HERGET, Paul - L8|N8.

THE FIRST ASTRONAUTS*

by Paul Herget
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Mr. Chairman, Colleagues, and Friends:

On the occasion of this award and this honor, my mind is flooded with the memories of my thirty years of association with Dirk Brouwer, Gerald Clemence and Wallace Eckert. The four of us were more fortunate in life than most men because of the warm camaraderie which we had together, both in our personal friendships and in our scientific collaboration. In all those thirty years I never once heard a heated word pass between any of us, and we shared many proud and happy moments together.

In my present state of retirement, I am not in any position to offer you a report on new scientific accomplishments or results. Instead, this occasion will be used to collect and to recollect some aspects of the early space program, under the title, "The First Astronauts", mostly as they were observed from my own vantage point. If we go back to the early 1930's, there was in the Army Air Corp at Wright Field, in Dayton, Ohio, a Capt. Stevens who was intent upon exploring the upper atmosphere above the level where propeller planes could fly. They made an air tight gondola and mounted it under a large balloon, but after reaching the more rarified levels of the atmosphere they had to abandon the mission because they became so cold that they nearly froze to death. So they painted the gondola black and tried their venture again. This time they again had to abandon the mission because they became so hot that they nearly suffocated to death. So finally they attached a highly polished aluminum shield which could be rotated around the gondola; and if they became too hot they could interpose the shield to reflect away the Sun's hot rays; and if they became too cold they could rotate the shield to the back side and expose the black gondola to receive the Sun's warmth. Now -- this story is undoubtedly a somewhat embroidered version of the truth, but the fact is that on 1935 Nov. 11, Capt. A. W. Stevens and Capt. O. A. Anderson ascended to a height of fourteen miles above sea level: farther out into space than any other human being had ever travelled up to that time. This expedition was conducted in cooperation with the National Geographic Society, and you may read about it in their magazine back in those years.

If we now come forward to the year 1956, there was at the Edwards Air Force Base a Capt. Iven Kincheloe, who eventually became a pilot of the specially-built X-2 jet engine plane. He undertook a unique mission; and I heard him tell this story himself. He sat in the normal position in his cockpit and held a sheet of cardboard at his eye level, but tilted downward 45 degrees. He projected this plane onto his plexiglass dome and drew a black china-pencil mark all around the sides and top. Then he took off with a full tank of fuel, tilted his plane up to a pitch angle of plus 45 degrees, and gave it full throttle. His black china-pencil mark now coincided with his horizon on all sides, and served as his main flight instrumentation. His flight plan was to fly upward along this 45 degree path at full power until his fuel was exhausted. Then he would be in free fall on a parabolic arc, and he would be "weightless" for quite some time, until he dropped down to the denser layers of the atmosphere where the aerodynamic pressure would exert forces on his fusilage, wings, aerilons, rudder, etc. During this time of "weightlessness" there was a program of things he was supposed to do.

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Well, it did not work out quite that way. He said that when he figured that he was getting near the end of his powered flight he looked at his fuel gauge, but it showed 95 percent full. The thought flashed thru his mind, "My God, I'm going out of this world". He said that he was so completely unnerved that he forgot all about the program he was supposed to carry out during his "weightlessness". Being an instinctive pilot, he began to pull on the "joy stick", but nothing happened. He said that he pulled so hard he was surprised that he did not break it off. Still nothing happened until he descended to about 40,000 feet. Between 40,000 and 20,000 feet he regained control of the plane and landed safely. Thus on 1956 Sept. 7, Capt. Kincheloe had travelled 24 miles out into space, farther than anyone else before him.

Let me remind you that if we imagine a model of the Earth which is seven feet in diameter, on this scale Capt. Kincheloe had been only one fourth of an inch above the surface, and the Mercury Astronauts who circled the Earth were only an inch above the surface of this model all the way around their orbits. The "little grapefruit", Vanguard I, has an orbit which is only four inches above the surface at its perigeee and two feet above at its apogee. This results in an eccentricity which is slightly less than 0.2.

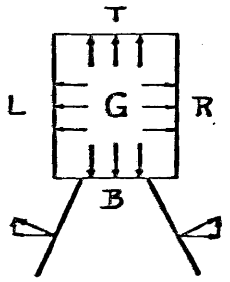
Allow me to digress for a moment to pay a belated tribute to one of the unsung heroes of the early space age: Karel Jan Bossart, affectionately known to his friends as Charlie. He was a native of Belgium; he earned a Masters degree at M. I. T. in 1929; and he was an engineer at Consolidated Vultee and Convair Astronautics during all of his career. He designed the Atlas Missile, which was our country's first effective I C B M defense, and it was the only available launching vehicle for the Mercury Astronauts. The Atlas had four distinctive features in its day. 1). It was the first missile to fly successfully which was aerodynamically unstable. 2). It was the first missile to operate successfully with gimballed motors. 3). It was built so light that it could not stand up on the launching pad under its own weight. It depended upon the internal pressure of its fuel tanks for much of its structural rigidity. 4). And finally, as an item of reliability, it had all of its rocket motors ignited on the ground before it ever left the launching pad. There was no possibility of failure to ignite the second or third stage somewhere in flight. During the years 1951 - 57, I worked on the guidance aspects of the Atlas, and I have always felt a sense of kinship with it. It gave me a special thrill whenever I viewed the launching of an Atlas on the T-V. The two little vernier rockets near the base were distinctive as they projected out at 45 degrees from the vertical. They counteracted any pitch or roll during powered flight, and after the main motors were cut off, they provided the final vernier thrust to ensure an accurate trajectory from Cheyenne to Moscow, or to provide the accuracy which the Mercury Astronauts needed to remain exactly in circular orbit all the way around the Earth. I take this occasion to pay my tribute to my good friend, Karel Jan Bossart.

My introduction to the Space Age was unusual and unexpected. In August 1955, only a few weeks after President Eisenhower had announced that there would be a U. S. Space Program, I had the first opportunity of my life to go to Europe. I was waiting in the Idlewild Airport until my plane's departure time, when I was paged over the P. A. system of the whole airport. My first thought was, "My goodness, what kind of calamity has happened at home - - that they would call me here at the last minute?" But it turned out to be Dr. John Mauchly of the Univac Corporation. I had known him for half a dozen years, and his father had once been a Physics teacher at the University of Cincinnati. He said, "We want to put in a proposal for the computer programs of Project Vanguard, and we want to know if you will be on our team. May we include your name in our proposal?" Well, I saw no reason to say No, so I said Yes;

and that was that. But after I arrived at the I. A. U. meeting in Dublin, Dr. John O'Keefe approached me one day and told me that the Army Map Service wanted to put in a proposal for the computer programs of Project Vanguard, and that they wanted me to be on their team. Would I agree? I did not tell him about Mauchly, but I did have to do some quick thinking about the propriety and the ethics of this situation. I concluded that in any event only one of them could win the proposal, and there was no conflict of interest on my part, so I told him that it was O K for them to include my name.

Near the last day of the meeting, Dr. John Hagen of N. R. L. took me aside in the big foyer of Trinity College, and he said, "You know, at N. R. L. we are going to get the satellite project, and we want you to be on our team to help us with the computing. Will you do it?" Naturally I said, "Sure". No matter whose proposal won, I was in. So it turned out that from the fall of 1955 until the spring of 1958, I was the nominal head of the Vanguard Computing Center.

After the first Sputnik was launched on Oct. 4, 1957, and we had lost the game to the Russians, the Congress took more of an interest in the program; and the old N. A. C. A. was changed into the new N. A. S. A. within six months. I had to make a crucial decision for myself - - and I decided not to leave the Cincinnati Observatory nor the astronomical community. So I withdrew from the Space Program activities and devoted all of my time to the Minor Planet Center. Therefore, a year later I felt very honored, even flattered, when the I. B. M. Corporation sent a personal representative to my home to invite me to join them in preparing their proposal to N. A. S. A. for Project Mercury, the first U. S. manned space flights. The preparation of this proposal was done during the week of Decoration Day in 1959.

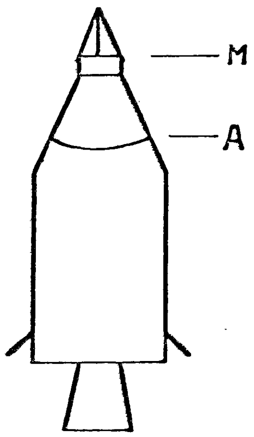


At this point a few peripheral explanations might be in order. The first concerns the operation of a rocket motor. Suppose one has a strongly built chamber which contains a very high pressure gas, labelled G in the diagram. This high pressure gas will exert strong forces against the walls of the chamber on all sides, as shown by the arrows. However, the forces at L and the forces at R balance each other (they are equal and in opposite directions) and so nothing happens. Similarly at T and B. But now suppose that the portion of the chamber at B is removed. The forces at B will drive some of the gas down through the nozzle below the chamber. Simultaneously, the forces at T will lift the chamber and drive it upward from the inside. It is the internal forces at T which cause the rocket motor to move upward. Whether the chamber is situated in air or in the vacuum of empty space, there will be some remaining gas pressure within the nozzle at B. This exerts forces against the interior of the nozzle, which can be divided into two horizontal components (which balance each other) and two upward components (which provide some additional upward thrust). Thus, the design of the nozzle's shape is an optimizing problem. 1). If it is nearly cylindrical it will retain a higher pressure at B, but there will be a very small angle for the upward component. 2). If the nozzle is flaired out too much, it will have a larger angle for the upward component, but the pressure at B will be greatly reduced, so that the forces exerted on the inside of the nozzle are lessened, and hence the upward thrust is lessened. Finally, for the rocket motor to continue to function, the high gas pressure at G must be continually maintained by a continuous combustion of fuels which are carried in the fuel tanks of the launching vehicle.

Another explanation concerns the geography of the Earth. The Air Force had chosen Cape Canaveral as the launching site for the A F M T C (Air Force Missile Test Center), later called A M R (Atlantic Missile Range), because shots which are fired in a generally southeastern direction would pass just to the north of a long chain of islands, including the Bahamas, Eluethra, Mayaguana, Antigua, and eventually Ascension Island, 6000 miles down range. The effects of the test shots could be observed from stations located on many of these islands. Furthermore, Cape Canaveral was easy to acquire, because it was nothing but a swampland full of snakes.

A general outline of the plans for Project Mercury had already been drawn by someone in N A S A, I know not whom. They included firing the launching vehicle in a generally northeastern direction, instead of southeastern, so that the space capsule would pass close to Bermuda, and be in an orbit whose plane was inclined about 30° to the equator. Then as the capsule reaches its maximum latitude, its orbit (if represented on a map of the world) turns down toward the Canary Islands, crosses the Sahara Desert, the Indian Ocean, a southernmost latitude over Australia, and back up across the Pacific Ocean near Hawaii, and finally over the continental United States. Such a circuit takes about 96 minutes, and during this time the Earth has rotated 24° toward the east, inside of the orbit which is standing nearly still in inertial space. After three such revolutions in the orbit, the Eglin Air Force Base in Florida has just about reached the position where the Canary Islands had been at the beginning; and the Atlantic Missile Range is now situated under the orbit in the position where it had first passed over the Sahara Desert. That is how far the Earth had turned during slightly more than three revolutions of the space capsule. Therefore, if the retro-rockets were fired so as to bring the capsule down after this length of time, it would come down to the Earth's surface right along the A M R and it could easily be observed for recovery. To achieve this, the retro-rockets had to be fired when the capsule was about half way between Hawaii and the coast of California.

Numerous considerations influenced the detailed plans. One of the most serious was the heat shield which had to withstand the extreme temperatures generated by the friction from the atmosphere upon reentry. Another, in the absence of any previous experience, was the possibility that the astronaut might lose consciousness after an extended period of weightlessness. Thus there were provisions to operate the system entirely by remote control from the ground. At the same time, there were provisions that allowed the astronaut manually to over-ride any automatic commands, in the event that these had their origin in some malfunctions of one sort or another, such as the two recent experiences at NORAD. There were certain emergency landing areas available at all times, in the event that it became necessary to bring the astronaut down before the full mission had been completed.



The Mercury - Atlas configuration consisted of several parts. The portion below level A in the diagram was the Atlas booster, with 367,000 pounds of thrust. The portion between levels M and A was the Mercury capsule, with the heat shield on the under side at A, and on the inside was the contour couch where the astronaut lay on his back. Thus the upward acceleration at launch gave him the sensation of "eyeballs in". During free flight the capsule was supposed to ride with the heat shield forward. Thus the decelerating forces of the retro-rockets and the atmospheric drag again gave the sensation of "eyeballs in". The portion of the capsule at M contained the stowed drogue chute and parachute which would be needed at the very end of the flight. The portion above the M-level was the "escape tower". In the event of a critical emergency during the early stages of the launch or a threatened explosion of the Atlas booster, the capsule could be disengaged at the A-level, and three rockets at the top of the tower would be fired. These would provide an immediate acceleration of 22 - g's to the capsule and tower alone, so as to remove the astronaut forthwith. To the best of my knowledge, this was never needed nor used.

Within the realm of this multitude of plans and preparations, the electronic computer was intended primarily to provide insurance of safety for the astronaut's life. I am proud to say that the design of these computer programs fell entirely to my lot. I asked only one question, "What do we get for observations?" The answer was an excellent one - - it left little more to be desired. The FPS-16 radar was available, and it was a transponder radar with a range accuracy purported to be between 50 - 150 yards, up to a range of 500 miles. It also gave readings of azimuth and altitude, but at a relatively lower level of accuracy. These FPS-16 radars would be stationed along the orbit path at Bermuda, Canary Island, Woomera (Australia), Hawaii, Guaymas (Mexico), Vandenberg, White Sands, Corpus Christi, Eglin Air Force Base, and Canaveral. Once the radar was locked onto the transponder by the operator as the capsule came up over the western horizon, the radar tracked automatically and the computer automatically received a complete observation message once every six seconds of time. Depending upon the geometry of the capsule's passage with respect to the station location, the readings lasted up to four minutes.

In this problem one counts in units of the mass of the Earth, the unit of length is the Earth's equatorial radius, and the unit of time is 806,832 seconds (corresponding to the 1/k mean solar days in the solar system). Thus the range accuracy of the FPS-16 radar corresponded to three arc seconds at unit distance. The geometrical circumstances were such as never to lead to an ill-conditioned solution. It was a problem which one could tackle with great confidence.

A word concerning the state of the art at that time may be appropriate here. The computer to be used was the I B M - 704. But in those days everyone used the computer for his own problem in a "stand alone" mode. There were no "operating systems" or "supervisory controls" as we know them today. There were compilers and subroutines in abundance, but that was all. Hence, the I B M Corporation decided to put a substantial effort into providing a supervisory program for Project Mercury, so that if everything went well the I B M - 704 could run itself completely during the entire time of the Mercury flight, under the control of its own Supervisor. This Supervisor knew whenever a new FPS-16 observation had been received. It knew how to store them. It knew when radar contact had been lost as the capsule passed below the eastern horizon. It then initiated the computation of the improvements which were to come from these newest observations, etc. It may well be said that this supervisory program was the precursor of all of our present day operating systems. I had no part in the preparation of that programming effort.

The Mercury flight consisted of three phases: a). the launch and powered flight, b). the free flight in orbit, and c). the reentry through the atmosphere. The first phase was controlled entirely from Cape Canaveral, and we had nothing to do with that. Suffice it to say that a nominal trajectory was computed beforehand, and as long as the launch vehicle remained within reasonable limits of this nominal, the launching operation continued to its completion. Therefore we could always assume that if and when control passed to us, everything was going reasonably well.

The computer programs of the second phase consisted also of three parts: 1). the numerical integration of the trajectory in inertial space, 2). the predictions for

FPS-16 acquistions, times to fire the retro-rockets, etc. and 3). differential corrections and improvement of the initial conditions for the capsule trajectory after each passage over a radar station. The three parts of the third phase were similar to these, except that the drag forces had to be taken into account.

Prior to all of this, however, there was a short and exciting operation which came to be known as "GO - NO GO". Long before powered flight ended, the "escape tower" had already been jettisoned, because it was no longer needed. As soon as powered flight ended, the capsule separated from the Atlas. But it was necessary to tumble the capsule through 180 degrees so that it would ride with the heat shield forward. Furthermore, this had to be accomplished within twenty seconds because of a condition which will become apparent subsequently. During this tumble the capsule was already in view of the Bermuda FPS-16, and this radar had been improved so as to provide a complete observation every tenth of a second. From these 200 observations we were required to compute the position and velocity vectors of the capsule in order to ascertain that the actual perigee height was in fact sufficiently great so that the mission could be completed safely, with no interference from undue drag. If the perigee height was not sufficient, the retro-rockets had to be fired immediately in order that the capsule would still be able to splash down in the Atlantic Ocean. Too great a delay would have caused it to land in the Sahara Desert. Hence the critical time limit of twenty seconds. If the crucial perigee height was sufficient, the mission was "GO", otherwise it was "NO GO". Fortunately this latter condition never arose, which is a great tribute to the performance of the Atlas missile.

In spite of the importance of this computation, the formulation is extremely simple. One has the Taylor's Series expansion for the position vector given by

$$\bar{r}(T) = \left[1 - T^2/2r_o^3\right]\bar{r}_o + T\left[1 - T^2/6r_o^3\right]\bar{v}_o$$

where the next term in each of the square brackets would contain the factors

$T^3\,(\bar{r}_o \cdot \bar{v}_o)/r_o^4$. If the midpoint of the twenty second time interval is taken as the origin of time, the T is always less than 1/80. The position vector, $\bar{r}(T)$, is observed by the radar (with suitable allowance for the rotation of the Earth), and there are only two simultaneous unknowns, namely the components of $\bar{r}_o$ and $\bar{v}_o$. Since the launching vehicle successfully followed the nominal trajectory, $(\bar{r}_o \cdot \bar{v}_o)$ is nearly equal to zero, and the scalar, r_o, in the denominator is also known with sufficient accuracy from the nominal trajectory. Thus we have only to make a least squares solution for three sets of two unknowns, using the 200 very simple equations of condition, as shown. They have the obvious disadvantage that $\bar{v}_o$ is relatively poorly determined because of the factor, T, in its coefficient, but this is inevitable and inherent in the nature of the problem, so that one can only try to make the best of a bad situation. The residuals from the solution were scanned to eliminate any points exceeding the 3-sigma level, and the solution could then be repeated. Immediately, the results were exhibited on the printer, and it was "GO" or "NO GO" for the whole mission. This was one of the greatest thrills of the whole project.

Riding the capsule with the heat shield forward at all times is not so simple a feat as it may seem at first glance. The astronaut had control of several small gas jet thrusters which were mounted in pairs so as to impart a torque to the capsule. But it is necessary to impart to the capsule a downward tumble which has the same period as the period of revolution of the capsule in its orbit around the Earth. To put it another way, "forward" or "level" always keep dipping downward as one moves along in the orbit. If one were not careful, it would require repeated corrections by means of the thrusters to maintain the required attitude of the capsule.

This "GO - NO GO" calculation also gave us the first set of initial conditions for the numerical integration of the capsule's trajectory. The computer memory contained assigned space for the three integration tables of x, y, and z in inertial space. The time interval was one minute, and the tables extended backwards for 80 minutes and forward for 300 minutes, or 5 hours. The basic dynamical differential equation was

$$\frac{d^2 \bar{r}}{dt^2} = -K^2 \left[1 + J_2 P_2(b)/r^2 \right] \bar{r} / r^3$$

where the first term on the right side is the Newtonian attraction of the mass of the Earth, and the second term is the gravitational attraction of the Earth's equatorial bulge. $J_2 = 0.00108$ and $P_2(b)$ is the second Legendre polynomial, which is a function of the latitude. An ordinary Cowell integration process was used, with the usual predictor and corrector formulas.

Once the three simultaneous integration tables were completed, the supervisory program instructed the computer to predict the times and angles for the acquisition of the transponder by each of the radar stations during the next revolution. These were immediately transmitted to each of the stations, in anticipation of the possibility that for some reason all future communications might be lost. Also the exact time for the retro-rocket firing was computed, based upon the new integration tables. The retro-rockets were located in front of the center of the heat shield, and their detonating mechanism was preset. This preset time of firing was known to the computer. The velocity of the capsule is approximately five miles per second. As long as the actual and the computed times agreed within twelve seconds (corresponding to 60 miles along the orbit), the preset timing was left unchanged. Otherwise it would become necessary to reset the preset timer. When all of this was completed, there was nothing more to do until more observations were received from the passage of the capsule over the next radar station along the orbit track. As indicated before, when that was completed, the Supervisor sent the computer to the Differential Correction program.

The Differential Correction program was unusual in several respects. Bear in mind that in this situation the purpose was not to compute the orbit which would best fit the available observations, but rather to derive a set of initial conditions at the most recent moment which would give the most reliable predictions for the immediate future. The Supervisor program initiated a pass through the Differential Correction program as soon as the capsule had passed by a station and the FPS-16 had lost radar contact. The new Epoch was chosen as the mean time of all the observations which had just been obtained from this last station. However, the computer then discarded every even numbered observation which had been obtained by the last previous station, so that in effect they were given half weight in the next solution. Similarly, half of the remaining observations from the second previous station were again discarded, so that in effect they had only one fourth weight in the next solution, etc. Finally, any observations which were made prior to 72 minutes before the new epoch were discarded entirely.

Secondly, we were dealing with a nearly circular orbit, so that most of the standard sets of formulas, such as Eckert and Brouwer, would give serious troubles with near-zero divisors and/or indeterminate forms. But this situation was an ideal application for the direct, brute force method of

$$\delta \bar{r} = f \, \partial \bar{r}_0 + g \, \partial \bar{v}_0 + \bar{r}_0 \, \partial f + \bar{v}_0 \, \partial g.$$

This formula has a deceptively simple appearance. Both ∂f and ∂g are very complicated, implicit functions of $\overline{r}_0$, $\overline{v}_0$, $\partial\overline{r}_0$ and $\partial\overline{v}_0$. However, the method will give a good direct solution for the six unknowns from observations distributed over nearly one whole revolution. Furthermore, it will give the least ill-conditioned solution in any case where the available collection of observations produces a less favorable situation. My introduction to this method came from a paper by E. C. Bower in the Lick Observatory Bulletin 445, and it is developed in full detail in The Computation of Orbits, page 75. Admittedly, the formulas are complicated and cumbersome, but once they are programmed and debugged, henceforth the onus rests upon the electronic computer.

The formulas for the partial differential coefficients take into account only simple, two body motion, but there were several other considerations which influenced the aforementioned choices. As described earlier, the Astronauts had the capability to fire small gas jets for attitude control, but there was no guarantee that these jets might not also impart a small non-gravitational impulse to the capsule's velocity vector. Here one is faced with conflicting circumstances. By diminishing the weights of the older observations in the solution, we also damp out the effects of these erratic impulses from the past in the new solution for the current initial conditions. On the other hand, the current velocity vector is better determined from observations which extend over a longer period of time. Hence we adopted this weighting and damping device to try and satisfy both conflicting conditions simultaneously.

Yet another possible circumstance needed to be taken into account. Suppose that the most recent pass by a radar station was low on the horizon and only a few observed points could be obtained. Or suppose that there had been a local lightning storm and the radar signals were very noisy. Was this most recent resulting improvement in fact better than the trajectory which we already had beforehand? This situation was tested in the following way. The previous solution and the most recent solution were each tested separately for a moment of time which was 15 minutes in advance of the most recent epoch. The probable error of the position vector at that moment is given by

$$(\text{p.e. } \overline{r}_{15})^2 = \sum_i \left(\frac{\partial\overline{r}}{\partial w_i} \right)^2 (\text{p.e. } w_i)^2$$

where w_i are the components of the position and velocity vectors at the respective epochs in the previous and the most recent orbits. If the most recent orbit produced a larger probable error than the previous trajectory, then the latter was retained. The partial differential coefficients were obtained from the same subroutines which computed the Equations of Condition for the Differential Corrections. In this comparison, the earlier result would be at a disadvantage because the moment of testing was farther from its epoch, and therefore the partial differential coefficients would be larger. But if the more recent solution were, in fact, a more weakly determined one, then its (p.e. w_i) would be larger. What was important was that we be able to select the more reliable prediction for the immediate future.

Once the time for firing the retro-rockets approached, the capsule had to be tilted upward to an angle of attack of about +15 degrees, so that the retro-rocket force operated not only directly against the magnitude of the velocity vector, but that it also imparted a slight downward component to it. Then the computer switched to a group of programs which differed primarily in that they depended upon a model atmosphere and they took atmospheric drag into account. When the velocity and the height above sea level diminished to the point where the drogue chute would be released, then the trajectory "rode a wire" to the Earth's surface; and the electronic computer's task was completed.

Anecdotes could be recounted almost without end. One circumstance which pleased me no end throughout the debugging stages of the work was the comparison of my hand computed spot checks against the results from the I B M - 704. I used a 10-decimal place desk calculator, and I always had 10-significant figure values. The I B M - 704 had a 36-bit word size, of which 27 bits represented the mantissa. Therefore the programmers, with their powerful electronic calculator, had only 8-significant figure results, and it was always a "put down" for them when we made comparisons. One day when they brought their computer print-outs to me for comparison, nothing which we attempted to compare would agree. Naturally, they began to think that I had done everything wrong. But then, all of a sudden, I realized that there were no 8's or 9's anywhere on their sheets. They had inadvertently called for an octal print-out instead of decimal; and so with red faces they went back to the computer and repeated their run.

One highlight of our experience occurred on 1961 Sept. 13, when an unmanned test vehicle was launched and preset to make only one complete revolution around the Earth. The launch operation from Cape Canaveral was successful; the capsule passed the "GO - NO GO" test; and everything was A - OK until it reached the Canary Islands. The first four FPS-16 messages were received during the 18 seconds after tracking began, but then everything went dead and stayed that way. The trouble must have been associated with the transponder. In any event, the retro-rocket timer was preset; the computer knew what this setting was; and it computed a trajectory based upon the available observations from Bermuda and the four points from Canary Island. Eventually, at the time of the retro-rocket firing, the computer used the position and velocity vectors from the stored integration tables as initial conditions for the reentry program, and blithely computed the splash-down prediction. However, for some unexplained reason, the FPS-16 observations were received in the normal manner as the capsule passed by Eglin Field. Without realizing the tension and the consternation which surrounded it, the computer calmly computed a Differential Correction and accurately predicted the actual splash-down point for recovery. This mission may have been a big disappointment for many other areas of the project, but to my mind it was a great triumph for the computer programs and for us, because they had operated with complete success under the most adverse circumstances.

One final anecdote: on 1962 May 24, I was driving from Cincinnati to Ann Arbor during the time that Scott Carpenter was in flight on his Mercury mission; and I listened to the radio news broadcasts. On this flight Carpenter used up more of his little gas jet thrusters than had been expected, so that when it came time to fire the retro-rockets he could not attain the intended upward angle of attack for the attitude of his capsule. Thus he over-shot the recovery area by about 250 miles. The radio announcer on the recovery ship declared in grim and somber tones that Carpenter was "lost". I could not help but thinking to myself, "The computer knows exactly where Carpenter is. It is the radio announcer who is more 'lost' than is the Astronaut."

Project Mercury was only one part of our total, national, space effort. It was a proud conquest and many pleasant memories remain. In years gone by Vannevar Bush wrote an essay, entitled "The Builders", by which he meant to refer to Scientists and their contributions to progress and to their fellowmen. In the last paragraph he wrote:

> "There are also the old men, whose days of vigorous building are done, whose eyes are too dim to see the details of the arch or the needed form of its keystone; but who have built a wall here and there, and lived long in the ediface, who have learned to love it and who have even grasped a suggestion of its ultimate meaning; and who sit in the shade and encourage the young men."

This we did. Dirk Brouwer built many walls and he singlehandedly initiated the Summer Institutes of Dynamical Astronomy. We joined him to "encourage the young men". I cherish his memory and the privilege to have been his friend.