Biographical Essays in Honor of the Centennial of Flight, 1903–2003

Realizing the Dream of Flight

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Who Was Hugh Dryden

and Why Should We Care?

MICHAEL GORN

DURING HIS LIFETIME, HUGH LATIMER DRYDEN (1898–1965) EARNED AN ENVIABLE REPUTATION AS ONE OF THE WORLD'S PIVOTAL FIGURES BOTH IN AERONAUTICS AND SPACEFLIGHT. Today, almost two generations after his death, his achievements are not well known and even forgotten. In part, Dryden contributed unwittingly to his own disappearance. Reserved and modest, he worked quietly to resolve scientific and bureaucratic problems, enabling others to benefit from his ideas. Moreover, although he made a number of crucial scientific discoveries, he never produced the one conceptual breakthrough that might have elevated him to enthronement among the visible saints of science.

Nevertheless, Hugh Dryden deserves to be remembered for a number of reasons. One of the rare individuals whose career transcended the panorama of 20th-century flight—from the earliest days of aeronautics to the initial human and robotic forays into space—he wedded an unparalleled knowledge of the requisite science and engineering with keen management and bureaucratic instincts. He knew virtually all of the prominent persons in his field, and not just in the United States; his foreign contacts covered nearly every part of the globe. Perhaps more than any other figure, he prepared America for the space age. During his 18 years at the top of the government's leading civilian air and space institutions (as Director of the National Advisory Committee for Aeronautics and as Deputy Administrator of the National Aeronautics and Space Administration), he became a controlling force in federally sponsored research on flight. His own scholarship made impressive and long-lasting contributions to the field. Finally, Hugh Dryden's personal story is a compelling one about an obscure child prodigy who rose ultimately to international prominence.

COMMON ORIGINS

The forbears of Hugh Dryden showed no sign of fame. His ancestors originated in Scotland, in the vicinity of Edinburgh. William and Agnes Dryden (or Dredden, as the family then called itself) immigrated to the colony of Maryland in 1682 seeking religious toleration in the face of Charles II's imposition of Anglican bishops on the Presbyterian Church. The Drydens settled in Somerset and Worcester Counties at the southern tip of the state. Townsmen in the old country, they rapidly accustomed themselves to farming in the New World, although many continued to pursue skilled trades like tailor, shipwright, shoemaker, and cooper. For the most part, they settled near the quiet Pocomoke River, a tributary of the Chesapeake Bay. During the 19th century, many of the Drydens embraced Methodism. For 200 years, then, this family—people of average wealth and station—worked at their occupations, paid taxes, and produced offspring.

Then, during the late 19th century, one Dryden broke ranks with family tradition. Samuel Dryden, the son of Isaac F. and Hester Ann of Pocomoke, Maryland, showed uncommon mathematical ability, and his instructors encouraged him to pursue it as a career. Accordingly, when he earned his high school diploma he also received a teaching certificate. After settling in Pocomoke City, he began a career in the classroom and soon became a vice principal. Samuel seemed destined for a life of at least local distinction. But after seven promising years in the profession, he resigned abruptly, removed his family from Pocomoke City, and relocated to a rural crossroads known as West Postoffice, Maryland. Perhaps the redirection occurred because of his reputed hot temper; perhaps it reflected his desire to better provide for his family. In any event, Samuel and his brother opened a general store in West Postoffice in 1900. Unfortunately, it failed in the panic of 1907, prompting Samuel, his wife Zenovia, and their two sons to leave southern Maryland for good.

Some years before this family crisis, Zenovia Dryden gave birth to her first son. She and Samuel named him for a Methodist clergyman popular in the region, Hugh Latimer Elderdice. Hugh Latimer Dryden entered the world on 2 July 1898 with some distinct advantages, as well as some equal disadvantages. On the positive side, he lived among a sea of relatives—gregarious and often inclined toward music—and witnessed the birth of no fewer than 28 paternal first cousins as he matured. Moreover, his mother, known by the nickname Nova, inspired Hugh with some of her best qualities, especially patience, modesty, and discernment. If young Dryden possessed his mother's temperament, he inherited the mental agility of his father. Precocious, he could read by the age of four, and by eight he had already begun to master the fifth-grade curriculum. But as a boy and young man, Hugh Dryden also lived with some less-than-satisfactory conditions. Try as he might, Samuel Dryden failed to provide his family with more than the bare essentials. Regarded as brilliant by his neighbors and well known for charity and generosity, he nonetheless lacked the toughness for commerce. In addition, the humble one-room schoolhouse in West Postoffice provided poor preparation for a student of Hugh's promise.

When the Drydens left West Postoffice in 1907, they settled in Baltimore, then a thriving port and home to many recent immigrants. The big city represented opportunity for Hugh but the end of ambition for his father. Samuel Dryden took a job with the Baltimore United Railways and Electric Company as a streetcar conductor and remained one the rest of his working life. While steady, his income just met the household's needs. Hugh, on the other hand, found a new world. He became a *Baltimore Sun* paperboy and took various other part-time jobs (working on an assembly line at the United Biscuit Company, sorting packages for an express delivery service, and toiling in a canning factory).

But struggle as Hugh might to augment the family fortunes, education remained the object of his desire, and he continued to be accelerated beyond his years. He enrolled first in Public School Number 85, where he completed the remainder of the fifth and then the sixth grade in just over one year. In School Number 52, where he studied with boys dressed in coats and neckties and girls trimmed in hats and dresses, he required only 18 months to finish grades seven and eight. About three years younger than the rest of his classmates, he started intermediate school at age 9 and graduated at 12. Yet, he continued to excel.[1]

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1 Michael H. Gorn, *Hugh L. Dryden's Career in Aviation and Space* (NASA Monograph in Aerospace History No. 5) (Washington, DC: NASA History Office, 1996), pp. 1–2; Dryden's remarks on paperboys quoted in Shirley Thomas, *Men of Space*, vol. 2 (Philadelphia: Chilton, 1961), p. 66; interview with Mary Ruth (Dryden) Van Tuyl, Silver Spring, MD (3 August 1994); interview with Nancy (Dryden) Baker, Rockville, MD (9 August 1994); interview with Nancy Baker by telephone (25 July 1994); and autobiographical sketch by Hugh L. Dryden (27 September 1965), Hugh L. Dryden (HLD) Papers, Ms. 147, Series 2.2, Milton S. Eisenhower Library, Johns Hopkins University (referred to hereafter as JHU). All interviews cited are in Michael Gorn's possession.

Most of his assignments involved brief essays on history, civics, geography, and the natural sciences. Although the writings of a child, they still show clear exposition and a logical sequence of ideas. Despite his age, he generally earned high marks. In an essay written in April 1908 entitled "The Fairyland of California," he revealed a charming sense of wonder about a far-off place.

> There are parts of California where it is summer all the year round. The flowers always bloom, and the trees are always green. In Los Angeles they sometimes have a festival of roses to celebrate the New Year. On a Christmas morning there you could go to the seashore, take a bath, and come back and set your Xmas [sic] dinner under the orange trees. Then you could go up on the mountains and see some of the finest Xmas [sic] trees in the world.[2]

The young pupil also took many spelling tests and demonstrated high proficiency. He impressed Mrs. Mary Kennedy, his arithmetic teacher, with his capacity to convert various types of weights and measures and to calculate weekly wages and deductions. Finally, in recognition of excellent attendance, he received a prize—a book of religious proverbs entitled *Many Thoughts of Many Minds: A Treasury of Quotations*. He wrote in it the words "a treasure worth keeping" and checked a few entries that especially appealed to him. One, quoted from the English clergyman and author Dr. Jeremy Taylor, sheds light on his developing mind: "Hope is like the wing of an angel, soaring up to heaven and bearing our prayers to the throne of God."[3]

While Hugh Dryden's education proceeded, Wilbur and Orville Wright's epochal flight in December 1903 became known, but not much heralded. Yet, once the Wrights demonstrated the capabilities of their aircraft to the U.S. Army and to European throngs, a wave of curiosity swept America. Just as Hugh Dryden entered puberty, Baltimore's residents beheld one of the aerial spectacles gripping the nation. The *Baltimore Sun*

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2 Dryden, "The Fairyland of California," school essay (15 April 1908), HLD Papers, Ms. 147, Series 1.1, JHU. See also the following school essays by Dryden in the same archive: "Indian Corn and the Corn Belt" (3 February 1908); "Robert Fulton and the Steamboat" (3 March 1908); "Life in the Timber Regions" (4 March 1908); "The Wonders and Treasures of the Rocky Mountain Region" (11 March 1908); "A Visit to a Gold Mine" (18 March 1908); "Eli Whitney" (20 March 1908); "San Francisco and the Chinese" (1 May 1908); "Our National Capital" (15 May 1908); "Baltimore Oriole" (21 May 1908); "A Visit to the President and to the Halls of Congress" (22 May 1908); "The Departments of the Government" (28 May 1908); "Baltimore and Our Oyster Beds" (5 June 1908); "In Philadelphia: A Visit to the Mint" (11 June 1908); "John C. Fremont and Kit Carson" (17 June 1908); "Review of Hawthorne Works" (29 October 1909); and "Science" (22 February 1910).

3 Dryden's collected spelling tests (4 May 1908–19 June 1908), HLD Papers, Ms. 147, Series 1.1, JHU; collected arithmetic tests (5 March 1908–10 June 1908), HLD Papers, Ms. 147, Series 1.1, JHU; and Louis Klopsch, comp., *Many Thoughts of Many Minds: A Treasury of Quotations from the Literature of Every Land and Every Age* (New York: The Christian Herald, 1896), pp. 3, 135, in the possession of Mary Ruth Van Tuyl.

offered a prize of $5,000 to the first flier to navigate the skies over the city. Sportsman and aviator Hubert Latham accepted the challenge. On 7 November 1910, he strapped himself into his French-made Antoinette monoplane and took off. Light at 1,300 pounds, the little vehicle performed well, attaining a high speed of 40 miles per hour as Latham looped again and again around the *Sun*'s downtown offices during his "great flight." Packed in with the rest of the population, Hugh Dryden also witnessed this modern wonder. Nova Dryden noticed that her son reacted to the demonstration not merely with youthful enthusiasm, but with a deeper appreciation. Partly, he must have caught the sense of awe present in the crowd. But more importantly, the event seemed to capture him intellectually. He wanted to know what forces sustained Latham in the air, to understand the mechanical workings of his plane, and to grasp the principles of flight itself. The sight formed a lasting picture in his mind, one that he recalled later in life.

Four days later, the young student wrote an essay based on Latham's flight. "The Advantages of an Airship Over an Aeroplane" revealed an independent mind at odds with the fervor of the day and with his teacher's preconceptions. He received an F and the comment "Illogical," because rather than write an homage to the airplane, he concentrated on the very real deficiencies of the new invention. Dryden grasped that these awkward machines were prone to failure, "the least break in [which] will hurl the aviator to the ground." He also understood that the frail Antoinette (like the other aircraft of the time) had very narrow capacities, limiting travel to short distances and greatly inhibiting the transport of people and products. Furthermore, they offered no competition to the speed or capacity of the existing railway structure. As a consequence, Dryden argued for the superiority of airships over airplanes "for commerce and exploration," due to their simplicity and potential to haul cargo. In short, the youngster understood that astounding though the Wright's invention may have been, its success depended on years of improvement and refinement. Of course, Hugh could not foresee that his own life would become the embodiment of this process. Nonetheless, during his boyhood and adolescence, no technology generated such exhilaration and excitement as aeronautics. This enthusiasm, coupled with Dryden's innate curiosity about the technical mysteries of flight, soon persuaded him to enter this daring new field.[4]

4 Autobiographical sketch by Dryden (27 September 1965), HLD Papers, Ms. 147, Series 2.2, JHU; Richard K. Smith, *Hugh L. Dryden Papers, 1898–1965: A Preliminary Catalogue* (Baltimore: Johns Hopkins University, 1974), pp. 19–20; Thomas, *Men of Space*, p. 66; interview with Nancy Baker, Rockville, MD (9 August 1994); Dryden, "The Advantages of the Airship Over the Aeroplane" (11 November 1910), HLD Papers, Ms. 147, Series 1.1, JHU; and Eugene M. Emme, "Astronautical Biography: Hugh Latimer Dryden, 1898–1965," *Journal of the Astronautical Sciences* 25 (April–June 1977): 152–153.

FIRST IN HIS CLASS

The next step in Dryden's education led him to one of the city's finest high schools, known as Baltimore City College. He began at age 12 and experienced some setbacks, including Fs on two different English compositions. But by the end of 1911, he had improved enough to earn an "Excellent" for a dual biographical sketch of two 18th-century figures, essayist Samuel Johnson and actor David Garrick. From that point on, his troubles with writing diminished (although he still faced such humbling remarks as "Have you heard of the article "the"? Use it occasionally—you are not writing a guide-book."). Finally, by the end of his tenure at Baltimore City College, his handwriting—and indeed his narrative style—began to assume the trademark compactness and simplicity associated with his later years. He also developed a fondness for books, formed his own little library, and for his 13th birthday received a book as a gift from a classmate.[5]

During his high school years it became clear that his greatest intellectual strength lay in mathematics. Like his father, who showed so much early promise in the subject, he excelled beyond all expectations. An envious fellow student proclaimed in Dryden's school year-book, *The Green Bag*, "behold the future professor of mathematics in general. This kid is some shark when it comes to handling the mystic 3-x, y, z—and what's more, he knows it. Hugh, sweet child, always studies his lessons. Then if he doesn't know them, the prof takes what he says, anyhow." The dimensions of his achievement became apparent at the June 1913 commencement exercises. He not only matriculated in three years rather than the usual four, but also became the youngest ever to win a diploma at the school. Because of his age and small size, and because he still dressed in knickerbockers, he looked out of place on the graduation stage; yet he ranked first among 172, the largest class in the history

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5 Autobiographical sketch by Dryden (27 September 1965), HLD Papers, Ms. 147, Series 2.2, JHU; autobiographical sketch by Dryden (15 September 1962), HLD Papers, Ms. 147, Series 2.2, JHU; interview with Mary Ruth Van Tuyl, Silver Spring, MD (3 August 1994); interview with Nancy Baker by telephone (25 July 1994); and Dryden, "An Evening Spent Alone in an Old House" (30 September 1910), HLD Papers, Ms. 147, Series 1.1, JHU. See also the following essays by Dryden in the same archive: "My Hero in Fiction" (14 October 1910); "A True Halloween Party" (28 October 1910); "How To Set Up A Tent" (9 December 1910); "A Winter Scene" (9 January 1911); "Resolved, That a College Should Be Located in a Small Town, Not in a Large City" (20 January 1911); "Evil Is Wrought by the Want of Thought as Well as by Want of Heart" (19 May 1911); "Resolved, That Moving-Picture Parlors of Instruction Should Displace the (common, everyday) Moving-Picture Parlor" (2 June 1911); "How the Debt Was Paid" (29 September 1911); "German Exercise" (11 October 1911); "The Veal Butcher's Stall" (27 October 1911); "Samuel Johnson and David Garrick" (8 December 1911); "How To Do Your Christmas Shopping" (22 December 1911); "A High School Paper" (1 March 1912); "A Railroad Accident" (15 March 1912); "Time Flies Over Us, But Leaves Its Shadow Behind—Hawthorne" (26 April 1912); "Brutus Was Justified in Killing Caesar" (10 May 1912); "The Greatest Obstacles to World's Peace" (24 May 1912); and "Botany" (27 March 1913). Dryden, "The Stage in Shakespeare's Time" (12 April 1912), and letter from Glen Owens to Dryden (22 August 1911), both in the possession of Leona "Peggy" Dryden, Hyattsville, MD. Rev. Charles Kingsley, *Hereward: The Last of the English* (New York: A. L. Burt Publishers), title page in the possession of Mary Ruth Van Tuyl, Silver Spring, MD.

Shown around 1919, Dryden earned his doctorate in applied physics under one of the eminences in the field, Joseph Ames, later President of Hopkins. Just 20 years old upon graduation, Dryden became the youngest person to earn a doctorate at the university. Ames—one of the original members of the National Advisory Committee for Aeronautics—found a position for Dryden at the National Bureau of Standards (NBS). Dryden remained at the NBS for 29 years, assuming positions of increasing responsibility. (Collection of Nancy (Dryden) Baker, Rockville, MD. Reproduced with her permission.)

of the college. During the ceremonies, he also received both the Peabody Prize for mathematics and the special notice of Baltimore's Mayor Preston. "I am so glad to hear of your fine record," wrote a classmate less jealous than the one who marveled at Hugh's mathematical talents. "You have gained an honor that could not be bought. Congratulate your mother and father for me. I know they must be very proud of you."[6]

During mid-1913, Samuel and Nova's son turned his attention to higher education. He had narrowed his choices to Johns Hopkins, a relatively new university founded 37 years earlier. By Dryden's freshman year, it had already laid claim to distinction.

Hugh Dryden had good reason to set his sights on the campus just northwest of his own neighborhood. For one, it had achieved national recognition in several subjects, including mathematics, the course of study he wanted to pursue. Continuing to live in the same city as his parents also enabled the teenager to maintain his regular patterns of family life and at the same time save money otherwise required for room and board. His sparkling academic record left no doubt about his admission to Hopkins. But clearly, without extensive financial assistance to compensate for the lack of family income, the young scholar would find the university outside his grasp.[7]

6 The envious remarks by one of Dryden's fellow students quoted in Thomas, *Men of Space*, pp. 65, 67; the remarks by a sympathetic classmate quoted in a letter from Glenn Owens to Dryden (7 June 1913), in the possession of Leona Dryden; Gorn, *Hugh L. Dryden's Career*, pp. 1–2; and autobiographical sketch by Dryden (27 September 1965), HLD Papers, Ms. 147, Series 2.2, JHU.

7 Interview with Nancy Baker, Rockville, MD (9 August 1994).

During the summer of 1913, he searched for the needed backing. He received invaluable assistance from two of his Baltimore City College math teachers, S. F. Norris and Richard Uhrbrock. They persuaded their protégé to apply for a Maryland scholarship, which paid all expenses for four years. Both men coached him for the examination. Meanwhile, Uhrbrock wrote a splendid reference to the Maryland Scholarship Board on Dryden's behalf. Even accounting for the inflated claims inherent in such letters, Uhrbrock made a powerful appeal for his pupil. "In my teaching experience of 25 years," he wrote, "I have never had a student superior to Hugh Latimer Dryden." Chronologically still a boy, Dryden nonetheless manifested some of the extraordinary personal qualities and intellect that foreshadowed the mature man.

> [Dryden] was in my classes in mathematics for nearly three years. At all times his conduct has been that of a gentleman, and his scholarship has been of the very highest order. His presence in the class has been a source of inspiration. He is a quiet and unobtrusive leader. By his work and conduct he has aroused and kept alive interest and enthusiasm in his classmates, without exciting the least jealousy or envy.[8]

Thanks to the strategies of his mentors, as well as his own talents, he won the scholarship and entered Hopkins in the fall of 1913 with full support for his entire undergraduate career. Not only that, during the summer he completed and passed two other tests—one oral, one written—under the direction of professor L. S. Hurlburt of the Johns Hopkins Mathematics Department. These exams, taken in lieu of coursework, freed him from taking analytic geometry, so that when he walked for the first time onto the university grounds at Charles and 34th Streets, the 15-year-old entered with advanced standing.[9]

OUT OF THE SHADOWS

Early in his career at Hopkins, Dryden encountered one of the great synthesizers in American physics, professor Joseph Sweetman Ames, chair of the department and later president of the university. In Ames, Dryden chose a formidable teacher. Hard driving and gruff—in part because of a lifelong stammer—Ames understandably lived by action, rather than conversation. He exercised a profound, almost parental influence over

8 Quoted in a letter from Richard H. Uhrbrock to the board awarding Maryland scholarships (3 June 1913), and S. F. Norris to Dryden (17 June 1913), both in the possession of Leona Dryden.

9 Letter from L. S. Hurlburt to Dryden (15 June 1913), in the possession of Leona Dryden; autobiographical sketch by Dryden (27 September 1965), HLD Papers, Ms. 147, Series 2.2, JHU; handwritten biographical statement by Dryden, HLD Papers, Ms. 147, Series 2.2, JHU; and personal history statement of Dryden (28 May 1947), HLD Papers, Ms. 147, Series 2.2, JHU.

In his early 20s, Dryden married a lively young woman whom he met at the Appold Methodist Church in Baltimore. Hugh and Libby (Travers) gave birth to Hugh, Jr., shown here. By this time (about 1923) Dryden became Director of the Bureau of Standards' Aerodynamic Section and, as such, managed its modern wind tunnel. (Collection of Nancy (Dryden) Baker, Rockville, MD. Reproduced with her permission.)

Dryden, considering him "the brightest young man [I] ever had, without exception." Ames mentored him through his bachelor's in mathematics (in three years) and guided him toward his master's in applied physics. Ultimately, Hugh Dryden earned a doctorate in physics in 1919 at age 20, the youngest Hopkins graduate to earn a Ph.D. His dissertation concerned the scale effects of air flowing around columns perpendicular to the wind, a subject of exceptional importance in the rising field of aerodynamics. The conditions under which he earned his degree affected the remainder of his career.[10]

Actually, Dryden earned his degree while he worked. Near the end of the First World War, Ames won a position for him at the National Bureau of Standards (NBS), situated in the Maryland suburbs, testing munitions gauges. After pursuing this project for a short period, Dryden's career took root. He quickly transferred to the bureau's newly opened Aerodynamics Section, equipped with one of the country's most advanced wind tunnels. Because Ames had recently been appointed to a seat on the fledgling National Advisory Committee for Aeronautics (NACA), which met in Washington, DC, he found it convenient to offer courses to Dryden and some of his other students living near the nation's capital. Meantime, in 1920—at the age of 22—Dryden became the first Chief of the Aerodynamics Section, in charge of wind tunnel research (a program subsidized in part by the NACA, starting with a grant of $40,000 in 1921 and rising to more than $100,000 annually during World War II). Perhaps even more impor-

10 Gorn, *Hugh L. Dryden's Career*, pp. 1–2. For an essay about the life of Joseph Ames, see N. Ernest Dorsey, "Joseph Sweetman Ames: The Man," *American Journal of Physics* 12 (1944): 135–148.

tant than his livelihood, during the same year the reserved young scientist married a vivacious, dark-haired woman named Mary "Libby" Travers whom he had met years before in Sunday school at the Appold Methodist Church in Baltimore. The couple relocated from Baltimore to a modest row house inside Washington, DC's verdant Rock Creek Park and began to raise a family.

Dryden achieved distinction soon after starting at the bureau. During the first six years he embarked on a research collaboration with Dr. Lyman J. Briggs, a mentor and friend who eventually became Director of the agency. Dryden decided to concentrate on transonic flight, a subject far ahead of its time and a theoretical curiosity in an age when the winner of the 1925 Schneider Cup Race flew at 233 miles per hour. Together with Briggs, Dryden focused on the problem of compressibility. During the early 1920s, the phenomenon manifested itself in the behavior of propeller blade tips. Attached to aircraft engines of increasing power, the blades rotated at transonic and supersonic speeds, resulting in unexplained boundary layer separation and buffeting. Dryden and Briggs predicted the effects in a seminal NACA Report (Number 207) published in 1925, entitled *Aerodynamic Characteristics of Airfoils at High Speeds*. The absence of research tools available to Dryden and Briggs suggested the vision inherent in the project; no wind tunnel yet existed to replicate the required wind velocity. They found a substitute in Lynn, Massachusetts, where the General Electric Company made available its large centrifugal compressors for the experiments. Here Dryden and Briggs made some of the earliest experimental observations about aerodynamic drag approaching the speed of sound, the effects of compressibility on aerodynamic lift and drag, and airfoil design modifications for propeller manufacturers. The results presented aerodynamicists with some of the earliest credible findings about travel approaching Mach 1, a generation before Captain Chuck Yeager's celebrated 1947 flight that exceeded the speed of sound in the X-1 aircraft. Dryden and Briggs reported five physical phenomena as airfoils neared supersonic speed:

Hugh Dryden eventually became Chief Physicist and, finally, Associate Director of the National Bureau of Standards. But on the retirement of George W. Lewis (Director of the NACA since 1919), Dryden became his successor. During his 10 years on the job, he transformed it from a purely aeronautical institution to one equally involved with spaceflight. He is shown here in September 1947, at the age of 49, just as he assumed Lewis's mantle. (Collection of Nancy (Dryden) Baker, Rockville, MD. Reproduced with her permission.)

1. The lift coefficient for fixed angle of attack decreased quickly as the speed increased.

2. The drag coefficient increased rapidly.

3. The center of pressure moved rearward, toward the trailing edge of the wing.

4. The speed at which such changes occurred declined by increasing the angle of attack and by increasing the camber ratio.

5. "The angle of zero lift shifts to high negative angles up to the "critical speed" and then moves rapidly toward 0 degrees."[11]

Several decisive research papers followed, the results of which prompted the aeronautics community to lay plans for wind tunnels capable of transonic airflows and above.

Hugh Dryden established his reputation with the release of this and several other NACA Reports about the aerodynamics of high-speed flight. His next project placed him in proximity to one of the pivotal figures in global aeronautics. In his study of compressibility, Dryden became conversant with one of the persistent flaws of existing wind tunnels—incidental turbulence generated as air caromed off the tunnel walls, thus compromising the accuracy of the aerodynamic measurements. He and Arnold Kuethe, his assistant at the bureau, found the answer in a simple but ingenious hot-wire anemometer, capable of detecting even slight variations in the speed of airflow. Since even minute fluctuations might cause wide experimental discrepancies—the data on one airship model tested in the bureau's tunnel differed 100 percent from the results obtained in the Washington, DC Navy Yard tunnel—Dryden adapted the instrument to detect these disturbances and to reduce their unwelcome effects. Using this device, he developed criteria by which to diminish turbulence in existing tunnels and to further reduce it in the construction of new ones. Dryden then tested these techniques in the bureau's own machine. Benefiting from the improvements, he succeeded in isolating the workings of the boundary layer (in particular the transition from laminar to turbulent flow), thus enabling him to verify experimentally Ludwig Prandtl's landmark boundary layer theory of 1907, one of the benchmark discoveries in the field of aerodynamics.

11 Gorn, *Hugh L. Dryden's Career*, pp. 3–5; Alex Roland, *Model Research: The National Advisory Committee for Aeronautics, 1915–1958*, vol. 2 (Washington, DC: National Aeronautics and Space Administration, 1985), p. 478; John T. Greenwood, ed., *Milestones of Aviation: Smithsonian Institution National Air and Space Museum* (New York: Hugh Lauter Levin Associates, 1989), p. 98; Lyman Briggs, G. F. Hull, and Hugh L. Dryden, *Aerodynamic Characteristics of Airfoils at High Speeds: National Advisory Committee for Aeronautics Report Number 207* (Washington, DC: Government Printing Office, 1925), pp. 3, 16.

The publication of Dryden's findings, which had profound research implications, caught the eye of one of the world's greatest and best-known aerodynamicists, the Hungarian-born Theodore von Kármán, Director of the Guggenheim Aeronautical Laboratory at the California Institute of Technology. The two men met during the early 1930s and became close friends. Their relationship gave new credence to the proverb that opposites attract. The laconic and understated Dryden and the expressive and flamboyant Kármán embarked on a 35-year personal and professional collaboration. Although a union of equals, Dryden did owe a debt in at least one important respect. Kármán, 17 years his senior, opened the wide realm of international science to him, introducing him to countless aeronautics practitioners in many nations. Once known, Dryden quickly developed his own following in these circles, due as much to his personal qualities as to his unusual scientific capacities.[12]

Indeed, Hugh Dryden began to assume an honored role in the profession just after meeting Theodore von Kármán, but not because of him. The American Association for the Advancement of Science elected him a member, as did the Washington Philosophical Society. He won promotion at the NBS, becoming Chief of the Mechanics and Sound Division, which included his own Aerodynamics Section. He also found his judgments sought after by some of the giants of aeronautics. Yet, Dryden did not seek recognition. Diligent, reserved, and self-effacing, he worked quietly on his own projects at the NBS, guided those of his subordinates, and earned a reputation for effectiveness. His lifelong and intense devotion to the Methodist faith may have contributed to his distaste for self-promotion.

Dryden's stature became evident at the Fifth International Congress of Applied Mechanics in 1934. Here—in his first trip outside the United States—he presented an important paper called "Boundary Layer Flow Near Flat Plates," one that added significantly to the understanding of the mechanics of laminar flow. He subsequently became a founding member of the newly formed Institute of the Aeronautical Sciences in New York, helped inaugurate its scholarly journal, the *Quarterly of Applied Mechanics*, and served on its board of editors. Dryden won further recognition in 1938 when the institute invited him to deliver the annual Wilbur Wright Lecture, the first American so honored. The NBS rewarded his rising eminence by naming him Chief Physicist.[13]

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12 For more about Theodore von Kármán, see Theodore von Kármán with Lee Edson, *The Wind and Beyond: Theodore von Kármán, Pioneer in Aviation and Pathfinder in Space* (Boston, Toronto: Little Brown, 1967), and also Michael Gorn, *The Universal Man: Theodore von Kármán's Life in Aeronautics* (Washington, DC and London: Smithsonian Institution Press, 1992). Hugh Dryden and A. M. Kuethe, *The Measurement of Fluctuations of Air Speed By the Hot-Wire Anemometer: National Advisory Committee for Aeronautics Report Number 320* (Washington, DC: Government Printing Office, 1929), pp. 359–361; Gorn, *Hugh L. Dryden's Career*, pp. 3–4, 6; and interview with Nancy Baker (17 June 1994).

13 Gorn, *Hugh L. Dryden's Career*, pp. 3–4.

A UNIQUE PERSONALITY

Although an introvert, Hugh Dryden's temperament did not hinder his rise. At social functions, for instance, he learned to mingle and relax even though he probably regarded such events with indifference at best. But he did adapt and developed some habits that helped. One involved alcoholic drinks. When he ordered, he always asked bartenders for the same simple mix—water and ice in a highball glass. Dryden then sipped and circulated, never telling anyone about his teetotal preferences. He also dressed well. He wore nicely tailored business suits, well-polished shoes, and in general made a refined appearance. His voice—clear, distinct, and pleasing—also contributed to his persona. Finally, although not a charismatic personality, he did project an amalgam of keen intellect and surprising personal warmth.

Dryden's religious faith played a profound role in his life. As a teenager, he felt drawn toward the ministry. Had one Methodist seminary accepted applications from 15-year-olds, Johns Hopkins, Joseph Ames, and the world of aeronautics might never have encountered Hugh Dryden. Despite his choice of the secular life, Dryden nonetheless pursued his spiritual calling as a lay Methodist minister and a persuasive preacher, witnessed by his many surviving sermons that expressed a fervent devotion (and submission) to God.

> You want sharpness and keenness to come into your brain; you want courage and strength to make decisions and carry them through. This is the secret. Yield yourself to God. "The Kingdom of God is within you." You do not need to hunt it from the outside, just release it, it is within you. You have been defeated in some situation. You have been educated, you have ability, you work hard, but you are defeated by worry, anxiety, and frustration. Establish the contact through faith.

Moreover, Hugh Dryden bore little resemblance to the solemn figure often depicted in his photographs. He had a fine sense of humor that often showed itself in wickedly accurate imitations of his friends and coworkers. He also possessed due admiration for the opposite sex. By present standards, Dryden's enjoyment of female company seems almost quaint. Apparently, he often assumed the task of grocery shopping to relieve his wife of one of her burdens, and his younger daughter Nancy often accompanied him. When they got inside the supermarket, he asked her to take part of the shopping list and fill it. Meantime, he headed for the meat counter where, as virtually the only man in sight, he got all of the attention of the women making their selections. Nancy Dryden called this harmless practice "being single with one eye."

Among Hugh Dryden's formative influences, his father Samuel played a decisive part. The elder Dryden possessed keen intelligence, but he also suffered a number of selfinflicted reversals early in his career. The effects of such behavior must have been perceived by young Dryden, who learned from his father's failings the qualities necessary to fashion his own career—patience, tolerance, and the capacity to collaborate with others. Dryden not only practiced these arts with rare skill, but also recognized and appreciated them in others.

Finally, Dryden also developed a profound commitment to international scientific cooperation, in part the result of his close association with Theodore von Kármán, but more importantly due to his uncanny instinct for merging complementary talents and personalities. Both men felt that alliances with foreign colleagues served as instruments of peace and of technical advancement. Dryden began during the 1930s and in time not only became the equal of his mentor, but even surpassed him. During the late 1950s, President Eisenhower appointed him a representative to the United Nations Ad Hoc Committee on the Peaceful Uses of Outer Space. This assignment led to his role as chief negotiator with Soviet academician Anatoly Blagonravov, a dialogue that resulted during the early 1960s in limited but unprecedented superpower cooperation on meteorology, communications, and magnetic field research. "I am persuaded," wrote Dryden with characteristic simplicity, "that there are very great values to the United States in this cooperation."[14]

AN INTERNATIONAL PROJECT

Not surprisingly, one of Dryden's most admired achievements occurred in the international arena. It originated with a long and fruitful collaboration between Theodore von Kármán and Army Air Forces General Henry H. Arnold. The two men had become acquainted during the mid-1930s when Arnold commanded March Field, California, in close proximity to Caltech. They established a friendship based on Arnold's desire to stay abreast of the latest aeronautical developments. As the Second World War approached, the general prevailed upon Kármán to devote an increasing proportion of his time to advising the Army Air Forces about the future of flight. On one occasion, the scientist flew to Dayton, Ohio on the invitation of General Frank Carroll, who asked him to calculate the likely success of flying at the speed of sound. Kármán's highly technical but affirmative answer set the wheels in motion for the development of the X-1 aircraft.

14 The overall assessment of Hugh Dryden's personality is based on research for a forthcoming book by Gorn entitled (tentatively) *To Ride the Air: NASA's Hugh L. Dryden*. In addition, see Gorn, *Hugh L. Dryden's Career*, pp. 4, 14. For a statement of Dryden's religious views, see "The Importance of Religion in American Life," letter written in March 1950, reprinted in *Hugh L. Dryden's Career*, pp. 123–130.

During the summer of 1944, when it seemed clear that the allies finally held the key to victory in Europe, Arnold contacted Kármán for the biggest assignment yet. The general asked for a complete, global review of the technologies underpinning the wartime advances in aeronautics and missilery. To achieve this end, he asked Kármán to travel to the far corners of the world to obtain data firsthand. More daunting, Arnold also wanted a comprehensive blueprint for future development based on the most recent discoveries. Realizing that this project required many hands, Kármán turned first to Hugh Dryden to be his partner and deputy. Dryden's own work during World War II raised his stature as a science advisor. Officials at the Office of Scientific Research and Development engaged him to supervise the development of the Bat Missile, a highly advanced naval air-to-surface weapon. A self-correcting, launch-and-leave gravity bomb guided by radar and steered by its own control surfaces, it posed not only formidable technical challenges, but also involved complicated management responsibilities for Dryden. To achieve success, he harnessed the research talents of scientists at the Bureau

This photo hints at Hugh Dryden's temperament. On the right is professor Theodore von Kármán, one of the most renowned aeronautical scientists of the 20th century. The flamboyant and highly animated Hungarian offered a sharp contrast to his close friend Dryden. Seen here around 1960, the two struck characteristic poses: Kármán entertaining his dinner companions, Dryden sitting quietly with a look of mild amusement and perhaps some discomfort. Much as he admired Kármán, Dryden preferred the self-effacing and undemonstrative approach. (Collection of Nancy (Dryden) Baker, Rockville, MD. Reproduced with her permission.)

of Standards, the Bureau of Naval Ordnance, and academia. Moreover, his assignment entailed not just the realization of a workable concept; rather, the Office of Scientific Research and Development instructed him to supervise the Bat's design, fabrication, and test, and then to field it as an operational weapon capable of destroying enemy shipping. Placed in the U.S. arsenal during the final months of the war, it succeeded beyond all expectation, actually sinking several Japanese ships at the Battle of Okinawa.

Fresh from the experience of managing a large federal research program, Dryden joined his friend in December 1944 and for the better part of a year collaborated with him in fulfilling Arnold's enormous task. They met in the recently completed Pentagon building and compiled the names of some of the most eminent American scientists to enlist for the project. After some discussion, they selected six researchers to organize the team, including Kármán's brilliant student Hsue-shen Tsien for rocketry and Dr. Louis Alvarez for radar. The more difficult job involved picking subject-area experts for the technical panels, a small cadre who converted the hard data gleaned in the U.K., France, Germany, Italy, the Soviet Union, Japan, and other nations into comprehensive reports and forecasts. They chose 21 individuals, most of whom from academia, and especially from Caltech.[15]

The group departed for Europe in April 1945 prepared to assess the current state of international aeronautics. In London, Kármán and Dryden donned uniforms bearing the simulated ranks of major general and colonel, respectively. They arrived in Paris (the embarkation point of the mission), traveled to and crossed the German border, and stopped at a huge aeronautics laboratory near Braunschweig, in the village of Volkenrode. Concealed from public view in a setting of forests and farms, it just had been discovered by U.S. forces. Dryden and Kármán interviewed some of the leading German officials about their guided missile and jet propulsion research and amassed some 1,500 tons of materials relating to swept-wing aerodynamics and high-speed human physiology, a treasure shipped back to the United States where it profoundly influenced postwar aeronautics. Dryden and Kármán then divided forces. Dryden and part of the group went to Munich, where he conducted intense interrogations about the V-1 and V-2 missiles with Dr. Wernher von Braun, his boss General Walter Dornberger, and some 400 scientists who had been relocated from the Peenemünde rocket facility. Dryden then returned home after retracing his steps through Germany, France, and England.

Rather than participate in the next round of globetrotting, Hugh Dryden decided to remain in Washington, DC and serve as the general editor of the technology forecast promised to General Arnold. In order to save time, Dryden assembled the report as

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15 Michael H. Gorn, *Harnessing the Genie: Science and Technology Forecasting for the Air Force, 1944–1986* (Washington, DC: Office of Air Force History, 1988), pp. 11–23; and Gorn, *Hugh L. Dryden's Career*, pp. 5–7.

events unfolded, that is, as the sections arrived by cable from overseas. Meanwhile, Kármán and his team went abroad again, this time aboard Arnold's own C-54 transport. They embarked on a whirlwind world tour that lasted much of the fall of 1945, visiting scientists and laboratories in the U.K., France, Holland, Switzerland, Sweden, and Italy. But age and exhaustion at last caught up with Kármán. He broke from the group and encamped in the luxurious Prince of Wales Hotel in Paris while the rest of his party journeyed to Australia, India, China, and Japan. Kármán took the opportunity to write the first chapter of the report, entitled "Science, the Key to Air Supremacy," a prescient account of airpower as it existed and as it might evolve.

At the same time, in Washington, DC, Hugh Dryden assumed the heavy responsibility of shaping Kármán's and the many other essays into an accurate and coherent summary of worldwide airpower developments. In essence, he assumed control of the project. In the end, the sprawling forecast arrived on General Arnold's desk on 15 December 1945. Called *Toward New Horizon*s, this seminal collection of 33 essays by 25 scientists served not merely as a blueprint for American survival in an age of potentially devastating attack from the air, but as a guide for civilian aeronautics—and indeed space research—for decades to come.[16] It looked to the future under broad headings such as aerodynamics and aircraft design, power plants, fuels and propellants, radar, weather and flight, and aviation medicine. *Toward New Horizons* also made recommendations to the Army Air Forces, urging its leaders to become more scientifically oriented and to reorganize in order to take advantage of the recent and future breakthroughs in aeronautics. But perhaps more importantly, Hugh Dryden's work offered military leaders and industrialists (as well as younger scientists and engineers just leaving military service) a clear agenda for postwar research, one that offered direction to generations of aerospace practitioners.[17]

SEEDS PLANTED ON EARTH

Meantime, at the NACA, its venerable Director of Research George W. Lewis—worn and ill after 28 years of service, as well as the rigors of intense wartime research—announced his retirement in the summer of 1947. To no one's great surprise, the unassuming yet eminently qualified Hugh Dryden, recently named Associate Director of the Bureau of Standards, succeeded him. His appointment initiated a remarkable transformation of the NACA.

16 Theodore Von Kármán, *Toward New Horizons* (Washington, DC: Army Air Forces Scientific Advisory Group, 1945).

17 Gorn, *Harnessing the Genie*, pp. 23–42; and Gorn, *Hugh L. Dryden's Career*, pp. 6–7.

Dryden began almost immediately to reorient the Agency toward high-speed flight. He assumed Lewis's job on 2 September and, by the end of the month, crossed the country to visit the Muroc Flight Test Unit, located in the isolated high desert of Southern California. Dryden made this trip for a good reason. Here, Walter Williams and his small NACA team prepared to challenge the sonic barrier, and, as a leading theorist on the subject since his youth, Dryden wanted to encourage and recognize their important work. More than mere recognition, however, his presence symbolized the new direction of his leadership—toward supersonic and eventually toward hypersonic flight. Until this point, the NACA's desert outpost existed as a temporary station of the Langley Memorial Aeronautical Laboratory, whose personnel first assembled in California solely to fly the X-1 and D-558 experimental aircraft. To affirm the importance of Muroc's role, Dryden directed that it join Langley and the other NACA facilities—the Ames and Lewis Laboratories in Northern California and Cleveland, respectively, and the Wallops Island, Virginia station—as a permanent NACA complex.

Dryden also took this measure because of his more recent involvement with high-speed flight. He served prominently on the joint NACA-Army-Navy Research Airplane Committee that, in mid-1944, launched the X-1 and D-558 projects in the first place. Once he became Director of the NACA, he naturally lent his support to these planned supersonic flights. A few years later, his support once again proved decisive in initiating and sustaining an even more advanced aircraft, the North American X-15. After a two-year gestation period at Langley, in 1954 Dryden approved the concept of a Mach-7 hypersonic airplane capable of achieving altitudes of 300,000 feet. He reconvened the Research Airplane Committee in October 1954, consisting of Air Force Brigadier General Benjamin Kelsey and Rear Admirals Lloyd Harrison and Robert Hatcher, the leaders of their services' research and development programs. Experienced at dealing with the armed forces, Dryden not only persuaded these officers to underwrite this expensive and risky venture (that offered no clear military value), but reserved the role of chairman for himself. Once in command, Hugh Dryden guided the fortunes of the first aircraft to fly hypersonically, to enter the realm of space, and to serve as a test bed for later, more daring activities outside of the atmosphere. He did so by controlling the X-15 committee, retaining for himself the power to call committee meetings, to organize X-15 technical conferences, and to assume direct control of the NACA's role in this project.[18]

The X-15 strained the NACA's resources like few other endeavors. It required intensive flight planning and pilot preparation, as well as unprecedented technical demands such as a computer-assisted control system, simulators more complicated and realistic than any ever attempted, a powerful new rocket engine, and state-of-the-art equipment necessary to conduct high-speed wind tunnel experiments. Dryden worked energetically to equip his Agency with the resources necessary for the X-15 to succeed.

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18 Hansen, *Engineer in Charge*, p. 385; and Arnold S. Levine, *Managing NASA in the Apollo Era* (Washington, DC: National Aeronautics and Space Administration, 1982), p. 11.

The implementation of the National Unitary Wind Tunnel Plan illustrates just one of his travails and successes. Originating conceptually with *Toward New Horizons*, the proposition of massive government research centers for aeronautics gained credence among the NACA, the Air Force, and the aircraft manufacturers. All of them pressed for federally sponsored, high-speed wind tunnel facilities, but the parties soon found themselves at odds over the location and control of these installations. Hugh Dryden played a decisive part in brokering these disputes. Had he objected to Air Force claims for a huge hypersonic wind tunnel complex, the entire initiative might have collapsed; instead, he offered no resistance to the establishment of the USAF Arnold Engineering Development Center in Tullahoma, Tennessee. In return, the NACA agreed to abandon its dream of a National Supersonic Research Center and instead accepted $136 million from Congress to build three supersonic and hypersonic tunnels at its existing laboratories. But the National Unitary Wind Tunnel Plan Act of 1949 forced Dryden to make a further concession; it reserved these NACA machines mainly for industry use. In the end, however, his compromise proved more than satisfactory. The aircraft industries never accounted for more than a fraction of the new tunnels' work schedules. Indeed, from the beginning, the new tunnels teemed mainly with NACA experiments. In fact, these machines opened just in time for some essential research. By the mid-1950s, X-15 models underwent critical aerodynamics tests at the Mach 2 tunnel at Lewis, the Mach 3.5 at Ames, and the Mach 5 at Langley.[19]

Other advances blazed a path for hypervelocity and, ultimately, for spaceflight. Ames Aeronautical Laboratory researcher H. Julian Allen announced in 1950 a surprising discovery. As they fell through the atmosphere, objects with blunt shapes generated lower temperatures than those with pointed noses or protuberances. Apparently, pressure drag caused rounded bodies in flight to dissipate heat into the atmosphere. Frictional drag, on the other hand, induced bodies with sharp angles to absorb the heat into themselves during reentry. Allen's colleague Alfred J. Eggers concluded that a conical design best embodied Allen's theory. These concepts—demonstrated in the Ames wind tunnels—also manifested themselves in actual flight conditions at the NACA's Wallops Island, Virginia Pilotless Aircraft Research Station, an outpost of the Langley Aeronautical Laboratory. Here, missiles and rockets attained speeds up to Mach 12, and the engineering staff experimented with such space-related developments as the Ames rounded nose cone, heat-resistant materials (like Inconel, the alloy used to fabricate the X-15), reaction controls,

19 Roland, *Model Research*, vol. 1, pp. 211–221; and notes from a telephone conversation between Michael Gorn and Dr. James O. Young, Air Force Flight Test Center historian (12 October 1998), relative to Dryden's role in the passage of the National Unitary Wind Tunnel Plan Act of 1949. Dr. Young conducted an interview with General Laurence C. Craigie, one of the chief Air Force figures involved in the Unitary Wind Tunnel Plan, in 1991 at the Air Force Village of the West in Riverside, CA. Craigie related to Young that in his capacity as NACA Director, Dryden could have derailed the negotiations at any time, but instead supported conciliation, as explained in the narrative above.

and dynamic stability. From 1945 to 1957, roughly 3,000 firings occurred at Wallops (an average of 250 launches per year during Dryden's tenure) with an approximate success rate of 80 percent. The power plants and fuels propelling these vehicles often originated in the test stands at the Lewis Flight Propulsion Laboratory (now the Glenn Research Center) in Cleveland, Ohio. By 1957, roughly one-fourth of its engineers and scientists devoted themselves to rocketry. The 10-foot-by-10-foot Unitary tunnel, opened a year earlier at Lewis, produced realistic data unobtainable by any other means. It complemented a new 20,000-pound thrust test stand complex, which allowed the firing of rocket engines double the size of the ones they replaced. The latter facility also made possible safe runs using high-energy fuels like hydrogen-fluorine and nuclear material.[20]

All of these space-related activities scattered across the NACA landscape required Hugh Dryden to find the human and material wherewithal to accomplish them. Unfortunately, Congress failed to appropriate more than token additional resources. Between 1951 and 1957, the NACA's budget rose only modestly, from $63 million to $77 million, leaving little for new ventures after accounting for inflation and large capital investments. Therefore, Dryden turned to the only means at hand: reallocating the assets under his control. During 1954, roughly 10 percent of the NACA's research related to space. Two years later, by scaling back aeronautics work, Dryden managed to dedicate one quarter of the Agency's total projects to investigations involving space travel. The Director's last budget estimate, submitted six months before NASA came into being, requested that half of all NACA activities concentrate on flight beyond the atmosphere. Yet, a simple budgetary profile fails to give a complete picture of Dryden's transformation of the NACA's mission. It ignores programs like the X-15, an endeavor funded mainly by the military services, guided by the NACA, and rich in technical achievements fundamental to the later space program. Also, the raw numbers alone do not illuminate the inherent obstacles faced by Dryden as he realigned the NACA. For one, he carried out his quiet revolution without the slightest change in the NACA charter. Until its last moments, it officially remained an institution devoted to aeronautical, not to space, research. Even more telling, Dryden began and then accelerated this momentous shift long before October 1957, the subsequent Sputnik panic, or any national consensus had emerged about the value of spaceflight. Essentially, he embarked on this program on his own initiative.[21]

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20 Gorn, *Expanding the Envelope,* pp. 256–257; Anon., "Wallops Gathers Hypersonic Flight Data," *Aviation Week and Space Technology* (3 June 1957): 14–15; and Robert Cushman, "Lewis Pushes Work on Rocket Engines," *Aviation Week and Space Technology* (3 June 1957): 6–9.

21 Levine, *Managing NASA in the Apollo Era*, p. 11; and Roland, *Model Research*, vol. 2, p. 475.

Yet, his reallocation efforts failed to win laurels. Once the American public realized the importance of Sputnik, many in Congress blamed the NACA and Hugh Dryden for failing to prepare the nation for this eventuality, even though most members of the House and Senate showed little or no interest in the subject until Soviet satellites flew over American soil. Indeed, in an atmosphere of denial and recrimination, both the NACA and its Director made a poor showing. Hugh Dryden's undemonstrative personality and his unobtrusive, incremental progress toward spaceflight not only epitomized his own style of operation, but that of the NACA as well. Throughout its history, the Agency's engineers worked almost anonymously, removed from public scrutiny as they documented and disseminated knowledge related to speed, altitude, stability and control, efficiency, and flight safety. But in a time of crisis, steadiness and self-effacement seemed out of season. As a consequence, on 1 October 1958, the NACA found itself supplanted by NASA. Moreover, T. Keith Glennan, President of the Case Institute of Technology, assumed the position of the Agency's first Administrator, but only on condition that Hugh Dryden remain as his deputy. In his 40th year of government service, a disappointed Dryden agreed to stay.[22]

Still, Dryden's main initiative as Director of the NACA—to carve out a role in spaceflight—paid handsome dividends during the formative years of NASA. Because of past preparation, Project Mercury, for instance, exemplified NASA's capacity to launch the nation into the space race with speed and sureness. During the summer of 1958 (still some months before the birth of NASA), Dryden persuaded Robert Gilruth, Langley's former Chief of Stability and Control and subsequently the director of the laboratory's Pilotless Aircraft Research Division, to transfer to NACA Headquarters and lead Mercury. Here, Gilruth worked with a small task group comprised of scientists and engineers from Langley and Lewis to create the essentials of the initial U.S. man-in-space program. Less than three months later, all of the main elements of Project Mercury became known: an orbiting capsule populated by a single human being; ballistic missiles pressed into service as launch vehicles; a reentry into the atmosphere made possible by the capsule's blunt body shape and heat shield; and a parachute landing at sea whereupon the U.S. Navy retrieved the ship and crew. Indeed, as Arnold Levine points out in *Managing NASA in the Apollo Program*, the "NACA was well on its way to becoming a space agency even before Sputnik."[23] Hugh Dryden, then, deserves much of the credit for laying the foundation of the early U.S. space program before NASA existed, and perhaps even more recognition for guiding it after the Agency came into being.

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22 Roger D. Launius, *NASA: A History of the U.S. Civil Space Program* (Malabar, FL: Krieger, 1994), pp. 30–31, 38; and Gorn, *Hugh L. Dryden's Career*, pp. 12–13.

23 Hansen, *Engineer in Charge,* p. 385; and Levine, *Managing NASA in the Apollo Era*, p. 11.

CONCLUSION

Hugh L. Dryden represented an indispensable ingredient in the metamorphosis of American flight, from its beginnings as a purely aeronautical pursuit to its gradual evolution as a field that routinely transported human beings outside the atmosphere. A man born in obscurity and almost lost to history due to his mild manner and to his abhorrence of self-promotion, Dryden commands a place among the most prominent figures in American aeronautics and spaceflight. His own research influenced the basic theories of flight. His leadership at the Bureau of Standards and later as Director of the NACA affected the research agenda of countless engineers and scientists, as well as that of the nation as a whole. During his decade at the NACA, he transformed it slowly but surely into an institution capable of sophisticated space research, the bedrock—not merely the forerunner—of NASA. His role in international scientific cooperation resulted in landmark contributions like *Toward New Horizons* and led to space agreements among the United States, the NATO nations, and the USSR during the Cold War. Finally, during the last portion of his career, Hugh Dryden played a decisive role in shaping the Mercury, Gemini, and Apollo programs, not only in structuring their managerial and technical priorities, but also as a pivotal technical advisor to the American Presidents on whose political authority the U.S. space program ultimately rested.