Theodore von Karman, the "Martian" Who Changed the Way We Fly

An Aerodynamicist Used an Ercoupe to Jumpstart the U.S. Missile and Space Programs

by Philip Handleman

The "Martians"

The brilliant aerodynamicist Theodore von Karman was one of five groundbreaking Hungarian scientists who moved to America to escape the ravages of Nazism. The others were: Edward Teller, the Manhattan Project researcher who later led development of the hydrogen bomb; Leo Szilard, the deep thinker who envisaged the chain reaction that made nuclear weapons and power plants a reality; Eugene Wigner, the theorist who perceived the symmetries in quantum mechanics for which he received the Nobel Prize; and John von Neumann, the mathematics whiz whose constructs gave birth to the computer.

At the beginning of his sweeping memoir that covers the revolution in physics during the 20th century, Teller dedicated the book to his fellow émigrés and lifelong friends, the transplanted scientists who, like him, had thrived in their adopted country. Operating within their own specialties, each of the five exceptional men contributed uniquely to major technical developments that changed the world in ways few imagined possible. For their unorthodox ideas that profoundly influenced the lives of so many people, they were accorded an offbeat sobriquet that they wore as a badge of honor.

Teller explained: "In jest, they were called the Martians. No accolade gives me so great a pleasure as that I was counted among them."

A Prodigy Makes His Mark

On May 11, 1881, Theodore von Karman was born in Budapest where, as he later wrote, "Horse-drawn droshkies carried silk-gowned women and their Hussar counts in red uniforms and furred hats through the ancient war-scarred hills." It was a charmed time in the city, a period of economic prosperity and cultural renaissance.

The third of five children, von Karman was raised in a nurturing home where schooling held sway as the top priority. His father, Maurice, was an intense and learned man who served as Secretary-General of the Austro-Hungarian Ministry of Education. His mother, Helen, was descended from a long line of scholars that included a famous 16th century mathematician.

Hints of the youngster's prodigious talents were evidenced early in his life. During shindigs at the family home in Budapest, when von Karman was only six years old, relatives congregated around him in the manner of carnival-goers. The lad entertained his kin and other visitors by calculating savant-style the answers to random six-digit multiplication exercises. The adults in the room would do the math in the usual laborious way with benefit of pencil and paper, and invariably the boy's answers proved correct.

His father was appalled by this "freak show" treatment and feared that his son might suffer mental stultification if permitted to fixate on mathematics. Accordingly, Maurice forbade the boy from such games and even from studying advanced mathematics until years later. The father decreed that his son would concentrate his studies in the social sciences and humanities to ensure that he received a rounded world view and that he acclimated suitably to his surroundings.

A deep-seated righteousness and an unbending will animated Maurice. He was in constant and sometimes acrimonious disputes with colleagues who held opposing views. While his son was still in high school, this obsession caused Maurice to suffer a nervous breakdown. A long-term stay in a sanatorium was required.

To save money upon graduating, the young von Karman enrolled in the Royal Joseph University of Polytechnics and Economics, a local institution of only middling stature. As a college student, he wanted to delve into scientific theory, but Maurice, who still exerted a powerful influence, insisted on engineering as a more practical subject. His son acceded, but excelled anyway. In a portent of what was to come from von Karman's fertile mind, he devised a mathematical method to rid engine valves of their clatter. Publication of the associated scientific paper was the first of an amazing 170 such papers to be published in his long and prolific career.

In 1902, von Karman graduated with distinction and was promptly conscripted into the Austro-Hungarian artillery for a year. When he returned home, he accepted a position as an assistant professor of hydraulics at the Royal Joseph. Within a few years, he produced a noteworthy paper on the buckling of structures that guided engineers long afterwards in the construction of bridges, buildings and airplanes.

His reputation grew and in 1906 he received a coveted fellowship to the University of Gottingen in Germany that was just then in the throes of its golden age. The formidability continued for at least the next 20 years, when the many great minds passing through the hallways of the university's spired and gargoyled buildings included Werner Heisenberg and J. Robert Oppenheimer, the two men who would later compete against each other as leaders in their respective countries' race to develop the atomic bomb. Von Karman was to study under the acclaimed Ludwig Prandtl, the distinguished professor of fluid mechanics and head of the Department of Applied Physics who many would later acknowledge as the "father of aerodynamics."

The university's strictures and regimented etiquette did not mesh well with von Karman's personality. He had evolved into an effusive intellectual bent on approaching work and play with gusto. In 1908, he earned his doctorate and swiftly took off for a two-week holiday in Paris.

In a break from the all-night partying, he happened by chance to bump into the daughter of a friend who asked him for a ride to the parade ground nestled along the River Gauche where an airplane was scheduled to attempt the first two-kilometer flight in Europe. Initially, von Karman refused, claiming he had no interest in viewing the box-kite spectacle. But the girl persisted and he gave in.

At dawn on March 21, the budding scientist observed Englishman Henry Farman alight in a Voisin flying machine. The splendor of the early morning flight left von Karman spellbound. The event profoundly influenced the course of his life. From that point, he knew that he would be inextricably linked to the sky.

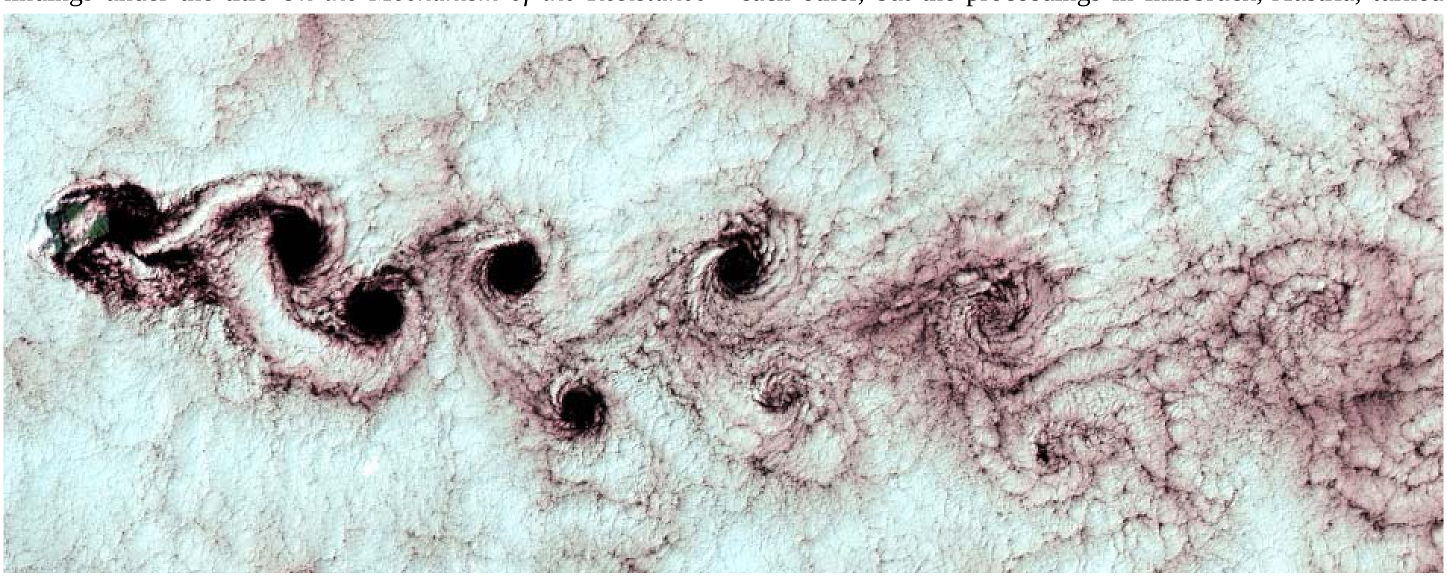
For the next few years, von Karman served as Prandtl's assistant at Gottingen. During that time, the up-and-coming researcher was very productive. In 1911, he published major findings under the title *On the Mechanism of the Resistance That a Moving Body Experiences in a Fluid*. The paper explained that form drag (a kind of parasitic drag) "occurs when the airstream fails to stick to the shape of the body, but breaks off behind it into wake." The discovery of these regions of rotation, called "von Karman Vortex Streets" (or "Trails"), catapulted the 30-year-old to worldwide attention. For decades to follow, the concept has been used to explain the oscillations that occur in structures from ships to bridges to airplanes.

Frustrated that his rise at Gottingen was hampered by the staid operating environment and a professor who increasingly viewed the young man with envy, von Karman delightedly accepted a professorship at the Technical University (Technische Hochschule) at Aachen, Germany, in 1913. The appointment included the Directorship of the Aachen Aerodynamics Institute.

About a year later, in August 1914, WWI broke out. Since von Karman was a reservist in the Austro-Hungarian Army, he was recalled to active-duty for the duration of the conflict. No furlough was granted the duration of the war, not even for the funeral of his father. Though a junior officer, von Karman's storehouse of technical knowledge caused him to be chosen to direct research for the Austro-Hungarian Aviation Corps. It was valuable preparation for his later work for the U.S. Air Force.

After the war, he briefly followed in his father's footsteps by serving as Hungary's Undersecretary of Education. In 1919, he returned to Aachen where he proceeded to build the Aerodynamics Institute into a leading center for research. He formed alliances with German companies and collaborated on projects with the farsighted German aircraft manufacturer Hugo Junkers.

Always an internationalist, von Karman decided that there should be periodic contact with scientists around the world. In 1921, he called for the first global conference in his specialty of fluid mechanics. At the outset, there was resistance to the idea because it meant that enemies of the recent war would be facing each other, but the proceedings in Innsbruck, Austria, turned



Ever wonder why a flag flaps in the breeze? Von Karman explained this phenomenon in his 1911 paper On the Mechanism of the Resistance that a Moving Body Experiences in a Fluid. *It wasn't until the creation of wind tunnels that we could readily observe these Von Karman vortices. With "eyes" (human and imaging) in space, we have observed these vortex streets in nature, illustrated here with a Landsat image of cloud patterns downwind of an island. (National Oceanic and Atmospheric Administration image)* out to be so successful that the conference became a regular event. The rewarding outcome validated von Karman's belief that science could trump politics.

Von Karman's investigations into the aeronautical unknowns continued apace. Working late one night at his suburban home with an assistant, he sensed that he was on the cusp of mathematically confirming his intuitively-derived law of turbulence. His assistant had to catch the last streetcar back to Aachen, so the two men walked to the nearby train stop. Von Karman impulsively continued scribbling his equations on the side of the streetcar in furtherance of his imminent breakthrough.

He begged the conductor to hold the train a little longer as he furiously etched yet more calculations onto the surface of the trolley. After a while the conductor's patience wore thin and the train started to pull away. The faithful assistant jumped aboard and scrupulously copied the elaborate formulae piecemeal at each stop along the route back into the city, saving von Karman's *oeuvre* for posterity.

The resulting paper, titled *Mechanical Similarity and Turbulence*, provided a mathematical framework for understanding turbulent flow and was destined to affect almost every aspect of aviation. Von Karman delivered the paper before the Gottingen Scientific Society. At the end of his talk, the room of fellow scientists uncharacteristically erupted into a rousing ovation.

Von Karman's peers had grasped the import of his insightful analysis. In a larger context, this epiphany, as von Karman put it, uncovered "the grand harmony that underlies and rules the motion of the universe." He was gratified that his revelation would make it possible for engineers to see that "complex phenomena. . . can be subjected to mathematical explanation."

Dr. von Karman Comes to Caltech

In 1921, when Robert A. Millikan assumed the reins of the California Institute of Technology he was on a mission to transform the sleepy Pasadena technical college into an educational and research powerhouse. A physicist by training, he soon distinguished himself by receiving a Nobel Prize for his electron experiments. He used his clout to lobby mining magnate Daniel Guggenheim and his aviator son, Harry, for a sizable grant to establish a world-class aeronautical laboratory on campus.

The Guggenheims, who had singled out aviation as a focus of their charity, agreed to provide the funds in the mid-1920s. They suggested that a prominent European academician be selected to lead the new lab in recognition of the superior standing of Europe's universities in the aeronautical sciences at the time. Theodore von Karman was high up on both the Guggenheim and Millikan lists.

Millikan had met von Karman at an overseas scientific conference and believed that the aerodynamicist possessed deep intellectual powers and strong classroom skills. Additionally, von Karman was known to be a committed and successful researcher. The courtship began in 1926 when von Karman was lured to Pasadena by a lucrative stipend.

During his travels across America, von Karman was impressed by the landscape and the people who populated it. The southern California climate was to his liking and the generously-endowed lab offered tremendous potential. But there was a stumbling block.

Von Karman had never married; instead, he lived with his mother, Helen, and his sister, Josephine (known as "Pipo"). Helen resisted the move from Europe for she was enamored of its Old World charms and felt the tug of familial roots. But by late 1929, the ever-perceptive von Karman could tell that the Nazi movement was gaining inertia, as sure as a streamlined model undergoing propulsive tests in his lab, and would soon make life untenable for Jewish habitants like him and his family members.

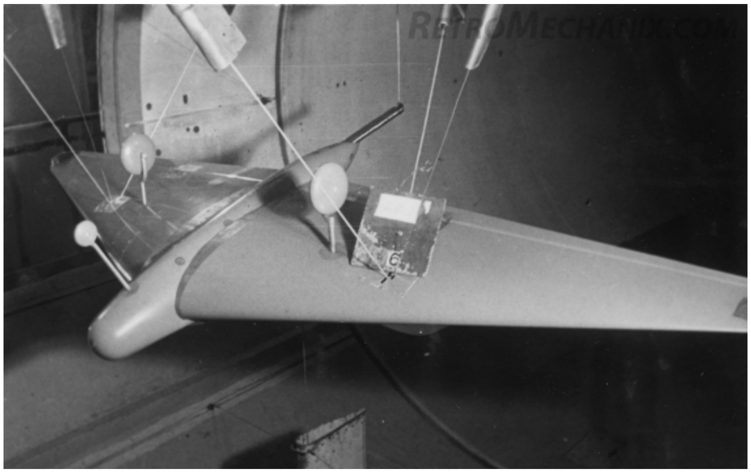
A lesser concern but one that plagued von Karman his whole life was his difficulty with the English language. He was fluent in German, French, Hungarian and even Yiddish, but for some reason he struggled for proficiency in the primary language of his country-to-be. The point was made by Gen. Curtis LeMay years later, after the two men had become friends. In an interview, the crusty Air Force Chief of Staff remarked, "In all the years I worked with von Karman, I knew he was doing a fine job, but I never really understood what he was saying."

In late 1929, von Karman sailed with Helen and Pipo for the modern Promised Land. The rising star of aerodynamics yearned for the expanded opportunity awaiting him as the Director of the Guggenheim Aeronautical Laboratory at the California Institute of Technology (GALCIT). As in his scientific life, von Karman had been insightful about political events. Five years after he left Germany, his former Jewish colleagues at Aachen were removed from the faculty by Nazi edict. In 1936, the onetime Austro-Hungarian artillery officer happily became an American citizen.

The von Karmans settled into a spacious Spanish-villa style home on South Marengo Avenue in a fashionable Pasadena neighborhood only two miles from the Caltech campus. Helen and Pipo were gracious hosts to an eclectic collection of family friends from the worlds of art, literature, music, film and, of course, science. Platters full of exotic delicacies were served by the elegant and sprightly ladies who could converse comfortably in several languages. In addition to Hollywood's leading lights and Caltech faculty and students, they entertained some of the century's scientific luminaries. Enrico Fermi, Niels Bohr and, yes, Albert Einstein, who von Karman had befriended at Gottingen 20 years earlier, were guests.

Even before von Karman accepted his permanent appointment, he had influenced the design of the planned GALCIT wind tunnel. With a 10-foot diameter, it was to be a cutting-edge tool for aerodynamic research. During consultations, von Karman argued for a closed, circulating design rather than the old open-ended type. He also urged that the wind tunnel's motor be located inside so as to be within the airstream.

While von Karman became the lab's intellectual dynamo, the wind tunnel served as its mechanical centerpiece. The many aircraft manufacturers headquartered in the area (Lockheed, Douglas, Northrop, North American, Hughes) were encouraged



Most of the major aircraft companies in the Los Angeles region made extensive use of the GALCIT wind tunnel. Douglas, Lockheed, North American and Vultee all booked time. In this photo, we see a Douglas "Model 9" flying wing being tested in the 1930s. A design most likely influenced by Jack Northrop. (GALCIT photo)

to reserve test times in the GALCIT wind tunnel to scrutinize their new configurations. When Douglas Aircraft engineers needed a solution to the buffeting encountered by their latest airliner, they turned to the lab in Pasadena. Model tests in the wind tunnel showed that, as von Karman had forecasted, a thin fairing or fillet at the wing root would ameliorate the problem. The fillet became a design feature of the famed DC-3.

Von Karman was on his way to not only building GALCIT into a premier research lab; he used his influence as sage and teacher to spread the idea that theory had to be mastered before one could make substantial leaps in real-world applications. His proselytizing on this point helped to return America to its aviation dominance after years of being usurped by Europe.

Rocketry

Rocketry was not a particular interest of the GALCIT Director. But when a graduate student named Frank J. Malina approached von Karman to be his advisor on a rocketry-related thesis in early 1936, the open-minded professor with a penchant for new ideas and an uncanny eye for hard-to-spot potentialities consented. His faculty colleague, Clark Millikan, son of Caltech's leader, had earlier declined.

Malina had been inspired by American rocket pioneer Robert H. Goddard, German experimenter Eugen Sanger and Caltech professor William Bollay. Word of Malina's planned rocket tests spread locally, which attracted enthusiasts John W. Parsons and Ed Forman to the endeavor. Others who became involved were Martin Summerfield and Hsue-shen Tsien, Caltech graduate students.

[Tsien was one of von Karman's closest protégés, a promising rocket scientist who von Karman described as "an undisputed genius." Von Karman's Chinese-born colleague was unfairly ostracized by the McCarthy Communist witch hunts of the 1950s. In disgust, Tsien returned to China with his family, never to set foot in the U.S. again. In China, he was hailed as a hero and proceeded to design the missiles that evolved into the Communist nation's increasingly cutting-edge arsenal of today. Thus, it can be said that von Karman is, by extension, one of the fathers of the Chinese missile and space program in addition to having a claim of paternity on the U.S. missile and space program.]

In October and November, Malina and his merry band experimented with their homemade rockets. Operating on a shoestring budget, these early tests were conducted in the open spaces of the Arroyo Seco, six miles from the Caltech campus and three miles from the Rose Bowl. By spring of 1937, von Karman was willing to let the rocketeers set up in the GALCIT building located on campus. Unfortunately, one of the indoor tests went awry, permeating the whole lab building with a cloud of pungent chemicals that stained valuable equipment. From then on the sometimes hapless experimenters were known as the "Suicide Club." (The term "Suicide Club" is used in von Karman's autobiography, but the term "Suicide Squad" appears in some other accounts.)

In 1938, Gen. Henry H. "Hap" Arnold, Chief of the Army Air Corps, made a surprise visit to the campus. He was a firm believer in the value of science and technology to warfare. During a walkthrough, he became intrigued by the work on rockets. Accordingly, he asked a grant-making committee of the National Academy of Sciences to consider funding further experiments in this nascent field.

At the time, the Massachusetts Institute of Technology was offered a chance to participate in the rocketry research, but Jerome Hunsaker, a highly-regarded professor who ran the prestigious institution's aeronautical lab, declined, calling the project a "Buck Rogers job." Von Karman, cognizant of the risk to his standing in academic circles should the rocketry experiments fail, embraced the project and supported Malina in the application for funding. In June 1939, $10,000 was provided to GALCIT for additional experimentation.

Not everyone in the process was convinced of the decision's wisdom. A top aide to General Arnold confronted von Karman, pointedly asking: "Karman, do you honestly believe that the Air Corps should spend as much as $10,000 for such a thing as rockets?" Years later, as the public realized the indispensable role of missiles in securing national defense and of booster rockets in facilitating the space program, more than one wag wisecracked that the early GALCIT rocket experiments may have been worth even twice the price!

Meanwhile, Malina's hands-on work coupled with his calculations caused him to believe that rockets had inherent limitations if they were the sole means of power. He felt that their best application would be as ancillary thrusters in conjunction with propeller-driven flight. Rockets could boost conventional aircraft on takeoffs, during climbs and on high-speed runs.

Malina and his compatriots in the Suicide Club still harbored dreams of soaring to the upper atmosphere and beyond, but those dreams had to be deferred. The key now was perfecting small rockets as supplementary propulsion for combat aircraft. With war looming, the project took on a palpable urgency.

Von Karman and Malina were not intimidated when experts said that there was no way to slow down the almost instantaneous burning up of solid propellants once ignited. The two worked out differential equations that solved the vexing problem. This was important because sustained fuel burns of up to 20 seconds were considered necessary to haul a heavily-loaded plane off the ground. Their math showed it would be possible to prolong the fuel burn by maintaining a constant chamber pressure. The trick was to keep a constant ratio between the exhaust nozzle's throat area and the propellant's burning area.

The Army Air Corps took note of the progress and upped the project's funding. At the same time, American rocket pioneer Robert Goddard had become secretive to the point of reclusiveness and refused to cooperate with the GALCIT team. His advances in rocketry were historic, but by the summer of 1940 the Suicide Club was on the verge of surpassing him.

In need of an expanded facility, the GALCIT team persuaded municipal officials to lease seven acres to the lab in the Arroyo Seco, the same place not far from Caltech where the Suicide Club had earlier begun rocket testing. Little could anyone have known then that the first ramshackle structure on the property, underwritten in part by the personal savings of the researchers themselves, would today be overtaken by a campus unto itself encompassing 177 acres where scores of buildings accommodate more than 5,000 employees and contractors who daily manage almost two-dozen ultra-sophisticated spacecraft cruising contemporaneously through various corners of the cosmos.

A year after von Karman and Malina hatched the theory for a long-duration, solid-propellant rocket engine, Suicide Club members perfected the actual item. The propellant charge consisted of a cylindrical casing 10 inches long and 1.75 inches wide packed with an amidic black powder and lined with an incremented blotting paper. In static tests, the two-pound fuel charge burned for 12 seconds and produced 28 pounds of thrust.

The rocket scientists were ready to fly their brainchild to ascertain the feasibility of boosted takeoff. An obvious question was what platform to employ. As they surveyed the possibilities, a newly-produced light plane looked like it might fit the bill.

Fred Weick and the Development of the Ercoupe

In 1936, the same year that Malina embarked upon his doctoral studies in the virgin field of rocketry, the assistant chief of aeronautical engineering at the National Advisory Committee for Aeronautics (NACA) left his job to join the ranks of private industry. Fred E. Weick had made a name for himself at NACA's Langley laboratory in the streamlining of engine cowlings, but was ready to apply his expertise in the real-world of aircraft design and manufacturing by joining the Engineering and Research Corporation (ERCO).

ERCO had been established in 1930 by Henry Berliner to produce tools for the manufacture of metal aircraft parts. He and Weick knew each other through their mutual interest in propellers. Berliner decided to branch out into production of aircraft and Weick was brought in to head the design team at the company's new facility in Riverdale, Maryland.

Earlier, Weick and some of his NACA colleagues in their spare time and at their own expense built a one-off aircraft designated the W-1. The design incorporated many innovative features to enhance safety, and Weick aimed to reprise the features in a new configuration for ERCO.

The resulting aircraft was the Ercoupe, a two-place (side-by-side), single-engine, low-wing, metal monoplane that, contrary to design conventions, had no rudder pedals. The cockpit's control wheel was linked to the elevators, ailerons and twin rudders so that flying the plane would be synonymous with driving a car. Indeed, the plane had tricycle landing gear with the nose wheel also linked to the yoke to make taxiing across airport surfaces like steering an automobile on roads.

The Ercoupe wasn't just simple to fly. Safety was uppermost in Weick's new design as it had been for the W-1. Elevator travel was limited to 13 degrees. This restricted angle of attack, thereby preventing entry into stalls. Through stall avoidance, the possibility of spins was eliminated.

Just as production commenced, the U.S. became engulfed in WWII. The military's voracious wartime appetite for aluminum caused only 112 Ercoupes to be built before production ceased for the remainder of the war. The flying public would have to wait until peace returned before having widespread exposure to the attributes of Weick's unusual design. When civil production resumed in August 1945, the type sold like hotcakes, but the boom was short-lived as most pilots were uncomfortable with the aircraft's absence of rudder pedals. *(Editor's Note: A conversion from a two-control system to a conventional three-control system incorporating rudder pedals became available later.)*

Rocketing on Wings

Reportedly, the GALCIT team had no difficulty deciding on the Ercoupe for its rocket-assisted experiments. The plane was new, easy to handle, theoretically spin-proof and offered good visibility because of its bubble-type canopy. Even more importantly, it was light, weighing in at 753 pounds empty and 1,023 pounds when configured for the experiments with the test pilot aboard. Another factor in the Ercoupe's favor was its aluminum fuselage that meant that it wouldn't be as susceptible to fire as light aircraft of the time that were mostly wood-and-fabric affairs. Moreover, if the Ercoupe came to grief, the economic consequences wouldn't be severe because of the plane's relatively inexpensive $2,300 price.

The model used in the tests was constructed on December 4, 1940, and designated YO-55. It was assigned Army Air Corps serial number 41-18875 and entered service on February 26, 1941. However, its wing still sported civil registration number NC28655 at the time of the experimental flights.

The research team attached a pod under each wing. The pods, in turn, each held three bottle-shaped solid-propellant engines. Logic suggested that the formal name for these devices should include the word "rocket." But von Karman was leery, some might say paranoid, about using that word in descriptions of his work. He feared that his peers might laugh at him because rocketry was still perceived as the stuff of pulp fiction, not suitable subject matter for tenured faculty.

He believed that adoption of the word "jet" would deflect disparagement and preserve his credibility as a serious researcher. By the early 1940s, jets represented an

Theodore von Karman, center, is fashionably attired in suit and Panama hat as he scribbles last-minute calculations on the Ercoupe's wing prior to a jet-assisted takeoff (JATO) flight test at March Field, Calif., in August 1941. More than a decade earlier, he similarly scribbled equations on the side of a streetcar. Then, the result of his impromptu figuring was his monumental law of turbulence. This time, the effect was to jumpstart the U.S. missile and space programs. Looking on, from the left, are team members Clark Millikan, California Institute of Technology professor and son of Caltech's leader, Martin Summerfield, a close von Karman associate and former graduate student, Frank Malina, another close von Karman associate who as a graduate student pushed for rocket-related experiments, and Army Air Corps Capt. Homer Boushey, the JATO project's test pilot who had studied under von Karman. Note the Wright Field arrowhead sewn into Boushey's leather jacket. Also, note that as von Karman scrawls with his right hand, his left hand holds a cigar. (NASA photo)

acknowledged field of study, even if not fully appreciated by Allied officialdom. In any case, because of von Karman's misgivings the supplemental-lift rockets went by the name jet-assisted takeoff, or JATO for short. The acronym has stuck to the present time.

On August 6, 1941, the Ercoupe was anchored to the ground at March Field near the town of Riverside, about 60 miles east of Los Angeles. The under-wing rockets were to be checked for the last time before taking to the sky. The static firings went according to plan and before the end of the day there would be an airborne evaluation.

The first flight test called for the aircraft to takeoff normally under its own power. Once established in cruise at 3,000 feet, the JATOs (only one rocket per wing in an abundance of caution) would be ignited. With Army Air Corps Capt. Homer Boushey, a former von Karman student, at the controls, the Ercoupe rose from the runway.

At its designated altitude, the diminutive plane was hard to see. Suddenly, parallel plumes of white smoke began trailing across the pallet of blue sky. The rockets were working!

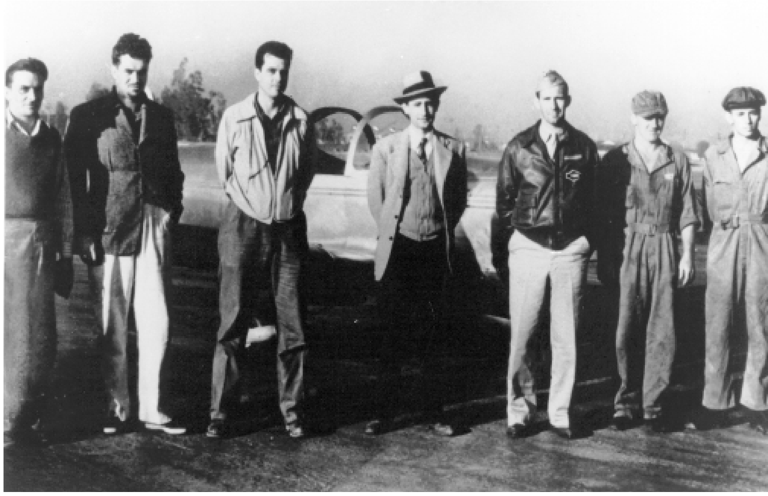
But the euphoria on the ground quickly receded as one of the cylinders exploded near the end of its fuel burn. Boushey rode through the jarring torrent and righted the plane in a masterstroke of superb airmanship. Thankfully, the Ercoupe and its pilot weren't harmed. The members of the Suicide Club had come disturbingly close to giving credence to their name and they knew that they had their work cut out for them to solve this latest problem.

John Parsons was the team's chemicals expert and he was stumped. A subsequent ground test caused damage to the plane and even burned a hole in its metal fuselage. Repairs were made as Parsons went back to his drawing board.

As he pondered the matter, he realized that only the loaded canisters that sat overnight were exploding. The variation in temperature from the cool overnight storage to the warm daytime desert sun led him to believe that the propellant might crack as a result. In turn, the deformed solid charges would be subject to uneven burning and explosions.

The trial and error had led him to his eureka moment. Parsons had figured it out. The charges had to be used soon after being packed; any delay would subject the propellant to changing temperatures that could spell disaster.

With hopes running high on August 12, Boushey throttled up the Ercoupe's piston engine and then, with the two-blade wood propeller whirring and the takeoff roll underway, he fired the JATOs. The "plane shot off the ground as if released from a slingshot" and zoomed aloft at a 50-degree angle! It flew like, well, a rocket. The plane got airborne in less than half the normal distance and the small pods slung under the wings did not impede flight in any meaningful way.



Members of the flight test team are pictured in front of the Ercoupe test aircraft at March Field. From the left are Fred Miller, an explosives technician, John Parsons, the chemicals expert, Edward Forman, a rocket engine mechanic, Frank Malina, Capt. Homer Boushey, and Army Air Corps mechanics Private Kobe and Corporal R. Hamilton. (NASA photo)

JATO charges bolt the Ercoupe off the March Field runway in August 1941, an early step in the American military's development of rocketry that gained momentum in the latter stages of WWII. (NASA photo)

Tests continued for the next couple weeks. On August 26, the team was feeling emboldened and decided to try a takeoff without conventional thrust from the Ercoupe's nose-mounted engine. In fact, not only was the engine kept dormant, the plane's propeller was removed.

To compensate for the lack of the plane's normal engine power, extra rockets were mounted under the wings. But the thrust-to-weight ratio wasn't sufficient and the plane simply traipsed along the runway, failing even to bob off the pavement. Not wanting to end the series of successful flight tests on a down note, Boushey suggested an idea.

Have a truck tow the Ercoupe to a speed of about 20 mph at which point he would ignite the rockets and hopefully bolt into the air. There was no mechanism for the tow, so Boushey gripped a rope with his left hand out the side window of the Ercoupe as the truck pulled the other end. Boushey kept the Ercoupe going straight by steering, literally, with his right hand.

During the one-of-a-kind takeoff roll, Boushey held on as long as he could. As he later said, the Ercoupe's speed advanced "somewhat below that wherein the arm-bone would have been pulled out of the shoulder socket." At that moment, he released the rope, drew his hand back into the cockpit and fired the rockets.

A cloud-like blast shot out from under the wings and the silvery plane rode a thick column of smoke in a steep climb. It was all too brief a flight. The plane peaked at 20 feet in a matter of seconds as the tiny cylinders expended their supply of powder. Reduced in an instant from thundering rocket-plane to limp sailplane, the Ercoupe then plopped back down onto the ground, concluding the trailblazing flight trials with a thump.

The excursion was a milestone – the first time an American pilot had risen skyward on rocket power alone. Though limited, Boushey's dramatic ride foreshadowed record-setting rocket-plane flights to the upper reaches of the stratosphere and roaring blastoffs of manned capsules into the vast void of space. It was a classic example of a small step presaging giant leaps.

Parsons developed a permanent fix to the temperamental solid propellant, enhancing its practicality. Nevertheless, the Army Air Force wasn't sold on JATOs; air commanders were content to extend runways with bulldozers to enable the takeoff of heavy, arms-laden aircraft. On the other hand, the Navy saw a need for the takeoff assist because of the inherent limitations of aircraft carrier flight decks.

In the thick of wartime innovating, von Karman and some of his colleagues formed the Aerojet Engineering Corporation (later to be known as Aerojet-General Corporation) to commercialize their rocket successes. The company's first office was in an old Pasadena fruit cannery. From that humble origin, it evolved into a leading supplier of propulsion systems for the military and NASA. The product line eventually included orbital maneuvering engines and attitude thrusters for the Space Shuttle.

The direction of von Karman's rocket research changed considerably after he viewed highly-classified reconnaissance photographs of German rocket launch sites in mid-1943. No longer was it adequate to think of rockets as supplemental thrust devices. To match and outdo the emerging enemy threat, a program focused on full-scale rockets was necessary.

The U.S. Army's ordnance branch set up an office to develop rockets. In November 1943, its liaison officers at Caltech were advised by members of the Suicide Club that the canister-sized JATO rockets could be the basis for the desired long-range missiles.

By next January, the ordnance branch looked to GALCIT to fast-track prototypes of a guided surface-to-surface missile capable of carrying a sizable warhead. Instead of thousands of dollars being offered as was the case with the early JATO project, the Army now expressed its willingness to fork over millions.

The official start of this new rocket program was July 1, 1944. On that day, GALCIT morphed into the Jet Propulsion Laboratory (JPL). As before, to obviate the stigma associated with the word "rocket," von Karman opted for insertion of the word "jet." From its aeronautical roots, the newly-titled lab prepared to develop vehicles capable of scaling the outlying threshold into the exo-atmospheric domain. For the time being, however, the government had other plans for JPL's cofounder.

Conceptualizing the Air Force of the Future

In early September 1944, Gen. Hap Arnold summoned von Karman. The resulting meeting a week later was a scene befitting the high-drama of a Warner Brothers classic like *Casablanca* (directed by Academy Award-winner Michael Curtiz, himself a Hungarian émigré). General Arnold was awaiting a change of planes under a cloudless sky at LaGuardia in New York. One of his aides drove von Karman to the end of the runway where the General's staff car sat parked. When von Karman transferred to Arnold's car, Arnold dismissed both his aide and driver to ensure maximum privacy.

Arnold and von Karman were feeling the effects of age, demanding work schedules and the pressures of war. Von Karman had just finished his recuperation from major intestinal surgery that summer and Arnold was coping with cardiovascular issues. They were weary, but determined to press on.

Not knowing what to expect, von Karman was all ears. Arnold turned to von Karman, who he had known since the scientist's early Caltech days, and declared that as far as he was concerned the war had been won. It was time, he said, to look to the future of air power. "What do you wish me to do, General?" von Karman asked.

The answer shot back without missing a beat. Arnold told von Karman to come to the Pentagon, assemble a group of the best scientists and develop an Air Force "blueprint" for up to the next 50 years. This idea for an overarching technological playbook with multi-decadal relevance represented a monumental crossroads – the beginning of the Scientific Advisory Group (SAG), now known as the Air Force Scientific Advisory Board.

Arnold, the air commander, and von Karman, the scientist, gave the appearance of the archetypical odd couple. Arnold traced his lineage to pre-revolutionary America. He was a stiff-collared professional military man, a West Pointer who was taught to fly by the Wright brothers. By contrast, von Karman was a heavily-accented cosmopolite, a Bohemian egghead who scratched out world-changing equations on any convenient surface while puffing on ubiquitous cigars.

To his credit, Arnold disregarded the extraneous factors and chose von Karman simply because he wanted the best person, the brightest mind, to recommend the way forward for the service he loved so much. For his part, von Karman saw in the old flyer a fellow visionary who understood the imperative to harness science as a means to keep the world free.

Another urgent need arose with the war winding down. Arnold wished to know the status of the Axis powers' aviation and rocket technologies. He charged von Karman with finding out. Caltech's Robert Millikan reluctantly consented to give von Karman a leave of absence.

Von Karman was hastily commissioned a major general and given a war correspondent's uniform. Leading a team of experts as part of Operation Lusty, he arrived in Germany as Allied troops were clearing out the last pockets of resistance.

In a twist of fate no one could have predicted, von Karman found himself at Gottingen sitting at the desk of his old professor. During the interview of his mentor-turned-rival, von Karman was deeply disappointed that Prandtl remained unrepentant for his collaboration with the Nazis throughout the war. The onetime student did not accept his former teacher's claim of ignorance of the Nazi atrocities.

When von Karman returned to the U.S., the first order of business was providing a report that compared U.S. and German technologies. On August 22, 1945, he submitted *Where We Stand*, a top-secret analysis that concluded, among other things, that the U.S. had the ability to build long-range ballistic missiles.

Then, on December 15, he presented the SAG's main report. Appropriately titled *Toward New Horizons*, the top-secret multi-volume study laid the foundation for Air Force preeminence. Many of the technologies that are now taken for granted were tagged for development in this far-reaching air power manifesto, including: supersonic flight, inflight refueling, precision munitions, pilotless aircraft, surface-to-air missiles, nuclear warheads, satellites and advanced electronics and communications.

Timeless truisms punctuated the analysis. Von Karman and his fellow authors admonished future Air Force leaders to have "a constant inquisitive attitude" and to be prepared for "swift adaptation to new developments." The roadmap drawn by von Karman and his handpicked associates enabled the Air Force to achieve and maintain global aerospace leadership for the remainder of the 20th century and beyond, just as Arnold had wanted.

In his executive summary, *Science, the Key to Air Supremacy*, von Karman emphasized the importance of not undermining research and development. He stated that adequate funding is vital. Also, he pointed to the potential for long-range strike capability to achieve control of the skies. Von Karman's work was a *tour de force*, the likes of which hasn't been seen either before or since.

In the early 1950s, von Karman suggested that NATO adopt a similar organization to the Scientific Advisory Board. Eventually, the Alliance's 12 member countries agreed to form the Advisory Group for Aeronautical Research and Development (AGARD). The U.S. Air Force acted as the new group's executive agent and fittingly installed von Karman as its head. Following a two-year trial, AGARD took on permanent status and its representatives annually reelected von Karman as chairman. In typical fashion, von Karman ensured that science trumped parochial interests.

In his waning years, von Karman made his base Paris, the city where he fell in love with flight. He kept a hectic globetrotting schedule as a much sought-after lecturer and consultant. Additionally, his output of scientific papers never let up.

Enduring Legacy

Receiving recognition from his peers meant the most to von

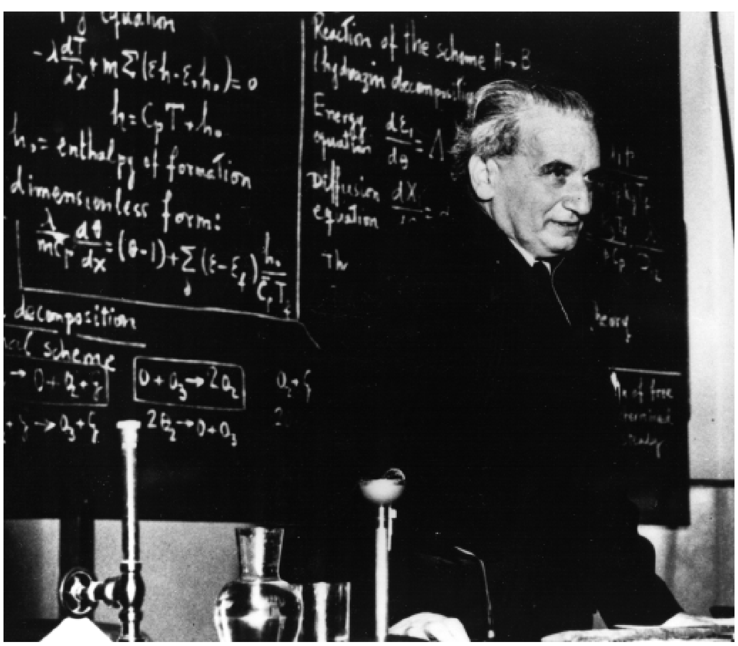
Karman. After WWII, universities around the world practically stood in line to lavish him with honors. In all, 29 institutions of higher learning conferred him with honorary doctorates.

In the U.S., the list included Princeton, Columbia, Yale and Brown. Representative of the overseas institutions were the universities of Paris, Brussels, Budapest and Istanbul. Technical institutes in Berlin, Aachen, Zurich and Haifa gave von Karman their highest honors as well.

Professional societies bestowed upon him their most prestigious awards. Some organizations went the next step and established awards in von Karman's name. An example is the von Karman Lectureship Award in Astronautics presented annually to an outstanding individual in the aerospace sciences by the American Institute of Aeronautics and Astronautics.

Von Karman was as much patriot as scientist, and the Air Force showed its gratitude for his numerous contributions to the advancement of American air power. In 1945, Hap Arnold personally pinned onto von Karman's suit the Meritorious Civilian Service Emblem. The following year, Arnold's successor, Gen. Carl Spaatz, pinned on the Medal for Merit, the highest military award for civilians.

By the early 1960s, as von Karman crossed into his 80s, the honors were not coming as frequently. The aged aerodynamicist began to wonder if his imprint on the science he had dedicated his life to was beginning to fade. Then, on the last day of 1962, while relaxing in the opulent canopied swimming pool at the Indio, Calif., ranch of legendary aviatrix Jacqueline Cochran, the phone rang and it was the White House calling for him. As if to answer his unspoken query and assuage his creeping doubt, Jerome B. Wiesner, the President's science advisor, informed a soaked and dripping von Karman that he had been selected to receive the first National Medal of Science.



Theodore von Karman gives a lecture in front of a blackboard filled with equations at Princeton University in 1953. Princeton was one of 29 institutions of higher learning that conferred honorary doctorates upon von Karman. (NASA photo)

Scores of other candidates had been considered. The depth of von Karman's aerospace achievements and his devotion to science, education and country were deemed nonpareil; his selection as the inaugural recipient set the bar very high for all who would follow. Dr. Wiesner, later to become Provost and then President of MIT, inquired if von Karman could come to Washington for the presentation ceremony.

On the morning of February 18, 1963, von Karman entered the Rose Garden of the White House where friends and colleagues from around the world had assembled to celebrate the moment that America's leader would hand the medal to the renowned aerodynamicist. The youthful vigor of President John F. Kennedy made for an interesting juxtaposition with the octogenarian scientist. The honor presented by the young head of state to the elder statesman of the aerospace sciences represented the thanks of a grateful nation whose incipient adventure into the New Frontier stood in large part on this humble giant's shoulders; the ceremony's handoff had reverse symbolism for as the medal transferred from presenter to honoree it meant that the torch was passed from the olden and learned to the fledgling and eager. In his responsive remarks, reflecting his appreciation for the opportunities that America had offered him, von Karman "pledged his brain as long as it lasted to his adopted country."

At another point during his visit to the White House that day, the agenda called for the distinguished party to descend a grand staircase. Von Karman paused before taking the first step due to arthritically-inflamed feet. Observing his distress, the Presidential entourage approached him and President Kennedy

President Kennedy awarding von Karman with the first National Medal of Science in the White House Rose Garden February 18, 1963. Photo of the medal is inset. (File photos)

The Mars rover Curiosity is one of JPL's latest accomplishments — part of an ongoing legacy that von Karman has left. You can just make out the "J" and "P" Morse code on the upper right tire thread (see inset). (JPL self-portrait photo)

himself reached out to give his ailing guest a hand down the stairs.

The scientist politely balked at the offer to assist. Always the teacher, the master of his classroom wherever it might convene, von Karman cast his eyes on those of his host and with a strained smile to mask his pain, he elfishly lectured: "Mr. President, one does not need help going down, only going up." It was a lesson, albeit more about pride than aerodynamics.

Sadly, neither President Kennedy nor von Karman lived out the year. They had, however, lived long enough to see some of the bountiful aerospace harvest from the scientific seeds that had been sowed. Things really picked up at JPL after the Soviet Union had lobbed Sputnik into orbit in October 1957.

At the outset of the "space race," JPL became one of the major research centers of the newly-created NASA. Indeed, America's first successful satellite, *Explorer 1*, was the pride of JPL. It launched in January 1958 and confirmed the existence of the radiation belt surrounding our planet.

Many other successes followed as JPL emerged as the world's leading developer of robotic planetary spacecraft. Notably, *Voyager 1* toured giant gaseous planets and beamed back clues about Jupiter's garish red spot and Saturn's dazzling rings. The probe kept going to where now, at more than 11 billion miles from the sun, it is poised to pass through the heliopause, the boundary of our solar system, and enter interstellar space, a first for a manmade object.

JPL's marvel of 1977-vintage has 68 kilobytes of computer memory, adequate to do the job of reporting back to Earth despite being only 1/100,000 the power of today's eight-gigabyte iPod Nano. It takes 17 hours for radio signals from this most distant of exploratory vehicles to reach Pasadena. Regardless of the time lapse, the information attained by today's JPL scientists sheds new light on an elusive region of the solar system and, in keeping with the performance of a workhorse, the transmissions are expected to continue until 2020.

Von Karman's enduring legacy continues to capture the public imagination. People have been entranced by JPL's highly successful Mars exploration rovers. The latest is *Curiosity*, a name that von Karman surely would have approved. The car-sized probe touched down in the Red Planet's Gale Crater in the late-night of August 5, 2012, amid the raucous cheers and deafening applause of JPL staffers on duty a short walk from the site in the Arroyo Seco where the Suicide Club conducted its first tentative rocket experiment with von Karman's blessing. In a further reminder of the high-tech craft's genesis, its landing occurred only a day before the 71st anniversary of the Ercoupe's first airborne test of the JATO rockets, the start of JPL's flights toward the heavens.

From its ingeniously-conceived descent onto the crater's floor by means of a bridled release to its multiple sensors and onboard analyzers, the nuclear-powered *Curiosity* has been hailed as "the most sophisticated roving laboratory ever to land on another planet." It has begun to unlock the secrets of the celestial body that has variously mystified and fascinated humanity through the ages.

Operating almost flawlessly since arriving on the Martian surface, the rover's mission is to search for the ingredients of life to determine the chances for past or present habitability. If all goes according to plan, JPL's mission team, from its control center in Pasadena, will command the rover to wheel itself to the base of the crater's central mountain, known as Mount Sharp, where it will stream back more data about Mars than ever before.

In the wake of its meanderings, *Curiosity* has been designed to leave visual markers in the form of tracks that spell out the letters "JPL" in Morse code in the Martian soil. Maybe Theodore von Karman's facetious nickname, shared by his fellow émigrés, wasn't far off after all. ✈

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Author

Author Philip Handleman has been an active pilot for many years. He currently owns and flies vintage aircraft including a WWII-era Stearman biplane.

Mr. Handleman has written or edited 22 aviation books. His ***Air Combat Reader*** (Potomac Books/Fall River Press) is in its fourth edition. It was co-edited with retired Air Force Col. Walter J. Boyne, the former Director of the Smithsonian Institution's National Air and Space Museum. This anthology was selected by the Air Force Association as its official gift to the more than 50 speakers at its annual Air and Space Conference in 2012 where presenters included the Chairman of the Joint Chiefs of Staff and the Air Force Chief of Staff.

Mr. Handleman has had nearly 100 articles published in magazines and newspapers. His writing has appeared in a diverse array of publications from the U.S. Naval Institute's ***Proceedings*** to ***USA Today***.

Mr. Handleman is President of Handleman Filmworks that has produced award-winning public television documentaries. His production ***Remembering the Holocaust*** received the Emmy for best documentary from the Michigan Chapter of the National Academy of Television Arts and Sciences. Also, Mr. Handleman's documentary about Vietnam-era MIAs/POWs, ***Our Missing in Action***, received the First-Place Award from the Michigan Sesquicentennial Film and Video Festival.

Mr. Handleman's still photography has been featured on U.S. postage stamps, notably those commemorating the 50th anniversaries of the Air Force (1997) and the Air Force Academy (2004). The stamps had print runs of approximately 45 million and 60 million, respectively.

The Tuskegee Airmen National Historical Museum recognized Mr. Handleman with its Outstanding Achievement Award in 1997 and its Lifetime Distinguished Achievement Award in 2005. Mr. Handleman received the Harriet Quimby Award from the Michigan Aviation Hall of Fame in 2008. Also, Mr. Handleman received the Combs Gates Award from the National Aviation Hall of Fame in 2010.

Mr. Handleman graduated from Washington University and subsequently completed the Executive Academy at the University of Michigan's Graduate School of Business Administration. He and his wife, Mary, divide their time between their home in Birmingham, Mich., and their private airport in the nearby countryside.