Eisenhower versus the Spin-off Story: Did the Rise of the Military–Industrial Complex Hurt or Help America's Commercial Aircraft Industry?

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In his Farewell Address, President Eisenhower warned that the military-industrial complex (MIC) threatened to dominate American research, crowding out commercial innovation. Ironically, a number of analysts point to spin-off benefits of the 1950s' military effort as a crucial source of American high-tech competitiveness, often citing the key example of the relationship between military jet aircraft and the Boeing's 707. But the huge military investment in jet aviation had both benefits and costs for the commercial industry. This article compares the development of the Boeing 707 and its relationship to military projects like the KC-135 tanker to the contemporary development of commercial jet aircraft by other companies that were also integral parts of the military-industrial complex (MIC), including Douglas Aircraft and its commercial DC-8 and Convair and its commercial 880 and 990. Using evidence from archives, interviews with retired company executives, contemporary trade press, and academic studies, the article concludes that membership in the MIC did not offer firms a leg up in commercial markets. President Eisenhower was generally right about the costs of the military effort, but military spending remained low enough to allow commercial industry to thrive in parallel to the defense industry.

In his January 1961 "Farewell Address," President Eisenhower warned of the rise of the military–industrial complex (MIC), whose

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"total influence—economic, political, even spiritual—is felt in every city, every State house, every office of the Federal government."[1] For the first time in American history, a large segment of industry invented, produced, and sold weapons to a government buyer on a sustained basis rather than as a temporary diversion from commercial markets. That new industry, combined with millions of people working in the government's military establishment, would be a new force in American politics. Though necessary to preserve American liberty against the Soviet threat, the MIC might simultaneously subvert the American democratic process: "In the councils of government, we must guard against the acquisition of unwarranted influence, whether sought or unsought . . . The potential for the disastrous rise of misplaced power exists and will persist." The concentrated interest might direct too much American effort toward the military, and the need for high-tech weapons might make "public policy . . . captive of a scientific-technological elite." President Eisenhower mainly called for statesmanship to preserve American liberty.

But Eisenhower also recognized that the American way of life relied on underlying American prosperity, also perhaps threatened by the MIC. Military effort could demand too much of the American economy. Military hierarchy, large organizations, and government direction of research funding threatened to stifle American innovation. Eisenhower warned, "a government contract becomes virtually a substitute for intellectual curiosity . . . . The prospect of domination of the nation's scholars by Federal employment, project allocations, and the power of money is ever present—and is gravely to be regarded." In sum, defense R&D might crowd out independent research and commercial investment, shifting funding and scientists' effort away from market-oriented innovation toward big projects for defense.

Ironically, others have hailed the same changes in high-tech industry in the 1950s that led to President Eisenhower's warning as the *source* of America's high-tech advantage. The intuition that military innovation "spun off" to the commercial sector—that membership in the MIC gave firms a major leg up over commercial competitors—has had a pervasive influence on public discussions, negotiators' positions in trade disputes, and prominent economists' models of high-tech

1. President Dwight D. Eisenhower, "Farewell Radio and Television Address to the American People, January 17, 1961," Dwight D. Eisenhower Presidential Library and Museum, http://www.eisenhower.archives.gov/All_About_Ike/Speeches/Farewell_Address.pdf.

trade. The leading example comes from the 1950s: analysts often cite the relationship between military jet aircraft and Boeing Aircraft Company's tremendously successful commercial jet, the 707.[2] The "military subsidy theory" is a useful name for this alternative explanation of the effect of defense spending on commercial industry.

Was President Eisenhower wrong? Did military spending help the U.S. economy? Few people remember the actual history of the connections between military and commercial aircraft projects at the dawn of the jet age, and fewer still have systematically considered how those connections affected competitiveness of firms and countries. This article explains the complex relationship between the MIC and civilian aviation. Empirically, it compares the development of the Boeing 707 and its relationship to military projects like the KC-135 tanker and the B-47 bomber to the development of commercial jet aircraft by other companies that were also integral parts of the MIC, including Douglas Aircraft and its commercial DC-8 and Convair and its commercial 880 and 990. The article concludes that while the MIC helped push the state of the art in aircraft technology, military contracts neither have a strong impact on particular firms' competitiveness in commercial markets nor create an American competitive advantage versus European aircraft manufacturers.

The 1950s were an era of large-scale innovation in both military and commercial markets. Overall, the huge military investment in jet aviation had both benefits and costs for the commercial industry. The military and commercial markets each had their own political economy, driven by different consumers. Military innovation responds to the strong interests of the military, and commercial innovation responds to the strong interests of commercial airlines. Military effort crowded out civilian effort within certain firms: the MIC aircraft firms as a whole did poorly in commercial high-tech markets, and by the mid-1960s, the most successful commercial aircraft firm, Boeing, was actually out of the military aircraft business. But overall the American defense effort did not swamp the available scientific talent or

2. See, for example, Ann Markusen and Joel Yudken, *Dismantling the Cold War Economy* (New York: Basic Books, 1992), 57; Paul Krugman, *Peddling Prosperity: Economic Sense and Nonsense in the Age of Diminished Expectations* (New York: W.W. Norton and Company, 1994), 238–9; Michael E. Porter, *The Competitive Advantage of Nations* (New York: The Free Press, 1990), 96; Laura Tyson, *Who's Bashing Whom? Trade Conflict in High-Technology Industries* (Washington, DC: Institute for International Economics, 1992); Gregory Hooks, "The Danger of an Autarkic Pentagon: Updating Eisenhower's Warning of the Military-Industrial Complex," in *The Military-Industrial Complex: Eisenhower's Warning Three Decades Later*, eds. Gregg B. Walker, David A. Bella, and Steven J. Sprecher (New York: Peter Lang, 1993), 159.

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overwhelm the attraction of profits from commercial markets: the United States was big enough to produce innovative aircraft for both military and commercial customers in the 1950s and 1960s.

President Eisenhower was right about the potential danger, but his own statesmanship as president bounded the scale of military effort in the 1950s. His successors should (and often did) heed his warning to keep defense spending enough in check to preserve commercial competitiveness and American prosperity.

The Military Subsidy Theory

The military subsidy theory holds that Cold War procurement of advanced military aircraft had indirect technological and financial benefits for the aerospace industry's commercial business.[3] Some authors have also used the theory to explain the competitive failure of the British and French aircraft industries—that is, the lack of adequate military support may have led to the demise of otherwise-viable European firms.[4]

The core of the military subsidy theory contends that a significant economy of scope links the commercial transport aircraft business to the business of developing and producing military aircraft. Few argue that the U.S. government has intentionally overpaid for its defense purchases to hide a subsidy to the commercial aircraft industry. The U.S. military generally feels pressed for sufficient budget authority to fund its response to international threats. Instead, the military subsidy argument emphasizes positive externalities that may link the military and

3. The same general story may also apply more broadly across high-tech industries, including modern electronics, communications, and computers; military spending has been one of the major mechanisms for government involvement in the economy. See, for example, Tyson, *Who's Bashing Whom?*, 82, 89; Kenneth Flamm, *Creating the Computer: Government, Industry, and High Technology* (Washington, DC: Brookings Institution, 1988), esp. 134, 208; Werner Neu, Karl-Heinz Neumann, and Thomas Schnöring, "Trade Patterns, Industry Structure and Industrial Policy in Telecommunications," *Telecommunications Policy* 11, no. 1 (1987): 39.

4. The European competitive failures allegedly explained by the military subsidy theory predate the formation of the Airbus consortium. In the British case, Keith Hayward points to the ramifications of the Defence White Paper of 1957. See Keith Hayward, *Government and British Civil Aerospace: A Case Study in Post-War Technology Policy* (Manchester: Manchester University Press, 1983), 37. In the French case, Bernard Marck points to the troubles of the Sud Caravelle in the early 1960s. See Bernard Marck, *Dassault, Douglas, Boeing, et les autres. . .: La Guerre des Monopoles* (Paris, France: Editions Jean Picollec, 1980), 56, 60.

Table 1 Summary of the military subsidy theory

Transmission mechanism	Explanation
Plant-level financial	(1) Military projects help amortize tooling costs. (2) Military projects contribute to cost-reducing learning.
Plant-level technological	(1) Military R&D spins off innovations. (2) Technological leadership helps commercial sales.
Firm-level financial	(1) Multiple projects reduce total technological risk. (2) Multiple markets smooth business cycle fluctuations.
Firm-level technological	(1) Military projects can keep commercial design teams together while they await new commercial projects. (2) Military systems integration experience transfers to complex commercial projects.

commercial market segments.[5] The American Cold War buildup allegedly served as an unintended industrial policy in the aerospace sector.[6]

Defense acquisition can directly affect commercial industry in four ways, classified according to the point at which the military expenditure would aid the industry (the plant level or the firm level) and according to the type of support that the military allegedly would provide (financial or technological).[7] We can therefore consider four "transmission mechanisms" by which military aircraft projects might affect the success of contemporary commercial aircraft projects. Table 1

5. David C. Mowery and Nathan Rosenberg, *Technology and the Pursuit of Economic Growth* (New York: Cambridge University Press, 1992), 185; Artemis March, "The US Commercial Aircraft Industry and its Foreign Competitors," MIT Commission on Industrial Productivity Working Paper, vol. 1 (Cambridge, MA: MIT Press, 1989), 16.

6. Tyson, *Who's Bashing Whom?*, 169; Shane Spradlin, "The Aircraft Subsidies Dispute in the GATT's Uruguay Round," *Journal of Air Law and Commerce* 60 (1995): 1217; Thomas A. Heppenheimer, *Turbulent Skies: The History of Commercial Aviation* (New York: John Wiley & Sons, 1995), 2.

7. William W. Sharkey, *The Theory of Natural Monopoly* (New York: Cambridge University Press, 1982), 73–80; U.S. Congress, Office of Technology Assessment, *Assessing the Potential for Civil-Military Integration: Technologies, Processes, and Practices* (Washington, DC: GPO, September, 1994), 101. Military spending may also have affected commercial high-tech industry through less direct routes, for example by expanding the supply of labor with relevant skills (through military funding of universities and, specifically, graduate student research). The relationship between the military and universities is the subject of its own vibrant scholarly literature, including Stuart W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford* (New York: Columbia University Press, 1993). That literature complements the present article by helping us understand the overall effects of the American defense effort. However, broad-based investments in human capital development are unlikely to explain different levels of competitive success among firms. If certain firms took better advantage of the labor market than their competitors, then we should attribute their success to their adroit hiring choices rather than to the nationwide investment in human capital.

summarizes the plant-level financial, plant-level technological, firm-level financial, and firm-level technological transmission mechanisms of the military subsidy theory.

The Plant-Level Financial Transmission Mechanism

The plant-level financial transmission mechanism suggests that an aircraft firm should be able to lower its production costs by working on both commercial and military projects in the same facility. Aircraft production is characterized by strong economies of scale—that is, by rapid reduction in unit costs as the total number of airplanes produced increases. If military production can contribute to a commercial product's cost-reduction trajectory, then that military production directly improves the firm's commercial competitiveness.

The economies of scale principally derive from two sources. First, designing and purchasing product-specific machine tools necessary to build airplanes is very expensive, and those upfront costs need to be amortized over as many units of output as possible, including both military and commercial production.[8] Second, commercial plant-level finances also may be aided by military production that helps to drive workers down the "learning curve" on a common design feature. Workers gain experience, make fewer mistakes, and identify important labor-saving shortcuts and process innovations as they work on more and more copies of the same aircraft model or part.[9] Any transfer of learning effects from military to commercial production—for example, if the same workers spent part of their time on each of two related programs—would constitute an economy of scope at the plant level that could reduce a commercial project's production costs and therefore increase its competitiveness.

However, countervailing factors limit the substantive importance of the plant-level financial transmission mechanism as a source of competitive advantage. Commercial aircraft final assembly involves a certain amount of tooling and learning, which are subject to economies of scale, but many of the details of commercial aircraft are customized for different airline buyers. Customization reduces the repetitive work that would contribute to scale economies. Plant-level financial effects are more likely to operate strongly for parts manufacturing, but

8. Richard J. Samuels, *"Rich Nation, Strong Army:" National Security and the Technological Transformation of Japan* (Ithaca, NY: Cornell University Press, 1994), 294–6.

9. Marc Busch, *Trade Warriors: States, Firms, and Strategic Trade Policy in High Technology* (New York: Cambridge University Press, 1999), 44–5.

parts are often made in subcontractors' facilities.[10] Either the subcontractors would garner the profits associated with the scale economies or the benefits would be shared among all potential customers of that subcontractor, any of whom could buy the part at a lower price.[11] Because subcontracting can (and did) extend internationally, plant-level benefits of military production for reducing the cost of parts manufacturing would not have changed competitiveness in the commercial aircraft industry at either the firm or the national level.

Evidence of the plant-level financial transmission mechanism of the military subsidy theory must focus on two things: (1) specific components whose cost amortization and learning effects contribute to both commercial and military products and (2) cost reductions that offer an advantage to one firm without offering the same benefit to competitors via subcontracting.

The Plant-Level Technological Transmission Mechanism

A second way that defense procurement might exert a positive externality on the commercial aircraft industry is by the spin-off of innovations.[12] If advances in the technological state of the art are an important source of competitive advantage for aircraft manufacturers, then military contracts may contribute to competitiveness if they

10. J. A. Alic, L. M. Branscomb, A. B. Carter, and G. L. Epstein, *Beyond Spinoff: Military and Commercial Technologies in a Changing World* (Boston: Harvard Business School Press, 1992), 168–9; Arthur James Raymond, "Applicability of Toyota Production System to Commercial Airplane Manufacturing," (Master's Thesis, Cambridge, MA: MIT, May, 1992), 70; J. W. Barton, "Factors Influencing Airplane Costs" (paper delivered at the SAE National Aeronautics Meeting, New York City, April 22, 1953), 35.

11. Especially during periods of technological change, downstream firms may not all take equal advantage of potential economic gains available at the subcontractor level: for example, only some final assemblers may be aware of a low-cost supplier that has benefited from military-derived economies of scale. But if one firm gained competitive advantage due to a favorable supplier network, its supplier-relations strategy (or dumb luck) should get credit rather than participation in the MIC—unless participation in the MIC specifically explains the downstream firm's choice of the "right" supplier. In practice in the jet aircraft industry of the 1950s and 1960s, as discussed below, the major aircraft manufacturers' supplier networks overlapped—in fact not just in theory—so the various aircraft manufacturers generally used directly comparable subsystems.

12. Michael Borrus, "Investing on the Frontier: How the U.S. Can Reclaim High-Tech Leadership," *The American Prospect* 11, (1992): 79; Keith Hayward, *The British Aircraft Industry* (New York: Manchester University Press, 1989), 71; David Weldon Thornton, *Airbus Industrie: The Politics of an International Industrial Collaboration* (New York: St. Martin's Press, 1995), 26.

push the technological envelope.[13] Firms that work on innovative military designs may apply the new technologies developed for the military to their commercial models.

As in the plant-level financial story, a plant-level technological externality can only reorder commercial competitiveness if it does not diffuse to competitors, and especially foreign competitors. The military subsidy theory therefore requires that aircraft firms with higher levels of military business have faster or lower-cost access to military-derived inventions. First, the military contracts might offer research scientists and design engineers intangible learning effects—benefits that cannot readily be transmitted to competitors even if the results of R&D contracts are made public.[14] Second, there may be official delays in the publication of research results that give an advantage to those (domestic) aircraft manufacturers who have early access to the inventions.[15] Finally, government research may be timed to favor the investment cycle of domestic manufacturers rather than foreign firms, and it may be targeted at technological problems linked more closely to domestic manufacturers' business strategies, making the results more useful to the home firms than to foreigners.[16] Any one of these three detailed transmission mechanisms might allow the plant-level technological transmission mechanism to function.

The plant-level technological transmission mechanism faces two separate constraints. First, military research and development spending focuses on innovations to help military users and

13. For the importance of innovation to aircraft industry competitiveness, see House of Commons, Trade and Industry Committee, *Third Report, British Aerospace Industry*, vol. 1, (London: HMSO, July 1, 1993), 26. For the role of military contracts in pushing the state of the art during the Cold War, see Michael Brown, *Flying Blind: The Politics of the Strategic Bomber Program* (Ithaca: Cornell University Press, 1992); Barton, "Factors Influencing Airplane Costs," 14–15.

14. Busch, *Trade Warriors*, 59; David C. Mowery, *Alliance Politics and Economics: Multinational Joint Ventures in Commercial Aircraft* (Cambridge, MA: Ballinger Publishing Company, 1987), 20; Lewis M. Branscomb and George Parker, "Funding Civilian and Dual-Use Industrial Technology," in *Empowering Technology: Implementing a U.S. Strategy*, ed. Lewis M. Branscomb (Cambridge, MA: MIT Press, 1993), 80.

15. National Research Council, *Conflict and Cooperation in National Competition for High-Technology Industry* (Washington, DC: National Academy Press, 1996), 41–3, 55–9; U.S. International Trade Commission, *Global Competitiveness of U.S. Advanced-Technology Manufacturing Industries: Large Civil Aircraft*, Investigation No. 332-332, Publication 2667 (Washington, DC: GPO, August, 1993), Chapter 5, 5.

16. Council on Competitiveness, "U.S. R&D Policy for Competitiveness Sector Study: Aircraft," in *Endless Frontier, Limited Resources* (April, 1996), 8.

consequently may not develop new products that are useful to the commercial aircraft industry—that is, there may be no spin-off at all. Second, technological improvements that do spin off from defense projects may be available to all competitors in the aircraft manufacturing market, specifically including international competitors. In that case, the entire, worldwide aircraft industry might benefit from the research, but the spin-off would not play any role in shifting competitive advantage among the various producing firms.

Strong evidence of the plant-level technological transmission mechanism would carefully show the specific competitive effect of an innovation originating in a military project applied by select commercial aircraft manufacturers but not by their competitors.

The Firm-Level Financial Transmission Mechanism

Large high-tech firms, including aircraft manufacturers, can gain a financial benefit by diversifying their risks, working on a portfolio of development and production projects at the same time. Firms that work on both military and commercial aircraft projects may gain a particularly large financial benefit. The military subsidy theory includes three specific firm-level financial arguments.[17]

The most commonly cited though least persuasive argument suggests that military contracts provide easy cash flow that American prime contractors use to launch commercial aircraft projects.[18] The idea is that aerospace firms might be able to "lose" the initial exploratory investment required by a new commercial model in the flood of Department of Defense (DoD) money. In its most extreme version, this story involves excess profits on DoD contracts that are readily transferred to commercial projects;[19] a more reasonable version suggests that the large scale of DoD projects provides a steady baseline on which aerospace firms can build a strong credit rating, hence the DoD work lowers firms' cost of capital and eases new investment.[20]

17. See March, "US Commercial Aircraft Industry," 16–18.

18. Steven McGuire, *Airbus Industrie: Conflict and Cooperation in US-EC Trade Relations* (New York: St. Martin's Press, 1997), 28; Ronald Miller and David Sawers, *The Technical Development of Modern Aviation* (New York: Praeger, 1968), 279; Hayward, *British Aircraft Industry*, 71; Vicki L. Golich, "From Competition to Collaboration: The Challenge of Commercial-Class Aircraft Manufacturing," *International Organization* 46, 4 (1992): 919.

19. Tyson, *Who's Bashing Whom?*, 169–70.

20. Keith Hayward, *International Collaboration in Civil Aerospace* (London: Frances Pinter Publishers, 1986), 159–60.

Proponents of the military cash flow hypothesis misunderstand the defense business, which is actually highly uncertain and sometimes unprofitable.[21] Defense firms face high obligations to pass on their revenue stream to suppliers, lenders, and workers, so little of their defense cash flow is available for use in the commercial business. The DoD is actually uniquely careful about monitoring its prime contractors precisely to ensure that contractors do not engage in slack accounting practices with taxpayers' money.[22] Aircraft firms are unlikely to be able to divert money meant for defense work to support commercial initiatives.

The other two firm-level financial transmission mechanisms both involve the smoothing of risk.[23] The simplest financial models of investment risk suggest that owning a basket of even very high-risk businesses is preferable to concentrating in a single, risky sector. In high-stakes R&D projects, no one can know *ex ante* which of several projects will be the winning bet, but a given firm is certainly more likely to have at least one winner if it is involved in more projects.[24] Adding military projects to commercial ones should not change the likelihood that any particular project will succeed on technological grounds, but it may make lenders willing to give money to the firm at a lower interest rate. Lower capital costs will improve competitive prospects for any project that does come to technological fruition.

Unfortunately, piling military projects on top of commercial ones may in fact reduce the likelihood of a technological success in the commercial sector by bidding up the cost of inputs. During surges in

21. William P. Rogerson, "Economic Incentives and the Defense Procurement Process," *Journal of Economic Perspectives* 8, 4 (1994): 74; Karen W. Tyson, J. Richard Nelson, Neang I. Om, and Paul R. Palmer, *Acquiring Major Systems: Cost and Schedule Trends and Acquisition Initiative Effectiveness* (Alexandria, VA: Institute for Defense Analysis, 1989), Section IV.

22. William B. Burnett and Frederick M. Scherer, "The Weapons Industry," in *The Structure of American Industry*, ed. Walter Adams (New York, 1990), 300–1; 303–8. In fact, much has been written about the competitive disadvantage that DoD overseers impose on defense contractors. For example, Alic et al., *Beyond Spin-Off*, Chapter 5; Jacques S. Gansler, *Defense Conversion: Transforming the Arsenal of Democracy* (Cambridge, MA: MIT Press, 1995).

23. U.S. Congress, Office of Technology Assessment, *Competing Economies: America, Europe, and the Pacific Rim* (Washington, DC: U.S. Government Printing Office, October, 1991), 342; Alic et al., *Beyond Spin-Off*, 176.

24. Richard R. Nelson, *High-Technology Policies: A Five-Nation Comparison* (Washington, DC: American Enterprise Institute, 1984), 7–8. In defense procurement, see Jacques S. Gansler, *Affording Defense* (Cambridge, MA: MIT Press, 1989), 224; Stephen P. Rosen, *Winning the Next War: Innovation and the Modern Military* (Ithaca, NY: Cornell University Press, 1991), 244–9.

aerospace investment, firms often find themselves desperate to hire new (or, better still, experienced) talent, and firms often have to pay exorbitant wages or delay projects.[25] Having to staff another military development project can make it that much harder for an integrated aircraft firm to find the resources to work on a commercial aircraft, which may tend to reduce the quality, increase the duration, and increase the unit cost of that engineering effort. These costs might counteract any capital market advantages of the firm-level financial transmission mechanism.

The final firm-level financial transmission mechanism argues that firms' participation in both the commercial and military aircraft businesses may smooth business-cycle risk. Because the business cycles of the military and commercial aircraft markets are not perfectly correlated, an uptick in one line of business may tide a firm's projects in the other line through hard times.[26]

But that model of risk diversification assumes that the financial cost of a loss in one sector cannot spill over to hurt the returns in other parts of the portfolio. That condition is not met when commercial investments are combined with the high-profile military aircraft business. Normally, an investor who splits $100 into two money-losing investments could be no worse off than one who put all $100 into one of the bankrupt targets: she stands to lose $100. But in high-capital-cost industries, each $50 investment is insufficient to cover the fixed cost of entry, so the investment is leveraged by borrowing. Debt repayment requirements of a money-losing project can divert needed fixed investment from other lines of business such that even investments that would otherwise be profitable can no longer meet their fixed-investment needs.[27] Even if only one of the two $50 investments fails, it may carry down the more successful investment with it. The empirical question about the financial risk-smoothing

25. Paul Eddy, Elaine Potter, and Bruce Page, *Destination Disaster: From the Tri-Motor to the DC-10: The Risk of Flying* (New York: Quadrangle, the New York Times Book Company, 1976), 44–5.

26. McGuire, *Airbus Industrie*, 28; Tyson, *Who's Bashing Whom?*, 171, 187; A. P. Ellison and E. M. Stafford, *The Dynamics of the Civil Aviation Industry* (Lexington, MA: Lexington Books, 1974), 40; John Olienyk and Robert Carbaugh, "Competition in the World Jetliner Industry," *Challenge* 42, 4 (1999): 72.

27. Richard A. Brealey and Stewart C. Myers, *Principles of Corporate Finance*, international edition (New York: McGraw-Hill, 1996), 923. The "lender" to the defense aerospace firms is frequently the U.S. government, and the government, especially the military during periods of high perceived threat, is in an excellent position to compel preferential treatment for its investment—which would hurt the ability of firms to maintain the minimum investment level in their commercial projects.

theory is whether the successful part of the portfolio is strong enough to pull through the failing part.

The core prediction of the firm-level financial transmission mechanism is that a firm with more commercial–military diversification will gain a competitive advantage, because it will have a lower total financial risk, hence a lower cost of capital.

The Firm-Level Technological Transmission Mechanism

Firm-level technological arguments focus not on particular technological spin-offs of the defense effort (the province of the plant-level technological transmission mechanism) but instead on supporting the general design capabilities of aerospace firms.[28] Roughly 1,000 engineers cooperate to develop a new aircraft model. Unfortunately, design organizations may be difficult to rebuild if broken up.[29] Firms also fear that keeping designers busy by letting them work for competitors will diffuse trade secrets.[30] So commercial aircraft companies pay designers' salaries each year, even if commercial market conditions do not offer the designers a project to work on. Of course, firms would like to earn a continuous return on that investment, so the ability to transfer a design team to a military project while waiting for a commercial market opportunity may help preserve aircraft design capability.[31]

The firm-level technological transmission mechanism may also operate by improving a design team's quality by allowing its members to gain experience on military projects. Each aircraft model that a

28. Alic et al., *Beyond Spin-Off*, 111–24.

29. Jeffrey A. Drezner, Giles K. Smith, Lucille E. Horgan, Curt Rogers, and Rachel Schmidt, *Maintaining Future Military Aircraft Design Capability* (Santa Monica, CA: RAND, 1992), 16–17; U.S. Congress, Office of Technology Assessment, "Competing Economies," 346; Burnett and Scherer, "The Weapons Industry," 309; Hayward, *International Collaboration*, 56.

30. March, "US Commercial Aircraft Industry," 11. Several histories of the American aircraft industry allege important cases of successful industrial espionage by hiring away crucial designers with their stock of specialized knowledge. For example, Douglas is alleged to have acquired valuable information in the pre-jet era by hiring John Northrop from United Aircraft and by "borrowing" competitors' proprietary experimental results from Cal Tech's contract wind tunnel facility. See William H. Cook, *The Road to the 707* (Bellevue, WA: TYC Publishing, 1991), 52–4, 230–2.

31. Tyson, *Who's Bashing Whom?*, 160; National Research Council, *The Competitive Status of the U.S. Civil Aviation Manufacturing Industry: A Study of the Influences of Technology in Determining International Industrial Competitive Advantage* (Washington, DC: National Academy Press, 1985), 25, 71; Keith Hartley and W. Corcoran, "The Time-Cost Trade-Off for Airliners," *Journal of Industrial Economics* 26, 3 (1978): 220–2; Stephen Hastings, *The Murder of the TSR-2* (London: MacDonald, 1966), 136–7.

design group works on and brings through the flight-testing stage helps hone intuitions about what technical directions are likely to solve unexpected problems.[32] If the military design learning curve transfers to the commercial industry even imperfectly, then commercial aircraft firms' success rate should improve if they employ designers with military experience.

On the other hand, working on military projects might have negative effects on commercial design teams, overwhelming the positive effects of consistent workload and learning. On-going military projects may demand engineers' time at the key moments when commercial design opportunities arise, or the high demand for skilled aircraft designers could drive input costs to prohibitive levels when new designs are launched simultaneously in both markets.[33]

Furthermore, military projects may actually teach design habits that are inappropriate for the commercial market. Cold War military aircraft projects rarely managed technological risk very well, providing few positive lessons for commercial efforts.[34] And even though the technical skills applied in the commercial and military aircraft businesses are for the most part quite similar, the tacit know-how and intuitions used in the two sectors sometimes differ substantially.[35] Advocates of the firm-level technological transmission mechanism of the military subsidy theory ignore these two costs of integrating commercial and military work.

Evidence for the firm-level technological transmission mechanism must focus on the compatibility of commercial and military product cycles to allow commercial–military integration to increase the stability of designers' employment and on the degree of similarity in aircraft design team cultures appropriate for commercial and military projects.

32. Drezner et al., *Maintaining Future Military Aircraft Design Capability*, 14, 16; Hartley and Corcoran, "Time-Cost Trade-Off," 211, 222; Kenneth R. Mayer, "Combat Aircraft Production in the United States 1950-2000: Maintaining Industry Capability in an Era of Shrinking Budgets," *Defense Analysis* 9, 2 (1993): 160.

33. Avinash K. Dixit and Gene M. Grossman, "Targeted Export Promotion with Several Oligopolistic Industries," *Journal of International Economics* 21 (1986): 233–49.

34. Harvey M. Sapolsky, "Equipping the Armed Forces," in *National Security and the U.S. Constitution*, eds. George Edwards and W. Earl Walker (Baltimore, MD: Johns Hopkins, 1988), 121–35; Dan Boger, W. R. Greer, and S. S. Liao, *Competitive Weapon Systems Acquisition: Myths and Facts* (Monterey, CA: Naval Postgraduate School, 1989). British defense programs were similarly plagued by cost overruns, schedule slippage, and inefficient design techniques, all of which directly hampered British commercial aircraft programs during the 1960s, when the Ministry of Technology was responsible for project management of both commercial and military aircraft. See Neil Cooper, *The Business of Death: Britain's Arms Trade at Home and Abroad* (London: Tauris Academic Publishers, 1997), 3.

35. Alic et al., *Beyond Spin-Off*, 112.

Evidence from the Early Jet Age

In the 1950s, as President Eisenhower's concern about the possibly pernicious effects of the MIC grew, several leading American aircraft companies launched programs to develop jet aircraft for commercial airlines. In the United States, the Boeing 707 and the Douglas DC-8 entered airline service in 1958, and Convair's 880 and 990 followed in 1960; all were four-engined, long-range aircraft designed for trans-Atlantic or trans-continental service. Meanwhile, the British firm de Havilland developed new versions in its Comet series of jets—smaller four-engined aircraft ready for long-haul service just before their American competitors—and the French company Sud Aviation produced the Caravelle, the first twin-engined, short-haul commercial jet transport. All of the American companies simultaneously sold complex weapons to the military, and their European competitors also made weapons for their respective governments.

Military subsidy theory proponents often hold out Boeing's 707 as the paradigm case for spin-off benefits. However, the detailed evidence on Boeing raises important questions for the military subsidy theory. Surprisingly, although advocates of the military subsidy theory have neglected the Douglas case, the strongest evidence in favor of their theory comes from the history of the DC-8, although it is only evidence for a limited military subsidy. On the other hand, the utter failure of Convair as a commercial jet producer despite its substantial military aircraft business is strong evidence against the theory.

The Boeing 707

From the dawn of the commercial jet age until the twenty-first century, Boeing held the largest market share of any commercial aircraft producer almost every year—whether measured by number of airplanes sold or by their value, by the number of new airplane orders or by deliveries. Boeing has also been a leading defense contractor, and in many years, particularly early in the Cold War, Boeing had more revenue from defense contracts than any other firm. Many analysts have interpreted this correlation as support for the military subsidy theory.[36] Many go on to allege that there were close linkages between particular Boeing commercial and military aircraft projects that provide corroborating evidence for their theory.

36. Alic et al., *Beyond Spin-Off*, 188, cites Boeing as a leading example of a firm organized to exploit the benefits of dual-use technology and commercial–military synergies.

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The experiences of Boeing's first commercial jet, the 707, and of its contemporary Air Force tanker program, the KC-135, are at the core of the military subsidy argument: advocates believe that the two aircraft were the same in all important respects, both derived from the "Dash 80" prototype, and that the Air Force KC-135 program covered Boeing's 707 costs, giving the commercial airplane a key competitive advantage.[37] A more sophisticated version of the military subsidy argument argues that the two planes have common lineage in the B-47 and B-52 programs, meaning that technologies like swept wings developed for the bombers produced and developed by Boeing gave the company a leg up in commercial markets.[38] But focusing on the four transmission mechanisms by which military projects might aid the commercial aircraft industry reveals deep flaws in the conventional wisdom story for Boeing's jet developments.

For the plant-level financial transmission mechanism to have contributed substantially to the competitive success of the 707, three conditions would have to be met. First, enough parts would have to be shared between the 707 and the KC-135 that tooling cost could have been amortized over both production runs. Second, those parts could not have also been shared by competitors' designs (notably Douglas' DC-8); had the parts been shared, the competitive aircraft would also have benefited from the military procurement and the defense procurement would have had little competitive effect.[39] Finally, any negative effects of sharing parts between the 707 and KC-135 must not have countervailed the competitive benefit of plant-level reductions in production costs.

37. Markusen and Yudken, *Dismantling the Cold War Economy*, 57; Krugman, *Peddling Prosperity*, 238–9; Porter, *The Competitive Advantage of Nations*, 96; René J. Francillon, *McDonnell Douglas Aircraft since 1920*, vol. 1, 2nd ed. (London: Putnam, 1988), 34; Mary Kaldor and Geneviève Schméder, "New Issues," in *The European Rupture: The Defence Sector in Transition*, eds. Mary Kaldor and Geneviève Schméder (Lyme, NH: Edward Elgar Publishing, 1997), 31; Hooks, "The Danger of an Autarkic Pentagon," 159.

38. March, "US Commercial Aircraft Industry," 76; Eugene Rodgers, *Flying High: The Story of Boeing and the Rise of the Jetliner Industry* (New York: The Atlantic Monthly Press, 1996), 110; R. E. G. Davies, *A History of the World's Airlines* (New York: Oxford University Press, 1964), 483; Alic et al., *Beyond Spin-Off*, 69–70.

39. Actually the parts need only have been "share-able," rather than actually shared. If Douglas, as part of its own business strategy, chose to forego any military spin-off benefits that accrued to Boeing by using different subcontractors or by manufacturing particular parts in-house, then government policy (i.e., the purchase of the KC-135 tankers) is hardly implicated as the key cause of Boeing's competitive success.

The 707 and the KC-135 actually shared many parts. A U.S. Air Force-sponsored engineering history confirms important technical similarities between the two airplanes.[40] The official Air Force history of the KC-135 project, produced by Air Force historians and originally classified (therefore not principally a PR document), also reports that the KC-135 and the 707 were built with many parts in common.[41]

However, the KC-135 program history also reveals more details about the cost-sharing between the military and commercial programs—the details of the plant-level financial transmission mechanism. In cases where the two programs shared tooling, Boeing and the Air Force split the tooling cost, with the Air Force allotted 80 percent of the non-recurring cost.[42] Boeing then paid the Air Force for the right to use the tooling for commercial aircraft. Even a report sponsored by the European Commission and written by the Washington, DC, lobbying law firm of Arnold & Porter was unable to conclude that Boeing "underpaid" for the use of the tools, which would have constituted a hidden subsidy.[43]

Similar offsetting costs and benefits undermine the argument that Boeing's 707 program gained competitiveness from plant-level learning effects. At the time the KC-135 contract was awarded to Boeing, the Air Force estimated that Boeing might obtain a 15 percent learning curve cost advantage on a commercial jet transport as a spin-off benefit of the military procurement. On the other hand, when the Air Force tried to bill Boeing for a share of that learning curve benefit, Boeing responded by threatening to bill the Air Force for Boeing's independent investment of some $16 million (1952 dollars) that it had put into its prototype tanker, the 367-80 or "Dash-80," before the Air Force had even specified a requirement for jet tankers. The matter was quietly settled in the contract negotiations: Neither did Boeing pay for its learning curve benefits nor did the Air Force pay for the up-front development spending.[44] At the time at least, these issues were considered of roughly equivalent value.

40. Joe Weingarten, *The Impact of Military Aviation on Civilian Aircraft Development: Evolution of the Boeing 386 Dash 80, KC-135 and Boeing 707* (Dayton, OH: Huffman-Wright Institute for Aerospace Research, May, 1994), 2, 11. See also Cook, *Road to the 707*, 213.

41. *History of the KC-135A Airplane, 1953-1958*, Volume 1: text, Originally Secret, Historical Study No. 320, June, 1959, 32–3, Air Force Archives, Maxwell Air Force Base, Microfilm Roll 23711, K201.95-K201.323.

42. "KC-135 History," 32–3.

43. Arnold and Porter, *U.S. Government Support of the U.S. Commercial Aircraft Industry* (November, 1991), 21.

44. "KC-135 History," 29.

Furthermore, even though the commercial and military aircraft shared many parts, Boeing shared much of the potential benefit at the parts level with its competitors. All of the aircraft prime contractors (Boeing, Douglas, and Convair for commercial jets in the 1950s) purchased major subassemblies from the same short list of firms: Cleveland Pneumatic for landing gear, Bendix for automatic navigation equipment, Garrett AiResearch for air conditioning and cabin pressurization equipment, Lear for autopilots and flight controls, Rohr for power plant packages and aerostructures, Sperry Gyroscope for integrated cockpit instruments, and Westinghouse for generators.[45] These same companies supplied comparable components for military projects like the B-58 and B-66 bombers; the F-102, F-104, F-105 and F-106 fighters; the KC-135 tanker; and the Bomarc, Snark, and Nike missiles. And several of these companies specifically worked as major subcontractors to the contemporary European commercial jet aircraft, diffusing any American military subsidy benefits internationally: Bendix sold flight controls to de Havilland; Garrett sold air conditioners for the de Havilland Comet, the Sud Caravelle, and the Vickers Viscount; and Lear produced autopilots "in quantity" for Caravelle sales.[46] These lists of subassemblies and suppliers are certainly incomplete, but they suggest a great deal of commercial–military and international integration at the subcontractor level. As a result, the plant-level financial transmission mechanism is unlikely to have had an important competitive impact in the 707 era.

Finally, Boeing's military relationship hampered the firm's sales relationship with commercial customers. When Boeing launched the 707, its relationship with commercial airlines was tenuous; after its Stratocruiser piston-engined transport failed to attract orders, Boeing had abandoned the commercial aircraft market in the early-1950s. Boeing was perceived as a military-oriented producer, and airlines were afraid that Boeing designs would inevitably compromise between military and commercial specifications—hence would not be as good for the airlines as airplanes produced by Douglas and Lockheed.[47] And the airlines feared for good reason, because in pursuit of its primary customer, the Air Force, Boeing explicitly promised in March, 1953, that any design conflicts between

45. Aircraft Industries Association, *Aircraft Year Book, 1957-1958* (Washington, DC: American Aviation Publications, 1958).

46. Aircraft Industries Association, *Aircraft Year Book, 1957-1958*.

47. Rodgers, *Flying High*, 180; "Jet Prices Too High: Littlewood," *Aviation Week* (December 22, 1952), 17.

commercial and military derivatives of its Dash 80 prototype would be resolved in favor of the military.[48]

The airlines were also skeptical of Boeing's schedule control: a surge in Cold War tension might have led the Air Force to demand priority for its production, disrupting airlines' delivery timing and hence their business strategies.[49] In 1955, in the face of what seemed to be mounting Soviet hostility, the U.S. Air Force's Strategic Air Command (SAC) threatened to demand delivery of its entire order of KC-135 tankers before Boeing would be allowed to market its commercial 707.[50] Boeing desperately tried to reassure its customers that it would receive Air Force permission to go ahead with civilian production, and Boeing privately invested in "a limited engineering program in an attempt to protect 1958 commercial delivery positions."[51] Nevertheless, several important customers shifted to Douglas' rival plane, the DC-8.[52] For Boeing in the 1950s, the commercial market was a nice sideline, if it could get the work, but the military work was the top priority, bread-and-butter market.[53]

In its initial sales efforts to both the Air Force and the airlines, Boeing clung to the idea of maximizing the commonality between the commercial transport and the military tanker. Boeing tried very hard to capture a plant-level financial benefit for its 707. But the customers were simply too powerful, and they shaped the designs of two different aircraft.

First the Air Force customer forced Boeing to change its Dash-80 design to adapt it to specific tanker mission requirements, reducing the commercial benefits of Boeing's military work. Prior to the Strategic Air Command's annual requirements conference in

48. Letter from Wellwood Beall, Boeing's Vice President for Engineering and Sales, to Major General Mark C. Bradley, Jr., March 26, 1953, Boeing Archives, Seattle, WA.

49. Airlines have always been very sensitive to the costs of disruptions to their scheduled aircraft deliveries—and to the windows of competitive advantage that disruptions might open for other airlines to expand service or to gain a lead in introducing a new technology. Donald A. Ingram, "America's Turbine Transport Progress," *Flight*, vol. 74 (December 19, 1958), 949. In 1950, Northwest Airlines sued Boeing for the enormous sum of $24.8 million after delays in the delivery of Stratocruisers. "Trouble for Boeing," *Business Week* (September 16, 1950), 25.

50. "Jet Transport Race Enters the Stretch," *Aviation Week* (June 13, 1955), 142.

51. Wellwood Beall, Letter from Boeing's Vice President for Engineering and Sales to C. R. Smith, President of American Airlines, May 9, 1955, Boeing Archives, Seattle, WA.

52. Pierre Muller, *Airbus: L'Ambition Européenne* (Paris, France: L'Harmattan, 1989), 19.

53. Memorandum from P. N. Jansen to W. E. Beall, E. C. Wells, and J. O. Yeasting, subject: Jet Tanker 367-80, June 23, 1952, Boeing Archives, Seattle, WA.

November, 1953, SAC's commander, General Curtis LeMay, had insisted that large, fast, intercontinental jet bombers (the B-52 and the upgraded B-36) would be the new American strategic nuclear strike force; consequently, the Air Force had not had a requirement for jet tankers to refuel its heavy bombers.[54] But by the end of 1953, the Air Force acknowledged that the B-52 would not attain an unrefueled intercontinental combat radius, suddenly creating a strategic requirement for a jet tanker fleet.[55] The Air Force scrambled in early-1954 to find a suitable candidate and was pleased to find that Boeing had invested its own funds in 1952 in a prototype aircraft (the Dash 80) suitable for rapid adaptation as a jet tanker.[56] If the Air Force had simply accepted the Dash 80 design for the tanker contract, Boeing would have been in position to enjoy a substantial boost to its aspirations to build a jet airliner: regardless of the diffusion of plant-level benefits through subcontracting for subassemblies and parts, Boeing's final assembly facilities, systems integration capabilities, and designers would have gained.

Instead, the Air Force announced a tanker design competition and invited Boeing, Douglas, Lockheed, and Convair to submit bids. In the meantime, SAC signed a contract for an "interim" purchase of 29 Boeing tankers.[57] Lt. Gen. Thomas Powers, Commander of the Air Research and Development Command, explicitly worried about an appearance of impropriety in the purchase of an interim tanker during the competition, but he felt that the terms of the competition designed by the Wright Air Development Center were sufficient to clear the

54. "Refueling Problem," *Aviation Week* (October 12, 1953), 13.

55. SAC accepted the need to use aerial refueling with at least the early-model B-52s (prior to the B-52D) as early as 1949-51 but waited until 1953 to finally determine that piston-engined tankers would not work. Brown, *Flying Blind*, 132, 135–6. See also Warren E. Greene, *The Development of the B-52 Aircraft, 1945-1953* (Historical Branch, Office of Information Services, Wright Air Development Center, Originally Secret, May, 1956), 15.

56. Boeing frequently proclaims that it spent company funds for the initial $16 million investment in the Dash-80 prototype without any promise that the military would buy a jet tanker. The company uses this fact to maintain that it is innocent of receiving any military subsidy. See, for example, "U.S. Government Response to the EC-Commissioned Report 'U.S. Government Support of the U.S. Commercial Aircraft Industry'," reprinted in the Report of the Industry Sector and Functional Advisory Committees, *The Uruguay Round of Multilateral Trade Negotiations* (January, 1994). Actually, we should assess the military subsidy argument with evidence of the real effects of defense research and procurement programs rather than evidence of their intent.

57. "KC-135 History," 8.

air.[58] With most of the big development contracts that were expected in the 1950s for bombers, transports, and fighters already let, the final tanker order was "the juiciest plum to be dangled before the aircraft industry in several years," and each of the competitors was willing to go to substantial lengths to win it.[59]

Despite Boeing's interim order, Lockheed's CL-291 design won the tanker competition.[60] But because Boeing was so much farther along in production (the Dash-80 was in flight test in the summer of 1954), and because Lockheed's design was only a "paper airplane" without any real tooling investment, the Air Force simply ordered Boeing to modify its tanker design to Lockheed's "ultimate configuration," and Lockheed never built the CL-291.[61] Fearing Air Force retaliation against other Lockheed contracts, Lockheed did not complain very much about the outcome of the tanker competition, despite losing a significant investment in development of its design.[62]

Of course the "ultimate configuration" was not the airplane that Boeing was trying to sell to the airlines. Because of the political power of the Air Force and the competitive threat that Lockheed might be awarded the tanker production contract, Boeing could not obtain the plant-level financial subsidy that it had sought for the 707.

Later in Boeing's jet sales campaign, the airlines also required substantial modification of the 707 design from its Dash-80 roots—in a different direction from the Air Force's modifications. Ultimately, the 707 sold because Boeing was responsive to commercial needs,

58. "KC-135 History," 7. Boeing's interim order was promptly extended to 88 aircraft. Robert Hotz, "Boeing Gets Order for 88 Jet Tankers," *Aviation Week* (August 23, 1954), 13–14. Douglas and Lockheed may not have objected too strenuously to the interim order because they expected that more than one tanker design would ultimately be produced, as multiple transport designs with similar capabilities had been purchased by the Air Force in the late-1940s. Terry Waddington, *Douglas DC-8* (Miami, FL: World Transport Press, 1996), 10–12.

59. "Tanker Competition," *Aviation Week* (August 9, 1954), 9. Waddington, *Douglas DC-8*, 10, reports that Douglas spent $3 million in preparing its design proposal.

60. Rodgers, *Flying High*, 173, suggests that Boeing's early start on the Dash-80 actually disadvantaged the company in the design competition, because Boeing was unable to design the aircraft to the particular Air Force specifications. Cook, *Road to the 707*, 213, suggests that Boeing designed the Dash-80 to maximize commonality with the B-52 design, to minimize spare parts costs, maintenance training, and inventory requirements at Air Force bases, but those desirable goals were not specific enough to match precisely the Wright Air Development Center competition standards.

61. "KC-135 History," 10.

62. Interview with Robert Ormsby, retired President of Lockheed-Georgia and later of Lockheed Aircraft Group, November, 1994. At the time of the CL-291 proposal, Ormsby was a systems analyst at Lockheed-Georgia, where he read the CL-291 proposal, although he was not part of the group that prepared it.

again in ways that reduced the technical commonality between the 707 and the KC-135.[63] Douglas Aircraft, perhaps because it was not involved in the KC-135 project and hence had no ties to a particular prototype design, was particularly responsive to the airlines' demands and threatened to run away with the commercial jet market (as it had in piston-powered generations of aircraft).[64] Boeing was forced to sacrifice its hopes for economies of scope between its 707 and KC-135 projects.

First, Pan American Airways insisted on an upgrade to Pratt & Whitney's J-75 engines so that its jets could provide non-stop trans-Atlantic service. Boeing declared the risks too high, because the new engines had not yet been developed from the J-57 model that the KC-135 and the B-52 used. But because Douglas was not yet committed to the J-57 on Air Force projects, it was willing to use the new engine for its DC-8, as long as Pan Am bought the engines independently and thereby took the investment risk. Boeing was forced to redesign its engine pods, nacelles, cowlings, etc., and to accept the risky new engine for the 707.[65]

Major domestic airlines then forced additional changes to the 707, because they required six-abreast seating, meaning the 707's fuselage would have to be wider than the KC-135's.[66] While commonality was maintained between the two aircraft on many parts supplied by subcontractors, Boeing's principal role as final assembler was divided between two separate production lines, one for the military KC-135 and one for the commercial 707.[67]

Even if the KC-135 probably gave at best only a small plant-level financial boost to the commercial 707, the military project might have

63. Miller and Sawers, *Technical Development of Modern Aviation*, 27; "Boeing Soars Ahead of Douglas in the Jet Race," *Business Week* (February 11, 1961), 64.

64. Heppenheimer, *Turbulent Skies*, 2, 166–7.

65. Robert Gandt, *Skygods: The Fall of Pan Am* (New York: William Morrow and Company, 1995), 30.

66. The report of an October 16, 1952, meeting of Boeing's sales and planning staff suggests that Boeing knew at an early date of the need to expand the 707's fuselage diameter for commercial sales, taking some of the competitive drama out of the story usually reported of Boeing's last-minute agreement with American Airlines to deny a big sale to Douglas' DC-8. Memorandum from Wellwood Beall to F. P. Laudan, E. C. Wells, and J. O. Yeasting (engineering department), Subject: Body Configuration, Model 367-80 Series, October 16, 1952, Boeing Archives, Seattle, WA. For an example of the dramatic version of the story normally told in non-academic books, see Clive Irving, *Wide-Body: The Triumph of the 747* (New York: William Morrow & Company, 1993), 153–6.

67. Weingarten, *The Impact of Military Aviation*, 3.

helped its commercial contemporary in other ways. The key to evaluating the plant-level technological argument is to follow the diffusion of innovations and their competitive effect. Many inventions applied in the 707 aircraft design derived from earlier military aircraft, notably the B-47, which was developed and built by Boeing.[68] But other companies had access to the same technology such that it provided Boeing with little competitive advantage. Douglas and Lockheed had even built B-47s on their own assembly lines beginning in 1950, giving them production experience with the new design characteristics.[69] A 1962 federal Tax Court decision concerning the application of excess profits tax to Boeing specifically held that the B-47 licenses had increased the financial risk to Boeing by diffusing technology to potential competitors for the commercial jet market. Boeing's high observed profits in the late-1950s were, according to the Court, simply an appropriate return on that heightened investment risk.[70]

Of course it is quite possible that the diffusion of the plant-level technological benefit of American military aircraft projects was limited to other American firms—to Douglas and Lockheed, who also produced the B-47, or to Douglas, Lockheed, and Convair, who were all involved with major, innovative military projects. In that case, all the American manufacturers would have gained a competitive advantage versus European producers. The military subsidy theory could then explain country-level rather than firm-level American competitiveness. However, we would then expect to see all of the American firms enjoying significant profits and none earning a disproportionate share, while in fact only Boeing's earnings soared. Douglas struggled along, Lockheed failed to enter the commercial jet competition of the 1950s, and Convair declared a $450 million loss (in 1961 dollars) when its competing product line (the 880 and 990) failed.

Meanwhile, not all contemporary European commercial jet projects failed: although the de Havilland Comet never sold well against the

68. Almarin Phillips, *Technology and Market Structure: A Study of the Aircraft Industry* (Lexington, MA: D.C. Heath and Company, 1971), 126; Rodgers, *Flying High*, 151.

69. Weingarten, *The Impact of Military Aviation*, 11. Of course production and design experience are not the same thing, but Boeing's competitors gained design experience similar to Boeing's from other military jet projects such as Douglas' A3D and B-66, preventing Boeing from gaining a major competitive advantage in design skills. Interview with Donald Douglas, Jr., former chairman of Douglas Aircraft, July, 1994.

70. Katherine Johnsen, "Impact of Boeing Profit Ruling Weighed," *Aviation Week* (January 22, 1962), 32.

superior American 707 and DC-8, the short-range, twin-engined Sud Aviation Caravelle succeeded in a different product niche. Every major European airline except for KLM and Lufthansa ordered the Caravelle. So did United Air Lines in the United States, strong evidence that the Caravelle could compete for sales to major airlines even on the American manufacturers' home turf.[71]

The 1950s jet race does not suggest that the U.S. manufacturers thrived because of a technological lead, military-derived or otherwise. Early on, the British manufacturers took a lead in the technology race: the Comet was the first commercial jet transport.[72] Even after the Comet 1's infamous crashes, which led both British and American engineers to a new understanding of the science of metal fatigue, de Havilland pressed on with the product line. The re-designed Comet 4 entered trans-Atlantic service with British Overseas Airways Corporation (BOAC) in October, 1958, just before the Boeing 707 entered service with Pan American.[73] From a purely technical perspective, the

71. Davies, *History of the World's Airlines*, 488. John Newhouse, *The Sporty Game* (New York: Alfred A. Knopf, 1982), 123, points out that United switched to flying Boeing's short-haul 720 in place of the Caravelle as soon as the Boeing airplane was available, because, he argues, the Caravelle was uneconomical to fly, particularly because it had only sixty-four seats. Airlines in South America, however, presumably partisans of neither American nor European manufacturers, earned profits operating the Caravelle. Robert Burkhardt, "Caravelle Makes Big Hit at Varig," *Airlift* (June, 1960), 59. The Caravelle may have been replaced in American markets for other reasons. Some sources allege that United wanted to operate a "family" of Boeing aircraft to reduce training and maintenance costs, and others argue that Sud Aviation and Rolls-Royce (the original engine contractor on the Caravelle) were less responsive than the American firms to customer requests and did not provide good after-sales support.

72. "Aviation: U.S. Lags on Jets," *Business Week* (June 23, 1951), 87–8. Rodgers, *Flying High*, 152, notes that the Comet 1 "had many limitations. A small, four-engine jetliner able to handle only thirty-six passengers, having a range of only fifteen hundred miles, it was frightfully expensive to buy and operate. It could hit five hundred miles per hour, but its wings were only barely swept back, making it aerodynamically inefficient, so it couldn't take full advantage of its engines for greater speed. Rudimentary flaps gave it poor takeoff and landing characteristics. . . . Neither the engines nor the airframe had the benefit of the wealth of experience developing military jets that American companies were accumulating." Yet in 1949, when the Comet 1 first flew, the U.S. firms were not in a position to make even a comparable commercial jet. A comparison of the 1958-vintage Comet 4's technical characteristics to those of the 707 and DC-8 is more appropriate for considering possible spin-off benefits of the American MIC. The Comet 4 was substantially larger and more technically advanced than the Comet 1, although it still lacked the trans-Atlantic range of the 707 and DC-8.

73. Hayward, *The British Aircraft Industry*, 57. The early-model Comets that flew in 1952 had mostly been used on "Empire" routes rather than in trans-Atlantic service (multi-stop service from London to Johannesburg and Singapore). The October, 1958, trans-Atlantic Comet service required one refueling stop, which was not necessary on the later 707 and DC-8 flights.

trans-Atlantic competition was on fairly equal terms: going into the 1950s, the British had a widely acknowledged lead in jet engine technology, while the American firms had a better understanding of aerodynamics and airframe design.[74] By 1958, however, the Americans had probably caught up with any British lead in jet engine technology, while the British had caught up with the American lead in airframe design, leaving the technological competition on equal footing.[75]

Pressure from powerful customers led the British aircraft companies to make poor design choices in the jet race, much as pressure from powerful customers forced Boeing to sacrifice plant-level financial benefits that the KC-135 might have provided to the commercial 707. In the late-1950s, when head-to-head jet aircraft competition began, the seating capacity of the 707 and the DC-8 (up to 180) was too big: the aircraft overwhelmed consumer demand for seats between almost any two cities, airlines lost money, and aircraft orders plunged during the early-1960s.[76] On the other hand, the eighty-seat capacity of the Comet 4 was too small to be economical once the larger American airplanes were available.[77] Yet there is no reason to believe that the British were incapable of building a bigger jet aircraft. British companies built heavy jet bombers and later built larger commercial jet transports.

British aircraft manufacturers simply made a poor business decision, because they focused on their monopsony customers, BOAC and British European Airways (BEA). BOAC and BEA had low-density "Empire" routes to serve that were important to them

74. One natural outcome of that situation would have been to put Rolls-Royce engines on an American airframe. Rolls-Royce strongly advocated just such a deal to the British Ministry of Supply, but the Rolls-Royce plan was rejected in favor of trying to exploit the British engine lead to pull along the lagging airframe sector. Letter from Whitney Straight, Chairman of BOAC, to Reginald Maulding, Minister of Supply, March 7, 1956, and subsequent letter from Maulding to Harold Watkinson, Minister of Transport and Civil Aviation, AVIA 63/1, 1954-56 Development of a Long-Range Jet Aircraft: Requirements and Specifications, British National Archives, Kew Gardens.

75. Miller and Sawers, *Technical Development of Modern Aviation*, 176.

76. ". . . And It Is Still the Right Size," *Flight* 81 (January 18, 1962), 82.

77. Miller and Sawers, *Technical Development of Modern Aviation*, 26–7, 43–4; Mahlon R. Straszheim, *The International Airline Industry* (Washington, DC: The Brookings Institution, 1969), 88–9. The British actually had believed that their smaller size would prove to be an advantage in inaugurating jet service on air routes with less traffic density than the busy North Atlantic and trans-continental U.S. routes. De Havilland and the British government felt that smaller airlines, which were expected to standardize on one aircraft, would inevitably choose the Comet 3 (slightly smaller than the Comet 4). "The Future of the Comet: De Havilland Appreciation," March 11, 1955, AVIA 63/26, 1954-59 Comet Programme—General Policy, British National Archives, Kew Gardens.

and only required aircraft of the Comet's size.[78] The British airlines feared, reasonably, that they would not be able to fill the seats of the larger American aircraft, so could not take advantage of the Americans' better seat-mile economics. They used their influence with the Ministry of Supply to divert de Havilland's Comet designs away from the larger size that would have been able to compete for sales to other (notably American) airlines. BEA service with the smaller Comets was reasonably profitable, but BOAC, which competed head-to-head with the larger American airplanes on the North Atlantic crossing, suffered a tremendous capital loss from its strategic mistake.[79]

Meanwhile, Boeing gained competitive advantage by maximizing its design flexibility and responsiveness to commercial customers rather than by exploiting particular technological innovations. The 707 outsold Douglas' DC-8 and recouped its investment costs more rapidly because Boeing offered more variations, suited to a wider range of airlines' route structures.[80] For example, in 1957 Boeing launched the 720, a short- to medium-range derivative of the 707 that was completely redesigned with respect to weight and structural strength. But the similar appearance of the 720 to its "parent" allowed the two designs to share the same parts for the flight deck and cabin configuration, beginning Boeing's famed competitive advantage due to its "family" of aircraft.[81]

Boeing did not learn this successful approach to its commercial customer relationship from its experience with military buyers—that is, this source of Boeing's commercial success was not a firm-level spin-off. If anything, Boeing's emphasis on product differentiation in its strategy for commercial aircraft is the opposite of the lesson that its

78. J. M. Ramsden, "The Case for the Comet," *Flight* 74 (August 22, 1958), 256.

79. Straszheim, *International Airline Industry*, 22. The largest part of BOAC's loss, however, did not come from the investment in the Comet 4, but from its original plan to operate turbo-prop Britannia's on the trans-Atlantic route, because BOAC realized too late that consumers would reject turbo-prop aircraft on long-haul routes, even through the turbo-props were probably cheaper on a seat-mile basis.

80. Davies, *History of the World's Airlines*, 490; "Boeing Soars Ahead," 65.

81. *Jane's All the World's Aircraft, 1958-1959* (London: The Trade Press Association, 1958), 267. The 720, before it was re-numbered, was originally designated as a variant of the 707 custom-designed for American Airlines, and many histories of the aircraft industry count 720 production as part of the total 707 run. In the long run, however, Douglas stretched the DC-8 into a larger version for the airline market of the late-1960s, while the 707's commonality of design with the KC-135—specifically the greater sweep back of the Boeing planes' wings (35° compared to the DC-8's 30°)—prevented a comparable extension. Miller and Sawers, *Technical Development of Modern Aviation*, 204; Newhouse, *Sporty Game*, 117. Douglas had a long history of stretching its designs to maximize their long-run sales (notably the DC-6 and DC-7). See "Douglas: Two-Way Bet to Ride a Boom," *Business Week* (July 16, 1955), 86. According to Waddington, *Douglas DC-8*, 13, the DC-8 design intentionally incorporated the possibility of stretching the airframe from the very beginning.

designers and marketers might have learned from the military business. The U.S. Air Force purchased large quantities of the same basic aircraft design, especially in the 1950s, and the most successful defense contracts were those that minimized changes during the production phase.[82] Any changes that were made to military designs during production were usually improvements to be applied to every aircraft that the purchasing service eventually accepted into the fleet. Military aircraft are not customized. Meanwhile, airlines' fleets were (and are) tailored to complex, variegated route networks. Each airline wanted to buy some medium-haul, high-capacity versions of the 707 and some long-haul, medium-capacity aircraft; long-haul, high capacity and medium-haul, medium-capacity aircraft were part of the fleet mix, too. Military and commercial purchasing patterns were quite different, giving Boeing's commercial design and sales teams little to learn from their military counterparts.

Finally, the near-simultaneous development efforts on the 707 and the KC-135 do not suggest firm-level technological or financial spin-off. During the period from 1952 to 1954 in which Boeing developed the Dash-80 prototype, the U.S. military launched ten aircraft development projects, each of which culminated in a major production contract, making those years the peak period of Cold War demand for aircraft design personnel.[83] Any design team demand-smoothing effect would have required commercial jet transport aircraft projects to be launched at the trough of military aircraft project starts in the early-1960s. Similarly, if the idea of the firm-level technological transmission mechanism is that commercial aircraft companies should exploit the experience that their designers have gained on earlier military projects, Boeing should have waited until the late-1950s to launch the 707 design.

In sum, the history of the 707 does not support the military subsidy theory. The different natures of the military and commercial customers undermined Boeing's efforts to transfer benefits from the KC-135 to the 707. The two airplanes' production configurations differed for good reasons, and part-level commonalities between the two aircraft are unlikely to have had an important competitive effect because

82. Thomas L. McNaugher, *New Weapons Old Politics: America's Military Procurement Muddle* (Washington, DC: Brookings Institution, 1989), 154–6, 159, 163. The terms of most defense contracts (the need to "buy in" with low-ball initial prices) actually gave prime contractors an incentive to file many engineering change proposals during the development phase, but once production began, manufacturers earned greater profits on military projects with stable designs.

83. Mayer, "Combat Aircraft Production," 163.

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subcontracting opportunities diffused financial and technological benefits to Boeing's competitors. This finding strongly undermines the military subsidy theory because the traditional spin-off explanation of the 707's commercial success has often been cited as the *best* evidence for the military subsidy theory—the case that advocates choose to talk about when given the opportunity to stack the analytic deck in their favor.

The Douglas DC-8

In some ways, the history of the DC-8 project is also strong evidence against the military subsidy theory: Douglas, without a military contract for a jet transport or tanker aircraft comparable to its commercial airplane, developed and produced a market success comparable to Boeing's 707.[84] Moreover, the 707 and the DC-8 shared many basic technological features, which implies that any plant-level technological benefit was equally available to the two projects, so Boeing's simultaneous work on similar military and commercial projects did not translate directly into a technological edge.

Nevertheless, careful examination of the DC-8 case might still yield evidence that supports the military subsidy theory. Both Boeing and Douglas did well in commercial markets compared to their competitors, perhaps because both companies benefited at the *firm* level if not the plant level from their military work. Douglas did a substantial military business in the 1950s, even though it did not sell tanker aircraft to the U.S. Air Force. The standout difference between the potential military spin-off to Douglas' DC-8 and Boeing's 707 is limited to the plant-level financial effects of the military work, and perhaps that difference in part explains why the DC-8 was not quite as profitable as Boeing's 707.[85]

The core similarity between Douglas' and Boeing's military relationships allows a focused comparison of the effect of the plant-level financial transmission mechanism that may be far better evidence in favor of the military subsidy theory than the Boeing 707 case that is usually cited by the theory's advocates. Even the evidence on the DC-8, however, suggests that the net effect of the military spin-off was smaller than the theory's advocates would like to believe, and important caveats in this case study suggest that, in the overall context of strong evidence against the military subsidy theory, we should not

84. "Corporation Revelations," *Flight* 81 (March 29, 1962), 465.

85. Interview with Donald Douglas, Jr., July, 1994. See also Douglas J. Ingells, *The McDonnell Douglas Story* (Fallbrook, CA: Aero Publishers, 1979), 131–2.

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conclude that military subsidy was very important to the success of the American aircraft sector.

At the firm level, the relationships between Boeing and Douglas and the U.S. military in the early-1950s were remarkably similar. Douglas, with its successful DC-6 and DC-7 piston-engined passenger transports, earned more from commercial sales than any other aircraft manufacturer during the decade of jet development from 1948 to 1957. But even Douglas derived 80 percent of its revenue from sales to the military.[86] The comparable Boeing figure was very close to 100 percent military revenue, with the only commercial component coming from Boeing's limited sales of the piston-engined Stratocruiser in the late-1940s.

Furthermore, Douglas' portfolio of technological investment was almost identical to Boeing's. Douglas built piston- and jet-engined transports for the commercial aircraft market; piston-, turboprop-, and jet-powered aircraft for both the Air Force and the Navy; and missiles for both the Army and the Air Force. Meanwhile, Boeing's portfolio included piston- and jet-engined commercial aircraft; piston- and jet- (but not turboprop-) powered aircraft for the U.S. Air Force (but not the Navy); limited production of small turbine engines for ships and helicopters; and missiles for the Air Force. Douglas' direct experience with commercial designs might have given the firm a slight edge with commercial buyers, but on the other hand, only Boeing had designed and built dedicated tanker aircraft (the KC-97 and then the KC-135), the military aircraft type most similar to commercial transports. That experience might have helped Boeing to capitalize more efficiently on any firm-level technological benefits, compensating for Douglas' commercial experience advantage.

Douglas' design team's extensive experience with jets began in the closing days of World War II, and the firm's designers worked with the same technological pieces that were applied at Boeing, Convair, and de Havilland.[87] Douglas' El Segundo, California, plant began quantity production of the F3D Skyknight twin-jet all-weather fighter for the Navy and Marines in early 1952, adding to the jet production experience of Douglas' Tulsa, Oklahoma, plant that made B-47s on an Air Force contract under a license agreement with Boeing. El Segundo also produced a supersonic fighter, the F4D Skyray, for the Navy using Pratt & Whitney's J-57 engine that later powered the initial

86. Miller and Sawers, *Technical Development of Modern Aviation*, 219; "Douglas: Two-Way Bet," 84.

87. Waddington, *Douglas DC-8*, 8; Interview with Donald Douglas, Jr., July, 1994.

versions of both the 707 and the DC-8. The contract for the A3D Skywarrior, a Navy attack airplane, gave Douglas experience with designing and producing podded engine mounts, a supposedly key role played by the B-47 and B-52 designs in Boeing's ability to develop commercial jets. Other experimental aircraft and rocket programs at Douglas emphasized high-speed flight aerodynamics and advanced materials' design. This long list of high-tech Navy projects makes it difficult to distinguish Douglas and Boeing on the grounds of the firm-level technological transmission mechanism.

However, the specific flow of design experience within the Douglas company is difficult to trace. Douglas' commercial jet transport design and production actually took place in different plants than the ones used for most of its military production. Traditionally, Douglas focused its Navy work at El Segundo, its Air Force contracts at Long Beach, and its commercial work at Santa Monica. Each facility had its own design staff.[88] The DC-8 required a longer runway than was available in Santa Monica, so its production was moved to a new plant across the street from Douglas' Air Force facility in Long Beach, but the DC-8 project's design remained in Santa Monica with the commercial experts. Work on the A3D during the time of DC-8 development prevented Douglas from directly moving designers with Navy jet experience from El Segundo to the commercial project, but proximity allowed substantial "cross-pollination" between the two design efforts.[89] The Douglas organization as a whole had the opportunity to internalize a great deal of learning on U.S. Navy jet development and production contracts.

At the level of the plant-level technological transmission mechanism, the DC-8 and the 707 reflect their designers' access to a similar pool of military spin-off technologies.[90] The major features of the two designs are similar, although the particular technical solutions to many problems differed between the competing models.[91] In some cases, the Douglas solution was better than Boeing's; in others, the reverse was true.[92] On balance, however, the Douglas technology might be judged to have been slightly better than that applied in the

88. Interview with Roger Schaufele, retired Douglas Vice President of Engineering, July, 1994.

89. In July, 1994, interviews, Roger Schaufele emphasized the difficulty in shifting design labor between the two plants, while Donald Douglas, Jr., emphasized the exchange of ideas between the two nearby staffs.

90. Phillips, *Technology and Market Structure*, 126.

91. Waddington, *Douglas DC-8*, passim.

92. Interview with Roger Schaufele, July, 1994.

Boeing design: the direct operating cost of the DC-8 was slightly less than that of the 707 during the airlines' peak use of the two models, even including a faster average depreciation rate applied by the airlines that bought the Douglas airplane.[93] The two models, however, were considered nearly interchangeable in the airlines' performance evaluations, which meant that many of the important sales campaigns fought between Boeing and Douglas were decided on price. Neither manufacturer could claim unique technological advantages to command an especially high price for its airplanes.[94]

The biggest difference between the military involvement in the DC-8 and the 707 programs was with respect to plant-level finances. As discussed in the section above on the Boeing 707, Douglas and Boeing shared many suppliers on the two programs, diffusing the benefits of military-derived economies of scale and learning effects in parts manufacturing. However, any benefits that Boeing derived specifically with respect to final assembly of the 707 and KC-135 on two parallel production lines in the same facility—perhaps jointly amortizing building and real estate overhead or cross-applying certain process improvements learned on one production line to the other—would not have been available to Douglas. Because final assembly cost is not an overwhelming portion of the total cost of developing and manufacturing a commercial airplane, and because Boeing may have paid enough or even too much compensation to the Air Force for its plant-level financial advantage with respect to facility costs and learning effects, this net military subsidy to Boeing relative to Douglas should only be expected to have had a small effect on the relative competitiveness of the 707 and the DC-8.

93. Miller and Sawers, *Technical Development of Modern Aviation*, 43–4. The major U.S. airlines did not all use the same accounting methods for their capital investment, and those that chose to fly the DC-8 happened, on average, to be those that depreciated their investments more rapidly. The result of that policy would be to inflate the declared operating cost of the DC-8 relative to the 707 during the early years of the planes' careers. Moreover, even in the early-1970s, as Douglas prepared to close the DC-8 production line to make way for the DC-10, stretched models of the venerable jet (the "Super Sixty" series, or the DC-8-60, -61, -62, and -63) were competitive with the new wide bodies on a direct operating cost basis, and they were more efficient when capital cost is included for comparable new DC-8-60s, DC-10s, and L-1011s. The DC-8 was simply a very good design from a technological, efficiency perspective. Robert G. Vambery, *Capital Investment Control in the Air Transport Industry* (Dobbs Ferry, NY: Oceana Publications, 1976), 142.

94. Matthew Lynn, *Birds of Prey: Boeing vs. Airbus: A Battle for the Skies* (New York: Four Walls Eight Windows, revised edition, 1997), 56–7; Harold Mansfield, *Billion Dollar Battle: The Story Behind the 'Impossible' 727 Project* (New York: David McKay Company, 1965), 83.

The biggest plant-level financial effect of military aircraft procurement on the DC-8 program, and presumably on the 707 program as well, came later in the production run, during the Vietnam War: a significant net negative effect on the commercial programs' success. Beginning in 1966, as the demand for military aircraft increased, the prices of subcontracted parts on commercial aircraft surged. Delays in obtaining parts disrupted production schedules, which directly increased costs as assembly processes were completed out of order. In some cases, problems (particularly with the supply of jet engines) disrupted delivery schedules for the DC-8 and DC-9, triggering penalty clauses in contracts with airlines.[95] Several European airlines threatened to shift orders to European aircraft manufacturers' competing models, including the Sud Caravelle, Hawker-Siddeley Trident, and the BAC 111.[96] These crowding-out effects on prices are precisely the kind of costs that President Eisenhower warned about and that advocates of the military subsidy theory tend to ignore.

The negative effect of Vietnam War procurement on the American commercial aircraft industry speaks to the alleged military-derived advantage shared by all U.S. manufacturers relative to their European competitors. But what of the effect of Boeing's limited plant-level financial advantage relative to Douglas, its U.S. competitor? In total, Boeing sold slightly more 707s than Douglas sold DC-8s: 725 v. 556.[97] Neither the military subsidy theory nor any other theory of government support to the aircraft industry makes fine enough predictions to attribute that difference to systematic variation; the theories can only

95. Waddington, *Douglas DC-8*, 68; "Pratt & Whitney feels the pangs of success," *Business Week* (August 6, 1966), 139. Similar delays also hurt Boeing's 707 and 727 programs. "Boeing Cancels Planned Production Rise," *Aviation Week* (December 5, 1966), 37. Eastern Air Lines was the only major American airline that actually cut back its planned service due to delays in aircraft deliveries, while other airlines compensated by running additional, less-efficient piston-powered flights. "Eastern Air Lines Cuts Some Flights, Cites Delay in Jet Delivery," *Wall Street Journal* (June 15, 1966), 17.

96. "Jets for European Carriers Delayed by Viet War Needs," *Aviation Week* (October 31, 1966), 37. The focus of the story is Iberia Airlines. It is not clear that any Douglas orders were actually cancelled as a result of these delays, but Douglas' sales department reported difficulty in subsequent sales campaigns as a result of the firm's failure to deliver its products reliably on time.

97. Production figures are taken from Bill Gunston, *World Encyclopedia of Aircraft Manufacturers* (Annapolis, MD: Naval Institute Press, 1993). Boeing's total 707-related production may be counted much higher than 725 if the 125 "derived military variants" such as liaison transports and Air Force One are included. Some authors also count the 153 copies of Boeing's model 720 in their 707 production figures, but the two aircraft were different enough that this counting rule seems inappropriate.

differentiate these two successes from clear failures like Convair's 65 sales of its 880 and Dassault's 10 sales of its commercial Mercure aircraft (a 1970s-vintage competitor of Boeing's 737 and Douglas' DC-9). On the other hand, the 707's longer production run is certainly consistent with the possible positive plant-level financial effect of Boeing's military work on the KC-135. To preserve the military subsidy theory if Boeing had sold fewer 707s than Douglas sold DC-8s, we would have to offer a particularly careful revisionist explanation—unnecessary because the 707 in fact sold more copies than the DC-8.

However, explanations other than the military subsidy logic account for part of the difference between the 707 and DC-8 sales experiences. Eighty-one 707 sales, a substantial portion of Boeing's advantage, came after the 1972 close of the DC-8 production line. Those late 707 sales were the most profitable ones, both because the up-front costs of the 707 had been completely amortized by the 1970s and because the price of the airplane rose when it lacked a direct competitor.[98] Furthermore, Douglas' profits on the DC-8 were undermined by poor business decisions during the 1960s that were completely independent of military influence on either the DC-8 or the 707. Douglas tried to maximize economies of scope between the DC-8 and the new twin-jet DC-9 by planning to manufacture the two airplanes on the same production line. But Douglas underestimated the surge in demand for the DC-9 when the airlines came out of recession in 1965, and the company had to scramble to accelerate production extremely rapidly. Eventually, the DC-9 was split off onto a separate production line at great expense, disrupting production of both DC-8s and DC-9s in the process.[99]

Overall, the DC-8 case again shows the MIC's mixed effects on commercial markets. Despite Douglas' relative disadvantage in plant-level integration between commercial and military work, the DC-8 took in some $4.2 billion in sales revenue. But the DC-8 only turned profitable for Douglas as sales of spare parts continued over the long term, and Boeing's 707 turned profitable faster.[100] The focused

98. Rodgers, *Flying High*, 319–20. Note that the DC-8 line was not closed because Douglas was "driven from the market" by the 707's success. Instead, the DC-8 was closed to make plant space available for Douglas' new flagship model, the DC-10. Prior to the closure of the line in 1972, the relatively new Super Sixty series of stretched DC-8s was selling better than the 707. Waddington, *Douglas DC-8*, 64–6, 78, 84; March, "U.S. Commercial Aircraft Industry," 52.

99. Waddington, *Douglas DC-8*, 59, 64.

100. Waddington, *Douglas DC-8*, 84; Interview with Dave Williams, General Manager, Strategic Business Development, Commercial Aircraft, Douglas Aircraft, October, 1995.

comparison between the 707 and DC-8 with respect to the plant-level financial transmission mechanism offers some evidence supporting the military subsidy theory.

The Convair 880 and 990

The Convair Division of General Dynamics is an often-forgotten case of a leading American military aircraft producer with a history as a major producer of commercial aircraft. In the 1950s, Convair sought to follow up its success as a manufacturer of short- and medium-range piston-powered commercial transport aircraft with its medium-range, four-engine jet 880 and 990 designs. Meanwhile, Convair remained one of the largest Air Force suppliers throughout the Cold War, with contracts for both aircraft and missiles. But the 880 and 990 were a financial disaster. In 1961, Convair declared an accounting charge of $425 million as it closed its commercial order books—a loss of $4.16 million per commercial jet sold. At the time, the loss was the largest ever declared by an American corporation that did not go bankrupt.[101]

Convair's strong, diversified, technologically advanced defense businesses did not provide the company with a military subsidy that led to commercial competitive success. Careful examination of the specific reasons for the failure of the 880 and 990 projects reveals the danger of applying the contracting and technology development strategies learned on successful defense projects to the commercial aircraft market. In essence, Convair's corporate culture, well suited to R&D and business development for the military market, did not similarly help the firm's commercial jet aircraft projects. This case provides specific causal evidence that the relationship with the military significantly hurt the commercial prospects of the aircraft industry—the very opposite of the military subsidy theory, and strong reinforcement for President Eisenhower's key fear that military work might undermine private industry's technological creativity and marketing savvy.

Convair split its aircraft business between two major plant complexes, constraining the company's potential to gain plant-level financial benefits from its defense contracts. Convair's two large military jets of the 1950s, the B-36 and B-58 bombers, were both developed and produced in Fort Worth, Texas, as was Convair's military turboprop transport, the C-131C.[102] Convair's commercial

101. Jon Proctor, *Convair 880 & 990* (Hong Kong: World Transport Press, 1996), 58.

102. Richard Balentine, "Turboprop Transport Battle Heightens," *Aviation Week* (May 31, 1954), 67.

aircraft, beginning with the piston-engined 240, 340, and 440 and followed by the jet-engined 880 and 990, were built in San Diego, California, along with Convair's Air Force fighters. At the time of the 880 development, Convair was working on the F-106, which had little in common with a commercial transport like the 880. Convair management decided that it was more important to keep commercial jet development in the same location as its piston aircraft sales force than it was to try to capitalize on any plant-level synergies with the Air Force bomber programs.[103]

At the subcontractor level, Convair integrated the 880 into the military aircraft production network, allowing Convair to appropriate some plant-level financial benefits of the Cold War defense buildup. However, subcontracting also allowed Convair's commercial competitors to share that benefit, minimizing its competitive effect. For example, Bendix supplied the autopilot for both the 880 and Boeing's 707, while Bendix' military flight control business provided for the F-101B, F-105, F-106, and B-58.[104] Cleveland Pneumatic, the leading manufacturer of landing gear, supplied the 880 and many other commercial and military aircraft projects.[105] Hamilton Standard furnished air conditioners and hydraulic pumps for both the 880 and the B-58, as well as for other aircraft programs including the F-104 and F-105.[106] Other prominent subcontractors including Garrett AiResearch, Rohr, and Sperry Gyroscope sold both to Convair for the 880 and to a range of military projects.[107] In cases of major subsystems in which particular suppliers did not furnish equipment to more than one aircraft firm, direct competitors in the aircraft parts sector are highly likely to have offered comparable products at comparable costs. All of the commercial aircraft firms had access to the same scale-induced or innovation-related benefits at the subcontractor level.

A similar argument applies to the diffusion of benefits from the plant-level technological transmission mechanism. Turbofan engine technology, embodied in General Electric's J-79, was the principal

103. Interview with William Channa, retired Convair executive, August, 1998. One early Convair commercial jet aircraft design proposal (c. 1953) explicitly was based on its YB-60 bomber design, but the company chose not to develop that design. Proctor, *Convair 880 & 990*, 8–9; Roger Franklin, *The Defender* (New York: Harper & Row, 1987), 149.

104. Aircraft Industries Association, *Aircraft Year Book, 1957-1958*, 135.

105. Aircraft Industries Association, *Aircraft Year Book, 1957-1958*, 141.

106. Aircraft Industries Association, *Aircraft Year Book, 1957-1958*, 145.

107. Aircraft Industries Association, *Aircraft Year Book, 1957-1958*, 143, 155, 158.

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innovation in the 880 design. GE developed the J-79 for the B-58 and other military programs, and it transferred the engine (without its afterburner) to commercial markets as the CJ-805. Convair hoped that this engine improvement would provide a substantial competitive advantage relative to Boeing aircraft equipped with the Pratt & Whitney J-57's commercial version, the JT3C.[108] However, the J-79 turned out to be an expensive engine both to manufacture and to operate—suitable for high-performance military markets, but less appropriate for cost-conscious commercial airlines.[109] Furthermore, Pratt & Whitney rapidly imitated the desirable features of the CJ-805 by designing a low-cost upgrade kit to improve JT3Cs to JT3Ds. American Airlines promptly converted all of its 707s and 720s to the new engine type, and the market for new Convair airplanes collapsed as Boeing's 720 matched the Convair's competitive advantage.[110]

To the extent that the plant-level transmission mechanisms apply to the Convair 880 and 990, Convair's commercial failure undermines the military subsidy theory's claim to explain the American commercial aircraft industry's success. But the plant-level mechanisms were not particularly important for Convair. The firm-level effects of military work were much more relevant: Convair learned from defense contracts to accept high levels of financial and technological risk, which were inappropriate for the commercial aircraft sector.

During the 1950s, General Dynamics, Convair's parent company, was extremely well diversified within the defense business: the company had recently been accused in Congressional hearings of trying to become the General Motors of the defense business, a reference to GM's strength in all subsectors of the automobile market.[111] By the mid-1950s, General Dynamics was a leading contractor on aircraft (B-36, B-58, F-102, and F-106); missiles (e.g.,

108. Franklin, *The Defender*, 162; Proctor, *Convair 880 & 990*, 9.

109. "Pratt & Whitney Feels the Pangs of Success," 144. The CJ-805's problems in commercial markets led to a $90 million loss for General Electric. Because of the CJ-805's high specific fuel consumption and its high maintenance costs, the big U.S. airlines retired their 880s early, when the price of jet fuel rose in the early-1970s. John Wegg, *General Dynamics Aircraft and Their Predecessors* (Annapolis, MD: Naval Institute Press, 1990), 216.

110. Proctor, *Convair 880 & 990*, 12, 55.

111. The allegation was first raised in an anonymous document that surfaced during the "Revolt of the Admirals," part of the Navy's controversial efforts to undermine Congressional support for Convair's intercontinental B-36 bomber and to rally support for the Navy's own proposal for a new class of large aircraft carriers. U.S. House of Representatives, Committee on Armed Services, "Investigation of the B-36 Bomber Program," *Hearings* (August 12, 1949). See also Franklin, *The Defender*, 137.

Atlas and Centaur); and nuclear submarines (e.g., Polaris).[112] Even if individual programs were highly uncertain, General Dynamics had a broad portfolio of investments to control its aggregate level of risk and because each of its projects was a high-priority part of the Cold War defense effort, cost overruns or technological difficulties on one program were less likely to spill over via the firm's integrated finances to damage the prospects of another program. According to the military subsidy argument, General Dynamics should have been able to build its commercial jet business on a stable financial base. While its profitable defense businesses helped Convair survive the financial disaster of the 880 and 990 commercial programs, they did not help Convair become a competitive commercial aircraft manufacturer.

The financial strategy that Convair applied in its attempt to enter the commercial aircraft market also looks very much like its successful strategy for winning defense contracts, and that strategy directly contributed to the commercial disaster. The defense procurement process of the 1950s encouraged contractors to "buy in" to defense contracts, submitting optimistic initial cost estimates in order to obtain contracts.[113] If the estimates proved too optimistic, as they often did, contractors could still profit on cost-plus-fixed-fee contracts, through high-priced engineering change orders, or through cost-escalation clauses that permitted sole-source contract renegotiation.[114] The buy-in pattern was encouraged by the military services' lack of well-developed capabilities to estimate development costs on programs that pushed the state of the art.[115] Because American politicians are rarely willing to recognize sunk costs and cut their losses, and because the high salience of the Soviet threat in the 1950s made even costly weapons projects seem vital to national security, the military rarely terminated programs to stop cost overruns. "Buy in" was the financial lesson of 1950s defense procurement.

The difficulty for Convair's commercial projects began when the company decided to apply similar financial principles in its proposals

112. General Dynamics also owned Canadair, which produced F-86 Sabers and upgraded Super Sabers for export, and Stromberg-Carlson, a major American manufacturer of telecommunications equipment.

113. Tyson et al., *Acquiring Major Systems*, IV-5. During many periods of the Cold War, the politics and regulations of defense procurement prevented buy in from growing into a terribly large problem for the defense budget; however, buy-in worked particularly well as a business strategy during the 1950s for firms that promised rapid technological progress as part of their proposals.

114. McNaugher, *New Weapons, Old Politics*, 60, 162.

115. Frederic M. Scherer, *The Weapons Acquisition Process: Economic Incentives* (Boston: Division of Research, Graduate School of Business Administration, Harvard University, 1964), 63–4, 81.

to launch-customer airlines: TWA on the 880 and American Airlines on the 990. For its launch order, TWA made a down payment of only $15 million (10% of the total value of the order) and did not commit to make any progress payments during the three-year schedule for development and production.[116] Of course, military contracts included progress payments to contractors, so TWA's purchase did not exactly follow the defense-contracting pattern. But in defense markets, progress payments during development were often set as a percentage of an optimistically-low total purchase price, meaning that in the military cases, as on the TWA contract, the contractor assumed financial risk until later price adjustments repaired its finances. In the case of the 880, Convair relied on TWA to make a follow-on purchase, which would help Convair break even on its design. But unlike the Air Force buyer for Convair's successful military programs, TWA neither renegotiated the price nor bought more aircraft.

One of the few subsequent 880 sales, to Capital Airlines, required Convair to accept still more financial risk. Capital could not afford to buy new aircraft, had recently deferred a major order for de Havilland Comets, and had applied for mail subsidies from the Civil Aeronautics Board, the first major airline to do so in five years. To sell 880s to Capital, Convair had to finance the purchase.[117] Capital eventually received several 880s, but the 880's weak customer base undermined Convair's hope to "get well" on follow-on sales.

Convair made similar financial concessions on its development of the 990 for American Airlines. The contract was for twenty-five 990s at a total purchase price of only $100 million. In lieu of a down payment, Convair accepted a trade-in of twenty-five piston-powered DC-7s, whose residual value was plunging with the debut of jet aircraft. And Convair agreed not to charge American for inventory storage costs on spare parts, cutting into the traditional high margins of the aircraft spare parts business. Convair offered American all of these concessions because of American's privileged position as the 990's launch customer.[118]

New management at Convair eventually ended this military-style business strategy of hoping for commercial profits based on "getting well" in the future. In 1960, General Dynamics merged with the cash-rich Materials Services Corporation, a supplier of construction materials. Henry Crown, formerly the head of MSC, became the head

116. Proctor, *Convair 880 & 990,* 10; Franklin, *The Defender*, 153.
117. "Capital Buy 880s . . .," *Flight* 73 (January 31, 1958), 157.
118. Proctor, *Convair 880 & 990*, 53.

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of General Dynamics' Executive Board, and he pushed Convair to cut its commercial aircraft losses.[119]

Lessons learned on Air Force procurements also had powerful, negative effects on the technological aspects of the 880 program. In the high threat environment of the 1950s, promises to achieve technological breakthroughs guided the military services' choices of contractors for major weapon system developments. The secret to winning defense contracts, as General Dynamics learned on the B-58 project in particular, was to build aircraft beyond the technological state of the art.[120] Convair won the B-58 contract in a competition with Boeing: Air Materiel Command branded Boeing "uncooperative" because it proposed a heavier airplane with better prospects for high-speed control, given what was then known about supersonic aerodynamics.[121] Speed was the specific key to the B-58 program, because Air Force strategy called for bombers to fly high and extremely fast, outrunning Soviet air defenses.[122] The Air Force, concerned to buy technologically advanced weapons as rapidly as possible, almost regardless of the cost, was willing to work with contractors who demonstrated diligent effort in pursuit of impossible technological goals.[123] The way to lose favor was to appear unwilling to throw in more resources. Contractors could also lose favor by scaling back technological aims in their design proposals.

Transposing the Air Force's role in defense technology development to the commercial market, Convair emphasized responsiveness to a lead customer during 880 development. Convair engineers had learned a particular set of technological goals and design principles from their Air Force projects, and they applied those lessons to the commercial market. Between 1956 and 1958, TWA chairman Howard Hughes micro-managed the design of Convair's proposed trans-continental jet, delaying the project so much that Boeing and Douglas preempted the long-haul jet market.[124] Convair then moved into the medium-haul market, in which the 880 faced no direct competitors until Boeing followed Convair with its 720.[125] Yet in leaving the long-range market, Convair failed to jettison Howard Hughes' influence: TWA purchased the first thirty 880 aircraft delivery slots, and the

119. Jacob Goodwin, *Brotherhood of Arms: General Dynamics and the Business of Defending America* (New York: Times Books, 1985), 83.

120. Brown, *Flying Blind*, 171–2.

121. Ibid; 173.

122. Ibid; 169–70.

123. Scherer, *Weapons Acquisition Process*, 81.

124. Wegg, *General Dynamics Aircraft*, 214.

125. Franklin, *The Defender*, 151.

contract prohibited Convair from even negotiating for sales to other airlines during a long stretch of the 880's development.[126] Convair continued to customize the medium-range aircraft for TWA's route structure, which hampered sales to other airlines.[127] To sell to other airlines, Convair ultimately developed an 880M derivative beginning in October, 1959, and the last seventeen of the sixty-five 880s sold were the new version; the need for major design changes during production increased costs and reduced learning effects, which increased Convair's loss on the 880.[128] Unlike the comparable military practice in which the customer paid for expensive engineering change orders, commercial airline customers did not help Convair with these extra costs.

The military-like emphasis on speed in Convair's commercial aircraft strategy also contributed to losses, particularly on the 990. As part of its sales contract with American Airlines, Convair provided extremely ambitious performance guarantees for the 990: the 990 would fly the New York–Los Angeles route faster than its competitors, or Convair would rebate a substantial portion of the purchase price.[129] The 990 would also fly from short runways at close-in airports like New York's LaGuardia and Chicago's Midway, each with notoriously difficult take-off and landing conditions.[130] These promises were considerably more aggressive than the comparable launch agreements on the Boeing 707 and the Douglas DC-8. When flight testing began in 1961, the 990 could not meet the performance guarantees. Transcontinental range was in question even at a reduced speed of 584 mph instead of the promised 635 mph. American Airlines allowed a limited renegotiation of the contract terms to provide Convair with more time to work out the technological problems, but the delay came at Convair's expense. The total order was reduced from twenty-five to twenty aircraft, and the per-airplane price dropped to only $3 million, far lower than Convair's costs.[131] Even though Convair's diligent effort to solve the 990's technological problems probably would have yielded a favorable contract renegotiation from a military buyer, Convair received no such relief in the commercial market.

Although no "smoking gun" evidence is available on the firm-level transmission mechanisms—we have no document from Convair's

126. Wegg, *General Dynamics Aircraft*, 214; Proctor, *Convair 880 & 990*, 8–9.
127. Proctor, *Convair 880 & 990*, 9; Franklin, *The Defender*, 148.
128. Wegg, *General Dynamics Aircraft*, 216.
129. Franklin, *The Defender*, 162.
130. Proctor, *Convair 880 & 990*, 53.
131. Proctor, *Convair 880 & 990*, 56.

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corporate archives indicating a specific intent to apply military-style development strategies to the 880 project—Convair's behavior on the B-58 and 880 projects is strikingly similar.[132] The circumstantial evidence is particularly strong on the firm-level technological transmission mechanism. The most supportive interpretation of the Convair case for the military subsidy theory would argue that Convair's military projects had little direct effect on the 880 and 990 because Convair segregated its bomber and airliner work at different plants. The implication would be that the military subsidy theory might not be incorrect; instead, it would simply not apply to every company that sold to both the military and commercial customers. The alternative interpretation recognizes the possibility of pernicious learning effects that defense work can have on commercial aircraft design and project management. That interpretation strongly undermines the military subsidy theory.

Conclusions

The military subsidy theory offers a counter to President Eisenhower's farewell warnings about the dangers of the MIC. If the military subsidy theory were true, the high level of defense spending in the 1950s that created a full-time, military-oriented segment of American industry to fight the Cold War would pose much less of a public policy problem. Instead of diverting commercial industry's financial resources toward military projects and crowding out civilian scientific work, the military effort would actually ease the way for civilian competitiveness by spinning off both financial and technological benefits.

President Eisenhower, on the other hand, feared that military and commercial projects were substitutes rather than complements. He identified "the need to maintain balance in and among national programs—balance between the private and the public economy, balance between cost and hoped for advantage . . ." Without balance, the MIC would divert effort from civilian projects; even if the public would prefer government spending on other projects, the MIC's concentrated political interest might allow it to avoid democratic checks and balances. Only "statesmanship" and "an alert and

132. Many records from Convair's San Diego complex were transferred to the San Diego Aerospace Museum, but the collection is incomplete. Specifically, the collection includes few, if any, business strategy or planning documents. Most of the files hold technical drawings and photographs of Convair airplanes.

knowledgeable citizenry" would protect American security, liberty, and prosperity.

Careful examination of the history of the aircraft industry of the 1950s and 1960s suggests that President Eisenhower was more right than the proponents of the military subsidy argument.[133] Case studies of commercial jet aircraft developed at the time when the MIC focused most directly on jet aircraft technology show that the defense effort only helped the commercial industry occasionally, in very limited ways. Meanwhile, defense contracts at Boeing, Douglas, and Convair also hurt the firms' commercial aircraft sales.[134]

In most cases, the final assembly contractors' military and commercial projects simply did not share much tooling or facilities investment: even the vaunted plant-level links between Boeing's 707 and KC-135 aircraft programs proved to be minimal. Most of the commonality fell to the subcontractor level, so spin-off benefits diffused throughout the aircraft market as multiple aircraft designs shared the same subcontractor network. Overall, though, the case of the Douglas DC-8 offers limited evidence in support of the plant-level financial transmission mechanism—support that should be weighed against the disconfirming evidence from the other case studies. Even for readers who find the Douglas evidence more convincing than the countervailing evidence from the other aircraft companies, the relatively small scale of the possible plant-level financial benefit revealed by the Douglas case is almost certainly overwhelmed by

133. The aircraft industry was only one component of the MIC of the 1950s, although it was the most technologically advanced and thus might offer especially important evidence for adjudicating between the military subsidy theory and President Eisenhower's warning. A truly comprehensive study of the MIC, though, would include other industries like shipbuilding and land vehicles and would more thoroughly cover upstream industries like electronics, materials, and machine tools. But by carefully choosing cases to study—in this case several firms in the jet aircraft industry—we can draw inferences about the overall MIC with a high (though imperfect) degree of confidence. Stephen Van Evera, *Guide to Methods for Students of Political Science* (Ithaca, NY: Cornell University Press, 1997); Daryl G. Press, *Calculating Credibility: How Leaders Assess Military Threats* (Ithaca: Cornell University Press, 2005), 31–8, 174.

134. By contrast, several careful studies of the development of the computer industry find support for the military subsidy theory through both technological and financial transmission mechanisms. See Flamm, *Creating the Computer*; Christophe Lecuyer, *Making Silicon Valley: Innovation and the Growth of High Tech, 1930-1970* (Cambridge, MA: MIT Press, 2006). For a careful effort to evaluate detailed transmission mechanisms linking military and commercial computer projects at IBM—and one that shares this article's skepticism about the military subsidy theory—see Steven W. Usselman, "Learning the Hard Way: IBM and the Sources of Innovation in Early Computing," in *Financing Innovation in the United States, 1870 to the Present*, eds. Naomi R. Lamoreaux and Kenneth L. Sokoloff (Cambridge, MA: MIT Press, 2007), 319, 321–2.

some of the negative effects of military work on commercial aircraft industry competitiveness transmitted via other mechanisms.[135]

Many of the empirical results that mitigate the importance of the plant-level financial transmission mechanism also apply to the plant-level technological transmission mechanism. But additional evidence further undercuts this form of military support. For commercial aircraft to gain from technology invented on military projects, the particular technological advances would have had to contribute to aircraft sales prospects. However, the technological advances incorporated in the Convair 880 and 990—to the extent that they worked at all—were either rapidly imitated by competitors or did not provide competitive advantage at all, as aircraft speed turned out not to be a vital source of competitive advantage for the commercial airlines.

The two firm-level types of military support may have directly hurt the competitiveness of the American commercial aircraft industry. The intense political pressure to perform on U.S. defense contracts during the Cold War overshadowed contractors' desire to concentrate on their commercial projects. The Boeing 707 case study shows this problem early on, when Boeing's image as a defense supplier hampered commercial sales; later, Douglas struggled to deliver commercial aircraft on time because military demand overwhelmed its production capabilities. Instead of helping the commercial efforts, the military projects took resources from them,

135. Further research should carefully explore the differences between the computer and aircraft industries and the two industries' different experiences with military buyers. As a candidate hypothesis to explain the seemingly different levels of empirical support for the military subsidy theory, future researchers might elaborate on John Alic's emphasis on the military's sometime purchases of the same microelectronics as commercial customers, while military and commercial aircraft differed, as explained in the text of this article. Kira Fabrizio and David Mowery similarly emphasize the general-purpose characteristics of information technology. Perhaps a fine-grained analysis comparing the effects of military procurement of unique computer equipment with the effects of military purchases of generic equipment, distinguishing which companies and plants supplied which kinds of equipment, would prove productive. Such a study would have to sort out the balance between positive effects due to economies of scale and negative effects due to the military's insistence that its suppliers match the pace and trajectory of investment to military rather than commercial priorities. See John A. Alic, *Trillions for Military Technology: How the Pentagon Innovates and Why It Costs So Much* (New York: Palgrave MacMillan, 2007), 5, 182–5; Kira R. Fabrizio and David C. Mowery, "The Federal Role in Financing Major Innovations: Information Technology during the Postwar Period," in *Financing Innovation in the United States, 1870 to the Present*, eds. Naomi R. Lamoreaux and Kenneth L. Sokoloff (Cambridge, MA: MIT Press, 2007), 287.

following President Eisenhower's diagnosis of the likely problems of the MIC.

The Convair case highlights the difficulty in applying technological lessons from military aircraft design efforts to commercial markets.[136] Convair tried to respond to its lead commercial customers in much the same way that it responded to its Air Force customer on the military side of its business, but TWA and American Airlines did not value the same things as the Air Force (speed and commitment to advance the state of the art), and they declined to reimburse Convair for cost overruns. Treating military and commercial projects the same way led Convair to make disastrous business decisions. As President Eisenhower explained, participation in the MIC threatened to change the character of American industry in a way that hurt performance of civilian tasks.

In the end, the military subsidy theory does not explain the competitiveness of the American commercial aircraft industry. It neither accounts for the different levels of success of the various American aircraft companies that produced airplanes for both commercial and military customers nor explains the success of American manufacturers compared to their contemporary European competitors, de Havilland and Sud Aviation. During the Cold War, the U.S. military was a very demanding customer that required prompt responsiveness from its suppliers. The way to win military contracts was to agree to develop and produce extraordinarily sophisticated aircraft, often beyond the technical state-of-the-art, on a rapid production schedule.[137] The military was particularly unlikely to reward firms for participating in the commercial aircraft market—a distraction, from the military's perspective. As a result, innovation and competitive advantage in the commercial aircraft market did not depend on the MIC.

136. Thomas Heinrich notes a similar negative learning effect on Silicon Valley defense contractors during the Cold War: they learned habits from their military work that hampered their commercial business from the 1950s through the 1970s; later, though, the military experience may have helped the microelectronics industry during the late-1980s, when the military market dwindled but some commercial markets became interested in sophisticated batch production. Like the present article, Heinrich's research points us toward careful analysis of specific transmission mechanisms. Heinrich's results also reinforce the conclusion that scholars have significant opportunities to gain from cross-industry comparison, specifically by investigating the relative importance of selling components instead of end-items and of selling custom products rather than general-use products. More broadly, scholars should examine any characteristics of industries that might change the effect of military business on related commercial industry. Thomas Heinrich, "Cold War Armory: Military Contracting in Silicon Valley," *Enterprise and Society* 3 (June 2002): 247–84.

137. Brown, *Flying Blind*, Chapter 9.

Nevertheless, the American aircraft industry flourished, despite President Eisenhower's fears. Widely available, fast air travel transformed society, and the aircraft industry led the list of America's top exporters for generations. Those firms that tried to combine membership in the MIC with sales to commercial airlines struggled. Douglas was the most successful, but its commercial business barely held on until the late-1990s; Convair's efforts to serve both commercial and military aircraft spectacularly collapsed in 1962.[138] Boeing, on the other hand, left the military aircraft market (but not all defense work) to pursue its commercial success: Boeing delivered its last military aircraft in 1965, thereafter focusing its efforts on commercial follow-ons to the 707 rather than on military successors to the KC-135.[139] That choice allowed Boeing the flexibility to respond to prominent commercial customers' needs and (partially) inoculated Boeing engineers and management from misapplying the lessons of military projects to commercial sales campaigns. Other factors, including a good dose of luck, surely helped Boeing's commercial success and sustained the company through near-death experiences, but resisting too strong a belief in the military subsidy theory helped, too.

President Eisenhower concluded his Farewell Address on an optimistic note. He felt that the American people were likely to heed his wake-up call to vigilance against the power of the MIC. For the most part they did. American defense spending rose and fell through several Cold War budget cycles, but the military effort never dominated the federal budget or engulfed civil society. President Eisenhower was right not only about the potential dangers of the MIC but also about the recipe for protecting the United States against them: the MIC protected the United States from the Soviet threat, even if it sometimes exaggerated the dangers; civilian ingenuity promoted economic growth, even if particular companies sometimes struggled; and statesmanship and an alert citizenry preserved checks and balances, even if they were not always swift with their moderating influence.

138. Another major defense contractor, Lockheed, tried and failed in the commercial jet aircraft market in the 1970s.

139. Boeing merged with McDonnell Douglas in 1997 and subsequently continued to make military aircraft like the F/A-18 that had previously been developed and produced by McDonnell. The legacy Boeing parts of the company still have not produced a military aircraft of their own, although legacy Boeing developed and produces roughly one-third of the F-22 for Lockheed Martin, the prime contractor.

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