

X-COUNTRY IN AN X-AIRPLANE

Getting an airplane from one place to another is an everyday occurrence. If the aircraft is a single engine, single seat airplane, the event becomes less ordinary. If the trip is across the United States, starts to get a little more interesting. But if that airplane flying across the United States happens to have an “X” designation, the feat becomes a little more spectacular. In February 2001 the Lockheed Martin X-35C departed Edwards Air Force Base (AFB) in California bound for the Naval Air Warfare Center Patuxent River (NAWC Pax River) in Maryland. The two-day trip marked what is believed to be the first transcontinental flight of an X-airplane under its own power.

Typically X-airplanes conduct their operations around a test facility. This is done for a variety of reasons. One reason is that test facilities have airspace in close proximity to the airfield that can be reserved for exclusive use for aircraft testing. Second, test facilities have the capability to provide tracking and control stations to support flight test activities. These stations provide a capability to monitor the test aircraft throughout its flight. Finally, the aircraft was probably constructed at or close to the test site and therefore probably has significant maintenance support available in that location.

On the morning of 9 February 2001, the Lockheed Martin X-35C took off from Edwards AFB and flew 1100 nautical miles (nm) to Ft. Worth, TX. The following day, the aircraft flew 1200 nm from Ft. Worth to NAWC Pax River. Each leg of the X-country was about three hours long, during which time the aircraft received fuel from a KC-135 tanker several times. Prior to this trip the aircraft had completed a little over 8 weeks of flight test at Edwards AFB.

Production aircraft that fly across the United States on a regular basis have undergone hundreds

and sometimes thousands of hours of testing. The X-35C, however, was in its initial stages of flight test when final preparations for the cross-country flight were taking place.

Preparing to fly the X-35C across the United States presented the test team with a wide variety of challenges. Just how do you go about ferrying an X-airplane, with less than 35 hours of flight time, from one side of the country to the other? First, you have to establish criteria that will evaluate the aircraft's readiness to undertake such a journey. Second, you have to develop a plan for how to move the aircraft from one site to another. Third, you must ensure the test team is ready and properly organized for the mission. Lastly, you have to execute that plan successfully. Each of these items has numerous components that took months of planning and evaluating by a large number of people from various engineering and flight test disciplines.

Is the Aircraft Ready to Go?

Before the X-35C could begin the X-country flight it had to have demonstrated airworthiness. But what constitutes airworthiness for ferry? Obviously, the aircraft was considered flight worthy since it was actively conducting flight test events. But the cross-country flight focused the team on a few specific criteria. The first was that the aircraft complete 20 hours and 20 flights. At the time, this seemed like a reasonable amount of time on the aircraft to have brought any serious problems to the forefront. Second was to complete the envelope expansion at least far enough to cover the ferry flight profile. This included Air Refueling qualification on both KC-10 and KC-135 tankers for flexibility, as well as clearing the altitudes and airspeeds required for the ferry. The envelope that was cleared prior to the cross-country flight is shown in figure 1.

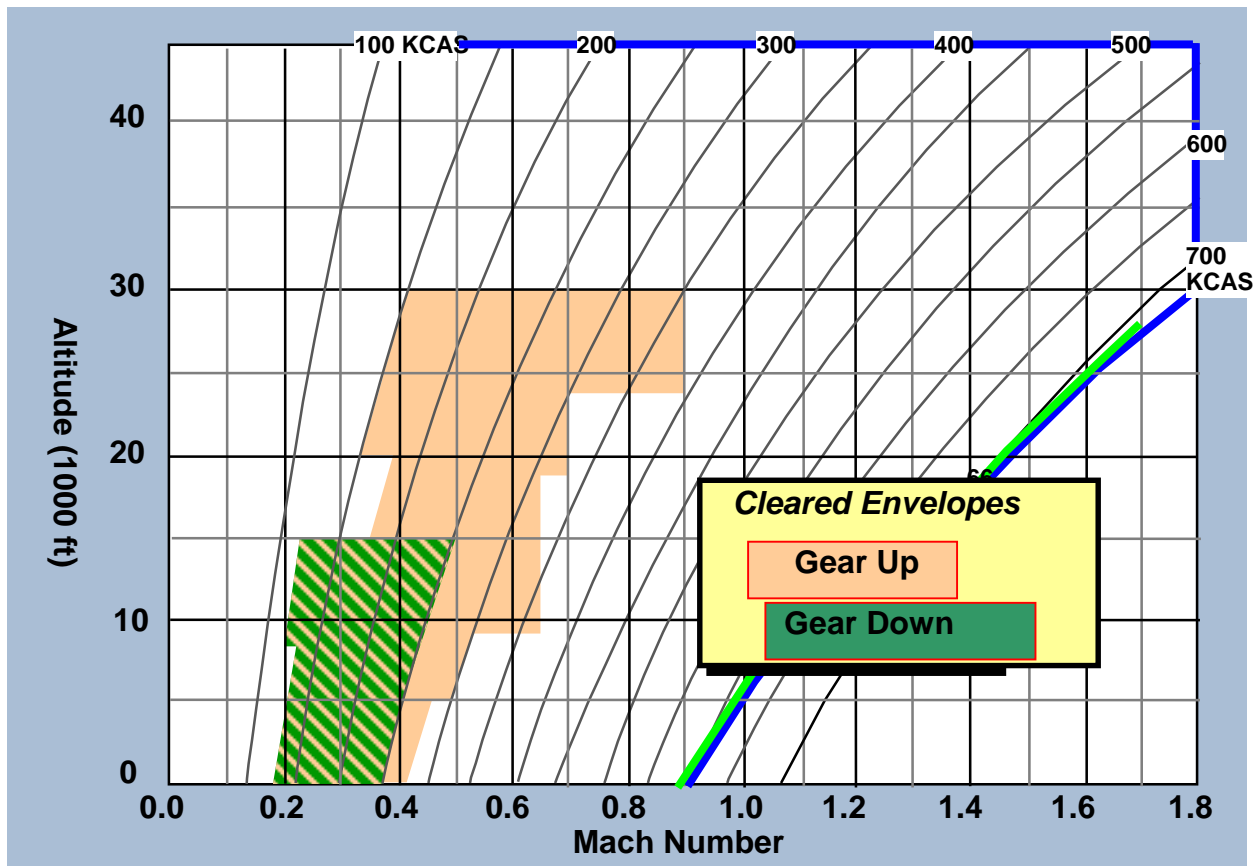


FIGURE 1

CROSS COUNTRY FLIGHT ENVELOPE

The next step was to complete an endurance flight of at least 3 hours. This duration was equal to the anticipated longest leg of the cross-country flight and would prove the aircraft and systems were able to withstand the long cross-country flight. Last was to complete two back-to-back flights with no significant anomalies. This would be the final check that the aircraft was behaving well. It would also give the test team reasonable assurance that the aircraft could safely operate away from the extensive monitoring available in the control room at Edwards AFB.

Flight test has come a long way since Chuck Yeager first broke the sound barrier. Today, thousands of aircraft parameters are telemetered down to a control room, from the aircraft, at the speed of light. In the control room, teams of engineers and test conductors vigilantly scan

computer displays, strip chart recorders, and TV monitors to track the status and health of the aircraft. Typically, only a small portion of this information is available to the pilot in the cockpit. This information can be separated into three general categories, Safety of Flight, Safety of Test and Other. The X-35 program set a goal early on to ensure that none of the parameters, that were not available to the pilot in the cockpit, were considered Safety of Flight measurements. By achieving this goal, the aircraft was allowed to continue flying while the control room troubleshoot telemetry problems, and did not have to immediately return to base. If this had not been achieved attempting to fly the aircraft across country would have much more difficult.

The requirement to complete back-to-back flights with no significant problems or anomalies turned out to be the pacing item. Finally, on the 7th of February all of the criteria required to begin the cross-country flight were complete. Some additional aircraft status information was made available in the cockpit. This additional information satisfied the requirement that all critical aircraft parameters could be monitored by the pilot.

How to Get from Point A to Point B?

At some point the decision had to be made of how to get the X-35C across the country. The idea of shipping the aircraft by ground, sea, or air was discounted early for several reasons, the most significant being the size of the X-35C. That left several options for flying the aircraft across country under its own power. These options ranged from a single flight, with multiple air re-fueling, to a flight with multiple en route stops for fuel along the way. The single flight option was the most attractive, in that it minimized the chance of the aircraft getting stuck at some intermediate stopover. This option would have required an endurance proof flight of about 5 or

6 hours. Since the X-35C was restricted to daylight operations only, the amount of daylight available at that time of year was another factor to consider. At the planned time of ferry, there were about 10 hours of daylight available. This was further complicated by the three-hour time change going from the West Coast to the East Coast. All of these factors combined, translated into a launch window of about an hour in order to be on the ground before sunset.

Weather was another major concern. The aircraft, due to certain instrumentation, was prohibited from flying through visible moisture. This meant that the aircraft would have to remain clear of clouds for the entire flight and could not penetrate any weather to get to a destination. The weather criteria that were established were that the divert airfields and destinations had to have weather better than 3000 foot ceilings and 3 miles visibility and no overcast layer below intended en route altitude. During the month of February, trying to find a day when the skies were clear between California and Maryland was no simple feat. As an added complexity, the aircraft also had to remain clear of clouds at the en route and re-fueling altitudes.

For the above mentioned reasons the decision was made to break the flight up into two legs of roughly equal distance, with an overnight stopover at the Lockheed Martin (LM) facility in Ft. Worth, Texas. This brought the flights down to approximately 3 hours apiece and it allowed for a larger launch window on each day. Another benefit to choosing the LM facility as a stopover point was that there was some limited support available for maintenance and flight preparation. Finally, the stop in Ft. Worth provided an opportunity for LM personnel located there to see their aircraft up close. Contingency plans were also put in place to allow a stopover at the LM facility in Marietta, Georgia. This was done in the event that bad weather on the East Coast, which was considered the most likely scenario, prevented completing the second leg of

the trip. Stopping in Marietta would have minimized the time and distance for the final leg into NAWC Pax River. The test team felt that it would be easier to find a suitable weather window into the East Coast with a shorter final leg.



FIGURE 2

X-35C BEHIND THE KC-135 TANKER EN ROUTE

A portion of the route of flight was selected based on what the F-22 had used for ferry of aircraft from Marietta to Edwards AFB. This route was fairly direct and utilized published jet ways. To the maximum extent possible the remaining portion of the flight from Marietta to NAWC Pax River was developed with the same philosophy. Another key element in selecting the route of flight was maintaining close proximity to suitable divert fields along the way. There were a few basic criteria for the selection of divert fields which included:

1. Runways long enough to accommodate all the aircraft in the flight which included the X-35C, F-16 Safety/Photo Chase, Citation and KC-10 or KC-135 tanker.
2. Crash, Fire and Rescue support available.
3. Located within 100 miles of the route of flight.
4. Open on weekends.

Although there were designated divert airfields along the entire route, the option to go to the nearest suitable field in the event of an emergency was left open for the pilot.

Is the Team Ready?

The test team had been conducting flight test with the X-35C for almost two months before the cross-country flight took place. Prior to that, the X-35A had completed a month long flight test program, with many of the same personnel. One of the unique aspects of preparing for the cross-country flight was that the test team would not be sitting in the control room looking at data. They would be onboard the tanker aircraft with nothing more than radio communications with the X-35C. Due to limits on the number of people allowed on the tanker, only key systems personnel were included in the final manifest. Their function was to be able to troubleshoot any aircraft problems that arose based on communication with the pilot.

Included in the test team on the tanker were an experienced X-35C test conductor and someone designated as the Mission Commander (MC). The MC billet was created so that one person could act as the overall coordinator for the evolution. The MC would initiate any mishap procedures if they were called for. He would update weather forecasts and destination information. Additionally, he would update the nearest suitable divert field as the flight progressed along the route. The pilot of the X-35C still retained the final decision on a course of action for any contingency. The MC's role was to alleviate as much burden from the X-35C

pilot as possible as well as act as the single point of contact for the mission. A Citation aircraft was included in the package with maintenance personnel on board that would trail the rest of the aircraft and follow the X-35C into any divert field if required.

No specific flight training was developed for the cross-country flight. Two pilots would fly one leg each of the cross-country flight. Each pilot had a recent air-refueling mission and was current in boom refueling. One of the pilots had performed the endurance proof flight of the X-35C while the other had spent a similar length of time in the cockpit during back-to-back flights where ground hot refueling took place.

Reviews of changes to normal and emergency procedures were conducted specifically for the cross-country flight. Each Warning and Caution listed in the flight manual was reviewed from the perspective of occurring anywhere along the route of flight. Any emergency procedure that called for a “land as soon as practical” was evaluated as to whether that would mean nearest suitable landing field, nearest planned divert field, or destination. The general philosophy was that if a malfunction affected only the landing phase of flight, and did not inhibit tanking operations, or if the package was within distance to arrive with 2,500 lb of useable fuel, there was no reason to cut short the en route phase. As a result, 18 Warnings and 38 Cautions were treated as continue on to destination. Remaining Warnings and Cautions would be handled on a case-by-case basis. As always, pilot judgment could always dictate immediate divert if required.

There were several significant events that the control room typically monitored during engine start, pre-launch and post flight checks. Since there would be no control room available at the intermediate stop in Ft. Worth, another way to monitor these events was required. Implementing a change that would display all the desired information in the cockpit would have been very time consuming. The solution to this problem was to use a laptop computer that

would be connected to the aircraft and would be able to monitor the required information during start, pre-launch and post flight checks.

How Did it Go?

As it turned out the execution of the plan may have been the easiest part. The aircraft was in good health for the morning of the first leg, the weather between Edwards AFB and Ft. Worth was clear. Despite a long delay waiting for the KC-135 tanker to be ready, the flight was for the most part uneventful. No aircraft “squawks,” or discrepancies, were written at the end of the first leg.

The second day brought some questionable weather at some of the mid route divers, destination and at Ft. Worth as well. Despite pressures to complete the trip the decision was made during the pre-flight brief to hold for weather. For the launch out of Ft. Worth, there was about a 4-hour window of opportunity based on arrival at NAWC Pax River prior to sunset. The Altitude Reservation (ALTREV) for the flight package was adjusted to cover the entire launch window. About halfway through the launch window the forecast weather at the divert fields improved enough to meet the established criteria. A plan was devised to rendezvous with the tanker above the cloud layer at Ft. Worth. This would give the X-35 and its F-16 chase aircraft maximum flexibility to maneuver around the clouds. As it turned out, delays in getting the tanker going provided enough time for the clouds to dissipate and allowed us to go back to the normal tanker rendezvous plan to be executed.

The second leg of the cross country into NAWC Pax River went as well as the first. The aircraft encountered no problems during the flight and once again had no squawks after landing. Bad weather followed the launches out of Edwards AFB and Ft. Worth. Three days after the

arrival at NAWC Pax River the weather began to degrade and remained bad for several days. As it turned out, the flight took place in what was probably the only good two-day good weather window in about a ten-day period.



FIGURE 3

X-35C WITH F/A-18 CHASE OVERHEAD PAX RIVER

Lessons Learned

During the brief the day before the flight, the team found out that the route of flight approved for the ALTREV was different than what had be originally submitted. Much of the planning for the flight including en route charts, waypoints, and distance to divert fields was already completed. Had the change been more significant, it could have affected which fields were suitable as divers, based on proximity to the route of flight. Prior coordination with the controlling agency for the ALTREV should have been accomplished.

The launch from Edwards AFB was delayed due to problems with the tanker that were not communicated until the X-35C was already in the hold-short area ready for take-off. There were some concerns as the X-35C waited, with the engines running, that the aircraft might get to a fuel state that was uncomfortably low. Had the tanker crew been properly briefed importance of adhering to the timeline after engine start, this situation may have been avoided. Although not standard practice, it would have been beneficial to hold the X-35C start until the tanker was ready for takeoff.

When considering situations that would have resulted in the aircraft going to a divert field, the possibility existed that the local Crash, Fire and Rescue unit may have had to work on the X-35C. As a way of providing some training to those crews in the event they were required to respond, X-35C information packets were sent to each one of the planned divers. These packets included pertinent information the Rescue personnel could use in the event of an emergency.

Although the laptop computer that was used to monitor the aircraft pre- and post-flight checks at Ft. Worth was successfully checked out on a previous mission, no actual dry run of the launch procedures at Ft. Worth was conducted. Fortunately, utilizing the laptop did not present any significant problems in and of itself. Communication between the pilot, ground crew with the laptop computer, and the test conductor was not ideal. The test conductor was in a building out of site of the aircraft on a UHF radio. The pilot and ground crew were in an enclosure and could communicate over the aircraft intercom system or with visual signals. This meant that the pilot had to relay information between the ground crew and the test conductor. This led to some delays and confusion during some of the pre-flight checks. Several things could have been done to eliminate this problem, such as locating the test

conductor with the aircraft or setting up a communications link between the test conductor and the ground crew.

As with any undertaking of this magnitude there was high-level interest in getting the flight completed successfully in two days. Although the entire test team was focused on accomplishing that mission, the right decisions were made waiting for our established weather criteria to be met before leaving Ft. Worth.

Finally, on a minor note, the X-35C has no auto pilot modes. Obviously no one considered this as a requirement for a test aircraft that would spend most of its time conducting test points and very little time steady state. This was in fact the case during all missions flown at Edwards AFB and NAWC Pax River. During the cross country flight however, there were no test points to accomplish. Apart from takeoff, landing and air refueling the pilot's task was simply to follow the tanker. Lack of auto pilot features was nothing more than a nuisance for the three-hour duration of each leg of the cross-country flight. It may have been more of an issue for pilot fatigue, had the decision been made to fly cross-country in one leg of 6 hours.



Figure 4

X-35C ON TOUCHDOWN AT PAX RIVER

Conclusion

In hindsight, there were several aspects of the planning and execution that could have been done a little better. All in all, cross-country flight of the X-35C was a huge success. The leap of faith required to cut the umbilical cord to the control room seemed quite large initially, but confidence in the airplane and confidence in the test team went a long way to making that leap less frightening. In the end the biggest factor that caused the test team concern was the one that there was the least control over, the weather. Whether it was luck or a good plan, everything came together for that two-day period in February, and the X-35C was able to successfully complete the first transcontinental flight of an X-airplane under its own power.