TAKING DELIVERY OF A KLM BOEING 737 IN SEATTLE

A great opportunity of blending commercial flying with a Delft Aerospace Engineering background

As part of their ambition for profitable and durable growth, KLM are currently rejuvenating their fleet of Boeing 737s. The “Classic” Boeing 737-300s and Boeing 737-400s are gradually replaced by new Next Generation Boeing 737s. KLM Flight Technical Group 737 plays an essential role in this replacement process. Remco van der Sluis, working as Assistant Engineering Pilot within this Group, and Delft Aerospace Engineering alumnus, gives an insight into the acceptance process of a new Boeing 737 airplane.

“Now knowing how to design them, I want to learn how to fly them”, I must have thought when I graduated from Delft University of Technology in 1999. With two tempting job offers from Shell and Heineken in hand, I decided to pursue what I liked most: enjoying the freedom of flying. A choice I will never regret. After finishing my training at KLM Flight Academy in 2002 I started with my first job within KLM as a Second Officer on the “Classic” Boeing 747-300. It was the last airplane within KLM’s fleet that was still operated with a Flight Engineer (“Boordwerktuikundige”) in the crew, and a great opportunity for me to be part of this unique crew concept.

In 2005 I was promoted to First Officer on the Boeing 737, which I have been flying now for more than six years, and I still enjoy it to the fullest.

In 2006 it was a matter of being at the right spot and the right time. I applied for the position of Assistant-Trainee Engineering Pilot at the Flight Technical Group Boeing 737 of KLM, and I got the job: a perfect opportunity to blend commercial flying with my Delft background. After two years I was promoted Assistant Engineering Pilot, a position I have held now for more than two years.

The Flight Technical Group Boeing 737 (FTG737) is the department within KLM Flight Operations responsible for the technical support of the Boeing 737 operation. The Group consists of seven people: two operations engineers, one training engineer and four technical pilots. This team is a vital link between the operator and manufacturer Boeing. Amongst other things, the Group produces essential manuals necessary for operating an airplane, like the Flight Crew Operations Manuals (FCOM) and Minimum Equipment List (MEL). Furthermore we are a focal point of technical information for crews and we are in close contact with Boeing to provide the answers and background.

KLM’s current Boeing 737 fleet consists of five submodels: the Classic Boeing 737s, like the Boeing 737-300 and Boeing 737-400, and the Next Generation Boeing 737 (-700, -800 and -900 series).

The Next Generation Boeing 737 models incorporate a new wing design that helps increase and improve fuel capacity and efficiency, both of which increase range. A few facts from Boeing:

1. The total wing area was increased by 25 percent, providing 30 percent more fuel capacity for a total of 26,020 liters.
2. The advanced wing airfoil design provides an economical cruise speed of 0.78 Mach — compared to 0.74 Mach for Classic Boeing 737 models.

3. Blended Winglets are available on the Next Generation Boeing 737, improving climb performance and fuel efficiency by lowering induced drag.

4. Range increased to approximately 5,926km, up 1,600km over earlier Boeing 737 models.

The Next-Generation Boeing 737 airplanes are capable of cruising to a maximum altitude of 41,000 feet, compared to 37,000 feet for the Boeing 737-300/-400/-500 models, and 39,000 feet for the Airbus A320 series, their main competitor.

In 2008 KLM started the phase-out of the Classic Boeing 737 and the replacement of these Classic Boeing 737s by factory-new Next Generation Boeing 737s. This investment in more fuel-efficient airplanes is a vital part of KLM's strategy pursuing profitable and sustainable growth.

KLM are continually exploring and investing to reduce their impact on the environment. In this way, they aim to play a leading role in the field of corporate social responsibility, to ensure sustainable success for customers, employees and broader society.

A number of our phased-out Classic Boeing 737s has found a new owner. The less fortunate airplanes are scrapped and their materials are re-used. For instance, the PH-BDA "Willem Barentsz", one of the first Boeing 737-300s that entered into service with KLM in 1986, was decommissioned in October 2009, after 23 years of reliable operation. On a beautiful clear-sky October afternoon, I flew "Willem" for the last time under KLM call-sign to its resting place on Kemble Airport, just west of London, awaiting its somewhat pitiful and seemingly ungrateful dismantlement.

By the end of October 2011 all Classic Boeing 737s will be phased out and KLM will have a Next Generation only Boeing 737 fleet. Flight Technical Group 737 plays an important role in this Fleet Renewal, both in taking delivery of the brand new airplanes from Boeing, as well as flying the Classics to their new (final) destination.

BUILDING A BOEING 737

Assembling a Boeing 737 is a complex job: take 367,000 parts, an equal number of bolts, rivets, and 58km of electrical wire and put them all together to form an airplane... Boeing is assembling a Boeing 737 in an astonishing eleven days with a current production rate of 31 airplanes a month.

The first Boeing 737s were built just across the road from Boeing Field near Seattle. Since 1970 the Boeing 737 is assembled at Renton, eight km south-east of Boeing Field. Not all parts of the Boeing 737 are built at Renton, as the fuselage is produced at a Boeing plant in Wichita, Kansas. In Wichita the nose section of the fuselage is attached to the centre and tail sections, whereupon the fuselage is strapped onto a railroad car for a 3,500km train ride to Renton.

When the train arrives at the Renton factory, the fuselage is transferred to a large cart and wheeled to the final assembly building, where it spends about eleven days. During the first stage of final assembly, factory workers focus on the interior. They install insulation material along the inside walls of the fuselage, then add wiring and plumbing. When the fuselage is ready to move to the next stage of production, an overhead crane lifts it high and places it down into its next position. Precision tools are used to install the landing gear and the two wings. At this point, the 737 can roll along the factory floor and take its position in the moving production line. Boeing became the first commercial airframe manufacturer to use the moving-line concept to build jetliners when first the 717, and then the 737, production lines were transformed. The 737s on the line move continuously at a rate of five centimeters per minute. The concept was invented by Toyota and Boeing transferred it to airplane series production.

Near the beginning of the moving line, the seven-meter-high tailfin is lifted into place for attachment. Next, floor panels and serving galleys are installed and functional testing begins. In a test called the "high blow," the aircraft is pressurised to create a cabin differential pressure equivalent to the airplane flying at an altitude of 93,000 feet, which is more than twice as high as it will fly in service. This ensures that there are no air leaks and that the structure is sound. In another test, the aircraft is jacked up so that the landing gear retraction & extension systems can be tested.

Near the end of the production line, the rest of the interior is completed - lavatories, luggage bins, ceiling panels, carpets, seats and other essentials are installed. Right before the 737 exits the final assembly factory, the jet engines are attached. Once assembled, the airplane is towed to a hangar for painting. When painting is complete, the airplane is ready for a Boeing test flight. After Boeing test pilots have completed their testflights successfully, the customer acceptance can start.

CUSTOMER ACCEPTANCE

The KLM 737 Acceptance Team consists of four team members: a type project engi-
neer, a cabin engineer and two technical pilots. About eight days before the airplane's scheduled delivery date, the team arrives at Seattle. The acceptance activities all take place at Boeing Field, where we join our KLM resident representative.

The first phase of the acceptance process is dominated by the Ground Checks, during which almost all systems pass in review and are functionally tested on the ground. Tests range from checking the pilot's seats for proper movement to a cabin leak check and from checking the windshield wipers to an extensive flight controls check. While the pilots perform their checks in the cockpit, the type project engineer inspects the airplane from the outside and the cabin engineer extensively checks the quality of the interior, like the passenger seats, correct markings and galley equipment.

During the Cabin Leak check, the airplane is pressurized to a differential pressure of two psi, using the Auxiliary Power Unit (APU) as an air supply. The airplane is then checked for any noticeable air leaks, by checking the doors and overwing exits from the outside, which is an exceptional and perfect opportunity to have a nice close-up view on the outside of the airplane.

During the Flight Controls Check, the type project engineer checks from the outside if the deflection of the control surfaces, including the tabs, are in conformity with the flight control deflections that are applied from the cockpit. It is always a challenge to plan these prolonged checks during an infrequent dry moment in between the many rain showers that blow over Seattle, and we have been lucky quite often so far.

Normally in one and a half day the Ground Checks are finished. Any complaints found will now be categorized as prior-to-flight or not-prior-to-flight items. The prior-to-flight items need to be solved by Boeing before the first customer flight (C-1) can take place. In most cases Boeing is able to achieve this such that this flight can be scheduled for the next morning.

The C-1 flight, the second phase of the process and the first flight with KLM employees on board, takes about three hours in total and comprises numerous tests, a few of which will be highlighted in this article.

THE CUSTOMER FLIGHT

The objective of the Customer Flight is to demonstrate to the customer that the airplane operates and performs as specified. The flight test profile that is used for this flight is set out in the Boeing Flight Test Procedures.

These procedures are flown with a Boeing test pilot in the right-hand seat as Pilot-in-Command, the KLM technical pilot as pilot flying in the left-hand seat and the other KLM technical pilot on the jump-seat doing systems tests on the overhead panel. After take-off from Boeing Field, we climb to 41,000 feet while overflying the state of Washington. When we are lucky, we get a nice view of Mount Rainier, a majestic episodically active volcano about 100 miles southeast of Seattle, and the tallest volcano in the contiguous United States.

During the C-1 flight we check the normal operation of the airplane, as well as the back-up systems: the safety net in case the normal system for some reason fails to operate. In other words, we check the operational envelope of the airplane, as well as the border of the envelope. A good illustration is the Stall Warning Checks we perform: we only test the activation of the stick shaker, but we will never intentionally stall the airplane. If the stick shakers do not activate by five knots below the charted value, the test is discontinued. This test is one of the interesting ones to fly, because it requires delicate inputs from the pilot, while flying real close to the edge of the airplane’s envelope. Delicate inputs are necessary to avoid any dynamic effects.

Another delicate test we perform is called Manual Reversion. The primary flight
control system on the Boeing 737 uses a conventional control wheel, column and pedals linked mechanically to hydraulic power control units which command the primary flight control surfaces: ailerons, elevators and rudder. The flight controls are powered by redundant hydraulic sources: system A and system B. Either hydraulic system can operate all primary flight controls. If both hydraulic sources are not available, ailerons and elevators can still be operated manually. This is called Manual Reversion. With both normal hydraulic sources unavailable, the rudder will be powered by the standby hydraulic system.

During the Manual Reversion test the pitch of the airplane is controlled by two manual inputs: the elevator, manually controlled by the control column, and the stabilizer, manually controlled by the stabilizer trim wheel. Control forces increase since now the aerodynamic hinge moments acting on the control surfaces have to be counteracted manually. Once the airplane is put into manual reversion, the airplane might start to pitch up/down and roll, as the now hydraulically unpowered ailerons and elevators align themselves with the existing aerodynamic flow. The pitch and roll change, if any, needs to be counteracted right away, in order to maintain level flight. The number of stabilizer trim wheel turns to maintain level flight, without control column input (trimming the airplane) has to be within defined tolerances. If the number of required stabilizer trim wheel turns is large, one can imagine the control column force required to keep the airplane in level flight, is large as well. For that reason this test requires full attention of everyone on board as the airplane could theoretically get into an undesired nose high/low attitude.

Another interesting test being performed is the Cabin Altitude Limiting and Oxygen Mask Drop test. During this test the cabin altitude, which is normally not more than 8,000 feet, is now brought up to 15,000 feet. We check that the intermittent cabin altitude warning sounds and cabin altitude warning lights illuminate at the correct cabin altitude (10,000 feet) and that the oxygen masks automatically drop from the ceiling in the cabin at the right cabin altitude (14,000 feet).

The last part of the C-1 flight consists of flying two approaches. We normally perform these approaches at Moses Lake - Grant County Airport, 200km east of Seattle. During the approaches we check autoland and auto go-around behaviour, as well as a number of Ground Proximity Warning warnings, like "TOO LOW GEAR" and "TOO LOW FLAPS", for unsafe terrain clearance at low airspeed with landing gear not down, or flaps not in a normal landing position, respectively.

The first approach results in a touch and go. The second approach ends in an automatic go-around initiated at 100 feet radio altitude. The flight is then continued back to Boeing Field for one last test: the Rejected Take-off.

After landing at Boeing Field the airplane is brought to a standstill on the runway and properly reconfigured for a take-off run. The remaining runway length is used to accelerate up to a groundspeed of 90 knots, after which the take-off is rejected. We check that the autobrake system immediately engages to maximum braking. The deceleration during maximum braking is enormous and quite impressive, and often smoke can be seen coming of the warm brakes.

Based on the outcome of the first flight, a second customer flight may be needed. For instance, for one new Boeing 737 in March 2011 a second flight was necessary because of low speed trim values that were out of limits. After small adjustments by Boeing a second flight had to demonstrate that the trim values were now within limits.

**AFTER THE CUSTOMER FLIGHT**

After satisfactorily completing the customer flight phase, and having checked that all other remaining not-prior-to-flight items have been addressed by Boeing to
our satisfaction, the airplane is ready for an important and vital step in the process: ticketing. It is the official approval by the Federal Aviation Administration (FAA) that the airplane is airworthy for commercial operations.

In the meantime, together with Boeing, the acceptance team is drawing up the Delivery Commitment Letter (DCL). The DCL is an appendix to the purchase contract that sets forth Boeing’s commitments to the customer which relate to configuration and/or condition items applicable to the airplane at the time of delivery. If, for instance, the airplane is eligible for a specific product improvement, not yet available at the time of delivery, this will be noted in the DCL.

After the DCL has been completed, and the airplane has been successfully ticketed by the FAA, the acceptance process reaches its pinnacle: the Transfer of Title (ownership) of the airplane to KLM. The transfer, which is a matter of putting a signature and paying a significant amount of money, takes place just prior to the flyaway of the airplane.

Symbolically the key to the airplane (the airplane actually has no key) is handed over to the acceptance team to celebrate a successful acceptance and delivery of a brand new Boeing 737 to KLM. The airplane is now ready for its first flight under KLM callsign, to Amsterdam.

**FLY AWAY**

We always try to plan a non-stop flight from Boeing Field to Schiphol Airport. With full tanks, almost no passengers on board, and a favourable tailwind, this is feasible.

The route normally takes us north of the Hudson Bay, over Kangerlussuaq in Greenland, south of Keflavik in Iceland, north of Scotland to Amsterdam. The non-stop flight takes about ten hours, which is an incredibly long flight for a KLM Boeing 737!

Sometimes, however, unforeseen circumstances interfere with our non-stop flight plan. In March 2011 we encountered very cold air over Greenland and Iceland. The outside air temperature was approximately minus 67 degrees Celsius. To prevent the fuel in the wing tanks from freezing, we were forced to descend from 41,000 feet to 29,000 feet. As a consequence our fuel consumption was more than planned for and we had to consider an intermediate fuel-and-go stop at Glasgow, as continuation to Amsterdam became impracticable. Fortunately the outside air temperature started to rise again over Scotland and we were able to climb back to 41,000 feet, continuing the flight non-stop to Schiphol Airport.

After arriving at Schiphol the airplane is taken to the hangar for the final work by KLM Engineering & Maintenance to prepare the airplane for its first commercial flight for KLM, the ultimate object of a successful acceptance!

**IN CONCLUSION**

So far I have been member of the acceptance team on ten deliveries, and every time it has been a great experience to work in such a professional manner with Boeing. In addition to the delivery activities we also take the opportunity to exchange views on our in-service experiences and give our opinion on future developments by Boeing. Not only can I give my opinion as a pilot (‘the user’), but also as an aerospace engineer (‘the designer’). This makes the combination of being both a pilot and an engineer particularly valuable.

It is gratifying to see that Boeing really values our inputs and is accessible to our suggestions. Ultimately it is a joint effort to make aviation even safer. It is rewarding to realize one can actively contribute to this, from both a pilot’s as well as an engineer’s point of view and I regard it as a true privilege to combine the freedom of flying with my Delft Aerospace Engineering background.

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**References**

- www.boeing.com
- www.klm.com