The National Aeronautics and Space Administration

X-tra

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The Ikhana

Uninhabited Aircraft System is changing the way fires are fought and proving to be a valuable science tool

New Heights

Multi-faceted aircraft offers flexibility and reliability

Above, *the Ikhana surveys fires during the Southern California wildfire emergency last fall. (NASA Photo ED07 0243-35 by Jim Ross)*

Cover, *Ikhana flies over the high desert. (NASA Photo ED07 0139-19 by Lori Losey)*

By Jay Levine
X-Press Editor

The Ikhana project's new manager has a special appreciation for the unique aircraft's potential.

When Ikhana flew missions over the deadly 2007 California wildfires, Tom Rigney was a Dryden project manager living in the Antelope Valley but he retained a home in Santiago Canyon – ground zero for some of the worst of the blazes. His home was surrounded by a 28,000-acre brush fire as Ikhana flew above the inferno and gathered information for firefighting commanders on the ground. It was a close call for Rigney, as the fire came within 30 feet of his house.

"The people themselves – not only the firefighters, but those people whose homes and lives are involved – want to know where the fire boundaries are," Rigney said. "They've been evacuated, and they have no way of finding out where the fire is. These images let people know where the fire is with accuracy.

"Having been in that situation myself, I know the value. It was very distressing."

The Ikhana, a civil variant of the General Atomics Aeronautical Systems Predator B, is a remotely piloted aircraft flown from a cockpit in a Dryden ground control station. The ground station, which is mobile, also houses monitoring and research capabilities necessary for carrying out the aircraft's science missions.

Over a five-day period last fall, the Ikhana team assisted the U.S. Forest Service with the California wildfire disaster by providing imagery in near real-time to emergency operation command centers and individual fire-incident commands. The team used skills refined while working on the Western States Fire Missions completed earlier in the summer, when the aircraft's thermal infrared sensors were used to map wildfires in six states on missions of up to 20 hours in duration.

ED08 0066-1 NASA Photo by Tom Tschida

Before Ikhana project manager Thomas Rigney came to Dryden, his home was threatened by a fire the Ikhana helped battle. Rigney has a special appreciation for the aircraft's capabilities and hopes to see it used to help others during future fire missions the way it helped him.

Just the facts

For more information:
call the Dryden Strategic Communications Office at 661-276-3449

Ikhana information:
http://www.nasa.gov/centers/dryden/aircraft/Ikhana/index.html

Ikhana images:
http://www.dfrc.nasa.gov/Gallery/Photo/Ikhana/HTML/index.html

For both missions, the team gathered information on the fires as they happened, identifying hot spots using instrumentation developed at Ames Research Center, Moffett Field, Calif. They coordinated that information and imagery with Google Earth maps to provide fire commanders on the ground with data to help them map strategy for fighting the blaze, explained Brent Cobleigh, former Ikhana project manager.

Rigney intends, if Dryden is asked to assist in the fire mission for a third straight year, for the Ikhana team to help fire authorities to continue developing life-saving strategies for fighting the fires. He also plans to help inform the public about the aircraft's role in keeping firefighters out of harm's way and in saving their homes.

In order for uninhabited aircraft systems, or UAS, to one day fly in the same skies as commercial aircraft, or the national airspace, the aircraft will have to be equipped with software and sensors that allow them to detect and avoid other aircraft, a future research role the Ikhana might fill, Rigney said.

The fire missions are but one example of the Ikhana's potential as a testbed for researching technologies, he said. He also envisions the UAS being used in other disasters or emergency operations as well as a platform for environmental science and study of areas of ongoing ecological concern such as ice shelves or coral reefs.

"It's exciting. It has a lot of potential," Rigney said of the UAS. "It's already showed some of its potential on the fire missions, with its ability to carry large sensors and transmit real-time images to the ground. I'm also impressed by the Fiber Optic Wing Shape Sensor experiment, which is happening on the Ikhana now." (See related story.)

Data obtained through that experiment, he said, could have applications for all aircraft as

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ED07 0038-017 NASA Photo by Tony Landis

Ikhana crew chief Joe Kinn gives the aircraft a final check.

COA

Before it flies in the same skies as piloted aircraft, the Ikhana must have an FAA-approved flight plan

By Jay Levine
X-Press Editor

Meeting complex requirements for the Ikhana to enter the national airspace, where piloted aircraft fly, has become Greg Buoni's area of expertise.

Buoni, the Ikhana project's lead operations engineer, has become skilled at determining the right steps to take to fulfill Federal Aviation Administration requirements for a special-permission Certificate of Waiver or Authorization known as a COA. A COA is required in order for uninhabited aircraft systems, such as the Ikhana, to be permitted to fly in national airspace.

The Ikhana, a General Atomics Aeronautical Systems Predator B adapted for civil science and research missions, flies in the national airspace with a COA in place describing its operations, ground station and telemetry system. The COA also contains information, Buoni said, about what the aircraft is specifically tasked with doing, and what happens should the pilot controlling it from a cockpit in the ground control station lose contact with the aircraft.

Buoni is honing his ability to secure a COA quickly and efficiently in the event Dryden is asked to provide the Ikhana for use in fire missions again this summer. Acquiring the first COA, for the 2006 fire missions, took six months. Dryden officials' diligence in obtaining COAs before they are needed coupled with a series of wildfire emergencies during the past two summers is leading to a more streamlined process, Buoni said.

Esperanza mission, November 2006

Long before the Ikhana was delivered to NASA or flew its first fire mission, Dryden was working with FAA officials to secure a COA for a General Atomics Aeronautical Systems Altair aircraft. Dryden leased an Altair, essentially a civil variant of the Predator B, for use on missions until the Ikhana was ready for delivery. That effort provided a solid foundation for accelerating COA procurement in emergency situations.

On Oct. 28, 2006, the California Governor's Office of Emergency Services and the Esperanza Fire Incident Command Center requested Dryden's assistance with imaging and fire mapping to help fight the Southern California blaze. In the aftermath of Hurricane Katrina, the FAA had developed an emergency COA process that could result in issuance of a COA amendment within 24 hours. The Esperanza wildfire spurred one of the first requests to use the new process, Buoni said.

Soon after the Esperanza fires broke out and lives were being lost, "Despite issues with time zones, the COA was approved by early evening because there was danger to life and limb – it was a real emergency,"

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he said.

Within 24 hours of the request the Altair was ready to fly.

The suspected arson fire, which claimed the lives of five firefighters and was driven by powerful Santa Ana winds, spread over 40,200 acres, or roughly 62 square miles, destroying 34 homes and 20 other structures.

From an altitude of 43,000 feet, over a 16-hour period on Oct. 28 and 29 the Altair's wildfire sensor collected and sent 100 images and more than 20 data files containing the location of the Esperanza fire's perimeter. Data from the NASA system were used at the Fire Incident Command Center to map the fire's location and behavior and direct resources to critical areas.

Western States Wildfires, 2007

In anticipation of 2007 fire missions, the Ikhana team began working in late 2006 to prepare a COA request. The 2007 COA request was based on the successful 2006 COA effort. Because of the larger geographic area identified in the request, negotiations and further agreements were required. The agreement gelled, but approval didn't come until well into fire season.

The COA request covered flights made at any time, from the Mexican border to the Canadian border and from the Pacific Ocean to central Colorado, wherever the wildfire happened to be – those were the requirements defined in connection with the Ikhana's use, Buoni said.

"This was referred to as 'the mother of all COAs,'" Buoni recalled. "Getting the COAs was one of the things we were on pins and needles about. There were good lessons learned and [the FAA] did issue a COA to do most of the things we were asking to do."

Creating the COA application became even more complicated when the FAA changed from a paper system to an online application process, though the online system undoubtedly made the FAA review process more efficient. Dryden submitted an application for a 2007 COA at the end of February in hopes of obtaining it by July, ahead of the anticipated need for it in August.

ED07 0243-14 NASA Photo by Tom Tschida

Dryden Ikhana ground crewmen Gus Carreno, left, and James Smith load the thermal-infrared imaging scanner pallet into the Ikhana's underwing payload pod.

The approved COA had its limitations, however.

"The approved geographic area was somewhat limited in comparison to the request, and the flight plan had to be submitted three days in advance. Three days is a long time when wildfires move and change. For that reason, we were mostly limited to [flying missions during] the big fires," Buoni said.

But FAA air traffic controllers were very accommodating when the wildfires moved and changes in flight plans were requested, Buoni added.

The first phase of the four flights began Aug. 16 as the Ikhana captured images of California wildfires, including the Zaca Fire in Santa Barbara County. The aircraft carried the NASA Ames-developed Autonomous Modular Sensor configured for wildfire sensing, which collected data while flying more than 1,200 miles over a 10-hour period.

Subsequent flights in this phase provided support to firefighters in Oregon, Washington, Utah, Idaho, Montana and Wyoming. The longest flight was more than 3,200 miles and took about 20 hours to complete.

In the second phase, the Ikhana team flew four flights over Southern California wildfires Oct. 24-28 and captured thermal-infrared imagery to aid firefighters battling the blazes. The Ikhana took off from Dryden for missions of about nine hours each.

Officials from the California Office of Emergency Services and the National Interagency Fire Center in Boise, Idaho, requested the flights, including those over the Santiago Fire mentioned in the lead story.

"The Ikhana team knew the data we sent to firefighters on the ground could help them save lives and homes. These missions were very fulfilling. We're hoping the Forest Service is able to acquire and use this technology in the future," Buoni said.

Developing new rules

For uninhabited aircraft and aircraft systems, hard-and-fast certification requirements like those for commercial and general aviation aircraft are not yet in place. And, Buoni said, the very content of what will constitute those rules is being studied and debated throughout the nation and the world because of concerns about flying remotely piloted aircraft in national airspace.

Ironically, manned aircraft may be the key to making UAS flights safe, he noted. Dryden is expected to engage in flight research using an F-16 recently loaned to Dryden from the Air Force for a series of missions that would examine the potential of collision-avoidance systems.

Automated Collision Avoidance Technology is one concept being explored to test how well a system works for automatically avoiding contact with the ground and potentially for detecting and avoiding other aircraft.

To provide see-and-avoid capability, current FAA policy requires a manned aircraft to accompany UASs flying below 18,000 feet. Above that altitude, air traffic controllers are responsible for monitoring aircraft and ensuring that they fly safe distances apart, Buoni explained.

Until new rules are approved, Dryden officials will continue taking steps to simplify the COA application process. More than 280 potential landing sites, for example, were identified for use in the event an emergency landing was required in the requested COA area.

Together with Lt. Cdr. Phil Hall of the National Oceanic and Atmospheric Administration, Dryden's Kathleen Howell, Jeri Myers, Range Safety Office and a crew of interns looked at available routes and compiled results into a large database detailing potential landing sites.

Information includes location and composition of the landing area (for example, whether it is paved or dirt) as well as Google Earth images of viable approaches to each site. The information was produced in a notebook that pilots could reference during each flight.

The net result of all the work undertaken since 2006 is a simple one – if Dryden is called to assist in fire missions this summer, the Ikhana team will be ready to fly.

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well as in adaptive control on general commercial aircraft, driving important advances in technology used to detect, identify and correct operational problems in flight.

An invaluable tool

As proven in the fire missions, the Ikhana is an excellent sensor platform, said Vince Ambrosia, senior research scientist at California State University, Monterey Bay, and at Ames.

"It's beyond the capability of manned platforms," he said of the work performed with the UAS. "It presents the ability to scramble a UAV when you need it, over critical events, and be able to linger over those critical events for a long period of time to monitor conditions. Ikhana fits that niche perfectly."

For fire missions, a reliable airborne science sensor system in use by NASA for decades was repackaged to operate autonomously, or via remote control from the Ikhana. Called the Autonomous Modular Scanner-Wildfire, the Ames-developed sensor can sense heat with two of its 12 channels, both of which are calibrated to measure temperatures from one-half degree to 1,000 degrees Centigrade, Ambrosia said.

"They're perfect and unique for assessing fires and burning conditions and, because Ikhana missions pose no physical threat to a pilot, volcanology," he added.

The instrument, with its three scanning heads, ultimately could be used for missions as diverse as calibrating and validating satellites, monitoring wildfires, assessing vegetation, ocean and atmospheric monitoring and study of volcanic plumes – all of which could be accomplished with the Ikhana, he said.

These are just some of the ways that the UAS could be tapped by customers seeking to use and learn more about uninhabited air systems for monitoring, surveillance and science needs.

NOAA missions

Another potential customer/partner for work with the Ikhana is the National Oceanic and Atmospheric Administration. NOAA's Lt. Cmdr. Phil Hall is currently on a three-year assignment to Dryden to learn more about UAS operations. He serves as Ikhana deputy project manager and has worked hard to get up to speed with his new assignment.

"I was pretty overwhelmed by the technology. It was a steep learning curve and I'm still learning," Hall said.

"The systems, subsystems and all the technology – the project even has a different language – is very complicated. I'm impressed with the competency of the people on the team and the people on the (flight) reviews. It's really clear that everything is looked at thoroughly and nothing is left to chance."

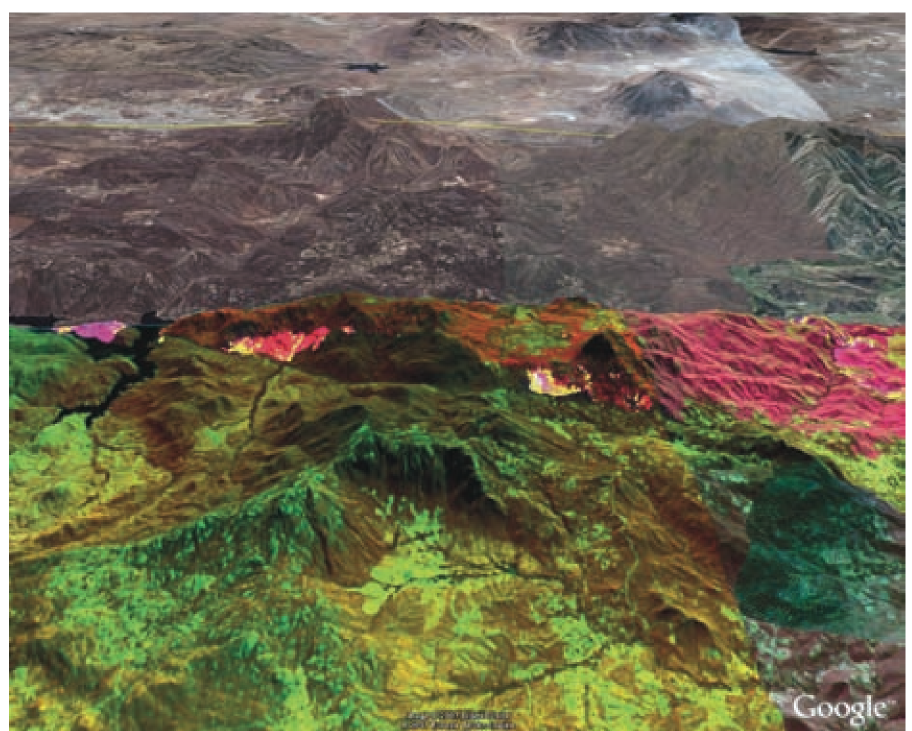
NOAA is interested in partnering with NASA to learn about uninhabited aircraft systems, Hall said. After all, fiscal year 2008 was the first time NOAA allocated funding – $3 million – for uninhabited aircraft, he said. NOAA's interest is with missions involving hurricanes, weather and climate. NOAA also will be involved with the science payloads for a NASA Global Hawk mission scheduled for the spring of 2009.

"We're in a learning phase and determining where we can use UAS aircraft. We need to determine where they can help in our mission of data collection and operations and how that will augment our fleet.

"I feel like I'm in the UAS nexus by participating with NASA," Hall said.

ED07 0243-37 NASA Photo by Jim Ross

Dryden's Ikhana surveys fires during the Southern California wildfire emergency last fall. The Ikhana team anticipates a second year of fire missions this summer.



Courtesy Ames/Ikhana team/Google Earth

ED07 0243-19 NASA Photo by Tom Tschida

Above, *Dryden engineer Kathleen Howell and former Ikhana project manager Brent Cobleigh check flight paths in the Ikhana's ground control station prior to takeoff.*

At left, *a sensor on board the Ikhana recorded this image of the Grass Valley/Slide Fire near Lake Arrowhead/Running Springs in the San Bernardino Mountains. The Ikhana carried sophisticated sensors that "peered" through the smoke and haze to reveal hot spots.*

The mobile UAS system

In addition to the Ikhana's ability to fly a diverse range of missions, it's also mobile and capable of flying day-and-night cycles totaling 24 hours, Cobleigh said. The aircraft flies at altitudes of more than 40,000 feet, depending on payload and mission parameters.

The Ikhana's versatility allows the system to be deployed to remote areas of the world where it could be used for volcano and ocean studies, emergency response and technology development efforts like collision avoidance, he said.

Ikhana crew chief Joe Kinn described how the aircraft is prepared for a remote mission.

"For transport we'll pull the wings, the rudder, the tails and the prop and we'll use a crane to pick it up and put it into what we call 'the coffin' – essentially, a big container – to transport the airplane. It (the coffin) will support the fuselage – after we lift it with the crane and retract the landing gear – and the rudder and tails," Kinn said.

"There's a separate container for the prop. That's basically how we transport it. It will all fit in a C-130, a C-17, a C-141, a C-5 or on a flatbed truck. The ground station also is self contained," he added.

Ikhana is remarkable not only for the primarily composite materials of which it is made, Kinn noted, but also because a majority of the aircraft is fully electric – the only hydraulics on the aircraft are for brakes. That translates to greatly reduced maintenance.

Transferring information

While the aircraft is unique for many of its physical qualities, it's what's on the inside that counts in moving information to the end user, said Russ James, Dryden range systems engineer.

"You get immediate feedback, positive or negative, on the quality of data that's being collected. The pilots are flying, and the researchers in the back (of the ground station) are telling them in near-real time if they want another pass over the area," James said.

The information on fire missions collected by the UAS is relayed through a Ku satellite communications link – essentially, a big satellite dish used to move information, he said.

"There was some preprocessing going on aboard the vehicle – on the payload itself – so that when the data got to the ground station it was immediately useful. Then it went down a dedicated Internet connection to the end users, so the fire commander was receiving the information in seven minutes," James said, adding that the Ku satellite link, like other Ikhana components, is fully portable.

"When we flew the Santa Barbara fire – the very first fire mission (last summer) – I got word, secondhand, that the incident commander reported because the smoke was so dense and they didn't know where the fire was, he was planning to send crews into an area where they would have been in harm's way if it hadn't been for the imagery he received from Ikhana," James said.

Adding capability

The aircraft's array of capabilities could be expanded later this

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Measuring up to the Gold Standard

By Jay Levine
X-Press Editor

The Ikhana uninhabited aircraft system is flying research missions with an advanced sensing technology installed on its wings that measures and displays the shape of the aircraft's wings in flight.

The new sensors, which incorporate fiber optic sensing technology, are located side by side with traditional sensors. Generations of aircraft and spacecraft could benefit from work with the new sensors if the sensors perform in the sky as they have in the laboratory, said Lance Richards, Dryden's Advanced Structures and Measurement group lead.

Aerospace companies, NASA mission directorates and other government entities are watching the experiments with interest. The weight reduction that fiber optic sensors would make possible offers dramatic possibilities for reducing costs and improving fuel efficiency, Richards said.

The potential for weight reduction, however, is but one small part of the picture. This technology also opens up new opportunities and applications that would not be possible with conventional technology. For example, the new sensors could enable adaptive wing-shape control – the concept of changing a wing's shape in flight to take advantage of aerodynamics and make the aircraft more efficient.

Six hair-like fibers located on the top surface of the Ikhana's wings provide about 2,000 strain measurements in real time. The fibers are so small that they have no significant effects on aerodynamic lift and weigh less than two pounds. The fiber optic sensors themselves are so small that they could eventually be embedded within composite wings in future aircraft, he added.

"The applications of this technology are mind-boggling," Richards said.

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ED08 0109-08 NASA Photo by Tom Tschida

The fiber optic wing shape sensor team is testing its work, which will compare a fiber optic-based system with conventional sensors in flight. The sensors, located along a cable the thickness of a human hair, aren't visible in the center of the wing, but could have ramifications for all future aircraft and spacecraft. Team members include, clockwise from left, Anthony "Nino" Piazza, Allen Parker, William Ko and Lance Richards.

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A winning proposal

Richards and his team submitted a plan to fly the fiber optic wing shape sensors on the Ikhana's long wings when proposals for research with the remotely piloted aircraft were requested in late 2006. NASA's Aeronautics Research Mission Directorate, through which the basic research development project with the sensors is funded, is supporting algorithm and systems development, instrument and ground test validation.

When using the fiber optic sensors, researchers do not require analytical models for determining the answers they seek for strain and other measurements on the aircraft because data derived with the sensors include all of the actual measurements being sought.

"There are 3,000 sensors on Ikhana that are imperceptibly small because they're located on fibers approximately the diameter of a human hair," Richards explained. "You can get the information you need from the thousands of sensors on a few fibers without the weight and complexity of conventional sensors. Strain gauges, for example, require three copper lead wires for every sensor."

The research team is taking that concept a step further by comparing results obtained with the fiber optic wing shape sensor against those of traditional sensors to validate the new sensors' accuracy.

"There are 16 strain gauges on the wing that are co-located with the new sensors for side-by-side comparison," Richards said.

Proving the technology

The Ikhana flights will represent one of the first comprehensive validations of fiber optic sensor technology in flight, an enabling step toward using the fiber optic sensors for active wing shape control. Richards said the team is pursuing flying the fiber optic wing shape sensors for research into aeroelastic wing shape control on Dryden's F/A-18 no. 853, which was used as the Active Aeroelastic Wing project testbed, if tests on the Ikhana go as planned.

"Active wing shape control represents the gleam in the eye of every aerodynamicist," he said. "If the shape of the wing can be changed in flight, then the efficiency and performance of the aircraft can be improved throughout the aircraft's widely disparate flight regimes, from takeoff and landing to cruising and maneuvering."

Another benefit of the lightweight nature of fiber optic sensors is that thousands of sensors can be left on the aircraft during its lifetime, gathering data on structural performance, he said. At the heart of the technology is the comprehensive measurement of strain, the parameter that allows engineers to determine the stress experienced by aircraft structures.

For the first time, Richards explained, aircraft designers can use the sensors to gain important information regarding the efficiencies of their designs and the validity of their assumptions. By knowing the stress levels at thousands of locations on the aircraft, designers can more optimally design structures and reduce weight while maintaining safety. The net result could be reduction in fuel costs and an increase in the distance aircraft are capable of traveling.

There are other potential safety applications for the technology. If an aircraft structure can be monitored with sensors and a computer can manipulate flight control surfaces to compensate for stresses on the wings, structural control can be established to prevent situations that might otherwise result in a crash. Richards said the fiber optic strain and wing shape sensing also has the potential to revolutionize ground-testing methods, analysis and flight research.

By extension, it could

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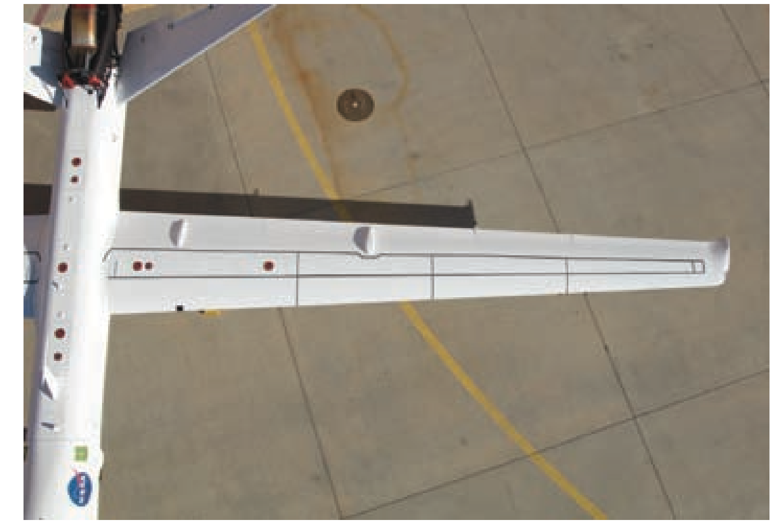

ED07 0287-08 NASA Photo by Tony Landis

At left, although the new sensors on the Ikhana, which are located on fibers that are the diameter of a human hair, are not visible, the sealant used to apply them can be seen in this view from above the wing.

Below, Larry Hudson and James Smith work on a ground validation test with the new sensors that led to validation flights with the aircraft.

ED08 0016-20 NASA Photo by Tony Landis

No one on board

Ikhana pilots fly aircraft from the ground

By Jay Levine
X-Press Editor

ED07 0248-06 NASA Photo by Tony Landis

Ikhana pilots Herman Posada, left, and Mark Pestana say flying from a ground cockpit is much different than flying traditional aircraft.

Guiding a mission remotely from a ground cockpit without the feel, smells and sounds of a traditional aircraft and the environment in which it flies is a challenge routinely tackled by Dryden Ikhana pilots Herman Posada and Mark Pestana.

Posada flew Predator unmanned aircraft systems for General Atomic Aeronautical Systems for 10 years prior to joining Dryden as an Ikhana pilot. Dryden's Predator B, a civil variant, is named Ikhana after the Choctaw Nation word "Ikhana" (pronounced ee-KAH-nah), which means "intelligent."

Posada adapted to differences between the Ikhana and Predator aircraft, learning the former's idiosyncrasies in order to fly it successfully.

"I think it's just experience," Posada said of piloting the Ikhana. "The experience is not for everybody. It's not a perfect system, but there are ways to make it work right."

For Mark Pestana, who never flew a UAV prior to his experiences with the Ikhana, it was an adjustment to fly without the sensations of the cockpit in the sky.

"The data and displays are presented for a pilot in a way that's different from a traditional cockpit," he said of the ground-station experience.

"Instead of physical switches – toggle switches or dials – you're using a keyboard and track ball and pulling down menus like you would on your personal computer, to activate systems. Understanding where all of these system controls are located and finding the right screen display to access the controls is challenging."

While the flight simulator offered stick and throttle familiarity, it didn't simulate how to use all of the aircraft's many displays, Pestana said. A home computer flight simulator offered help, but produced sound when he made engine adjustments to signal that acceleration was successful. When piloting the Ikhana, he has to visually confirm the engine power readings and airspeed readout to determine whether the airplane is doing what he commanded through the throttle.

"We use the simulator as a tool to get the gist of the operation," Posada added. "They're trying to teach you how to fly an aircraft in a completely different way than most pilots have learned how to fly. We use it to go through procedures and to familiarize the pilot with where the different buttons live and do some maneuvers in the simulator that we wouldn't do with the real aircraft. Basically, we use it as a procedures trainer."

Landing the aircraft can be another challenge for pilots unaccustomed to the ground station cockpit because of the absence of sound and sight cues, including peripheral vision, available in a manned cockpit, Posada said.

And because of the flood of information available to the pilot and the stresses of the ground cockpit, pilots fly no more than two hours at a time. When shifts of up to 12 hours are required additional pilots are contracted, with none flying more than two hours at a time, Posada said. Ikhana missions can total more than 20 hours.

Two fully operational pilot stations are occupied for takeoffs and landings, although only one pilot can fly at a time. A single pilot can handle the aircraft during flight and requires assistance only with the demands of takeoff and landing.

"There's a lot of stuff you're looking at while working the radios and checklists. It's a little too much for one (pilot). You need an extra set of eyes because sometimes you're drowning in information. Having other people say your speed is high or fast, or telling you to watch your

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sink rate is important," Posada said.

And a second set of eyes offers another benefit.

"A second pilot is sitting at the rack (pilot station) in case there are problems. That allows us to switch racks, because a pilot is sitting there and ready to take control of the airplane," Pestana said.

Piloting the Ikhana does have some similarities to flying manned aircraft.

"It's a team effort. There are a lot of people on the team. Without their vital support, we couldn't get the airplane in the air," Posada said.

On flight days it's not uncommon for the first crewmembers to arrive at midnight for a morning flight because of the Ikhana's special start-up requirements, Pestana explained.

Unlike a traditional aircraft, for example, in which the ground crew can call for a fuel truck and have the aircraft fueled well before the mission, the Ikhana must be turned on and operational for refueling. The engine powers a generator that provides electricity. In the event of a generator failure, the backup system takes special batteries that must be charged several hours before flight. That's why the first team members must arrive so far in advance of takeoff.

Pilots and crew generally arrive three hours prior to the flight for completing work such as preparing the ground station, verifying software, checking flight plans, programming an emergency flight plan and fueling and preparing the aircraft.

The Ikhana system also offers capabilities that are key for certain science missions.

"A primary advantage that this system offers over traditional aircraft is endurance and altitude," Pestana said. "For example, atmospheric scientists prefer to have continuous data collection over a full day's cycle, where the presence or absence of sunlight may drive chemical reactions in the atmosphere that affect weather and climate.

"This aircraft makes it possible to cover long distances and over 24 hours on a single mission."

Posada and Pestana have an appreciation for the complexity of the aircraft they fly and the team that makes it possible to succeed in new types of missions.

ED07 0243-18 NASA Photo by Tom Tschida

Dryden research pilot Mark Pestana prepares to fly the Ikhana aircraft remotely from the ground control station at Dryden.

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revolutionize wing design efficiency and that of wind turbines by making the wing more efficient by a few percent.

"A few-percent improvement equals a huge economic benefit," Richards said. "The sensors could also be used to look at the stress of structures, like bridges and dams, and possibilities extend to potential biomedical uses as well."

"There are 3,000 sensors on Ikhana that are imperceptibly small because they're located on fibers approximately the diameter of a human hair."

Lance Richards, Dryden's Advanced Structures and Measurement group lead

Origins

Richards, who holds a doctorate in mechanical engineering, watched with interest as fiber optics began to evolve in research laboratories throughout the 1980s. In the mid-1990s, he began to consider aerospace applications of that technology for sensors. An internal Dryden Code R competition for grants resulted in seed money enabling him and his small team to begin filling in gaps in research that would validate sensing technology for broad use. No commercial technology is available for real-time wing shape sensing, he added.

Once he obtained funding, Richards assembled a team of Dryden engineers. He and William Ko developed optimized structural algorithms, Allen Parker developed the systems and originated data processing algorithms, and Anthony "Nino" Piazza is the team's strain measurement expert. The group developed the sensor and the supporting avionics system and algorithms that make the fiber optic wing shape sensors work, and has applied for two patents for use of the algorithms developed during the course of the work.

In 1996 Richards developed a partnership with a NASA Langley Research Center team led by Leland Melvin, currently an astronaut and a former Langley engineer. Increasingly complex research examined a technique patented by Mark Froggatt, formerly of Langley, for applying fiber optic technology to flight. Gains Melvin's team made in 1994 provided a foundation for its 1996 work in the development of a facility that provides a means of performing advanced sensor and laser research for development of military, space and civil aircraft health-monitoring systems.

Richards' team began incrementally, through laboratory experiments, to accumulate research showing that fiber optic sensors could match performance by the gold standard in sensors, strain gauges. A baseline was developed and the fiber optic sensors performed within a few percentage points of strain-gauge performance in side-by-side laboratory comparisons. The accuracy of the fiber optic sensors was proven – important data he felt were missing in the literature prior to his own research, he said.

After a lot of perseverance, the crucible of flight research is about to distill the scientists' contentions. Fiber optic wing shape sensors will compete head-to-head with strain gauges in the rigorous environment of flight where vibration, temperature and other challenges will prove the sensors' merit.

The Ikhana team stands ready for whatever mission it is called on to complete, such as sending the aircraft to monitor more western wildfires.

ED07 0248-01
NASA Photo by Tony Landis

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year when research begins on the Airborne Research Test System, or ARTS III, a third-generation system. Previous generations were used at Dryden to investigate technologies such as the Flush Air Data system algorithms on the F/A-18 (no. 845) and neural network control systems on the F-15 (no. 837), said Yohan Lin, Ikhana chief engineer.

The ARTS III was designed as a research system for use in conducting advanced experiments. It could be configured, for example, with software to allow "intelligent" mission management on the Ikhana so the vehicle can search autonomously for forest fires, Lin explained. Personnel at the U.S Forest Service command center would be able to request that the aircraft survey the highest-priority fires by pointing and clicking on them on a map. This information would be sent to the vehicle.

The ARTS intelligent mission algorithms, along with instrumentation on board the Ikhana then would "manage" its own mission by mapping an efficient route, flying there, and surveying the fires.

"Think of it as a virtual onboard pilot," Lin said. "The ARTS III is engaged by the pilot in the ground station and control of the aircraft is given to the ARTS. The aircraft will stay with the priorities and execute the mission.

"However, before it works like that, there will be more engineering and a number of modifications to the ground control and aircraft software. The ARTS III is a flexible system and this is just one facet of what it can do. System health monitoring and collision-avoidance maneuvering are other possibilities."

Whatever the Ikhana's next mission or future uses, one thing is certain – it will all play out on the forefront of technology.

The Ikhana completes a checkout flight.

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