Competition in the Wide-Body Aircraft Market*

> The business of making and selling commercial airliners is not for the diffident or faint of heart. It is remarkably difficult and, by anyone's standard, intensely competitive...
>
> What really sets the commercial airplane business apart is the enormity of the risks as well as the costs that must be accepted; they create an array of obstacles to profitability, hence viability, which discourages all but the bold and committed...
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> And while the fee for entering the competition is injuriously high, the process itself is exciting and the rewards, if attainable, are high... Hence, many have tried, few successfully.[1]

The birth of a new market

The above remarks apply particularly well to the wide-body aircraft industry, a relatively new industry segment that dates back to the 1960s. It all started when Juan Trippe, PanAm's visionary chairman, decided that the future of the airline industry was in extra-large commercial planes. In 1965, Boeing and PanAm signed an agreement whereby PanAm would secure the first order of a new large aircraft to be developed by Boeing, the 747.

A few days after Boeing and PanAm's contract was signed, F. Kolk from American Airlines sent Boeing and the other manufacturers a proposal for a new aircraft of larger size than the existing ones but smaller than the proposed 747. With Boeing busy with the development of the 747, this left McDonnell Douglas and Lockheed as the potential contenders to enter the market "created" by AA's proposal.[2]

Not long after Kolk's proposal, the U.S. government announced it was dropping its plans to support the development of the supersonic transport (SST) project.[3] Lockheed, which had invested heavily into the SST project, decided to transfer that effort, and the staff involved in it, to working on Kolk's proposal. The credibility of Lockheed's decision was strengthened by hiring one of Boeing's senior engineers (Lockheed experience in civil aeronautics being limited). Despite Lockheed's move and the perception that the market would likely not hold more than two firms, McDonnell Douglas decided, three months later, to enter the race with its own design.

The first seriously credible signal that the companies were committed to the market was seen in September 1967, when specific design proposals were sent to the main airlines. The proposals appeared within a few weeks' difference: McDonnell Douglas had closed the initial gap by developing the first draft of blueprints in six months (as opposed to Lockheed's nine months).

The market and the players

McDonnell Douglas Corporation's DC-10 was designed in the hope of filling the market hole between the 727 and the new 747. Despite its illustrious past (in the post-war years the DC-3 captured as much as 95% of its market), McDonnell Douglas had been overtaken by Boeing. The DC-10 was viewed as an opportunity to strike back and close the gap with respect to the industry leader.

Lockheed considered the L-1011 decisive for the company's future in civil aviation: only by joining the exclusive family of wide-body aircraft producers could it hope to eventually

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[1] John Newhouse, *The Sporty Game*, New York: Alfred Knopf, 1988.

[2] Although the initiative came from American Airlines, several other airlines agreed that the 747 was too big for their needs.

[3] In fact, funding was only discontinued in May 1971; cf Bluestone et al. (1981), p. 65.

compete with a full range of aircraft. Lockheed expected that the expertise acquired with the SST project would be sufficient to build a competitive product. However, by undertaking this project it was stretching its financial resources to an extent that even a shortfall of sales below the desired level could lead to the company's demise.

As mentioned above, Lockheed and McDonnell Douglas entered the market at approximately the same time, with the first proposals submitted in September 1967. Between October 1967 and January 1968, the airlines studied these proposals. Not surprisingly, the aircraft designs were similar in their main characteristics: length, width, wing span, capacity, range, speed, engine thrust, seat-mile costs (see Exhibit 1). From an engineering point of view, Lockheed was generally preferred; but most airline executives had greater trust in McDonnell Douglas as a company: there was no clear winner among these two. The process was further complicated by the general disagreement regarding the choice of engine manufacturers: some airlines preferred a GE engine, whereas others favored Rolls-Royce.

Boeing's market position was considerably stronger than its competitors', having taken the industry lead with the introduction of the 707 and the 727 trijet. By the mid 1960s, over one third of all planes in the air were produced by Boeing. The Boeing 747 was by far the largest commercial airplane in the world. Its targeted maximum capacity was close to three times that of existing aircraft and significantly greater than the L-1011 or the DC-10.

It is not easy to define the wide-body aircraft market. In fact, it is not obvious that we can talk about one market as opposed to two markets. While the L-1011 and the DC-10 are clearly close substitutes, the same is not obvious about the 747 with respect to the former. Different possible market segmentations can be considered based on characteristics such as range, number of engines, passenger capacity, size (length and wingspan), and so forth. According to some of these, the 747 would be in a market of its own (see Exhibit 1). In practice, however, most airlines viewed the three designs as fairly close substitutes in the long-haul, high-capacity, aircraft market.

Market size and break-even level

Company estimates in the late 1960s showed that the market potential for wide-body aircraft would be between 1,000 and 1,300 units worldwide in the ensuing five years, with about one-third of the demand coming from airlines outside the United States.[4]

Break-even calculations were influenced by several factors: the large outlay of capital expenses in early stages of the product life, the slope of the learning curve (how costs decline with cumulative production), and the intensity of price competition.

Overall, both Lockheed and McDonnell Douglas expected to sell for a price in the range of $15million to $17million (including concessions). Indeed, real prices were remarkably constant over the production run of the planes. By contrast, average variable costs were expected to be $100million for the first unit, falling roughly by 23 per cent for each doubling of cumulative output, which results in $15.5million for the 150th unit produced (assuming a stable order and delivery flow).[5]

How to sell an airplane

Selling aircraft involves several steps. At a first stage, a team of salespeople and engineers meet with the customer (the airline) to discuss financial and contractual matters, as well as the aircraft's technical details. When the sale process is approaching completion, however, a more senior figure usually takes over the lead role, granting concessions regarding price or financing at his or her discretion.

Beware of their bargaining power, the airlines often demand extraordinary privileges, so-called "green stamps." PanAm, for example, received from Lockheed credits totaling over $2 million per plane, in addition to credit allowances of $12 million for spare parts, a $600,000 "promotional support allowance," and a number of other arrangements that eventually lowered total cost by about $42 million.

Due to the high level of government involvement in national airlines, even bribes to foreign officials are at times paid, a practice

[4] *Aviation Week & Space Technology (AW&ST)*, May 13, 1968, p. 36.

[5] Reinhardt (1973), p. 824.

which led Lockheed into trouble as the governments of Japan, the Netherlands and Italy were accused of accepting bribes from the former in connection with the purchase of L-1011 planes. Consultancy fees are also regarded as part of the game. In Boeing's 1976 and 1977 annual reports, we read that it is "advisable ... to continue to engage consultants and pay commissions and financing and consulting fees in certain countries for assistance in those countries."[6] On some occasions, the governments themselves join the action by granting financial aid to foreign buyers purchasing domestic equipment.

The number of different types of special arrangements between aircraft manufacturers and airlines is almost as large as the number of deals; each deal is tailor-made and accompanied by last-minute concessions granted by the senior negotiator. However, while there are many different dimensions, it is generally agreed that price per passenger is the essential feature.

The learning curve

Estimates from the aircraft industry indicate that a doubling of cumulative production is normally associated with a 20 per cent fall in production cost. Learning in aircraft production, a labor-intensive industry, takes place through rationalization in production. For example, in the late 1960s Boeing employed 25,000 workers to produce the first 747s at a rate of seven per month. A decade or 400 units later, the same output could be achieved with only 11,000 workers.[7]

The learning effect, however, is partly offset by organizational forgetting.[8] Employees leaving the company or moving on internally imply a loss in workers' experience and expertise. This is a problem in the aircraft industry because turnover and volatility are very high.[9] It is therefore common practice to treat large proportions of the labor force as variable. As soon as a trough in production can be foreseen, workers are laid off and then rehired as soon as production recovers. However, it is often impossible to rehire the same workers; all of the new workers must then be trained, a process that can take up to a year for a machine operator and up to four years for a machinist.[10] This in turn implies that, after a period of high turnover, productivity can fall below levels previously attained through accumulation of experience.

The learning curve has important implications for the dynamics of industry competition. A temporary slip in orders can throw a competitor out of the game, since the leading manufacturer, having moved down the learning curve and become more competitive, can now price more aggressively and further extend its lead. To make things more dramatic, the demand for aircraft consists of very few very large orders, so that the outcome of the game is decided on a relatively small number of events.

Let the games begin

By the beginning of 1968, Boeing had a one year lead with respect to Lockheed and McDonnell Douglas. The latter submitted their first bids in February 1968. The bids were reportedly within two hundred thousand dollars of each other, a trifle by comparison with the overall size of the order in question. On February 19, American Airlines announced the first order—to McDonnell Douglas. Despite this first setback, Lockheed did dot give up; and, by means of aggressive marketing, it managed to secure the next three large orders. The pressure was now on McDonnell Douglas to leave the market while it was time to do it. In fact, their contract with American Airlines gave McDonnell Douglas the option of canceling the order if within ninety days two other airlines hadn't ordered the DC-10.

Attention was now centered on United Airlines, the next airline expected to place an order. Although all previous orders had specified Rolls-Royce engines, United preferred the GE engine. A proposal was made to Lockheed for supplying the combination L-1011/GE. Lockheed's response was negative, perhaps because it sensed it had won the race and gained sufficient bargaining power, as no airline would

[6] Bluestone, p. 58.

[7] Bluestone et al. (1981), p. 123.

[8] See Benkard (2000) and references therein.

[9] In the New England aircraft industry, which consists mainly of parts manufacturers, historical turnover ratios of 20 per cent were common. Overall, the aircraft industry experienced a 35 per cent increase in net employment between 1964 and 1968 and a contraction of the same magnitude in the following four years. Cf. Bluestone et al. (1981), p. 125–139.

[10] Bluestone et al. (1981), p. 133.

want to place an order on McDonnell Douglas' nearly orphaned design. As it turned out, in April 1968 United placed an order with McDonnell Douglas, thus cementing the market into a triopoly that would eventually lead both Lockheed and McDonnell Douglas to huge losses.

The choice of the Rolls-Royce engines continued to be a problem for Lockheed. Rolls-Royce's RB.211 engines compared favorably to P&W's and GE's in terms of operating economics, but several airlines preferred the American engines. In early 1969, PanAm and Japan Airlines showed interest in the combination Lockheed/P&W. Later in the year, a European airline consortium consisting of KLM, SAS, Swissair, and UTA (Union de Transports Aeriens) ordered 36 DC-10s mainly because of their previous experience with GE engines and McDonnell Douglas, thus delivering another blow to Lockheed.

Lockheed considered adding the P&W JT9D as an option to the RB.211. However, the additional installation and certification costs were estimated at more than $100m and the plan was delayed indefinitely.[11] Instead, Lockheed decided to intensify price competition.

Engine trouble

The RB.211 engine project was a very ambitious endeavor, promising to achieve unprecedented operating performance. The main innovation consisted of making the fan blades out of a new composite, hyfil. Hyfil was lighter and, according to Rolls-Royce, as durable as the customarily used titanium.

Airlines did not fully trust the new material, however, and insisted on the development of an alternative blade made of titanium. For a while, Rolls-Royce ran two production lines in parallel, with the inevitable increase in costs. To make things worse, the first units of hyfil-blade engines failed the "chicken test" and the blades had to be replaced with conventional titanium ones.[12]

[11] *AW&ST*, April 28, p. 26-27.

[12] The chicken test experiments the stability of the engine blades by actually firing a chicken at the running engine. Rolls-Royce fan blades were reported to have broken under the impact of the chicken. See Newhouse, op. cit., p. 174.

Rolls-Royce

In addition to technical problems, 1970 was the beginning of a period of financial distress for Rolls-Royce. Development costs for the RB.211 were much higher than predicted, making it uncertain whether Rolls-Royce would break even on the Lockheed project.[13] To make matters worse, the Lockheed orders were not coming as steadily as expected. The first signs of Rolls-Royce's financial strain showed in 1970, when the company announced the layoff of 3,500 workers due to reduced profitability.[14] Rolls-Royce's stock, which was at $6.72 when Lockheed announced its choice of engine, dropped to $2.52.[15]

The U.K. government, through the then-created Industrial Reorganization Group, issued a $48m loan, spread over a two-year period. But this was not sufficient and Rolls-Royce turned again to the government for support. Prime Minister Edward Heath granted the funds under the condition of an independent audit. The audit produced a dismal picture: the $100m that Rolls-Royce had requested were not sufficient to keep the company—or the RB.211 program—alive. The questionable profitability of the RB.211 was now translated into an expected loss of $264,000 per engine under the initial contractual conditions. It was in the British government's interest to keep the military operations of Rolls-Royce running and to preserve the brand name as a national icon. However, Heath made it clear from the beginning that the government would not be willing to sustain the RB.211 program, as it had "no liability in respect of the contract between Rolls-Royce and Lockheed."[16] Consequently, while there was no governmental interest in Rolls-Royce vanishing, the main burden to save the program was placed on Lockheed, and the only way of achieving that was to renegotiate the contract in Rolls-Royce's favor.

An intricate process of multilateral negotiation ensued, involving Lockheed, Downing Street, the White House, the initial customers of the L-1011—and Rolls-Royce, who was practically confined to a role of spectator, having recently moved into receivership. Lockheed attempted to convince customer air-

[13] *AW&ST*, May 25, 1970, p. 22.

[14] *AW&ST*, January 12, 1970, p. 61.

[15] *AW&ST*, March 16, 1970, p. 23.

[16] Newhouse, op. cit., p. 177.

lines to bear part of the financing burden necessary to lift Rolls-Royce, but failed. Eventually, Daniel Haughton, Lockheed's president, emerged as savior not only of Lockheed, but also of Rolls-Royce. In May 1971, he negotiated a government loan guarantee for Lockheed, a price increase of $640.000 for each L-1011 sold, part of which would be paid in advance, and the guarantee that the British government would bear all additional development costs of the RB.211 engine.

The forgetting curve

In spite of the Rolls-Royce complication, very few airlines previously committed to Lockheed canceled their early orders. However, it is likely that the uncertainty around the future of Rolls-Royce engine harmed Lockheed considerably: during the early 1970s, orders for the L-1011 dropped significantly.

The dynamics of the learning and forgetting curve started to kick in. First, Lockheed's production rates had to be cut down, thus causing a move backwards on the learning curve ("organizational forgetting") and an increase in production cost (see Exhibit 2). Second, low cumulative orders implied uncertainty about long-term survival, which in turn drove away potential demand. Finally, Airbus' entry in 1971, with a strong financial backing from European governments, made Lockheed's long-term survival even more uncertain.

McDonnell Douglas

While Lockheed had problems with its L-1011 engine supplier, McDonnell Douglas experienced even bigger problems with the DC-10. In 1974, a tragic crash near Paris killed more than three hundred people. Public confidence in the DC-10 dropped dramatically, which benefited the rival planes. TWA, for example, stressed in its advertising that it only flew L-1011s and 747s. Several airlines tried to get rid of their DC-10s; many orders were canceled.

Industry analysts wondered whether this and other crashes were rare events or rather accidents that were waiting to happen. In retrospect, the DC-10 panic was blown out of proportion. By the end of the century, the statistics on the rate of hull losses per million departures show 1.90 for the 747 (early models); 0.77 for the L-1011; and 2.57 for the DC-10.[17] Though certainly the highest among the three, the DC-10 number hardly justifies the public's reaction. Or the FAA's: after the 1979 Chicago crash, which killed more than two hundred people, the FAA withdrew the DC-10's airworthiness certificate.

An improved, supposedly safer, version of the plane was later introduced by McDonnell Douglas: the MD-11. Sales never took off, however. Ironically, at 6.54 crashes per million departures, the MD-11 holds the second worst safety record in history.

Boeing: how the war was won

The early 1970s were a time of crisis not only for Rolls-Royce and Lockheed but also for the entire aviation industry. Many aircraft orders were canceled. At one point, British Overseas Airways Corporation, a leasing corporation, had to store three newly delivered 747s because United Airlines didn't want to lease them.[18] Even Boeing's viability appeared fragile and forced the company to cut its workforce from 105,000 in 1968 to 38,000 in 1971.[19] But throughout the 1970s Boeing benefited from Lockheed's and McDonnell's trouble and the 747 eventually emerged as the winner of the first wide-body race:[20] by the late 1970s, the 747's share of new orders was greater than fifty per cent (see Exhibit 3).

As history proved it, there was nothing fundamentally wrong with the L-1011 or DC-10 designs. In fact, in many respects these were superior aircraft. However, the learning curve dynamics transformed a series of temporary advantages into a permanent one. The more Boeing got ahead of the race, the more efficient it became at producing the 747, and the more competitive it became in future sales. As one aerospace analyst put it,

> If someone hired me to rebuild the Great Pyramid, I'd ask Lockheed to design it and Boeing to assemble it.[21]

[17] *The Wall Street Journal*, September 19, 2000, p. A18.

[18] *AW&ST*, June 1, 1970, p. 28.

[19] Bluestone et al. (1970), p. 57.

[20] The advent of Airbus marks the start of the second race.

[21] Newhouse, op. cit., p. 139.