Missions for America
Semper vigilans!
Semper volans!

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FEATURE ARTICLE

THE WRIGHT BROTHERS, PARADIGMS OF THE ENGINEERING ART
by
Stephen M. Rocketto

Some 20 years ago, I got involved in a project tentatively titled "From Kites to the Wrights," a proposed interdisciplinary curriculum package for celebrating the centennial of flight in 2003. My involvement in this effort started in typical fashion. Gordon Schimmel, the Superintendent of Schools in Mansfield, CT called Ralph Yulo, Professor Emeritus of Education at Eastern Connecticut State University. He asked Ralph if he might recommend someone and Ralph mentioned me.

I have always liked projects like this one. Even if they do not fulfill their expectations, enough good material can be developed to make it all worthwhile. Besides, the collegiality and fellowship of the other participants buoys my spirit and brightens my occasional dour disposition. But this project was a real bonus. My earliest memories are entwined with things aeronautical. Flying, model building, and studying the history of aviation has diverted me from the mundane, emptied my pockets, and enriched my soul. So I eagerly seized the opportunity to minimize my sleep and complicate my life. Some people just cannot say "NO!"

One meeting led to another and the project focused on developing a set of interdisciplinary modules centered on some sort of laboratory exercise or construction activity which is directly related to

the experiences which Wilbur and Orville Wright underwent between 1895, when the first heard about the gliding experiments of Otto Lilienthal and 1905, when they produced the improved model of their 1903 Flyer.

In 1895, the Lilienthal glider was the first successful aircraft to receive a U.S. patent. This replica is on display at Long Island's Cradle of Aviation Museum.

Emulating the Wright Brothers, I entered into a bibliographical search of the literature which might assist me in producing one or two useful segments for the project. I was especially interested in the convergence of talents, social conditions, and technology which contributed to the Wright's success in controlled, powered, manned, heavier than air flight; a goal which was eluding many notable scientists and experimenters. Four books proved especially helpful. The first was Tom Crouch's biography of the brothers, *The Bishop's Boy's* (A Life of Wilbur and Orville Wright). The second and third were Octave Chanute's *Progress in Flying Machines* and Orville Wright's *How We Invented the Airplane (An Illustrated History)*. Both of these volumes were readily available in Dover Publications editions. As an aside, Dover should be commended for their consistent policy of producing inexpensive reprints of seminal writings in science, mathematics, and technology. The last book which I considered was Peter L. Jakab's *Visions of a Flying Machine (The Wright Brother and the Process of Invention)*. This is another of the fine Smithsonian History of Aviation Series. The two historical reprints would serve as a "reality check" as I considered the theses offered by Crouch and Jakab.

The best recent biography of the brothers is Crouch's, *The Bishop's Boy's*. Crouch develops a detailed and coherent narrative of the unusually close relationships among the Wrights; the father Milton, the sister Katharine, and especially, the youngest brothers, Wilbur and Orville. One of their favorite toys was a Penaud helicopter, a variation of the familiar rotor on a stick, which soars aloft when twirled by a sidewise motion of the hands or by the stored energy of a twisted rubber band. The 11 year old Wilbur tried, with little success, to scale up this clever mechanism and exhibited a lifetime interest in building variations of this classic child's toy.

The earliest business ventures of the brothers involved the construction and utilization of a series of printing presses and for a number of years, they were involved in the dual business of publishing and press manufacture. But in 1892, the bicycle craze swept into Dayton and they swiftly transitioned from riders to sellers, repairers, designers, and manufacturers of the safety bicycle. They outfitted a machine shop, designed their own gas operated power plant, and engaged in the production of high quality to-wheelers.

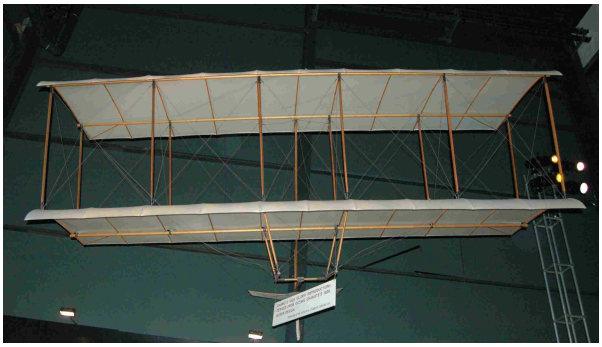
One of the Wright Cycle Shops at 22 South Williams St., Dayton. Their printing business was on the second floor. The Wrights invented the self lubricating hub and were also the first to machine left hand threads on the pedal crank arm to keep the arm from unscrewing.

As the last five years of the century played out, Wilbur started to exhibit an interest in heavier-than-air flying machines, initiated by reading about the experiments in gliding which Otto Lilienthal had been carrying out in Germany. Wilbur read Marey's *Animal Mechanisms* and started to consider the problems inherent in building a flying machine. Both brothers were keen observers of bird flight and Orville stated that "If the bird's wing can sustain it in the air without the use of any muscular effort, we did not see why man could not be sustained by the same means." The use of the verb "sustain" indicates thinking beyond short glides, such as practiced by Lilienthal, to flights in which altitude is not constantly lost. They observed the wide variety of flying creatures and could not see any reason why, in principle, why many could not accomplish the same feat.

In 1899, the physicist Samuel Pierpont Langley was the leading experimenter in aerial enterprises in the United States. Langley, Secretary of the Smithsonian Institution and a scientist noted for his work in stellar astronomy, had in 1896, first flown a steam powered model and two years later, received a $50,000 grant from the U.S. Army for the development of a man-carrying version of his Aerodrome. Wilbur wrote a letter to Richard Rathbun, Langley's assistant, requesting information on the current status of

aeronautical science. Rathbun sent Wilbur a collection of pamphlets and a suggested reading list which included Octave Chanute's *Progress in Flying Machines*.

Chanute was a remarkable man with a national reputation as a surveyor of railroad lines, bridge builder and inventor. In 1888, Chanute retired and concentrated all of his attentions on a 30 year advocation, aeronautics. He compiled all of the experimental reports which he had collected during that time and published a series of articles which became the book *Progress in Flying Machines*. A perusal of this text reveals that the book is a comprehensive study from Chinese kites and Leonardo da Vinci's ornithopter in 1500 to the 1890's trials of Hiram Maxim, Lawrence Hargrave, and Lilienthal. But Chanute was not merely a researcher and archivist. He and his assistant, Augustus Herring, conducted over 2000 gliding experiments on the shores of Lake Michigan. Research and experiment led Chanute to the conclusion that the development of a method for aircraft control was the key to practical flight. The Wright Brothers concurred.



A Chanute Glider at the Museum of the USAF

However, the eminent Langley and the inventive Maxim were convinced that the evolvement of a suitable power plant was the major problem to be solved. Furthermore, since most of the practitioners were doing their research with models, stability was a highly prized characteristic of any design. The Wrights, taking their cue from Chanute and Lilienthal, eschewed stability in favor of controllability.

This difference in design philosophy foreshadowed the arguments in the manned space flight program over automatic systems or pilot controlled vehicles. The U.S. astronaut corps forced the engineers away from the "Spam in a can" model favored by our designers and adopted by the Soviet program. The Wrights opened up a correspondence and a friendship with Chanute which was to continue until his death in 1910. Chanute personally visited their camp at Kill Devil Hill in 1901, 1902, and 1903 and served as their unofficial spokesman. Within several years, with Chanute's encouragement and assistance, the Wrights surpassed their mentor's achievements and Chanute saw the dream of practical flight achieved.

Orville's text, *How We Invented the Airplane*, is a succinct and profusely illustrated account of their adventure in invention. As might be expected, they were also amateur photographers and carefully documented each step in the process of invention. The stark landscape of Kitty Hawk forms a dramatic backdrop. The poised figures at launch and the clean images of flight are a delight to the eye. Commentary is supplied by a Wright biographer, Fred C. Kelly. Their first personal account to the public, a 1908 article from *Century Magazine* is included as an appendix.

This brings us back to the question of why the Wright Brothers were so successful when so many other people failed. After all, neither of them had completed high school, they were not part of the elite scientific establishment, and they lived in the Midwestern backwater of Dayton, Ohio.

Jakab's *Visions of a Flying Machine* subtitled "The Wright Brother and the Process of Invention" successfully explains their achievement by examining how Wilbur and Orville were guided by their mechanical skills, scientific skepticism, "Yankee" pragmatism, and the technical spirit of the time in which they lived. Whereas Crouch is somewhat diffident in analyzing their engineering aptitudes, Jakab's spares no ink in a close analysis of the technical issues which confronted them and how they

mastered each of them in turn. As a result, Jakab's book is more a philosophy of engineering rather than a discursive history of the process by which Wilbur and Orville built their Flyer. One can understand the Brothers as prototypical engineers and in their career, mark those qualities which are the hallmarks of good engineering practice.

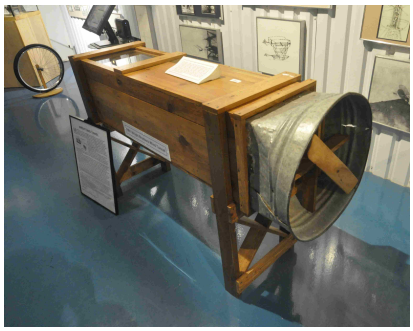
They could clearly define a problem. In the case of their aircraft, they quickly understood, from their experiences with kites and bicycles and their technical readings, that control was the key to success. In order to produce an airplane one had to experiment with models and manned craft and if the craft were to be manned, they had to be controllable. In a clear vision of priorities, unlike their many competitors, they postponed considerations of engines until they resolved the more fundamental issues. Basically, controllability and airfoil optimization could only be done by flying. This realization led to a series of experiments, in 1900, with kites and gliders.

Wright Kite at the USAFM

Operating at the remote site of Kitty Hawk, North Carolina, selected for its favorable winds, added logistical difficulties to their technical burdens. They developed the "wing-warping" technique for control but disagreements between the experimental values of lift measured and the theoretical values calculated from the standard tables of their precursors revealed that the traditional data regarding what we now call lift and drag were in error. They also encountered the problem of adverse yaw, a phenomena which caused an aircraft when banked in one direction to point its nose in the opposite direction.

By 1901, they were somewhat discouraged but Chanute visited with them for several weeks and convinced them that, for all their difficulties, they were far in advance of the field. They did not quit and they modified their program to meet the difficulties which arose. Although the Wrights claim to have entered aviation as a sport, they "reluctantly entered upon the scientific side of it" and established a rigorous program for investigating the myriad elements of fluid mechanics such as airfoil geometries and pressure distributions. hey then constructed simple devices for airfoil studies which culminated in their wind tunnel and by late 1901, had rectified the lift and drag tables and could find a rational relationship between their theoretical values and their experimental values.

Above, a bicycle modified with a force balance and used by the Wrights to test airfoils, a converse wind tunnel. Below: A replica of a Wright wind tunnel on display at the General Thomas Stafford Aerospace Museum.



Of paramount importance in their progress was their ability to visualize solutions. The "visions" in the title of Jakab's book refers not to some dream of a flying machine but to the specific mental constructs which allowed them to analogize between the abstract concepts of theory and the concrete products of the artisan's

craft. It was once said of Kelly Johnson, the engineering genius of Lockheed's Skunk Works, that "he could see air."

Likewise, Orville and Wilbur Wright could see, in their mind's eye, the relationships of forces and mechanisms which they turned into a wind tunnel, qualitative and quantitative measuring instruments, and ultimately, a practical airplane. Jakab argues that a facility for nonverbal thought was a key element in the Wright's success and my experiences with first class engineers supports this conclusion.

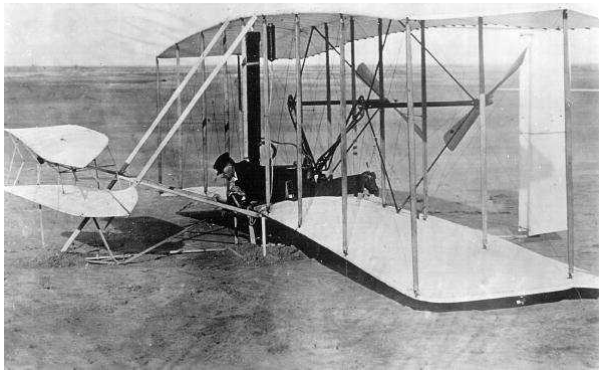
Much of their equipment was made from off-the-shelf supplies as their facile imaginations saw new possibilities in old things. The addition of a rudder, whose movements could be coordinated with the warping of the wings, corrected the problem of adverse yaw. Bicycle chain drives were adapted to mate engine with propellers.

During this period another engineering asset, their skill with tools and their sensitivity for the materials of construction served them well since constant repairs were necessary to keep their delicate machines airworthy. Consequently, during the next year, they completed around 1000 glider flights and started to the acquire the aviator skills and experience which are needed to maintain the equilibrium of the aircraft in flight.

1902 Wright Glider

Then they attacked the issue of motive power and did so in typical Wright fashion. They calculated how much power they required and then designed and built, with the assistance of their mechanic, Charlie Taylor, a 12 horsepower engine. Their past work with airfoils, and the ability to visualize that an "airscrew" was just an airfoil which rotated and followed a helical path allowed them to design and construct the first practical propellers.

And so, on December 17th, 1903, Orville made the initial takeoff, flying a distance of 120 feet in 12 seconds. Three more flights were made that day, the final one piloted by Wilbur logged 852 feet in 59 seconds and the age of aviation was launched. Within two years, they had perfected the original machine and, in 1908, Wilbur captivated Europe with his flying demonstrations and personality.



Orville at the controls. This is the finale of the unsuccessful attempt on December 14th which ended with a broken skid.

The period of time during which the Wrights grew up was a time of great technological and cultural change. The railroads opened up the west and telegraphy and telephony offered new possibilities in communication. Automobiles and bicycles gave people a new individual mobility. Everything seemed possible.

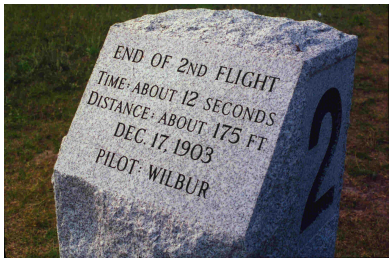
The Wright Brothers Collection at Wright State University in Dayton and the list of books which they took to Kitty Hawk indicates wide reading in the mathematics and sciences including technical publications in French and German. Their biographers indicate that their readings extended into literature, history, and philosophy. High school educations were not common and neither of the brothers completed high school. But they were voracious readers, deeply curious, and possessed finely honed intellects.

The Wright brothers were brought up to be confident and self reliant and lived in an age when such characteristics were prized. They entered into heated debates with each other over technical issues in which the give and take of the dialectic would lead to a solution to the problem under discussion. Yet their close personal relationship did not allow for the rancor which might have developed otherwise. These cultural and personal circumstances, melded to their methodical approach to problem solving contributed to their efficacy as engineers and makes them worth studying as a model of what engineering is all about.

If the reader wishes to further pursue the remarkable story of the Brothers Wright, I would recommend two recent publications. The first is David McCullough's, *The Wright Brothers*, a biographical treatment similar to Crouch's *The Bishop's Boy's*.

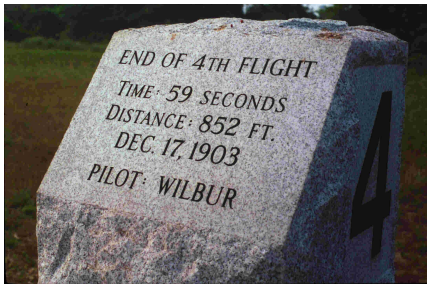
The second book is Larry E. Tise's photo-essay, *Hidden Images of the Wright Brothers at Kitty Hawk.* Tise has collected a delightful collection of imagery which not only reveal details of the brother's life on the Outer Banks but also presents a plethora of photographs of the Kitty Hawk community members who supported and assisted them.

Flight One Marker



Flight Two Marker

Flight Three Marker



Flight Four Marker

AEROSPACE HISTORY ANNIVERSARIES

December 17, 1903 - First Flight

The famous First Flight Photo was taken by John T Daniels, US Lifesaving Service. After the camera was set up, he was handed the shutter actuating bulb and told to squeeze it if anything interesting happened. It did and he did.

The Path of the Flights. Kill Devil Hill and the Wright Monument are visible in the rear background.

That's All Folks! *(Photo Credit: S. L. Carpenter)*

AEROSPACE CHRONOLOGY FOR THE WEEK

December 18, 1947 - First flight of the Chase YC-122 Avitruc.

December 19, 1928 – The world's first formally designed airport, Port-Aviation, opens outside of Paris.

The airport was a circular field, 1.8 miles in diameter which allowed aircraft to land and take-off in any wind.

Seven of the eight aircraft in the 1913 event are visible in the photo. In the centre, nearest the camera, Audemars' Demoiselle and Deletang's Blériot, behind them, from left to right, Dufour's Voisin, Ladougne's Goupy, Champel's Voisin, Dubonnet's Tellier and Burgeat's Antoinette.

December 20, 1969 – The highest-scoring ace of the Vietnam War, North Vietnamese pilot Nguyễn Văn Cốc scores his final victory. Seven of these shoot-downs are acknowledged by the USAF: two F-4D Phantoms, 3 F-105D and one F-105F Thunderchiefs and an F-102A Delta Dagger.

These kills were all scored flying a MiG-21 using the Atoll heat-seeking missile. He is also credited by the Vietnamese Air Force with shooting down an AQM-34 Firebee UAV and possibly an OV-10 Bronco but neither are confirmed by the USAF.

December 21, 1936 – Mercenary pilots head for Spain aboard the *SS Normandie*. They will join the Yankee Squadron of the Republican forces fighting the Nationalist rebels.P ay was

$1,500/month with a $1,000 bonus for each Nationalist aircraft destroyed. The six pilots were Bert Acosta, Eddie Schneider, Edwin Semons, Hilaire du Berrier and Gordon Berry commanded by Frederic Ives.

Above: Ives, Top Right: Acosta and Berry, Bottom Right: Lt. Gen. du Berrier, four years later, as self proclaimed Lieutenant-General and Chief of Staff for Air, under Gen. Yeh Peng, in the army of Wang Ching-wei, China, 1940!!!!

Upon arrival they immediately ran into problems. Required to fly immediately, they were assigned a motley collection of obsolete aircraft, no flight clothing, and no local training. Lord protested and to prove his point, took the Spanish commander aloft in a Bréguet 19 and the upper wing collapsed. Lord managed to get back on the ground but his protests were ignored and he was nearly arrested.

The Bréguet 19 (Credit: Peyot Collection)

The 1922 design was withdrawn from service within a year. Other aircraft flown included the obsolete Potez 54. The unacceptable aircraft, lack of logistical support and the denial of bonus money cause disgruntlement in the Yankee Squadron.

Within a month, Acosta, Schneider, Berry, and Lord attempted to flee Spain but were caught, jailed temporarily, partially paid in pesetas (useless outside of the Republic) and expelled. Back in the United States, the brought legal action against the Spanish government but it all came to naught.

Semons remained. He has served as a recruiter and became liaison between other American pilots and the Spanish. Hilaire du Berrier was loyal to the Spanish Republic and sensed an opportunity. He attempted to become a double-agent, posing as an anti-communist and "changed" sides, flying for Franco's rebel. Unfortunately, the Italian fascist supporters of Franco revealed that previously, du Berrier had flown for Haile Selassie and the Ethiopians against the Italians. He was arrested, sentenced to death but then released to avoid affecting American sensibilities.

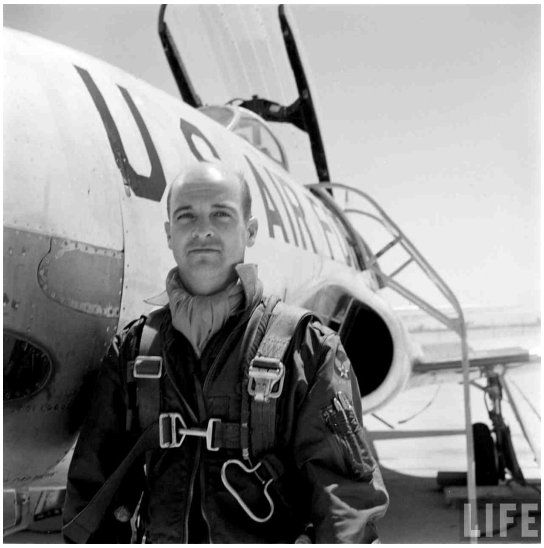
At least 15 or 20 other Americans served as mercenary pilots on both sides in the Spanish Civil War but that is a story for a future edition.

Dec. 22, 1954 – Test pilot Capt. Richard Harer is flying a Lockheed F-94C Starfire at Edwards Air force Base. His mission is to test the usefulness of the drag chute, generally used to brake when landing, as a combat tool if deployed in flight.

F-94C and Harer

Capt. Milburn Apt was flying chase. The deployed parachute failed to release with the manual control and two other methods also fail. The plane became unstable and heads down.

Harer managed to gain enough control to put the Starfire down on the lake bed but it catches fire. Apt, who had followed him down, landed immediately and attempted to release the canopy using the emergency release. It failed. Apt bashed the canopy repeatedly with his hands but only succeeded in injuring himself.



Milburn Apt
(Credit: Life Magazine)

A jeep arrived with a five pound fire extinguisher which did nothing to extinguish the flames. Apt grabbed the empty extinguisher, about the size of a two liter soda bottle and repeatedly struck the canopy. The canopy held fast and the flames reached Harer. The jeep driver came back with a five gallon can filled with water weighing about 50 pounds. Apt managed to smash open the canopy and managed to extract the severely burned Harer.

Harer survived but had both his feet amputated. Apt was awarded the Soldier's Medal, the highest award for valor in a non-combat mission.

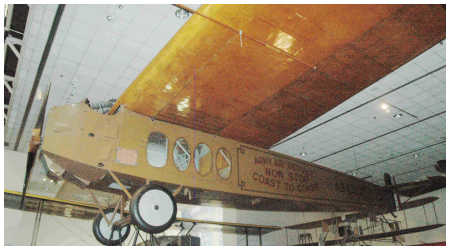
Apt went on to be the first pilot to exceed Mach 3 flying the Bell's X-2 Tragically, just after setting the record, the aircraft became unstable due to a new phenomenon known as inertial coupling. Roll coupling occurs when the inertia of the aircraft's fuselage overcomes the ability of the control surfaces to restore stability.

Apt sits in the cockpit, Iven Kincheloe, a Korean War ace, stands on the ladder. Kincheloe was killed flying a Lockheed F-104 when he ejected and his parachute failed.
(Credits; USAF/NASA)

Apt used the escape capsule but its parachute failed. He then attempted to bail out of the capsule but it was too late and he was killed when the capsule hit the ground.

December 23, 1939 – Anthony Fokker goes West. Fokker was one of the most prolific of the early aircraft designers. A Dutch national, he built his first aircraft in 1910 and continued developing designs into the early 1930s.

Fokker Dr.1 Dreidecker replica at Olde Rhinebeck Aerodrome.



Fokker C-2 in in which Lts. John Macready and George Kelly made the first non-stop transcontinental flight.

After his death, the eponymous Fokker

Corporation continued his brand and by the time it went bankrupt in 1996 over 100 aircraft bore his name.

Last of the modern Fokkers, a Fokker 100 in the livery of Groton-based Pilgrim Airlines.

COMMONPLACE BOOK

Ernest Gann
Aviator and Author

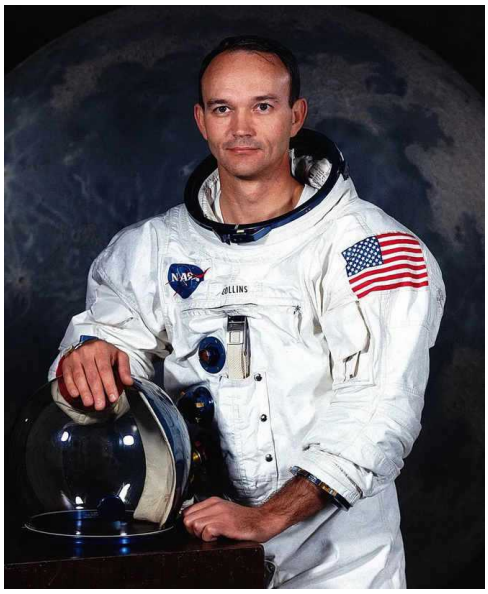
You can always tell when a man has lost his soul to flying. The poor bastard is hopelessly committed to stopping whatever he is doing long enough to look up and make sure the aircraft that is purring overhead continues on course and does not suddenly fall out of the sky. It is also his bound duty to watch every aircraft within view take off and land.

Antoine de Saint-Exupéry
Author and Pilot

I fly because it releases my mind from the tyranny of petty things.

Michael Collins
Apollo II Command Module Pilot

"Q: What were you thinking when your colleagues were out there making cosmic history?
A: I just kept reminding myself that every single component in this spacecraft was provided by the guy who submitted the cheapest tender."



A. Scott Crossfield
Engineer and Test Pilot

Strive for simplicity. You never have to fix what you leave out.

Jimmy Doolittle
Aviator, Engineer, Warrior

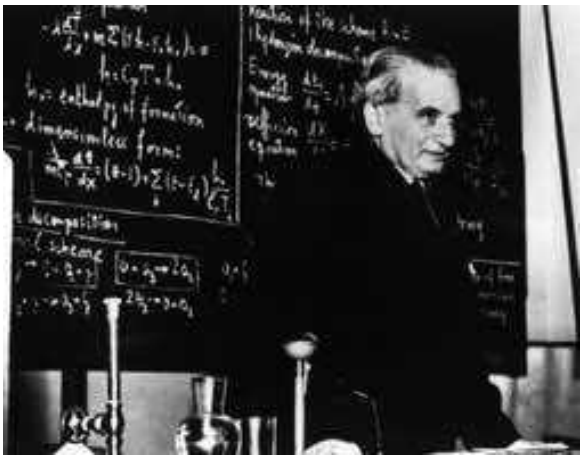
I am not a very timid type. It's very important to some people, but not to me. I have a simple philosophy: worry about those things you can fix. It you can't fix it, don't worry about it; accept it and do the best you can.

Eddie Rickenbacker
Auto Racer. WWI Ace. Entrepreneur

The four cornerstones of character on which the structure of this nation was built are: Initiative, Imagination, Individuality and Independence.

Theodore von Kármán
Aerodynamicist and Engineer

A scientist describes what is. An engineer creates what never was.



Bessie Coleman
Pioneer Aviatrix

Behind the parents stands the school, and behind the teacher the home.