Book Reviews

The Strivings of a Pioneer

The Papers of Robert H. Goddard. Including the Reports to the Smithsonian Institution and the Daniel and Florence Guggenheim Foundation. ESTHER C. GODDARD, Ed. G. EDWARD PENDRAY, Assoc. Ed. McGraw-Hill, New York, 1970. 3 vols., boxed. Vol. 1, 1898–1924; vol. 2, 1925–1937; vol. 3, 1938–1945. xl, 1708 pp., illus. $150.

The process by which scientific genius evolves is a subject of fascination for scientists and laymen alike, and the attraction is compounded when, as in the life of Robert H. Goddard, the nation's celebrated rocket pioneer, an element of tragedy is present.

The available record of Goddard's life, inevitably fragmentary, does offer clues to the shaping of this remarkable individual: a secure and happy childhood, devoted and intelligent parents, an early familiarity with tools, exposure to some gifted and stimulating teachers more interested in solving problems than in conveying facts, access to university lectures throughout boyhood, a catholic range of interests stimulated by subscriptions to *Scientific American* and *St. Nicholas* magazine, and a continuing interest in music. Two other factors appear to have been critically important. First, from earliest childhood, while enjoying nature walks with his father, Goddard was taught to be a keen observer, a discipline he intensified later in life when he took up watercolors as a hobby. And second, prolonged illness, including a bout with tuberculosis, precluded the usual adolescent sports and gave him the leisure to reflect on what he saw and to dream creative dreams. Many of these elements can be found in the backgrounds of other scientists. Why did they generate in Robert Goddard such singleness of purpose and such a sharply focused drive to reach the stars? Looking back later in life, Goddard himself indicated that reading science fiction such as H. G. Wells's *The War of the Worlds* was pivotal, but although this may explain the direction, it hardly accounts for the intensity and enduring quality of Goddard's aspiration. His decision to strive for outer space was not a gradually evolving conviction but one that came to him suddenly while he was sitting in a cherry tree near his home one beautiful afternoon in October 1899, when he was 16 years old. Thereafter, year in and year out, his laconic diary faithfully records 19 October as "Anniversary Day" and mentions ritual visits to the cherry tree, a practice strongly suggesting that his decision was indeed a "conversion." Such clues to the psychology of this complex genius abound in the letters, working notes, reports, and diary entries that comprise the work under review.

A B.S. degree at Worcester Tech and an M.A. and Ph.D. in physics at Clark University, followed by a postdoctoral year of research at Princeton, laid the formal base of Goddard's education. But there were other elements, too, among them persistent, disciplined efforts at writing articles for *Scientific American* and similar journals. One such, "On the Possibility of Navigating Interplanetary Space," written in 1907, when the author was an undergraduate, concluded that "atomic disintegration" would eventually provide the energy necessary for space travel. This particular effort was rejected by the editor of *Popular Astronomy*, who regarded such speculations as "not helpful to science" because "the impossibility of ever doing it is so certain." Undeterred by this kind of myopia, the young physicist pushed on. "See it through," he wrote in his notebook on Anniversary Day 1910. "Be the one that can find what can be done." Even before he accepted an instructorship in physics at Clark in 1914, he had secured a patent on multistage rockets using liquid propellants.

A turning point in Goddard's career came in 1917 when the Smithsonian Institution awarded him a $5000 grant to fund his already impressive research. In those departed days the process was simplicity itself. Three months and three brief letters after the initial approach, the grant was his. He recorded his mother's reaction: "I think that's the most wonderful thing I ever heard of. Think of it! You send the Government some typewritten sheets and some pictures, and they send you $1000 and tell you they are going to send four more." The coming of war temporarily diverted Goddard's efforts to the development of a portable, solid-fuel, bazooka-like recoilless weapon for the Army. The interlude gave him ample experience with the frustrations of dealing with the military bureaucracy. More important, it deflected him from his earlier interest in liquid propellants to undertake work on a high-altitude rocket based on the successive firing of solid-fuel charges mechanically delivered to the combustion chamber.

In spite of wartime interruptions, by the fall of 1919 Goddard was able to publish his most important scientific paper, "A Method of Reaching Extreme Altitudes," appearing as volume 71 in the Smithsonian Miscellaneous Collections, a medium scarcely calculated to achieve instant popular acclaim. This was precisely what ensued, however, for the article not only established the investigator's reputation in scientific circles but also generated a wave of fanciful newspaper headlines about moon flights. This dual reaction clearly reflected the qualities typical of Goddard's approach. In lucid prose he described imaginatively conceived experiments in which he had achieved efficiencies up to 64 percent with smokeless power rockets, yields higher, he claimed, than those of any heat engine previously tested. Then, having laid his sober foundation of fact, he concluded disarmingly that it remained only to perform "certain necessary preliminary experiments" before it would be possible to achieve escape velocities and reach "any desired altitude." Something of the elegance that characterized Goddard's work is evident in his demonstration that rockets would work in a vacuum: a blank cartridge pistol mounted so as to swing freely around a vertical shaft under an evacuated bell jar rotated rapidly when fired electrically from outside, thus affording ample armor against editorial sneers in the *New York Times* that rockets would not work in outer space beyond the resistance of the earth's atmosphere.

During the '20's the Smithsonian authorities continued to support Goddard with small grants but grew restive when he failed to obtain the spectacular results his initial paper had led them to expect. As a true scientist, he was more concerned with proving the soundness of his theories and the reliability of each newly designed component before moving on to the advanced designs than he was with high-altitude flights that might catch popular fancy but prove nothing. The Smithsonian officials were not unsympathetic; their dilemma simply mirrored a problem common to virtually all funding agencies. They wanted to foster sound research, but they also needed results that would impress those individuals, including congressmen, who could contribute to the Institution's endowment. Threatened with loss of support, Goddard reluctantly undertook to design for altitude by a 20-fold increase in scale, a move he was to regret because it increased costs and upset his careful step-by-step approach.

Goddard was ambivalent about publicity for his researches. A painfully shy man, he understood but recoiled from the necessity for record flights: "no support until results are had, and no results unless sufficient support is had." Moreover, publicity brought requests for details from investigators and government officials in Russia, Japan, Germany, and elsewhere. He responded when Hermann Oberth asked for a copy of his Smithsonian paper, only to be incensed when the German investigator made use of his fundamental ideas but disparaged the feasibility of his designs and ignored the priority of his work. This and several similar experiences intensified Goddard's tendency to secretiveness. Ironically, it was newspaper publicity that led the Daniel and Florence Guggenheim Foundation to consider supporting his research just as the Smithsonian phased out. Through the mediation of Charles A. Lindbergh, then at the peak of his popularity and prestige, the Guggenheims in 1930 made the first of the many large grants which were to sustain Goddard for more than a decade of rocket research at a site near Roswell, New Mexico, where climate and terrain were ideal.

The record of the years in New Mexico overflows with passages that give insight into the creative process, including diary entries on how the investigator's subconscious mind came up with novel theories and designs. Supported only by three or four machinists and helpers, Goddard was both scientist and engineer, projecting theories and then designing and building the apparatus in his own shop to test them. Step by step he worked his way through the problems: combustion chamber design for fuel efficiency and effective cooling, fuel flow (by tank pressure or pumps), stabilization during and after burn, and so on. This incremental approach led to the development of ever more complex rockets, by 1940 an 18-foot liquid oxygen and gasoline model producing 2800 horsepower, as well as to dozens of flights, the best of which reached approximately 7000 feet and a speed of 700 miles an hour. Seen in perspective, this was remarkable progress; Goddard all but single-handedly tackled problems sufficient to busy a corps of engineers.

While Goddard's fertile imagination and insistent drive were crucial, the contributions of others are not to be overlooked. President W. W. Atwood of Clark granted Goddard repeated leaves of absence in the face of departmental chafing; the Guggenheims provided not only money but remarkable understanding and patience. In this, Lindbergh's periodic assessments favoring continued support appear to have been decisive. (Was the reason behind them the appreciation of one loner for another?) Yet even Lindbergh was unable to persuade Goddard to cooperate effectively with others in the academic world, notably the Caltech group, which was beginning to take an interest in rockets in the late '30's. All such schools the lonely investigator regarded as threats to his priority; instead of training students and publishing his findings in scholarly journals, he secured patents, eventually 214 in all, on every major feature of his designs.

When the war came Goddard repeatedly approached the military services for financial support to press on with his rocket research, only to be disappointed. He was coldly furious when the National Research Council granted funds for research not to him but to Von Kármán's students at Caltech, whom he rated as 15 years behind himself. The military authorities were more than willing to employ Goddard as a consultant to pick his brains, but the only support he was able to secure was a contract to develop a variable-thrust device for jet-assisted airplane takeoffs. Though cruelly disappointed, he loyally poured his energies into this project, on which he was still working when the appearance of German V-2 rockets heralded a new era of warfare. Subsequent investigation revealed that in principle and in design the V-2 bore a remarkable similarity to the rockets for which he had vainly sought military funding. Even so gentle a soul as Goddard could be forgiven for harboring bitter thoughts at this turn of events, but the diary, at least as published, gives no hint of recrimination down to the date of his death from a malignancy in 1945. It is easy to blame the military for folly in dealing with Goddard, but his own papers suggest another view. The very qualities that drove him so relentlessly, committed him so completely, and unleashed his creative energies so fully imposed serious limitations on his capability for scientific cooperation; he was a man doomed by the sum of his own virtues.

This magnificent compilation offers a treasure trove for a multitude of readers. Historians of science and technology, rocket specialists, space buffs, students of the psychology of creativity, military officers, aerospace executives, and foundation administrators can mine insights almost at random from these fascinating pages, including the bibliography, patent checklist, chronology, and other information in the appendix. While the Guggenheims deserve credit for funding the publication of such a full record, lavishly illustrated with photographs, drawings, and diagrams, there can be no mistaking the primary role of Goddard's widow, who poured years of her life into the task of editing. For any who may question her exclusions and elisions at some points, the full manuscript record is available at Clark University.

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Darwin as Seen from Paris

La Sélection Naturelle. Etude sur la Première Constitution d'un Concept (1837–1859). CAMILLE LIMOGES. Presses Universitaires de France, Paris, 1970. 184 pp. Paper, 25 F. "Galien."

When, in 1878, Darwin became a corresponding member of the French Academy, his supporters found it necessary to have him elected to the botanical section. This episode has virtually become a conventional symbol of the curious history of evolutionary biology in France. Evolution was accepted most reluctantly, and natural selection even now seems to baffle the French mentality. The appearance, in the French tongue, of a serious work on the history of evolutionary theory thus presents us with an opportunity to con-