The Trailing Edge

May 2022

Flying a Piece of History – C-53D Skytrooper

On 25 March 2022, I had the privilege of flying "D Day Doll" with three of my colleagues from the USAF Test Pilot School staff. "D-Day Doll" was a Douglas C-53D Skytrooper, Air Force serial number 42-68830. It was operated by the Commemorative Air Force Inland Empire Wing, based at Riverside Municipal Airport.

A C-53 Skytrooper was mostly a DC-3 built for the Army Air Forces. A C-47 differed from the DC-3 by having a larger cargo door, a hoist attachment, and a reinforced floor. The C-53 had none of these modifications. All C-53s were built at the Douglas Aircraft Santa Monica plant. C-47s would be built in Santa Monica, at the Douglas Aircraft Long Beach plant, and many other locations under license. Only 380 C-53s were built.

Besides having the name and nose art of "D Day Doll", this aircraft actually participated in the Normandy invasion in 1944. From the Commemorative Air Force's web site:

> It was built at the Douglas factory in Santa Monica, California. It is one of 159 C-53Ds and was delivered to AAF on July 7, 1943. It was assigned to the 434th Troop Carrier Group and was stationed at various locations (Alliance Field, NE, Baer Field, IN, Fullbeck, UK, and Welford Park, UK) before arriving at Royal Air Force (RAF) Aldermaston, UK in March 1944.
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> The 434th TCG consisted of HQ and the 71st to 74th Squadrons. Aircraft 830 was assigned to the 72nd Squadron (CU).
>
> The group's D-Day mission was to tow gliders carrying reinforcements to 101st Division troops who had been dropped earlier in the night near Utah Beach.

At 0119, June 6, 1944, 52 of the Group's airplanes, each towing a Waco glider, took off from RAF Aldermaston Airfield for Normandy. Aircraft 830 flew three missions on D-Day and the next day.

While in the ETO it participated in the D-Day invasion, Operation Market Garden in Holland, the re-supply of Bastogne, and the crossing of the Rhine.

It also flew various support missions and wounded evacuations to England.

"D Day Doll" also flew in the 75th anniversary celebration of D-Day over the Normandy beaches of France on 6 June 2019.

Right behind the nose art was a door colloquially referred to as the "hamburger hatch". I used to think that this was the private entry door for the pilots, but I had not seen any pictures with ground support equipment that would provide stairs to get to this door. As explained by the crew, in the days the DC-3 was designed, airlines made a substantial part of their income from hauling the U.S. Mail. Regulations required a secure location for the mail away from the passengers and passenger baggage. For the DC-3, this location was right behind the cockpit. The regulations

also required that the postal clerk be able to access this secure location without passing through any passenger areas. As such, this door was included to allow secure access for the mail.

It was referred to as the "hamburger hatch" because it was located just forward of the left propeller, and if you opened this door while the left engine was running, you would likely be chopped up into hamburger. As it was, this door would not be convenient for entering the airplane anyway. The vertical dimension was shorter than a normal personnel door. Note how the top of the door was below the sill of the pilot's window.

In this picture you can see the top of the "hamburger hatch" behind the pilot. The bottom of the door was actually below the level of the floor shown here. This door was not a preferred egress option because of its height above the ground, the proximity of the propeller, and the inconvenience of trying to go through it.

Having the "hamburger hatch" in the end was ironic, since the DC-3 was the first aircraft design that could be operated profitably on just passenger traffic, without carrying the mail.

The airplane was set up as it was on D-Day, configured for jumping paratroopers. The seats were super comfy aluminum pans down both sides of the cabin. Overhead on the left side was the cable for attaching the parachute static line.

Note the integral stairs on the closed door. I assume that on jump missions the door would be removed, since the door opened outward. As this was not an airliner, no bulkhead was installed behind the door to separate the baggage area from the passenger area. In this airplane a curtain was installed at this location, shown drawn in this picture.

Three windows were configured as emergency exits. One can be seen on the far (aircraft left) side in this picture- the third window forward of the door has a twist handle under it. The panel around the window was hinged to the fuselage across the top. Two windows on the right side were configured the same way. Opening one of these exits resulted in a rectangular hole that was surprisingly small. I've heard people were smaller before WWII, but I can still imagine them having a hard time squeezing through that hole. Even if they did get through it, there was still quite a large drop to the ground.

View out the window as we turned on to Taxiway C. The propeller isn't bent—that's just the rolling shutter effect.

View down the left wing in flight. The aileron extends from the last white invasion strip all of the way to the wing tip. Given the size of this aileron, plus the one on the other side, it's not surprising that it would be hard to move it to full deflection using that little control wheel.

Here I am flying. Note the "period correct" glass displays and GPS navigator, which probably weren't there in 1944. Then again, I wasn't there in 1944, so I guess I'm not period correct either. Note also how the windshield is almost completely vertical—certainly good for visibility, as well as ensuring the airplane has sufficient drag to make the choice of engines worthwhile.

Taxi

Taxiing the C-53 was almost as big a challenge as in the HU-16, but for different reasons. The tail wheel was not steerable, but could be either locked straight ahead or left free-swiveling. Once pointed in the right direction, taxiing in a straight line was easy-peasy with the tail wheel locked. With the tail wheel unlocked, all of the taildragger issues reasserted themselves, trying to make you ground loop and roll backwards. Fortunately, because of the size of the airplane, the time constant to ground loop was long enough that you had plenty of time to prevent it.

Like the HU-16, differential power could be used for making turns. Also like the HU-16, this method had some lag to it, taking a while to start the turn. Also, power to stop the turn had to be applied at least 30 degrees before the desired heading.

Differential braking worked, but not very well. The brakes were hydraulic expander brakes. We are used to brakes where pushing on the top of the rudder pedal applies pressure to a master cylinder, which hydraulically moves a cylinder at the wheel which pushes the brake shoe against the drum. In the DC-3, pushing on the top of the rudder pedal opened a hydraulic valve, which allowed hydraulic fluid under pressure to flow to the brake, where it filled a device similar to an inner tube that pushed the brake shoe against the drum. Because pushing on the brake pedal was just opening a valve, there was no real feedback as to how much braking was being commanded. As such, at low speeds, expander brakes tend to be very grabby, going from no brakes to abruptly applying full brakes. This was not as noticeable when the wheels were turning fast, as on landing rollout, but very noticeable at taxi speeds. Everyone who tried to steer with brakes at low speeds had the same abrupt result of grabby brakes.

One other interesting way of controlling direction was to use ailerons. Much like adverse yaw, deflecting full aileron created a yawing moment, but in the opposite direction of deflection. That is, full left aileron caused a right yaw. This did require some forward speed to happen. Apparently the aileron deflected down created a lot of drag, while the aileron deflected up was mostly blocked by the wing, which was at a high pitch angle because of the tailwheel configuration. This effect can also be seen on the Beech 18, another taildragger. Combining the yaw direction opposite of the control input with the desire of a taildragger to ground loop can create a real helmet fire!

Takeoff

The propeller effects that cause an HU-16 to turn left when full power was applied for takeoff were mostly overcome in the C-53 by the locking tailwheel. Align with the runway centerline, lock the tailwheel, and the airplane will track straight down the runway as power is applied. By the time the tailwheel can be raised off of the runway the rudder has sufficient authority to maintain directional control.

Sitting sideways in the passenger compartment, the deck angle combined with the acceleration from the high static thrust of the propellers makes for a powerful and impressive force trying to make you fall over.

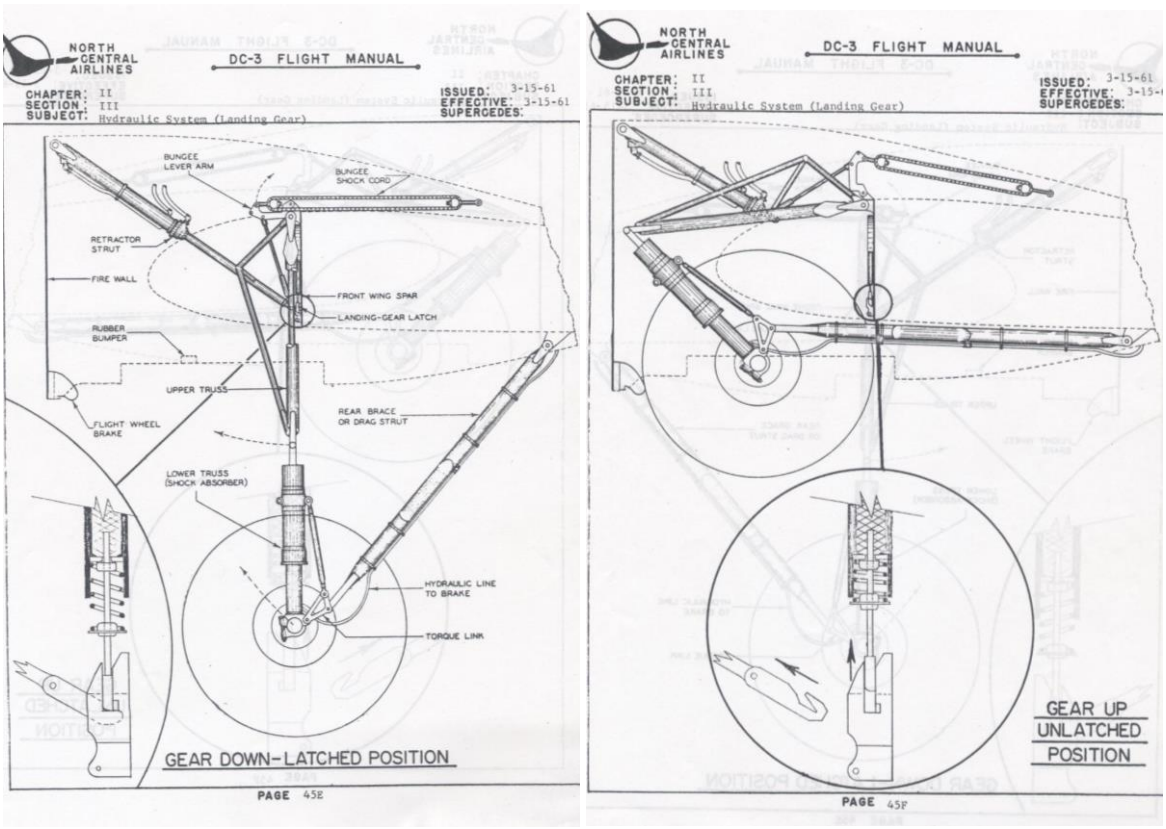
The takeoff takes a significant amount of time, which to a brain tuned to jet speeds seems like it would be a very long distance. However, because of the much slower speeds involved, the actual distance used was quite short.

The initial climb rate seemed similar to the Bearhawk, implying around 1000 feet per minute. However, this was in an airplane that was empty except for six people. Imagining a similar airplane loaded to max gross weight would result in a much flatter, and thus more concerning, climb angle. We are really spoiled with the performance of modern day airplanes, compared to what C-53/C-47 pilots, such as those flying the Hump or the Berlin Airlift, had to deal with.

Landing Gear Operation

The landing gear design and operation is fascinating because of its lack of sophistication. This was a very early retractable gear design, especially for this size of airplane, and much of the required sequencing is done manually. Unlike later landing gear designs where the pilot flipped a switch and all of the required actions happened in order automatically, on the DC-3 each operation was done manually. The simple act of raising or lowering the gear required a procedure with its own checklist.

The basic gear leg holding the wheel was of a similar design to your own body's leg. There was an upper arm (similar to a thigh) and a lower arm (similar to a shin) connected together with a knee pivot joint. When the gear was down, these two arms were aligned, just like your leg when you are standing up. A hydraulic cylinder was connected to the center of the thigh, and when that cylinder shortens, it pulls the knee up, such that the retracted position resembles your leg while you are squatting.



There was a drag strut attached to the back of the "ankle" which keeps the knee from folding backwards (i.e. "kneeling") while on the ground. The drag strut also guides the wheel up into the well and keeps the shin from flopping around under the knee.

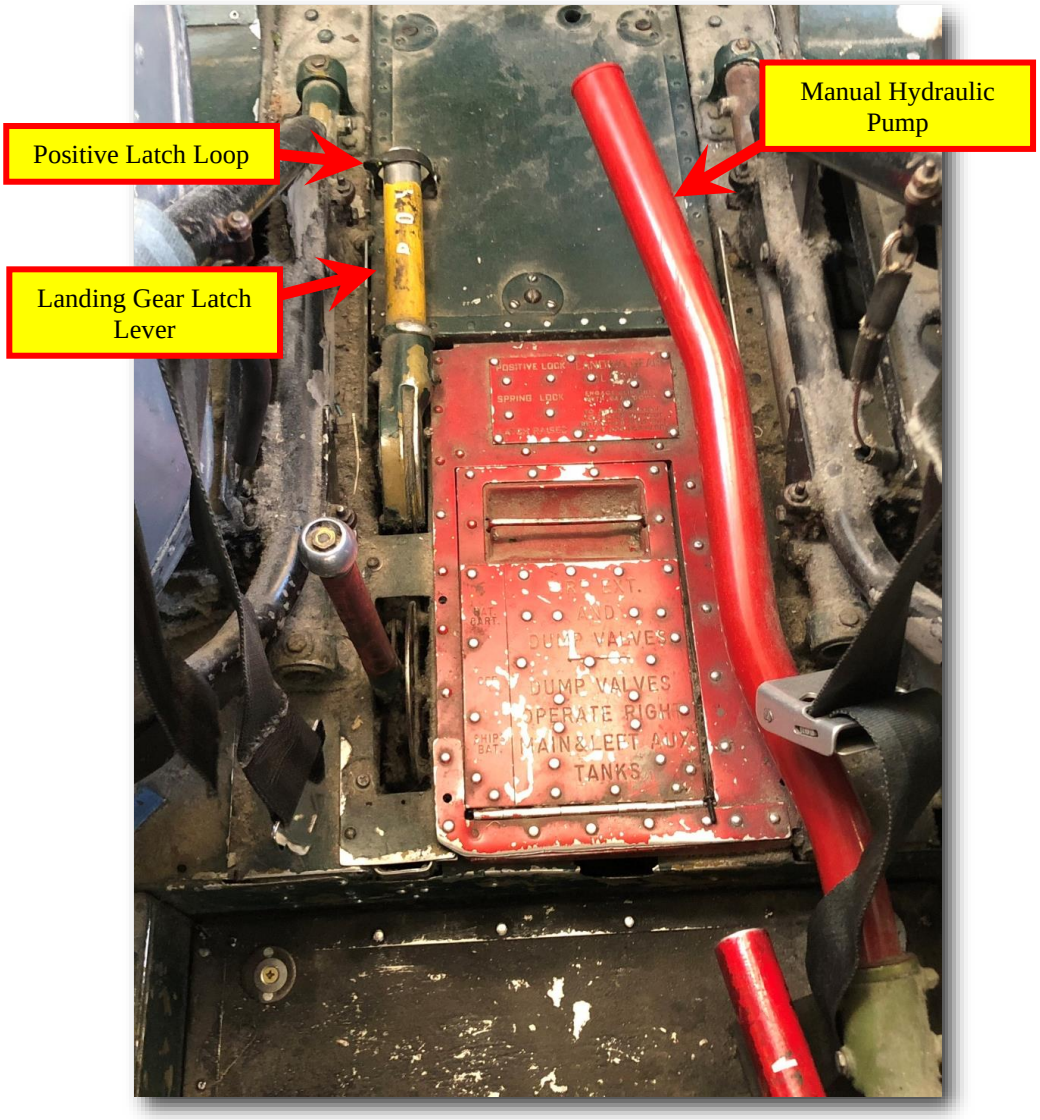
A key concern while on the ground was to keep the leg straight, that is, keep the knee from bending. This was accomplished in two ways. While stationary on the ground, a landing gear latch holds the thigh in position against the bulkhead of the wheel well. This latch was a simple plate of metal that was pushed by a spring into a slot at the end of the hydraulic actuator. This latch was strong enough to hold the gear in place while stationary or being towed on the ground. When the aircraft was taxiing, taking off, or landing, a stronger solution was required. To accomplish this, the hydraulic actuator was pressurized in the extending direction by a minimum of 500 psi hydraulic pressure. This kept the thigh pushed into the extended position.

The landing gear latch ("spade") was controlled by a short lever on the floor of the cockpit, just to the right of the pilot's seat. Pulling up on the handle pulled the spade out of its slot, releasing the gear. When the landing gear latch was in the full down "engaged" or "positive latch" position, a small metal loop swung up over the handle to prevent it being lifted. Thus the security of the landing gear remaining extended fell to a small loop over the end of a lever. No solenoids, no limit switches, no software. This handle also controlled a pawl on the landing gear hydraulic valve handle which controlled the ability to move this handle to the "retract" position. The landing gear latch handle had three positions:

1. Full down (Positive Latch). In this position, the spades were engaged, preventing the landing gear from retracting. The pawl on the landing gear hydraulic valve handle was engaged, preventing the handle from being moved up to the "retract" position.

2. Halfway up (Spring Latch). In this position, the spades were retracted against the springs. The pawl on the landing gear hydraulic valve handle was engaged, preventing the handle from being moved up to the "retract" position.

3. Full up. In this position, the spades were retracted against the springs. The pawl on the landing gear hydraulic valve handle was retracted, allowing the handle to be moved up to the "retract" position.



The landing gear hydraulic valve handle was directly attached to a hydraulic valve which directed hydraulic fluid under pressure to either end of the hydraulic actuator that moved the landing gear. Pulling up on the handle raised the gear. Pushing down on the handle lowered the gear. This handle was normally operated by the copilot, but could be operated by the pilot. Pushing down on the handle was a long stretch from the pilot seat. Returning the handle to the neutral position closed the valve and trapped hydraulic pressure in the lines.

Normally the pilot flies the airplane while the copilot configures the landing gear. The procedure for raising the gear was:

1. Move the loop off of the landing gear latch handle.
2. Raise the landing gear latch handle full up. This retracts the spades, releasing the landing gear, and retracts the pawl on the landing gear hydraulic valve handle, allowing it to be raised.
3. Move the landing gear hydraulic valve handle out and up. This applies hydraulic pressure to the retraction actuator.
4. When the gear is fully up, move the landing gear hydraulic valve handle back to neutral. This closes the hydraulic valve and traps fluid in the system.
5. When the landing gear hydraulic valve handle moves back to neutral, the landing gear latch handle should snap down to the halfway up position. This keeps the spades retracted, but engages the pawl preventing the landing gear hydraulic valve handle from being raised.
6. Visually verify the wheels are retracted.

Once retracted, the landing gear was held in place by the high pressure fluid trapped in the system. Because the landing gear pressure gauge was on the down side of the actuator, when raised there will be no noticeable pressure indicated. If the high pressure fluid leaks from the up side of the actuator to the down side of the actuator, the indicated pressure will start to rise. In this case, the landing gear latch handle was pulled full up to release the landing gear hydraulic valve handle. The landing gear hydraulic valve handle was pulled up, then returned to neutral. That is, the landing gear were just moved back up to the full up position.

To lower the gear, the procedure was:

1. Verify the landing gear latch handle is in the “spring latch” position (halfway up). This was to make sure it was not stepped on or otherwise pushed all of the way down.
2. Move the landing gear hydraulic valve handle out and down. This applies hydraulic pressure to the extension actuator (same thing as retraction actuator).

3. When the gear pressure comes up and stabilizes, the landing gear is locked down. Move the landing gear hydraulic valve handle back to neutral.

4. Verify the Green landing gear light (just one) is on.

5. Push the landing gear latch handle full down to the "positive lock" position and engage the little metal loop to keep the handle in position. This engages the spades to further lock the landing gear down.

6. Visually verify the wheels are extended.

If the indicated pressure for the landing gear hydraulics fell below 500 psi, the landing gear hydraulic valve handle was pushed down, then returned to neutral. This re-pressurized the down side of the landing gear actuator.

Flap Operation

The flaps were all-metal split flaps, stretching from one aileron to the other, including underneath the fuselage. The flaps were hydraulically extended and retracted. Flap position was shown by a knob moving across the pilot's instrument panel below all of the instruments. In this position it was difficult for the pilot to see the flap position indicator. However, it was reasonably easy for the copilot to see the flap position indicator, and the flaps were normally moved by the copilot at the pilot's command.

The flaps were controlled by a handle that directly moved a hydraulic valve that sent hydraulic pressure to the flap actuators. This handle was moved up to raise the flaps and moved down to extend the flaps. Intermediate flap positions were selected by moving the flap handle back to neutral when reaching the desired flap position. This could be tricky as the flaps moved pretty fast.

The flap handle was located just above the landing gear handle, and both looked rather similar. In this airplane, the flap handle was painted yellow and the landing gear handle was painted red. To prevent confusion, our IP told us that when you want to move the flaps, be sure to grab the handle that feels yellow.

Flying Qualities Investigation

The main control inceptor was a control wheel, comprised of approximately two thirds of a circle. Full elevator deflection was within the normal range of arm motion. Full aileron deflection required turning the wheel approximately 180 degrees. While this was in excess of the full motion recommended by MIL-STD-1797, it was common for fully reversible flight control systems in order to have sufficient mechanical advantage to move the large ailerons. Roll forces were significant, but pitch forces were also significant, such that control harmony was acceptable. Since the throttles were mostly set to a desired power setting and left there, and considering the high control forces, it seemed very natural to fly with both hands on the control wheel. The control forces were manageable for a short period of time with just one hand if necessary to use the other hand to actuate another control or make notes.

Many people seem to have come to the conclusion that the ideal flight control system would be very light to the touch. While this is true for aircraft that are meant to be highly maneuverable, such as aerobatic airplanes or military fighters, it is quite the opposite for airplanes, such as airliners, that are intended to cruise at constant altitude for great distances. In this case, high but manageable forces are desired, because high control forces indicate a high level of stability. Considering that this airplane was designed with a very simple autopilot, having a very stable airplane would be highly desirable for long range cruising under manual control. All flying qualities investigations were done at 120 KIAS, and normal cruising speeds would be expected to be 15 to 20 KIAS faster. The control forces would increase slightly with the higher speeds.

Rudder doublets were not allowed, so the Dutch Roll mode was excited at 120 KIAS using adverse yaw from an aileron doublet, limiting bank angle changes to 15 degrees in each direction. The response was snaky, showing that the dihedral effect was not excessive. Damping was reasonable, with no more than three overshoots. The Dutch Roll was not a nuisance, being otherwise not noticed during the remainder of the flight.

Simple pitch, bank, and heading captures were accomplished at 120 KIAS. The short period was heavily damped, so pitch captures were easily done with no significant overshoots. The pitch control forces were not light, but were easily manageable. Bank angle captures were similarly easy, again with forces not light but manageable. An intentional push on the rudder was necessary to maintain coordinated flight. Forgetting to use rudder would swing the nose in the opposite direction because of adverse yaw. Because the bank angle was easy to control, rolling out on a particular heading was similarly easy.

An attempt was made to generate maximum roll rate during a 45 degree bank-to-bank roll. The intent was to rapidly turn the control wheel 180 degrees and hold it there through the roll. However, aerodynamic forces on the ailerons were so high that the wheel felt like it hit a hard stop at about 135 degrees of rotation. The IP was able to show that it was possible to force the wheel to 180 degrees of rotation, but there was no significant increase in roll

rate from that last bit of wheel rotation. The roll rate was as expected for a large aircraft, fast enough to handle sudden gusts but not so fast as to be disorienting or make control difficult.

The same pitch, bank, and heading captures were tested again with a simulated engine failure. For this short evaluation, the rudder forces were not trimmed out. Rudder forces were easily managed, and in an emergency could be maintained until trim could be applied. The results were not significantly changed by the simulated engine failure. Rudder and aileron authority were sufficient to easily bank toward or away from the failed engine and to control sideslip.

Trim Changes with Configuration Changes

At approximately 7500 feet altitude and 120 KIAS, the great lever dance to lower the landing gear was accomplished. While manageable from the pilot seat, pushing the landing gear hydraulic valve lever to the down position did require a significant lean to the right just to reach it. No significant pitch trim change was noticed.

Also from the pilot seat, the flaps were lowered, first to 1/4 deflection. The flaps moved surprisingly faster than expected, and this action highlighted the fact that the flap indicator was located so low on the pilot's instrument panel that it was effectively blocked from the pilot's view by the control wheel. No significant pitch trim change was noticed.

Altitude was maintained, and the airspeed slowed because of the additional drag of the extended landing gear and flaps. Below 97 KIAS the flaps were lowered to full down. Full flaps did cause a noticeable pitch trim change, pitching the nose up (if I remember correctly). The pitch force change to maintain attitude was less than 30 pounds and easily trimmed out with a small motion of the trim wheel.

Raising the flaps to 1/4 had a similar trim change in the opposite direction, again easily managed. Raising the remainder of the flaps had no noticeable trim change.

Raising the gear was another great lever dance, but did not have a noticeable trim change. Landing gear operation, while not a simple as flipping a switch, was a higher workload if done single pilot, but was manageable. With two pilots it was indistinguishable from any other airplane.

Trim Changes with Load Shift

Not only does an airliner or cargo plane need a large c.g. range to deal with varying cargos, but for the airdrop mission, that cargo moves around. The traditional way to create a large c.g. range is to have a large horizontal stabilizer.

This test was set up to test the trim changes that might be caused by paratroopers jumping or cargo drops. Airspeed was approximately 120 KIAS, too high for paratroopers (95 KIAS max) but good for an initial buildup. The moving cargo consisted of three crewmembers, with a combined weight in the neighborhood of 500 pounds.

The load shifters gathered at the front of the passenger compartment just behind the cockpit. The trim was adjusted for level flight. Once trimmed, the load shifters walked to the rear of the passenger compartment next to the entrance door. The change in force required to maintain pitch attitude was noted and trimmed out. The load shifters then walked to the front of the passenger compartment. The change in force required to maintain pitch attitude was noted and trimmed out again.

In both cases, the change in pitch force was small and manageable (under 30 pounds). The resulting trim change was easily trimmed out.

Operational Evaluation

For an operational evaluation, the crew hearkened back to the bad old days of the Vietnam War when already "old" C-47s were pressed into duty as gunships. In the AC-47, three GAU-2 miniguns were installed, two shooting out the windows on the left side just ahead of the entrance door and one shooting out of the door. These guns were fixed in position and were aimed by maneuvering the aircraft. The airplane was flown in a pylon turn around the target. The effective range of the guns was about 1 kilometer, or about 0.54 nautical miles.

As seen in the previous pictures, miniguns were not actually installed on this aircraft. Thus, all gun firing was simulated. The airplane was flown at 110 KIAS at an altitude of 1000 feet AGL and a left bank angle of 25 degrees. This was calculated to give a turn radius of 0.37 nautical miles.

A suspected marijuana farm or possible meth lab (temporary building covered in plastic) was selected as a target. With no actual gun sight, or guns for that matter, this was essentially an exercise in keeping the target at one location in the pilot's window while flying circles around it. With excellent coaching from the IP to make up for lack of experience in flying this maneuver, it was a reasonably low workload to keep the wing pointed at the target. Since the bank angle was fixed, slight climbs and descents were used to move the target forward or aft in the pilot's field of view.

An additional learning point was the importance of a gunship not entering a fair fight. Because the GAU-2 minigun used rifle ammunition (7.62x51mm, 30 caliber), the effective range was fairly short in airplane terms. While in this orbit, the target looked surprisingly close, and I could imagine being worried about someone shooting back at us. Later gunships, such as the various models of the AC-130, had larger weapons and therefore greater standoff ranges.

Landing Approach

Per TPS rules, landing approaches by non-Air Force rated pilots were flown to 100 feet AGL, at which time the IP took the controls and finished the landing. Even while flying in the "traffic pattern" the pattern was much larger than flown in a light aircraft, resulting in final being more of a straight-in approach.

The approach was flown as a stabilized approach, with only small and infrequent corrections. The engines were set to a power setting known to give the desired approach angle. Airspeed was maintained and adjusted with the pitch controller. Any further adjustments to flight path were made by moving the flaps. This was possible because the flaps did not have set detents, but could be moved to any desired deflection. Increasing flap deflection caused more drag, resulting in a steeper approach. Decreasing flap deflection caused less drag, resulting in a shallower approach. This was very similar to spoiler usage during a glider approach.

Once stabilized on the approach, flying was very simple, consisting mostly of being patient while waiting to get to the runway. This was demonstrated on a smooth air day, and presumably there would be more corrections needed on a turbulent day.

A wheel landing was the preferred method. Three-point landings were not allowed for fear of stalling the airplane while too high above the runway, resulting in a dropped in landing.

- Russ Erb