

OOPSLA 2000 Practitioner Reports

Title: "Application Integration Framework for a Large Business Process Redesign Project"
Author: Jon Sholberg
Subject: Accompaniment for OOPSLA 2000 Practitioner's Report Presentation

The Boeing Company – Commercial Airplane Division

The Boeing Commercial Airplane Group (BCAG) is the world's largest producer of commercial jetliners. BCAG has about 290 customers including airlines, leasing companies, governments and private firms. Boeing provides a complete product line of 29 airplane models to serve every passenger market from 100 seats to nearly 600 seats, as well as a complete line of freighters.

Define and Control Airplane Configuration / Manufacturing Resource Management (DCAC/MRM)

DCAC/MRM is a "breakthrough" initiative that will improve the processes the company uses to produce airplanes and further reduces costs, cycle time and defects. DCAC/MRM will significantly enhance the company's ability to deliver more value to its customers.

DCAC/MRM will simplify and improve internal processes for handling airplane configuration data. These processes will enable BCAG to generate the data defining a customer's requested configuration for an airplane to meet their particular requirements. Data such as the type of seats, galleys, lavatories, carpet, avionics, and engines will be used to turn a "basic" airplane into a customer's individually configured airplane.

Manufacturing Resource Management (MRM) will simplify and improve the manufacturing processes that are driven by the airplane configuration data.

DCAC/MRM has four main activities:

First, DCAC/MRM will create a simplified business system for handling the flow of parts data by grouping the parts in modules (a collection of parts, plans and tools). The modules will be grouped according to "tailored business streams," depending on their degree of variability. There are three business streams: basic and stable for the parts that are used on each airplane model; available options for parts we have already engineered and delivered to the customer (e.g., galleys) and unique options or newly designed parts that have never been certified and delivered before. An airplane will be configured by grouping existing modules together with any new modules designed for that particular customer.

Second, DCAC/MRM will simplify the current configuration management process within BCAG. Today's "effectivity" system -- the process by which a customer identification code is assigned to engineering drawings -- will be replaced with a new, automated system of configuration control based on a unique airplane identifier and modules. Each airplane will be

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assigned an aircraft identification number (like an auto Vehicle Identification Number) that will be used to identify all the airplane's parts by part number.

Third, DCAC/MRM will develop a single source of product data (SSPD) for each airplane that includes a "single bill of material." The data will be structured in such a way that everybody who needs it will have access to it. Each functional group will use flexible computing application programs that will allow them to extract only the data they need in a form that will be most useful to them.

Fourth, DCAC/MRM will take advantage of the tailored business streams to implement in the factory environment new, simplified methods of tracking and ordering parts, scheduling production, and managing inventory for each business stream.

The new DCAC/MRM processes are planned to be fully implemented in 2000. This will greatly streamline and simplify major processes within BCAG and transform the content of many jobs.

The DCAC/MRM project is the largest re-engineering project of its kind and unifies our people around common processes, simplified systems, and accurate data. Employee teams can now eliminate non-productive work, select the right process for each job, and understand their contribution to our products.

Computing Systems

The various applications employed by DCAC/MRM reside on Hewlett-Packard application servers, utilizing database services on IBM Numa-Q data servers, at 77 work sites throughout the company. The DCAC/MRM system architecture and software are designed to support up to 65,000 employees using PC and UNIX workstations. All the information needed to configure, define, produce, and support Boeing airplanes is represented by the SSPD, which replaces 410 internally developed computer systems once used throughout the company. However, integration is still required between DCAC/MRM and some of the existing production systems running on mainframe computers (MVS, IMS, VMS, etc.).

Third Party Systems

In November of 1994, the Program Technical Advisory Board (PTAB) was formed to direct application and technology integration. This board is comprised of senior technical representatives from Boeing and representatives from the following strategic vendors: Baan, CIMLINC, HP, IONA, Oracle, SDRC, IBM, and Trilogy. This board meets quarterly to discuss the strategic direction of all of these partners to ensure the continued success of the program. Also, the CEOs of the vendor partners meet with Boeing senior management on a quarterly basis to discuss the partnership.

In addition to senior level technical and management involvement, there is a tactical on-site product manager and technical team for each partner to help with the vendor-specific technology.

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Project Information

Early in 1994, Boeing Commercial Airplanes Group President Ron Woodard initiated the DCAC/MRM process improvement effort. DCAC/MRM is a “breakthrough” initiative that will improve the processes BCAG uses to configure and produce airplanes and is the single largest opportunity to further reduce costs, cycle time and defects. It will significantly enhance Boeing’s ability to deliver more value to its customers.

Production

The first production release of DCAC/MRM was for parts fabrication plants in February 1996, integrating three of the COTS systems: Enterprise Resource Planner (ERP), Product Data Manager (PDM) and Computer Aided Process Planner (CAPP). This release only required a handful of communications between systems. In response to this, each system’s Application Program Interface (API) was encapsulated by a single CORBA object; this was accomplished using IONA’s Orbix product. This initial integration architecture was not designed for the total system. Rather, it demonstrated the use of technology to meet the company’s business needs.

With each release, more systems are being integrated, and more communications between systems exist. Because future releases are expected, and more systems with more communications will be integrated, a scaleable architecture is required.

In 1996 and 1997 19 parts fabrication plants went into production.

In 1998 and 1999 major components of Define (DCAC) went into production

The next release will provide the assembly and installation plants with the MRM processes, and a significant part of this release will be complete by mid-2001.

Workstations

- 26 IBM NUMA-Q data servers
- 162 HP K570 and K460 application servers
- 40,000 PC and Sun workstations

Tools and Languages

- C Used within COTS applications
- C++ Used within Application Integration layer
- Perl Used within COTS applications and Application Integration layer
- Tcl Used within COTS applications and Application Integration layer

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- Java Used within COTS applications and Application Integration layer
- Rational Clearcase Used within COTS applications and Application Integration layer
- Rational Rose Used within COTS applications and Application Integration layer
- Paradigm Plus Used within COTS applications and Application Integration layer
- HP Softbench Used within COTS applications and Application Integration layer
- HP ITO Used in the System management component of Application Integration layer
- Boeing Internal Web Used for development efforts, to share electronic files, provide documentation, and deliver training. We deliver more than 30 percent of our business process training via the Boeing intranet

Commercial-Off-The-Shelf (COTS) Products

DCAC/MRM is emphasizing the use of COTS software packages, for prime business processes.

Baan's ERP (Enterprise Resource Planner) has been selected as the enterprise resource management component.

SDRC's Metaphase has been selected for Product Data Management (PDM), which will manage the configuration and versioning of engineering releases.

CimLinc's Linkage Computer Aided Process-Planning (CAPP) has been selected for manufacturing process planning.

SalesBuilder, by Trilogy has been selected to offer basic and optional equipment to airline customers.

IONA Technologies Inc. has been selected to offer the Object Request Broker software and CORBA compliant services for our Application Integration framework.

RogueWave Software is used for C++ class libraries in some applications.

Oracle RDBMS is used for database services, and for linking application and data servers.

Client Server Model

The DCAC/MRM system is based on open standards, client-server computing, and commercial off-the-shelf software applications. The application architecture is based on the use of emerging standards defined by the Object Management Group and a combination of Object Request Broker and the Messaging Oriented Middleware technologies. The delivery system is a multi-tiered, client-server architecture consisting of data servers, application servers, and a variety of desktop devices. The systems management architecture is based on a centralized help desk that activates

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various levels of technical assistance using internal and external resources. The help desk uses a detailed set of procedures and a suite of systems management tools.

Custom Application

DCAC/MRM represents a radical overhaul of the way we use information technology. It integrates complex, flexible data sources, so our users find information easier to access than in the past. Using distributed computing technology, the resiliency of DCAC/MRM allows our business practices to evolve in our constantly changing environment.

We avoided creating systems with rigid business practices built into them. The systems integrated by DCAC/MRM can change rapidly in response to external issues, such as market and government requirements. The challenge was to integrate software applications that had not been designed to work together into a cohesive, easy-to-use system.

The Application Integration project is chartered with producing the architecture and designing and building the integration layer that allows Commercial Off-the-Shelf Software (COTS) application packages and existing Boeing production systems to interact under the guidelines of CORBA standards.

The Application Integration mission is to integrate multiple, diverse applications within a heterogeneous computing environment in a de-coupled, cost effective, flexible fashion with maximum reuse and assurances of data consistency.

We succeeded by using a loosely-coupled integration approach. Every software package maintains its individual integrity. We incorporated the packages into DCAC/MRM by creating standardized "plugs" that allow us to remove or upgrade one package without disrupting the whole system.

The "application integration architecture" at DCAC/MRM is based upon CORBA. It defines a set of business objects, facilities and services necessary to enable the integration of our diverse business applications, each with varying requirements. For instance, COTS components will support event-based communication, security, transactional interfacing and enterprise-level system management under the umbrella of CORBA specifications.

The distinguishing feature of this architecture is the integration mechanism partitioned around "integration business objects," instead of having a single object encapsulating the entire component system. The integration business object concept is supported in this architecture by a client side View (stub) and server side Portal (skeleton). The View/Portal pair combined form a single integration business object. The View/Portal pair are designed to enable the application of integration services such as support for asynchronous communication, routing, auditing, etc.

Unfortunately, simply providing a set of integration business objects does not meet all application integration requirements. First, the integration code is written in C++. Not all component systems, including COTS and legacy systems, are written in languages that allow

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direct invocation of C++ member functions. This introduces the notion of adapters. Client adapters are technology bridges that provide a method for a component application programmer to invoke on a C++ member function in the application integration code. Server adapters are necessary for the same reason. Technology bridges will be put in place wherever they are required.

Auditing and system exceptions are handled from within the View and Portal. Auditing addresses data integrity issues in the distributed system. Auditing simply means that messages passed between component systems will leave behind a persistent set of "audit trail" records. By matching and resolving audit trail records, potential data integrity errors can be identified.

Asynchronous communications and fan out (publish/subscribe) are handled using OrbixTalk from Iona. This service enables one application to send a message to a second application without waiting for a return message. In addition to providing asynchronous communication, the application integration layer provides a guaranteed message delivery capability by using MOM technology from IBM.

An integration business object in this architecture is a CORBA object that represents a business concept such as a Process Plan or Bill of Material. An example of usage of integrated business objects would be a manufacturing engineer using the CAPP application to access Bill of Material and Part information from the PDM application to build a Process Plan. The business objects are expressed in the Boeing Common Object Model, which was introduced as part of the BPR effort.

Representing application integration in the form of business object interactions has a number of distinct advantages:

- It enables the integration technology to reflect the business process, thus providing a more intuitive understanding of how the business is being supported;
- It promotes improved communication between business process and integration teams
- It improves overall system adaptability to business changes, promoting an improved competitive posture
- It results in reduced software maintenance cost, production support, and maintenance cycle time
- It demonstrates a commitment to object-oriented technology (which may inspire COTS vendors to be more object-oriented)
- It represents a significant step toward a long-term application integration architecture, one that is flexible and provides the ability to grow and adopt newly emerging technology.

Distributed-object technology was our key enabler. Applying the OMG Common Object Request Broker Architecture (CORBA) led us to an innovative system integration approach that helped us design a reliable information system with great flexibility. We were one of the first end-user members of OMG and the first to investigate and prototype the use of distributed-object technology in a large-scale, complex manufacturing environment, deployed over a widely

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distributed network with a diverse set of users. Of the approximate 1 million transactions per day, over 125,000 are COTS-to-COTS and are processed by the CORBA integration layer.

Current DCAC/MRM Deployment: (after end of September 1998, release)

- 38,000 users
- 19 Parts Plants MBUs
- 20 remote sites

From phase to phase, we added large numbers of users and largely because of the CORBA architecture, we were able to add hardware without changing code to support this scaling.

Phase I	25,000 users
Phase II	30,000 users
Phase III (current)	38,000 users

In summary, our architecture and technology selections have allowed us to add more users, more sites and more functionality. All of this has happened without experiencing the debilitating impacts that changes to projects of this scale normally endure.

Benefits

Quote from previous BCAG President Ron Woodard:

“We’re the world’s leading producer of commercial jetliners, and we’ve used the skills and talents of our employees to make our complex, costly and outdated processes and systems work over time. We have to implement DCAC/MRM because it will give us simpler, more efficient ways of configuring and building airplanes – and do it at much less cost.”

Quote from DCAC/MRM Vice President Bob Hammer:

“Our airplanes are modern, state-of-the art and best in the world. I’m afraid we cannot say the same about our business processes and systems. Today, we have an army of people who do nothing but check and recheck the data in our systems to make sure it’s accurate. We want to substitute our current systems with a system that provides reliable, accurate data in the first place.”

Since the 1940s, when The Boeing Company pioneered the mass production of large airplanes, we have built on our tradition of engineering and technical excellence. Over the decades, this tradition established us as the world’ s leading manufacturer of large jet airplanes. Our engineers used the latest technologies to develop innovative airplane components and systems driven by customers’ needs. Our competitive dominance continued, but it was based more on technologies applied to airplane component design than on efficient processes and systems.

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In the 1980s, we recognized that the business systems we used to manufacture airplanes had not progressed as quickly as our airplane technology had advanced. Although we made several attempts to improve our processes, progress was slow -- largely because the proposed improvements were local rather than company-wide. It was clear that, to maintain our market position and keep a stable, well-motivated workforce, we needed to revolutionize the way we do business.

We studied other companies around the world and realized that to stay ahead of our competition, we had to plan for the future. Our processes had to be flexible enough to evolve as the market changed. At the same time, we needed to reduce production costs and defects by at least 25% and time-to-market by 50 percent while completely satisfying our customers.

Before the 1996 implementation of DCAC/MRM, the very size of our company was a detriment to its efficiency. The Boeing Company had grown and divided into separate organizations, each with its own products, goals, and objectives. Business processes and interlocking information systems evolved to meet the needs of these organizations instead of the needs of a unified Boeing enterprise. We used more than 800 computer systems to design, manufacture, control, and support airplane components and assemblies. Most of these systems were aligned according to function, were not integrated, and did not communicate with each other. To add to the complexity, some of these systems were as much as 40 years old.

Our complicated processes and systems required new design and planning every time we built an airplane even though up to 75% of the airplane components are common to all airplanes of the same model. Furthermore, the list of components, or bill of material, created for each airplane had to be converted for, or manually re-entered into, as many as 14 bill-of-material systems.

Compounding the problem was a configuration control system that assigned a customer-specific identification number to each engineering part drawing. Even when parts did not change, drawings had to be changed, in some cases, dozens of times. Of the engineering time spent revising a drawing this way, the majority of the effort, in many cases, added no value to the final product.

Under DCAC/MRM each piece of data within the company is owned, managed and updated in one place -- thus creating what Boeing calls a SSPD. Rather than airplanes being associated with parts, parts are now associated with airplanes. The latter approach is made possible through the elimination of the traditional part-drawing storage system. Storing part details within the SSPD allows Boeing to keep track of parts while also maintaining details of individual airplane designs. The integrated system will reduce the time spent designing and building airplanes while providing improved services to sales, engineering and support staff who require easy access to specific airplane configuration details.

DCAC/MRM allows our employees to access data much faster than before. People share access to information and recognize how their work contributes to the company's business of building airplanes. When a customer or a supplier has a question about a component that involves more than one manufacturing or assembly unit, a Boeing employee can find the answer quickly by

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accessing the SSPD. Our sales representatives use SSPD to help our airline customers understand exactly what factors affect the cycle time, weight and cost of producing an airplane.

Early on, Boeing made a decision to integrate its chosen software packages with CORBA. This approach allowed the project to make rapid initial steps by avoiding extensive application-level revamping and allowed Boeing to take full advantage of its decision to buy instead of build. As a result, Boeing was able to establish communication between its various applications in a decoupled manner while allowing the applications to remain autonomous.

This new architecture will contribute to the reduction of the product development cycle of 24 months to only 6 months. Furthermore, the more cohesive nature of the solution means less error and a more flexible development environment. The ability to add components quickly and easily to the system will allow Boeing to respond rapidly to market demand. Boeing will gain the added benefit of being able to quickly and easily design new planes according to customer requirements. Largely due to the planned integration of sales and engineering data, DCAC/MRM will allow Boeing to customize planes according to three business streams, covering minor changes to major new development. Sales staff are able to check designs against the parts database and send potential designs from remote locations. We can provide airplane components just in time for installation and create a single bill of material for each airplane, rather than the multiple bills. This will reduce inventory buildup, and conversely, decrease the impact of shortages which cause production slowdowns.

In summary, the evolution of information system technology allows us to leverage that technology and apply it to our manufacturing environment on a massive scale. Because we can now apply this advanced technology, we are making a significant contribution to our goal of reducing by 50 percent the time between initial negotiations with our customers and the delivery of a finished airplane.