PLM: Boeing's Dream, Airbus' Nightmare

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By Mel Duvall and Doug Bartholomew

Seattle, Tuesday, Oct. 3, 2006 – Half a world away, Airbus chief executive Christian Streiff had delivered a speech announcing that the company's A380 superjumbo would be delayed by at least two years. The delay and resulting changes to the program were expected to cost Boeing's fiercest competitor as much as $6 billion in lost profits. The cause, Streiff said, was due to compatibility issues with the sophisticated computer-aided design software used by engineers to architect the A380.

Airbus engineers in Germany, where the plane's rear fuselage section was being built along with the hundreds of miles of electrical wiring that power the main cabin, were using an older version of Dassault Systèmes' trademark Catia computer-aided design software—version 4. Engineers in Toulouse, France, where the A380s were being assembled, were using a newer version of the software, Catia V5.

When the first wiring bundles, large packs of preconfigured wires to power everything from lights to in-seat entertainment systems, began arriving at the assembly plant in Toulouse last June, Streiff said they didn't fit properly from the rear section into the front section of the fuselage. Workers tried to pull the bundles apart and feed the wiring through the fuselage by hand, but with 300 miles of wire and some 40,300 connectors on each plane, the immensity of the problem soon became obvious. An unthinkable blunder had happened—as the computer-aided design files were passed between the different versions of the Catia software, the company said errors occurred. And software experts familiar with the incident say the errors included changes in measurements. Those errors are going to cost Airbus billions.

Boeing was using the very same Catia software from Dassault as a cornerstone of the 787 program. Could the same errors derail the Dreamliner? Boeing believes it has taken the right steps to prevent the same thing from happening.

But others aren't so sure. Like any other large software implementation, be it enterprise resource planning (ERP) or customer relationship management (CRM) systems, there is plenty of room for error. "On paper, PLM looks like it delivers a perfect world," says Robert Bean, COO of Kubotek USA, a Marlborough, Mass., firm that specializes in CAD systems. "But we're not living in a perfect world. And when you're talking about something as complicated as an aircraft, you're dealing with a massive movement of data." The data warehouse for the Dreamliner project, for example, is 16 terabytes.

In fact, Kubotek released a study in October, the same month Streiff revealed the extent of the problems at Airbus, highlighting widespread compatibility problems between different CAD programs. ***The survey, which queried 2,800 CAD engineers, found that 50% of all respondents indicated they had to <u>redesign</u> a new part or tool <u>on a weekly or more frequent basis</u> after 3D models were exchanged between CAD systems, due to errors that were introduced – such as changes to measurements.***

Reward Versus Risk

The missteps at Airbus, and Boeing's own reliance on Dassault's sophisticated software, underscore the reward-versus-risk scenario offered by PLM. The number of modules in a PLM suite varies from vendor to vendor and the industry being addressed, but there are usually three core offerings: a CAD system like **Catia**; a digital manufacturing system, like **Delmia**, which allows companies to simulate how a product will be manufactured; and a product data management (PDM) system, such as **Enovia**, which manages all the data associated with a product, such as CAD drawings and specifications.

Using the CAD software, manufacturers can create detailed 3D models of their products and run those designs through a battery of virtual tests, such as stress, vibration, noise, wind and even crash tests, long before a cent is spent on manufacturing. Using the digital manufacturing software, companies can explore how those parts or components can be produced by simulating the process. Products like Dassault's Delmia help manufacturers determine how many people, robots or other manufacturing resources will be required, whether existing machinery can be utilized or new purchases will need to be made, and whether processes can be automated or will need to be performed manually.

While the PDM piece of the suites is focused on managing the data associated with a product's development, it really forms the basis of a collaboration platform. Using software such as Enovia, companies like Boeing can hand off responsibility for designing parts or components to those partners who will ultimately be responsible for their manufacture. Designs can be polished, and the most efficient and cost-effective methods of production can be determined long before the first length of sheet metal is stamped.

The aerospace industry is far from alone in latching on to the potential benefits offered by PLM. Most Fortune 500 manufacturers, from Toyota (which uses Dassault's complete PLM suite—Catia, Delmia and Enovia) to General Motors (a UGS client), golf club manufacturer Ping (PTC) and consumer goods makers such as Playtex (Agile Software), are at various stages of implementing PLM suites.

Potential savings vary depending on the complexity of the product being manufactured, but some analysts estimate that the time and cost savings on more complicated products can be as much as 50%. That has translated into PLM becoming a hot software category, growing at an annual compound rate of about 8.3%, according to research firm CIMdata of Ann Arbor, Mich. ***In a report released in October, 2006, CIMdata forecast that investments in PLM would grow from about $19 billion in 2006 to $27 billion by 2010.***

But underlying that promise are very real dangers. And the potential pitfalls, such as compatibility problems between different CAD packages, are more common than most chief information officers might admit, according to Kubotek COO Bean. Other challenges include everything from maintaining a current and accurate data warehouse for product information, to ensuring that multiple manufacturing partners have the latest software updates, dealing with user training issues and gaining executive support so that rules can be enforced across department and inter-company boundaries.

The risk is compounded by the fact that companies are basing their product rollouts, and by extension their very businesses, on these platforms. Mistakes can exact a heavy price. Airbus' $6 billion problem offers technology leaders and CEOs a number of stark lessons in what can go wrong in implementing PLM systems. But even more important, Boeing's response to the problems at Airbus, and its own use of PLM on the 787 Dreamliner program, offer guidance on what can and should be done to avoid the same turbulence.

Born in a Storm

Airbus' 2006 nightmare with PLM can actually be traced back to the giant company's difficult birthing process in 2001. Work on the A380 was carved up among four players, so that at its founding in 2001, Airbus had offices and factories at 16 sites spread across four countries and employing 41,000 people. Each country had a level of independence to go its own way when it came to systems and technology.

This lack of strict uniformity of processes and technologies laid the seeds for what was later to grow into an entangled vine of trouble for Airbus. The systems had been set up under the old structure. No one was watching who was using what versions of Catia. It may be a systems issue, but as much as anything, it was a management issue.

Airbus' lax enforcement of a single lingua franca for design was at the heart of the A380's later problems. While there are many ways that different CAD systems, and even different editions of the same CAD programs, can trip up a product's design, those ways become multiplied with the complexity of the end product and the increased number of suppliers creating parts or components for its manufacture.

By contrast, Boeing's management took no chances. Well before Airbus' problem became public, the U.S. aerospace manufacturer had put into place a rigorous set of requirements to ensure that the same edition of Catia was used by everyone connected with the shaping of the Dreamliner.

At least one Airbus manager was well aware of a CAD incompatibility disaster. Martin Horwood, lead engineer for CAD capability development at Airbus U.K., co-authored an article titled "CAD Data Quality" in the May-June 2005 issue of Engineering Designer in which he warned, "With data arriving into the digital mock-up (DMU) from a globally dispersed design community, including industrial partners, suppliers and subcontractors, it is imperative that the CAD data is of the right quality. Failure … will cause the DMU to be inaccurate and not fulfill its task, leading to expensive reworks in real life."

And fail it did. With its German designers creating wiring bundles to fit inside one set of spaces in the A380's fuselage using Catia V4, and the French designers having created the fuselage wiring spaces using the more modern Catia V5, the actual wiring bundles were unable to fit.

Says Peter Schmitt, VP of Marketing at Dassault Systèmes of America, "The $6 billion loss at Airbus was the result of a fairly simple problem that could have been fixed with a fairly low investment." His message was clear: Companies using PLM should make sure they are using the same software package and version. ***"Manufacturers using PLM,"*** *Schmitt adds****, "should make sure everybody is working with the same set of data."***

Although Airbus has remained mum on exactly why the German designers used an older CAD package, most observers believe the reason was simple Eurodollars and Eurocents.

The cost to train the engineers in Catia V5 may have been the sticking point for Airbus that led to the A380's multibillion-Euro design flaw. That's the view of a firm that trains Airbus' suppliers to use Catia. "Airbus made the decision not to migrate Germany to Catia V5 because it would have meant a complete retraining," says Geoff Haines of Cenit Ltd. in Oxford, England. "They decided not to do it for budgetary reasons."

So great is the chasm between the two versions that someone schooled in Catia V4 trying to get up on V5 is similar to a motorist learning to fly an airplane. It takes six months to a year before they become fully proficient, Haines says. "It would be like starting from scratch," he adds. Those unfamiliar with CAD software may be wondering just how two versions of the same software package could be incompatible, or for that matter, require such extensive retraining. The reason is the two software editions differ in their basic treatment of drawings, so the way digital models are created is different.

Both systems are able to represent objects in 3D, but that's where the similarities end. Engineers using Catia V4 must use a manual process to create the geometry of a model. To create a hole inside an object, the system requires them to subtract a cylinder from the space to define where the hole should exist. The product designer using Catia V5 simply feeds in a set of engineering instructions—describing the location and dimensions of the hole—and the geometry is automatically created. "V5 is higher-level, more intuitive," says Doug Cheney, product manager for CAD interoperability at ITI TranscenData, a developer of CAD translation software. "With the older system, the engineer figures out the geometry; with the new one, the system finds the best geometric solution."

Airbus engineers ran afoul of this basic difference when creating the miles of wiring to be inserted inside the A380 fuselage. ***The engineers' "notes"—appendices that describe details of models such as curves—sometimes are not replicated in the translation between Catia V4 and V5. In other words, key notes required to duplicate a 3D model showing electrical wires as they twist and bend through the aircraft may fail to reappear in full and accurate detail when a design file in one system is converted to a file in the other.***

For example, something basic such as the tolerance level of a metal part, noted by an engineer in the appendix to a 3D drawing, may be left out when the model is converted from one system to another. The result can be that the manufacturer—or a supplier—may produce the part to the wrong tolerance.

In addition, units of measurement, when carried over from one CAD system to another, can create havoc for designers, says Brian Barsamian, president of V5 Engineering, a

Newport Beach, Calif., firm that trains engineers to use Catia V5. "There was a complete rewrite of the code from V4 to V5," he says. "You have to be careful to set parameters defining whether you are exporting metric units or English units; otherwise, a 1 millimeter part can become 25.4 millimeters, because it sees 1 millimeter as 1 inch."

Still, most CAD vendors offer their customers a smooth path to convert their data from an earlier version to a new one, according to Prawel. "Every vendor does a good job of backward compatibility, except Dassault," he says. "Why some of the biggest aerospace companies and automotive manufacturers in the world didn't force them to do a better job of backward compatibility is a mystery to me. Now Airbus is paying the price." ***To solve this problem, Prawel says many Dassault customers have decided to start from scratch to re-create, or remaster, the data in all their existing models in Catia V5 because of its lack of smooth interoperability with the earlier version.***

Dassault owns up to the programs' dissimilarities, and the potential minefield they pose for manufacturers adopting PLM midway into an upgrade cycle, or just trying to get the pair to coexist. "If in one organization they are using both versions in parallel and have to synchronize data on a constant basis, that is what causes problems," Schmitt says. However, he says using the two versions does not necessarily spell trouble. Schmitt notes that Dassault has several customers that have successfully used Catia V4 and V5 concurrently on long-term projects.

Another area where Airbus tripped up was in the 3D digital mock-up of the A380. Both companies, Airbus and Boeing, use a digital mock-up as a final design step. Boeing is meticulous in its 3D mock-up process, having had extensive experience in using a virtual mock-up for its earlier 777 jet and in later iterations of its top-selling 737 plane.

The 3D DMU of the A380, however, was done well behind schedule, with a new design team that was under pressure to get it completed. "The problem is the 3D DMU, which facilitates the design of the electrical harnesses' installation, was implemented late, and the people working on it were in their learning curve," says an Oct. 3, 2006, Airbus press release. The company signed its first major contract for DMU software just that past year.

Boeing Takes a Different Flight Path

When the Boeing board of directors gave formal approval to the 787 Dreamliner program in April 2004, work had already been going on for two years behind the scenes to get ready for the formal launch. In early 2002, Carol Pittman (COE President Tom Crume’s boss, two levels up), then IT director for the 787 program, began meeting with Kevin Fowler, the systems integration chief, to sketch out a technology strategy.

Pittman and Fowler agreed to anchor the Dreamliner on Dassault's PLM platform, largely based on the success Boeing achieved in the all-digital design of the 777. They would use all three major components of the Dassault PLM suite: Catia V5 for the design; Delmia, the virtual manufacturing package that allows partners to take the electronic designs created in Catia and simulate how those parts or components will be manufactured on the factory floor; and Enovia, the collaboration platform that provides engineers with access to the master vault of information on the 787, such as electronic designs and component specifications.

One of the first critical strategies they agreed upon was ensuring software compatibility. Fowler says Boeing was already well aware of the difficulties that could be encountered from exchanging information between different CAD systems through Boeing's extensive experience working with various CAD packages throughout its operations. Fowler says he wanted to avoid such trouble on the Dreamliner. There was simply too much at stake.

While it has recently been stealing business from Airbus as airlines look for alternatives to the superjumbo, that hasn't been the general trend. In fact, Airbus overtook Boeing in 2001 as the world's largest manufacturer of commercial airplanes and led every year until Boeing's comeback in 2006. Aside from competitive reasons, the Dreamliner also represents a dramatic change in manufacturing for Boeing—one that makes ensuring software compatibility that much more critical.

When the Dreamliner takes to the skies in 2008, it will be the first commercial jet to have a fuselage and wings made almost entirely of plastic-like composite materials—mixtures of high-strength fibers, resins and carbon. The new materials, combined with other advancements such as an improved aerodynamic design and more efficient engines, will allow the 787 to burn 20% less fuel than comparable airliners and achieve a 10% to 20% reduction in maintenance costs. The project's development budget is confidential, but estimates are in the range of $8 billion to $10 billion.

In the past, the standard practice for Boeing has been to design the plane in-house, then pass blueprints for parts or whole sections of the plane to manufacturing partners. This time, Boeing is turning that process on its head, designing the 787 in collaboration with its partners using the PLM software from Dassault. Essentially, some 6,000 engineers around the world are jointly designing and engineering the aircraft. Partners include companies such as Alenia Aeronautica of Italy, which is building the plane's main fuselage; Japan's Kawasaki Heavy Industries, which is also building part of the fuselage as well as the wings and landing gear; and Goodrich Aerostructures of Chula Vista, Calif., which is constructing the nacelles (shell around the engines) and thrust reversers.

"There are a number of advantages to putting the people closest to the work in charge," Fowler says. The manufacturer of the fuselage, for example, will ultimately know the most cost-efficient method to build the structure. Component manufacturers can point out whether their existing machinery can manufacture a part, or whether new robots or tools will need to be purchased. By altering the design, say, by using a 6 millimeter fastener instead of an 8 millimeter fastener, they may be able to produce the part with existing machinery or manufacture the part faster, saving time and money.

Pittman and Fowler agreed that all engineers working on the 787 would work in Catia V5—no substitutions. This is not as simple as it sounds. For starters, it requires a large up-front investment. Boeing and its suppliers are paying an estimated $20,000 per seat for the software, which, based on 6,000 engineers worldwide, works out to about $120 million. In addition, engineers do not always adapt well to being told what software to use. Most have spent years learning how to use a specific software package, often customizing it to meet their preferences and learning through experience exactly how digital designs translate into actual engineering.

"We considered allowing our partners to use their own preferred applications, but we decided it wasn't feasible because of [data] integration challenges," Pittman said. "It wasn't a popular decision, and we really had to work on explaining why we're doing it."

Boeing provided its suppliers with a financial incentive to get on board with Catia V5. "If you use the common Catia tool, Boeing will provide you with the tool and the support for free," says Barsamian, who trains Boeing engineers to use the software.

Another key plank in the company's strategy was ensuring software version control. Even though all Boeing engineers and partners were starting off with the same version of the various software packages, there is ample opportunity to lose control as updates are released and new partners are brought on board. The team decided that software updates would take place at four specified points in a year—referred to as Block Points—and that all Boeing engineers working on the Dreamliner and all outside partners would receive software updates at the same time.

Again, this understates the complexity of the task. For starters, the updates include far more than Dassault's software; they involve dozens of other applications that are used in the design and engineering process to do everything from test the stress tolerance of composite materials to achieve optimum aerodynamics. Many of the applications have been internally developed by Boeing; however, a number have been developed by third-party vendors, such as Metrologic, whose software is being used for analyzing 3D measurements. In all, some 150 applications are updated at each Block Point.

The updates also include software from other PLM vendors. Boeing is using Windchill, a software package from PTC in conjunction with Dassault¹s Enovia, to streamline the process of managing changes to components on the Dreamliner. If changes are made to a window design, for example, those changes need to be conveyed to manufacturing partners and internal Boeing designers working on areas affected by the change. PTC's Windchill manages that process, ensuring that engineers follow a consistent set of steps to resolve any conflicts and that changes are completed as requested.

A final cornerstone of the Dreamliner technology strategy involves the use of a master data repository for all design and engineering information. Enovia, the Dassault platform, is used as a gateway to a 16-terabyte data warehouse in Bellevue, Washington. Boeing encourages its partners to send updates to the data warehouse at least twice a week, and sometimes more frequently depending on the stage of work in progress. The warehouse is housed on Unix servers running IBM's DB2.

Boeing chose to use CAD and PDM systems from the same software firm, Dassault, thereby ensuring tight integration. Airbus, on the other hand, decided to mix and match. The European aerospace company is using a CAD package from Dassault and a data management system from PTC. In September 2005, PTC announced that Airbus was extending the use of its data management solution, Windchill, as the platform for managing all CAD models for the A380 that are used in its digital mock-up.

But mixing and matching your CAD and data management vendors can require extra work to ensure a smooth fit. "If you want deep integration with your CAD data, it's best to go with a PDM system from your CAD vendor," Cheney says.

There are signs, though, that Airbus is already having second thoughts about PTC. In July 2006, Dassault announced that Airbus had chosen the Enovia platform for all its aircraft development programs. "Airbus has decided to expand the use of Enovia VPLM [virtual product lifecycle management] to all programs," Dassault said. The Catia/Enovia VPLM combination is becoming the standard for all new programs at Airbus.

Does that mean PTC's Windchill must go? Airbus isn't saying, but management has a ways to go to straighten out confusion engendered by allowing different versions of the same CAD program, not to mention competing data management packages.

Meanwhile, Boeing's Dreamliner seems set to take off into much friendlier skies. Pittman and Fowler both say that perhaps the most important factor in ensuring the program's ultimate success was gaining executive support at the onset. Without this backing, they say it would have been impossible to ensure that partners and even all Boeing engineers were complying with 1) demands to use the same software, 2) update on schedule and 3) save data when required.

Dreamliner's "Virtual Takeoff"

In December, Boeing held a "virtual rollout" of the Dreamliner. It demonstrated how the aircraft has been designed and will be manufactured to about 3,000 employees and more than 100 visiting airline representatives.

As part of the demonstration, Boeing showed how in the early design stages, it was discovered that an electronics box manufactured by supplier Hamilton Sundstrand wouldn't fit into the plane's electrical equipment bay. The conflict was caught, and highlighted in red, by the Catia design software. Engineers were able to redesign the bay, essentially by shifting a beam, so the box would fit. If that conflict had not been caught until production began, it could have led to lengthy delays or a costly retrofit.

As impressive as the virtual rollout seemed, it was just that—a virtual rendition of the plane. A Dreamliner has yet to be built, and despite Fowler's confidence, Boeing cannot be certain it won't run into the same difficulties encountered by Airbus, or new, as-yet-undiscovered challenges involving the heavy use of composite materials in the plane, says Hans Weber, president of Tecop International, a San Diego aviation consulting firm.

But a DMU has its benefits. Just over a year ago, pilots began putting the 787 design through its flight simulations. During one such test, where the plane is evaluated on whether it could take off on a single engine, pilots determined it didn't have enough "fin control"—that is, fins used to stabilize the aircraft weren't functioning as desired. Over a period of four weeks, engineers evaluated more than 50 different fin configurations to give pilots the performance they needed. "Traditionally, we might have been only able to evaluate three or four options, and it would have taken three months," Fowler adds.

Second, Boeing expects to achieve a 20% to 25% cut in development costs by eliminating costly mock-ups and by working out kinks in manufacturing before going into production. Based on the plane's estimated $8 billion to $10 billion development budget, it could translate into savings in the area of $2 billion to $3 billion.

"One of the biggest lessons we learned on the 777 program," Fowler points out, "is that there is tremendous value in the digital data in terms of how it can be utilized throughout the entire life cycle of a project. "That has been our biggest objective with the Dreamliner—to use that single source of data from when we take customer orders through design, through manufacturing and right through to support after the customer takes delivery," he says. "That's the real power and where the real benefits come from with PLM."

BASELINE GOALS:

- Maintain position as world's largest producer of commercial airplanes
- Shave 20% to 25%, or about one year, off the time it normally takes to develop a new plane, from six years in 1995 with the introduction of the 777 to five years with the planned launch of the Dreamliner in 2008.
- Reduce development cost of Dreamliner through the use of PLM software by 20%, from about $12 billion to $10 billion.
- Reduce time it takes to assemble a 787 from about six days at start of production in 2008, to about three days after it builds the first 100 planes in 2010.

Technologies To Help the 787 Take Flight February 5, 2007

The 787 Dreamliner project marks the first time Boeing is making its partners responsible for the design of the parts and components they will ultimately manufacture. New 3D design and collaboration technologies are powering the initiative.

Application	**Product**	**Supplier**
3D computer-aided design	Catia V5	Dassault Systèmes
Manufacturing simulation	Delmia V5	Dassault Systèmes
Product life-cycle management collaboration	Enovia V5	Dassault Systèmes
Database supporting Enovia	DB2	IBM
Digital content delivery management	TrueDelivery	Radiance Technologies
Airplane sales configuration	Teamcenter	UGS
Shop floor information system	Velocity	Intercim
Multimedia collaboration centers	Various videoconferencing units	Tanberg
Composite material simulations	FibreSIM	Vistagy
Dynamic systems simulation (hydraulic, pneumatic, mechanical, etc.)	Easy5	MSC Software
Machine tool simulations	CAM-POST, Virtual Machine	ICAM Technologies
Measurement and analysis	Metrolog V5	Metrologic
Aerodynamics testing	Cray X1 supercomputer	Cray
Supply chain management	E2open	Exostar
Flight control operations	Integrity-178B	Green Hills Software
787 avionics control center, including plane's environmental, electrical, mechanical, hydraulic and cabin services	Common Core System	Smiths Aerospace