Air and Space this Week

Item of the Week

First Round-the-World Non-Stop Flight

Originally appeared February 22, 2021

KEY WORDS: Round-the-World Non-Stop Macready Kelly Spaatz Eaker Halverson Quesada Question Mark B-50 Lucky Lady II

The Transcontinental Reliability and Endurance Test of 1919 and the Air Mail race of 1921, topics of last week's Item, were pivotal moments in aircraft development. Flying long-distance cross-country and rapid mail delivery by air were major accomplishments. But what about flying across the United States without stopping? Or better yet, what about flying around the **world** *without stopping? And the ultimate: Flying around the world* **without refueling** *at all?*

The impetus for this Item topic is that Friday, February 26, is the 72nd anniversary of the start of the first round-the-world non-stop flight.

Airplane technology advanced rapidly after WWI, and began to spread from military applications to the civilian sector, as seen in last week's A+StW Item. Not long after the 1921 Transcontinental Air Mail Flight, the Army Air Service decided to publicly demonstrate their growing prowess in projecting airpower by setting a number of endurance records. The immediate goal was to not only fly coast-to-coast, but to do so without stopping.

The problem of how to accomplish such a long flight was attacked on two fronts: either learn how to refuel aircraft while aloft or use a bigger airplane with more reliable engines.

A Bigger Plane

The first of the two methods tried was to use a better airplane. It would need to have durable engines, be large enough to hold enough fuel for the entire trip across the country, and have a provision for two pilots to switch controls while in flight.

Enter the Fokker F-IV, a large (for the time) cargo carrier. The Army had just procured two of them (which they designated as F-2) as test beds for the new Liberty 12-cylinder engine, and one of them was assigned to the project. Fuel tankage was increased by adding a tank in the center of its large, single, overhead wing, and a large tank in the fuselage. Structural members were upgraded to handle the additional weight. A second set of controls was added, to facilitate the hand-off of controls between the two pilots required.

Army Lieutenants John Macready and Oakey Kelly would be the pilots for the attempt to fly coast-to-coast non-stop. The first thing to decide was the direction to take. West to east was chosen, in order to take advantage of generally-prevailing winds. They would take off from Rockwell Field, near San Diego, on October 22, 1922, and fly eastward,

After a coin toss, Kelly took off. The heavily-loaded plane struggled to gain altitude, barely skimming above the waves. Their flight plan was to use the pass at Banning to get through the coastal mountains, but fog intervened, and they had to circle waiting for it to clear. Their fuel supply was barely sufficient to make it to the East Coast, and they soon got to the point where a successful mission was not possible.

The intrepid pilots managed to get some value from their initial failure. They flew back to Rockwell Field and began circling it. And circling it. The pilots had decided to break the world flight endurance record, and at least prove that the *T-2* was capable of a flight of the same duration as would be required going coast-to-coast. After 35 hours aloft, they finally landed, low on fuel. Had weather not intervened, they would have been successful.

Macready and Kelly tried again, after the *T-2* underwent additional repairs/modifications, taking off from Rockwell Field on November 3. This time the weather was favorable, and they cleared the coastal mountains easily. As they crossed the Colorado River, Macready took over, but a lot of additional climbing was needed to clear the ever-higher terrain they encountered. The Fokker barely had enough oomph, and actually had to make two runs to clear the Continental Divide.

Darkness soon fell, requiring a couple of hours of blind flight until moonrise. The pilots navigated by following railroad tracks in the dim moonlight, and by seeing the lights of the few small towns along the way. They flew on during the night, dodging storms and struggling to keep their bearings. They switched off again as dawn approached, and passed over St. Louis without further difficulty.

But they were far from home-free. They had noticed some minor cracking on one of the cylinder jackets early in the flight, but the damage was (then) minor. However, the crack grew, and began leaking coolant. By the time they got to Indiana, the engine was overheating, and Macready began planning an emergency landing. Kelly was dumping additional fluid into the water tank, and Macready slowed the engine a bit, allowing them to make Indianapolis. They landed in the infield of the Indianapolis Motor Speedway.

Undaunted, M and K began planning their next attempt. They realized that flying west-to-east did give them somewhat of an advantage of the wind, but having to cross mountains early in the flight was really difficult since the *T-2* was heavy with fuel. If they flew east-to-west, they could burn off much of the fuel weight before having to gain a lot of altitude. A wintertime attempt was out of the question, so they overhauled the *T-2* and got ready to try it again. They estimated that it would take them **27 hours** to complete the trip.

On May 2, 1923, at 4 AM local time, they took off from Roosevelt Field. The *T-2*, as always, struggled to gain a single foot of altitude. In fact, the only way they got into the air at all was that, at the edge of Roosevelt Field, the ground dropped 20 feet abruptly, and was clear of obstructions (it was the neighboring Hazelhurst air field). The *T-2* dropped a few feet and took several minutes to no longer need to dodge trees.

A voltage regulator that managed the plane's electrical system failed after a few hours of flight. The T-2 could continue for a few hours at most on battery power. Macready took the controls, and Kelly managed to access and repair the regulator. He took back the stick and they flew on.

Bad nighttime weather was encountered again in the Midwest. The flew over St. Louis, and followed the Missouri River westward. They could see the lights of Jefferson City, but the weather soon worsened and they had to fly by compass in pitch blackness.

The weather began improving in the wee hours. By 6 AM local, they were over eastern New Mexico. The Rio Grande was a good landmark. They knew that they had a couple of hours cushion on their fuel supply, but there was some topography ahead. They had to deviate a bit from the planned routes in order to minimize the fuel-consuming climbing needed.

Macready flew across Arizona, passing just north of Phoenix. Kelly took over as they picked up the Southern Pacific railroad at Wickenburg. The path west was open and easy, at least to the coastal mountains. They gained the altitude needed, and landed at Rockwell Field without incident. The trip had taken **26 hours and 50 minutes**.

Macready celebrated by getting married a few days after the landing.

The non-stop aspect of their trip created quite a public sensation, and the two pilots, and their aircraft, became famous. Macready's hope for some leave for an extended honeymoon was dashed, however. The AAS wished to expand the value of the trip as a public relations coup, and ordered pilots and plane to Washington, where *T-2* was donated to the Smithsonian Institution. It was displayed prominently in the Pioneers of Flight gallery for many years in the National Air and Space Museum, ending only during the current renovation of the 1976 building on the National Mall.

Aerial Refueling

The range of the DH-4 aircraft in the earlier events was much too short to go more than a few hundred miles, no matter how much extra fuel its limited carrying capacity could accommodate. The only remedy would be to refuel the airplane while it was still aloft. This was actually accomplished on June 27, 1923, when gasoline was passed from one DH-4 to another through an overgrown garden hose with a shut-off valve at each end. The giving plane flew ahead and above the receiving plane, letting gravity to induce the flow of fuel. Improvements in the handling of the transfer soon followed.

The transcontinental T-2 had an endurance limit of about 30 hours, a little longer if it didn't have to climb over mountains. But it had been modified to carry a fuel load several times larger than it would use as a transport plane. Adding even more fuel would mean more weight, which would require more fuel, in a spiral of diminishing returns. Long endurance flying would absolutely require aerial refueling.

To demonstrate the practical value of refueling, at least for military purposes, a flight was conducted from Washington state to Rockwell Field, using a short-legged DH-4 (operational range was 275 miles). On October 25, 1923, a DH-4 piloted by Lowell Smith flew 1280 miles, refueling over Eugene, Oregon, and Sacramento.

The *T-2* had already demonstrated that long-distance flight was possible without aerial refueling, so the impetus behind the tactic diminished. But when the Belgian Air Force set a new endurance record of over 60 hours of continuous flight, the Americans took notice. But not the Army Air Service this time (at least at first). Army Lt. Elwood Quesada and a Marine Corps aviator planned out how to break the Belgian record. Quesada's motivation was partially personal; he had been injured in a plane crash caused by fuel deprivation. When the Army got wind of the plan, their brass quickly took it over for the Air Corps alone.

Another Fokker aircraft was to be used for the endurance record, a C-2A trimotor, much larger than the *T-2*. It normally carried 192 gallons of fuel in wing tanks, and was modified with the addition of two 150-gallon tanks in its fuselage. A hole was cut in its roof to allow a refueling hose to be received from an aircraft above. The system was awkward; the wing tanks fed the engines by gravity, but the fuel in the fuselage tanks had to be hand-pumped to the wing tanks.

Two refueling planes were prepared, both were Douglass C-1 single-engine biplane transports. Two 150-gallon tanks were installed in each, and a hole was cut in each floor to allow a hose to be dropped to the C-2A below.

The C-2A was not-particularly-optimistically given the name "Question Mark," and it would carry a crew of five: Maj Carl Spaatz, Capt Ira Eaker, 1Lt Harry Halverson, 1Lt Quesada, and Sgt Roy Hooe.

If you are familiar at all with AAF history of World War II you will no doubt recognize those names! We encountered Spaatz last week in the air race story; he would command the U.S. Strategic Air Forces in the ETO, establish the Strategic Air Command, and was the first Chief of Staff of the United States Air Force. Eaker would command the Eighth Air Force in England in 1942, then all AAF forces in England, then became C-in-C of the Mediterranean Allied Air Forces in early 1944. After WWII, Eaker served as Chief of the AAF Air Staff. Halverson would command the Tenth Air Force in 1942, planning for an early strategic bombing of Japan from bases in China. His long-range B-24's were needed elsewhere, so the Tenth was shifted to make a bombing attack on the vital Nazi oil refinery complex at Ploesti, Romania, on June 11, 1942, the first of many, larger raids. "Pete" Quesada would hold a number of responsible positions during WWII, retiring as a Lt. General in 1951. He was appointed by President Eisenhower to chair the Airways Modernization Board, and would become the first administrator of the Federal Aviation Agency. And Sgt. Hooe was inducted into the Airlift/Tanker Association Hall of Fame in 2001.

Even their ground control chief, Capt Hugh Elmendorf, had a great career with the AAF; he's the namesake of a large airbase in Alaska.

The flight of the *Question Mark* began at 7:26 AM on January 1, 1929. The plan was to remain in the general vicinity of the LA airport, to allow a rapid landing should problems develop, and to make sure that the record they were setting was "official," since take-off and landing at the same airport was required. The Rose Bowl annual football game, a hugely-popular and newsworthy event, was also held that day, and the *Question Mark* would overfly the Rose Bowl stadium several times.

Spaatz was handling the refueling gear in the wee hours of January 2. A bit of turbulence pulled the refueling hose loose, and he was doused by gas (the flow rate was 75 gallons/minute). The gas was highly caustic, and he got fuel vapor in his eyes, but he carried on. He would have risked a nighttime bail-out rather than abort the mission. When it came time to refuel again, Spaatz showed up in his birthday suit, to prevent having to sit in another gas-soaked outfit. Sure enough, he got sprayed again. And again later.

The days went by, with only a few minor mechanical problems that the crew could fix in flight. When a window blew out, one of the refueling planes passed down a replacement and it was repaired. They were even passed food, ice cream, and mail while aloft! However, on January 7, the left engine of the tri-motor failed. The other two engines could barely handle the extra load, and Sgt. Hooe crawled out on the service catwalk to effect repairs. No joy. It was time to land.

The *Question Mark* had flown over 11,000 miles, refueled 43 times (12 at night), and consumed 5660 gallons of gas and 245 gallons of oil, on their record-shattering flight of 150 hours, 40 minutes, and 14 seconds.

Around the World

After WWII, the leadership of the AAF was focused on airpower with a global reach. Another public demonstration of capabilities was desired. The need was particularly acute, because the USSR had just shut down access to Berlin, underscoring the importance of aerial resupply and having bombers that could reach Moscow from European bases, if need be.

The first attempt at a demonstration mission involved three B-29s from the 43rd Bombardment Group based at Arizona's Davis-Monthan base. The plan was for the three aircraft to circumnavigate the globe in 14 days, with eight stops *en route* for fuel. One crashed in the Arabian Sea, but the other two, the *Lucky Lady* and the *Gas Gobbler*, made it. The trip began on July 22, 1948, and ended on August 6, one day over the two-week goal. They flew more than 20,000 miles in 103 hours and fifty minutes.

But flying around the world had been done many times before, and while the B-29 attempt was noteworthy, it wasn't particularly newsworthy.

The next step was to make the circumnavigation flight without stopping, using aerial refueling as necessary. The aircraft, Lucky Lady II, was a B-50 Superfortress, an improved version of the B-29 than bridged the gap between WWII and the Jet Age. A number of B-29s had been modified to be aerial tankers (B-29M). A boom had been invented that would allow its operator, stationed in the former tail gun position, to hook up with the receiving aircraft. Gravity feed was no longer used; the boom and pump system could supply fuel at the rate of 700 gallons/minute.

Failure was not an option, but just in case, this second attempt was kept secret prior to its success. Three B-29M tankers were pre-stationed at four refueling sites: the Azores, Saudi Arabia, the Philippines, and Hawaii. Five B-50s were prepared for the flight. The flights would begin and end at Carswell AFB, in northern Texas.

The first off, on February 25, 1949, was the *Global Queen*, but she limped into the Azores with serious engine problems. *Queen* was out of action. On the **26th**, the second-up aircraft, the *Lucky Lady II*, took off from Carswell. Their successful flight took 94 hours, 1 minute, without incident. The crew officers received DFCs. The tanker guys got a hearty, "well done," and General LeMay, head of the Strategic Air Command, announced that the United States could now "deliver an atom bomb to any place in the world that needed one."

The transition to jet-powered bombers came soon after. On January 16, 1957, a B-52B named "Lucky Lady III" completed a circumnavigation (24,325 miles) in under 46 hours, requiring five aerial refuelings. The Air Force could readily project significant power anywhere in the world.

And that was before long-range ballistic missiles. "World-wide Delivery in 30 Minutes or Less – Or the Next One is Free!"

Round-the-World without Stops OR Refueling

That's really the ultimate step, isn't it?

All of the previous flight milestones documented above and in last week's Item were conceived in part to send a message and in part to publicly demonstrate an aerial capability. This next step was motivated similarly.

Modifying an existing aircraft design for greater endurance and developing aerial refueling techniques were difficult, but do-able with (improved versions of) existing technologies. Creating an aircraft capable of circumnavigating the Earth without refueling was another matter. New lightweight aircraft components and a revolutionary engine were absolute requirements for success.

Burt Rutan was an accomplished aircraft designer and materials expert. He founded a company, Scaled Composites, in 1982, to develop experimental aircraft. He had already succeeded with home-built designs (*e.g.* VariViggen) and the Beech Starship, a corporate aircraft. He worked with his brother, Dick, a decorated Air Force and test pilot, and a talented team for over six years to design an aircraft capable of the round-the-world flight. The resulting aircraft, *Voyager*, contained almost no metal, and was built almost entirely from a very lightweight graphite composite material. The aircraft weighed only 939 pounds. It was basically a set of flying fuel tanks with a really long wing; its fuel load at take off was 7,011 pounds (72.3% of its gross takeoff weight).

Many tradeoffs had to be made in the design process. Creature comfort for its pilots, Dick Rutan and SC test pilot Jeana Yeager was spartan, to say the least.

Voyager had two engines mounted on its fuselage. The front one was a Teledyne Continental 0-240, and was used only when extra power was needed for takeoff, weather avoidance, and once to cover for a fuel-feeding problem with the rear engine, which was of a novel design (110 HP, Teledyne Continental IOL-200, which ran the entire flight).

The plan was for *Voyager* to take off and land at Edwards AFB, taking advantage of its 3-mile-long runway. Its wheels left the ground at 8:01 AM PST on December 14, 1986. It had needed

almost every foot for its take-off run, dragging both of its wingtips at takeoff, causing damage to both. The long wing had been fitted with small winglets at its tip, designed to lift the flexible wings to prevent fuel from escaping via the wing vents. A quick maneuver was made to make the damaged winglets drop off, which would reveal any mission-threatening damage while *Voyager* was near Edwards if a quick return was necessary. Both winglets detached without further damage; one was recovered and is in the possession of the National Air and Space Museum, the other was never recovered.

The flight lasted nine days, with a landing back at Edwards at 8:05 AM PST on December 23. Dick and Jeana had flown 24,986 miles, averaging 115 MPH, with an elapsed time of 216:04:44. The trip was relatively uneventful; the dragging wingtips, a weather-induced radical bank quickly corrected, and a fuel lock causing the rear engine to shut down temporarily were the only significant problems encountered. If you don't count pilot boredom!

The Rutans, Yeager, and crew chief Bruce Evans were recognized by award of the Collier Trophy for 1986, the most prestigious award in aviation. Dick and Jeana flew *Voyager* once more, hopping from Edwards to Mojave, California, home of Scaled Composites. From there, the Voyager was trucked to NASM's Garber Facility. It was prominently displayed in NASM's Milestones of Flight gallery, along with the *Spirit of St. Lewis* and the Apollo 11 Command Module (and the filming model of *Star Trek*'s *USS Enterprise*) for years, until the present renovation of NASM's building on the National Mall.

In the Pipeline

You'd think that would be the final flight in the story, but it isn't. The next step was a solar-powered aircraft that can aloft indefinitely, the *Solar Impulse 2*. It actually completed a round-the-world flight on July 26, 2016. It has an enormous wing, covered with 17,248 solar cells, and was a showpiece of composite engineering. Its total weight was only 5000 pounds, including the lithium batteries that kept its props turning all night long. It would climb to 30,000 every day, then trade most of that altitude for motion during the night to save battery power. The flight took 550 hours, averaging only 30 MPH ground speed. While such flight is not practical for air travel or cargo, the technologies developed for *Solar Impulse* are finding their way into conventional aviation.

BAE and others are working on a variety of high-altitude, long-duration, UAVs.

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Last Edited on 21 February 2021