➤ BY MIKE PRINCIPATO

Manufacturing at Mach 2+

Making of the F-22 Raptor fighter jet.

All images: Lockheed Martin

In this first installment of our new Made in America series, CTE *columnist Mike Principato gets up close and personal with the F-22 Raptor, the world's most advanced fighter jet … and, after a turn in a cockpit demonstrator, learns he'd better keep his day job.*

It's not every day you get an insider's look at the making of the ultimate aircraft. So when the nice people who make the baddest fighter jet on the planet offered me a behind-the-scenes tour of their operation—not to mention a ride in a $1.5 million cockpit demonstrator—I accepted faster than you can say "wheels up."

And so it was that on a crisp autumn morning I arrived at the entrance of the den of the F-22 Raptor: Lockheed Martin Aeronautics Co.'s mammoth Marietta, Ga., Plant B-1. Once past a serious security checkpoint, I arrived in the plant's lobby/air-and-space museum, an understated but effective testimonial to this venerable defense contractor's rich heritage of producing some of the world's most famous aircraft.

No modern military aircraft has quite captured the imagination of the American public like the Raptor. It has a look that George Lucas might have conceived of if he'd taken origami lessons, and performance stats that make every military jet built before it seem quaint. If the F-22 was a guy, he'd be dating Uma Thurman.

And I was going to see her being built. The Raptor, I mean, not Uma.

'First look, first shot, first kill'

One thing's for certain: If control of the military skies is the goal, the Raptor is the ultimate predator. With Pratt & Whitney F-119 engines developing, "unofficially," 39,000 lbs. of thrust in "supercruise" mode, the most advanced avionics in the sky, armed with AIM-120 air-to-air missiles (affectionately called "Slammers") and a 20mm Vulcan gatling gun, the Raptor is a flying can of whup-ass.

"It sounds maudlin, but we say the Raptor's strength is its 'first look, first shot, first kill' capability," explained Keith Bilyeu, business development for Lockheed. That means that the F-22's speed, stealth technology and highly advanced, forward-looking radar systems can see—and shoot down—enemy aircraft well before that enemy even knows the Raptor's there.

Entering the Raptor's Nest

My hosts from Lockheed—Bilyeu and F-22 communications representatives Kate Lowe and Rob Fuller—greeted me graciously and whisked me from the lobby to the cleverly named "Raptor's Nest." This is a large,

well-furnished conference area lined by flat-screen monitors and dominated front and center by a slick-looking cockpit simulator I'd later be "flying" (see sidebar, page 35).

"You'll need to remove all your jewelry and any other loose objects," Bilyeu genially directed, offering a quick explanation of the dangers of what's known in Lockheed parlance as "FOD," short for Foreign Object Damage prevention.

Tech manufacturers have cleanroom conditions and regulations; so do aircraft manufacturing plants. The big difference between the two is that if a foreign object winds up in an aircraft, someone can die. To drive home the criticality of FOD rules to employees, Lockheed distributes a brochure that cites, among other examples, an incident where "178 people perished in the crash of an aircraft in which simple tape was mistakenly left on altimeter ports."

Serious stuff indeed, and I'm moved to request permission to carry my notebook and pen into the Raptor manufacturing area. Permission is granted, and for the rest of the tour I hang onto my Waterman like it's the last writing instrument on earth.

With a visitor's badge hanging from my neck and safety glasses perched on my nose, Loran Bodnar, senior manager, F-22 final assembly, led our group onto the plant floor.

Keeping the world safe —from writers

The best thing I can say about my brief "flight" in Lockheed Martin's F-22 Raptor cockpit demonstrator is I am supremely grateful my teenage son wasn't there to witness my ineptitude. For years he's chided me for my complete lack of enthusiasm for the video games he loves so dearly, and snickers at my all-thumbs approach to a game controller.

On Dec. 1, 2005, flying into enemy airspace, I paid dearly for my indifference to Super Smash Brothers, Call of Duty 2 and a hundred other accursed, microchip-enabled games.

Keith Bilyeu, Lockheed's business development honcho and all-around nice guy, gave me a simple preflight briefing to prepare me for a once-in-a-lifetime opportunity behind the stick of a genuine Raptor digital dashboard. Once in the demonstrator, I proved once and for all that I did not miss my calling, lapsing into sensory overload at the sight of row upon row of buttons, blinking lights and video screens.

"This is supposed to be easier than analog cockpits?" I wondered to myself as Bilyeu implored me to bank, flatten, increase speed and, above all, shoot the bad guy flying in front of my Raptor on a movie-sized video screen. I did none of this, instead resorting to a kind of frantic, whirling dervish approach to the controls: Press everything—you're bound to make something good happen, right?

Something did: Bilyeu reached over into the demonstrator, grabbed the stick, shot down the bad guy and saved the day for democracy—and this writer. *—M. Principato*

A Raptor team member works on the fuselage. The plant features near-cleanroom conditions.

Shock and Awe

If you're a manufacturing geek—and I am—you can find something unique and interesting about the way even the most mundane product is made. There's absolutely nothing mundane about the Raptor or its Marietta birthplace. I freely admit that it took about one step onto the manufacturing floor for me to develop a genuine "proud to be an American" lump in my throat.

Bodnar smiled, noticing that my eyes were instantly drawn to the west wall of the cavernous plant, which is adorned by a gigantic American flag. Under the Stars and Stripes, in 2' high letters, a sign declares, "Through these doors pass the most awesome fighters in the world." To the left of this hangs another sign that succinctly sums up the importance of quality in this one-of-a-kind manufacturing operation: "A mistake covered up can cost the life of a brave pilot." During the next 2 hours I'll see many examples of quality-assurance practices, but none as dramatic.

Bilyeu said the elite fighter pilots who fly the F-22 often visit the plant floor to chat with members of the 500-person team who build their jets. "It has a real impact on them, as you might imagine." I can.

The plant itself is a megabuck, megawatt exhibit of the best manufacturing gear and practices taxpayer money can buy. In a scrupulously clean and organized sea of customized racks, gantries, tooling and technology, eight Raptors in various states of production are being swarmed by teams of intense workers. The plant is quiet and uncluttered—amazingly so, given the level of activity on the floor.

"All our utilities in this plant are under the floor," explained Bodnar, which keeps the manufacturing area free of the clutter caused by wiring, pneumatic hoses and compressors. The jet's unique composite and alloy materials and methods of construction also mean an absence of rivet-driving noise.

Hatching a Raptor

From the beginning, the F-22 program has involved experienced manufacturing engineers who spent months designing the fighter's highly special-

ized production processes. Given that the projected production run of the jet is, as of this writing, 180, the challenges of balancing costs and customer requirements are not all that different from a small machine shop: Labor, tooling, raw materials and delivery deadlines require continuous attention, but on a much more massive scale, especially given the division of manufacturing responsibilities of the Raptor program.

Components of the Raptor are produced in partnership with Boeing Integrated Defense Systems and by more than 1,000 suppliers in 42 states, and eventually wind up in one or several F-22 plants. Lockheed's Fort Worth, Texas, and Palmdale, Calif., facilities, respectively, build the center fuselage and nose; Boeing builds the wings and aft fuselage. Eventually, it all winds up in Marietta, where subassemblies are mated, aircraft sections are joined, engines are added and each Raptor is thoroughly tested before delivery to the Air Force.

The Marietta plant is a choreographed ballet of incredibly precise and expensive parts (made mostly of classified composites, titanium and Inconel) and subassemblies that move between seven stations, each of which is manned by a highly trained mini-army of specialists and engineers. Lockheed lore has it that when airframe parts are joined, the fit is so precise that there's an audible "click," made possible, in part, by a laser-measured 0.003" tolerance from the Raptor's 61' nose to tail. Every tool is cataloged and has its place in customized holders; no personal tools are permitted inside the plant.

There's little talking while components are being assembled, but the atmosphere is not unpleasant. Rather, the whole place has the distinct aura of a manufacturing facility where serious and competent people are taking responsibility for their contribution to a serious product.

Raptors await their chance to take flight.

Bill Wolcott, a manager in the corrective action department and part of the Raptor program since 1992, said the smooth choreography is not accidental. "Detail design (the creation of the specialized tooling, fixtures and testing equipment for the Raptor) happens concurrently in engineering, development and manufacturing. It took about 2 years to ramp up" to current production levels, he said. Currently, Lockheed hatches a Raptor every 2 months, which is down from 3 months when production started 2 years ago. "Eventually, as we move toward a more in-line flow, we expect we'll produce [a Raptor] every 10 days," said Wolcott, noting that such streamlining will also reduce the per-aircraft cost over time. The output depends solely on how many the Air Force can buy.

Shop-floor computerization plays a key role in production flow, according to Bodnar. Manufacturing schedules, workflow and output are tracked in detail and accessible to everyone on the shop floor. The result is a surprisingly participative, even entrepreneurial, operation belying its 500-employee workforce—and one that's not bogged down in the minutiae that sometimes plagues computerized manufacturing operations. That's a result of another Lockheed innovation, a simple, easel-mounted whiteboard display of the day's production status at each station. "We boil down 100 metrics onto this one board," noted Bodnar.

Bilyeu said the Raptor team's philosophy of manufacturing is based on a simple mission: "Best aircraft, best practices." For the team at Lockheed Martin, that means producing the world's most advanced fighter jets—and protecting the lives of brave pilots. △

About the Author

Mike Principato owns a machine shop in Pennsylvania and is the author of "Manager's Desk," a column that appears monthly in CTE. *He can be e-mailed at ctemag1@netzero.net.*