On 22 December 1964, Lockheed test pilot Bob Gilliland flew the SR-71 on its first flight. Taking off from the (then) Lockheed facility in Palmdale, California, Gilliland flew the aircraft (US Air Force serial number 61-7950) for just over one hour and reached a speed of more than 1,000 mph.

Once operational, the SR-71 became legendary almost instantly. It was top secret; it flew higher, faster, and farther than any aircraft in history; and it covered enemy territory with impunity, apparently invulnerable to surface-to-air missile attacks, and certainly unapproachable even by interceptors as advanced as the Soviet MiG-25.

As sophisticated as it was, the SR-71 flew from relatively primitive forward operating locations, bases without the usual infrastructure, without difficulty. During its operational career, crews in the thirty-two SR-71s built logged a total of 53,490 hours of flight time, of which 11,675 was spent at Mach 3-plus. They flew 3,551 operational sorties all around the world.

These images are from the SR-71’s first flight. The main shows Gilliland making a low pass at Palmdale, near the end of the flight. Company pilot Bill Park, who would later make the first flight of the Have Blue stealth demonstrator, flew safety chase in a Lockheed F-104 Starfighter.
ABOUT THE COVER

Front: US Navy test pilot Lt. Cnmr. Theodore Dyckman guides F-35C test aircraft CF-5 in for another landing during the third day of Lightning II operations aboard the USS Nimitz (CVN-68) in November 2014. These tests marked the first F-35C operations aboard a carrier at sea.  
Photo by Andy Wolfe

Back: The Republic of Tunisia received its second C-130J Super Hercules during a ceremony at the Lockheed Martin facility in Marietta, Georgia, on 11 December 2014. Shortly before the ceremony, this formal portrait of the aircraft was set up and photographed.  
Photo by John Rossino

OUTSTANDING IMAGES
Some Of The Best Aircraft Photos From 2014

ADP ARES PROJECT
Compact Battlefield VTOL Air Vehicle

F-35 OPERATIONS AT YUMA
Bringing The F-35B Into Operation

LM-100J: Airlifter For Hire
Coming Soon To A Dirt Strip Near You

F-16 EVOLUTION
The Road From The YF-16 To The Block 60

MAD Mutt
The X-56 Aims To Tame Flutter

C-5M SPECIAL DELIVERY
Clean Room To Orbit Via Truck, C-5M, And Atlas V

JPADS SMART CARGO, READY TO FLY
Dyess C-130J Crews Hitting The Target From High Altitudes

U-2 DRAGON LADY TODAY
The Reconnaissance Aircraft [Not The Rock Band] Still Flying High

F-35 YEAR IN REVIEW
2014 Was A Banner Year For The Lightning II
The best aviation photographer can capture this feeling and convey it as a single image. As legendary nature photographer Ansel Adams noted, “A great photograph is one that fully expresses what one feels, in the deepest sense, about what is being photographed.”

That sentiment is particularly true for aviation photographs, starting with the very first one. John Daniels, assigned to the Life-Saving Service station at Kitty Hawk, North Carolina, tripped the shutter on a pre-positioned box camera just as Orville Wright lifted off for the first time on 17 December 1903 at 10:35 a.m.

But beautiful aviation photographs do not come easy. Those who have set their alarms for four a.m. to get to an air base to catch a sunrise takeoff know of the level of effort necessary for an exceptional image.

To get that dramatic nose-on air-to-air shot, a photographer may have to be held in place with nothing more than a nylon cargo strap – while standing on the edge of the open cargo ramp of a C-130.

Air-to-air photography of one fighter from another fighter has its own unique complexities. Anyone who has changed a compact flash card (or can remember changing rolls of film) after experiencing the body blows of multiple high-g turns has a refined appreciation of the dynamics behind a good aerial photo of an F-16 or an F-35. Air-to-air photographers deal with subjects moving in three dimensions from a platform that is also moving in three dimensions.

Dynamic and colorful images have been a hallmark of Code One throughout its thirty-year history. The magazine’s exceptional access to the units that fly Lockheed Martin aircraft has resulted in images that haven’t been seen anywhere else. In addition to our staff photographers, the magazine also has regularly showcased the work of world-renowned freelance shooters and the best shots from the hundreds of military photographers around the world documenting daily operations oftentimes in hazardous locations.

Over the course of a year, Code One editors look at hundreds of images. Most are used to illustrate a specific feature article or an item for our News section. But quite a few—like the ones in this gallery—are just simply outstanding images. This gallery has been populated with new images of current or legacy Lockheed Martin aircraft out there that are still being flown.
Two 37th Airlift Squadron C-130J Super Hercules crews from Ramstein AB, Germany, practice formation flying.

A C-5M Super Galaxy crew taxis to a parking spot at Dover AFB, Delaware.

An F-22 Raptor pilot performs a high-speed pass at the Arctic Thunder Open House at JB Elmendorf-Richardson, Alaska.

A P-3C Orion aircraft from Patrol Squadron 40 (VP-40), home based at NAS Whidbey Island, Washington, flies a mission during GUAMEX 2014.

F-16 pilots from the 148th Fighter Wing, the Minnesota Air National Guard unit at Duluth, fly over the fall foliage.

A U-2 Dragon Lady pilot flies over the wind farms in the Mojave Desert near Palmdale, California.

A KC-130J Super Hercules tanker crew from Marine Aerial Refueler Transport Squadron 352 (VMGR-352), flies over the Mediterranean Sea.

An F-22 Raptor takes fuel from a KC-10 Extender tanker on the first night of Operation Inherent Resolve. This mission was the first time F-22s were flown in combat.

A U.S. Navy P-3C Orion crew assigned to Patrol Squadron 9 (VP-9) prepares to land at NAS Sigonella, Sicily.

F-35B Lightning II meets AV-8B Harrier II at a static display at Edwards AFB, California.

A U.S. Air Force Reserve Command crew from the 705th AS, at Dobbins AFB, Georgia, lands at Fort Huachuca, Arizona.
A U-2S pilot takes off from Beale AFB, California.

US Army paratroopers from the 82nd Airborne Division’s 2nd Battalion, 505th Parachute Infantry Regiment prepare to land on a C-130.

An F-16 Fighting Falcon pilot assigned to the 35th FS, Kunsan AB, South Korea, takes off from Eielson AFB, Alaska, during Red Flag Alaska exercises.

US Air Force Capts. Matthew Upchurch (left) and Jennifer Nolta (right), 9th Airlift Squadron C-5M Super Galaxy pilots, prepare their C-5M for take off.

An F-16 Fighting Falcon pilot takes off during exercise Beverly Midnight 14-2 at Kunsan AB, Republic of Korea.

Overhead view of F-35C CF-3 and CF-5 on the deck of the USS Nimitz (CVN-68) during the initial carrier trial testing for the carrier variant of the F-35 Lightning II.
PROJECT ARES

The Pentagon’s Defense Advanced Research Projects Agency, better known as DARPA, has a reputation for demonstrating innovative solutions to practical problems. Supplying and supporting dispersed troops in the field while getting personnel and vehicles off of roads with threats such as improvised explosive devices, or IEDs, is one such problem. DARPA is addressing this problem in a program called Aerial Reconfigurable Embedded System, or ARES. The reconfigurable part of the name describes multiple mission capability from a single vehicle and the embedded part refers to having this system operated by infantry soldiers and Marines.

BY ERIC HEHS ILLUSTRATIONS BY DOUG MOORE

“Transporting and resupplying troops in rugged, austere terrain has become a major challenge, especially as the US military shifts to using smaller and more distributed combat units,” explained Kevin Renshaw, Lockheed Martin Skunk Works lead on ARES.

The Skunk Works formed a team in 2010 with Piasecki Aircraft Corporation and Ricardo, Inc., that was selected for the DARPA Transformer program, as it was known at that time. In its original requirements, DARPA asked participants to “demonstrate a flyable/roadable vehicle that provides the warfighter terrain-independent mobility… The vehicle will have VTOL capability with a minimum combat range of 250 nautical miles on a single tank of fuel.”

In the first phase of the program, the Skunk Works team performed trade studies and defined the concept of a modular VTOL UAV system with separable independent flight and ground components.

The scope of the program has since been refined to delete the roadable capability and focus on the common VTOL lift module that could service multiple missions with interchangeable payloads, leading to the new program name — ARES.

The program, currently in Phase 3, seeks to demonstrate a new generation of compact, high-speed, autonomous, unmanned vertical takeoff and landing, or VTOL, delivery systems.

ARES will demonstrate several key technologies to achieve an operational VTOL system with a more compact footprint than those of conventional helicopters and copters with higher cruise speeds,” Renshaw noted.

PRELIMINARY WORK

After being selected for Phase 2 of DARPA’s program in 2011, the Lockheed Martin team matured its concept and completed a preliminary design review with DARPA and other technical experts in 2012.

The preliminary design was the basis for the Phase 3 effort, which involves designing and building the prototype system. Lockheed Martin’s team won the Phase 3 contract in late 2012 to perform detail design work and risk reduction tests that led to a Critical Design Review in late 2013. Following this review, DARPA has decided to exercise a further option to build and fully the ARES prototype in 2015.

Lockheed Martin has a head start in developing and fielding unmanned VTOL systems with the K-MAX unmanned cargo helicopter currently in operation with the United States Marine Corps in Afghanistan. K-MAX helicopters are flown by remote pilots with navigation automated between mission waypoints and payloads carried on an external cargo sling.

Engineers with Lockheed Martin Mission Systems and Training demonstrated the use of these unmanned helicopters to deliver more than three million pounds of cargo to the Marines. The system reduced their exposure of the military personnel to IEDs by tens of thousands of hours. The success of K-MAX in Afghanistan led the Marines to extend the demonstration indefinitely. LM Mission Systems and Training successfully completed a contract with the Office of Naval Research to demonstrate advanced sensors and controls for VTOL unmanned air systems, or UAS, under the Autonomous Aerial Cargo Utility System, or AACUS, program.

AACUS tested sensors and flight control software to allow the next generation of VTOL UAS to autonomously identify landing zones, avoid obstacles, and complete landings without a remote pilot. The system will be designed to be programmed by soldiers and Marines in the field, with simple, intuitive control interfaces, such as military smart phones or ruggedized tablet computers.

This technology ties directly into ARES as part of the maturation path from the DARPA prototype to the fully operational system.

DESIGN AND HARDWARE

The ducted fan VTOL flight module designed for ARES could adapt to multiple missions with interchangeable payloads. The payloads could include cargo pods, medical evacuation units, delivering tactical ground vehicles, troops, and armed scout, reconnaissance, and strike capabilities.

The vehicle’s tilting ducted fans allow for a safer operating environment by combining faster transit speeds with a landing zone half the size of a typical helicopter with a similar payload. This also leads to a system that could fit into small ship hangars or into C-130 transports. The ducted fan design, with no exposed rotors, would also improve troop safety on the ground.

The ability to use the same flight module to perform multiple missions with a common system could reduce fleet costs. ARES could supplement more expensive
specialized helicopters that require trained crews. "The modular concept enhances the original DARPA vision by enabling a variety of roles, offering versatility now and adaptability in the future," Renshaw added.

The transitions to and from vertical flight for takeoffs and landings would be done automatically. The operational version would autonomously navigate to the desired delivery site while avoiding obstacles en route or in the landing zone. The ARES Flight Control System design is taking full advantage of the digital fly-by-wire VTOL control work that Lockheed Martin has done in the past fifteen years with the X-35 and F-35 programs. The design also benefits from the team’s previous experience with autonomous control of unmanned air systems. "Operating this type of system in VTOL, transition, and cruise flight requires a sophisticated fly-by-wire flight control system," said Renshaw.

Piasecki Aircraft, a long-established helicopter and VTOL research company, is responsible for the flight module design, including the design of the lift system drivetrain. Frank Piasecki invented the dual rotor system for helicopters in the 1950s. Dual rotors are used today on the CH-46 Sea Knight and CH/MH-47 Chinook helicopters. The company’s previous ducted fan VTOL experience includes its VZ-8 AirGeep series of demonstrators. Piasecki has also studied the potential for lift system modularity under the US Army Combat Medic casualties evacuation project.

"The operational system was always meant to have the capability to be flown as a highly autonomous UAS with the flight module able to return to base after dropping off the payload," Renshaw explained.

In Phase 3 during 2013, the Lockheed Martin team created detailed drawings of the hardware for a full-scale prototype flight module. The hardware design includes the structure, drive shafts, propellers, control actuators, and lift system drivetrain gearboxes. Those items were in hand or are in fabrication to support assembly in 2014.

The team has selected existing flight control computers to be used for the digital flight control system. The team has also identified sensors, GPS navigation aids, and datalinks for the UAS operation, based on other Skunk Works UAV efforts. The team is creating the digital flight control laws and flight control software to manage hover, transition, and cruise flight.

Simulations of the control and handling qualities of the system are now running in the flight controls labs. These simulations are designed to test the software package for hardware-in-the-loop tests and flight test.

Long lead items, such as gears and bearings, have been delivered to support initial drivetrain tests scheduled for late 2014. "Existing helicopter turboshaft engines will power the prototype," explained Renshaw. "The team is selecting available components wherever possible to minimize the cost of the prototype."

The team has built and tested a one-third-scale powered wind tunnel model to test in the fall of 2013 and summer of 2014. The wind tunnel tests measured the aerodynamic and propulsion effects across the full range of thrust, duct angle, and control inputs. This data is being used to finalize the flight control laws and software for the prototype.

Construction of the prototype has begun with the ducted fan drivetrain, propellers, and duct structure in mid-2014. Subsystems, flight controls, and electronics will be added next. Tests of the complete system on a ground test stand will be used to measure thrust and UAV control responses. The test stand will also allow tests of failure modes and emergency procedures with flight hardware and software in a controlled environment.

The program will conclude with demonstrations of the flight module’s ability to perform vertical takeoffs, hover, make smooth transitions between hover and forward flight, and meet predicted flight performance. After the prototype proves that it can fly as predicted, additional tests with a variety of payload types could be performed. Specifics of those tests would depend on service user requirements.

"We’re contacting operators from the United States Marine Corps, US Army, and Special Operations Command to help identify how they would use this system in the field," said Renshaw. "Once fully developed, ARES could provide future commanders increased flexibility and options for transporting personnel, performing reconnaissance missions, and supporting troops in the field." Renshaw concluded. "The ability for small units in the field to get in and out of compact, austere forward bases and to move supplies or evacuate wounded troops without having to schedule high demand helicopters could revolutionize dispersed operations."
Marine Corps Maj. Aric Liberman landed the first F-35B at MCAS Yuma on 16 November 2012. That same day, Marine Fighter Attack Squadron 121 (VMFA-121), known as the Green Knights, transitioned from F/A-18 Hornets to Lightning IIs. State and local officials and dignitaries, high-ranking representatives from the Department of Defense, F-35 program officials from the United States and abroad, and executives from the aerospace industry as well as members of the squadron, their families, and friends attended the formal transition, which was a milestone for the US Marines and the F-35 program. With the newly arrived F-35B as a backdrop for the ceremony, VMFA-121 officially became the first operational F-35 squadron. **BY ERIC HEHS**

“After all the dignitaries and everyone else went home, we had to move the aircraft out of the weather and into a hangar,” recalled Gunnery Sgt. Jason Gillette, chief of quality assurance at the squadron. “The move took several hours.”

Gillette and members of the ground crew weren’t unprepared. They were deliberate. The post-ceremony repositioning was the first time a maintenance team with 121 was wholly responsible for towing an F-35. “We wanted to do everything right,” Gillette continued. “We were taking measurements and reviewing procedures very closely before moving anything.”

That same attention to detail applies to every task the unit performs with their new fifth-generation fighters. “Our formal training may give us a good foundation. But actually performing a maintenance task for the first time is a reality check for us,” Gillette said. “We want to make sure we are doing everything correctly. Today basic tasks, such as towing the F-35, are second nature to us. They take minutes.”

Becoming more efficient is a common theme at Yuma. “Young Marines are on our flight line maintaining our F-35s, which is great to see. They have learned how to maintain the airplane efficiently in a short amount of time. Now we are working at making those operations even more efficient,” explained Lt. Col. Steve Gillette, commander of VMFA-121 (and no relation to Jason Gillette).
Colonel Gillette underscores that the VMFA-121 is the first organization in the Department of Defense that has to maintain its F-35s with uniformed service members. “This is how the Marine Corps is going to staff and equip an F-35 squadron,” he said. “Yuma operates differently from a test site. Test sites, like Edwards AFB, have a lot more engineering support. Eglin is much closer to Yuma in terms of how it is operating the F-35. But at Eglin, Lockheed Martin provides contract logistics support and maintenance.”

The contractor presence at Yuma is indeed less numerous. A small contingent from Lockheed Martin, led by Jason Higgins, consists of field support engineers and subject matter experts who support maintenance, the supply chain, and the automated maintenance system known as ALIS (for Autonomic Logistics Information System). They also operate the ground-based training simulator. Representatives from the F-35 Joint Program Office, Pratt & Whitney, and Rolls-Royce also provide support.

“Dependency on our field service engineers at Yuma has diminished,” said Higgins, who came to Lockheed Martin and this base near the California border after a career as an aircraft maintenance officer in the Marines. “At first, the unit had only a handful of maintainers who could not do much without our support. They have since developed very fast and are now performing a large portion of the maintenance activities relatively autonomously.”

Today the Lockheed Martin team at Yuma functions more in a higher level support role. “We tend to deal with issues that are programmatic in nature and that require attention outside the squadron,” Higgins said. “Resolving these issues usually involves a combination of personnel from the F-35 program office as well as personnel from industry partners.”

**BUILDING UP**

The F-35 population at Yuma has expanded since that first airplane, F-35B (Bureau Number 168717), was delivered in late 2012. The VMFA-121 now has its full complement of seventeen F-35Bs—the last three delivered in December 2013. The pilot population has increased as well. When the Marines initially stood up the squadron, 121 had only two or three pilots qualified to fly the F-35. “The rest of us were here looking at the new airplanes and waiting to go to training,” said Capt. Brian Miller, who was selected to fly the F-35 in 2011. He arrived at Yuma in January 2013 and flew the F-35 for the first time in June 2013.

Miller and most of the other assigned pilots cycled through three months of F-35 flight training at Eglin AFB, Florida, after they arrived at Yuma. They came to Yuma first to help establish the squadron, which had moved from Arizona to NAS Miramar in California. As of March 2013, VMFA-121 had sixteen pilots assigned. When fully staffed, the unit will have twenty-six pilots.

Additional aircraft and pilots as well as increased efficiencies in maintaining the F-35 have combined to impact flying rates. “Our flight operations have certainly ramped up,” noted Colonel Gillette. “We flew roughly 400 flight hours for the first year we had the airplane at Yuma. In the last two months, we have flown more than 200 hours.”

“Our rates have improved significantly,” added Miller. “When I got back from flight school, everyone was flying once every two or three weeks. Now pilots are flying at least once a week and logging about four hours of flight time per week.”

F-35 missions at Yuma can run more than three hours as most include two or three takeoffs and landings with hot pit refueling (ground refueling while the pilot remains in the cockpit with the engines running). The squadron began flying night missions in December 2013 and was flying them in March during the Code One visit.

As the Green Knights build up, Yuma will gain additional F-35 squadrons as other units at the base replace AV-8B Harriers with Lightning IIs.

**THE TRANSITION**

The move from Harrier and Hornet to the Lightning II has not been an issue for those who have made the transition. Miller, who came from the F/A-18D, explained the transition in simple terms: “In a Hornet, we had a center stick. In the F-35, we have a sidestick. I don’t even think about the difference now. Once I landed and took off in the simulator a couple of times, I was comfortable with the stick location.”

Getting accustomed to the F-35’s short takeoff/vertical landing procedures, however, adds another dimension to the transition discussion. “You would think former Harrier pilots would have an advantage with the F-35 STOVL modes since they have experienced those modes before,” continued Miller. “They may be more versed in the engineering dynamics and physics of STOVL operations. But in terms of cockpit controls, STOVL mode in the F-35 is almost completely backwards from the Harrier. So F-18 pilots may have an advantage since they don’t have to unlearn STOVL habits.”

Capt. Jonathan Thompson, a former Harrier pilot now with the VMFA-121, confirmed Miller’s observations. “The F-35 is designed to be very intuitive in hover mode,” he explained. “To a pilot coming from a conventional fighter, hover mode is intuitive. Push down on the stick and the aircraft goes down. Pull back on the stick and the aircraft goes up.”

Hover mode control in a Harrier, however, is a little different. Up and down movement is controlled with the throttle. Left and right movement is controlled with the stick.

“Whereas I used to pull back on the stick to point the thrust down to land the Harrier in hover mode, I push forward on the stick to land the F-35 in hover mode,” Thompson continued. “That said, the F-35B hover technique is just as easy to learn and just as easy to become second nature. Former AV-8 pilots just have to be more deliberate until STOVL mode operations become more routine. Short takeoffs and vertical landings are..."
As pilots become more proficient, these new capabilities bring the F-35 into a new era of aviation. "The way the F-35 is easy to fly. Capability, on the other hand, represents a much more significant difference—ones that pilots are just beginning to explore," said Colonel Thompson. "Although we aren’t flying with all the capabilities of the F-35 yet, we are aware of what is coming," Thompson said. "In the six months I have been here, I’ve seen systems that we couldn’t touch before they came online."

One increased capability is the radar. "The biggest situational awareness enhancer in the F-35 is the radar," Thompson continued. "The way the F-35 presents the picture in the cockpit is most impressive. The ease of use is an eye-opener. But the Harrier has the APG-65 radar, which is very old. Still it provided a lot of situational awareness we would not have otherwise. But I can’t tell you how many times I flew the AV-8 without a working radar. We performed the mission anyway, but without as much situational awareness."

The F-35’s helmet-mounted display adds to situational awareness. "Hornet pilots may have experience with a [Helmet Mounted Cueing System] before coming to the F-35," Thompson said. "But the ability to have a contact on the radar and then be able to look out the cockpit and have that contact appear on my visor is as different as night and day from Harrier operations."

The pilots and planners at VMFA-121 are part of a larger team to develop tactics and procedures that capitalize on these new capabilities. "As the radar gets more stable, as the electro-optical targeting system, or [Electro-Optical Targeting System], gets more reliable, as pilots become more proficient, as the flight envelope opens up, we can look at the tactics, techniques, and procedures we can bring forward from legacy aircraft," explained Miller. "We can consider performing those procedures differently in the F-35 because of all the new capabilities it brings to the fight. We are just starting to break the surface on tactics development."

Six months ago we were working on basic proficiency stuff. While we’re not out there flying the aircraft as we would in combat, we are practicing armed reconnaissance and close air support missions. We will soon be transitioning to tactical intercepts."

"People don’t realize how far along we are with the F-35," added Thompson. "My friends are surprised when I tell them how many aircraft we have in the squadron. They think we have two or three airplanes and they don’t get to fly at all. We’re a whole division flying three or four days a week. When I arrived six months ago I didn’t think I was going to fly much my first year. I was flying right after I got here."

IMMEDIATE FUTURE

Pilots at VMFA-121 are anticipating improvements in the form of software upgrades that will come to their F-35Bs. "The new capabilities present in the cockpit picture are coming," said Miller. "We are being patient because we still have so much to learn before those systems are cleared for use. In the meantime, we still try to find enough time to study those new capabilities and to catch up on our understanding of, for example, the new symbology used in the cockpit displays."

Similarly pilots are looking forward to a larger part of the flight envelope being cleared. "Flying at 400 knots and pulling 4.5 g’s in this fighter is difficult because it wants to do so much more," Miller said. "Tactically we are rarely going to be flying the aircraft at less than 400 knots."

The upcoming Block 2B software provides weapon capability and expands the flight envelope to Mach 1.2, 5.5 g’s, and fifty degrees AOA. The F-35Bs will eventually be cleared to operate at Mach 1.6 and seven g’s.

THE ATTRACTION

Being on the ground floor as these new capabilities are incorporated into the US Marine arsenal is part of the attraction for personnel at VMFA-121. Colonel Gillette, the squadron’s second commander, explained: "The ability to influence the next generation of aircraft and the next community of Marine Corps tactical aircraft was very appealing to me. This is hard work, but very rewarding."

The commander is not alone in his sense of significance. "I am contributing to the future of the Marines," said Miller. "Don’t get me wrong. I love flying the F-18. But most of us are here because we want to fly new airplanes. More importantly, we want to advance the capabilities of the US Marine Corps. We know that the end-state is what the country needs."

The newness of the F-35 also tends to level the playing field with lessons learned and experience. "If I were flying a Harrier or Hornet pilots, I couldn’t tell them anything they’ve not already learned. They are that experienced with their aircraft," explained Thompson, one of the newest pilots at the 121. "Not so with the F-35. We are still experimenting with how we are going to employ its capabilities. Even someone with less experience in legacy fighters can discover some new functionality in the F-35 that no one else has even thought about."

Accomplishing firsts attracts Marine maintainers to the first operational F-35 squadron as well. "We tell the new technicians, especially the younger ones, that they are in an awesome spot," explained Gunny Gillette. "We tell them that they are at the beginning of a process for fielding the first fifth generation fighter for the Marines. They should be sponges and soak up everything they can about the F-35. This is a new adventure. We get to set the foundation for the F-35. What we are doing now will have long-term effects. We are influencing a program more than we would on a legacy aircraft. Plus everything is new and shiny."

EYE-WATERING PROGRESS

The amount of progress the F-35 and VMFA-121 has made over the last sixteen months is eye-watering," summed up Colonel Gillette. "Nothing has become that routine. We are learning a lot in a short amount of time. We are focused on efficiencies in the maintenance department. We are building the foundation for pilot training. And we are working on things we know we need as we march to IOC [initial operational capability], when an aircraft is cleared for combat operations]. The big pieces are falling together. I am confident we will get there."

"The lessons we are learning here will have a far-reaching impact on other Marine squadrons as well as on the Air Force, the Navy, and on international operators of the F-35 as they begin to stand up squadrons. The first year in the F-35 business, regardless of the uniform worn, will be much easier because of the work we are doing here at MCAS Yuma in Marine Fighter Attack Squadron 121. Eric Hehs is the editor of Code One."

Eric Hehs is the editor of Code One.
LM-100J: AIRLIFTER FOR HIRE

BY JEFF RHODES

From delivering food during the Biafran relief operation in Africa; to spraying dispersant on the waters of Prince William Sound in Alaska after the Exxon Valdez oil tanker disaster; to carrying Keiko the killer whale from a Mexican amusement park to a rehabilitation facility in Oregon, crews flying the L-100 transport have done many hard jobs in oftentimes the hardest of places.

A total of 115 L-100s, the commercial variant of the C-130 Hercules airlifter, were produced from 1964 through 1992 at the then Lockheed-Georgia Company facility in Marietta, Georgia. More than fifty-five of those airlifters are still in service worldwide used for civil airlift missions in places where jet aircraft operations are impractical.

The L-100s service a niche market, delivering oversize cargo such as oil and natural gas drilling equipment to short and often unimproved airfields that have no infrastructure other than maybe a forklift and a flatbed truck. In addition, L-100s, recognizable by the absence of the two lower windows underneath the aircraft’s windshield, are also used for humanitarian aid, airdrop, aerial spray, VIP transport, aerial firefighting, and other, similar operations.

Analysts predict that Latin America, Africa, and Middle East countries will see double digit growth in air freight business over the next decade. Overall, the world’s air cargo trade is expected to grow by four percent annually for at least the next several years. Even higher growth rates are predicted for niche operators.
Even more than passenger airlines, air cargo operations operate on razor-thin profit margins. The twenty-to-forty year old L-100s do have higher direct operating costs relative to the ex-Soviet-bloc An-12 transports operating in many parts of the world, as well as the ubiquitous 737 airliner, many of which have been converted to freighters. However, the 737’s need special cargo ground handling equipment, which adds cost and time and are limited in areas where the Hercules operates most effectively.

To respond to these challenges, Lockheed Martin officials submitted a Program Notification Letter to the Federal Aviation Administration on 21 January 2014 for a type design update for the Model L-382 transport, a civil-certified variant of the C-130J Super Hercules. This commercial variant will be marketed as the LM-100J.

WHAT’S THERE

The LM-100J looks much like its military C-130J Super Hercules counterpart. The main exterior difference is the lack of lower windows under the windscreen, which allow the C-130J pilots to look ahead and down to see drop zones. The new air intake has the same Dowty R391 propellers with six scimitar-shaped composite blades and a black de-icer boot at the base of the vertical fin.

Internally, the LM-100J, like the C-130J, features an Enhanced Service Life, or ESL, center wing box, enhanced icing protection, and the numerous reliability and maintainability improvements that are a part of the basic C-130J design.

The LM-100J uses the same Rolls-Royce AE2100D3 engines as the C-130J. These engines, rated at approximately 4,600 shaft horsepower each, or roughly 150 more horsepower than the legacy T56 engines, feature a full-authority digital engine controller, or FADEC. The engines are expected to exceed FAA Stage IV standards, so there is significantly less fly-over noise with an LM-100J than with an L-100.

The LM-100J has the same automatic engine thrust control system as the C-130J. This system automatically adjusts for axisymmetric thrust conditions—in other words, if one engine loses power, the other engines automatically compensate to keep the aircraft flying safely.

The Northrop Grumman low-power color weather and ground-mapping radar data is presented to the two-pilot flight crew on any of the four head-down color displays on the flight deck. All primary flight information, including altitude, heading, and airspeed is presented on two see-through head-up displays in the crew’s field of view. The LM-100J has a Category II autopilot which can take the aircraft down to 100 feet decision height for landing with 1,200-foot visibility.

On the flight deck, the LM-100J will have a microwave oven, like on the C-130J. However, inclusion of a coffee maker is a customer option.

WHAT IT DOESN’T HAVE

On a commercial air freighter, any equipment that doesn’t need to be on the aircraft is extra weight that can be eliminated. Less aircraft weight means fuel saved. Less equipment equals less complexity and reduced maintenance time. That’s why all of the military-specific equipment found on a C-130J has been removed or disabled on the LM-100J.

The LM-100J has an unobstructed, flat floor with tie-downs and provisions for roller racks for palletized cargo. There are no litter stanchions for casualty evacuation, as casualties are usually evacuated on military transports or dedicated civilian aircraft. The flush toilet has also been removed because it takes up space and adds weight and most LM-100J flights are relatively short.

In the cargo compartment, the LM-100J uses the same Rolls-Royce AE2100D3 engines as the C-130J. These engines, rated at approximately 4,600 shaft horsepower each, or roughly 150 more horsepower than the legacy T56 engines, feature a full-authority digital engine controller, or FADEC. The engines are expected to exceed FAA Stage IV standards, so there is significantly less fly-over noise with an LM-100J than with an L-100.

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The LM-100J has the same automatic engine thrust control system as the C-130J. This system automatically adjusts for axisymmetric thrust conditions—in other words, if one engine loses power, the other engines automatically compensate to keep the aircraft flying safely.

The Northrop Grumman low-power color weather and ground-mapping radar data is presented to the two-pilot flight crew on any of the four head-down color displays on the flight deck. All primary flight information, including altitude, heading, and airspeed is presented on two see-through head-up displays in the crew’s field of view. The LM-100J has a Category II autopilot which can take the aircraft down to 100 feet decision height for landing with 1,200-foot visibility.

On the flight deck, the LM-100J will have a microwave oven, like on the C-130J. However, inclusion of a coffee maker is a customer option.

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The LM-100J will have fuselage doors at the rear of the aircraft, but these doors don’t open fully like the para-troop doors on the C-130J. The paratroop air deflectors mounted ahead of the doors on the LM-100J are deactivated simply because they’re not needed, and the engineering cost to remove them completely would be substantial.

Every C-130J includes provisions for defensive systems such as chaff and flare dispensers, which are not needed for a commercial transport. Secure communications and electronic warfare equipment, racks, and wiring are all eliminated.

Rather than a complex liquid oxygen tank and the associated ground servicing equipment, the LM-100J crew will use a simpler gaseous oxygen system with two walk-around oxygen bottles for emergencies.

Crews flying the LM-100J will generally fly single-ship operations, so the low-voltage formation lights on the C-130J aren’t installed, as is the Station Keeping Equipment, or SKE, which is necessary for formation airdrops with the C-130J.
WHAT IT DOES (OR MAY) HAVE

At the back of the aircraft are external controls to open the cargo door and lower the ramp to reduce time on the ground and to allow for maximum loading capacity.

Internally, the LM-100J crew will be separated from the cargo compartment by a door, unlike on the C-130 which simply has a cutout in what is called the 245 bulkhead (i.e., 245 inches from the nose). The LM-100J has a cargo net able to withstand 9-g force, so it can contain almost anything. The aircraft will also have provisions for widely used commercial cargo handling systems.

Rather than sound-deadening and temperature-controlling insulation blankets used on C-130s, the LM-100J will have a hard liner that is essentially like a bedliner in a pickup truck—able to withstand repeated bumps and scrapes without requiring regular repair or maintenance.

The LM-100J avionics system includes a commercial Traffic Collision Alert System; the latest-generation CNS/ATM equipment and software; commercial takeoff and landing data; and GPS position data reported to the aircraft’s emergency locator transmitter, so if there is an accident, the system sends out exact coordinates to rescue crews.

Structurally, the LM-100J will have reinforced bird strike plates around the windscreen and a commercial standard, bird-resistant windscreen. Externally, the LM-100J will have an INMARSAT radio and commercial GPS antenna on the top of the fuselage.

For nearly every commercial flight, the crew will know in advance whether their cargo for the day is steel pipe, bags of grain, or a truck, and whether they need rollers or a flat floor. The Enhanced Cargo Handling System, or ECHS, in the C-130J allows crews to rapidly change from rollers to tie downs. However, the flip-over roller trays do add some weight. Although the ECHS is not a part of the original baseline LM-100J design, it may still be offered as a customer option.

With aircraft, drag is a bad thing. Lift and thrust have to overcome gravity and drag for an aircraft to fly. A possible second visible external difference between the LM-100J and the C-130J seems to be counterintuitive: installing eighteen small, lightweight, strike-like devices called microvanes on each side of the aircraft’s aft fuselage near the cargo ramp door and horizontal tail.

These roughly ten-inch-long vanes create minimal localized drag. However, working as a group, the microvanes slow the natural, much larger drag-creating vortex that forms as airflow goes over and under the wing and swirls around the aft end of the aircraft. The net result is a fifteen-count reduction in drag at long range cruise speeds, which equates to about a twenty-five gallon per hour saving. Microvanes are being looked at as a customer option on the LM-100J.

ON THE RAMP

Time and payload equal money to air freight operations. Anything that puts more cargo in an aircraft and gets that payload to its destination faster means more money in an operator’s pocket. All of the features of the LM-100J result in a civil-certified transport that will carry one-third more payload, with twenty percent or more greater range, and at ten percent faster speeds than the L-100.

As a practical mission example, a crew flying an L-100 with a max normal gross takeoff weight of 155,000 pounds and a 35,000 pound payload will take off at a max normal gross takeoff weight of 164,000 pounds; reach a cruising altitude of 28,000 feet, where the engines are more efficient, in less time than it took the L-100 crew to reach 18,000 feet; and fly at 310 knots.

Hugh Flynn, the chief executive of the Dublin, Ireland-based ASL Aviation Group, signed a letter of intent for up to ten LM-100Js at the Farnborough International Air Show in England, on 16 July 2014. The aircraft will be flown by SAFAIR, an ASL-associated company based at Johannesburg International Airport, South Africa and Air Contractors, also located in Dublin. SAFAIR currently operates a fleet of six long fuselage L-100-30 aircraft. Air Contractors currently operates one L-100 under the Oil Spill Response, Ltd., brand.

Engineering and detailed design of the LM-100J is currently underway. Assembly of the first aircraft will begin in 2015 and first flight of the LM-100J is expected by early 2017. Because much of the flight test done to civil certify the C-130J in the late 1990s will be directly applicable to the LM-100J, testing and certification of the newest Hercules variant is expected to take about twelve months.

The LM-100J is expected to start earning its keep for commercial operators shortly after the certification process is completed.

Jeff Rhodes is the associate editor of Code One.
The F-16 was designed as a lightweight air-to-air-day fighter. Air-to-ground missions immediately transformed the first production F-16 into multirole fighters. The F-16s that followed expanded and refined these roles with beyond-visual-range missiles, infrared seekers, precision-guided munitions, and many other capabilities. Current and planned versions of the F-16 build on these refinements, enhancing capabilities even further.

BEGINNINGS

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The development of the F-16 optimized a design for performance. The evolution of the production F-16s, on the other hand, became a balancing act between adding and streamlining capabilities and maintaining the original design’s optimized performance.

The first production aircraft following the YF-16 prototype, YF-16 No. 1, was rolled out in October 1976. External differences between it and the YF-16 (left) were kept to a minimum to maximize aerodynamic performance. However, the Lightweight Fighter competition had not yet begun, so most of these modifications for the F-16 were made in groups, or blocks, to track items on the production line. Whenever a new production configuration for the F-16 is established, the block number increases.

THE ORIGINAL F-16

All of these technologies had been explored before in a variety of other aircraft and research programs. But the F-16 prototype, or YF-16, was the first to actually realize all of them into a producible design.

But the fundamental strengths of the original design remain. At the heart of every Fighting Falcon is the lightweight fighter concept championed by Col. John Boyd and the other members of what came to be known as the Lightweight Fighter Mafia in the US Air Force and Department of Defense. This group favored simple and small fighter designs that could change direction and speed faster than their potential adversaries—designs that were harder to detect, designs that were inexpensive to produce, operate, and maintain. The Fighter Mafia advocated using technology to increase efficiency or reduce cost. They went so far as to question and thoroughly analyze the basic assumptions of how fighters were judged and compared.

ENGINEERS

Engineers in Fort Worth transformed these ideas into reality in the 1970s. The resulting lightweight fighter combined a host of advanced technologies that had never been used in operational fighters. A blended wing-body, variable camber wings, and forebody strakes provided extra lift and control. Fly-by-wire flight controls improved response time and replaced heavy hydro-mechanical systems with lighter and smaller electronic systems. Relaxed static stability, made possible by the fly-by-wire system, enhanced agility and stability. A side-mounted throttle and stick, head-up display, thirty-degree seat back angle, ballast, and a blended wing-body, the electronic revolution, the original design, its g-tolerance and situational awareness.

F-16 EQUATION

F-16 EVOLUTION

The all-glass cockpit (no mechanical gauges) of the latest F-16 is the manifestation of many of these improvements. Three large five- by seven-inch color multifunction displays transmit information from a variety of sensors to the pilot in a straightforward color graphics. The cockpit features hands-on throttle and side-stick switch controls, night vision goggles—compatible lighting, a color moving map, and a large head-up display. A helmet-mounted cueing system provides a color moving map, and a large head-up display. A helmet-mounted cueing system provides.
of twin doors on the nose landing gear well, and a self-contained engine starter. The canopy transparency was strengthened to withstand a four-pound, 350-knot bird strike. The radome was hinged to ease access to the radar.

The YF-16 validated the aerodynamics, propulsion, and handling qualities of the aircraft’s basic design. With the major design issues out of the way, engineers concentrated more on internal details—such as the electrical system, hydraulics, and avionics—with the FSD aircraft. The FSD aircraft had no block numbers, though such as the electrical system, hydraulics, and avionics were extensively used in tests that went beyond the original scope of the FSD program.

The 123rd Fighter Interceptor Group in Jacksonville, an interceptor with the 125th Fighter Wing at Hill AFB, Utah, and later became the 51st Fighter

BLOCKS 1 AND 5: GOING OPERATIONAL

After the prototype and AGM programs, the Joint Program Office began to build Block 1 F-16s in November 1977. The aircraft was first assigned to the 388th Tactical Fighter Wing at Selfridge Air National Guard Base, Michigan. The aircraft was eventually sent to Lowry AFB, Colorado, as a student trainer. The first operational F-16 is now on display at Langley AFB, Virginia.

Ninety-four Block 1 and 197 Block 5 F-16s were manufactured through 1981. The canopy transparency was strengthened to withstand a four-pound, 350-knot bird strike. The radome was hinged to ease access to the radar.

The F-16 was designed to replace older aircraft in the fleet, such as the F-4 and F-106. It was intended to be a multirole fighter capable of both air-to-air and air-to-ground missions.

The Block 15 F-16 is a variant of the Block 15 F-16 equipped with additional systems for the air-to-air role. It has improved APG-66A radar, an APX-109 identification friend or foe interrogator, ARC-200 high-frequency radio, and a 150,000-candlepower spotlight mounted on the left side of the forward fuselage. In the late 1980s and early 1990s, 271 Block 15 airframes were converted to the Air Defense Configuration (ADC). The Block 25 F-16 refitted for ADC is the most advanced F-16 variant in the fleet, incorporating the latest avionics and weapons systems. It is a true multirole fighter capable of performing both air-to-air and air-to-ground missions.

The Block 30 F-16 achieved the first Block 30 production. The F-16N also carried the APG-66 radar of the F-16A models and minor structural differences for meeting Navy requirements. The aircraft had no internal 20-mm gun. Twenty-two F-16Ns and four TF-16Ns (two-seaters) were built from 1987 to 1988. They were used for dissimilar air-to-air training with three Navy adversary squadrons and at the Navy’s Fighter Weapons School (Top Gun) until 1994.

The LANTIRN pods also necessitated moving the landing lights from the front of the main landing gear to the leading edge of the nose gear door. The larger wide-angle collimating, or WAC, Pod was no longer needed for LANTIRN as well. This wide-angle RUID, as it is called, is capable of displaying the infrared image from the LANTIRN navigation pod used in low altitude night navigation.

The precision weapons incorporated by Block 40/42 include the BDU-50, AGM-88, and AGM-158. The Block 40/42 is a significant upgrade to the F-16, providing enhanced air-to-air and air-to-ground capabilities.

The US Navy once again began flying Fighting Falcons in early 2002 when the first of ten single-seat and four two-seat F-16s were delivered to NAS Fallon in Nevada (the current home of Top Gun). These aircraft, with distinctive paint schemes, are low-hour F-16As that had been in storage.

The landing gear of Block 40/42 was strengthened and extended to handle the Low Altitude Navigation and Targeting Infrared for Night, or LANTIRN, targeting and navigation pods. The new landing gear bay doors bulge slightly to handle the larger wheels and tires.
The Block 50/52 F-16 continued to be improved, and the current aircraft sold to the FMS customers is equipped with the APG-69(V) radar, which offers longer range detection to targets and higher reliability. The Block 50/52 now includes embedded global positioning system/inertial navigation system, a larger capacity data transfer cartridge, a digital terrain system data transfer cartridge, a cockpit compatible with night vision systems, electronic data modem, an ALT-56M advanced radar warning receiver, an AN/ALQ-51 threat-adaptive countermeasure system, and an advanced interrogator for identifying friendly aircraft. In the cockpit, an upgraded programable display generator has four times the memory and seven times the processor speed of the system it replaces. New VHF/FM antennas increase reception ranges. The Block 50/52 is powered by the increased performance engines—the General Electric F110-GE-129 and the Pratt & Whitney F100-PW-229—each with a thrust of 29,000 pounds of thrust in afterburner. Block 50/52 are the first F-16 versions to fully integrate the AGM-84 Harpoon anti-ship missile. New-production Block 50/52 aircraft ordered after 1996 include color multifunction displays, the modular mission computer, and a multitasking video recorder. All international versions of the Block 50/52 have LANTIRN capability. The Block 50/52 F-16 has been delivered from production lines in Fort Worth, Korea, and Turkey. The Fort Worth production line is currently the sole source for all Block 50/52 aircraft. The other production lines have completed their production runs and have been shut down.

**COMMONALITY**

With all the variants of the F-16 produced through the years, the US Air Force decided to standardize its F-16 fleet to simplify logistics, maintenance, and training. The service, building on the success of the MLU program, implemented the Common Configuration Implementation Program (CCIP) in 1997 to bring all of the Block 30/32/40/42/50/52 into a common avionics configuration. The CCIP added color displays, communications, and an improved modular mission computer module as Block 40/42 and Block 50/52 F-16s as well as an advanced datalink, called Link 16, to the US Air Force and NATO aircraft. The upgrade also included the multi-service standard joint helmet-mounted cueing system (JHMCS). This system was then wired to the high-off-boreight AIM-9X air-to-air missile as well as other sweeper sensors and provides the pilot with other situational awareness and navigation data without looking in the cockpit. More than 200 Block 50/52 and 420 Block 40/42 aircraft were delivered from the CCIP program. The Air National Guard (ANG), Air Force Reserve Command (AFRC), and active duty Air Force units are now operational with the upgrades. This program successfully completed in 2011, and now all of the US active duty aircraft fly with communications and navigation improvements.

**ENGINES**

The engines that power the F-16 have improved in more ways than in maximum afterburner. Engines used in early F-16s required from six to eight seconds to spool up from idle to afterburner. Since then, electronic controls have replaced hydraulic-mechanical systems. These changes allow current engines to go from idle to full afterburner in two seconds. Engine reliability and ease of maintenance have also been improved significantly today. F-16 engines can be expected to deliver straight to ten years of operational service between depot inspections.

**THE EVOLUTION CONTINUES . . .**

In recent years, significant improvements have opened and added to the stream of software and systems upgrades that have been part of the program from its inception. Most significantly, the US Air Force is fielding the Automated Ground Collision Avoidance System, or AGCAS, which provides the pilot with improved situational awareness of imminent collision with the ground. The system can take control of the aircraft to avoid a collision, but if the pilot doesn’t respond to the visual cues.

Additionally, to implement customer requirements for newer, more advanced capabilities and to meet the data processing loads required to fulfill those requirements, the avionics configuration of the Block 60 was developed to keep the F-16 capable and relevant. The V-configuration incorporates an improved MMC, upgraded programmable displays generator, an active electronically scanned array radar, a large, high-resolution center pedestal display; and integrated weapons and electronic warfare displays and systems all supported by a gigabit Ethernet architecture.

**STILL EXCEPTIONAL**

In the 49 years since the YF-16 was flown for the first time in the Air Force Flight Test Center at Edwards AFB, California, it has continued to evolve to meet new requirements for each of the twenty-six customers who operate the F-16. The first production Block F-16 rolled out of the factory in Fort Worth in August 1978. Since then, more than 4,700 Block 60’s have rolled off assembly lines in five countries. The F-16 will continue to serve as a frontline fighter and sustainment will extend well beyond 2030. The present state of the F-16 encompasses a broad range of configurations. While the earliest F-16s perched atop poles for public display, others tested the latest weapon and sensor technologies. Those rolling off the factory line represent the aircraft that powers the majority of F-16 fighters worldwide.
Flutter occurs at the point where aerodynamic forces acting on an aircraft in flight and the structural dynamic properties of the vehicle combine, or couple, to produce an often violent, harmonic vibration. The resulting vibration creates a potentially catastrophic condition that can quite literally break a wing or tail surface off an aircraft.

In simple terms, think of a flag on a pole. The wind blows at a specific speed, but the flag, with a specific set of structural properties, doesn’t wave uniformly from side to side. It usually dips, or swells, or bends. When conditions are right to cause the flag to pulsate, the flag is basically experiencing induced flutter. If the wind is too strong and the grommets or stitching fail, the flag is ripped from the pole.

Flutter has been a known hazard almost from the beginning of powered flight. Even with more than a century of aircraft design experience, conditions where flutter occurs can still be hard to predict precisely. Aircraft designers traditionally have dealt with flutter by trying to avoid it—through such methods as adding structure.

By building enough stiffness into a specific structure, the natural tendency of structural dynamics and aerodynamics to couple can be prevented—even at conditions way outside an aircraft’s normal operating flight envelope. But the increased stiffness also adds weight—sometimes considerable weight—which, in turn, increases fuel use. And the end result—reduced range.

The X-56 team hopes to do something that is completely different. “The aim of the X-56A program is to mature flutter suppression technologies,” notes Burnett. “If we can suppress flutter by using the same flight control technologies used to provide vehicle stability, designers can use longer, more flexible wings and lighter weight structures. That will allow future aircraft to fly higher, faster, and farther than before.”

X-56A UNMANNED RESEARCH AIRCRAFT:

Mad Mutt

BY JEFF RHODES

LONG AND THIN

Long, thin, high aspect ratio wings are considered key to the design of many future long range manned and unmanned aerial vehicles and fuel-efficient transports. These future aircraft will likely bear many of the same features designed into the X-56, including a blended body, long thin swept-back wings, and very thin airfoils.

The X-56 was funded by the US Air Force Research Laboratory, or AFRL. The contractor test team hopes to demonstrate that they can accurately predict the onset of flutter, and by using the flight controls, actively suppress the aerelastic instabilities of the aircraft.

Two types of wings will be tested on the X-56—a stiff set and a flexible set. The stiff set of wings is designed in the traditional manner with beaded up structure to avoid having flutter within the flight envelope. These are used for the initial airworthiness tests of the aircraft and any future non-flutter flight research. Flutter was deliberately designed to be deep in the flight envelope of the X-56A’s flex wing configuration. Because flutter is a natural coupling of the aerodynamics and structural dynamics, simply flying fast enough causes it to occur.

The X-56A is designed to have three different flutter modes within the flight envelope—body freedom flutter, or BFF, symmetric wing bending torsion, and anti-symmetric wing bending torsion. The active flutter controls on the X-56 are designed to suppress all three modes simultaneously.

The aircraft has external mounts that allow the wings to be removed easily and replaced with the flexible wings. The external wing attach points are covered by an aerodynamic fairing that looks like an upside down hot dog bun. Switching the wings takes about fifteen hours to complete.

“The internal structure of the wings is the same on both designs, but the flutter wings are flexible,” noted Kent Burns, the X-56A program manager. “Both sets are made of a carbon fiber internal structure of spars and ribs, but the stiff wings have very thick, highly tailored carbon fiber skins and the flex wings have very thin fiberglass and foam skins.” Three identical sets of flex wings were built, just in case one set fails in flight as a result of flutter.

The flutter wings have internal water tanks and water pumps. The weight of the water is used to simulate the fuel that would be required for long duration flight such as a long-range transport or high altitude reconnaissance aircraft. “Due to the nature of this type of research, it’s possible that we could break a wing off during testing,” Burns continued. “If that happens on this vehicle, we’ll only be spilling water instead of fuel.”

FIDO AND BUCKEYE

The two parts of the X-56 program each have a descriptor. The test program is the Multi-Utility Aerelastic Demonstrator, or MAD, and the aircraft itself is the Multi-Utility Technology Testbed. So the team picked up the name MAD MUTT.

Following up with the canine theme, the test team had a dog tag painted on the underside of each of the two identical aircraft. Fido—from a slogan the team uses—Flutter It, Drive On—is the primary test aircraft while Buckeye—named for the Air Force program manager’s dog and the mascot of his alma mater—is the backup.
The X-56A program began with small independent research and development contracts in 2005. “We built five small hand-launched vehicles that had wings made of carbon fiber and Styrofoam. They were essentially designed to break in the wing structure and then to send computer data to the ground in the form of flutter predictions to the ground control computer for the stiff flight test programs. The second phase of testing with Fido will use a flexible set of wings that have known structural instabilities within the flight envelope. The team finalized development of the flight control law gains in the fall of 2014. These flight control law gains will simultaneously control the vehicle and the structure to make it seem to the pilot that the X-56 is a stable, rigid aircraft.

Additionally, the Skunk Works team is working with NASA engineers to ready Buckeye for the first phase of NASA’s flight test program. These test flights will provide NASA with confidence in their aircraft control system for the stiff wing configuration that will allow for future flight test programs.

It’s been said that flutter is a particularly nasty dragon that lives in one corner of the sky. “The work we’re doing with the X-56A may not kill flutter completely,” observed Burnett. “But we will have a much better understanding of how to tame it.”

Jeff Rhodes is the associate editor of Code One.
The AEHF system will consist of six cross-linked satellites that eliminate the need for ground relay stations; a mission control segment that includes mission control, training, and logistics functions; and a terminal segment that includes fixed and ground-mobile terminals, ship and submarine terminals, and various airborne terminals.

In addition to Special Operations and a number of service-specific applications, AEHF will provide real-time situational awareness and enroute planning and targeting data for the Air Force; a battlefield common operational picture and precision engagement data for Army units; and air tasking order transmission and battle damage assessment for the US Navy. Canada, Netherlands, and the United Kingdom are partners on AEHF.

AEHF-1, launched in 2010, and AEHF-2, launched in 2012, and AEHF-3 are all now operational. In addition to initial US testing, the Canadian and Dutch militaries have each conducted tests of their ground terminals.

In 2014, AEHF-4 will be assembled in the same clean rooms at Lockheed Martin Space Systems Company in Sunnyvale, California, where the Milstar satellites and numerous other satellites and spacecraft were built. At the same time, AEHF-5 and AEHF-6 are in component production.

**FIRST TIME, EVERY TIME**

“A satellite has to work first time, every time,” said Mark Calassa, the Lockheed Martin vice president of Protected Communication Systems who oversees the 500-person AEHF program at Space Systems Company: “There are no second chances. We can’t bring the satellite back to fix something.”

Every satellite is thoroughly tested at every stage of construction. Counting test, it takes about 100 people seventy-two months to build a single AEHF satellite, noted Calassa. “We test everything at the component level first and then test small numbers of components together. Testing the complete satellite takes twenty-four months.”

Unlike previous generations of satellites where the entire spacecraft was designed and built to order, AEHF, as well as satellites for the military’s other new satellite system, the Mobile User Objective System, or MUOS, use a common modular bus—the Christmas tree that the various sensors and antennae needed for a particular satellite type are hung on—called A2100.

Developed as a way to increase reliability and reduce cost for commercial satellites, the A2100 bus features a simplified structure to reduce parts count. It is made of lightweight all-composite materials to increase strength, reduce weight, and minimize thermal distortion.

Testing at the component level and assembly takes about two years. The AEHF payload is built by Northrop Grumman and is assembled in parallel to the bus components. Next comes the baseline integrated systems test, or BIST. “This is the first time the vehicle is powered on in an airtight environment,” said Calassa. “Acoustic testing, which simulates the vibration and noise of the rocket launch, comes after that.”

Thermal vacuum testing, or TVAC, which takes two months on AEHF, follows. “We simulate the environment of space and turn the satellite on. We subject it to the coldest cold and the hottest hot to make sure everything still functions,” noted Calassa. The final integrated system test, or FIST, is the comprehensive exam where the final measurements are compared with initial test results.

At this point, the pyrotechnic devices needed to open the sensor arms in space are installed, and the solar array is attached. Space Systems Company now builds its own solar cells as a way to reduce costs. When extended, the solar panels give the AEHF satellite a span of ninety-eight feet.

“We add the last thermal blankets, attach the access panel cover plates, and button up the vehicle. This whole process takes about six months,” noted Calassa. The satellite is then ready to ship.

**A VERY LARGE BOX**

In mid June 2013, about a month before AEHF was ready for shipment, a C-5 Galaxy transport crew flew into Moffett Federal Airfield, which shares a fence with the Lockheed Martin facility in Sunnyvale, to deliver a very large, very specialized container called MATS.

“The Miller Automated Transportation System is named after the engineer who designed it,” said Jorge Martinez, Lockheed Martin engineer whose team is responsible for all fixtures and dollys necessary to move satellites through integration, test, and transport. “Convair built MATS in San Diego in the 1980s for another program, and it was modified for SBIRS [Space-Based Infrared System] and AEHF transport in 2006. It’s a temperature- and humidity-controlled box designed to safely transport satellites that cost almost $1 billion.”
The MATS container has a mechanical arm with a gimbaled motor at the base. The arm is raised, and the satellite is attached. The arm, with the satellite attached, is then rotated down cantilevered in the container. Packing peanuts or foam cutouts aren’t an option.

For as long as the satellite sits in MATS, a nitrogen purge is used to keep the electronics free from debris and protected from corrosion. The container keeps the satellite at room temperature with low relative humidity.

Early in the morning of 10 July, the MATS container, with the AEHF-3 inside, left the east side of Travis Air Force Base and was transported very slowly through the common fence to neighboring Moffett Field.

“It’s an old tale that we move spacecraft at night to keep the Russian satellites from watching,” said Calassa.

“There may have been something to that during the Cold War. But the fact is, a daytime loading puts stress on the environmental control system. It’s just cooler to load at night, particularly in the summer.”

Just before dawn, a crew of about twenty technicians and the aircrrew gently and precisely loaded MATS container on to the front end of the C-5’s cargo compartment. The aircrrew had only the eighteen-inch width of the catwalks along the fuselage sides to get around the satellite. The gap from the top of MATS to the walkway of the aircraft’s crew compartment was only two and one-half inches.

Supporting equipment, including the specialized tractor trailer, filled the remainder of the cargo hold.

CLEAR THE TREES

The journey to deliver AEHF-3 actually began in October 2004, when this particular C-5B Galaxy transport (Air Force serial number 86-0013) was flown to Lockheed Martin Aeronautics Company in Marietta, Georgia. This aircraft was the first C-5 to go through the Reliability Enhancement and Re-engineering Program, or RERP, modification line. New engines were installed and more than seventy other improvements were made. The transport, now a C-5M Super Galaxy, was first flown in 2006.

“A lot of these types of missions are now going to the C-5M,” noted Capt. Gene Pasker, who has approximately 3,000 flight hours in legacy C-5s.

“About the only difference on a mission like this is we have to pay closer attention to pressure and temperature,” said TSgt. Kevin Calhoun, the lead flight engineer. “Cabin pressure has to be regulated to no more than 500 feet per minute change on descent.

Five plus hours after takeoff from Moffett Field, the C-5M crew touched down on the 15,000-foot-long, 300-foot-wide Space Shuttle runway at the Kennedy Space Center.

The process of unloading the satellite and all of the support equipment began minutes after the engines spooled down. Portable lights were set up as the sun set.

TO ASTROTECH AND BEYOND

First off the C-5 is the specialized transporter. As a safety precaution, the truck cab was used to put the MATS container on the C-5. It was flown with just enough fuel to get off the aircraft. Warning forklift drivers moved the other boxes of gear—filled with hoists and shop aids for the satellite—onto two separate flatbed trailers. The aircraft was knelt in the back to get the truck off and was then raised.

The nose was then knelt to get the satellite off. The entire load/move/truck cab that was used to put the MATS container off the aircraft to discuss taking the MATS off the plane. The scene looked like a larger-than-normal football huddle. The driver raised the trailer to meet the aircraft’s ramp height exactly. The trailer was then the only C-5M base. “The flight crew was basically the next names up on the board. We did look for a little more experience because this is a high priority mission. But with our current operational level, it was mostly a case of picking the people who were available.”

The augmented flight crew of ten—pilot, aircraft commander, relief pilot, two flight engineers, and three loadmasters—also included two flight mechanics. “We take the flight mechanics along when we go places where there’s no C-5 support,” added Pasker.

Pasker, who has approximately 3,000 flight hours in legacy C-5s and an additional 1,000 flight hours in the C-5M.

Despite having a national asset in the cargo hold, no special route planning was required, nor did the crew have a reserved airspace corridor. The crew flew at normal cruise speeds, but did fly a parallel path to the original flightplan and at a slightly higher altitude to avoid thunderstorms and rough air.

About the only difference on a mission like this is we have to pay closer attention to pressure and temperature,” said TSgt. Kevin Calhoun, the lead flight engineer. “Cabin pressure has to be regulated to no more than 500 feet per minute change on descent.

Nearly three years before AEHF-3 lifted off, construction of the Atlas V Mainland Operations Center next to the Atlas/Centaur processing facility about six miles from the launchpad. The idea is to get the crews used to how the launch process will be conducted. Both teams are brought together to simulate the entire launch. “For this rehearsal, the computer thinks everything is flying. We go through everything up to simulated spacecraft separation,” Fust said.

The launch director sitting in a room overlooking the control room gives permission to launch, and the launch conductor directs the independent console operators. A final poll of the launch team is taken at the built-in hold at T-minus-4 in the countdown. Just like in the movies, there is a big red button on the launch coordinator’s console that can stop the process. But computers actually start the engine and launch the rocket.

“We want to launch in the first hour of the first day of the launch window,” Fust noted. “The longer we wait, the chance of something going wrong increases.” AEHF-3 lifted off at 4:10 A.M., delayed sixty-six minutes to allow rain clouds near the pad to clear. The launch of AEHF-3 marked the seventy-fifthULA launch and the fortieth Atlas V mission.

The C-5M crew probably missed watching the launch on TV. They were likely on another mission. Staff post-launch parties in Sunnyvale, Los Angeles AFB, and at the Cape marked the launch team’s success. But the next day, it was back to work. There’s another spacecraft to deliver and to launch...
“JPADS is the Air Mobility Command equivalent of a smart bomb,” stated Col. Howard Wajd, then commander of the 317th Airlift Group, the US Air Force C-130 Super Hercules unit at Dyess AFB, Texas. “If a load of ammunition, food, medicine, or other high-value cargo has to be airdropped on a specific ridgeline or inside the walls of a forward operating base from standoff distance, JPADS is the only way to do it.”

The Joint Precision Airdrop System, or JPADS, is a multi-part, GPS-based method that allows for highly accurate parachute airdrop of cargo loads of various sizes from altitudes as high as 25,000 feet. And, with only a forty-seven-pound flying time from Dyess to the extensive training ranges and drop zones at Fort Hood, Texas, the 317th AG, with its two flying squadrons and nearly complete fleet of C-130Js, has become a recognized leader in C-130 precision airdrop operations. “You’ll get a big grin from an Army ground commander when you tell him you’re going to be able to consistently drop his supplies within 100 meters of the target,” said Maj. Justin Brumley, then the 317th AG chief of standardization/evaluation. “JPADS is a win for both parties. The warfighter on the ground gets resupplied, and the warfighter in the air can now fly straight and level at high altitude, deliver the cargo to a specific point, and avoid the enemy’s weapon engagement zone.”

Full development of JPADS began about ten years ago. When Operation Enduring Freedom began in Afghanistan in 2002, it soon became apparent that, because of shifting winds and mountainous terrain, cargo airdropped by conventional ballistic parachutes wasn’t always getting where it needed to go. A later, secondary reason for the official interest in precision airdrop was the increasing threat from roadside improvised explosive devices, or IEDs, to ground convoys. IED casualties suffered while on convoys forced commanders to shift to using aircraft to resupply forward-deployed troops. “Legend has it that a couple of Army guys went to a local post exchange and bought a commercial GPS and rigged it to a cargo load to try to guide it,” noted Brumley. “That didn’t exactly work, but the experiment did seem to be the spark that got the Army interested in precision airdrop.”

The US Army is responsible for development of parachutes and basically everything else related to airdrop other than the aircraft itself, so technical experts at the Soldier Research, Development, and Engineering Center at Natick, Massachussetts, more commonly known as the Natick Labs, took on the challenge of guided airdrops. A rapid engineering development effort led to the fielding of a JPADS unit capable of delivering a one-ton payload. A crew from the 774th Expeditionary Airlift Squadron at Bagram AB, Afghanistan, the C-130 umbrella unit composed of crews and aircraft deployed from several US bases, carried out the first JPADS combat airdrop on 31 August 2006.

Today, there is a JPADS variant for very small loads, called Microfly, and for loads weighing more than 10,000 pounds, called Dragonfly. The most commonly used variant is Firefly, which is a Container Delivery System, or CDS, load (known as a bundle) of up to 2,000 pounds. The only significant difference among the three types of loads is the size of the parachute used.

A Firefly bundle, which is a second-generation precision airdrop system, consists of a fifty-three inch by forty-eight inch plywood skidboard; a number of cardboard energy dissipating pads, or honeycomb, depending on how critical and/or fragile the load is; an Autonomous Guide Unit, or AGU; a small drogue chute; and a steerable, airfoil-shaped, 1,925 square foot main parachute with a fifty-six foot wingspan.

The eighty-pound AGU houses a battery power pack, GPS receiver, guidance, navigation, and control software package; and the servos that pull on the parachute risers, or steering lines, to make turns to get the bundle as close as possible to the target, which is known as the Point of Impact, or PI. After the bundle is released and current position determined, the AGU then steers the parachute to fly the load to a pre-determined spot on the ground. On its way down, the AGU makes corrections as necessary, much like a trained parachutist would do to land on the fifty-yard line to bring the game ball into a football stadium. While much of a CDS bundle is discarded, the ground unit receiving a Firefly bundle is charged with making sure the AGU is recovered and transported back to a main base so it can be reused.

A new guidance unit design, called a Modular AGU, or MAGU, (pronounced Magoo), is now being fielded. “MAGU is the wave of the future,” noted Adolfo Gutierrez, Jr., the Air Force’s contracting officer representative overseeing Trailboss, a civilian company providing aerial port services at Dyess. “This unit, which has a wood and metal frame, weighs only forty-seven pounds and can be broken down for easier transport by ground troops. It also has a six-point parachute that provides better stability during the drop.”

The thirteen Trailboss employees—mostly prior service loadmasters or aerial porters—build up the Firefly training bundles as well as heavy equipment and Improved CDS, or ICDS, training loads. Like JPADS, ICDS bundles are also guided, but have a much smaller range of motion because a ballistic parachute is used. ICDS bundles are usually dropped from lower altitudes.

The Trailboss employees take the Firefly out to the C-130J waiting on the ramp. While one or two Firefly bundles are dropped on a typical training mission, multiple JPADS loads can be released on a single flight. Dyess crews have also demonstrated the system’s capability to send loads to distinct drop zones that were several miles apart.

**PREPARATION**

The cargo compartment of the aircraft is a busy place prior to engine start. The aircraft’s loadmasters—two are carried on JPADS drops—along with the Dyess Joint Airdrop Inspection team make sure the bundle is secure and is receiving the correct drops. The Trailboss employees take the Firefly out to the C-130J waiting on the ramp. While one or two Firefly bundles are dropped on a typical training mission, multiple JPADS loads can be released on a single flight. Dyess crews have also demonstrated the system’s capability to send loads to distinct drop zones that were several miles apart.

**PARTS OF THE WHOLE**

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The target location data was originally programmed into the AGU once it was loaded in the aircraft on the ground. However, depending on mission changes, it can also be reprogrammed while airborne. As the crew approaches the drop zone on a second pass, and the AGU knows where it is and where it’s supposed to go, the small display on the side of the unit flashes READY TO FLY.

The bundle is released, the drogue chute opens to slow it down. Once the load is stable, the paratrool opens. "We work very hard to set the bundle up for success," said Capt. Eric Dueno, a pilot with the 317th OSS. “But once we release the load, the trip is in the hands of the AGU. We can't really make any claims for accuracy. We don't watch the load drop. We just button up and press on.”

All of the components in the aircraft—the GPS repeaters, the DRS, the cable, and the laptop—can be fitted to a C-130H or to a C-17. "We generally make JPADS drops only during the day, as the troops on the ground don't really want to look on target, as the air mass it's measuring generally extends for miles. Wind data from a successful sonde drop is valid for approximately two hours.

The sonde data is received by the UHF antenna on the bottom of the aircraft and the signals are fed through the Directional Retransmit System, or DRS, receiver that is located in the cargo hold. The DRS converts the data to a digital signal that is then sent over a long Cat 5 Ethernet cable to a ruggedized laptop computer on the flight deck.

The fifth member of the aircrew is a pilot or navigator trained as the PADS operator, or PADSO. Sitting at the augmented crew position behind the pilots on the C-130 flight deck and using the laptop, the PADSO determines the winds and develops a highly accurate Computer Aided Release Point, or CARP. The two pilots, flying the aircraft and talking to the Air Force tactical air controller on the ground, fly the aircraft to the right position at the right time to make the drop.

Prior to the drop, the aircraft is depressurized and the cargo ramp is lowered. As most JPADS drops occur well above 10,000 feet, the crew, already wearing body armor and helmets, also has to don oxygen masks. "Crew resource management is dramatically different on oxygen and wearing a helmet, so we train for that," noted Capt. Jonathan Esses, a pilot with the 317th Operational Support Squadron at Dyess. "It's harder to determine who's talking through the masks. But if somebody is talking on the intercom at that point, he's saying something important."

The loadmaster, who is also wearing cold weather gear, walks to the back of the ramp to release the sonde. "We're taught to throw the sonde like we're spiking a football. But once the sonde gets in the slipstream, it just goes out of your hand," observed SSgt. Justin Magno, a loadmaster assigned to the 317th group staff. Added SSgt. Shawn Rumbaugh, a loadmaster with the 39th Airlift Squadron, “We want to make sure the sonde spirals down. If it tumbles, it will usually lose the GPS signal. We have to have good sonde data to make an accurate drop."

**READY TO DROP**

As the sonde descends, it sends data back to the aircraft. Slowed by a small parachute, the sonde's trip to the ground takes about six minutes. It's not critical for the sonde to land on the target, as the air mass it's measuring generally extends for miles. Wind data from a successful sonde drop is valid for approximately two hours.

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The low-cost, single-use sondes, which bear a resemblance to 1970s-era lawn darts, have a built-in GPS receiver and UHF transmitter. As the sonde is critical to success of the airdrop, multiple sondes are carried on each mission to be used for different drop zones or as backups. But usually only one sonde is required to get wind data for the actual drop.

Brumley noted that having to make two passes over a drop zone is problematic from a tactical standpoint. Crews want to minimize exposure to—not increase the chances of—taking fire from insurgents with shoulder-fired missiles or from potential enemies with an air defense system. Two passes also requires ground troops to hold a drop zone for a longer period of time.

"One solution could be to incorporate LIDAR [Light Detecting and Ranging] or to build-in autonomous wind detection in the C-130's low power color radar," explained Brumley, who joined the Air Force Reserve and took a new job as an instructor at the Advanced Airlift Tactics Training Center at St. Joseph, Missouri, in summer 2013. "A change of that magnitude eliminates the sonde airdrop pass altogether, but it is likely expensive. The next generation of precision airdrop, whatever form it takes, will require innovation."

"Now we have to input a lot of data into the laptop for a JPADS drop that creates a potential for human error. Other improvements are more fundamental."

"We now can be miles away from the target zone and get the load down nearly on the PI," Ward concluded. "And that capability is only going to get better. It's an exciting time to be an airlifter."

Jeff Rhodes is the associate editor of Code One.
Even though the aircraft has undergone at least seven fundamental changes in its operational history, it is still referred to as the U-2. To overcome some of the perception issues, Austin makes sure to include two photos in her presentations for audiences unfamiliar with the U-2. The first photo shows the cockpit of the original U-2A with all its scratched and worn dial gauges. The second photo shows the current U-2S cockpit with shiny new flat panel color multifunction displays.

After seeing those photos, people realize we are discussing two completely different airplanes," she continued. "I then explain that the U-2S is also a new airframe with newly upgraded systems that go beyond the cockpit improvements. More significantly, it is the only high-altitude platform that can perform certain critical reconnaissance missions."

Thirty-four U-2s are flying today. Most were built in the 1980s as TR-1s though a few are U-2Rs built in the late 1960s. All of these aircraft were re-designated U-2S in 1999, with two exceptions. The two-seat trainer version, accounting for five airframes, is referred to as the TU-2S. The NASA version, accounting for two airframes derived from the U-2S, is referred to as the ER-2.

The end of U-2 production in 1989 marked the beginning of a host of evolutionary upgrades. One of the first and arguably one of the most significant upgrades came in the form of the F118-GE-110 turbofan engine that was integrated into the airframe in the mid-1990s. The engine was lighter, more powerful, more fuel efficient, and easier to maintain than the Pratt & Whitney J75 engine it replaced. "We upgraded the engine out of necessity," explained Greg Birdsall, Lockheed Martin sustainment manager for the U-2 program. "The U-2 was the last aircraft in the inventory to use the J75. It didn't make sense economically for Pratt & Whitney to continue to support the J75 because the U-2 fleet was too small. Fortunately we had enough notice to develop an alternative engine, which just happened to benefit the U-2 in many ways."

The 1,500 pound weight savings created by the new engine allowed the U-2 to increase time on station or to carry more fuel or more sensors. The aircraft could now carry sensors for multiple missions on a single flight. The F118 also provided additional electric power generation capacity that enabled upgrades that followed. The electrical system itself was modernized in the late 1990s. Legacy wiring was replaced with advanced fiber-optic technology, which lowered the overall electronic noise signature to provide a quieter platform for a new generation of sensors.

The Raytheon Remote Airborne Sensor, or RAS-1R, a radio frequency signals intelligence suite was added in 2001. The color flat panel multifunction displays, referred to as the glass cockpit or Block 20 Modification, were added in 2003. A variety of the U-2’s Mission Systems received significant upgrades in their capabilities and performance from 2000 through 2005. These systems consisted of an advanced defensive suite, the AN/ALQ-221, which protects the aircraft with a radar warning receiver combined with electronic countermeasure system; a nose-mounted synthetic aperture radar system, known as AN/ASQ-230, which captures ground images from a range of 100 miles and operates in search and spot modes against moving and stationary targets; the Dual Data Link 2 system, which allows the aircraft to transmit collected intelligence to ground sites where the US Army, Navy, or Marines can have immediate access to intelligence images; an electro-optical reconnaissance system, designated SYERS, which provides very high resolution imagery from long distances at day or night. A radio frequency signals intelligence suite, the AN/ASQ-230, was added in 2008. This system detects, collects, processes, identifies, and geo-locates radio frequency signals automatically.
SINCE THE CARE MODIFICATION, NOT ONE U-2 PILOT HAS SUFFERED FROM DECOMPRESSION SICKNESS.

"Decompression sickness was becoming more of an issue because of the longer flight durations and increased sorties pilots were experiencing for missions over Afghanistan," explained Ross Cooper, Lockheed Martin chief engineer for the U-2 program. "Pilots were flying more sorties for longer durations, up to twelve hours." Before CARE, pilots were flying these missions at an equivalent altitude of 15,000 man-hours. Every U-2 goes through PDM every six years or 4,000 flight hours, whichever comes first. With a thirty-two aircraft fleet (NASA does its own periodic maintenance), the requirement equates to four to six airframes being processed through Palmdale every year.

"I don’t know of another military aircraft program in which every aircraft in the fleet is completely disassembled and rebuilt on a regular schedule," added Baughman.

The most recent upgrade, the Cockpit Altitude Reduction Effort, or CARE program, was done in 2013. This modification involved reinforcing the airframe structure, replacing valves, changing the bleed air system logic, and altering some cockpit controls to lower the altitude the pilot experiences when in high flight, reducing the physical strain of high-altitude flight. The CARE modification thereby significantly reduces the risk of pilot decompression sickness.

Essentially, our operation is a restoration shop," explained Baughman. "We take the airplane apart, inspect it thoroughly for corrosion and cracks, repair and replace equipment as required, put it back together, paint it, flight test it, and return it to the fleet."

The aircraft come in looking well-worn and depart looking factory fresh. Besides being structurally checked out and refreshed, all of the internal equipment is brought up to the latest standards.

The process, referred to as programmed depot maintenance, or PDM, requires about eleven months and approximately 15,000 man-hours. Every U-2 goes through PDM every six years or 4,000 flight hours, whichever comes first. With a thirty-two aircraft fleet (NASA does its own periodic maintenance), the requirement equates to four to six airframes being processed through Palmdale every year. The rigorous maintenance process is a testament to the importance of the U-2’s unique mission and to the longevity of the structural design. The flight hours for a U-2 airframe average 17,000. The airframe with the highest accumulated hours. “Here we are fifty years after the U-2 mission kept getting extended. The test involved putting more than 1,000 strain gauges on one airframe and measuring the loads in different areas to calculate the expected lifespan.

The longevity of the U-2 program can be credited to its effectiveness. In her presentation to those unfamiliar with the mission: "The 9th Reconnaissance Wing is looking for a few officers with the professionalism and flying skills necessary to pilot the U-2 Dragon Lady and to provide our nation’s decision-makers with critical high-altitude Intelligence, Surveillance, and Reconnaissance."

Eric Hehs is the editor of Code One.
This year marks the inevitable arrival of the future forecast in the 1989 film Back to the Future II. While we do not have flying cars or hoverboards as the movie predicted, the F-35 program is performing feats beyond the wildest dreams of Marty or Dr. Emmett Brown. Some of the major feats performed in 2014 are detailed in this edition of Code One.

Looking ahead to 2015, I am eager and enthusiastic. Our F-35 team has a lot to accomplish in the next twelve months, and it will take a world-wide effort to make it all happen. A glimpse of what’s ahead:

• The U.S. Marine Corps declaration of Initial Operating Capability
• F-35 operational testing aboard the USS Wasp for the US Marine Corps
• The first F-35 operational flight weapons drop for the Marines
• The beginning of F-35 pilot and maintainer training at Luke AFB
• Block 2B software training release and its availability to the US Air Force fleet

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27 January 2014
First F-35B High AOA Flight With External Stores
Marine Corps Lt. Col. Patrick Moran flew the first F-35B high angle of attack test mission with external stores on F-35B test aircraft BF-2. The external stores included two AIM-9X sidewinder missiles and empty weapon pylons on the other four wing stations.

14 March 2014
First Luke F-35A Formally Delivered
The first F-35A Lightning II assigned to the 56th Fighter Wing was formally delivered in ceremonies at Luke AFB, Arizona. Several hundred dignitaries, local civic leaders, wing military and civilian personnel attended the ceremony.

10 January 2014
First Flight With Ten Weapons
Lt. Col. Brent Reinhardt was at the controls of F-35A test aircraft AF-1 for the first test mission flown with ten weapons. The flight, which originated from Edwards AFB, California, was used to evaluate the handling qualities of the F-35A. The weapon load consisted of six 500-pound GBU-12 Paveway II bombs (two mounted in the internal weapon bays and four mounted under the wings), two AIM-120 AMRAAMs mounted in the internal weapon bays, and two AIM-9X Sidewinder air-to-air missiles mounted under the wings. This was the 350th flight for AF-1.

25 February 2014
Longest Flights To Date
Two F-35 test pilots broke the single flight F-35 duration record during the first AMRAAM launch at White Sands Missile Range, New Mexico. Air Force Maj. Mark Massaro flying F-35B BF-1, and Lockheed Martin test pilot Dan Levin, flying F-35B BF-5, conducted the mission from NAS Patuxent River, Maryland. The mission was used to evaluate the effects the aircraft had on one another while in STOVL mode to ensure F-35Bs can perform safely in formation while flying in an operational environment. The first F-35B formation takeoffs and landings were conducted on 8 January.

6 March 2014
Italian Wing Components Make First F-35 Flight
The first F-35 wing components manufactured by Alenia Aermacchi were flown for the first time. The Italian-manufactured wing components were installed on F-35A (US Air Force serial number 11-5033) that was later delivered to the 33rd Fighter Wing at Eglin AFB, Florida.

11 February 2014
First STOVL Formation Flight
Two F-35Bs were flown in close formation for the first time while in short takeoff/vertical landing, or STOVL mode. BAE test pilot Peter Wilson, flying F-35B test aircraft BF-1, and Lockheed Martin test pilot Dan Levin, flying F-35B BF-5, conducted the mission from NAS Patuxent River, Maryland. The mission was used to evaluate the effects the aircraft had on one another while in STOVL mode to ensure F-35Bs can perform safely in formation while flying in an operational environment. The first F-35B formation takeoffs and landings were conducted on 8 January.

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21 March 2014
100 Pilots (and 1,000+ Maintainers) Qualified
The 33rd Fighter Wing, the F-35 Lightning II training unit at Eglin AFB, Florida, reached a milestone as a class of six pilots from Marine Fighter Attack Training Squadron 501 (VMFAAT-501) completed the sequence of F-35B academics and training flights, bringing the number of pilots qualified by the base to 100. These pilots join the 1,082 F-35 maintainers who have been trained at Eglin.

“Where are we? When are we? 2015? You mean we’re in the future.”
— Marty McFly, Back to the Future II
31 March 2014
First Australian-Built F-35 Vertical Tail
Marand, an Australia-based engineering and industrial manufacturing company, delivered its first shipment of F-35 vertical tails in ceremonies at its Melbourne facility. The work on the F-35 vertical tails is subcontracted to Marand by BAE Systems and is one of the largest planned manufacturing projects for the F-35 in Australia, with 722 shipsets anticipated.

24 April 2014
F-16/F-35 Joint Training
F-16 Fighting Falcon pilots from the active duty 388th Fighter Wing and Air National Guard’s 189th Fighter Wing, both deployed to Hill Air Force Base, Utah, deployed to Eglin AFB, Florida, and carried out the first joint air-to-air combat training missions with F-35A Lightning II pilots from the 58th Fighter Squadron. Hill F-16 maintainers also received an in-depth overview of the F-35’s Autonomic Logistics Information System. Hill is slated to receive its first operational F-35A in late 2015.

6 May 2014
500 Flights For CATBird; Turkish F-35 Order
The F-35 Cooperative Avionics Test Bed, or CATBird, completed its 500th flight for the F-35 test program. Also on this date, the Defense Industry Executive Committee, the highest decision making body for Turkish Defense acquisition programs, tasked the Turkish Undersecretary for Defense Industries, or SUK, in Turkey, to order the country’s first two F-35A Lightning II multibrole fighters. Current Turkish defense plans call for 100 F-35As.

15 May 2014
Final F-35A Flutter Points
Lockheed Martin test pilot Dave Nelson was at the controls of F-35A AF-6, AF-7, BF-18, and CF-8 with CATBird, two air targets, a tanker, and multiple ground targets was accomplished; eight total aircraft launched for the mission.

27 May 2014
First AIM-120 Live Launch For F-35B
Marine Corps test pilot Lt. Col. Andrew Allen, flying F-35B test aircraft BF-18, sequentially engaged two targets with AIM-120 missiles. This shot, completed at the Sea Test Range near Naval Base Ventura County at Point Mugu, California, marked the first dual AIM-120 launch from any F-35 variant and the first live F-35B AIM-120 shot.

16 July 2014
Warlords To Beaufort
Marine Fighter Attack Training Squadron 501 (VMFAT-501) officially relocates to MCAS Beaufort, South Carolina, from Eglin AFB, Florida. MCAS Beaufort will be responsible for all Marine Corps, Royal Air Force/Royal Navy, and Italian Navy F-35B pilot training. VMFAT-501, formerly Marine Fighter Attack Squadron 451, was stationed aboard MCAS Beaufort from February 1993 until January 1997. Known as the Warlords, the squadron began moving back to MCAS Beaufort earlier this year. The relocation is scheduled for completion in the spring of 2015.

1 May 2014
Four-Ship MADI/Fusion
A four-ship Multifunction Advanced Data Link, or MADI, fusion flight test aircraft AF-6, AF-7, BF-18, and CF-8 with CATBird, two air targets, a tanker, and eight total aircraft launched for the mission.

15 May 2014
Final F-35A Flutter Points
Lockheed Martin test pilot Dave Nelson was at the controls of F-35A AF-1, flying from Edwards AFB, California, when the aircraft was used to complete the last F-35A flutter points. The test marked the final speed envelope expansion for the F-35A fleet. The achievement included test points required for both Block 2B and Block 3F software.

19 August 2014
Mega-Ship Mission
The F-35 Integrated Test Force at Edwards AFB, California, carried out one of the largest and most complicated test flights to date. The objective of the mission, which pitted two F-35s against five Edwards-based F-16s over the Sea Test Range near Point Mugu, California, was to stress the fusion algorithm in the F-35’s mission systems software keeping track of target aircraft maneuvering in multiple dimensions and at various speeds. The profiles chosen during the test were representative of tactical maneuvers that an F-35 pilot may encounter in wartime. Nine total aircraft were involved, including one KC-135 tanker.

7 August 2014
Lightning II To Eielson
US Air Force officials announced that Eielson AFB, Alaska, is the preferred alternative to host the first F-35A Lightning II squadrons in the Pacific area of responsibility. Officials noted basing the F-35s at Eielson will enable the Air Force to take advantage of approximately 65,000 square miles of available airspace in the Joint Pacific Alaska Range Complex for realistic training.

9 August 2014
Mode 4 Formation Testing Completed
F-35B aircraft BF-1 and BF-4 completed Mode 4 formation testing required for Block 2B software capability. In Mode 4 operations, the STOVL Propulsion System is engaged, the lift fan, roll post nozzle, and three-bearing-swivel nozzle are operating, and all propulsion system doors and inlets are open. Flight testing validated the F-35B variant’s ability to operate in this configuration during formation flight. This supports operations around the ship.

15 August 2014
F-35B Weapon Separations Completed For Block 2B
Marine Corps test pilot Capt. Mike Kingen was at the controls of BF-3 for the final weapon separation test required for 2B software flight release for the F-35B. Kingen’s successful launch of an AIM-120 missile over the Atlantic Test Range was the second such launch in two consecutive days. Both flights originated from NAS Patuxent River, Maryland.

9 September 2014
First Flight With Gen III Helmet
Lockheed Martin test pilot Mark Ward flew the first 3iR4 software and Generation III helmet mounted display during an airworthiness flight in AF-3. The mission was flown from Edwards AFB, California. The first night mission with the new helmet was flown nine days later.

24 September 2014
South Korea Finalizes F-35 Decision
The Republic of Korea government finalized its formal selection of the F-35A Lightning II for its F-X Lightweight Fighter acquisition program. A Letter of Offer and Acceptance between the US and South Korean governments will be signed for forty F-35A conventional takeoff and landing aircraft with initial deliveries to the Republic of Korea Air Force beginning in 2018. Following a comprehensive evaluation process for its F-X program, Korea announced the selection of the F-35 in March 2014. Korea will purchase its aircraft through the US Foreign Military Sales program.

3 September 2014
First CAS Mission
Lockheed Martin test pilot Mark Ward flew CF-8 from Edwards AFB, California, over Fort Irwin to complete the first F-35 day Mission Effectiveness Close Air Support flight. Eielson AFB, Alaska, was named as the preferred site for operational CAS. Fort Irwin is a major training area for the US military forces in the Mojave Desert in California. The close air support test flights needed for Block 2B software, including night CAS missions, was completed on 21 October.

9 September 2014
First CAS Mission
Lockheed Martin test pilot Mark Ward flew the first 3iR4 software and Generation III helmet mounted display during an airworthiness flight in AF-3. The mission was flown from Edwards AFB, California. The first night mission with the new helmet was flown nine days later.

7 August 2014
Lightning II to Eielson
US Air Force officials announced that Eielson AFB, Alaska, is the preferred alternative to host the first F-35A Lightning II squadrons in the Pacific area of responsibility. Officials noted basing the F-35s at Eielson will enable the Air Force to take advantage of approximately 65,000 square miles of available airspace in the Joint Pacific Alaska Range Complex for realistic training.

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24 September 2014
**BF-5 To Eglin For Climatic Testing**
Lockheed Martin test pilot Billie Flynn ferried BF-5 from NAS Patuxent River, Maryland, to Eglin AFB, Florida, in preparation for climatic chamber testing.

29 September 2014
**Australian F-35 First Flight**
The first F-35 for the Royal Australian Air Force was flown for the first time from the Lockheed Martin facility in Fort Worth, Texas. Lockheed Martin F-35 Chief Test Pilot Alan Norman put the aircraft through a series of functional checks during the sortie that lasted two hours. The aircraft, (RAAF serial number A35-001) is scheduled for delivery later in 2014 and will be assigned to Luke AFB, Arizona. Rollout ceremonies for the first two Australian aircraft were held on 24 July. The first Australian F-35 (RAAF serial number A35-002) was flown to Luke AFB, Arizona, on 18 December.

30 September 2014
**Weapon Separation Tests For 2B Software Completed**
US Navy test pilot Lt. Cmdr. Theodore Dyckman launched an AIM-120 missile from test aircraft CF-2 during Flight 302 from NAS Patuxent River, Maryland. The launch marked the last weapon separation test needed for Block 2B software.

2 October 2014
**F-35C To Lemoore**
The US Navy announced its decision to base F-35C aircraft at NAS Lemoore, California, pending public comment and approval of the Final Environmental Impact Statement. A total of 100 F-35C aircraft in seven Navy Pacific Fleet squadrons (ten aircraft per squadron) and the Fleet Replacement Squadron (thirty aircraft) will be based at Lemoore beginning in 2016. All aircraft are expected to be delivered by 2028 timeframe. The 100 F-35C aircraft will replace seventy older F/A-18 Hornet fighters at the base near Fresno.

9 October 2014
**First Operational Testing F-35B**
Marine Operational and Evaluation Squadron 22 (VMX-22) received its first F-35B Lightning II for operational testing at Edwards AFB, California. This is the first of four F-35Bs that will be assigned to VMX-22. Operational testing will determine the effectiveness and suitability of the F-35B in its intended operational environment. Flight will be conducted at Edwards, China Lake and MCB Twentynine Palms, California; Nellis AFB, Nevada; MCAS Yuma, Arizona; and aboard the USS Wasp. Known as the Argonauts, VMX-22 conducts operational testing and evaluation of US Marine Corps fixed and rotary wing aircraft, tiltrotor aircraft, and other systems.

16 October 2014
**CF-5 Sets Record For Sorties In One Day**
US Navy test pilot Lt. Cmdr. Theodore Dyckman, flying CF-5, completed fourteen sorties to finish all of the shake, rattle, and roll testing for catapults and arrestments. US Navy test pilot Cmdr. Christian Sewell completed an additional three field carrier landing practice sorties in CF-5 later in the day. The mission count of seventeen set a record for sorties in a day for a single aircraft for the F-35 program.
18 October 2014
First F-35B Hover In Fort Worth
Lockheed Martin test pilot Bill Gigliotti executed the first F-35B hover in Fort Worth, Texas, during the third company test flight of BF-38. Exercising the vertical lift system of the F-35B models becomes part of the acceptance test process with this flight.

21 October 2014
First GBU-39 Separation
Lockheed Martin test pilot Mark Ward was at the controls of AF-1 for the first separation test from an F-35 of a GBU-39 Small Diameter Bomb. The GBU-39 is a 250-pound precision-guided glide bomb. The test flight originated at Edwards AFB, California.

3 November 2014
First Carrier Landing
US Navy test pilot Cmdr. Tony Wilson made the first arrested landing of the F-35C Lightning II on an aircraft carrier. Wilson landed F-35C test aircraft CF-3 at 12:18 p.m. local time aboard the USS Nimitz (CVN-68) underway in the Pacific Ocean. Wilson caught the number three arresting wire. The arrested landing is part of initial at-sea developmental testing for the F-35C. The first F-35C catapult launches would come on 4 November.

14 November 2014
Initial F-35C Sea Trials Completed
The initial sea trials for the F-35C ended with pilots performing 124 arrested landings; 222 touch-and-goes; two bolters, both intentional for test purposes; and 124 catapult launches on thirty-two flights covering 38.6 flight hours.

11 December 2014
F-35 International Maintenance Sites
The F-35 Lightning II Joint Program Office, or JPO, announced that Italy will be the European location for F-35 heavy engine and heavy airframe maintenance, repair, overhaul and upgrades, or MRO&U, with initial capability to be provided by 2018. Engine heavy maintenance will initially be provided by Turkey by 2018, with Norway and the Netherlands providing additional capability two to three years later. The JPO announced on 17 December that the assigned F-35 Regional MRO&U capability for airframes and engines for the Asia-Pacific Region will be provided by Japan for the Northern Pacific and Australia for the Southern Pacific, with both capabilities required by early 2018. For heavy F-35 engine maintenance, the initial capability will be provided by Australia by early 2018, with Japan providing additional capability several years later.

31 December 2014
Flight Test Totals
The F-35 Integrated Test Force at Edwards AFB, California, and NAS Patuxent River, Maryland, exceeded 5,000 total flights in the System Development and Demonstration phase of the F-35 program. For 2014 alone, the program completed 1,354 test flights that covered 10,000 test points. The F-35B test fleet completed ninety-eight vertical landings, 297 short takeoffs, and 253 short landings.