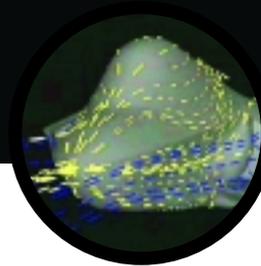


Case Study



Proficiency in Every Sense

■ By Belinda Jones

For the airplane aficionado, the appeal of the Joint Strike Fighter (JSF) is clearly its sleek, powerful contours and its stealth capacity. For the military, JSF symbolizes combat air dominance with next-generation, affordable tactical aircraft. But for the engineering connoisseur whom revels in "all that truly works", the Joint Strike Fighter program exemplifies proficiency in every sense of the word. It puts the "high" in the high-tech realm of aviation, engineering, manufacturing and inspection technologies.

Lockheed Martin (Fort Worth, TX) leads the effort to bring the Joint Strike Fighter to fruition. Partnering with Northrop Grumman and BAE SYSTEMS, Lockheed has formed the JSF Team – a group of industry experts pouring ingenuity to areas critical to the program's success. These specialists focus on one principal concept: a common design with affordable, and supportable variants that fulfills the distinct needs of each military service. The resounding mandate of the JSF project is leaner-than-lean manufac-

turing based upon a technical recipe called "the digital thread". It is this methodology that will capture the heart of any engineer or IT professional involved in streamlining product development. In a nutshell, the JSF program embraces elite concept-to-asset practices *without* reinventing the wheel.

The Digital Thread

The digital thread starts in the JSF design phase and distributes its benefits throughout every process.

Lockheed Martin - Joint Strike Fighter (JSF)

Leica
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The Joint Strike Fighter Program Captures Essence of Engineering Know-how

JSF Digital Thread Enables Mission Critical Engineering and Inspection Technologies

According to JSF spokesperson John Kent, the fighter will be the first aircraft entirely designed in 3D solids using CATIA software (Dassault Systems). Three-dimensional solid models provide an exact representation of each part, thus forming the foundation of the digital thread. JSF will take full advantage of the digital model and carry this product data, this thread, into simulation, tooling, fabrication, assembly and mating.

Everyone involved in the project, at varying degrees, will utilize the same precision product data including the assembly line, the supplier, the CAM programmer and the laser tracker operator. Moreover, this methodology diminishes the paper chase characteristic of traditional engineering, and saves the customer millions of dollars by eliminating the need for expensive upfront tools. Additional savings will be realized in the long run because maintenance costs are also drastically reduced.

Setting the Stage

"Back in 1997, when we started the process of building the JSF concept demonstrators, there were two things done in parallel," said G.B Bailey, Director of JSF Manufacturing Integration. "From the onset, we knew we had to build three variants, and we knew we could not put all of the advanced manufacturing technologies into the CDA concept. But there were a number of key manufacturing processes we eventually wanted to use on the airplane. So while designing and building the 3 variations of the aircraft conventionally, the JSF team began to survey the processes we wanted to use on the production JSF. We initiated an Airframe Affordability Demonstration program that would allow these technologies to 'win' their way on to the program."

The Airframe Affordability (AAD) program is exhibited in a high visibility demonstration area located on

Lockheed's impressive one-mile-long shop floor. The area consists of JSF tooling and components that are used to illustrate manufacturing processes in both the detail and the assembly level.

"Between Lockheed and our JSF partners, we were able to scrutinize the manufacturing methodologies of almost every modern war fighter – F-16, F-22, F-117, B-2, Eurofighters, F-18 E/F. All processes implemented have demonstrated they are low risk and a real asset to the production of the aircraft. So in the AAD area, this is the best-of-the-best competition. We will use these enablers to pull the digital thread through the entire JSF program," states Bailey.

Laser Tracker Technology Wins Position on AAD

At the AAD location, Lockheed uses an LTD500 (Leica Geosystems, Norcross GA) industrial measurement system during their main

demonstrations to show module mating concepts. The state-of-the-art laser tracker is a precision instrument used in conjunction with an engineered jacking system to execute a JSF final aircraft mate demonstration. The laser tracking technology is also utilized to set up, measure and inspect assembly tooling details based on CAD models. The LTD500's 3D laser interferometer and angular encoders deliver a high-speed measuring rate of 1000 points per second, and a measurement volume of 70m diameter.

Rina Molari, in-house measurement/inspection expert and member of the Manufacturing Engineering staff, is responsible for gathering and analyzing the data collected by the LTD500. During the AAD demonstration, Molari performs the module mate alignment manually by driving the tracker's laser beam and target ball out to each of their six check points, which are small circular slots designed into the tool for this application. After a reading, she will adjust the jack system and watch the laser tracker feedback coordinates until the mate is aligned. The next step is simple, the aft fuselage slides easily into position for connectivity.

"Each day before I start a job or an AAD demonstration using the laser tracker, I perform a quick system check and when the indicator comes back, it confirms the whole system is working well," states Molari. "Mobility around the factory is a key benefit. The LTD500 is light, sturdy, and easy to transport on its cart. I often travel to other Lockheed facilities to perform measurement work. The instrument ships safely in its original box. The back check test

takes no more than a few minutes, and 99% of the time, I am ready for the inspection job at hand. Every piece of equipment we have purchased from Leica has worked well. From an operator's standpoint, the real advantage of the Leica trackers is their reliability," concludes Molari.

Weaving the Thread through Part Final Aircraft Mating

Although the laser alignment mate system concept is new to Fort Worth, other industry partners have this type of equipment and reported very good results. Chet Burge, JSF Airframe Mate and Delivery Integrated Product Team Lead, cites the technology has proven itself and the team has adopted this type of system for JSF.

"When people first see our mate joint concept on the AAD floor, there are a lot of questions. But this is not a new concept," states Burge. "BAE SYSTEMS used this joint concept for the Tornado fuselage mate, and it is also similar to the F-16 wing attach joint. This mate joint has machined planes with pre-drilled holes on each module, which allow them to simply be aligned and bolted together. To do this mate concept on the earlier programs, control tools and gages were used to maintain very close tolerances. Those control tools were shipped all around the world to wherever the aircrafts were built. On the JSF, we are mating four complete modules that plug and play. We eliminate the control tools and gauges through the use of coordinate data derived from the digital thread, and by having processes and machines to accomplish this level of tolerances. The laser tracking allows us to validate our designs and close tolerance work on the JSF. In the past, we did not have the real-time measurement capability to confirm tolerances. Today, we can do inspection work on the fly and the resultant data is a by-product of doing the task. 3D CAD, the Internet, going directly to NC, and the laser tracking systems ... all create a strategic loop for precision in the JSF program," said Burge.

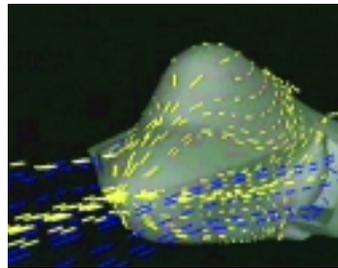


According to Burge, theoretically one person could do the whole mating process, but for obvious safety reasons more people will be involved. When compared to the F-16 and other part aircraft mating systems, the JSF mating process is much faster ... a quantum leap. Today it takes about 8-10 days, depending on what flavor of F-16, to mate the aft fuselage with the center fuselage. Going back to the digital thread, what makes JSF unique is its simple mate joint design. Merge that efficiency with the laser tracker and the innovative jack system, and the result is a rapid, accurate procedure. Burge projects the JSF mate will be completed in about a two-shift operation. So instead of ten days, its mating cycle will be more like 20 hours.

When the production schedule is set up, even on Ship One, Lockheed will have five working days to load components into the tool, align them, bolt them together, and install the main landing gear. Once the company completes 200 to 300 JSFs, they estimate those same tasks can be accomplished in one TAKT day (that's a little more than 19 hours, or slightly more than two working shifts).

"When producing 17 airplanes a month (capacity) and delivering one JSF every two shifts, you do not want anyone doing best-fit, trial-and-error, or trying to do alignment without a measuring device," confides Burge. "We will see cost savings from reduced labor ... and if you look deeper, the possibility of even eliminating rate tools. We forecast that there will be only two tools needed to mate the aircraft when we are





running at capacity. When compared to the F-16, when they were running at full rate (20 to 22 airplanes per month), that program had about nine tools at the mate stations.

"What has impressed me and other people, and this may be oversimplifying it, is just the repeatability of the Leica laser trackers. We can go out everyday, and plug into the measuring system, line up fuselage, and it rolls and bolts together perfectly. The demonstration only shows the mating of the aft fuselage, but all of our joints are designed using this concept and joined in a similar manner ... the wings to the center fuselage, and the forward to the center fuselage. All four components will be mated using this technique to drive the process."

The JSF mate process will enjoy further timesavings once the operation is automated. With Leica's patented ADM (absolute distance meter), the laser tracker can be pre-programmed for point-and-shoot measuring and will search out the coordinates. The tracker laser beam will be shooting toward each target awaiting the operator to put the target into the check point hole. The ADM allows the operator to move around the area freely, and if a beam is broken, it can be retrieved at its last location.

Burge's team is also looking at how they will further integrate laser tracking into their mating process. Using an APS that attaches to the Leica tracker, they could allow the tracker to literally drive the jack system. This would automate a large portion of the operation, and let the feedback guide the operator. Later this year, tooling suppliers will be brought in to preview several concepts.

Quality Built into JSF Tooling

The JSF program incorporates another primary laser tracking application. "A lot of our tools are being designed and built with tracking systems in mind," continues Burge. "The work we have seen to date on F-22 shows part fit capabilities are very good. The tracker is a huge tool in allowing us to pull this thread all the way through the design-build on JSF."

"One thing you will notice in the AAD demonstration area is modular tooling," reports G. B. Bailey. "Quite a contrast to the F-16 line that has rigid welded structures that are very difficult to change. With the JSF modular tooling concept and the use of the laser tracker, you can set a locator and put your locating eye directly on it. Tomorrow, if you want to make a change to a detail that locates with a laser tracker...it can be done very easily. With this type of configuration, it allows the program to constantly upgrade our processes without expensive changes to the tooling. And again, we can tailor the airplane to satisfy the efficiencies of the variant of the service, without paying the price in the number of tools."

When assembling the tools, Lockheed will track a locating point over the life of the tool to see if there are any variations. Using the laser tracker, they setup 3D coordinate points in space and verify them initially and on an ongoing basis. In fact, one of the criteria for becoming a participating tool manufacturer for the JSF program is the supplier must demonstrate they have the capability to use laser trackers, and those features will be designed into the tool.

"With the tight tolerances we are trying to maintain for this program, you have got to be able to fabricate and validate a tool quickly and accurately" said Burge. "When building a conventional aircraft, a lot of time is spent loading and unloading fixtures. For the JSF, we are eliminating this operation. We will build the assembly in a tool, move the tool and assembly down the production line using the same tool throughout the assembly process. This is one idea that helps us achieve a 90% reduction in tools."

This method will foolproof the system and also remove manual error. The JSF program also aimed for 70 to 90 % of common parts on all three variants, so the learning curve would be shortened for those involved in assembly. In reality, there is about 80% uniformity in all the parts. Once again, the digital thread allows the mechanic (or any party who needs access) to call up 3D visual assemblies and electronic instructions



Electronic Documentation and Training: Natural Progression from the Thread

With the digital thread, the JSF team will use electronic work instructions. The intent of the JSF program has been to eliminate 2D drawings. For the CDA aircraft, over 200 NC parts were built at Lockheed, with no drawings ... a 100% digital process. And that is no small feat.

As shown in the AAD demonstration simulation, the company can generate working steps based on the 3D models to illustrate how to use the laser tracker. Using Leica's process automation module (PAM), Molari can program the system to literally prompt the operator for each step as the laser tracker acquires data, it will move on to the next step.

when needed. Lockheed projects that maintenance cost for the airplane will plummet to about half the cost of the current generation of fighter planes. Why? In part because field personnel have immediate access to an accurate reference ... and speed equates to saved money.

Powered by the digital thread and technologies like laser tracking, the JSF program is ready to reap multifaceted benefits in compressed timelines and bottomline savings. When the world's most brilliantly conceived stealth fighter rolls off the assembly line, it will be a national security asset and engineering icon rivaled by none. All the more reason that its development can not be hampered with second rate manufacturing processes and antiquated measuring tools. And you can bet your last dollar that Bailey, Burge, Molari and the rest of the JSF team are on top of the situation.



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