and revise Engineering Authorizations online, and makes it easy for engineers to add graphical elements such as photographs, diagrams, and drawings to what had once been text-only documents.

New Architecture Opens the Door For Advanced Imaging Apps

Having deployed a new document management architecture in Tech Ops, Continental is now much better positioned to deploy rich media such as imaging to further enhance the performance of its engineers, technical writers and technicians. Some prominent examples of the integration of imaging within Continental's Tech Ops include:

- *Image-Enhanced Inspection and Collaboration*—Scenario : a mechanic discovers corrosion in the course of a routine inspection that falls outside of documented procedures and needs to know how to proceed. Using a digital camera, the mechanic can now send an image of the corrosion to a special engineering group within Continental. After evaluating the image, an engineer will then issue a specific engineering authorization advising the mechanic how to proceed. Status : Currently being done.
- *Real-time Video-based Instruction*—Scenario : a mechanic is executing a complex, unfamiliar procedure outlined in a task card or Engineering Authorization. The mechanic then clicks on an icon embedded in the Engineering Authorization that runs an Java applet-based streaming video that provides detailed instructions on the procedure. Further down the road, technicians may view the same type of content through a heads-up display. Status : Currently being tested.
- *Visual Flagging of High-Risk Procedures*—Scenario : a mechanic is executing a routine procedure associated with a relatively high rate of errors. Embedded in the task card is digital photo and/or an icon leading to a streaming video that alerts the mechanic to the risk of error and provides recommendations on how to avoid an error. Status : Currently being tested.
- *General Enhancement through Graphical Illustration*—Scenario : a mechanic or technician conducts maintenance, inspection or repair following either a task card or an Engineering Authorization. The mechanic or technician completes the job more quickly and accurately because photos, diagrams, or drawings are presented alongside textual information, Status : Currently being used.

Key Components of Continental's Solution

IDC classifies Continental's Tech Ops solution as an example of Infoimaging by virtue of its use of imaging technology to improve the communication, presentation or interpretation of information. Under the Infoimaging framework, components used to develop such a solution fall under three categories:

- Devices, which are used to capture, process, or output images (e.g., scanners, digital cameras, printers, and hand-held devices);
- Infrastructure (including IT and networking resources) which is used to store, process and deliver image-based information.
- Services/Media (including the software, film and services) which are used to access, analyze and print images.

To put its Tech Ops solution in place, the majority of Continental's investment was in the area of Services/Media , reflecting the cost of CCC's software, the Documentum and Oracle database underlying the solution and the associated deployment costs. Other software costs included the deployment of plug-ins that would allow workstations to read CGM (Computer Graphics Metafile) files, the standard format used for high-resolution graphics on the system.

Key Infoimaging Components of Continental's Solution

Devices	Infrastructure	Services/Media
Hi-Speed Scanners	Storage Area Network	CCC's Software
Digital Cameras	Servers	Database Software
Printers		Graphics Drivers

Source: IDC, Continental

In the area of Infrastructure , Continental's required investments included dedicated servers to run Documentum (dedicated servers were employed to guarantee 24/7 availability) as well as a 300 GB storage area network used for storing the solution's text and graphical data. Although Continental's intranet is the channel through which the solution is accessed, investments in intranet infrastructure are considered incidental (i.e., not directly attributable) to Tech Ops solution. Continental's required investment in Devices was fairly minimal, by virtue of Tech Ops' ability to repurpose its existing base of high-speed scanners (used to scan the small base of documents still delivered in hard copy) and digital cameras.

Continental's Infoimaging Benefit Profile

Viewed broadly, the most significant benefit of Continental's XML-based document management initiative has been a major improvement in the efficiency of Technical Operations. In addition to helping

> "By delivering a richer array of data to our technicians, we've begun to achieve a higher level of accuracy and a lower error rate for both routine and non-routine maintenance. There's also been a major cultural change in that technicians have come to expect—even demand—pictures in their task cards."
>
> — *John Stelly*

Continental manage its documents and data, its recent initiative has greatly improved its ability to perform its core mission: keeping its aircraft clean, safe, and reliable in the air. On a practical level, this means enabling planes to receive regular maintenance at night and still stay on Continental's schedule (read: generate passenger revenue). One of the most important ways the solution helps Tech Ops keep planes in the air is to arm technicians with more and better information—enabling them turn around jobs faster, and with fewer errors. And as Continental's Stelly points out, technical documentation enhanced with image-based data is one of the best ways to achieve this. "By delivering a richer array of data to our technicians, we've begun to achieve a higher level of accuracy and a lower error rate for both routine and non-routine maintenance," says Stelly. "There's also been a major cultural change in that technicians have come to expect—even demand—pictures in their task cards."

The benefit of integrating graphical content within aircraft maintenance documentation has also been the subject of academic inquiry. Stelly cites a particular study related to the integration of graphical images into task cards as evidence of its positive impact. "The research showed a marked improvement in the effectiveness of technicians through a reduction in errors and an ability to perform their job faster in cases where illustrations were added to textual documentation." Concurring with Stelly is Dr. Colin G. Drury, Distinguished Professor of Industrial Engineering at University at Buffalo, who has performed human factors research in the area of aircraft inspection and maintenance for the past 15 years. "My research has shown that the best way to reduce aircraft maintenance errors is to design better documents," says Drury. "And the best way to design better documents is to intelligently integrate graphical data and text."

Not surprisingly, some of the most dramatic benefits came as a result of its shift from paper-based to Web-based document distribution. Foremost among these benefits is a dramatic shortening of document management cycle time, which allows the airline to get materials to the field more quickly. Take the example of revisions to the Aircraft Maintenance Manual sent by manufacturers, which previously took Continental 60 to 90 days to produce and distribute to its technicians. By adopting a more flexible, Web-based document management scheme, Continental cut that time to just 14 days.

IDC Analysis: The Growth of XML-based Content Management Technologies

Continental's Tech Ops solution exemplifies a broadening trend toward companies using XML-enabled content management platforms to integrate different kinds of content faster and more efficiently. This has been fueled by the steady integration of XML support into content management products, search technologies, authoring tools, and rich

media witnessed over the past 12 months. IDC sees the basic requirements of a Web-based content management platform as:

- storing of structured, semi-structured, and unstructured data;
- communicating with other platforms across the Internet; and
- delivering content to any type of client device.

XML is especially suited to separating content from its presentation, providing the user with greater access and ability to "slice and dice" content for reuse. XML is also enabling content to evolve at a rapid pace on the Web and play a role in integrating with other enterprise applications, resulting in new market opportunities and partnerships. The increasing use and acceptance of XML—and its ability to separate content from presentation—has created a need for tools to author content in XML. Over the past year, the market for XML-based content authoring tools has grown considerably. IDC forecasts the worldwide market for XML-based authoring tools to grow from $106.1 million in 2002 to $394.7 million in 2006, representing a compound annual growth rate of 41.5 percent. In the short term, demand for XML authoring tools should provide steady growth for vendors in content management and publishing applications.

In the area of aircraft maintenance, the operational benefits of XML-based content management platforms has been clear—as evidenced by the success of Continental's Tech Ops solution. Another high-profile example of such a solution is currently being by developed the U.S. Air Force. When completed, it will provide more than 1 million users with a single point of access to information ranging from engine schematics and equipment repair manuals to flight schedules and internal memos. As with Continental, the goal is stimulate higher levels of operational efficiency by allowing convenient access to a richer array of content.

The Future: Building on Success

Going forward, Continental plans to expand the scope of its document management, with an even stronger emphasis on integrating both still photos and digital images. For instance, Stelly's Technology group is now working with the Tech Ops training department automate instructional manuals by adding video elements. His vision beyond this: "We want to create a whole library of video 'objects' that our technical writers can access and append to particular training documents," says Stelly. "We're essentially building an infrastructure for adding rich media to the training experience." Similarly, Stelly's group is moving toward establishing an archive of images taking by technicians for diagnostic purposes and establishing an archive for future reference.