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Introduction

The Propeller and the Modern Airplane

On the afternoon of Wednesday, April 6, 1938, a United Air Lines *Mainliner*, a Douglas Sleeper Transport, departed from the Newark, New Jersey, airport with fourteen passengers aboard, a crew of three, and enough fuel to reach Chicago. They rolled on the runway for only a brief fifteen seconds before lifting off. Then pilot George Grogan, sitting in the left seat, pointed the futuristic silver twin-engine airliner northeast toward New York City. As they cruised over Central Park at 6,000 feet and just over 200 mph, the propeller on the right engine stopped turning (Figure 1). To any observer, that was an indication of engine failure, loss of power, and an impending crash. Remarkably, Grogan maneuvered the *Mainliner* through the clouds, climbed, and turned without losing speed or altitude. When he was finished, Grogan restarted the right engine and the motionless propeller began whirling again. He then shut down the left engine, stopped its propeller and set its blades parallel to the wind like he had for the other, and proceeded on with an aerial tour of New York, Connecticut, and New Jersey before returning to Newark on two running engines.[1]

The passengers aboard Grogan's *Mainliner* had experienced the first public demonstration of a revolutionary aeronautical innovation, a practical propeller capable of maximizing the power of an aircraft engine and the performance and safety of an airplane overall. The next day, United Air Lines inaugurated its fifteen-hour coast-to-coast transcontinental service with Douglas Sleeper Transport (DST) and DC-3 airliners capable of

[1] James V. Piersol, "Air Currents," *New York Times*, April 10, 1938, p. 164; "New Propellers Installed," *Aero Digest* 32 (May 1938): 27.

FIGURE 1 George Grogan's United Air Lines *Mainliner* DST with one engine shut off over Manhattan in New York City in April 1938.
Courtesy of Hagley Museum and Library.

flying as high as 20,000 feet at an unprecedented speed of three miles a minute across the United States.[2]

The Douglas airliners and their propellers were "modern" in every sense of the word. Compared to the slow, fabric-covered biplane of the World War I era, they were the state of the art in aeronautical technology; the flying embodiment of the combined aerodynamic, structural, and propulsive innovations that first made flight a global endeavor. These high-speed streamlined metal monoplanes resulted from an Aeronautical Revolution that swept through North America and Europe during the twenty years between the world wars.[3] Parallel and intertwined advances

[2] "Fast Air Liners Go into Service," *Los Angeles Times*, April 8, 1938, p. A2; United Air Lines, "United Announces the Nation's Fastest, Most Powerful, Quietest Large Airliners!" *Chicago Daily Tribune*, April 20, 1938, p. 4; American Society of Mechanical Engineers, *Hamilton Standard Hydromatic Propeller: International Historic Engineering Landmark*, Book No. HH 10 90 (November 8, 1990), 3.

[3] "Aeronautical Revolution" goes beyond the technical emphasis of John B. Rae's "airframe revolution" or Larry Loftin's "design revolution" to fully encompass the interrelated technical and nontechnical changes witnessed in aviation overall during the

in technology, governmental regulation, entrepreneurial growth, and cultural awareness created aviation as we know it today.

At the center of this revolution in the sky was an international community. These designers, engineers, inventors, entrepreneurs, military officers, pilots, and many others represented a myriad of aeronautical specialties. They reinvented existing technology to create new airplanes. Their shared culture of performance inspired, pushed, and enticed competing visions of expanding the capabilities of aeronautical technology in the name of advancing humankind.

Within the aeronautical community, there was a group of specialists dedicated to one critical part of the modern airplane, the propeller. Their work to reinvent that one component resulted in a transformative technology that enabled commercial and military aircraft to climb quicker and cruise faster using less power and, if need be, fly to safety on one engine. When integrated into increasingly sophisticated aircraft, the airlines used them to connect the world by airplane and air forces used them to fight a global war in the air. These modern propellers and their ability to "shift gears in the air" to meet different operating conditions helped make the system of the airplane a world-changing technology. This book is the story of those specialists, their beliefs, their successes and failures, and the propellers they created while standing at the intersection of the technical and cultural forces that shaped the airplane over the course of the twentieth century.

A Culture of Performance and the Reinvention of the Airplane

The first airplane took to the air at Kill Devil Hill on the desolate windswept dunes off the Outer Banks on the coast of North Carolina on Thursday morning, December 17, 1903. At the controls was Orville Wright, who with his older brother, Wilbur, brought their *Flyer* from Dayton, Ohio. This original flying machine had two wings, a horizontal elevator mounted in front, and a vertical tail in the rear constructed from wood, covered in muslin, and joined together with wood struts and wire. Power came from an aluminum reciprocating piston engine connected by chains to two wood propellers. The *Flyer* flew four times that morning.

1920s and 1930s. John B. Rae, *Climb to Greatness: The American Aircraft Industry, 1920–1960* (Cambridge, MA: MIT Press, 1968), 58; Laurence K. Loftin, Jr., *Quest for Performance: The Evolution of Modern Aircraft* (Washington, DC: National Aeronautics and Space Administration, 1985), 77.

The last saw Wilbur pilot the biplane as high as fourteen feet, at speeds approaching 20 miles per hour over a distance of 852 feet. During those 59 seconds, the brothers knew full well they were the first to conceptualize, design, and construct, in other words, invent, an airplane capable of practical, sustained flight. While the achievement is theirs, Wilbur and Orville were also the preeminent members of an emergent community of aeronautical enthusiasts.[4]

This aeronautical community grew as it improved, developed, and used the Wrights' creation through those early days of flight, World War I, and on into the 1920s. The famous flights of Frenchman Louis Blériot, German Manfred von Richthofen, American Charles Lindbergh, and other pioneering pilots represented the cultural acceptance of the airplane from an entertaining novelty flown by gentlemen-aviators at air meets into an instrument of commerce, a weapon of war, and a vehicle for spectacle. In response, a significant portion of Western culture, primarily in the United States, embraced a new form of technological enthusiasm called "airmindedness" that called for the zealous support of aviation to bring about the next great era in human civilization, the Air Age.[5] That reaction revealed a strong cultural undercurrent, characterized by the rapid and continual technical development of time- and distance-shattering technologies. The popular passion for the fast-sailing clipper, steamship, railroad locomotive, automobile, and airplane as well as their perceived contributions to society reflected the Enlightenment ideal of "Progress" where "Technology" autonomously drove humankind forward through history. For airminded America and Europe, the concept of the airplane as a vehicle to utopia was easy to grasp.

New communities of aeronautical specialists in North America and Europe created the technical foundation that energized the growth of airmindedness in the popular imagination. Unlike the Wright brothers,

[4] Tom D. Crouch, *A Dream of Wings: Americans and the Airplane, 1875–1905* (New York: Norton, 1981; reprint, Washington, DC: Smithsonian Institution Press, 1989), 19.

[5] Joseph J. Corn, *The Winged Gospel: America's Romance with Aviation, 1900–1950* (New York: Oxford University Press, 1983), 12, 31, 135. Studies focusing on European and transnational aeronautical enthusiasm that complement Corn's work include: Peter Fritzsche, *A Nation of Fliers: German Aviation and the Popular Imagination* (Cambridge, MA: Harvard University Press, 1992); Robert Wohl, *A Passion for Wings: Aviation and the Western Imagination, 1908–1918* (New Haven, CT: Yale University Press, 1994), and *The Spectacle of Flight: Aviation and the Western Imagination, 1920–1950* (New Haven, CT: Yale University Press, 2005); Guillaume de Syon, *Zeppelin! Germany and the Airship, 1900–1939* (Baltimore, MD: Johns Hopkins University Press, 2002).

these designers, engineers, and inventors focused on creating, innovating, and introducing improved components and systems of the airplane, from innovative aerodynamic shapes, structures, and engines to cockpit instruments, landing lights, and structural fasteners.[6] These largely anonymous technical personnel worked either for themselves, small companies, government research institutions, or octopus-like corporations. They shared the historical stage with executives, entrepreneurs, government and military officials, pilots, journalists, factory workers, and even family members in the larger aeronautical community. To one observer, it was the "passion of the specialists" and the "fervor of those individuals" that created a heritage of research, development, and foundational work in aeronautics.[7] There were many lifetimes of work, investment, and dedication to these distinct areas within aeronautics.

The specialists saw themselves as pioneers of a technological frontier in the sky as they toiled to make airplanes fly higher, farther, and faster than ever before.[8] Adopted by historians almost to the point of cliché today, the phrase "higher, faster, and farther" reflected an interrelated technical and cultural pursuit by the aeronautical community since the days of the Wright brothers.[9] To the specialists, a seemingly limitless increase in

[6] Walter G. Vincenti's pioneering study of engineering knowledge documented "communities of practitioners" acting as "social agents for the production of knowledge" during the first half century of flight. Walter G. Vincenti, *What Engineers Know and How They Know It: Analytical Studies from Aeronautical History* (Baltimore, MD: Johns Hopkins University Press, 1990), 238–239.

[7] H. M. "Jack" Horner, in *We Saw It Happen*, United Aircraft Corporation, 1953, motion picture.

[8] David T. Courtwright, *Sky as Frontier: Adventure, Aviation, and Empire* (College Station, TX: Texas A&M University Press, 2004), 14–15, 97–105.

[9] Dominick Pisano, "The Literature of Aviation," in *Milestones of Aviation*, ed. John T. Greenwood (New York: Hugh Lauter Levin Associates, 1995), 311. Greenwood's entire volume discusses the development of the airplane through chapters entitled "farther," "higher and faster," "bigger," and "better." For works that also convey the "higher, faster, and farther" theme, see Mark P. Friedlander, Jr., and Gene Gurney, *Higher, Faster, and Farther* (New York: Morrow, 1973); Terry Gwynn-Jones, *Farther and Faster: Aviation's Adventuring Years, 1909–1939* (Washington, DC: Smithsonian Institution Press, 1991); and Stephen L. McFarland, "Higher, Faster, and Farther: Fueling the Aeronautical Revolution, 1919–1945," in *Innovation and the Development of Flight*, ed. Roger D. Launius (College Station, TX: Texas A&M University Press, 1999), 100–131. The first significant appearance of the phrase was in a popular history of the United States, which celebrated the fact that "planes [*sic*] steadily flew higher, faster, and farther" as they circumnavigated the earth, raced the sun across the continent in one day, and soared over the North Pole among other aeronautical achievements. Walter S. Hayward and Dorothy A. Hamilton, *The American People: A Popular History of the United States, 1865–1941* (New York: Sheridan House, 1943), 222–223.

aircraft altitude, speed, and range as the measure of performance served as a clear indicator of two things. First, ever more sophisticated aircraft increasingly expanded the commercial and military capabilities of aviation. Second, that performance validated their culture's celebration of the airplane as a vehicle of "Progress." The influential editor of the British aeronautical journal, *The Aeroplane*, C. G. Grey, reflected in 1924 on the first twenty years of flight and observed this relationship as culture and technology merged into the "conquest of the air." He suggested what might follow in the future of aviation – bigger, more efficient, and safer aircraft flying along established airways – and that they would "all come in due course."[10] This airminded culture of performance saw inevitability in the continually progressive evolution of the airplane and what the result would do for the world.[11]

During the 1920s and 1930s, the aeronautical community came together collectively and created new technology as it expressed its enthusiasm for flight. Through innovation in aerodynamics, structures, and propulsion, the specialists and their nontechnical partners reinvented the airplane.[12] They took the system invented by the Wright brothers, the wood, strut-and-wire braced biplane, and refined further by an international aeronautical community during the 1910s and World War I, and made it better. The end result was the airplane in its first "modern"

[10] C. G. Grey, "On the Coming of Age of Aviation," *The Aeroplane* 27 (December 17, 1924): 565–566.

[11] Historians have debunked the idea of the inevitability of technology shaping history, specifically referred to as technological determinism, and the temptation to oversimplify historical trends in their lexicon in favor of more complex and nuanced interpretive frameworks. Merritt Roe Smith and Leo Marx, *Does Technology Drive History? The Dilemma of Technological Determinism* (Cambridge, MA: MIT Press, 1994).

[12] Robert T. Jones, a discoverer of the swept wing, used the term "reinvented" to describe his experience working with pioneering aerodynamics researcher Fred E. Weick at the Langley Memorial Aeronautical Laboratory of the National Advisory Committee for Aeronautics (NACA) in the 1930s. Fred E. Weick and James R. Hansen, *From the Ground Up: The Autobiography of an Aeronautical Engineer* (Washington, DC: Smithsonian Institution Press, 1988), vii. James R. Hansen provided the historiographical framework for interpreting the technical development of aircraft in the 1920s and 1930s as a process of reinvention beginning with the Wright *Flyer* and ending with aircraft like the Douglas DC-3. James R. Hansen, "Flight and Technology: An Overview," in *National Aerospace Conference Proceedings: The Meaning of Flight in the Twentieth Century, October, 1-3 1998* (Dayton, OH: Wright State University, 1999), 156–158; and "Introduction to Volume II: Reinventing the Airplane," in *The Wind and Beyond: Journey into the History of Aerodynamics in America; Volume II: Reinventing the Airplane*, NASA SP-2007–4409, ed. James R. Hansen (Washington, DC: Government Printing Office, 2007), xxi–xxv.

form – the high-speed, metal, streamlined, cantilever-wing monoplane with retractable landing gear and advanced engines and propellers. On both sides of the Atlantic, the introduction of revolutionary aircraft in the mid-1930s astonished the international aeronautical community and a largely airminded mainstream society with their ability to transport people, cargo, and weapons higher, farther, and faster over countries, continents, and oceans.

The emergence of the modern airplane was a major event in the history of Western civilization. For many, Grey's predictions were coming to fruition. On Thursday evening, May 30, 1935, American aeronautical engineer and aviation entrepreneur, Donald W. Douglas, delivered the prestigious Wilbur Wright Memorial Lecture before the Royal Aeronautical Society of Great Britain. His talk, given in the shadow of the Wright brothers' *Flyer* on display at the Science Museum in London, addressed the development of the "modern" airliner in the United States. The products of American manufacturers, built to fly high and fast over the long distances of North America, epitomized the state-of-the-art in aeronautical technology. To Douglas, the "rapid technological progress" that culminated in his successful DC-series airliners reflected the existence of a "golden age" of aeronautics.[13] In making that distinction, he placed the development of the modern airplane squarely within a long-standing cultural mind-set. Beginning with the Greek poet Hesiod in 800 BCE, observers and historians described a particular moment of extraordinary achievement in the history of a culture as an idealized period of great happiness and prosperity.[14]

Douglas believed there were many groups responsible for the success of the modern airplanes that were about to help change the world. The airlines, research organizations, and airframe, engine, instrument, and radio manufacturers all had their part in the process as members of the aeronautical community. Of those contributors, he saw propeller makers and their creations as fundamental to that achievement. Without them, the "glorious future" Douglas predicted for aviation was impossible.[15]

[13] Donald W. Douglas, "The Development and Reliability of the Modern Multi-Engine Air Liner," *The Journal of the Royal Aeronautical Society* 40 (November 1935): 1042–1043, 1046.
[14] H. C. Baldry, "Who Invented the Golden Age?" *The Classical Quarterly* 2 (January–April 1952): 83–92.
[15] Douglas, "The Development and Reliability of the Modern Multi-Engine Air Liner," 1043.

Lessons from an "Invention of a Smaller Nature"

In the ten years following Douglas's speech, world society embraced the airplane and excited, amazed, shocked, and terrified itself with the promise and power of aeronautical technology. It was, in the words of the prominent American sociologist and pioneering historian of technology, William Fielding Ogburn, a "big invention" that enabled individuals, institutions, nations, and communities to express their hopes, dreams, and ambitions for a myriad of economic, political, military, and technological reasons.[16] The exploration of those themes and the inclusion of social and cultural factors have expanded our understanding of flight and technology as a major force in society into the twenty-first century.[17]

Understanding how that "big invention" came to be as a technical system from the perspective of designers and manufacturers of complete aircraft is fascinating and important.[18] Another way to comprehend the origins of the modern airplane is to consider it, once again in Ogburn's words, as a "cluster of inventions of a smaller nature."[19] Unraveling and explaining the evolution of the different technologies making up the airplane offers different perspectives on engineering, research and development, design, and the multilayered social, cultural, financial, commercial, industrial, and military infrastructure of aviation during the Aeronautical Revolution.[20] To understand fully the modern airplane and the community that created it during the 1920s and 1930s, so much depends

[16] William Fielding Ogburn, *The Social Effects of Aviation* (Boston, MA: Houghton Mifflin, 1946), 58.

[17] The writing of aviation history has grown with the larger discipline of the history of technology from a focused look at famous engineers and the "nuts-and-bolts" of great machines to investigations of nontechnical issues involving society and culture. To learn more about the crucial turning point in the discipline, see James R. Hansen, "Review Essay: Aviation History in the Wider View," *Technology and Culture* 30 (July 1989): 643–656. Roger Launius recognized that many of those trends were coming to fruition in the form of a "New Aviation History" that in the case of innovation, cast the technical development of aeronautical technology as an integral part of the human experience. Roger D. Launius, "Patterns of Innovation in Aeronautical Development," in *Innovation and the Development of Flight*, 14–15.

[18] See Philip Jarrett, ed., *Biplane to Monoplane: Aircraft Development, 1919–1939* (London: Putnam, 1997); and John D. Anderson, Jr., *The Airplane: A History of Its Technology* (Reston, VA: AIAA Press, 2002).

[19] Ogburn's main purpose in *The Social Effects of Aviation* was to predict future trends in aviation at all levels of civilian life, but his acknowledgment of the airplane's place in American society up to the 1940s as well as its technical makeup was especially prophetic. Ogburn, *The Social Effects of Aviation*, 58.

[20] James R. Hansen asserted that a focus on these topics would contribute to a "demystification of the aeronautical enterprise." James R. Hansen, "Aviation History in the Wider View," 649; and "Demystifying the History of Aeronautics," in *A Spacefaring*

upon an understanding of its component parts and the specialists that produced them.[21]

An airplane is a synergistic collection of technologies, with the propeller as the crucial link among them during the Aeronautical Revolution. It bridged the gap between the two major technological advances that made higher performance possible: innovations that reduced aerodynamic drag, and improvements in propulsion technology that increased power output. Streamlined design, which included enclosed cockpits, cantilever monoplane wings (that is, wings without external, drag-producing struts or braces), and retractable landing gear, reflected the latest in aerodynamic knowledge. Sophisticated engines, fuels, and supercharging increased power. The propeller, through its spinning helical motion, converted that energy into thrust the same way a wing generated lift to propel an airplane forward. Reinventing propellers to "shift gears in the air" for maximum efficiency during takeoff, climb, and cruise resulted in higher performance at crucial moments in the technical development of the airplane and the history of the national aeronautical cultures that used them.

The "propeller people," as one executive called them, represented a distinct specialist community within aviation.[22] At its core were airminded inventors and engineers that were either celebrated leaders in their fields or largely anonymous in the historical record. Their educational backgrounds ranged from being self-taught to extended formal training in

Nation: Perspectives on American Space History and Policy, ed. Martin J. Collins and Sylvia D. Fries (Washington, DC: Smithsonian Institution Press, 1991), 153–166.

[21] Early American historians have provided important models for studying material culture to gain a broader understanding of technology and the cultures that created them. Judith A. McGaw advocated a "direct treatment of the 'thing'," specifically "small things," as she explored everyday technologies of colonial American life. Judith A. McGaw, "'So Much Depends upon a Red Wheelbarrow': Agricultural Tool Ownership in the Eighteenth-Century Mid-Atlantic," in *Early American Technology: Making and Doing Things from the Colonial Era to 1850*, ed. Judith A. McGaw (Chapel Hill, NC: University of North Carolina Press, 1994), 328–357. Focusing on insights gleaned from the study of "ordinary" household goods, Laurel T. Ulrich sought to reveal how nineteenth century New Englanders found meaning in a world "cross-snarled and twined" together. Laurel T. Ulrich, *The Age of Homespun: Objects and Stories in the Creation of an American Myth* (New York: Alfred A. Knopf, 2001), 6–8. For broader discussions of the topic, see Steven Lubar and W. David Kingery, eds., *History from Things: Essays on Material Culture* (Washington, DC: Smithsonian Institution Press, 1993).

[22] George J. Mead, in Report of the Second Meeting of the Technical Advisory Committee of the United Aircraft and Transport Corporation at Seattle, Washington, December 2–6, 1929, Claire Egtvedt Files (hereafter cited as CE), Boeing Company Archives (hereafter cited as BCA), 379.

industry or at a university. At the personal level, they yearned for the same things other technologists desired. They wanted to reap financial rewards, achieve professional recognition, satisfy their intellectual curiosity, and to experience the satisfaction of a career in a new and exciting industry. To the spouse of one of the specialists, "all they wanted was a drawing board and a sharp pencil and a chance" to reinvent their one part of the airplane.[23]

For this specialist community, the development of propeller technology generated a dynamic environment that facilitated coexistence, collaboration, and conflict. A few worked as individuals in the mode of the celebrated independent inventor of the late nineteenth and early twentieth centuries.[24] Most found employment during World War I in newly created government and industrial engineering organizations. Those establishments served as collective "inventive institutions" that provided an equally nurturing and challenging environment in which experimenters could cultivate, explore, and evaluate their novel ideas for propellers.[25] In response, the members of the propeller community built coalitions throughout the 1920s and 1930s in the United States and Europe to complete the research and development process.[26] Inventors and engineers and government research institutions and manufacturers all needed each other. Individuals needed resources to support further development of their ideas while organizations sought the latest innovations to increase aircraft performance.

Cooperation was never universal. Individuals, teams, groups, and institutions did not triumphantly move forward in lockstep toward the common and singular goal of developing improved propellers. Depending on their place within the community, whether it was a lone inventor,

[23] Juliet Blanchard, *A Man Wants Wings: Werner J. Blanchard, Adventures in Aviation*, 1986, www.margaretpoethig.com/family_friends/pete/wings_bio/index.html (Accessed May 24, 2012), 14.

[24] Thomas P. Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm, 1870–1970* (New York: Penguin, 1989), 7–8.

[25] David Edgerton, *The Shock of the Old: Technology and Global History since 1900* (New York: Oxford University Press, 2007), 192, 197. The concept of "inventive institutions" has been explored in more detail in regard to aircraft propulsion technology by Hermione S. Giffard, in "The Development and Production of Turbojet Aero-Engines in Britain, Germany, and the United States, 1936–1945" (Ph.D. diss., Imperial College, 2011), 20–21, 177–242.

[26] Called "heterogeneous engineering," the process is a central tenet within the history of technology. Launius, "Patterns of Innovation in Aeronautical Development," 13; John M. Staudenmaier, "Rationality, Agency, and Contingency: Recent Trends in the History of Technology," *Reviews in American History* 30 (March 2002): 173.