The evolution of a manufacturing Web site

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Abstract

The Boeing Commercial Airplanes Wing Responsibility Center (WRC) needed a way to communicate quickly and effectively between its various plant locations. An important requirement was the ability to provide a common means to update and disseminate information, such as vital organizational statistics, in a timely manner.

Several Web applications were built for the site, providing data entry and validation, charting, reporting, paging, e-mail notification, automatic detection of broken links, and the ability to build and update pages without the knowledge of HTML or a Web authoring tool. The site and its applications work daily to support the people who build the wings for Boeing airplanes. © 2000 Published by Elsevier Science B.V. All rights reserved.

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1. Introduction

In 1995 Boeing Commercial Airplanes (BCA), the division of The Boeing Company that builds internationally famous airliners, created responsibility centers. This was done to focus attention on major segments of the airplane by having all of the functional areas required to design, build, and service in one organization. Wings and empennage (the tail sections) constitute such a segment, and make up the Wing Responsibility Center (WRC).

The WRC is accountable for all aspects of designing, producing, and supporting wing and empennage components for BCA. In doing so, the WRC is also responsible for the quality, cost, and delivery of these products, as well as the safety and morale of its employees [2].

The customers who benefit from these products and services are the 717, 737, 747, 757, 767, and 777 airplane programs.

The WRC is located at several plants in the Seattle, Washington area and also in Toronto, Ontario, Canada. The organization consists of about 6000 employees, most of whom work directly on the factory floor.

The WRC’s goal is to help the airplane programs meet their production targets. To accomplish this goal, the WRC web site was created as part of the Boeing Intranet.

2. Purpose

The original purpose of the WRC Web site was to give a comprehensive view of the factory status on a daily basis and to provide the primary means of communication between the vice-president and his management team. Later, enhancements to the site enabled all levels of management, employees, and internal suppliers to see the same information.
Additionally, it was anticipated that this manner of information sharing would reduce travel time along the 77 mile interstate highway corridor between WRC locations, as well as allow employees from the Toronto plant to participate in meetings held in the Seattle area. As a result of this site, the days of chart-lined visibility rooms and meeting attendees laden with stacks of status printouts and view foils are dwindling. In addition, WRC management can instantly post critical information to the home page when it needs to be disseminated quickly. For example, during an emergency (an injury to a worker, severe weather, a volcanic eruption, etc.) employees can look quickly to a ‘panic button’ link on the home page for instructions.

3. History

The site went online in the fall of 1996 as a set of static pages and was completely redesigned by the Web team in the winter of 1996 in response to new customer requests. A process has been followed to enhance the site and solve problems encountered in daily operation, for example, when content providers break links to their files on a server. When a linked file is moved, renamed, or deleted without prior coordination with the Webmaster, a broken link results. Two of the Web applications covered later in this paper were written to solve this problem. Much of the site is now interactive and uses a combination of tools the Web team has selected and assembled.

Tool selection is based on customer requirements. Table 1 details some of the requirements and the tools ultimately chosen to support them.

4. Design

Initially, the WRC Web team decided to use frames to make the navigation more consistent and the menu entries easier to update. Frames also simplify the design scheme for many of the content providers by wrapping the site navigation around their Web pages. In addition, most of the requirements for posting to the Boeing Intranet are included in the frames documents so the content providers do not have to consider them when designing a page.

The WRC home page has two menus. The menu on the left side is set up to follow the same hierarchy as the WRC organization chart. Since each WRC location has unique information, the left menu on each location’s home page changes, depending on which part of the site the end-user is viewing. The second menu can be found at the top of every location’s home page and always remains the same since it contains information common to all the sites.

A style guide was set up to encourage a similar look and feel across all the sites. For example, the background color, menu colors, fonts, and link colors are all covered in the style guide.

Eventually, a series of drop down boxes containing the same information found in the top and left menus was added to the home page to provide another way to navigate the Web site.

5. Current state

The WRC Web site now has over 3000 pages and averages 782 user sessions (37,229 hits) every weekday. The average user spends about 18 min on the site. The site was designed with few formal controls to allow for individual creativity. Because of the lack of constraints, the page count grew exponentially. End-users went from seeing the Intranet as a toy to using it to daily access a library of information that helps them perform their jobs.

This Web site is a vital, dynamic, working tool and provides the whole engineering to manufacturing perspective. For example, legacy applications now have Web interfaces for engineers, parts are ordered using a Web paging system, machines are monitored by an attached online system, and the factory status metrics are available 24 h a day.

6. Web applications

Several applications were developed to provide extra functionality to the WRC Web site. For example, ‘Vital Measures’ was the outcome of the former vice-president’s desire to see real-time data on the health of the WRC; OEE (Overall Equipment Effectiveness) was developed to visually show the real-time status of factory machines; the SHEA
### Table 1

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Tool</th>
</tr>
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<tbody>
<tr>
<td>Create a Web page of dynamically generated thumbnail charts enabling the customer to quickly scan the health of the WRC and to drill down to a larger, more detailed chart.</td>
<td>Microsoft® Active Server Pages technology includes VBScript, a subset of the Visual Basic language designed to run ‘in the box’ on the browser without I/O capability. The similarity between the two languages, and the use of Microsoft® Access to build initial back-end databases, made it easier for our experienced Windows application developers to learn how to develop Web applications. Software F/X’s ChartFX (an ActiveX control useful for producing charts from a database) had just been released as well, so we chose Microsoft® Internet Information Server (IIS) as our Web server platform.</td>
</tr>
<tr>
<td>Find a search engine that could scan the Web site and additional data repositories not linked to any Web page, and produce a catalog of all HTML, Microsoft® Office, and Adobe® Acrobat® files found.</td>
<td>The Web team was also interested in the possibilities offered by personalization so Microsoft® Site Server was selected as the search engine.</td>
</tr>
<tr>
<td>Provide a ‘chat room’ that is capable of threaded messaging so employees from different time zones and/or different work shifts can communicate with each other on a variety of topics.</td>
<td>After researching products available at the time, O’Reilly® WebBoard™ was chosen because of its easy administration, live chat capability, threaded messaging, archiving options, and cost. WebTrends® and Tetranet’s Linkbot™ were picked to help satisfy these requirements, based on product cost and features.</td>
</tr>
<tr>
<td>Analyze the Web server’s logs, and find and fix broken links.</td>
<td>When IIS 4.0 was released, we were already using an ASP SMTP mail component, but discarded it in favor of the component now included with IIS.</td>
</tr>
<tr>
<td>Provide the ability to send e-mail notifications through any Web application.</td>
<td>At first, a commercially available Java applet with an expandable menu listing was selected to perform this task. However, it was slow to load and sometimes would not load at all when the server was running with high processor utilization (we have not been able to determine the reason). The applet was then phased out and replaced with a new menu based on JavaScript functions.</td>
</tr>
<tr>
<td>Provide a menu for the site that includes a long list of links without overwhelming site visitors.</td>
<td>(Safety, Health and Environmental Affairs) application implemented a WRC-wide standard process for the first time; ‘Part Paging’ allows a paging request to be sent over the Web to retrieve a needed part from storage; and both the ‘Web Link Checker’ and ‘Database Grid application’ were created to deal with the problem of broken links.</td>
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</table>

### 6.1. Vital Measures application

The vital statistics of the WRC — items such as how many wings were delivered during a given week, the number of engineering releases, and the current staffing level — give a detailed picture of our manufacturing organization’s health in real time. The Vital Measures application makes it easy to see these critical statistics and includes a thumbnail view of all the measures for a quick scan of data trends, as well as the capability to drill-down to a more detailed view of the data.

Fig. 1 shows sample measures, one per row, for all of the airplane models Boeing builds in the Seattle area. The database-driven, thumbnail-size charts for Measures 1 and 2 show the trend of the latest data for each measure. Image files, colored green, yellow, or red, show the overall health of that measure for all of the models, both for the current period (usually week or month) and the previous period. The information for these database-driven measures is input through Web pages on the site.

The charts are created with the ChartFX software package listed in Table 1; ChartFX is a commer-
cially available C++ ActiveX control installed on the WRC Web server. VBScript Server Side Includes were written to set and invoke Chart FX objects, properties, and methods to create the desired charts.

Icons for Measure 3 are linked to chart files, such as Excel charts. The key icons for Measure 4 indicate that file viewing is restricted by NT ID permission to particular end-users. Clicking on Measure 1’s thumbnail chart for the 757 provides more data on the 757 airplane model (Fig. 2).

The blue vertical bars in Fig. 2 show the actual Measure 1 data by week. The middle green horizontal target line indicates where the data numbers should be, showing in this case that the data numbers were originally too high but the problem has been brought under control. The top red and bottom magenta horizontal lines (above and below the green target line) show the upper and lower control limits for statistical process control purposes. The links in the first row beneath the chart access similar detailed charts for the other airplane models and totals for the single-aisle and twin-aisle airplane programs. Other rows (not shown) provide links to the pages for other WRC health measures.

6.2. OEE application

The OEE (Overall Equipment Effectiveness) system records machine set-up, run, and loss time, effectively measuring asset capacity, efficiency, availability, and quality. When combined with TAKT Time (actual customer demand for product based on planned production time), OEE can be used to determine how effectively an asset (in this case a machine tool) produces a product and the number of assets required to meet customer demand. Improving OEE results can dramatically decrease the number of assets required to meet current flow-through requirements and eliminate or reduce the need to purchase more equipment to meet future increases in customer demand [1].

The OEE machine status interface shows the real-time state of individual machines using colored circles (green = running, blue = idle, yellow = idle with a reason, red = stopped) and is automatically updated. It also provides additional information, such
as time elapsed since the machine entered the current state, job and part numbers, loss code descriptions, and shift status.

Data input, capture, and analysis are for the most part done automatically, although a small amount of data is input manually. For example, the OEE system automatically records whether a machine is running or is stopped. When the machine is stopped, the operator can then input the reason using a computer on the factory floor. Depending on the setup, the operator either selects the reason from a drop down menu on the OEE interface or wand over a bar code.

Lights attached to the machines are wired into the OEE system and are used as visual aids, supplementing the status provided on the Web site.

The OEE system can page one or more people as needed. For instance, if a machine is stopped, a supervisor can be notified of a potential problem or a maintenance person can be called for repairs. Supervisors can use the system to more efficiently allocate the available resources. If one machine is stopped because no work is available for it and another machine is stopped for set up, work can be diverted to the first machine.

Using the OEE system, the machine operators can view the status of the machines around them. For instance, the operator of Machine B, which receives parts from Machine A, can check the status of Machine A and plan work accordingly.

Charts displaying the data captured are also available via a Web interface, allowing anyone with a browser to view them. Analyses of these charts point out opportunities for better capacity utilization, such as restructuring the number of employees assigned to different shifts and decreasing the set up time. Employees used to spend as much as four to six hours summing up a week’s worth of data for just one machine; now it takes just five minutes [3].

Fig. 3 is a sample screen print of the OEE system.

6.3. SHEA application

Safety, Health, and Environmental Affairs (SHEA) data are tracked by safety focal at each
Boeing plant location. If a SHEA-related incident occurs (e.g., a WRC factory employee becomes injured), the incident information is entered into a form using the SHEA application (Fig. 4).

Partial information about a safety-related incident can be input and stored until all the data have been gathered, at which time the incident data are submitted to the database. Then, the general supervisor listed to be notified is automatically e-mailed a message of the incident. These notification rules are also updated through the application. In addition, incident data can be searched for and revised once more accurate information is available.

The SHEA application charts data in several ways, using the Chart FX ActiveX charting tool. Many combinations of data fields can be used to produce the charts, such as factory location, injury date, control code, etc. (Fig. 5).

6.4. Part Paging application

This Web application automatically pages the appropriate workers in the factory when parts or part information is needed. Previously, workers had to manually locate the specific routing for each part and ensure that both a primary and backup person were notified of a part request. This application automatically provides the correct information and has significantly reduced flow time. Wing assembly parts or information about the parts, such as build work orders and details, replacement work orders, and Kanban (visual aid) cards, can be requested through
the application. When the form on the application’s Web page is submitted, a message is sent to the pager of the attendant at the parts storage area. Pages sent to initiate an order process may be delivered to several individuals or queues so no more requests are lost in the mail or forgotten.

6.5. Web Link Checker application

Content providers with little knowledge of the Web or computers are often asked to post information to the WRC Web site according to documented roles and responsibilities. Unfortunately, this situation produces a major problem — broken links caused when the content provider moves, deletes, or renames a file. The Web site is so large that it is difficult for the Web team to know when broken links occur. The content providers often do not know why their actions break links or how to correct the problem.

To solve this problem, a Visual Basic application was written that checks the Web pages twice a day for broken links. If a broken link is found, e-mail notifications are automatically sent to the designated content provider and the Webmaster.

The notification includes the URL of the broken link, the URL of the Web page on which the link is located, and the name of the link as it appears on
the page. The Web Link Checker increases visibility of broken links and allows Web team members to pinpoint the source of the problem, ensuring that it is fixed quickly. Once the notification system was put in place, the Web team began work on a solution to prevent the occurrence of broken links, called the Database Grid application.

6.6. Database Grid application

This application tracks and displays a grid of links to files found on a specified NT server share. A share on any NT server in the Boeing network can be used for this application as long as the share is established as a virtual directory on the WRC Web server.

The Database Grid application allows content providers to create or update Web pages without having to know HTML or a Web page authoring tool. The content providers simply drag and drop files within a server share, eliminating the chance of breaking links by adding, deleting, or renaming folders, subfolders, or files.

The advantage this application provides over enabling directory browsing is the ability of the user to quickly see the context each file falls into among the categories and subcategories. In addition, the use of directory browsing is discouraged within the Boeing Company for security reasons.

Fig. 6 displays the files that are found within a set of folders and subfolders in a sample share (‘Initiatives’) on an NT server. Its folders and subfolders correspond to the rows and columns of the grid, an HTML table with cells containing ‘crosshair’ image files.

When a file is found in a particular subfolder, the
crosshair image file corresponding to the file’s extension is displayed in the table cell at the intersection of the grid row and column. The image file contains a blue oval and indicates the format of the file (e.g., DOC is a Word file, HTM is a Web page, etc.). If no file is found, an image file of only the crosshair lines is displayed.

If more than one file is found within a subfolder, an image file that says ‘MULTI’ is displayed in the corresponding grid table cell. A Web page listing the multiple files as links is then generated from the database.

Fig. 7 shows the Web page produced when five files are found within the ‘717’ subfolder of the ‘Initiative 1’ folder. A linked crosshair image file is shown to the left of each file’s name.

The only limitation on the use of the Database Grid application is that each folder must have a similar set of subfolders. For example, Fig. 8 shows the subfolders set up within the ‘Initiative 1’ and ‘Initiative 2’ folders.

The grid page is produced from a database periodically updated by a Visual Basic executable. This program runs as an automatic service on the WRC Web server. The service runs continually through a set of shares specified in the database and updates the database with the folders, subfolders, and files found on each share in each pass.

The Database Grid application code is currently being enhanced to show multiple levels of matrices through the use of a ‘MATRIX’ crosshair image file. This will enable the grid pages to handle multiple levels of folder and file hierarchy.

7. Tools used to accomplish Web site goals

In addition to the Web site and its applications, organizational tools were established to ensure the success of the site and promote communication. A good combination of software also contributed to the Web site’s success.

7.1. Web team

The WRC is spread across six different locations, with plants in Washington and Canada. When the Web site was first launched, it focused on providing
information for the executives. Because each of the current six locations produces different products, it became apparent that each needed to have its own section of the Web site. To facilitate communication with the primary customer of the Web site, employees from each location who understood the business processes were invited to be Web team members.

The WRC Web team members work toward commonality, and exchange information about ongoing projects and new technology. No one is required to attend, but people do because the work is significant, creative, and fun.

Team members include a Webmaster, a Web application developer, and a site focal from each location, as well as a project manager to organize the group, a graphic artist, and a Web server administrator. Team members determine the architecture of the Web sites and the standards that will be followed, and develop complex Web applications. The Web team members provide the data owners (who actually post and maintain the data on the Web site) with both the tools and the means of publishing to the Web, and also guidance and training.

The Web team is given high-level direction by WRC management but allowed creative license on lower-level design content. All employees are encouraged to make their line of business information and processes generally available by posting them to the Web site.

7.2. Software tool kit configuration

The software tool kit configuration is shown in Table 2.

<table>
<thead>
<tr>
<th>Software tool kit</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Adobe Acrobat®</td>
<td>Microsoft® FrontPage®</td>
</tr>
<tr>
<td>Adobe Photoshop®</td>
<td>Microsoft® GIF Animator</td>
</tr>
<tr>
<td>Allaire HomeSite™</td>
<td>Microsoft® Internet Information Server (IIS)</td>
</tr>
<tr>
<td>HTML 4.0, VBScript, Visual Basic, JavaScript</td>
<td>Microsoft® Office</td>
</tr>
<tr>
<td>IIS SMTP Mail Component</td>
<td>Microsoft® Site Server</td>
</tr>
<tr>
<td>Macromedia® Dreamweaver™</td>
<td>O’Reilly® WebBoard™</td>
</tr>
<tr>
<td>Macromedia® Flash™</td>
<td>Software FX ChartFX Internet Edition</td>
</tr>
<tr>
<td>Macromedia® FreeHand™</td>
<td>Tetranet Linkbot™</td>
</tr>
<tr>
<td>Microsoft® Active Server Pages</td>
<td>WebTrends®</td>
</tr>
</tbody>
</table>

8. Future

The spring of 1999 brought new management into the WRC and with it a new vision of how the Web site should look. Web technology has matured, providing reliable solutions to fulfill several new customer and Web team requirements, including making more information visible at the top level pages. This will reduce the number of mouse clicks needed to access the data, and give end-users insight into the information available under each menu heading. The future vision is to show a new, united WRC, with more focus on The Boeing Company.

To this end, the Web team is implementing a dynamic HTML-based home page, including numerous navigational improvements. Fig. 9 is a sample view of the new WRC home page.

The action of moving the mouse over any entry in the top or left menus loads a new page into the lower right portion of the screen. In applying this technology, we have overcome technical difficulties such as slow page loading upon a mouseover event. Mouseover-based loading was chosen as the best alternative to avoid initially loading 22 pages at the same time; however, this alternative needs work and the Web team is refining this solution.

9. Results, benefits, and lessons learned

The main result of the evolution of the WRC Intranet site has been the simplification of page creation and maintenance by end-users, and the quick detection and prevention of broken links. Valuable Web applications which save time have been created in response to customer requirements and needs. As
a result of this site, much of the work of creating charts to status organizational measures has been eliminated. Now the data are available 24 hours a day, seven days a week in one easy-to-access, central location. WRC management can quickly post critical information for organization-wide dissemination.

The WRC’s initial Web site successes often had to do with providing some incentives, such as a fun experience, recognition, prizes, and/or awards. In the early days it was especially important because it was difficult to get the message out that the Web site was now the primary means of communication. Several feedback forms and surveys were tried but received few responses. The Web team learned how to creatively work with content providers and end-users to ‘turn them on to the Web.’ When new Web products came out on the market, our Webmaster designed on-site classes for employees so they could learn the latest technology and receive company-recognized training credits. The Web team also learned that those who worked daily with the content providers had the most success getting them interested in Web work. ‘Fun and familiarity’ were key words to working with our customers.

An extremely popular part of the Web site, the WRC scavenger hunt, was created as part of our second survey attempt and featured a prize drawing for participants. 543 people logged on to the hunt, and 188 left their contact information to be eligible for the drawing. End-users were asked ten questions about specific areas of the Web site (each question was displayed along with the appropriate area of the Web site). Once the contestants answered all the questions, they were able to view dynamically generated pie charts comparing their score to previous contestants. This particular survey allowed the Web team to showcase new technology and introduced our end-users to different areas of the Web site.

The lessons learned include obtaining signed off customer requirements for significant site changes, keeping content up to date when providers are assigned to other duties, providing incentives for customer participation, and coordinating the content providers’ changes to links and pages. The Web
team’s goal is to create as simple a customer interface as possible. All of these lessons have helped the WRC Web team make the site and its applications work daily to support the people who build the wings for Boeing airplanes.

Acknowledgements

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References