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Dominant Design in the Aircraft Industry

Torsten Frohwein

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Herausgeber	Wolfgang Burr
	Betriebswirtschaftliches Institut der Universität Stuttgart Lehrstuhl für ABWL, Forschungs-, Entwicklungs- und Innovationsmanagement
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Dipl. Vw. Torsten Frohwein
Lehrstuhl Forschungs-, Entwicklungs- und Innovationsmanagement
Prof. Dr. Wolfgang Burr
Universität Stuttgart
Keplerstrasse 17, 70174 Stuttgart
http://www.uni-stuttgart.de/innovation
e-mail: torsten.frohwein@bwi.uni-stuttgart.de

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1. Einleitung

Die Fallstudie beschäftigt sich mit der Frage nach dem Entstehen eines dominanten Designs im Flugzeugbau. Die historische Entwicklung des Flugzeugbaus soll untersucht und anschließend den Entwicklungsphasen zugeordnet werden.

2. Fallstudie[1]

Introduction

If there was ever a competition to determine which airplane was the true workhorse of the air, the Douglas DC-3 would surely win hands down. This truly remarkable aircraft has been in service for almost seventy years, as a civilian and military carrier, and as a weapon of war, serving in every theatre of operations during the Second World War and in almost every war since that time. The 65th anniversary of the first flight of the DC-3 was on 17 December 2000. DC-3 is the abbreviation for its true title, Douglas Commercial No. 3. Many are still flying in Canada, the United States and other parts of the world, still performing useful service. To better understand the development of the DC-3, one should examine its predecessors.

Development

Early Airliner: Junkers Flugzeug und Motorenwerke AG of Germany designed and built the first all-metal, cantilever, passenger aircraft in 1919. This aircraft, the Junkers F-13, was very successful and evolved into the W-33 and the W-34, an example of which is displayed as an exhibit at the Canada Aviation Museum as CF-ATF. A later model, the tri-motor Ju 52/3m, was widely used by airlines before the Second World War and by the German Luftwaffe during the war. In

[1] Die Inhalte der Fallstudie sind teilweise den im Literaturverzeichnis aufgeführten Quellen entnommen.

the United States, the Ford Motor Company designed and built an all metal aircraft, the famous Ford 4-AT TRIMOTOR. The model 4-AT first flew in June 1926. Two hundred and five were built and several remain in limited service today.

Wooden Aircraft: Several airlines were still using aircraft of all-wood construction; one example was the Fokker F-10 TRIMOTOR. On 31 March 1931, one of these aircraft crashed, killing all on board. The cause was determined to be the wooden wing spar, which failed while flying in turbulent air. As a result of this accident, the United States Bureau of Air Commerce issued a directive for the frequent inspection of the wing spar on all aircraft of wood construction, a very expensive procedure. This, plus the adverse publicity following this accident, reduced public confidence in aircraft of wood construction, creating a strong incentive to design and build all-metal, stressed skin, multi-engined aircraft. However, it would be his Tri motor aircraft that would emerge as the dominant design used by the post WW1 airlines and this engine layout would be ‘copied’ by virtually all-subsequent aircraft manufactures. In America, Ford would use three engines on their 5A-T 'Tin Goose'. In Germany, Junkers built the JU52. Meanwhile, in Italy the SM73 of Savoia-Marchetti also used the three-engine layout while in Britain, both Handley Page and Vickers followed suit with the Argus and the Viastra. The Tri motor was especially popular with the airlines as it was felt passenger safety would be better and had it not been for the outbreak of WW2 then it has been suggested that this layout would have continued to dominate aircraft design. However, in America, the need to win a lucrative airline contract saw the Lockheed Company reject the tri-motor layout in favour of the greater speed offered by streamlining the nose of the aircraft. When coupled with the introduction of new, more reliable engines and an all-metal airframe, the modern airliner as we know it today began to emerge. While the Lockheed Vega was the result of this marriage of technology, the first truly modern airliner would be the Boeing Model 247, a twinengine, all-metal, monoplane aircraft

Metal Aircraft: The Boeing Airplane Company responded with a low-wing, all metal structure, with a smooth duralumin skin and a retractable undercarriage.

This aircraft, designated Model 247, was developed from Boeing's earlier Model 200 MONOMAIL and from Models 214, 215 and the B-9 bomber. The new model, powered by two 550 hp Pratt and Whitney WASP engines, had seats for ten passengers and a crew of three. The design was so promising that 59 orders were placed during the mock-up stage of development. It was considered to be the first "modern" airliner and 75 were produced. One example, a 247D serial number CF-JRQ, is currently on display at the Canada Aviation Museum. Trancontinental and Western Airline (TWA) tried to buy 247Ds but, because of the large number of previous orders, Boeing was unable to oblige. Therefore, TWA decided to issue its own specifications for a new all-metal airliner. These specifications were very demanding for the time. The aircraft had to be equipped with three 550 hp engines and carry twelve passengers over stage lengths of 1,080 miles (1,740 km) at 150 mph (240 km/h). In addition, it had to be capable of climbing safely, after take-off with a full load, on one engine from any TWA airport.

Douglas DC-3 Evolution

(The Douglas DC-1 & DC-2)

In America, the Boeing, Douglas and Lockheed aircraft companies had all designed aircraft for military as well as civilian purposes and while the US airlines were predominately concerned with serving the domestic market, Pan American depended upon its overseas routes for its livelihood. Consequently, the commercial needs of Pan-Am and their requirement for long-range aircraft would effectively dictate the way all future airliners would develop. They would also enable the Boeing company become the predominant force in civil aviation for the next 50 years. However, before all this would happen, Donald Douglas would produce an aircraft that was not only revolutionary but can still be found in service today, the Douglas DC3.The DC3 is not so much an aircraft but more of an institution. First built in 1936 It offered 21 seats and could cruise at 170 mph on its 2 Wright 1820-G2 engines, In contrast, the Boeing 247D of 1932 could only carry 10 passengers at a cruising speed of 160 mph on its 2 Pratt & Whitney 1340 engines while the Lockheed Vega of 1937 could top 200mph - but it could only carry 12 passengers. With its lower operating costs, the DC3 became the only plane to buy for the emerging airline industry and along with its military transport counterpart, the C47, it was produced in vast quantifies, with over 10,000 being produced. The Douglas Aircraft Company designed a twin-engine aircraft that would exceed TWA's specifications and be superior to the Boeing 247D. The result was an all-metal, low-wing monoplane, with retractable undercarriage, powered by two 690 hp Wright SCR-1820-F CYCLONE engines. It first flew on 1 July 1933 as the Douglas Commercial No. 1 (DC-1). After a few modifications, this aircraft flew from Los Angeles, California to Newark, New Jersey in 13 hours and 4 minutes. Only one of this model was built. The sole DC-1 was subsequently modified by upgrading the engines to 710 hp Wright CYCLONEs and it was given a modest fuselage extension, allowing seating for 14 passengers. The modified aircraft was designated the DC-2 and TWA added 20 production models to its fleet, the first of which flew in May 1934. The DC-2 was a great success and was ordered by American Airlines, Eastern Airlines, TWA and Pan American Airlines in the United States. About 200 were built and many served in the military during the Second World War and continued to serve in civilian roles following the war. American Airlines operated the DC-2 mainly in the Eastern areas of the country. Their transcontinental route ran south through Dallas, Texas, farther and longer than their competitors. In keeping with railway practice, they provided "Pullman style" sleeping accommodation aboard their Curtiss CONDOR 2 aircraft, which were obsolescent when first flown in 1933. American Airlines wanted a new aircraft, but wanted to retain the "sleeper" option. Neither the Boeing 247D nor the Douglas DC-2 could be modified to this use.

(The Douglas DC-3 Emergence)

American Airlines approached Donald Douglas with their problem. The Douglas design team quickly realized that this would require a completely new design. However, since they were fully occupied with DC-2 production and were of the view that American Airlines could not pay the costs associated with the development of a new aircraft, they were not enthusiastic. Further, Douglas felt that orders for a specialized type would be small and would not cover the development costs. Because of this, American Airlines engineers did much of the design and structural change calculations. C.R. Smith, president of American Airlines, assured Douglas that he could obtain a government loan and that the new aircraft could fly both as a day liner and as a "sleeper". Smith also agreed to buy 20 aircraft of which 10 would be "sleepers". It was hoped that the new aircraft would have 25% commonality of parts with the DC-2. However, in the final design there was only a 10% commonality. In reality, the Douglas Sleeper Transport (DST) DC-3 was a completely new aircraft, introducing to aviation such innovations as an auto-pilot and de-icing equipment. The first DST was fitted with two Wright SLR-1820-G2 CYCLONE engines, each providing 1,000 hp for take-off. After the first flight on 17 December 1935, the test-flying program began in earnest and by the end of December, twenty-six hours had been flown. Performance and handling were as expected, except for excessive take-off distance and adverse directional stability on approach to landing. The former was corrected by engine modifications, giving higher horsepower, and the latter by adding a small dorsal fin. An Approved Type Certificate, ATC No. 607, was issued on 21 May 1936 and the DC-3 was born. United Airlines (UAL) requested modifications to their DC-3s, the main one to replace the Wright CYCLONE engines. The new version, designated DC-3A, used 14-cylinder Pratt and Whitney R-1830 engines, fitted with the Hamilton-Standard full-feathering, constant-speed propellers. These engines provided 1,200 hp at take-off and 1,050 hp at 7,500 feet (2,290 m). After 1942, all DAKOTA, C-47 and DC-3 aircraft were fitted with the Pratt and Whitney engines. The DC-3 was the first airliner that could operate at a profit and, therefore, was received with enthusiasm. Orders were placed by most U.S. airlines and overseas orders were received from airlines in Holland, Switzerland, the Soviet Union, China, France, Japan and others. In total 609 aircraft were ordered, but 149 of these were requisitioned for use by the U.S. military while still in the factory.

Flight Characteristics of the DC-3/Dakota

Take-Off: The DAKOTA can take-off at maximum gross weight of 29,000 lbs (13,150 kg) in very short distances from very rough air strips. For example, using one quarter flaps and maximum allowable power, (48 inches of mercury and 2700 rpm)1 the aircraft can be pulled-off a sod-turfed strip at 80 mph (129 km/h)

Indicated Air Speed (I.A.S.) in about 850 feet (260 m) or 1,550 feet (470 m) to clear a 50-foot (15 m) obstacle. This performance assumes a 20 mph (32 km/h) headwind. The aircraft has little tendency to “swing” on take-off except perhaps in a cross-wind, in which case the aircraft had a tendency to “weather-cock” into the wind. This is easily corrected by slowly operating the throttles differentially, heavy use of rudder and by keeping the tail-wheel on the ground longer than usual.

Climb and Cruise Procedures: When safely airborne, the undercarriage is raised while keeping the nose at minimum climb angle in order to attain the critical single-engine safety speed of 105 mph (169 km/h). Should engine failure occur at this point, the aircraft can still climb slowly provided the landing gear and flaps are retracted and the propeller of the “dead” engine is fully feathered. In a normal take-off, the flaps are retracted at 500 ft (150 m) altitude above ground level. The recommended climb speed is 120 mph (193 km/h), requiring engine settings of 41 inches of mercury and 2,550 rpm in auto-rich mixture. On reaching cruising altitude, power is reduced to 29 inches of mercury and 2,250 rpm. In auto-lean mixture, about 180 mph (290 km/h) IAS can be maintained at 29,000 lb (13,150 kg) weight. With one long rangefuel tank of 80 Imp Gals (364 L) installed in the cargo compartment, the aircraft can remain airborne for about fourteen hours.

In Flight Characteristics: The aircraft is stable about all axes under all conditions of flight. The rudder is moderately heavy at all speeds, but very effective. The ailerons are light and effective but tend to be a bit spongy. The elevators are moderately light and effective at all speeds. Stalls. When doing an intentional stall, it is essential to climb to a safe altitude and slowly reduce power while holding the nose slightly above the horizon. As the airspeed decays, there is little warning of the approach to stall except for a slight buffeting of the tail about 5 mph (8 km/h) before the actual stall. This occurs at 77 mph (124 km/h) with a light, all-up weight of 24,000 lb (10,886 kg) and with the landing gear and flaps in the up position. With the gear and flaps down, the stall speed is 67 mph (108 km/h). At the stall, the nose of the aircraft will drop gently and power must be applied to fly out of the stall and attain normal cruising speed. With power “on” and gear and flaps down, the aircraft will tend to roll to the left and immediate corrective action must be taken to avoid entering a secondary stall. Stalling speed increases with increased angle of bank (over 100 mph [161 km/h] in a 45 degree bank turn). In a turn of this nature, the lower wing will stall and the aircraft will roll in that direction. Intentional spinning of the DAKOTA is, of course, prohibited. Should a spin develop, recovery is normal, but care must be taken not to overstress the aircraft on pull-out. Loss of altitude will vary from 500 to 1,500 feet (150 m to 460 m), depending on the flight conditions at the stall.

Single Engine Operations: With one engine shut down and the propellor fully feathered, the aircraft can be trimmed to fly almost hands-off at 110 to 115 mph (177 to 185 km/h). Good flying technique requires that all turns be made toward the operating engine and to land at the nearest airport. The circuit is kept as close to the airport as practical and altitude is conserved in case the other engine should fail. Only when certain of reaching the runway should the undercarriage be lowered and a gradual application of flaps begun. The aircraft is re-trimmed as power is gradually reduced and a normal landing performed. No attempt should be made to overshoot nor should any attempt be made to taxi the aircraft on one engine.

Approaches and Landings: Landing the DAKOTA is relatively straight-forward. After joining the landing pattern on the downwind leg, the speed is reduced to 160 mph (257 km/h), the undercarriage is lowered and locked, and the mixture placed in auto-rich. On the base or crosswind leg, flaps are cycled to one quarter down, speed is reduced to 110 mph (177 km/h) and maintained on the turn to final. Final approach speeds, with flaps down and weight of 27,000 lb (12,240 kg), are normally 90 mph (145 km/h) with power “on” and 100 mph (161 km/h) in a glide approach. Landings are normally “wheeled” landings with the tail up and the aircraft in a normal flight attitude. A three point landing, with full flap extended, is difficult but can be used in special circumstances. Three point landings are no problem with flaps retracted.

Cross-wind Landings: In cross-wind landings, the line of approach is maintained by “crabbing” into wind and lowering the “upwind” wing. When over the runway, rudder is applied and ailerons leveled to straighten the aircraft as required. Cross-wind landings require the use of the wheel landing technique. In very strong cross-winds, it is easier if no flap is used. The aircraft can land over 50-foot (15 m) obstacles, such as trees, onto a runway of firm dry sod with a 2,800 ft (850 m) landing roll. This is reduced to 2,600 ft (790 m) on a tarmac runway. In wet slippery conditions with poor braking, this roll-out can rise to as much as 5,100 ft (1,554 m). If there is a need to overshoot, the throttles are “opened” to 41 inches of mercury, 2,250 rpm and the aircraft will climb-out without difficulty. The undercarriage is raised and, at 200 feet (60 m), and the flaps are raised in stages until fully retracted. Ski Operations. The DAKOTA could be fitted with retractable wheel-skis which incorporated a small airfoil at the trailing edge. The aircraft takes considerably longer to take-off from a frozen lake in this configuration because of the increased drag. As a rule it was a very rough ride and might require JATO to assist in clearing obstacles! JATO or jet-assisted take-off, used a solid fuel rocket to propel the aircraft forward and upward on take-off from a confined area or when carrying an excessive load. When airborne, it is important to reach the single-engine safety speed of 105 mph (169 km/h) before raising the skis. At this speed, the small airfoils at the rear of the skis produced sufficient lift to level the skis and allow them to be to be raised into position under the engine nacelles. If the skis are retracted too soon, there is a real danger of damaging oil cables located under the engine cowling, causing leaks with disastrous results.

Glider Towing Operations: A longer take-off run is required when towing a military glider loaded with troops, guns, and/or vehicles. The maximum glider speed is 105 mph (169 km/h). In the event of an engine failure on take-off with a glider attached, there is no recourse but to release the glider. Formation flying with gliders in tow is difficult because of the reduced maneuverability caused by the excess weight and slow speed.

3. Aufgabenstellung

3.1 Dominantes Design

Definieren Sie Dominantes Design und stellen Sie Dominantes Design in Zusammenhang mit der Systemarchitektur.

3.2 Branchenlebenszyklus

Wie bestimmt sich das Verhältnis von Produktinnovationen zu Prozessinnovationen im Branchenlebenszyklusmodell nach Abernathy/Utterback? Nennen und beschreiben Sie die wesentlichen Merkmale der einzelnen Phasen des Entstehungsprozesses dominanter Designs. Welche Rolle spielen Standardisierung und Massenfertigung in diesem Modell?

3.3 Entwicklungsphasen

Beschreiben Sie die Entstehung des dominanten Designs im Flugzeugbau. Ordnen Sie jeweils die Entwicklungsphasen zu und grenzen Sie die Phasen anhand von Beispielen aus der Fallstudie ab.

4. Literatur

4.1 Literaturquellen

o.V. www.aviation.technomuses.ca/assets/pdf/e_DouglasDC3.pdf

4.2 Weiterführende Literatur zum theoretischen Hintergrund der Fallstudie

4.2.1 Literaturhinweise zu ‚Dominantes Design'

Henderson, R.M.; Clark, K.B.(1990): Architectural Innovation: The Reconfiguration of Existing Product Technologies and the Failure of Established Firms, in: Administrative Science Quarterly 35, S. 9-30

Abernathy, W.J., Utterback, J.M. (1978): Patterns of Industrial Innovation. Technology Review, Vol. 80, No. 7, S. 41-47

James M. Utterback and William J. Abernathy, "A Dynamic Model of Product and Process Innovation," Omega, Vol. 3, No. 6, 1975, pp. 639-656.

Utterback, J.M. (1996): Mastering the Dynamics of Innovation.

Lee, J.-R., O'Neal, D.E., Pruett, M.W., Thomas, H. (1995), "Planning for dominance: a strategic perspective on the emergence of a dominant design", R&D Management, Vol. 25 No.1, pp.3-15.

Corsten, H., Gössinger, R., Schneider, H. (2006): Grundlagen des Innovationsmanagements. Vahlen, 1. Aufl.

Gerybadze, A. (2004): Technologie- und Innovationsmanagement. Vahlen, 1. Aufl.

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