SPACE & AERONAUTICS TECHNOLOGY
- PAST & PRESENT-

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As an English Poet once said, "He who builds under the stars, builds too low". The space program carries on the American tradition of exploring – of expanding our knowledge and horizons.

In looking back, it is a great time to have lived – all the major inventions, with the exception of the printing press and the steam engine, have taken place in my lifetime. In 1939, the NACA (predecessor to NASA) Chief of Research testified before Congress that the law of diminishing returns had been reached in aeronautics and all important research had been accomplished. History has shown the absurdity of his prediction. Technology is in its infancy and still growing asymptotically. We tend to always underestimate the technical future but I think you will agree that Engineers and Scientists will be center stage.

It was a great time to have had a career. I've had a chance to work with the aviation pioneers Hunsaker, Dolittle, Thompson, Dryden, and to be a peer with those who will eventually be referred to as space pioneers – Armstrong, Gilruth, Kraft. Neil Armstrong and I had adjoining offices for almost a year. Neil was a technically competent aeronautical engineer but it was difficult for him to do any job in Washington. He was constantly requested by legislators for appearances and photo sessions. If you ever have a chance to be a national hero, turn it down – it's an impossible job. I never discussed the lunar mission with Neil. He was besieged with insane questions. However, on one occasion, he volunteered that looking back at the earth was much more spectacular than the moon itself. Looking at that beautifully colorful marble in space had a profound effect on Neil and other astronauts. The realization that this fragile ball, with its tenuous atmosphere, was man's responsibility to destroy or preserve. When we talked, many times, Neil would prop his feet on my desk. I confided in him that I couldn't look at his foot without seeing his footprint on the moon. He laughed but when he left Washington he gave me a large signed picture of that famous lunar footprint which I still proudly display in my den.

Aviation has come full cycle in one generation, from the airplane to the spacecraft to the first hypersonic aircraft-the shuttle-and with a one stage to orbit spacecraft now approaching reality. One of the primary reasons for the rapid technical advances lies with the improvement in sensors. We have progressed from crude low response sensors such as the early undamped manometer tubes for airfoil pressure distributions and visually observed tufts to exotic strain & pressure sensor and laser velocimeters which yield many orders of magnitude more data per unit of time than before. However, one of our best and sometimes most reliable sensors still is human observation. The argument still exists between manned and unmanned spacecraft for space exploration with worthy advocates and arguments for both. The space exploration picture would not be complete without both. I recall one graphic example of effective use of the human sensor in research. It involves Dick Whitcomb, an aeronautical engineer at NACA and later NASA Langley Research Center. Dick made several significant aeronautical discoveries such as the area rule, the supercritical wing, and winglets. Dick wasn't a highly theoretical researcher but he was born with the innate ability to understand how air flows around objects. He would file a little here and a little there on wind tunnel models, reducing drag with each stroke of the file. The contributions of his area rule made it possible for fighter aircraft of the day to meet drag specifications, saving the nation billions in redesign costs.

To discuss space history, it is important to review the environment that existed at the time. In the late 40's and early 50's, several groups in the U.S. were doing some space related research. Von Braun and his Penimunde Group, working with the Army, carried on a small effort in rocket research. JPL researched solid rocket propulsion. Jack Townsend, of NRL, headed the development of the Vanguard orbital rocket and NACA launched multistage sounding rockets, at Wallop's Island. Max Faget of NACA started his career as the conceptual designer of the nation's manned spacecraft with sketches of the "Hy Ride" which later became Project Mercury.

All this effort, at best, was fragmented with little dedicated funding. Space Research went from the back burner to the front burner in 1957 with the successful Sputnik launched by the Soviets. Sputnik came as a shock to our technical superiority. Our national prestige took another blow when the first Vanguard collapsed on the pad. It wasn't until a year later that Von Braun was able, with crash effort, to launch Explorer I, into orbit carrying Van Allen's spacecraft to measure the earth's radiation belts. Concern in 1957 by the Congress and President Eisenhower led to formation of NASA to reestablish our national prestige. Eisenhower and Senator Lyndon Johnson were convinced the new space program should be separated from the military to avoid escalating cold-war tensions. James Killian, Eisenhower's science advisor, is given credit for pulling together the organizations (NACA, JPL, Redstone, and NRL) which became NASA. All these had outstanding characteristics in common:

- They all had committed outstanding scientists and engineers. Bob Gilruth once told me the story regarding his employment into NACA. Five thousand engineers took the exam for Junior Engineer. Gilruth was the one selected – a highly selective process to say the least.

- They were all in-house organizations where hands-on experience and individual technical excellence was the norm..

- They all stressed individual responsibility for problem solving through personal attention to detail without having to rely on inspectors and quality controllers.

It was a judicious selection of the parts which made NASA an organization well suited for its task. Homer Newell of NRL brought the nucleus of a space-science program. Jack James of JPL brought the management expertise for complex science projects. Von Braun brought his mission vision and expertise for large liquid rockets. Hugh Dryden and NACA brought probably the most productive federal research organization in existence. The National Advisory Committee for Aeronautics (NACA) was formed in 1915. Professor Jerome Hunsaker, of MIT, had visited Europe earlier and reported that the U.S. was woefully behind in aeronautics. The Russians, British, and Germans all had over 1,000 aircraft while the U.S. had less than 30. President Wilson signed a Navy appropriations bill which included a rider establishing an aeronautical research laboratory "within overnight boat or train from, Washington, DC." Langley Field in Hampton, VA met this criteria and the first NACA laboratory was formed there. We all know that management by committee is ineffective; however, the NACA was run by a Committee both effectively and well. Men like Dolittle, Hunsaker, and Orville Wright comprised the Committee which met periodically, made recommendations as to new research problems and reviewed progress on existing work. The Committee understood its job of guiding research and assuring progress in an environment favorable to innovation and as free from bureaucracy as possible. The NACA and its four laboratories and 8,000 people became the largest segment of the newly formed NASA in 1958. It was a busy time for NASA. Project Mercury was started by the Space Task Group under Bob Gilruth at Langley. New booster systems were started including Centaur and Saturn. However, of the 37 satellite launches attempted by NASA less than 1/3 reached orbit. NASA got its start in the communications satellite game with the successful launch of Echo, a 100 ft. diameter mylar balloon, intended as a passive reflector of radio signals. Active communication satellites later proved to be much more reliable than some envisioned, negating the need for passive reflectors. Echo's biggest impact was that it was visible to the whole world, boosting the U.S. national prestige. Echo was an interesting development job. Acres of ½ mil. aluminized mylar had to be folded and packed in a 27 inch diameter spherical container. The first attempt resulted in filling a small room in place of a small sphere. The key came when I observed my wife take out her rain hat (folded in a neat strip) and unfolded it to a perfect hemisphere. We made scaled up fold patterns based the rain hat and successfully folded Echo.

Jerome Wiesner, science advisor to Kennedy, chaired a committee critical of the Space Program and questioned its cost & future. Conveniently, the Soviets came to the rescue with the orbital flight of Yuri Gargarin in 1961. The fact that Shepard flew his Mercury capsule on a 15 minute suborbital flight a month later did little more than prove we still lagged in the race. Both Congress and Kennedy were concerned and looking for solutions. Jim Webb, the new Administrator of NASA, provided an aggressive 15 year plan including a guaranteed way to win the space race by leapfrogging the Soviets with a manned lunar landing. Webb was one of the super-managers who thought in options; therefore there were few surprises even in gigantic undertakings such as Apollo. He had previously been the head of the Bureau of the Budget and knew all the important decision makers in Washington by first name. He was certainly the right man for the time. At a NASA-alumni meeting recently, Webb said he told Kennedy he would undertake the moon landing if Kennedy would accompany him to personally talk to the Congressional leaders and get their blessing for the project. As he related it "The President and I received 100% agreement on the Hill." Webb also said that later his staff presented him with a cost estimate for Apollo. He doubled it on the spot, and after thinking about it overnight, he doubled it again. It turned out to be about right. Let me remark for those of us who have big engineering egos, that Webb, who had no scientific degree, had more impact on the space program than any other one person.

Webb was pleased with the blank check he now held to proceed with the lunar project. Gilruth, obviously, was somewhat shocked since he was still in the midst of Project Mercury problems. However the NASA technical team accepted the additional challenge and proceeded to sort out problems and look at solutions. First, we knew little of the detail of the moon. Geologist, such as Shoemaker, predicted up to 50 ft. of dust on the surface. Gold predicted surface dust so fine that landing would be hazardous. We referred to this as "Gold Dust." It was interesting that the geologists interpreted the first high resolution lunar photographs as supportive of their individual predictions. Ranger and Surveyor, being developed at JPL to provide lunar photos and scientific data, were reoriented to answer some of the lunar surface questions and to aid in selecting an Apollo landing site. The Ranger experienced five straight failures. Jack James, of JPL who took over the project management, recognized that the many spacecraft systems were sound but the interfaces were faulty. He reorganized the management team into a cohesive project group with all systems represented on a full time basis. The last three Rangers were successful. This was the first recognition of the necessity for a full-time project office with meticulous attention to detail (including the interfaces) and it set the precedent for all future NASA Science projects.

The first Surveyor came within a few seconds of its soft landing on the moon and all communication was lost. I was a part of the failure investigation team and we were baffled by the unique circumstances. We finally subscribed the failure to a burn-through and explosion of the surveyor retro rocket motor which had experienced similar development problems. However the telemeter record had stopped abruptly, which was uncharacteristic of an explosion, and called for a double failure. In any case the rocket motor nozzle was "beefed up" on succeeding Surveyors and all soft landed successfully and provided photographic proof that the lunar surface would support the manned landing.

It was recognized that in addition to the Ranger and Surveyor data, selection of a lunar landing site required high resolution mapping of the moon. The Lunar Orbiter provided a high resolution map of about 90% of the moon-even of the lunar backside which was previously unobserved by man. The Lunar Orbiter made photographs from lunar orbit on film using image motion compensation to allow for the high forward velocity of the spacecraft. The film was later scanned and the digitized data returned to earth and reconstructed, thus providing many times the data that would have resulted from real-time video transmission as was done with Ranger and Surveyor.

In 1959, George Low, head of manned space flight office of NASA, had the for-sight to initiate a series of studies aimed at solving the many problems associated with a manned lunar mission. These studies helped to prioritize the key Apollo hardware developments. Guidance and Control was given top priority. To hit a small target in space where both the launch site and landing site moved relative to each other was recognized as a complex task. The contract for the Guidance and Control system was the first major Apollo contract and was given to the Stark Draper Laboratory at MIT. Major advances by the Draper Laboratory in gyros and computer systems led to a successful Guidance and Control system.

The development of the F-1 engine for the Saturn V launch vehicle was undertaken by Wernher Von Braun and his team.

Many equally complex problems such as re-entry, power systems, radiation protection, and weightlessness were tackled and solved.

The mission mode was very controversial with direct landing and earth rendezvous preferred. However, John Houbolt, of Langley, persistently pushed the lunar rendezvous mode which was finally accepted as the mission mode. Von Braun wasn't entirely pleased with the decision because even though it was more efficient, it precluded the development of a gigantic Nova launch vehicle which he envisioned as needed for future manned planetary missions.

It was now clear that rendezvous and docking in space had to be mastered in order to complete the Apollo mission. A hurry-up scale up of the Mercury capsule was named Gemini and provided invaluable information on man's ability to work in space, to withstand prolonged weightlessness and to rendezvous and dock. The advances in fuel cells, control systems, navigation, space suits, and the melding of a large NASA—contractor operational team made the Apollo problems much easier to solve using the Gemini experience.

All went well until a fire in Apollo command module during pre-flight tests killed 3 astronauts. Webb reflected the country's shock while reminding of the risk of space flight. He expressed amazement that the "first tragedy would be on the ground." Unlike the Challenger accident, NASA appointed an accident investigation team the next day headed by Floyd Thompson, senior NASA Engineer and head of the Langley Research

Center. A through review of all spacecraft internal systems, and materials was made. George Low took over as Project Manager and deserves much of the credit for making the changes which made the spacecraft much better, safer, and ultimately successful.

Later I was a part of the Apollo 13 investigation team. You will recall that the oxygen tank exploded during flight. Fortunately the tank failed outward, away from the astronauts or we would have had the first catastrophe in space. Use of the oxygen from the lunar lander, attached to the command module, allowed the astronauts to safely return to Earth. The culprit was small thermal switch, which could be purchased commercially for a few dollars. It was too small and welded shut, pumping more and more heat into the tank which eventually exploded. We, the investigating team, might have eventually found the specific problem but I cannot be sure. The project team, headed by Rocco Patrone, understood the hardware in great detail and succeeded in mocking up the hardware, reproducing the explosion and pinpointing the faulty thermal switch in a few weeks. I believe that the resistance to aid from the NASA project personnel after the Challenger accident for fear of a cover-up, was a mistake. I submit that an in-house NASA investigation could have pinpointed the management and technical problems with much less time and cost and had the Shuttle flying safely again years earlier.

The Challenger and Hubble telescope are prime examples of lack of attention to detail. Neither of these were high tech problems. "O" rings have been used for years. A knowledgeable engineer would have recognized the faulty "O" ring design in the Challenger solid rocket motor. In the case of the telescope, spherical aberration is not a new or high tech problem. Lack of attention to detail by knowledgeable people cannot be replaced by after the fact inspectors or accident investigators.

Early in NASA's History there were arguments in NASA and even in Congress between manned and unmanned programs. It was clear that Apollo would demand a large share of NASA's budget. It was also clear that the preponderance of Congress wanted emphasis on manned programs because of international prestige.

Webb somewhat defused the criticism of Apollo by designing and selling to Congress a broad program of Space and Earth sciences and meteorological and communication satellites to go along with the manned program. The manned versus unmanned controversy still exists today. Manned advocates contend that to stop manned exploration would be as inane as sending robots to explore the Western U.S.A. originally.

The first weather satellite (Tiros I) was launched in 1960. A vidicon camera sent photos of cloud cover back to Earth in digital form where it was reconstructed. Since 1965, weather satellites have tracked every dangerous tropical storm. Weather forecasting has been greatly enhanced by the capability of "met" satellite program.

Probably the most notable commercial success from space is communication satellites. Starting with the launch of the Early Bird satellite in 1965, world-wide voice and video are now the norm. The idea of a communications satellite at synchronous altitude was advanced by Hughes Aircraft which led to the launch of the Syncom Satellite. Synchronous satellites became the basis for the world wide communications system which we enjoy today. The Comsat Corporation was set up by the Congress with 114,000 stock holders and became an outstanding financial success.

Planetary exploration started with Mariner IV fly by of Mars, providing the first close up views of the planet. Later landing on the Martian surface by two Viking Spacecraft provided a whole new insight into our planetary neighbor. However, sophisticated sensors failed to detect any life forms. Viking represented a technical achievement close to that of Apollo. The Mars mission was originally proposed for a Saturn V launch vehicle; however when the estimated mission cost became prohibitive, a much smaller spacecraft was designed for launch on a Centauer. Through a quantum state-the-art advance in microminiaturization of electronic components, Viking contained all the data gathering capability of the much larger Saturn V spacecraft. Design of a tripod legged lander versus an omni-directional lander represented risk of the space craft "stubbing its toe" on a large rock on landing. Subsequent photos of the rock-strewn landing site showed that the cause for concern was real. The gamble paid off with both spacecraft landing safely. The tripod design allowed for much more instrumentation within the overall weight allowances.

The planetary exploration program provided detailed insight into our planetary system. Voyager gave us spectacular pictures of Jupiter, Saturn and Uranus. Two JPL scientists (Reed and Solomon) originated a software "error –correction-code" which they convinced the Project Manager to include on Voyager. Like all good Project Managers, he was reluctant to employ the new software; however, he agreed when the first Voyager photos appeared quite fuzzy. The use of the Reed-Solomon software immediately made a remarkable difference in picture quality. Today a 15 billion dollar industry has grown up in the U.S. using the Reed-Solomon digital data recording techniques. The Japanese have used the basic idea for over 65 additional patents.

I recently headed a study which attempted to quantify the effect of NASA technology on the United States GNP. Economist at the Midwest Research Institute using a method devised by Dr. Solo concluded that for every dollar spent by NASA there has been a $9.00 return. The fact the Dr. Solo won the Nobel Prize for his method lends credibility; however, even if the answer is only half right, it is still an attractive return on the national investment.

In conclusion, it has not only been a spectacular and astounding three decades in terms of aeronautics technology and space exploration, but it has also been extremely profitable to the country. The space program has served as a forcing function for technology. Advances in communications, guidance and navigation, and computers, have resulted. It has given us the ability to better understand our own Earth and its complex systems while there is still time to have a positive effect on our environment.

We must continue mankind's exploration and search for knowledge to remain a viable people. "To quote from the Bible" "Where there is no vision, the people perish."