Overwhelmed by Success: What Killed Douglas Aircraft

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We thank Noam Yuchtman for his comments and Thomas Rhodes of Smith, Gambrell & Russell for his assistance.

I. Introduction

Despite the virtues of learning from other's mistakes, students of business rarely find inspiration in the death of a company, even one as successful as Douglas Aircraft had been. Douglas dominated commercial aircraft manufacturing before WWII. In 1939, Douglas aircraft flew 90% of the world's commercial airline traffic [U.S. Centennial of Flight Commission]. As in any post-mortem, we know how this story ends: Douglas was acquired by McDonnell Aircraft in 1967. We even know who pulled the trigger: Lazard Frères, acting on behalf of Douglas' banks, triggered a liquidity event that forced Douglas' sale. While the fall of the mighty is hardly unique, the path from 90% market share to sale of the company is not an obvious one.

Most companies fail when customers do not buy their products. Douglas failed because customers did buy its products. Douglas fell with a successful innovative product, the DC-9, and an order backlog in excess of $3 billion and growing, enough work to keep its production lines humming for years. How can a company fail with a $3 billion book of unfilled orders? The answer involves both the alignment of Douglas ' strategy with the characteristics of the aircraft industry, and Douglas' tactics as it operated in that industry. The first explanation is that at a technological discontinuity, Boeing enjoyed a first mover advantage into jets that Douglas and others never recovered from. The second potential explanation is that the industry only has room for one firm. In textbook treatments, the industry has been described as a natural monopoly (McAfee). This is driven by three factors which compound each other with crushing force: 1) immense fixed-costs to develop and produce a new plane, 2) economies of scope across a family of planes, and 3) steep learning curves. In the strongest form of these structural explanations, Douglas' fate was pre-ordained once it chose not to enter first into an industry with room for only one firm. In a dynamic variant of this explanation, steep learning curves gave firms an incentive to price below costs, contributing to a war of attrition. The third explanation, favored by Douglas itself, is that Douglas fell as a result of supply shocks induced by the Vietnam War. The fourth explanation is more mundane but compelling: Douglas failed to execute. We consider both Douglas' strategic setting and its tactics in turn. Company internal operations are normally shrouded to outsiders. Using both internal production records and records from a round of litigation surrounding Douglas' fall, we can see inside Douglas at this critical juncture and observe a fatal series of execution errors.

Between 1947 and 1967 ten firms would enter the market for commercial jet aircraft. All had prior experience manufacturing earlier generation aircraft, and many had experience producing jet aircraft for the military. Each would project break-even at between roughly 60 and 200 aircraft. By 1977, their number had fallen by half despite a growing market. Their error lay not in the calculation of break-even in a one-shot investment project, but in their conception of how competition in this market would evolve to exploit economies of scope, to differentiate across a family of aircraft, and to drive down learning curves to engage in a war of attrition. Companies' fates would turn not on how well they had engineered a plane to fit a particular niche, but on the option value they had designed into their planes. Douglas met its fate in the transition of commercial aircraft from product to platform. In this unforgiving strategic setting, Douglas would seal its fate by failing to execute.

II. Original Sin

In the 1990s, a McDonnell-Douglas Vice-President explained to us that the proximate cause of his company's demise in commercial aircraft was the Boeing contract. He was referring to an order Boeing had secured four decades earlier. Just as many cultures have creation myths, Douglas embraced this story of original sin. As they prepared to enter the commercial jet age, Douglas and Boeing enjoyed similar financial positions, with $80M and $81M of working capital and peak market capitalizations for the year of $320M and $265M respectively in 1954. By gaining an order for 250 Air Force KC-135 tankers in 1955, Boeing secured an advantage with persistent after-effects. Government funding for the military aircraft and the plant and tooling with which it was produced laid the foundation upon which Boeing designed and built its first commercial jet aircraft- the 707. This is a style of argument of which Airbus would later become fond. Some would claim the 707 shared a fuselage with the KC-135, or a wing with the KC-135, B-47, or B-52 –all Boeing products. Boeing itself would claim that "Every large jet aircraft today is a descendant of the B-47" the first multi-engine swept-wing jet aircraft [www.boeing.com/history/boeing/b47.html].

Wartime Germany would provide a key innovation. During Germany's post-war occupation, a Boeing aerodynamicist discovered reports on swept-wing jet designs which would become the basis for the wings of Boeing's B-47 and subsequent jets. However, it would have been hard for Boeing to keep the swept-wing design secret, or to leave Douglas (or Lockheed) inexperienced in jet aircraft production, not least because 274 B-47s were produced under license by Douglas itself.

Relying on Boeing's first mover advantages suffers from a brutally simple shortcoming: Boeing was not the first to manufacture commercial jet aircraft. DeHavilland had pioneered commercial jet manufacture with its Comet in 1949, a full eight years before Boeing's 707 first flew in 1957. The Comet illustrates the bleeding edge aspect of moving first, as some early models suffered metal fatigue leading to catastrophic rupture. The redesigned Comet stalled when the Royal Air Force demanded that its deliveries take precedence over those of airlines (Hayward, p.56). Later in 1949 Avro's C102 Jetliner became the second commercial jet airliner to fly, although it never sold. Treated to a ticker-tape parade after its first flight to New York, its return leg via train was less feted. As another example of risks at the leading edge, Avro's lead customer, Trans Canada Airlines, despite having participated in its design, changed its mind refusing to be the first airline to employ the new jet technology. Avro was then ordered to focus on military aircraft during the Korean War, turning aside Jetliner customers at the direction of Canada's Minister of Industry and Transport, C.D. Howe (Chandler, 2009). The next entrant, Sud Aviation's Caravelle, first flew in 1955[1]. Boeing's advantages would be of the less-celebrated fourth mover type.

Boeing's advantages were more subtle than simply moving first to introduce new technology, or to develop a strong reputation or relationship with suppliers or customers. At the time, Douglas enjoyed the strongest reputation and relationship with the airlines, in a market in which Boeing's previous offerings had flopped. Indeed many of the major carriers were willing to wait the better part of a year after the 707 began revenue service to take delivery of Douglas' competing DC-8. The key technological advance was the jet turbine engine, but these were manufactured by specialist firms not bound to a single airframe maker. Jets had been used since the war in military aircraft made by all the major rivals. The heart and soul of an airframe manufacturer is wing design. Since 1941, Boeing had owned the only high-speed wind tunnel in private industry. Here Boeing's bomber experience would prove useful. In 1953, William Allen, Boeing's President, explicitly laid out Boeing's strategy to piggyback the development of commercial jet transport on military experience:

"The intention of the Boeing Airplane Company to design and build, with its own funds, a prototype jet transport, was one of the important decisions made by the company during [May 20] 1952. We … can build a test vehicle which will enable us to demonstrate to the military the principal characteristics of a combination tanker and jet transport and, at the same time, demonstrate to the airlines the principal characteristics of a production jet airliner. …It will be a demonstrator model, the basic design of which will be adaptable to two production models: first, a versatile military airplane for aerial refueling of fast jet bombers and fighters, and for cargo and troop transportation fitted to the tempo of jet-age military tactics; second, a high-speed, economically operating airline transport for passengers and cargo…. The undertaking follows naturally, however, from our experience in the application of jet power to large

[1] The Soviet Union's Tupolev 104 first flew in 1955, and its Ilyushin Il-62 in 1963, but these were not viable in the Western markets their bomber cousins were designed to address.

aircraft. Designing, building and flying the B-47 Stratojet bomber and the new B-52 eight-jet Stratofortress heavy bomber have given Boeing an unparalleled background of experience. It has included, for example, 14,500 hours of jet wind-tunnel research and more than 5,000 hours of test and research flying. " (Allen, 1953).

Boeing's Dash-80 prototype first flew on July 15, 1954. Douglas, Boeing, and Lockheed all prepared bids for the Air Force's tanker contract, which would pay $100M in development costs. Lockheed – not Boeing- won this jet tanker contest. Within weeks of the Boeing Dash-80 prototype's first flight, the Air Force bought Boeing KC-135 tankers as a 'temporary" measure because Lockheed would not be able to deliver for two years. Lockheed would never produce the tankers. Boeing had leveraged its long experience building long range bombers for the Air Force, its close relationship with Air Force General Curtis LeMay, and its ability to anticipate Air Force requirements.

Subsequently, the development of the military KC-135 tanker and the civilian 707 diverged. First, the Air Force demanded that the prototype's 132" diameter be expanded by 12" for the KC-135. Then Juan Trippe of Pan Am, wielding the threat of Douglas' planned wider fuselage DC-8, pressured Boeing to widen the 707's diameter. Boeing's decision to bring the 707's diameter up to 148" was accelerated by United Airline's defection to the DC-8's six-across seating. With the plan for a common fuselage scrapped, but still with largely common wings, the 707 and the KC135 would share at least 20% of their parts and tooling (Lawrence). The two were also produced in the same government plant. Boeing could also benefit from R&D spillovers. Boeing's head of sales and engineering at the time said: "We looked hard at our B-47 and 52 when we first thought about jet airliners and you couldn't use one bolt. On the other hand, facilities for building and testing such aircraft could be very useful…" (Beall, 1960, p. 603). The Boeing 707 and Douglas DC-8 were very similar planes, but it would cost Douglas from 23% to 115% more and an additional year to develop the DC-8, suggesting Boeing's benefit from prior bomber and Dash-80 experience.[2] Discussing the 707 prototype, Boeing said "It benefits from more than 22,000 hours of Boeing wind tunnel testing on multi-jet powered airplane types and their components. The experience gained through more than 11,000 hours of experimental and production test flying by Boeing crews has gone into the plane, in addition to that gained in manufacturing more than a thousand multi-jet airplanes." (Boeing, 1954, p.15).

[2] Mowery and Rosenberg (1982) present the spillover argument. For a critique of spillovers, see Gholz (2011).

At the cusp of a technological disruption, the fateful decision was whether to take the risk of investing in jets, or wait for that technology to mature while continuing to harvest piston engine profits. Douglas decided to wait. The question of whether incumbents should lead or lag at product innovation has generated a deep literature with predictions that depend on case specifics. In various models, an incumbent is more likely to defer innovation the more it has to lose by cannibalizing its own old technology profits, the less it fears future rivalry, or the more that new technology would disrupt core strengths and relationships (Ghemawat, 1997). Sutton's (2001) and Phillips' (1971) descriptions of the aircraft industry look elsewhere, and seem particularly apt: Douglas made a decision to defer innovation, waiting for jet technology to mature.

In retrospect, they would have to play catch up after this decision, but at the time they and many others viewed the market and technical risks as daunting. Without the benefit of hindsight, this was a sober decision in light of the exploding Comet, the exit of Avro, the failure to sell any Caravelles in a joint venture with Sud Aviation, and the advice they had received from some major customers. C.R. Smith, CEO of American Airlines told Douglas that the time was not yet ripe for jets, and that nobody would ever buy a Boeing jet. United Airlines CEO echoed this skepticism towards jets (Newhouse, p. 133). In 1952 Smith placed a $40M order for the new plane he wanted, the piston-engined DC-7, enough to cover Douglas' development cost and to "talk Mr. Douglas into delaying the DC-8 launch" (Waddington, 1996, p. 9).

Under the circumstances, nursing the option value of waiting for jet engine technology to mature could credibly have outweighed jumping into the technological and economic risks of jets. Douglas would have found harvesting the old technology even more attractive because of the $750,000 in profits they reportedly enjoyed on each piston driven DC-7, and by the reassurance that Douglas' reputation with the airlines was so strong that they would wait for it to catch up, as many – but not all- did after Boeing beat it to market. Boeing's position was asymmetric: it had no viable piston airliner, and no customers to whom they had recently sold planes now to be made obsolete. Ironically, American Airlines would become one of the 707's first customers.

On October 13, 1955, Juan Trippe placed simultaneous orders for 20 Boeing 707s and 25 Douglas DC-8s. By the end of 1955, Boeing had taken orders for 70 707s, while Douglas had 73 orders for its similar DC-8s. While the aircraft were operationally similar, Boeing took the sales lead in this category the following year and never relinquished it. In April 1963 Douglas launched the DC-9 targeted to a short-range market Boeing did not have an entry in. Douglas saw this as a do or die decision. In the event, it would be both. Already burdened with slow DC-8 sales, when initial DC-9 sales came in below expectations Donald Douglas, Jr. directed in a January 17, 1964 internal memo:

"I feel we have spent too much effort in talking to ourselves and reorganizing ourselves and not enough on either selling or finding out why we can't sell. … [It is] "compelling" to "sell, sell, sell" (Gambrell, p. 8) With that clear direction from the top, Douglas proceeded to sell.

The Dog That Didn't Bark

To look only at the entrants narrows the focus to a timing game. While the timing of the decision to enter the jet market was important, there was a third option between the old technology of piston-driven propellers and pure jets. Turboprops use jet turbines to turn propellers. Lockheed shared many of Douglas' advantages at the beginning of the jet age, including successful sales relationships with commercial airliners, and experience building military jets including the B-47. Its design had been good enough to win the critical Air Force jet tanker competition in 1955. Like its rivals, Lockheed's proposal built in commonalities with a jet transport. Significantly, Lockheed looked ahead to potential competition with Boeing enjoying the tanker benefit, and shelved its L-193 jet airliner. Lockheed then made an interesting decision that Bristol, Vickers, Fokker and others would all take. Lockheed chose turboprop technology for its Electra, first flying in 1957. For the airlines, the turboprop Electras were a hedge against the risk of pure jets. As pure jet technology rapidly advanced, selling that insurance became a short-lived business. Turboprops would remain viable for short range flights, but their performance over longer ranges was soon eclipsed by pure jets. In its range class, Lockheed had chosen a technological dead end.

III. How Many Firms?

The second structural argument is that Douglas may have simply been one firm too many in its industry. With free entry, homogenous products, and identical technology, the number of firms in an industry is a function of product demand and cost parameters, decreasing in fixed-cost and increasing in demand. Although the commercial aircraft industry has been described as a natural monopoly because of its huge fixed costs (McAfee, Tyson), it has always had more than one producer. When Douglas entered the short to medium range market with the April 1963 launch of the DC-9, it expected to break-even if it could sell 125 planes in a market it estimated at about 1,000 planes through the end of the decade. Initial requests for bids on components were based on 125 ship-sets (Waddington, p. 16). Between 1963 and 1969, the first seven years of DC-9 orders, 622 DC-9s were ordered along with 256 737s, at least 153 BAC 1-11s, and perhaps 50 Caravelles. Using Douglas' expected breakeven point in either its expected 1,000 plane market or in the realized market for 1,081 short to medium range jets, there would have been room for roughly eight manufacturers[3]. By January 1965 when the first DC-9 rolled out, Douglas executives had raised their expected break-even point to 200 units (New York Times, January 13, 1965), still leaving room for five similar firms to enter. A steep learning-curve or higher fixed-costs would have reduced that number, while differentiation would have increased it.

This rough calculation accords with the existence of multiple producers and suggests that the demand for short-to-medium range jet transports was sufficient to offset the considerable fixed-costs of entry into this market in the 1950s and 60s. Between the first flight of the Comet in 1949 and that of the 747 in 1969, at least 9 different firms produced commercial jet aircraft. Government policy to consolidate in both Britain and France would reduce this number. By themselves, it is unlikely that fixed-costs in this market drove Douglas out. But Douglas also competed in the long-range market, with more difficult economics. When it launched, Douglas expected the market for DC-8s to total 200 (Waddington, p. 22). The prime long-range routes at the time were across the North Atlantic and across the US. DeHavilland's Comet 4 pioneered jet service across the Atlantic in 1958, but was soon overtaken by the faster and larger capacity American long-range jets. The Comet's early technology wings and engines uneconomically restricted its size and range. The 150 overwater DC-8s and 707s sold in the first year were enough to supply all North Atlantic seat miles (Flight, November 2, 1956). As DC-8 and 707 orders continued rolling in, the residual demand left for any 3rd producer shrank to unattractive levels. DeHavilland abandoned plans to compete with a proposed long range 118. In 1956 Convair launched its 880, designed to be smaller and faster than its rivals. It badly misjudged the niche, selling only 65 and losing more than $185M, the largest corporate loss at the time. Having cancelled its proposed model 1000 in 1955, Vickers entered in 1962 with the VC-10, expecting it would have to sell between 35 and 80 to break-even. Hampered by high operating costs, it sold only 54, including military versions.

The combination of a smaller number of economically viable long-range routes at the time and higher development costs makes a stronger argument that there was only room for a few firms to compete in the long-range segment. Ex post the DC-8 was at best modestly profitable. Why not then enter the less risky small to medium range market first? First, the technical advantages of jets over pistons had greater force over longer distances. Second, the same factors that limited the number of firms in the

[3] A broader market definition would include longer range aircraft such as the HSA Trident with perhaps 89 orders, and the Boeing 727 with 694 orders during the period.

long-range segment meant that incumbents would benefit from an entry barrier. Third, the U.S. Air Force was not in the market for bombers or tankers to serve short to medium runs.

Differentiation Game

This period marks a critical change in development cycles. One of the keys to Douglas' success before the jet was that it built option value into its initial designs. Airframes were built to be stretched, and to accommodate stronger wings and more powerful engines[4]. This allowed Douglas to stretch and improve the DC-1 into the successive DC-2 and DC-3 models sharing a common fuselage cross-section. The same strategy succeeded as the DC-4 was developed into successive DC-6 and DC-7 models with longer fuselages and more powerful engines. Douglas would continue building optionality into its planes in the DC-8 and DC-9, but it would execute this strategy on a significantly compressed time-scale. In 1966, Donald Douglas Jr. explained "Because of our competitive race with Boeing, we are turning out more brand-new aircraft. " (Business Week, 1966, p. 178).

While option value was built into engineering decisions, the available evidence on launch decisions depict them to have been evaluated largely as a single stage comparing the expected present discounted value of future profits to development costs[5]. As aircraft manufacturers considered entering the jet age, they generally contemplated development costs in the range of $60 to $200M (current dollars) which they compared to their expected profits selling that model. Development costs for a new model had long been increasing as aircraft became more complex, but these increased dramatically in the transition to jets. The first DC-1 cost $325,000 dollars to design and produce in 1933 (Douglas, 1935). This is equivalent to about $6M in 2010 dollars, which we use in the following comparisons. The DC-4 was introduced in 1942 at a cost of about $41M dollars. The DC-6 was launched in 1947 at a cost of $118M. Douglas' final piston aircraft, the DC-7, cost $310M to bring to market in 1953. Development costs leaped with the introduction of jets. Boeing's 707 was introduced in 1957 at a cost of $1.3B. The Douglas DC-8 first flew a year later in 1958, with development costs given between $1.6B and $2.8B (Waddington, 1996). It would be years before either manufacturer could recoup the cost of entering the commercial jet age.

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[4] The Dassault Mercure is a compelling example of the inverse, in which engineering triumphed over business considerations. With a single-minded focus on optimizing very short range performance, option value was systematically stripped from the plane along with any possibility of extending its range, weight, or fuel capacity. Twelve were sold. To a less extreme extent, the BAC 1-11 was also a good plane but a poor platform.

[5] Government launch aid was motivated by larger commercial and strategic concerns.

At the time, Douglas's investment in the DC-8 was the largest privately financed project by a single company. Douglas's extreme costs on the DC-8 were a product not just of the well-known and expensive transition to jets, but also of a less noticed decision. By 1957 Boeing was offering the 707 in varieties with 3 different fuselage lengths, 2 different wings, and 3 different engines (Flight, 1957). Boeing would later enjoy economies of scope in the escalating differentiation game by using the same fuselage diameter on the 707, 727, 737, and 757. Douglas introduced four different variants of the DC-8 at the same time in an attempt to saturate a variety of market niches and capitalize on the immense sunk investments in the DC-8. These four variants (DC-8 Series 10, 20, 30 and 40) varied primarily in engine type and in fuel capacity.

These were just the entry moves, soon followed by desperate leapfrogging investments. In short order the initial variants were followed by Series 50, which first flew in 1960 incorporating superior turbofan engines. These outperformed the rival 707-320, prompting Boeing to sink additional investments into a crash program for an expensive new wing for its 707-320B which in turn outperformed the DC8-50 and secured Boeing's lead. Douglas responded by investing an additional $334M (2010 dollars) (Mecklin, 1966, p. 171) to develop the stretched Series 60 with first flight in 1966. The Super 60s would spark a resurgence in DC-8 sales and extend sales into the next decade. In January 1966, Donald Douglas Jr. said "The proliferation of models I am sure has given us a strong sales position, but it has also given a gastronomic pain in the first order." (Gambrell, p. 17). Awkwardly for the early mover story, Boeing had found itself having to adapt to the decisions of the putative follower first by increasing the 707's fuselage diameter, then by increasing wing area and adopting a stronger engine, and then by designing a new wing. The competitive response cycle had become more front-loaded.

This rapid differentiation game severely compressed the development cycle, and increased corporate debt as each successive wave of development pushed break-even back further. In effect, what airframe manufacturers had treated as a one-shot game – invest in a new model and expect to break-even after selling a certain number of planes- had become a multi-stage game – invest in a model and -having sunk that investment- then sink further investments in variants in an attempt to recoup the initial sunk investment.

This is game theory's war of attrition, with hundreds of millions in development costs at each stage. In this high-stakes and risky game, both Boeing and Douglas raised the stakes by compressing the development cycle to introduce multiple new variants more quickly than in the pre-jet era. In business settings, wars of attrition are typically modeled as playing out in price wars. The airframe industry expanded the palette of tactics to include horizontal differentiation (customizing for various niches[6]) and vertical differentiation[7] (improved fuel efficiency, passenger capacity, range, and reliability), as well as pricing (often buried in favorable financing, lease or buyback terms, or in the provision of service and spares). Co-production and offsets were also used. Douglas secured orders from Trans Canada Airlines soon after ordering wings from DeHavilland of Canada, and it secured orders from AerItalia soon after ordering fuselage panels from Aerfer of Italy.

As in any war of attrition, this would be a costly and prolonged affair. The battle of planes was becoming a battle of platforms. Competing against a good platform, having a good product would no longer be sufficient. Ironically, despite having been pushed by its customers into a 707 fuselage wide enough for 6 across seating, Boeing would later enjoy economies of scope by using the same fuselage cross-section on succeeding 727, 737, and 757 models. Pinched by the direct competition between the 707 and DC-8, Douglas made a different decision on its next jetliner. It specialized the DC-9 fuselage for the short-range market, raising its development and tooling costs and giving up some platform economies.

IV. Vietnam

The Vietnam War claimed many casualties. Douglas Aircraft would count itself among them. Douglas suffered a stunning financial reversal, plummeting from a pre-tax profit of $25M in 1965, to a 1966 loss of $52M. The paternity of this defeat was hotly contested. In its 1966 – and last- Annual Report, Douglas explained that "Escalation of the Vietnam War and a general rise in business activity created shortages of material, parts and skilled labor which affected both the Aircraft Division and its suppliers. Delays in the delivery of engines, landing gear and other key components to Douglas seriously disrupted the acceleration of aircraft assembly rates programmed for 1966. " (p.4) . Douglas, and its successor, McDonnell Douglas, would argue repeatedly that the Vietnam War had been its downfall.

Pratt and Whitney, the dominant supplier of engines for the Douglas DC-8, and the sole supplier for the DC-9, was overwhelmed by government demands to accelerate the delivery of military engines. (Eastern Air Lines v. McDonnell-Douglas, para 108). Beginning in late July 1966, the delivery of engines fell sharply (Beecher v. Able). On September 29, Pratt & Whitney reduced its previous commitment for DC-9

[6] Boeing chopped 10' from the fuselage of a 707 to sell 10 planes to one customer: Qantas.

[7] Sutton (1998, Ch. 16) analyzes this escalation process in R&D. Huge increases in development costs led to a collapse in profits at Boeing, Douglas and Lockheed after 1958. Phillips (1971) first described the aviation industry's escalating R&D rivalry.

and DC-8 engine deliveries(Beecher v Able 1977). By October, Pratt's deliveries to Douglas were a month behind (Business Week, 1966, p.178). Menasco, the prime supplier of DC-9 landing gear, also reported facing increasing military demands and was delivering four months late in 1966 (Eastern Air Lines v. McDonnell-Douglas, n.86). According to the California Department of Employment Research (1967), "The coincidence of the upsurge in the demand for aircraft production workers and the accelerated hiring among firms affected by developments in Vietnam, caused a rapid spread of recruitment problems involving a wide variety of occupations. …The renewed demand quickly exhausted the supply of qualified machine shop metal trades and related workers."

Congress passed the Gulf of Tonkin Resolution on August 7, 1964. U.S. ground troops would not begin operations in Vietnam until March 1965, which also witnessed the first major air campaign of the war, Operation Rolling Thunder. In November 1963 -ten months before the Tonkin Gulf Resolution- Douglas' internal Operating Plan had predicted "probable skill shortages in successive stages of DC-9 buildup" (Gambrell, p. 7). Before the first DC-9 had even flown, Douglas was already anticipating inventory write-downs on its DC-9 program (Douglas, 1964). Since planes are built to order on fixed-price contracts, this means that by January 1965, a month before the DC-9's first flight and 2 months before Rolling Thunder, Douglas was anticipating increases in its costs of producing those planes. By its 1965 Annual Report Douglas was reporting "a massive build-up in inventories" despite which "a significant rise in profits may also be anticipated." (p.5).

Douglas was late delivering aircraft. Douglas planned to deliver 39 DC-8s and 93 DC-9s in 1966 (Douglas, 1965). It would actually deliver 32 and 64 respectively. For the DC-9 line, we have evidence on the prevalence and length of delays. Deliveries were delayed by an average of 2.6 months among a set of ten DC-9s with delivery dates promised between May 1965 and October 1966.[8] (Eastern Air Lines v. McDonnell-Douglas) Delivery delays increased from 49 and 60 days on the first two, to 90 and 96 on the last two. Douglas re-contracted on July 14, 1966 to defer delivery by two months. Even after re-contracting for this extension, Douglas proceeded to slow down further and miss the extended delivery dates by an average of 22 days. The 99 planes delivered to Eastern between April 1966 and January 1969 were delivered on average 2.5 months late (Eastern Air Lines v. McDonnell-Douglas) .

In its July 12, 1966 debt prospectus, Douglas stated that the net proceeds of $73.8M would be used to repay short-term bank debt incurred to finance the build-up of work-in-process and inventories for

[8] The case record shows 755 days of delay, but the last plane was physically delivered 96 days after the contracted date, yielding 794 delay days.

commercial jet aircraft (Beecher vs. Able). Douglas was holding greater inventories both because it was building more planes and because it was holding inventories longer. Between 1965 and 1966 Douglas' inventories increased from $234 to $402 million. At the 5 1/4% prevailing prime rate it would cost Douglas $21 million a year to carry those inventories, or $9 million for the incremental inventories. Holding inventories an extra 2.5 months at those levels contributes $4.4 million to carrying costs. In addition, delays could also trigger penalty payments to airlines for late deliveries, litigation from dissatisfied carriers[9], and increasing demands for advances from suppliers. These delays would tar Douglas' reputation with suppliers, creditors, and customers.

We can see the elements of the causal chain that Douglas itself urged, from Vietnam to a surge in demand for aerospace products, to shortages of parts and personnel, ending up with Douglas announcing a loss in 1966 before swanning into McDonnell's embrace. Delays were costly and substantial for a company with net income in 1965 of $14.6 million after tax. The additional $4.4M of carrying costs due to delays pushed Douglas closer to the precipice.

As it lost its independence, Douglas pointed to forces beyond its control. However, Douglas was not the only company affected by Vietnam. Some insight into whether the fault lay in Long Binh or in Long Beach can be seen by comparing Douglas to a peer subject to similar shocks. Boeing had a similar mix of military and commercial revenues at the time. In 1966 52% of Boeing's revenues and 54% of Douglas' revenues came from the government. The victor's claims echoed those of the vanquished. Boeing announced in May 1966 that 707 and 727 deliveries extending as far as 1969 would suffer from one month delays because of "the increasing military requirement for [Pratt & Whitney] engines and engine parts". (Eastern Air Lines v. McDonnell Douglas, para 88). More than a year later, Boeing was still advising customers to expect one to two month delays through 1968 (Wright, 1967). In its 1966 Annual Report Boeing stated that "Difficulties were encountered in acquiring qualified employees in an extremely tight labor market, with the attendant problems of skill dilution, attrition, and major training programs. Extended lead times, delivery delays and increased costs for procurement and subcontracting work were also experienced. ….While the total national industrial expansion caused shortages in the supply of materials and parts, the most serious delay relayed to the inability of the engine manufacturer to support jet transport delivery schedules. …Due to the unavailability of engines and other factors the delivery of 20 727s and 14 707s was delayed." (p.13). Douglas couldn't have said it

[9] A jury in 1973 awarded Eastern Airlines $31.9 million in damages suffered from late Douglas deliveries between 1966 and 1968. After partial reversal on appeal, the matter was privately settled.

better.   But if it rained as much in Seattle that year as in Long Beach, why did only Douglas get soaked and suffer a fatal chill? The comparison is particularly sharp because both companies point explicitly to engine shortages and both relied not only on the same manufacturer, Pratt and Whitney, for both the DC-8 and the 707, but also in the case of the DC-9 and the 727, on the same engine, Pratt's JT8D. This can't just be about the rain. It must have something to do with umbrellas.

Table 1 compares inventories, sales, and inventory turns at Boeing and Douglas.   Inventories increased dramatically at Douglas in the fateful year 1966, but they increased more in both absolute ($286M vs. $168.3M) and in proportional terms (132% vs. 72%) at Boeing. Sales increased faster at Douglas (37%) than at Boeing (17%), so Boeing's ratio of inventories to sales also grew faster than Douglas'.   However Boeing was so far ahead in inventory management that Douglas still looked worse even after Boeing slowed down.

While comparisons depend on the accounting systems in use at each company, the difference in inventory turns (sales divided by average inventory) indicates an important difference between the companies. Boeing consistently turned over its inventory much faster than did Douglas. Both got worse in 1966, but even after this deterioration Boing was turning over its inventory twice as fast as Douglas (6.6 turns vs. 3.3 turns).   At least one hedge fund reasoned at the time that Boeing would be less seriously affected than Douglas by shortages of engines and landing-gears because of differences in organization of their production lines.[10] [SEC, 1970]. Even after Vietnam delays roiled the industry, Boeing's inventory carrying costs per plane would be half those of Douglas.

The manufacturer's exposure to inventory risk depends also on the terms on which they are financed. Short of cash, Douglas had innovated when it launched the DC-9 by having a set of major suppliers help finance development and agree not to take payment until each plane was delivered. This proved untenable, and Douglas, like Boeing, would make advance payment to suppliers. Both airframe manufacturers reported receiving advances and progress payments from customers at the same proportion of work in progress- 55% [11]. With similar advances from customers, Douglas' inventory carrying costs were greater than Boeing's because it held more inventories per plane.

Tying Douglas' downfall to the Vietnam War ignores the surge in demand that Douglas would benefit from as a military contractor. The argument also suffers from issues of timing and over-determinacy.

[10] This may refer to greater production in parallel rather than in sequence.
[11] Commercial customers typically advance 35% at least 6 months before delivery. The government advanced 80 to 90% of a contract that usually underestimated the eventual price.

Figure 1 plots DC-9 assembly hours by delivery date, along with the real value of the backlog to non-government customers of engines and aircraft components (product code 3722024) at the end of the month in which the plane was delivered, as reported by the U.S. Department of Commerce, Current Industrial Reports. [12] The learning curve in aircraft assembly is apparent, as is its stall in 1966 and deterioration at the beginning of 1967. The early 1966 stall pre-dates the surge in engine and parts backlogs at the end of 1966. Assembly hours were high even before the engine and parts backlog increased. McDonnell Douglas managed to sharply reduce assembly hours after mid-1967 even as the backlog rose to even higher levels. The Vietnam backlogs could not have helped commercial airframe manufacture, but Douglas' problems pre-dated the backlog surge, and McDonnell Douglas managed to dramatically improve assembly efficiency even as the backlog grew.

The Boeing comparison suggests that Boeing's internal management differed from that of Douglas. As a thought experiment, suppose we could equalize the management knowledge base across companies, for example by moving Boeing's top manager in charge of sales and engineering to Douglas. This thought experiment is a bit redundant, as both customers and suppliers are usually generous sources of rival manufacturer's plans. As Boeing was developing the B-47, B-52, Dash 80 and 707 its Vice-President for both Sales and Engineering was Wellwood Beall. In 1952 Beall became Boeing's Senior V.P., a position he retained until Boeing announced his "temporary retirement" in February 1964 [Flight, 1964]. In July 1964, Douglas reorganized its top management team, with a central role for the newly created position of Executive Vice-President of Operations, a position it filled with the same Wellwood Beall. On that day, on the major strategic aspects of operations, pricing, engineering, and plans, there would have been little that Boeing knew that Douglas was not also privy to. By that point, the DC-8 had already been flying for more than 6 years, and the DC-9 was half a year from its first flight.

V. Management Systems and Execution

While the structure of the airframe industry and the Vietnam supply shock both made Douglas' position difficult, neither seems sufficient to fully account for Douglas' demise. That requires in addition a set of execution errors: selling too aggressively, promising more than it could deliver, failing to manage order flow and inventories, whipsawing investors. All can be taken as symptoms of a deeper problem: either as the desperate decisions of a company struggling against a financially stronger rival, or as mistakes

[12] The backlog data is reported by the largest US aircraft engine and component manufacturers representing the bulk of the industry. A few months are interpolated because of missing data, and because the government suppressed data during the Vietnam War. Deflation is with the GNP price index for durable goods manufacturing reported in U.S. Bureau of Economic Analysis, [1977].

made by a weak management team. The seeds of Douglas' demise were planted not only by the structure of the market it competed in, but also by a failure of management systems and execution.

Donald Douglas Sr. ran his company in an unusually centralized manner. Twenty seven vice-presidents reported directly to him. All major corporate decisions were either made by or went directly through him. At the cusp of the jet-age the weakness of that system became apparent In 1957, Donald Douglas, Sr. enthroned his son as President. With Project Forge, Donald Douglas Jr. reorganized the company to allow more decentralized decision-making. A second reorganization in 1961 divisionalized the company and put Jackson McGowen in charge of the Aircraft Division. Were rapid decisions required and with good information and coordination systems and a cadre of experienced managers in place, this might have been good management. At Douglas none of the pre-requisites prevailed. Seasoned managers left Douglas in two waves. First when Donald Douglas Sr. isolated himself by installing his mistress as the gate-keeper to his office (Biddle, p. 318). Then between 1959 and 1962 Douglas again hemorrhaged experienced leaders as ten vice-presidents quit or were fired (Mecklin, 1966). In the judgment of the Fifth Circuit Court of Appeals, " the entire aviation industry [was] aware that Douglas' catastrophic financial crisis was, to some degree, precipitated by internal management difficulties" [Eastern Air Lines v. McDonnell-Douglas].

Douglas had neither good management controls nor good communications in place. Lazard Frères reported to Douglas and its bankers in December 1966 that Douglas suffered from "an overly sales-oriented operating management in the Aircraft Division which appeared to be functioning with little coordination with corporate staff, and a central corporate staff of generally mediocre caliber. [Douglas Aircraft] had gone, in a decade, from the tightly centrally controlled management of Douglas, Sr., with a position of unequalled leadership in the commercial aircraft industry, to a decentralized company which over the years had lost much managerial talent, and was left with inadequate leadership." (Gambrell, p. 18). An internal Douglas committee reported in August 1966 that "As commercial aircraft sales grew, production rates were changed and adjusted without adequate coordination and planning in both the Corporate Office and the Aircraft group." (Gambrell, p. 27). A McDonnell Co. executive investigated Douglas' operations in 1967 and reported "The over ambitious commercial delivery commitments overtaxed Engineering design output capabilities and disregarded the inherent lead time in the design/development cycle…It is difficult to understand how knowledgeable people throughout Douglas failed to recognize the potential problems and sound the alarm early in the program. The impending dangers could have been foreseen as the sales orders were logged…Only by extremely poor communication could the seriousness of the program have been ignored for so long. Certainly the organization structure was at fault in isolating management from such a problem. " (Gambrell, p. 11, p. 36).

With these weak systems in place, Donald Douglas Jr. gave the order to "Sell, sell, sell" (Gambrell). The salesmen did, and Douglas would soon collapse under the weight of their orders. When it launched the DC-9 program in 1963, Douglas expected to sell 400 of the planes over the next decade (Mecklin, p. 258). In a remarkable burst, Douglas sold 209 DC-9s in 1965. By year end 1966, DC-9 sales reached 424. Douglas had already exceeded its 10 year sales projection. The closest competing plane, Boeing's 737, would not enter commercial service for another two years. Despite facing little direct competition in the DC-9s short-range niche, Douglas priced low and promised early deliveries. As an outside consultant to Douglas would later report "[the Aircraft Division] went on a selling spree and sales exceeded its resources and its capability to produce" (Gambrell, p. 37).

In 1967 Donald Douglas, Jr. would explain these events by saying that his company has been "outrun by its own success" (Davies, 1967). Douglas' weak internal controls and lack of coordination between sales and production let events surprise and overwhelm the company. Douglas top management was surprised to belatedly learn they could not meet promised delivery dates or projected financial returns. The reversal was so sharp that disappointed investors sued the company in numerous proceedings for securities fraud and failure to disclose material information. Delays in delivering planes to Eastern Airlines, one of Douglas's largest customers, resulted in additional litigation. This mass of litigation offers an unusual window into Douglas's internal operations at the time, and reveals that Douglas's investors were not the only ones left in the dark. Top Douglas executives also appear to have been taken by surprise as Douglas's finances unraveled in the Spring of 1966. Douglas forecasts, internal as well as public, of sales, production, and earnings were both wrong and slow to catch up with reality.

Aircraft manufacturers plan output rates a year or more in advance. In a rare and risky move, Douglas launched the DC-9 in April 1963 with no orders in hand. With only 24 orders by January 1964, Douglas already planned to reach a maximum rate of eight DC-9s per month by the latter part of 1966 (Douglas, 1963). One year later with an additional 34 firm orders in hand, Douglas refined this plan to reach output of two per week by June of 1966, for an annual production plan of 82 (Douglas, 1964). The October 1964 internal operating plan increased planned 1966 deliveries by 27%.

Douglas had pioneered a new model of supply chain management. Still burdened by the DC-8s high development costs and slow sales, and short of cash to develop the DC-9, Douglas had engaged eight major suppliers and 20 sub-contractors in an attempt to shed some of both the costs and risks of project startup. In return for fixed-price contracts for an initial 125 ship-sets of sub-assemblies and parts, the suppliers would share in development and test costs and help finance development by agreeing not to take payment until each plane was delivered (Waddington, 1998). Although Douglas believed incentives were aligned, it was to discover that these contracts had no credible enforcement threat. With no revenues in sight, over-extended suppliers facing delays threatened either to further delay Douglas, to stop investing in the project, or to go bankrupt. Douglas learned how powerful the weak can be in such re-contracting negotiations, and was forced to advance working capital and divert Douglas managers and engineers to its wing and empennage (tail) supplier, DeHavilland of Canada[13]. DeHavilland had informed Douglas that DC-9 wings would be supplied late because Douglas had been late producing the final engineering drawings. Despite these problems, Douglas increased DeHavilland's delivery schedule by 50% in March, 1965[14] (Gambrell, pp. 9-10). By May, 1965 the DC-9 missed production milestones. It would not get back on schedule until late 1968. In September 1965 Douglas replaced its top manufacturing executive as a consequence of deteriorating performance in the Aircraft Division (Gambrell, p. 18).

Douglas had also fallen short in the management of basic business processes. Almost 70% of orders received by the purchasing department in FY1966 were received with less than the company's own 30 day minimum lead time (Gambrell, p.19). Planes were sometimes released to begin manufacture without any engines having been ordered, in what Douglas' Director of Commercial Contracts Administration would in 1967 describe as a "gamble". In some cases engines lay on Pratt & Whitney's shipping docks awaiting the arrival of shipping stands from Douglas (Gambrell, p. 20).

By November, 1965, sales orders reached a new record at Douglas. On January 31, 1966, Douglas increased planned FY1966 DC-9 deliveries to 93 (Douglas Aircraft, 1965, p.16). At the same time Douglas knew it would be unable to meet delivery dates it had contracted for under contracts signed 6 months earlier (Eastern Air Lines v. McDonnell Douglas, para 7). By mid-year 1966 planned deliveries

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[13] It is ironic that four decades later Harry Stonecipher, a former McDonnell-Douglas CEO who had become CEO of Boeing would lead Boeing down the same path. Boeing's attempt to off-load costs and risks in developing its 787 met with similar disastrous results.

[14] As they became direct competitors, DeHavilland would exacerbate Douglas' cash-flow problems by forcing Douglas into a $86M Fall 1965 buyout of its DC-9 interests. Douglas was also investing in the C5A competition.

had dropped to 78, and by the end of September 1966 to 63 (Business Week, 1966, p.178). Douglas would deliver 64 DC-9s in FY1966, 29 short of the plan set just 10 months earlier.[15] Even at mid-year Douglas was still underestimating this decline by half. As orders took off, production fell 31% below a plan not yet one year old. The company had lost control.

Historical counterfactuals are risky terrain, but the idea that Douglas could have competed using later and more accurate delivery dates is strengthened both by the fact that the 737's first flight was more than two years after the DC-9s, and would also quickly develop a backlog.

What They Didn't Know and When They Didn't Know It.

At its annual meeting on April 20, 1966, Donald Douglas, Jr. boasted that the company was "in one of the most satisfactory phases of its history." (Eddy, 1978). Douglas stockholders were told that earnings would improve in FY1966 over its 1965 level of $3.15 per share. The extensive litigation record indicates that investors were not the only ones in the dark. Poor information and controls allowed Douglas top management to be taken unawares by reversals in its most important division.

By February 1966 Jackson McGowen had begun warning some airlines of delays. This news would not reach Donald Douglas, Jr. until May 27 (Gambrell, p. 25), when he learned that the Aircraft Division was experiencing inefficient production and supplier delays. Four days later, he learned that the delivery of eighteen airplanes would be delayed into the next fiscal year, and that earnings for the year would drop to about $2.00 per share [Financial Industrial Fund]. Over the next 16 days, $11M in earnings would evaporate from Douglas' internal earnings projections for FY1966. On June 7, Douglas announced earnings of 85 cents per share through April 30, 1966. Unusually, this report was for the first five months of its fiscal year.

Additional troops were deployed, but the die had already been cast. By June 7 Douglas borrowed $30.4M short-term. On June 17th Douglas sent fifty to seventy engineering, estimating, and accounting officials to investigate delays and rising costs in the Aircraft Division (Beecher v. Able), a clear sign that Douglas had lost faith in Division management. Corporate was informed on June 20th that the expected six months earnings figure would be about forty-nine cents. The same day Douglas informed Merrill Lynch, underwriter of a Douglas debt offering, that Douglas now expected to have little or no profit for FY1966 (Robards, 1968). After meeting with outside auditors, Douglas decided on June 22 that a

[15] At FY1966 year-end management was reduced to shturmovshchina (storming). Three DC-9s were delivered at the fiscal close, exhausting the pipeline until the next delivery 15 days later.

substantial inventory write-down was required to reflect higher than expected costs. On June 24, Douglas issued a special earnings statement with the startling news that its earnings for the first six months of its 1966 fiscal year (through May 31) were 12 cents per share, and that it expected that its earnings for the full 1966 fiscal year would be nominal, if any (Shapiro v. Merrill Lynch). A financial tsunami was washing over Douglas, and the company's internal forecasts never caught up with its plummeting earnings (Table 2). In a sharp reversal from its $4M profits in 1966Q1, Douglas would subsequently report net losses of $3.5M in Q2, $17M in Q3, and $11M in Q4.

On July 8 Douglas Jr. reported to his Board that the Aircraft Division expected a pre-tax loss of $27.8M for the fiscal year (Beecher vs. Able), a $44.7M drop from the $16.9M profit planned just four months prior, dryly allowing that "perhaps commercial transport orders were received at too fast a pace" (Gambrell, p. 26).

On October 10, Douglas' banks suspended its line of credit as a result of the sharp downturn revealed in its August 31 interim financial statement (Beecher vs. Able). The banks demanded that Douglas raise another $100M in equity, but Douglas's Investment banker, Merrill-Lynch, advised against attempting a public offering. Douglas stock, which had soared to a record $112 in May 1966, had crashed to $30. The capital markets were closed to Douglas at this point.[16] By January 13, 1967 Douglas' bankers had pushed it into McDonnell's embrace. Douglas had lost $52M pre-tax by the end of FY 1966, $77M in its Aircraft Division.

Douglas's Business Plan

Combining internal Douglas production records with scattered published shards, we can assemble enough pieces of Douglas's business plan for the DC-9 to get a sense of where the plan fell short. Douglas spent $100M to develop the DC-9, and expected to reach break-even at about the 150th plane (Birtles, 2002). Assume the $100M includes all relevant fixed costs. With interest, this means that the expected excess of revenue over variable cost on the first 150 planes was at least $123M. DC-9s were initially listed at $3.1M. Ignoring both possible discounts below list and subsequent price increases, expected revenue on the first 150 planes would be $465M. To break even the aggregate variable costs on these planes could not exceed $342M. Douglas had contracted for the first block of major components in contracts totaling $108.1M for 125 ship-sets[17] of wings, tail, and empennage, air

[16] The capital needed to compete, and investors view of the future of the jet age, can be seen in Boeing's success raising $113M in additional equity and $368M of additional long-term debt during 1966.
[17] Development costs increased over time.

conditioning and heating equipment, engine pods, generators, flight controls, and landing gear [Douglas, 1964]. Engines represented roughly 1/5 of the plane's price. The listed equipment and sub-assemblies total $223M pro-rated over the first 150 planes. The remaining variable cost, for production labor and other parts, would have been less than $120M to break even on the first 150 planes.

Internal Douglas records show that assembly hours on the first 150 DC-9s produced through August 1967 were 2.23 times greater than planned for, enough to increase Douglas' wage costs by some $32M[18] and push it deeply into the red. These additional unexpected assembly costs held Douglas' financial head under water.

Douglas expected that marginal revenues would exceed its manufacturing costs beginning with the 21st plane (Mecklin, 1966, p. 256.). Internal records show that Douglas expected to take somewhat less than 70,000 hours to assemble that plane. In practice, assembly hours would not fall below this level until the 220th plane was delivered in December 1967, 19 months after Douglas had expected to begin earning a return on its investment.

Assembly costs had spiraled out of control. In the internal records on DC-9 assembly, we can distinguish whether cost overruns in assembly were due to extra production hours or to extra development work taken on in producing new models and variants. The Douglas records show the 20% learning curve they were expecting (exact to 4 decimal places)[19], as well as actual hours categorized as either production, development, or unscheduled[20]. Classifying planes by the quarter in which they were delivered, we find that development work during assembly accounted for only 14% of the excess hours during FY1966, and these were front-loaded. Douglas' attempt at mass customization was costly, but far from fatal. The majority, 69%, of excess hours came about because production took more time than expected. These production overruns became worse in the fourth quarter, as engine delays became worse. Development and unscheduled hours fell sharply during the first year's output and contributed to a learning curve, but production hours themselves remained stubbornly high.

Douglas expected to lose $15M building the first 20 DC-9s (Mecklin, 1966, p. 256). It lost $25M, as their production extended into March 1966. Through the fateful fiscal year end 1966, excess production

[18] Production workers in the airframe industry averaged $3.34/hour with over-time in 1966. (U.S. B.L.S., 1979).
[19] This had long been the industry rule of thumb.
[20] These are hours classified as neither production nor development.

hours would have cost Douglas this $10M overrun on the first 20, plus roughly $13M[21] on the next 47 FY1966 deliveries. The combined $23M assembly cost overrun can account for much of Douglas' unanticipated $52M pre-tax loss for the year. Douglas' accounts also suffered from the delayed recognition of previously incurred expenses. Rather than expensing the DC-9's $100M development cost, Douglas amortized the expense at $200,000 per plane beginning with the 21st plane. This resulted in an additional –predictable- $9.4M expense in FY1966. The costly surprise at Douglas was that assembly hours failed to fall as rapidly as had been expected.

Financial Management

Douglas had stopped paying dividends for six years, only restoring them in March 1965. The profits reported in 1964 and 1965 depended entirely on Douglas' 1963 decision to amortize, rather than expense, DC-9 development costs which far exceeded reported earnings in those years. On April 13, 1966 Douglas called its $27.9M 4% convertible debt. Since the market price was above the conversion price, virtually all (97%) bondholders converted. Three months later, on July 12, Douglas offered $75M of new 4 ¾ % convertible debt. This is an expensive round-trip into a higher interest rate. On its face, this looks like financial mismanagement, or at least a company that was surprised after it called its debt to learn it needed more. This simple inference unravels completely: the two transactions were planned at the same time. On March 31, 1966 Douglas signed a letter of intent with Merrill-Lynch to underwrite new convertible debt to follow the redemption. On April 12, 1966 Douglas signed a stand-by agreement with Merrill-Lynch to manage the redemption of its outstanding convertible debt. [SEC File 3-1680]. Why would a firm foreseeing financial problems pay a million or two in transaction fees to call 4% debt only to attempt to replace it with more debt at a higher 4 ¾ % interest rate?

Calling the 4% note when the stock price exceeded the conversion price served to increase Douglas's equity. A secondary stock issue could be priced poorly if it were seen as sending a poor signal. Unlike a secondary stock issue, the company's downside on the price of the new equity in the conversion was bounded by the conversion price. Douglas timed its call and its earnings announcements so market price exceeded the conversion price, ensuring that it would secure additional equity. The additional $23.6M paid-in capital in turn could be used to help support the issue of greater debt, as Douglas would quickly do. These actions are consistent with a company that by March of 1966 realized it would need to strengthen its balance sheet, but preferred to raise equity without going to the equity market.

[21] This is calculated by applying Douglas' reported manufacturing loss of $200,000 per plane around the 50th plane delivered divided by this plane's excess hours, to each plane's production hours in excess of the 70,000 hour cross-over point.

Earlier in 1964 Douglas had become the first firm in the industry to finance its customers. The Douglas Finance Corp. issued $18M of secured debt in 1964. By 1966 this had ballooned to $110M. Douglas lit both ends of this candle, borrowing $103M from (presumably other) airlines in the form of interest bearing advances.

VI. Conclusion

While DeHavlland, Avro, and Sud-Aviation long ago vanished in Boeing's wake, their departure and a growing historical haze has led to a survivor bias that has transformed the subsequent success of a 4th mover into a first mover advantage. Entering commercial jet transport well before Boeing, these companies managed to offset the putative advantages of prior entry. DeHavilland would discover the hard way that square windows on aircraft travelling at high altitudes were a bad idea because they concentrated forces that would explode the plane, taking down some of the firm's reputation with it. Avro found pilots so afraid of popping noises on its first publicity flight that they grounded the plane, a Minister of Industry so focused on the prospects of military production that he refused to entertain commercial orders, and a launch customer CEO who cancelled out of fear that potential passengers were afraid of jets. Sud Aviation aimed too small with its Caravelle, and then too early became enamored of the prospects of supersonic transport.

This is not just a list of idiosyncratic exceptions. The advantages of early movers inevitably come bundled with an abundance of risks. Early movers face technological risks (DeHavilland), political risk (Avro, DeHavilland trying to enter US), market risk (Avro, Sud Aviation), and production risk (Douglas) any one of which can take the company down.

The Vietnam supply shock by itself cannot explain why Douglas fell while Boeing prospered. Douglas performed worse under stress because of poor management information, planning and coordination systems that let it sell planes that could not be produced on time even before Vietnam brought these problems painfully to the surface. Delays would increase Douglas' assembly and carrying costs by about $27M in FY1966, more than half the loss that would drive it into McDonnell's embrace.

The dawn of the commercial jet age soon developed into a war of attrition played out in increasing investments in differentiation. High fixed-costs coupled with strong learning curves would limit the number of producers and yield a cost advantage to those who could harness economies of scope with broader product lines. In this unforgiving environment, it's failures to execute drove Douglas out of business.

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Table 1: Inventory and Inventory Turns at Douglas and Boeing

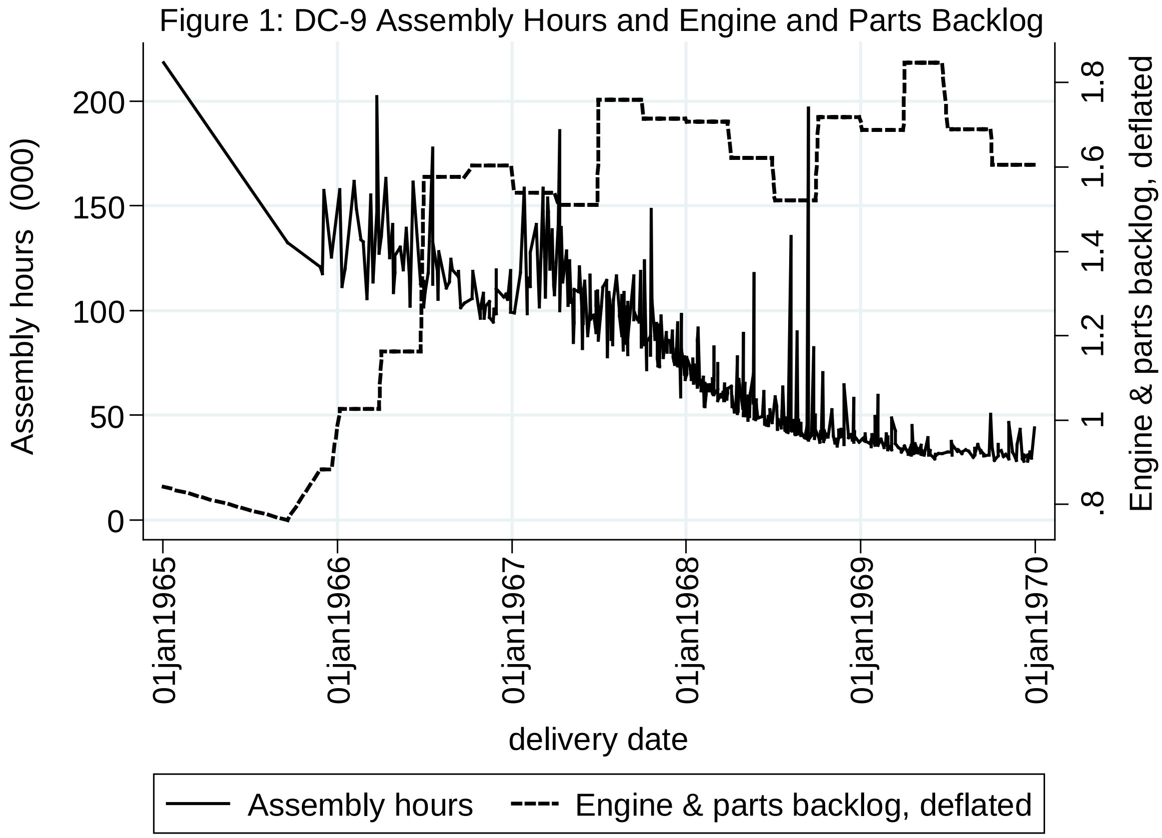
Douglas Aircraft					
	1966	**1965**	**1964**	**1963**	
Sales	1,048	767	650		
Inventory	401.9	233.6	128.8	118.9	
Average Inventory	317.75	181.2	123.85		
Sales/Av. Inventory	3.3	4.2	5.2		
%Delta Sales	37%				
%Delta Inventory	72%				
Boeing					
	1966	**1965**	**1964**	**1963**	
Sales	2,357	2,023	1,969		
Inventory	501.7	215.8	195	318.1	
Average Inventory	358.75	205.4	256.55		
Sales/Av. Inventory	6.6	9.8	7.7		
%Delta Sales	17%				
%Delta Inventory	132%				

Source: Boeing and Douglas Annual Reports.

Table 2: Douglas Aircraft Co.'s Earnings Projections for Fiscal 1966.

Date of Projection	Estimated After Tax Earnings for Fiscal 1966	Per Share
Feb. 15, 1966	$19.2 Million	$4.15
Apr. 12, 1966	$16.9 Million	$3.22
	$21.5 Million	$4.11
May 31, 1966	$10.5 Million	$2.01
June 17, 1966	$470,000 loss	$.09 loss
June 19, 1966	$994,000	$0.19
	$26,000 loss	$0.00 loss
	$2.27 Million loss	$0.43 loss
June 21, 1966	$1.026 Million	$0.20
	$6,000	$0.00
	$2.24 Million loss	$0.43 loss
June 24, 1966	$662,000	$0.12
July 8, 1966	$519,000 loss	$0.10 loss
Realization	$27.6 Million loss	$5.23 loss

Sources: Beecher v. Able; Douglas Aircraft Co. 1966 Annual Report



Sources: Douglas Aircraft Co.; U.S. Department of Commerce, 1968-1976.