BRIGHT LIGHTS BELONG IN BIG CITY, NOT COCKPIT, SAYS FIGHTER-PILOT-FOR-LIFE.

SEE STORY, PAGE 2.
The NIGHT HAS A THOUSAND EYES

By JOE BILL DRYDEN

As I have wandered through the hallowed halls of the world of aviation, I have run across many of my fellow pilots who have had a real aversion to flying at night. I must admit that I, given a choice, would rather fly in the light of day. But I can now say truthfully, with the work we have been doing with the F-16 over the past few years, that flying at night is not so bad. It can even be a lot of fun!

With the exception of the usual night proficiency requirements and the occasional high flight, I didn't do an inordinate amount of night flying until I showed up in Southeast Asia (SEA) in 1967-1968. As a member of "D" flight in the 555th TFS "Triple Nickel", I was having a hell of a good time going north until LBJ, for reasons that he did not share with us, decided to keep us out of Route Package 5 and 6.
Flying at night with the standard HUD.

It even gets worse . . . Would you like to go home?

The pilot's night vision is improved with LANTIRN Head-Up Display.

Better . . . Let's stay awhile.

Night flying is no longer a problem with NAV FLIR/LANTIRN and Night Vision Goggles.

Now . . . We can be somebody!
As a result, 7th AF, now with an extra squadron on their hands, decided that we should join our fellow squadron, the 497th, in its efforts at night work. Although I personally never did mind flying at night, trying to use an F-4D as an instrument of war, in the dark, was not my idea of the most efficient use of the available equipment. In the daytime, I had the distinct impression that the cockpit had been laid out by a drunk hobo, on a blind burro, in a snow storm. At night, the cockpit was even worse! With systems no more sophisticated than the human eyeball and the intelligent use of the occasional flare, we were supposed to deny the bad guys access to South Vietnam.

I was amused at all the advice the “old heads” were putting forth about the techniques to use at night:

1. Don’t use the AB at night because that gives away your position. (How is that any different from the daytime, when they can see you all the time?)

2. You must not strafe at night because the muzzle flash will give away your position. (Same reasoning as No. 1.)

3. Don’t use more than 60 degrees of bank at night. (Are the laws of aerodynamics different in the dark?)

This advice, as well as the cockpit layout and the night lighting in the F-4 was, shall we say, less than optimum. I did take a cue from the guys in the 497th as to the use of tape. I know I must have shifted the CG forward at least one percent after I had finished taping up the nuisance light sources in the cockpit. I finally arrived at the following solution. Heavy use of tape, then turning the cockpit light rheostats almost (in some cases completely) off, I would then take the red filtered map light, stretch out the cord to full length, route it under the manual canopy release handle on the right side of the cockpit and clip it on the glareshield and point it to shine on the ADI. With a three-axis gyro on the F-4 ADI and the use of the aural tone for angle of attack, I created a poor-man’s HUD (although I didn’t realize it at the time . . . more on that later.) I would then depend on my long-suffering GIB (guy in back) to provide me the rest of the information unless it was only available in the front cockpit. If that was the case, I would either fly straight and level or give him the airplane and turn up the lights to get what I wanted, turn them back down, and proceed with the mission. Despite all this aggravation, we did some very good work from time to time, although I hardly think we really affected more than ten percent of the night traffic inbound to South Vietnam (or Veeetnam . . . as Robert Strange used to say).

Why so dark? (Another of my rhetorical questions.) If you want to see out of your cockpit at night, then you must make sure the inside is dark as well. The same is true with the panel lights in your car. If you are serious about seeing anything while you are driving in the dark, you should ensure that they are turned way down. I am always tickled passing people on the freeway (they were only going 54 mph) and seeing the level at which they have their panel lights. (Especially those with the latest “fad” digital panels. They are usually so bright the headliner, and the driver’s eyebrows, are starting to smolder . . . I doubt they can see past the hood ornament, but they want the rest of the bourgeoisie to know that their new car is on the leading edge of technology.)

The same holds true with today’s F-16. If you want to see outside at night, then it must be dark inside. But, with today’s technology there are a lot of other systems you can use besides the aforementioned mark-one, mod-zero eyeball and the SUU25 flare dispenser.

The one you are probably most familiar with is Martin Marietta’s LANTIRN. A very good system to help you fly in the dark. However, we have been looking at some ways to be even more effective at night than with LANTIRN alone. Now I am not going to insult your intelligence by saying I am going to turn night into day! Only God can do that . . . and he has proprietary rights! But, I will say that, with very few exceptions, you can fly the F-16 at night in exactly the same manner you can in the daytime: the same maneuvers, the same delivery systems . . . everything.

LANTIRN gives you a FLIR (forward-looking infrared) picture that is then presented on the HUD and a TFR (ter-
rain-following radar) system to allow you to fly at low altitude, which also makes the FLIR picture look better. All this is accomplished through the use of the NAV (navigation, but I’ll bet you knew that) pod that is installed on the left inlet chin station (5A). On the right inlet chin station (5B), you can carry the targeting pod that allows you to see further forward and off-axis by use of magnified and/or gimbaled FLIR images and to control and hand off weapons to other systems that are already on the airplane, to include perform-

The full-up LANTIRN system is a great first step.

stance, tell me which end of the bridge or what corner of the building you are interested in, because it will usually take you precisely there! (We enter coordinates down to six feet of accuracy.)

If you have to fly over long stretches of water or extremely flat land, the system will degrade gracefully, meanwhile making automatic allowances for this degradation with no action required of the pilot. If the NAV symbol was in the center of the HUD, the worst you would see would be the target in the HUD field of view. This system falls in the category of digital terrain systems (DTS) and, more specifically, TERRPROM. TERRPROM stands for terrain profile matching and is a product of British Aerospace. There are several other DTS systems in development, but this is the one we have been working with and it works in spades! It has to be shown to be believed. The accuracy, without the requirement to make any updates, regardless of the length of the mission, is astounding! If you would allow me to put my retired USAF fighter pilot hat back on, I would say that it should be an urgent-action TCTO on every TAF aircraft that is presently equipped with INS.

By always knowing exactly where you are, and how long (to the second) it is going to take you to get exactly where you want to go, the reduction in cockpit work load is staggering. The Global Positioning System (GPS) can also be very accurate, but, because of the way it works, it can only do accurate navigation. The GPS is referenced to the center of the earth, or at best sea level, and does not have the first clue as to the big rock rapidly approaching the end of your pilot boom. However, because of the way that TERRPROM works, you also get two other very important capabilities for the same price, size, and weight. Since TERRPROM uses the terrain profile for its navigation, it can also use the same data concurrently to provide a predictive, all-attitude ground-proximity warning system. The operative word here is predictive. Every other system in being, or under development, is an historic ground-prox warning. In other words, the system says, “By the way, Maverick, you just screwed up!”, as the nose of the aircraft starts deforming at ground impact. The TERRPROM will tell you well in advance, regardless of the pitch or roll attitude of the airplane, that if you insist in continuing with what you are doing, for the next ten to twenty seconds you are going to pass closer to some terrain feature than you
told me to warn you about. This feature can work the same, whether the upcoming clearance problem is due to the ground or is a man-made object.

Finally, while TERPROM is doing the two tasks above, it can also provide indications on the HUD to allow you to fly a very covert, yet very accurate, terrain-following profile. These are the three main items that all go a long way to improve operability, increase safety exponentially, and make a drastic reduction in the cockpit work load. Not at the top of the list with the other three but still very useful is that TERPROM can provide a passive ranging to use with the present F-16 delivery modes. This passive ranging can actually improve CCIP operation at shallow dive angles.

If you have seen the LANTIRN HUD, you will have noticed that it is not quite like the HUD used in the other C Models. The symbology is nice and clear and the field of view is about two and one-half degrees bigger on either side. This is nice to have if you are flying at night, depending only on the LANTIRN system, but we have seen a companion system that, as I said before, would improve the operation of LANTIRN or could be used independently. This falls under the heading of night-vision goggles (NVG). While the LANTIRN HUD is nice at night, it is less than optimum in the daytime. And rather than try to improve the fixed field of view by making the HUD larger, why not work on the field of regard? This field of regard can be increased tremendously with the intelligent use of the right kind of NVG. The ones we have been using are called “Cats Eyes” (a product of GEC Avionics) and work very well. It is important to make this distinction as there are other types of night-vision devices that, while they provide some measure of night vision, are not very compatible with the F-16 cockpit (or any other fighter cockpit). I have heard all the arguments about how the NVG are heavy, awkward, have a narrow field of view, etc. All these criticisms are true in varying degree, but I have to ask, What capability do you have without them? A big zero. There are better systems being developed and we will be flying them soon. For example, we are looking at helmets that integrate, into the body of the helmet, all the cabling that is hung out in front at present. But in the meantime the NVGs provide several capabilities that are missing at present:

1. Although there is a technique to using the NVGs that must be learned, the NVGs provide almost the same size field of regard that you have naturally in the daytime.

2. Almost as important is that the goggles are simply light-amplification devices that use whatever available light is present to provide a usable picture to the wearer. Even on nights when there is only very faint starlight, the NVG can provide useful details to the pilot. Of equal importance is that the goggles operate in a different part of the spectrum than the FLIR systems utilize. As a result, the “Force” has much more likelihood of having some capability on any given night.

Although FLIR systems look good in the desert, they may not play so well in SEA (or any other high-humidity area) during the wrong time of the year. The FLIR performance depends on the total amount of water vapor in the air. In other words, the absolute humidity and not the relative humidity. This characteristic is measured in terms of so many grams of water vapor per cubic meter, e.g., seven grams of water per cubic meter. It is important that you understand this characteristic as it makes a big difference in your mission planning. If you go on the more widespread relative-humidity measurements, you can often come up with the wrong answer. For example, I have flown in the area around Fort Worth when the weatherman was reporting a 65% relative humidity. Under these conditions, I had a FLIR image that showed me usable details less than two miles in front of the airplane. Conversely, I remember flights in northern Europe when the weather-guesser was calling the humidity at 94% and I could see nearly six miles! In the first example, the dew point was 76 degrees F. In the second, 28 degrees F.

As a result, the first flight was looking at an air mass containing more than twenty grams per cubic meter, and the second contained less than three. I can remember flying in rain that was falling through a dry-enough air mass that I could still see about three miles. So when someone (your author excepted, of course) shows you a tape of some system’s FLIR performance, be very skeptical unless they specify under exactly what absolute-humidity conditions the flight was conducted.

The point is that you need both a FLIR system and some sort of low-light-level NVG to be sure of having a usable weapon system on any given night in any given area. In the same location I have flown one night with a very wet air mass but with a quarter moon that resulted in great NVG performance and only marginal FLIR operation. At a slightly different time the following night (after a front passed), I was flying in a nice dry air mass before moonrise, with an overcast that extended to above 35,000 feet where I could see next to nothing with the NVG. Nevertheless, the FLIR was beautiful.

I have already touched on how I feel that the cockpit should be dark in order to see outside. This is vitally important if you are depending on seeing outside using just your eyeballs. It is even more important if you are trying to use NVGs. The underlying reason comes from opposite ends of the problem, however. Without the NVG, it is important that you dark-adapt. Any light will reduce your capability to adapt and use what innate night-vision capability that humans possess. With NVG systems, you never dark-adapt. But, if the cockpit is not dark, the NVGs pick up reflections in the cockpit that you would not be aware of otherwise and reduce the capability of the goggles. A very insidious, and potentially very dangerous side effect exists for those of you who still want to fly around with your cockpit lights turned up.

It goes without saying that TERPROM should come first on everybody’s list! With such a system you can do everything better, day or night, rain or shine, regardless of what your mission is.
On more than one occasion I have visually tracked F-16s and F-15s outside of ten miles, at night, using nothing more than NVGs and the light cast by the glow in the canopy from their cockpit lights. Not a very good deal if you want to survive for the next sortie.

By now I can hear all the gears turning. How do you fly with a dark cockpit? Simple. With all the lights off, you will be using the HUD. Before you say anything, I know what the official policy is in that regard and I encourage you to reread the several previous articles on that subject in Code One (Vol. 2, Nos. 1 and 4; Vol. 3, No. 1). But what better way could there be? You have the FLIR image being displayed on the HUD and with the HUD symbology superimposed, you have nearly all the information you need to fly the airplane at very low altitudes and high airspeed. (Before this is all over, I will list what I think is the ideal equipment suite in order to safely and effectively fly at 100 to 200 feet, in excess of 340 knots, in the dark! So please stay tuned.) As I mentioned above, with the F-4 it is difficult to fly with the lights off all the time because I can’t see the fuel gage, the engine gages, etc. So, from time to time I was forced to find the light rheostats (which meant changing hands and flying left-handed for a while...ughhh) and turn the lights back up, check everything, and then turn them back down. This would be the case in the F-16 as well, except we made a very useful change in the interior lighting panel. We added what is, in essence, a master switch in much the same manner as the external lighting panel. The only difference is that the interior master switch is in series with a hands-on switch that will go on the stick or throttle. Now, I use the rheostats to set the lights in the same manner I did in the past, except I set them up even brighter than before so I can see everything clearly, with no fear of misinterpretation. Arm the system with the master switch, labeled NVG (smart—n’est pas?) and turn the lights off with the hands-on switch until I need to check something. Then it’s—click—check what I want—click—off. The lights that I am talking about now are all the incandescent lights in the cockpit; you still set the HUD, SMS, REO, or MFDs independently as you did before.

As you recall, you do not have to worry about dark-adaptation. Remember, you never dark-adapt with the NVG, anyway. Sounds kind of scary, but it works superbly. Everyone to whom I have demonstrated this technique, although maybe skeptical at first, has come away saying this is a very useful capability. The Israelis are putting it into their next block of aircraft. It really does work and allows you to keep the cockpit dark to keep the reflections down, see outside, yet check the systems quickly when you wish. We also have finally come up with some effective filters for the REO in the A/Bs and the MFDs in the C/Ds that completely eliminate the reflections that would be left from them.

How about the goggles? I mentioned before that you would use the goggles to look outside of the HUD field of view using low-light-level techniques and the HUD for control of the airplane and to view the world as the FLIR system thinks it looks. How can I see the FLIR image while I’m looking through the goggles? Easy. We put a little sending unit at the base of the HUD field of view and a receiver on the goggles so that, as I look at the HUD, they shut off automatically and then turn on instantaneously when I look off the HUD field of view. I can also select the goggles to stay on while I’m looking at the HUD for those nights when the humidity has the FLIR working at a disadvantage. This allows me to look everywhere I could in the daytime as well as at night. With any background light at all it is almost as good as the daytime, with the exception of the field of view (small—but the field of regard is still large) and the fact that everything is green. It works great.

The use of this HUD/NVG (with the cutoff) combination allows for another interesting technique. As I roll into a turn I simply turn my head in a natural manner (avoiding the possibility of dis-
orientation by using any kind of "snap look" techniques) and check what I can expect to encounter during the course of the turn. I then return my head toward the center and stop just short of the point that I would turn the NVG off. Now, with only eye movement (a technique with which you were born), I can look across both the NVG and HUD field of view.

This provides about a 40- to 50-degree field of view which does wonders for your SA. Depending on the number of degrees to be turned, I glance well into the turn, as necessary, until I roll out, each time returning to the point just short of turning the NVG off. Smooth!

So... lots of background, but how does this all play together? Follow me.

1. It goes without saying that TEPROM should come first on everybody's list! With such a system you can do everything better, day or night, rain or shine, regardless of what your mission is.

2. Make the cockpit lighting mod. This capability is useful for all your night sorties, even if you can't afford the rest of the equipment or your mission does not require you to fly at low altitude in the dark. With it, you are now ready to go...

3. NVGs. With the cockpit good and dark you can now use the goggles like gang-busters on the nights where the ambient lighting conditions allow. By the way, the Cats Eyes are completely compatible with the HUD symbology, so there is no problem looking forward and seeing the HUD symbology at the same time. Don't worry about not having the LANTIRN HUD. The goggles negate the requirement for the larger field of view anyway. Next... .

4. FLIR pod to be carried on Station 5A. If the equipment is not available or you can't afford the LANTIRN system, there are several contractors who have supplied us usable pods that are very effective, e.g., Pathfinder (which is a derivative of the all-up LANTIRN NAV pod, also made by Martin Marietta), Atlantic (another product of GEC Avionics) etc...

5. Some sort of targeting pod at 5B. If you are lucky enough to have access to the LANTIRN system, use it. If not, there are other systems standing in the wings that may suffice.

You are now ready to go to work in the dark and gloom of night. As I said before, we have not turned night into day. But I will say in the strongest possible terms that, with the only exception of flying out a little longer and turning back in a little easier, if multiple attacks are required, I fly the F-16 with this equipment in exactly the same manner I do in the daytime. Exactly!

I have the navigation equipment to navigate and find the target. I have a system that I can use to fly covert terrain-following precisely. If I already have the full-up LANTIRN system available, I have the choice of which sensor I want to use as the tactical situation dictates. Or, with very little extra integration, I can run both through a kalman filter arrangement to use both in the most effective manner. I can also use any bank angle that I can personally handle without fear of overloading the sensor. I have a FLIR system to use to actually see the countryside and goggles to fill in the field of regard, as well as back up the FLIR system on the nights when the weather does not cooperate. My precise navigation system is accurate enough that I can find the target in my precision strike pod (LANTIRN or otherwise) to ensure a first pass attack on the target, all the while reducing the cockpit work load and allowing me to scan for threats that I did not have the time to do before. The goggles allow me to use the total field of regard to employ offset pop tactics in exactly the same manner as I would in the daytime. I can now be somebody at night. Although there will be doubting Thomases reading this, I can assure them that they can use this equipment to fly as low as 100 feet, as fast as their configuration allows, pop for low-angle low drag, or pop to the moon for really steep deliveries, release the weapon, and immediately dive steeply into a black hole to get back down to very low altitude—all on the first pass. I have had too many people doing it on their first sortie in the airplane to feel otherwise.

We are also working on a concept that shows a lot of potential as well. We have labeled it "Falcon Eye." It involves a head-steered FLIR so you can use an IR system over the whole field of regard just as you would look around in the daytime. This offers the additional flexibility to display symbology in front of my eyes all the time instead of being restricted to the HUD (another boost to your SA.) In order to provide the flexibility in the frequency spectrum that the FLIR pod-NVG combination does, we are meshing-up a low-light-level TV camera that will display on the HUD where the IR image used to be displayed. Slick. I'll keep you advised.

It would sure be great if I could go back in time to the 1967-68 era in SEA and take this equipment with me. I know a couple of nine-level gunners and truck drivers just north of Mu Gia pass and just off "Thud Ridge" I sure would like to cross paths with again.

I saw a good cartoon from the A-10 guys showing the guy saying that "It doesn't matter who won the air war if the Russian tank commander is eating his lunch in your snack bar." Well, it doesn't matter how you are doing in the daytime if, as you walk out to your jet for the "Dawn Patrol," you find your steed crushed into aluminum splinters by the tread of a T72 tank while you were in bed.

Check Six! Even in the dark.
A voice sounds over the in-flight headset, "Welcome to the world of low-intensity conflict." Out of the plane's side window, all is dark. According to the flight plan, there's a lake down there somewhere. A video monitor illuminates the faces of the passengers. The screen displays small black rectangles slowly moving on a field of light gray. "As you can see," announces the copilot to the other six passengers, "even from several thousand feet the infrared line scanner can easily distinguish boats."

These infrared images of cool boats at their slips on a warm lake are being transmitted to the screen from a canoe-shaped pod attached to the belly of the plane. The pod, a reconnaissance pod originally designed for the F-16, comes from the Fort Worth Division of General Dynamics. The plane, a Caravan, comes from the Cessna Aircraft Company (a General Dynamics subsidiary) in Wichita, Kansas. Together, the pod and plane provide high-tech reconnaissance at a relatively low cost.

Guy Woodard, who is in charge of developing the military muscles of the Caravan, has a colorful way of explaining the requirements of his market: "Some of our customers want something you can haul goats in during the day and fly reconnaissance with at night." The Caravan has always had multiple personalities. Federal Express is the largest customer, with about 110 in operation and 90 on order. And the plane (which can be converted into a floatplane) has a wide appeal to bush pilots in Alaska and Canada. Woodard's military market will further split the Caravan's personality. For example, the reconnaissance pod can be popped off, the seats pulled out, and the plane is ready to haul building materials, ammunition, or spare parts — or goats, for that matter. The 341-cubic-foot capacity can also accommodate a 50-caliber Gatling gun, a missile launcher, and 14 paratroopers. As the voice said, this is the world of low-intensity conflict.

Low-intensity conflict is a term that is gaining currency throughout high offices in the U.S. government. It comes from a desire to match our response to a given conflict or problem. Specifically, amendments to a 1987 appropriation bill called for a re-evaluation of our conventional defense forces and for a drug interdiction program for the armed services. As a result, military leaders are looking at low-cost systems for improving the nation's ability to respond to limited conflicts, counter terrorism, and fight the importation of illegal drugs.

The Caravan (designated the U-27 by the military) is an ideal aircraft for low-intensity conflict for several reasons. One, it is big. Whereas an F-16 can almost fit in a garage...
(the ultimate in sports cars), the Caravan could be a garage. Two, it looks small. From high above, the Caravan with its overhead wing, fixed landing gear, and nose-mounted propeller, looks like a small recreational plane. As Woodard says, “The plane hides in its own identity.” Three, it’s inexpensive. At about $90 per hour for operation and maintenance, the Caravan is from $100 to $600 per hour cheaper than a helicopter for the same mission. And Cessna already has a

The Caravan — with reconnaissance pod attached — makes a sweeping turn high above Possum Kingdom Lake in north central Texas. The canoe-shaped pod is only one of an array of plug-in options for the military version of the Caravan. The plane is also being used as an inexpensive platform for improving the F-16 version of the pod.
worldwide service network (the Caravan is currently hauling medical supplies in Africa). Its Pratt and Whitney engine is powering planes in 148 countries. Four, the plane, as noted earlier, is flexible. U-27 versions, which have already been sold to Nigeria and Brazil, have hardpoints for attaching the various weapons and equipment quickly and easily.

Woodard and his colleagues anticipate high demand for an aircraft with the attributes of the Caravan. In fact, the Army may begin purchasing the $1.5 million U-27C/D aircraft this year. These planes can fulfill six primary missions: utility, fire suppression, command and control, electronic jamming, troop transport, and reconnaissance. With plug-in equipment called “mission-configuration units,” each plane can fly any mission. A mission-configuration unit can be (among other things) a seat, an electronic jammer pod, a Gatling gun, or a missile. It can also be a reconnaissance pod, which is the $2.4 million crown jewel of these mission-configuration units.

Reconnaissance for a single-engine prop plane could mean pointing and praying while holding an Instamatic out the window. For the Caravan, however, it means a sophisticated reconnaissance pod inherited from the F-16. This pod was originally developed as a demonstration prototype for the Advanced Tactical Reconnaissance System (known as ATARS). This system was used to develop electro-optical equipment for tactical reconnaissance. The Air Force is planning to use this equipment either to upgrade, replace, or upgrade and replace its aging RF-4Cs, a reconnaissance version of the F-4 Phantom. The F-4 has been in service since the early 1960s. At this writing, the decision has not been made; however, the F-16 (which would be designated the RF-16) is a logical candidate for replacing the RF-4C.

Whatever the decision, electro-optical sensors will eventually replace the existing film-based system. In one sense, the Air Force is trading in its Super-8s for a camcorder. For home movie makers, such a trade reduces film and processing costs. Similar reductions, though on a much larger scale, are expected for the Air Force. But money is only one side of
the story. Electro-optical reconnaissance systems also will allow instantaneous transmission of images. This means instant confirmation by interpreters sitting in front of video monitors. No longer will pilots have to wait for film to be processed, enlarged, and analyzed. Command chains, like the jet aircraft themselves, are becoming more streamlined.

The reconnaissance pod can contain a variety of sensors, which can be configured to meet customer needs. The basic $2.4 million configuration for the U-27C/D contains an infrared line scanner manufactured by Texas Instruments and a three-lens electro-optical camera made by CAI Division of Recon/Optical Inc. Images from the camera and from the infrared line scanner are displayed on two black-and-white monitors inside the plane. Both sensors have a magnification capability, and images can be stored on standard (VHS) video recorders. Since the pod was originally designed for the 9-G, Mach 2.2 flight envelope of the F-16, it required few modifications to meet the 4-G, 184-mile-per-hour flight envelope of the Caravan. The system really is “off-the-shelf.”

The pod may end up being as versatile as the Caravan itself. On a recent demonstration flight over the trans-Alaska pipeline, the Caravan/reconnaissance pod combination displayed its qualifications as a pipeline-leak detector. Passengers were surprised when the infrared sensor detected several large warm areas around an underground section of the pipeline (which is mostly above ground). An inspection team was later dispatched to the area, and they found that an underground stream was eroding part of the pipeline. The Caravan and pod may also serve the Canadian pipeline, which runs mostly underground. In Canada, leaks are first detected by a pressure drop. Since pressure indicators are spaced at 50-mile intervals, it takes some time to pinpoint the actual leak. In fact, it may take several months, and leaks are usually detected by dead vegetation, killed by the leaking oil or natural gas.

The reconnaissance pod has also been demonstrated to the Coast Guard, which is interested in new systems for coastal surveillance and rescue. The applications for the reconnaissance pod, like applications for the Caravan itself, seem to be limitless.

The infrared line scanner is still on as the plane heads back to the airstrip. The light gray on the monitor shifts to a darker shade; beneath the airplane, the warm water has been traded for a cooler land.
WILD WET SHOWS AIR PERFORMANCE

It takes plenty of imagination to grasp the wonders that water works within.
by TIM WILSON  
Aerospace Technology Laboratory

Under checkered water towers on the far side of the maintenance shed is the Hydro-Flow Facility. Even if it didn’t take much imagination to come up with a name for this place, it takes plenty to grasp the wonders that water works within, for this is the home of the “water tunnel.”

In the middle of the room, supported by structural steel about five feet off the ground, is a 3000-gallon blue fiberglass tank. The sides of the tank are two feet high and contour down to a two-foot-square plexiglass section six feet long. This is the water tunnel, a plain contraption that looks at first like a prop for a magician’s trick. Inside, however, is a white eighteen-inch model of the F-16 Fighting Falcon, suspended in the middle of the test section. At a high angle of attack in the flow of water that can be adjusted from .1 to 1 foot per second, the model is about to give engineers a close-up look of what happens around an F-16 in flight. The vortices created by the strakes and wings in the air can now be seen in the form of brightly colored dyes that swirl and curl and loop in the wild blue water.

The water tunnel was designed principally for flow-visualization studies such as this. The bright colors come from dyes squirted from tiny ports on the model, much as an octopus squirts ink. The dye flows over the wings, strakes, tail, and other areas of interest, producing data that are recorded by remotely controlled cameras set up around the tunnel. The cameras are connected to a quad-splitter, which puts up to four pictures on one video tape. Hard copies can then be made from the videos created, or, for better quality, the model can be photographed to produce prints. The video operation is automated, and can be operated by one “pilot” from the control room who can even change the model’s attitude.

The advantage of the water tunnel over other methods of testing new configurations is in speed and low cost. Changes can be made to the model, for example, simply by plugging on prefabricated parts, usually without taking the model out of the water or stopping the tunnel (because of the tunnel’s horizontal configuration). When prefab parts are unavailable, resourceful engineers have been known to make their own parts from materials as diverse as brass shim stock and aluminum foil tape.

Water simulates wind most closely in conditions of sharp leading edges and high angles of attack. However, as any fledgling physicist knows, the properties of air and water are very different, and water can be run much slower to allow vortices to be viewed more clearly. Six different dyes (very like food coloring available in the corner market) separate flow vortices better than a single smoke element in a wind tunnel. To present an even more effective picture of flow over a model, real-time rather than high-speed cameras are used to record the flow.

Only a few years ago, rudimentary testing devices were adequate to validate the comparatively glacial advances in aerospace technology. Today, however, the pace of technology development puts the double whammy on engineers: they must come up with not only technological advances to meet the customer’s increased-performance demands, they must also develop the testing devices, such as the water tunnel, and new methodologies to help make those advances possible.

For example, a testing method under development involves “seeding” the water with tiny particles and using a laser light screen to highlight the particles. Stereo-digital cameras interfaced with a computer can then develop 3-D pictures. And, although static-force testing a sting-mounted model in water is not possible right now, dynamic-force models are being tested and developed — all at highly competitive costs. Costs can be held to a minimum because lower tunnel speeds mean lower data-acquisition rates, which mean less sophisticated equipment.

Finally, the water tunnel’s 3-D capabilities provide designers with data that 2-D theory and analysis can’t come up with. Because new and better data in the hands of impatient engineers ultimately means new products that can out-perform anything available today, it pays to look in unlikely places. Even in a tank of water.

The properties of air and water are very different, and water can be run much slower to allow vortices to be viewed more clearly.
Early in World War II, Rosina Bona Vita patriotically left her apron in the kitchen and went to work building airplanes on an assembly line during the height of wartime mass production. It was later purported that Rosina, aided by a coworker, once riveted 3,345 rivets into the wing of a Grumman Avenger in six hours.

Thereafter, Rosina was dubbed Rosie the Riveter, a name that became a household word associated with women in industry, the spirit of the blue-collar worker, patriotism, and the American way. Likenesses of Rosie were posted everywhere, often as encouragement for other women to join her ranks. Thousands did. Although Rosina Bona Vita was somewhat lost in the shuffle, Rosie the Riveter lived on. She even appeared on the cover of the May 29, 1943, issue of the Saturday Evening Post, courtesy of artist Norman Rockwell.

Artists were not alone in their attempts to capture the essence of Rosie. Since World War II, manufacturers and engineers have sought ways to bottle those complex human skills that made Rosie and other assembly line workers better than machines. The thought was that if these skills could be bottled, perhaps they could be recreated and scientifically bestowed on a mechanical counterpart. Since there was no word in English to describe such a thing, we borrowed one from Czech author Karel Capek, who, as far back as the 1920s, had fantasized about such machines. From the Czech word robota, meaning work, he coined the word robot. It stuck.

Somewhere during this process, both manufacturers and the general public became increasingly enamored of robots — those mechanical, sometimes lovable inventions magically equipped with the logic of the computer, the strength of
metal, and, in the movies anyway, a simplistic but wise touch of humanity. Capabilities of most robots actually used in industry fall far short of the talents of this still primarily mythical creature, although the pursuit of a more human machine continues to be a source of constant engineering fascination.

This fascination extends to General Dynamics, where three robots conceptually spawned in the Robotics Laboratory have been developed to revolutionize automated machining. Skills bequeathed to these machines — including two load/unload robots and one tooling tab removal station (TTRS) — eventually will be totally integrated into the new General Dynamics flexible machining system (FMS), an automated machining work cell installed on the factory floor and already in early production phases.

The robots ultimately will serve this work cell by eliminating manpower requirements and by enabling the FMS to operate completely unmanned. Other flexible machining systems in defense industry production at this time operate either as manned or semiautomated work cells incapable of unmanned production. The current timetable for total production integration of all three robots is April 1989.

The FMS load/unload robots primarily will perform complex material-handling tasks for billets and a growing family of aluminum parts, which are designed in many sizes and shapes arranged in numerous configurations. These materials in the past were handled almost exclusively by human hands because of the need for human sensory perception, mental capabilities, finger dexterity, and movement.

Senses and “thinking” skills of the three robots in no way duplicate the full complexity of the human body or mind, 26-year-old Allen Robinson, General Dynamics robotics deputy project manager, quickly asserts. However, he describes capabilities incorporated into the robots as significant advances that will have a major impact on FMS robotic technologies and their applications on the factory floor.

Assigned to the FMS robotics project in 1985, less than a year after the four-year effort began, Robinson worked in the proverbial trenches as the robots evolved from design to implementation phases. Promoted to deputy project manager in February 1988, Robinson previously worked with the robotics team as lead applications engineer, a position primarily devoted to drafting complex robot, vision, and tooling specifications that help to give the robots their technological individuality.

A small fraction of the FMS, the robotics development project was funded for $2.6 million, a total investment made up of $1.75 million in capital resources and $860,000 in development allocations.

The FMS project was funded as a significant portion of the Advanced Machining System (AMS) Program, a $40 million, four-phased, four-year contract research and development (CRAD) program that began in 1984. Incorporated into this investment were funds authorized by a $12.97 million cost-share contract between the Air Force Wright Aeronautical Laboratories (AFWAL) and General Dynamics. Of the $12.97 million total, 81 percent was contributed by AFWAL and 19 percent by General Dynamics. General Dynamics also committed more than $17 million for capital facilities and $10 million for support programs related to AMS projects.

The basic structure procured for the FMS load/unload and TTRS robots was the Cincinnati-Milacron T3-786, an articulated-arm robot capable of operating in a large work envelope and of supporting heavy payloads. Elaborate networks of control devices, including automated vision equipment, flexible grippers and end effectors, automated controls, and artificially intelligent computers were interfaced with FMS robotic systems to enable them, in a mechanical sense, to see, touch, think, and, in a manner of speaking, learn. (See “Is AI the Real Thing?”, Vol. 2 No. 4.)

The robots needed all of these capabilities to more closely imitate their human counterparts in manual machining work cells. Although Rosie on the factory floor tends to perform one or two major machining or assembly operations, she also more than likely performs several underlying tasks. For example, she views and identifies certain part features, performs visual part inspections, and judges quality, in addition to moving or picking up parts as necessary to perform major operations of her work cell. As manufacturing needs change, she is taught new tasks. In time, as her experience increases, she also learns to improve her own efficiency.

Tasks performed by the two load/unload robots involve
three primary operations — loading raw stock onto mill fixtures to be machined at five-axis machining centers, turning over parts between two machining stages, and unloading the mill fixtures and returning parts to storage.

The third robot, TTRS, is designed to perform load/unload tasks for the slurry finishing system, a system that covers aluminum parts with a uniform matte finish to reduce cutter mismatch marks. This robot also removes tooling tabs, which are remnants of original billets that were used to clamp the billet to fixtures during the FMS machining cycle.

At last count, Robinson said the robots were prepared to perform their own operations on 96 different parts. As the part family grows, he said new parts will be added to the system.

Sight is especially valuable to FMS operations, since this method of perception enables the robots to recognize and identify each of the 96 parts. Besides merely seeing and recognizing the parts, the robots need sight to guide them toward the parts, which are stored in 400 different storage trays in the Automated Storage and Retrieval System (AS/RS), a system that automatically stores and retrieves FMS parts and materials. Vision is also required to realign the position of the robots as necessary to correct part grip or to verify that the proper mill fixture is present for loading and unloading.

These vision capabilities were provided by equipping all three robots with a three-dimensional guidance system developed by a subcontractor, Machine Vision International (MVI). Many robot vision systems were investigated during the FMS project, but Robinson said the robotics team was unable to find any other system as sophisticated or as applicable to FMS needs as the one created at MVI.

"It is really remarkable how these robots can be guided to unfastened parts in 3-D space," he said.

Many robots are equipped with vision systems, but Robinson said most of them operate on fixed, point-to-point movement, which means they do not find parts. Instead, these robots are dispatched to specific preassigned locations where parts are known to be. They are not equipped to flexibly compensate for variable part or object placement or other environmental changes. Parts to be modified or moved by a robot with these common sight limitations must be placed in precisely the same location before each operation. Otherwise, the robots cannot make contact with the part.

Although FMS robots are also programmed to operate from a single reference point, they can compensate for differences in placement and respond appropriately to different sizes, weights, shapes, and locations encountered. Programs for these parts are resident in the FMS control system, which is made up of many independent computer processors linked by a high-speed local area network (LAN). For each part number machined, three computer programs are created and provided to each robot. Each program corresponds to a stage of operation.

"If 120 parts are included in the system, then 360 programs are provided to each robot," Robinson said. "We will be adding more parts. If we get too many for the current system, we can just add a new chunk of memory."

Sight is provided by three cameras, which photograph objects to be viewed and identify features. Special teaching programs, Teach by Show® software, have been incorporated into vision systems to teach the robots to identify four or five features. Lighting sometimes prevents the cameras from identifying all five features, although generally only three features must be identified to establish a part location.

"Of course, robot vision systems are restricted in what
they can see. They need special lighting. If a light bulb goes out, any vision system is not as good as the human eye,” added Robinson.

Special lighting enhances viewing when parts or billets are gripped by the robot or when parts are being viewed in a storage tray. A single light panel, consisting of a bank of fluorescent tubes placed behind diffusing material and mounted directly above the area to be viewed, provides an evenly illuminated light source.

This lighting generally enables the robots adequately to see a part to make a logical decision, Robinson said. Occasionally, however, like the superlogical, half-Vulcan Spock in a recent Star Trek movie, the robot system must make its best guess, a task often performed in the human realm but seldom assigned to machines.

“Even if light limits what the system can see, the robot still must make some decision,” said Robinson.

The guess factor arises in circumstances when only one or two features can be identified. In these cases, Robinson said, the system considers features that can be identified, calculates the likelihood that certain other features are present, and weighs the significance of the presence or absence of certain features.

After the system analyzes views from the three cameras, the robot vision system considers its most likely options and chooses the best course of action in such situations. Sometimes the choices are to notify maintenance and abort the procedure. In other cases, the system may decide it can best-guess the part position and continue working, or it may choose to stop working the job and proceed to the next scheduled job.

When the robot picks up a part, the vision system verifies that the robot has gripped the object correctly. The robot presents the part to one or more cameras to determine accuracy of the grip and to decide if placement and grip conform to a specified tolerance.

Flexible movement, good finger dexterity, and a strong structure are required to handle the 96 parts, including their 288 different shapes, sizes, and weights. The smallest part is approximately 3/4 of an inch high, 3 inches wide, and 5 inches long, while the largest part is approximately 8 inches high, 13 inches wide, and 32 inches long. Parts or billets in the FMS weigh as little as 10 pounds or as much as 90 pounds. In a manual environment, more than one person assisted by a hoist or crane lifts the largest parts or billets. One clear advantage the robots offer is capability to lift the largest of these materials alone, without a hoist or crane.

“The robot is not going to hurt his back,” said Robinson.

General Dynamics engineers designed both hands and fingers for the load/unload robots because both appendages are needed to successfully pick up, move, or turn over parts. Fingers provide the dexterity necessary to use or change all tools required to perform FMS operations appropriate for each part.

Robinson describes the basic gripper end effector as one of the most versatile and accurate robotic gripping tools in existence. This end effector, originated at Montforte Robotics Inc. and modified at General Dynamics, can open or close to a programmable width ranging from 0 to 7 inches with a 0.032-inch degree of accuracy. Seven sets of fingertip tooling can be used with the gripper as required to accommodate the 96 parts.

“It’s quite a task to get one machine to handle so many shapes and sizes. This is a real challenge,” said Robinson.

Most grippers are designed to handle large quantities of a single part, rather than small quantities of many parts, he said. However, the nature of the aerospace industry is to produce many parts in low volume. To successfully respond to this need for versatile production, the FMS load/unload robots were designed to change gripper tools rapidly. Tooling for FMS load/unload robots can be automatically changed in 10 to 20 seconds, Robinson said.

The bolt-driving end effector, one of the most versatile of the robot end-of-arm tools, clamps and unclamps parts and billets at tooling mill fixtures and inserts or extracts bolt and disk clamp assemblies. Although robots commonly use end effectors to insert fasteners into various materials, Robinson said other robots do not use the same end effector to perform both insertion and extraction operations.

End effectors and the safety system are controlled by process controllers, which also function as communicators with vision and robot systems. Each process controller is made up of an Intel 8086 microcomputer that communicates with cell components.

Any errors or status reports in the work cell are communicated to the cell controller, the next higher control, which either sees that appropriate action is taken or passes this information to the FMS controller to obtain further direction. Two cell controllers, one for load/unload and another for TTRS, have been incorporated into robot material-handling stations to communicate and coordinate data movement to and from the work cell.

Some robotic thinking is performed at all control levels, including robot, vision, process, and cell control systems. If the control system at one of these levels is unable to solve a problem, Robinson said the issue is passed up the chain of command to the next higher control, a procedure followed until an appropriate response is determined at one of these levels. If an appropriate action is not determined within this realm, the issue is passed to the FMS controller, which is located at the top of the thinking hierarchy both for the robots and the FMS as a whole.

An artificially intelligent system, the FMS controller automatically schedules and coordinates all FMS work, including jobs to be performed at load/unload and TTRS workstations. The controller determines which jobs should be performed next and coordinates flow of work and resources to machines, which it automatically assigns to perform appropriate tasks.

As new parts are added to the FMS, the robots must learn
to process them. This learning primarily will be accomplished off-line with the aid of two new off-line programming methods. Teach by Show® software produced at MVI will be used to teach the robot vision system to see and identify new parts, while the Robotic Off-line Programming System (ROPS) developed in-house will be employed to teach robots new movement coordinates. Robinson said these off-line teaching methods will reduce time required for on-line training by 80 percent, which means robots can be taught with minimal interruption of actual manufacturing time.

Together, the complex tools and systems that operate FMS load/unload and TTRS robots appear to have given life to systems that have created Rosie the Robot, an unhired hand with a firm footing on today's factory floor and an even brighter career outlook for the Factory of the Future.

Developments inherent in FMS load/unload and TTRS robots potentially can be applied to many other factory floor processes. Robinson said assembly applications are the most immediate additional applications being considered for FMS robotic technologies.

The next step in robotic technologies probably will involve creation of a large cell in which major aircraft sections will be assembled. Robinson projected that robotic drilling and riveting might be combined into a single assembly work cell. Vertical fins already are assembled on the factory floor, but Robinson said some of the new FMS robotics applications also might be applied to assembly of a fuselage section.

"In future years, we will see more and more work cells like the FMS. Right now, the FMS still is an island of automation. Raw stock enters into the front of the FMS and is processed to go out into a primarily manual environment," said Robinson. "The possibilities for further application exist all around the FMS work cell, up and down the factory floor. The next step is to create more automated work cells and to bridge these islands of automation."
ZOOT SUITS, PARACHUTES, and WINGS of SILVER, TOO
As Millie Davidson and Kay D’Arezzo drove through the gate of Avenger Field on November 5, 1943, they saw what looked like a typical Army air base: barracks, control tower, aircraft hangars, and two runways with planes landing and taking off. But mounted on the roof of the administration building was a 10-foot-high sign with a giant portrait of Fifinella, the Walt Disney gremlin who served as mascot to the Women’s Airforce Service Pilots.

“Fifi was a real show-stopper in her gold and red outfit, with matching blue wings and goggle,” Kay recalls. “I grew up on Army bases, since my father was a career officer. But Avenger was going to be different. It was an exciting place to be in those days. We felt we were getting the chance to show what we could really do.”

That day, 93 young women from all over the United States joined Millie and Kay at the base, just outside the small West Texas town of Sweetwater. They belonged to class 44-W-4 of the 318th Army Air Force Flying Training Detachment, one of the most remarkable experiments in military aviation — a program to train women to fly “the Army way.”

The Women’s Flying Training Detachment (WFTD), as the 318th was first known, was the brainchild of Jacqueline Cochran, the famous American aviatrix. Cochran saw an opportunity for women flyers because of the enormous demand for qualified men to fly in combat. She persuaded the Army to create a training unit to prepare women pilots to ferry military aircraft from manufacturers to embarkation points for shipment overseas or to stateside military bases (much like the Women’s Auxiliary Ferry Service, known as the WAFS).

The WFTD was formed in November 1942, and was based at Howard Hughes Field in Houston. However, within only a few months the unit had outgrown its makeshift operation at Hughes. With requests from the U.S. Air Transport Command for 750 women pilots before the end of 1943 and an additional 1000 pilots during 1944, the 318th desperately needed a larger and better-equipped facility. Avenger Field, on the rolling prairie 40 miles west of Abilene, was the solution.

In March 1943, new classes began training at Avenger while a program to train British cadets was phased out. Classes that had begun training in Houston transferred to the new base in stages. When the last of the British cadets left that spring, Avenger became the only all-female Army air base in American history.

As the war progressed, demand grew for pilots to perform a variety of essential but undramatic flying responsibilities, ranging from towing target sleeves for antiaircraft gunnery practice, to breaking in new engines or testing repaired planes. Cochran convinced General Henry “Hap” Arnold, commander of the Army Air Forces, that women could handle these noncombat duties. In June 1943, General Arnold ordered the WFTD and WAFS to consolidate under Colonel Cochran’s command into the Women’s Airforce Service Pilots, better known as the WASP.

Millie Davidson heard about the formation of the WASP while she and her friend Kay D’Arezzo were working as secretaries in the Adjutant General’s office in Austin. The two young women had been drawn to each other because they were in similar circumstances. Millie’s husband had been shot down over the German coast early in 1943. Kay’s husband had been in the Philippines during the fall of Corregidor in April 1942. Both men were listed as missing in action. Kay and Millie were waiting for news.

Both had also studied flying. Millie persuaded Kay the waiting would be easier, and their contribution to the war effort more meaningful, in the cockpit of a plane than in a secretary’s chair. They pushed to earn their private pilots’ licenses and log the 35 hours necessary to qualify for the WASP, passed the required physicals and aptitude tests, and were accepted.

Millie and Kay joined 1828 other women who took part in the WASP experiment. From all over the country and from all walks of life they came — teachers and actresses, secretaries and journalists, heiresses and housewives. The women had one thing in common: they loved to fly. And they got plenty of opportunity during the six-and-a-half months they spent at “Cochran’s convent,” as Avenger came to be known. (During its first week as an all-female base, Avenger experienced more than 100 “forced” landings by male cadet pilots from nearby training schools. Cochran immediately sent down the word: Avenger was closed to all outside air traffic except in emergencies.)
Life at Avenger was tough and exciting but also often tedious. The women lived six to a bay in eight barracks. The furnishings were standard Army cots and double-sized footlockers. Somehow everything had to be kept spotlessly clean for the periodic white-glove inspections, despite the ever-present West Texas dust.

Like all soldiers (although technically WASPs were civil servants), the student pilots marched everywhere, singing funny and bawdy cadences as they tromped between barracks, mess hall, and flight line. And when they weren't marching, they were riding in the crowded "cattle trucks" that hauled them out to auxiliary fields or into Sweetwater.

The standard uniform of the day, Army surplus mechanic's overalls, size 44 and up, quickly became known as a "sot suit." This was complemented by a piece of ladylike headdress nicknamed "Urban's Turban," for Major Robert K. Urban, who began serving as base commander in June 1943. Early classes had no uniforms to wear for more formal occasions, such as graduation ceremonies and visits by dignitaries. But the general store in Sweetwater and the BX at Dyess Field in Abilene solved that problem — an official trainee "uniform" of short-sleeved white shirt, men's khaki pants (which had to be altered to fit WASP anatomy), and a general's cap.

The luck of the alphabet made Kay and Millie bay-mates. Kay's military background made her a natural for class commander for Flight 1, and she promptly used her authority to appoint Millie as one of the two flight lieutenants. The other was Madge Leon, a native of Haskell, Texas, who came to Sweetwater from Dallas, where she had been going to college. As flight lieutenant, Millie was in charge of waking everyone up for breakfast and shouting the marching commands for the flight. Because of the shortage of planes and instructors, they alternated ground school and flying time with the students in Flight 2.

WASP training was almost identical to that of male aviation cadets. Initially, the training program consisted of 115 hours of flight training and 180 hours of ground school. Later the numbers grew to more than 200 in the air and nearly 400 on the ground, the equivalent of a college degree in aeronautics. The women spent many hours during primary training perfecting loops, chandelles, and spins, the basic aerobatic maneuvers they would need to do their jobs and perhaps even save their lives. Then they went on to instru-

ment flying, radio-beam navigation, night flying, and cross-country navigation.

The first milestone of flight training was the solo, after six to 10 hours of instruction. When the first woman in a class soloed, she became the acknowledged "hot" pilot and was honored with a dip in the Wishing Well, zoot suit and all. The Wishing Well was a shallow reflecting pool near the barracks. Anxious trainees would toss in pennies before their all-important Army "check rides," praying that they wouldn't receive a dreaded "pink slip" for an unsatisfactory rating. At any stage, trainees could wash out. More than 550 WASP hopefuls over two years didn't meet the stiff requirements.

"All of our instructors were civilians," Millie recalls. "They were severe and profane, but we learned. Or at least some of us did. The washout rate was grim. Primary training was first in the Fairchild PT-19A, but after 10 days we were switched to the bi-wing Stearman PT-17. In January, we stepped up to the North American AT-6. We all loved our Sweet Six, but some couldn't handle the greater power and faster landings, so our ranks were decimated even more. Ground school was getting tough, too, but I don't think anyone washed out because of classroom deficiency. Instrument flying was done in the Vultee BT-13, and we learned cross-country navigation in both PTs and AT-6s."

Class 44-W-4 was the first to skip Basic-level training. They went directly from Primary to Advanced in order to complete the program more quickly.

WASPs had plenty of Texas-style challenges to cope with as they learned to fly. In the summer, temperatures boiled and tumbleweeds blew onto the runways. In the winter and spring, heavy rains sometimes grounded the planes, forcing student pilots to scramble to make up lost flight time on the weekends. Howling dust storms, plagues of crickets, and rattlesnakes that crawled up inside the warm metal planes were simply part of life in West Texas.

Nevertheless, the prairie surrounding Sweetwater did offer plenty of open space for hundreds of planes to fly, and also it supplied ideal navigational aids, since all the roads ran north-south and east-west. This was particularly helpful during the early phases of training, when the student pilots flew planes without radios or navigational equipment. However, Millie learned firsthand that "contact flying" wasn't always easy.

"About half of our flight had been sent out to our practice area, which was about 40 miles from Avenger, to work on
aerobatics," Millie recalls. "It was cold and had started to snow. We wore fleece-lined pants and jackets, a helmet and goggles, but those open-cockpit planes had no heaters, and I continually wiped the snow off my goggles as I did the spins, loops, and lazy-8s. During a snap roll, my compass spilled out, but I wasn't worried because I knew I just had to follow the railroad tracks back to the base. But when our practice hour was up, all trace of the tracks had disappeared under the snow! The only landmarks were the section fences and a watering tank here and there, but otherwise the country was barren."

Huddled miserably in their planes, the trainees flew in circles, and communicated by waving their arms. Finally, an Army pilot came to the rescue, sent out to look for the missing pilots when they didn't return to the base on schedule.

"We heard through the grapevine he later told his friends that, after 50 combat missions over Europe, this was the most dangerous of all, trying to evade all those Stearmans coming at him from every direction!" Millie remembers with a laugh. "I know all I wanted to do was get right under his wing so he wouldn't run off and leave me."

When she was learning to fly the AT-6, Kay had an adventure of her own. "This day I was out with my instructor, and we had been practicing coming down low for forced landings. After a while, he took over, and the first thing I knew we were buzzing someone's ranch, going full speed just a few feet off the ground, with people on the ground watching and waving. As we were gaining altitude, he must have been looking back at his audience (I was sitting in front, so I couldn't see him). Suddenly, trees appeared in front of us
and he clipped the tops, putting a bite in each wing about two or three feet across and one foot deep!” she remembers.

“He immediately radioed the base for an emergency landing directly into the wind and told me not to lower the flaps until the last minute. I think he was afraid they might not work. We landed without serious problems, but my heart was in my throat the whole time. The instructor was fired, and I was confined to the base for about eight weeks.”

Later that spring a more serious incident occurred, one no member of Class 44-W-4 could forget. On April 16, members of 44-W-4 headed out over the Texas countryside on short cross-country flights to various destinations. Coming in for a landing early in the afternoon, a member of 44-W-4 collided head-on in midair with a plane flown by Elizabeth Erickson of class 44-W-6. Both pilots were killed.

“No one knew who it was,” Kay remembers with sadness. “Two people were overdue, and Millie was one of them. When we saw the last plane coming in, I hurried down to the flight line to meet it. I was so relieved when I saw Millie, but that meant that Mary Howson had been killed. It was such a tragedy.”

Millie recalls, “The return route for my cross-country flight was within 30 miles of my grandparents’ ranch near Llano, so I deviated from the course to wiggle my wings and wave at them. I had called to let them know I was coming, so they were out in the yard, waving madly. I didn’t buzz or fly very low, but I could see them quite clearly. The bluebonnets were in bloom, and the whole area was a sea of blue. It was a wonderful excursion and only put me about 20 minutes off my ETA. But that was enough to scare Kay and the others.”

Eleven WASPs lost their lives while training at Avenger. Most accidents were not that serious, however, and some were even amusing. The aerobatic maneuvers of primary training initiated more than one WASP into the Caterpillar Club — those airmen (and women) who had safely bailed out of an airplane. The first caterpillar at Avenger had fallen out of her plane when her seat belt unfastened during a practice spin. Her instructor brought the plane in, then sent a jeep toward the white spot drifting down toward the horizon. She was retrieved safely, scratched and bruised, but smiling and waving her caterpillar badge of honor — her parachute ripcord handle.

Although the women spent most of their time in training, they still had some time left over for fun. The townspeople of Sweetwater did what they could to make the WASPs feel welcome, inviting the young women to attend their churches and including them in Sunday dinners afterwards. They also contributed the Avengerette Club where, on free evenings, the trainees could spend a little R&R time, listening to music and drinking Coca-Cola until the 10 p.m. curfew. Though Nolan County was dry, some WASPs managed to put their hands on liquor to spike their Cokes every now and then. Lunch or dinner at the Bluebonnet Hotel was a welcome treat. And those with access to a car would often spend their days at Lake Sweetwater, sometimes in the company of young men from Dyess Field and neighboring bases.

While at Avenger, both Millie and Kay got news of their missing husbands. For Millie, the news was tragic. Bill Davidson was declared killed in action. Kay learned that Al had been captured at Bataan and was being held in a prisoner-of-war camp. She wrote to him, but never let on she was doing anything more dangerous than typing letters for the Judge Advocate General in Austin. When Al was released at the end of the war, she learned that he had been telling his fellow POW officers that she was a pilot. When he heard that women were flying, he figured Kay had to be involved.

Graduation day for 44-W-4 was May 23, 1944. Kay and Millie stood proudly with 50 other graduates in new Santiago blue uniforms to receive their silver wings. During the ceremony, Millie also received Bill Davidson’s posthumously awarded Air Medals and Purple Heart. Kay was named outstanding graduate and awarded a War Bond. Despite the buzzing incident, her record was exemplary. After graduation, Millie was stationed at Maxwell Field in Montgomery, Alabama, and Kay went to Love Field in Dallas. Seven months later, they and all their sister WASPs were permanently grounded.

For many months, Jacqueline Cochran had worked for militarization of the WASP. In February 1944, the Military Affairs Committee of the House of Representatives reported out a bill in Congress granting full military status to the WASP. However, the tide of the war was turning. As the demand for pilots declined, many male Civil Service flying instructors faced unemployment. The original purpose of the WASP — to fill in for men who were needed elsewhere — was no longer operative. The bill was defeated in June, and four months later Cochran issued the order for deactivation.

The 18th and last class of WASP trainees graduated on
We are Yankee Doodle pilots,
Yankee Doodle, do or die.
Real live nieces of our Uncle Sam,
Born with a yearning to fly!

On November 23, 1977, President Jimmy Carter signed
a bill conferring official military status on these re-
markable women, giving them access to the veteran’s
benefits they had been denied for 33 years.

The photos identified below are courtesy of the WASP historian:

Page 23. WASP Louise Thompson in front of P-38 at Dallas, Texas.
Page 24. V. M. Saunders dons life preserver with B-26 in background.
Page 25. Shots from Camp Davis, North Carolina (bottom),
Houston, Texas (middle), and atop aircraft wing (location unknown).
Page 26. WASP Dora Dougherty at controls of UC-78.
Page 27. WASP’s in winter flight gear at Sweetwater (upper right),
three WASP’s on a Curtis Helldiver (bottom left), with a B-17 at
Lockbourne AAB, Columbus, Ohio (upper left), and graduating
class on parade in Sweetwater, Texas (lower right).

Copyright © 1988 by Sheila Henderson. All rights reserved.

December 7, three years to the day after the attack on Pearl
Harbor. The Avenger Field gymnasium was filled to over-
flowing with families, AAF officers, and more than 100 ac-
tive-duty WASPs who had returned to say goodbye. General
Hap Arnold commended and thanked the WASPs for their im-
pressive record; Colonel Cochran expressed her pride and ap-
preciation for the women who had been under her command.
Then General Arnold pinned silver wings on the 68 WASPs
in class 44-W-10. They were the last of their kind.

The great experiment was over, and it had been a resound-
ing success. One thousand and seventy four women had com-
pleted training at Avenger Field. The women had flown every
type of aircraft the Air Force had, including the heavy bomb-
ers, like the B-17 Flying Fortress, and the “hot” pursuit
planes, like the P-47 Thunderbolt. They had logged more
than 60 million miles, ferrying more than 12,000 planes and
performing other essential wartime jobs. In the process, they
had freed 1000 men for air combat and had proven that
women were capable of handling the rigors of military
aviation.

However, not until 1977 did women again graduate from
Air Force pilot training. It is unlikely that there will ever
again be an all-female military base. Certainly, never one
like “Cochran’s convent.”
BUT IT'S JUST A LITTLE WHITE LIE

by Larry F. Smith, Aerospace Safety
Nothing grates on a pilot’s logical thought processes more than lights in the cockpit that don’t quite mean what they say.

By now you R&W-200 drivers are probably familiar with the BUC caution light and that it doesn’t necessarily mean that the engine has transferred to BUC. If the engine’s main fuel pump fails (output pressure low), the BUC caution light illuminates.

Of course, the accompanying loss of thrust and the numerous other lights associated with a flameout make it readily apparent that something more than a normal BUC transfer has occurred.

In the GE engine world, the SEC caution light doesn’t necessarily mean that the engine has transferred fully to SEC. It may also indicate that your engine is in what the engineers call the hybrid mode.

Hybrid is characterized by an operating nozzle and AB capability, whereas a complete transfer to SEC results in a closed nozzle with no AB capability.

The F-16 flight control system (prior to Block 40/42 digital flight controls) also provides its own little white lie in the form of the red dual FC warning light.

Illumination of this warning light doesn’t necessarily mean that your flight control system has experienced a dual failure. In fact, there is a single failure that can cause a unique and distinguishable light show that includes the dual FC warning light. This single failure is loss of Branch D flight control power.

Flight control Branch D contains non-redundant logic circuits used to determine when to illuminate the dual FC warning light; the ADC, LE FLAPS and FLT CONT SYS caution lights; and the P, R, Y, and standby gains lights. Since the logic circuits are non-redundant, a failure that removes Branch D power also removes any future failure reporting involving these lights.

Thus, these lights are illuminated to advise the pilot that this situation has occurred. But how should the pilot handle this light show?

As an example, suppose that the Branch D flight control inverter/pump supply fails. Your first knowledge of that failure will likely be when “Betty” calls your attention to the dual FC warning light.

Shortly thereafter, you’ll also hear Betty alert you to the caution lights. And you’ll no doubt check the flight control panel and see the lights on there. Which checklist procedure should you use?

You might be tempted to go to ADC Malfunctions since the standby gains light is on.

However, you’re not flying on standby gains. The leading-edge flaps are still operating and the aircraft should feel no different than it did before the failure.

Plus, the dual FC warning light doesn’t illuminate when the flight control system decides to try out standby gains.

The best checklist choice, with some minor modifications, is the P, R, and/or Y Malfunctions procedure. This checklist first has you maintain a maximum of 400 knots (subsonic).

Then, following the steps under the dual FC light-on portion, the procedure warns you not to perform a servo or electrical reset and directs you to land as soon as possible. However, these latter steps are intended for a real dual-failure situation.

But let’s continue with the checklist before we modify our thinking. The steps after the “if statement” also apply since the P, R, and Y lights are also on.

Accomplishing the first of these (FLCS power test switch to test) provides three green lights for Branches A, B, and C (only the Branch D power light remains off).

Aha! The clue bird has arrived, telling you that things aren’t quite what they seem. The previously mentioned light show, along with three green lights for Branches A, B, and C power, means only one thing - a single flight control system failure has occurred and has caused the loss of Branch D power.

But what now? Should you continue to look for an as-soon-as-possible place to land and possibly subject you and your air machine to an increased pucker factor landing under less than desirable conditions?

No. Since you’ve now identified this unique single electronic failure, let’s treat it as such.

Let’s go back into the P, R, and/or Y Malfunctions checklist and follow the portion after the “if statement” that says the dual-fail warning light is not on (after all, this light is not really telling you the truth).

You may now attempt an electrical reset. If the lights go out, and stay out, you can continue your mission (the probability of successfully resetting a branch power failure is low). If the lights don’t reset, or come on again, it’s time to land as soon as practical.

Remember that the left toe brake in Channel 2 is inop with no Branch D power. Also remember that the ADC, LE FLAPS, and standby gains lights aren’t real either, inasmuch as your air data system is still functioning normally.

The flight manual doesn’t describe the Branch D power failure light show. However, the addition of information regarding this unique failure will be a topic for discussion at the next flight manual review conference. Until this information appears in the flight manual, you’ll have to rely on the Section III introductory text which says, “... It is essential to determine the most correct course of action by using sound judgment and a full understanding of the applicable system(s).”

And, honestly speaking, that “full understanding” includes your knowledge about a little white lie.
75th ANNIVERSARY

Seventy-five F-16s for 75 Years. The Royal Netherlands Air Force celebrated its 75th anniversary recently with activities including fly-bys by 75 Fighting Falcons. An aircraft painted with special markings for the occasion is shown in top photo. Part of the display, a formation of 14 Dutch aircraft, is shown above.
35th ANNIVERSARY

The 306 Tactical Reconnaissance Squadron of the Royal Netherlands Air Force celebrated its 35th anniversary in September. A highlight of that event was the “homecoming” of a familiar old friend, which until recently belonged to the Greek Air Force. Can you identify this old-timer, shown here being escorted back home by a RNLAF F-16A?

F-16 ACHIEVES 2,000,000 FLIGHT HOURS

The worldwide F-16 fleet has surpassed two million flight hours in operation with the U.S. Air Force, U.S. Navy and the air forces of 12 other nations.
COMPANY SPOKESMAN

Nick Esquivel started out nine years ago as a mechanic in the Transportation Department. But now he is one of a kind. Today he has a highly specialized job, working away day after day on a little low-tech island in the churning high-tech sea that is General Dynamics Fort Worth Division. Esquivel fixes bicycles.

Bicycles — 1400 of them — are the principal mode of transportation for personnel who serve as the communications link between different areas of the plant, who deliver and pick up parts, and who, frankly, need to get from Point A to Point B. "Bicycles are a cheap mode of transportation, and pretty reliable," Esquivel says.

"Although the new ones are expensive, some as high as $300, we get good bicycles and we take care of them. I worked on one a few days ago that the company bought in 1946. I noticed that on the paperwork. She's still going strong."

"Nope," he says, "we don't have any ten-speeds. These bicycles are heavy-duty, work bikes. No flashy stuff. And we have only boys' bikes, no girls' bikes. They're sturdier." These plain bicycles are nevertheless jealously guarded by regular pedalers who stake out a claim to their personal machines. "I know one fellow on the second shift who's been riding the same bike out here for 30 years. He doesn't want anybody messin' with his bike. If its bearings wear out, or if he has a flat, he has to use a "loaner" until I can get it back to him. He doesn't like that."

In addition to routine maintenance and fixing flats, Esquivel is set up to sandblast and repaint old bikes and to hammer out dents that result from fenderbenders. "Yessir," Esquivel says proudly, "out here in the garage we work on everything that moves: sweepers, mowers, forklifts, scooters, trucks, pickups, and cars. We even have a railroad locomotive that needs work from time to time. But I think I have the best job. I like bicycles."

What else would you expect from the company spokesman?
SSgt.
USAF

**Goody**

THIS BIRD CAME IN 'CODE ONE' FROM A MISSION...

...WITH ONLY TH' CENTERLINE TANK INSTALLED.

NOW TH' JOCK WANTS TO ADD TWO 370'S.

CAN WE FORGET TH' CENTERLINE 'CAUSE WE KNOW IT'S A-OK?

NOT ON YOUR LIFE!

YOU GOT TO CHECK ALL THREE EXTERNALS!

TH' SYSTEM'S SEQUENCIN' CIRCUIT IS AUTOMATIC ONCE YOU'RE SURE IT'S OPERATIONAL, BUT...

...SAFETY ISN'T AUTOMATIC! GOIN' BY TH' NUMBERS DOWN HERE WILL MEAN SMOOTH GOIN' UP IN TH' WILD BLUE YONDER.