The Early Days of Simulation and Operations

The following is an attempt to capture some of my memories of my work at NASA starting July 7, 1959 until I left in August 1970. It is not meant to be a definitive history of what went on in those early days.

Harold G. Miller

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Great Falls, Virginia

The Early Days of Simulation and Operations

In September 1959 a group was formed under Jack Cohen to develop a program for training the personnel who would support Project Mercury. These personnel to be trained were to be located at the Mercury Control Center (MCC) at Cape Canaveral, Florida, and around the world at the Mercury remote sites. This training group was called the Simulation Task Group. Assigned to the group was Arthur (Art) Hand, Glynn Lunney and myself, Harold G. Miller. Richard (Dick) Hoover and Stanley Faber would join the group soon. Richard (Dick) Koos would join the group Sept. 19, 1960. William (Bill) Sullivan transferred into the group from NASA's Langley Research Center (LaRC).

The initial team was located in a small room just off John P. Mayer's branch on the U.S. Air Force (USAF) side of the NASA Langley Research Center (also Air Force Base), Hampton, Virginia. About a year after the group was formed we were moved to another building and had our offices over a wind tunnel. Jack Cohen left the Simulation Task Group after about a year. Shortly after the group was formed Art Hand transferred to the Cape Canaveral Mercury Control Center. Stan Faber transferred from Crew Training and was the effective lead engineer until just before we transferred to Houston, Texas. He became one of the lead guys in flight crew training. Glynn transferred after a few months to the Flight Dynamic position which served him well. Bill Sullivan who was supposed to head the Simulation Design Section decided not to transfer to Houston and returned to Langley Research Center. Hoover stayed with us until we went to Houston where he was head of the requirements group for the MCC-H [Mission Control Center – Houston]. I left about the time of the lunar landing to work on Eugene (Gene) Kranz's staff and look after the contractors that supported the flight control operations. Robert (Bob) Eddy

joined us at Langley and moved to Houston but resigned after about a year. Of the original group, Koos was the last man standing.

John Hodge caught me in the hall as I was headed for coffee and told me I was to be the head of a simulation design section and the section would be working for Tecwyn Roberts. (Yes it really did work like that in the early days.) I stayed at Langley until early 1961 and moved to Houston after MA-7 [Mercury-Atlas 7, Aurora 7]. Peter Segota was an initial member of the section. He started work on the interface between the control center and the Gemini Procedures Trainer (GPT). Dick Koos was moved also and we were assigned several Philco people to run simulations for MA-7. Dick was the lead in this simulation and I was the simulation supervisor [sim sup]. It was the first documented set of simulations. I think Gene still has a copy of the sim cases. Prior to MA-7 the documentation for the sim cases were single sheets of paper, sometimes with scribbled notes. Typing was optional. Dick developed and ran the MA-8 simulation from Houston, and a after a reorganization returned to the Simulation Design Section to help in developing the simulation system for the MCC-H.

I came to the position of Section Head of the Simulation Design Section by a somewhat roundabout way. As I was about to graduate from Tennessee Polytechnic Institute, I was offered a job with NASA's Langley Research Center. I was never to be a member of LaRC's organization. I accepted the job only to discover two weeks later that I also had an offer from Western Electric at Winston Salem, North Carolina. The offer had been lost. The offer from Western Electric was for $100 more a month or about $6500 a year versus. $5430 at LaRC. In an act nobody would today understand, I told Western Electric I had already accepted a job and thanked them for the offer. So this was my first mishap that led me to the Space Task Group (STG).

The second occurrence happened the day I reported to the personnel office at LaRC, July 7, 1959. There were nine new employees reporting that day to be located in different organizations at LaRC. After the director of personnel had interviewed all of us he came out of his office and pointed to the first guy seated around the wall and said he was to go to "Space." The next guy was to go to Langley and so on till he came to me and said I was to go to "Space" and that the Space guys were to report to Thomas Markley on the USAF side of the base. Space was of course the "Space Task Group" charged with the responsibility to put a man in orbit. If I had been setting in a different seat I would have been working for the LaRC. Years later I found that this was the personnel director's way of doing business.

I duly reported to Mr. Markley where he explained that we were not a part of LaRC but were attached to Goddard Space Flight Center (GSFC) and were expected to be transferred to Greenbelt, Maryland, in about 6 months. Three years later we moved to Houston, Texas. My badge number, which was given in the order that we were hired into the Space Task Group, was 167. When we moved to Houston personnel made us give up our old badge, sigh.

Mr. Markley patiently explained that the job of the STG was to put a man in orbit. At which time, with my best dead pan face, I asked what an orbit was. I don't believe he ever recognized I was pulling his chain. Not being quite sure what to do with me, he assigned me to John Mayer's branch. This branch was in Charles (Chuck) Mathews' division. Christopher C. (Chris) Kraft was the deputy.

I reported to John Mayer's Branch where there were a great bunch of people who were mostly hired straight out of college. I will forever remember Shirley Hunt [Hinson], Claiborne (Clay) Hicks, Glynn Lunney, Arnold (Arnie) Aldrich and others. Some of the people I had gone to school with also hired into NASA's LaRC and the STG. Most of the younger guys like me

were offered a chance to go directly to Cape Canaveral, Florida, to work at the launch site. A guy I went to school with, Thomas (Tom) Williams took this opportunity and left immediately for the Cape.

Our offices were on the Air Force side of the base and we had little opportunity to interface with the research facility. Their facilities were exotic – wind tunnels that made great rackets and could only run at night because of the power they took; experimental airplanes and a model of the Echo satellite in one of the hangers. Sunday afternoons was sometimes spent watching jets take off and land on the base. In 1959 this was still an awesome sight.

Our office accommodations were utilitarian but functional. I, along with the others, was assigned one desk in a large room and of course there was only one phone for the branch of 20 or so people. If you needed to dial out everyone could listen in, of course. We were given a two inch thick book of collected papers on spaceflight (which I still have). We were expected to become familiar with all sections. I found the math fascinating. I was seated by a Langley guy named Robert (Bob) Davidson who was touted as one of five people in the country who could handle tensor math. Bob elected not to go to Houston with us. I can remember trying to read papers that Bob wrote and not understanding a word of them. The people were wonderfully bright.

About the time I came on board, a crew of folks from Canada joined NASA. A company, AVRO, had lost an Air Force contract and had senior/experienced engineers that NASA could get to help on the manned spaceflight program. You might ask with all the experienced NASA engineers why did we need to get help from outside the agency, which had just become NASA from NACA [National Advisory Committee for Aeronautics]. The truth was that a lot of NASA engineers did not want to risk their career on a program that most considered was not going

anywhere. So NASA was left to bring on people from outside and new hires directly from college who didn't know any better and had nothing to lose.

I was assigned in September 1959 to work in the newly formed Simulation Task Group for Jack Cohen. The Simulation Task Group was never (to my knowledge) on any organization chart that I have ever seen**.** Our first task was to write the specifications for a simulation system that would be installed at the Mercury Control Center at Cape Canaveral. This was documented in the "Plan for Control Center Training Simulations," dated March 31, 1960. I was assigned the task of defining how to simulate the communication system to be used for Mercury. I was also the general flunky. I did sim room drawings and interface specs [specifications]. These specs were incorporated into the Western Electric contract that had been awarded July 30, 1959. Our principle task was to establish the interfaces with the Mercury procedures trainer (MPT) that would simulate data from the real spacecraft and provide data for the consoles both in the MCC and at the remote sites.

There were two main interfaces areas with the Mercury Procedures Trainers. The first was the systems data and the other was the connection of the crew audio into the control center communications system. It was decided to have the trainer (MPT) output a data stream like the real spacecraft such that as much of the control center and technical support staff as possible would be exercised during the training sessions. This was a crucial decision since the other option was to have the systems data and the medical information connected directly to the flight controllers consoles. This interface would have been very complicated and would not utilize fully the control center backroom hardware making additional test and checkout necessary. There was considerable discussion regarding these two options.

The single wire interface philosophy was carried over when my section later wrote the specs for the Houston Control Center and negotiated the agreements with the crew training devices for Gemini and Apollo. The voice interface was easier to define and mainly required making sure that the wire room com [communication] equipment could tie into the MPT system. Control over both streams of data was from the Sim room in the control center. In addition to the training provided, the simulation system provided valuable shake down testing of the equipment that the controllers would use during the actual flight. The simulations provided extensive exercising of the total control center systems (with the exception of the command system) during the many simulation exercises run for each mission. In Gemini and Apollo simulations the command loop would be closed so that the flight controllers could exercise the proper procedures (i.e., aborts).

Prior to having a training facility available in Florida, we established an interface with a local Mercury Procedures Trainer that was located in the LaRC full scale wind tunnel, about two or three blocks from where our offices were. Partitions were erected that would permit remote site controllers to pretend they were at the Mercury sites located around the world. The exercise was mostly useful to teach people how the communications systems would work and to let the astronauts work with the ground controllers at each remote site. As a means of communications, the flight controllers were taught how to send Morse code, which was never to my knowledge used. The astronauts would lie in the Mercury trainer and talk to the ground controllers. The training in the full scale wind tunnel was marginal at best. Maybe it served a purpose to build a team. It was certainly very crude and unsophisticated.

My role in this early activity was to help establish the interface between the MPT and the Mission Control Center. The MCC at Cape Canaveral was in the Engineering Support Building

(Telemetry No. 3 building) at the east end of Mission Control Road, about 0.5 mile (0.8 km) east of Phillips Parkway. My principle interest was in the voice systems. Dick Koos and Dick Hoover worked the systems information. There was no trajectory data between the MPT and the control center as was later the case in Gemini and Apollo. Glynn worked the problem of trajectory information for the flight controllers and was instrumental in the trajectory tapes used during the simulations.

We did not have anyone experienced in Medical simulation. I do remember that we simulated several medical problems for Dr. Charles (Chuck) Berry. I was fortunate to work with a very experienced wire com expert at Western Electric, Dick Koch. He was on loan from Bell Telephone to set up the voice systems between and within the remote sites and the control center at the Cape. The wire room (where the voice com equipment was located) was staffed by launch communications technical staff. Most of the personnel had been on the Cape since the start of the launch facility and could tell stories that should be recorded. I soon learned that voice wire cables had a color coded system of blue, orange, green, brown, and slate with a red and white tracer. There were also terms like *ring*, *release*, and *hold* that had meaning to wire people. Of course all this information was rather useless in the world of manned spaceflight.

After a year or so of in-house work at Langley on simulations and developing an understanding of Project Mercury the travel started. At first we would leave Monday after work and fly on a Martin 404 to Patrick Air Force Base and then return to Langley on Friday night. The flight was jokingly called the fruit flight because coming home the plane would be loaded with Florida fruit, mainly navel oranges at $3 for a 20 pound bag. The per diem in those days was $16 a day. Needless to say joint occupancy was a necessity. I roomed quite often with Dick Koos and Carl Huss. We would rotate weekly who slept on the cot. Our days were to go to the

control center and run sims or prepare for the flight, and then about 5 p.m. or so we would head out to a bar (Dick Koos reminds me that one of our favorite places was the Red Knight) for a couple of drinks and then on to someplace for dinner. A lot of the sim guys stayed at the Polaris Motel, which had a bar and restaurant call the Mouse Trap. Not a bad place at all. After dinner, which being from Tennessee I called supper, we would have a couple of more drinks and turn in. This was the standard daily routine. Our travel increased from the weekly trip to several weeks because of flight slips. We were supposed to be there two weeks before the flight, however since the flight was subject to a lot of constraints (wind and weather for instance) we would often be there as long as six weeks. Of course the controllers who went to the remote sites were in some foreign environment, sometimes not pleasant. (e.g., the ships, the middle of Australia, Zanzibar, etc.)

There were two NASA crews at the Cape. One, the ops [operations] guys, of which I was a part of, and the engineering team that worked the open items on the Mercury Capsule in Hanger H. We had not a lot of contact with the engineering except to learn about some last minute change to the spacecraft which we would need to simulate as best we could.

The control center housed the communications gear, the Mercury Procedures Trainer and various administrative offices of the local work force. The technicians were old hands who had seen many launches and were full of stories about the early mishaps of launch vehicles. Especially interesting were stories of how contractors would leave the safety wires on the launch vehicles so that the range safety offices could not destruct the vehicle if it was going astray. They tell of the many birds in the Banana River with a slight chuckle. The stories of the early launches were always fun to hear. Things like the 10 foot alligator the decided to take up residence in the entryway to one of the blockhouses, such that the launch controllers couldn't get

out until the guards ran it off. Many times when a missile blew up, especially a solid rocket, the burning propellant would set the palmetto afire causing all sorts of animals to run from the fire. The guards would align themselves along the road with shotguns and shoot the snakes as they were crossing the pavement.

The simulation room in the control center housed the Mercury Procedures Trainer and the consoles for the simulation guys to use for the simulations. The astronauts were frequently in and out of the sim room and were forever giving us a hard time about unrealistic failures. Alan B. (Al) Shepard was by far the most vocal and he would one day chew us out and the next day thank us for the exercises. Since all the simulations were open loop and the trajectories were planned weeks in advance, we were somewhat restricted in our ability to vary the scenarios that we presented to the flight controllers. Dick Koos had some control of the systems information but not much. Riley McCafferty of McDonnell was most helpful in trying to keep the MPT current in terms of accuracy of the data. The MPT was set up with an analog commutator like the one in the real spacecraft. The idea was to present the systems data into the control center as if it was coming from the capsule. That would bring the all-important back room technical staff into the operation since the first thing the controllers have to determine is if they saw some anomaly. "Is it real or bad data?" The involvement of the MCC tech staff was a key training goal. The GE Burroughs guidance system tapes were input data that was transmitted real time to Goddard where calculations were made and transmitted back to the MCC for the FIDO [Flight Dynamics] and RETRO [Retrofire] officers to evaluate the orbital parameters for their go/no-go decisions. This handling of the trajectory data duplicated the actual data transfer in a mission. Trajectory data was shipped to GSFC where calculations were made and the results transmitted back to the control center displays.

The Simulation Room in the Mercury Control Center at Cape Canaveral, Florida

Miller gets chewed on by Shepard, Shorty Powers while Art Hand watches.

The Cape's communications system was called the MOPIS. This was the communications system that the launch controllers used to conduct the countdown to launch. Sometimes after launch a sim guy in the sim room would give a running commentary of what was happening during the flight. This was the only case I know of where a sim guy had an operational job.

For those of us who got rental cars, they were abysmal. All were identical gray 1960 four-door sedans. They were so alike that one day three of us went to lunch with Chris and when we came out of the cafeteria we jumped in the car and headed back to the control center when

one of the guys said his brief case was missing. We went back to the cafeteria only to discover an identical car with his brief case in it. We got out of the car, got into the correct one with the owner/renter none the wiser.

Al Shepard, (yes the crew drove the same cars) always the dare devil, would first pump the tires up to 80 psi to see how fast he could take the right angle corner before going through the checkpoint to get on the base. One occasion I witnessed. I was sitting on the step going into the control center when I saw a cloud of dust on the road leading to the control center. In hot pursuit of the car was a Cape policeman with lights flashing, both cars at a high rate of speed. The front car skidded into the control center parking lot and the police car skidded to a stop right beside it. I am sitting on the step about 20 feet away. Out jumped Al and stood there while a young policeman ran up to him. When he recognize Al he stammered and said to Al, "You must slow down Mr. Shepard," and as quickly as he could jumped back into his cruiser and sped off. Al walked by me with a grin and went into the control center as if nothing unusual had happened.

The simulation's launch cases were usually near nominal with some cases that required the flight controller to call for an abort. System problems would be varied for nominal trajectory. Attention was paid to make the flight controllers communicate and find workarounds (solutions) to problems. It was not uncommon to tell a flight controller that his console was dead and he would have to act accordingly.

Medical problems were of course faked with either the flight crew or controllers. We could at any time walk down to a controller and tell him that he was experiencing a heart attack or some other debilitating condition that would require him to leave his position. The flight director would have to deal with the lack of a controller. Serious on orbit medical problems were

not simulated because of the sim rule on not giving the controllers a problem that couldn't be solved. Other cases would tax the controllers in developing work around solutions.

Gene Kranz was master at coming up with contingency plans. On several occasions sims were deemed non-realistic when there would be a failure that they didn't think was possible. One that comes to mind was the loss of the Cape control center. At one point the whole control center was shut down. The flight controllers considered this an unrealistic failure. This was really put down until a bull dozer cut through the power cables leading to the control center rendering the control center dead for hours. Fortunately, this occurred several weeks before one of the manned missions. Backup procedures were quickly developed.

Since the spacecraft was built, where possible, triple redundant (fail op, fail op, fail safe) the sim guys could fail a valve or signal and the controllers could analyze the system and then tell the astronaut what to do. Most of the time the crew had figured out what was going on. Since the trajectories for the sims were pre-taped, off nominal cases that required aborts, the sim guys had to guess when the controller would call for an abort. If the controllers called for an abort earlier than the sim guys anticipated, the trajectory would show the booster continuing to fly. Life was much simpler running the Gemini and Apollo Sims with closed-loop trajectories. As it has been said many times, the simulations were to develop team work and procedures. A controller who didn't understand basic systems or trajectories would not last long at a console.

The loose heat shield problem of MA-6 was simulated in a network simulation, open loop without John Glenn participating. This case in actual life provided a much more interesting problem of self dependency than most of the simulation cases. When the apparent problem was discovered during the first orbit of MA-6, Kraft asked the McDonnell representative in the Control Room for a recommendation as to whether or not it was an instrument failure or was the

heat shield really loose and what should they do about it. For two revs no recommendations, despite Chris's continuing request, were forth coming from the spacecraft contractor. Finally Chris, with the recommendation from his NASA team, made the call to leave the retro package attached in case the heat shield was really loose.

Somewhere along the way key decisions were made that affected how simulations were conducted. I have listed some of these that I consider important. Other folks could compile a similar but different list.

- The idea of integrated flight crew/flight controller training. I don't know who made this but Mathews was the division chief and Chris Kraft was his deputy. This would have been in late 1959.
- The use of the Crew Procedures Trainer as a data source. By using the crew trainer, flight controllers could work with the astronauts. We wrote the specs and talked with McDonnell Douglas before they delivered the two trainers, one for Langley and the other for the Cape.
- The decision to include the backroom personnel in the training. The output of the Mercury crew trainer used an actual Mercury capsule commutator such that the data stream duplicated the real telemetry stream. The interface to the control center was much simplified.
- The use of control center operations hardware and software as much as possible. No brainer with the interface above. This helped to shake out any bugs in the MCC.
- The decision to do closed-loop training. This was my call (Hodge hired me to develop the sim system for MCC-H). Chris Kraft approved it and we were able to highly increase both the fidelity and quantity of simulation.

- The decision to use digital real time simulation for the spacecraft and Agena. Melvin (Mel) Brooks wanted to use actual hardware. The problem of keeping highly classified hardware current made this difficult. IBM supported me and Hodge approved it in the Stahl-Meyers offices, sometime in early ‘63

- Chris Kraft, in an all afternoon grilling of me about the Apollo simulation system, gave the go-ahead to proceed. The results were that the sim system requirements were include in the MCC-H statement of work and the system was integral to the building of the control center, early ‘63.

- The decision to simulate the Saturn boosters. This was part of the closed-loop simulation decision. This really took a bunch of doing. Marshall Space Flight Center (MSFC) was really reluctant to give us the data that would let us run closed loop simulations. They wanted to use FMEA [Failure Mode and Effect Analysis] as a source of failures which was counter to our way of doing business. (e.g., they objected to us doing a two engine out on the SII until it showed up in real life.)

Philosophy of Simulations.

- Simulations were to exercise procedures, interfaces (both human and hardware), mission rules, etc. They were not to teach systems. Classroom training was handled separate.

- The simulations were used to screen the flight controllers, to weed out people who were not adept at real time operation. Some personnel just didn’t handle real time operation well. The flight directors were the say on who were on the consoles. They would sometime ask for input. Not very often.

- All failures were possible! Failure probability was rarely if ever used.

- The original sims were not to certify formally the flight controllers individually; they were for team integration, both within the control center and between the flight controllers and the flight crew.
- No grades were ever given or implied. This was a job of the flight director to pass on the readiness of the team.
- And of course no catastrophic failures. There had to be a way out.

Types of simulations

Not counting the simulations at LaRC there were two types of simulations run for the flight controllers. The first was launch aborts and the other the network sims.

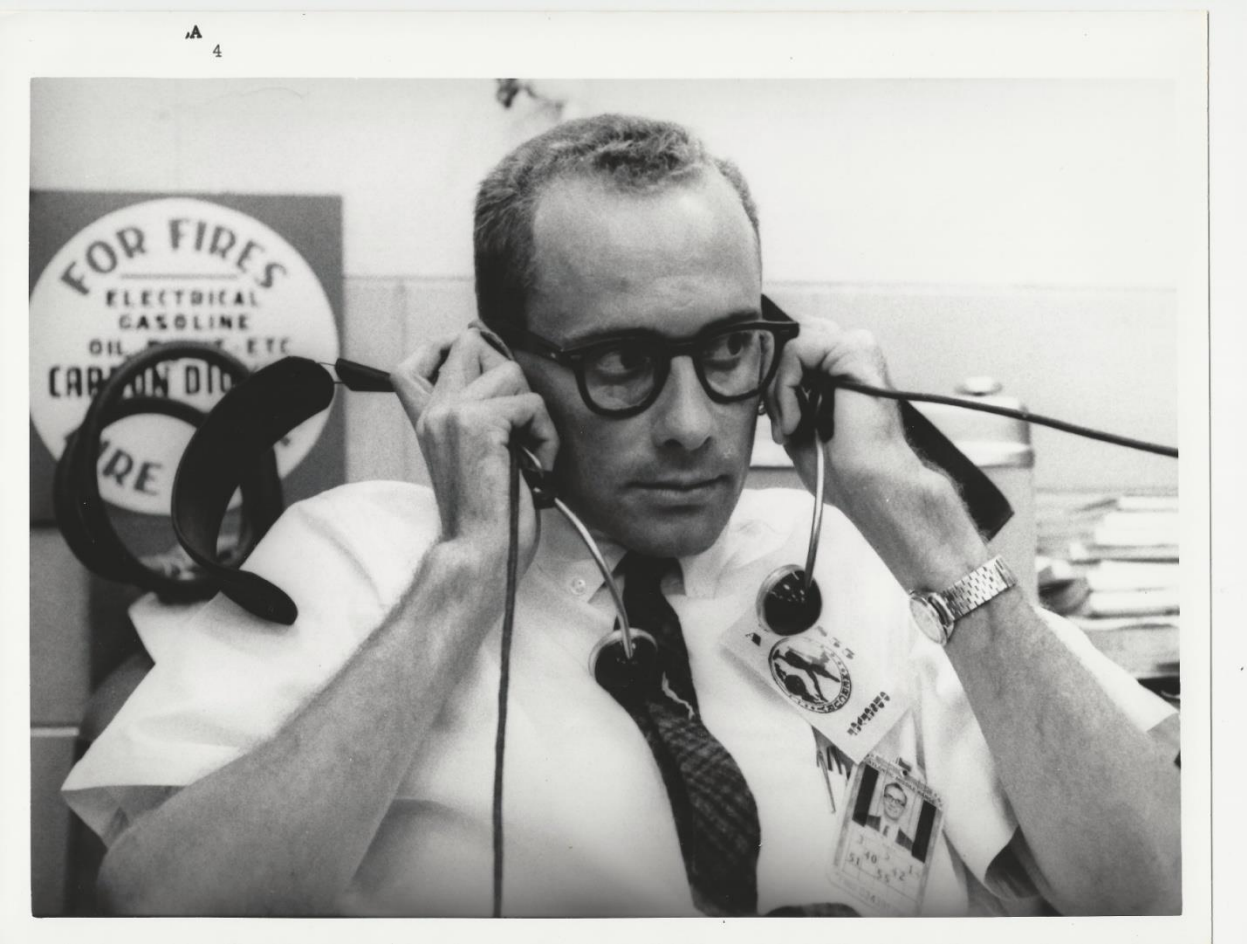
The launch sims at MCC-C [Cape Canaveral] were open loop, in that the trajectory was fixed. The system information was closed wherever we could, but it was at best somewhat flakey. The flight controllers knowing our dilemma were very good sports. Kraft would give the sim guys heck with his grin when he could catch us up short. Depending on the circumstance the launch trajectories were generated directly and drove the Flight Dynamics Officer's plot boards, or a data stream was sent to GSFC where the trajectory data was calculated and shipped back to the control center. For each mission we usually had five to seven launch profiles that would represent nominal and off-nominal conditions.

Network sims were a much more complicated subject. All network sims that were run with flight controllers on their remote site were open loop, Mercury through Gemini. However all network sims were not open loop. We had in the MCC-H two remote sites with waiting areas for teams who were getting ready for their pass. In this respect these network sims were closed loop. The two sites were to permit overlap in the passes. Some argued for three based on the

800 mile orbit apogee case. The sim displays were set up to help enable the sim guys to keep track of who were to move into which remote site. Altogether they were rather awkward, but most of the controllers endured well and seemed to get some benefit from seeing closed-loop data before they had to actually deploy.

There was a training exercise called paper sims that were to the best of my knowledge a creation of the flight controllers, not the simulation group. I believe Gordon (Ferg) Ferguson created these when he worked for Mel Brooks. Gene may have (and probably did) have a hand in their use and creation. To the best of my knowledge the sim group (under me) never developed or ran paper sims.

I want to thank Dick Koos and remember Peter Segota for helping bring back some long ago memories.



Dick Koos (1960?), the last man standing of the original Sim Guys

Glynn Lunney, FDO MCC Canaveral. One of the original Simulation Guys.

1G

H Wiles
Flight Ops Dir.

NASA -Langley
Research Center

Plan for

CONTROL CENTER TRAINING SIMULATION

March 31, 1960

(Prepared jointly by Western Electric Co. team members and NASA)

Cover sheet for the requirements for the simulation system in the MCC at Cape Canaveral

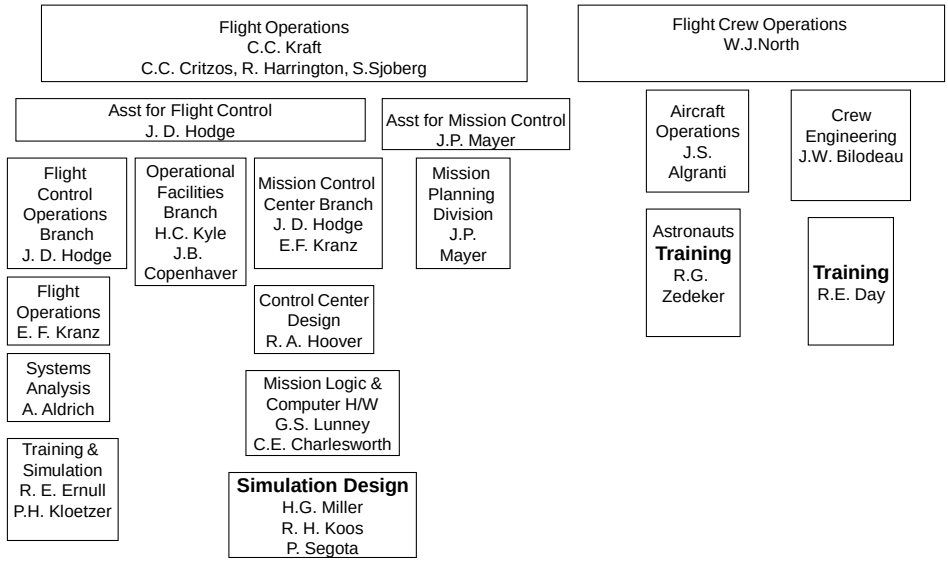
Houston Stuff, May 1962

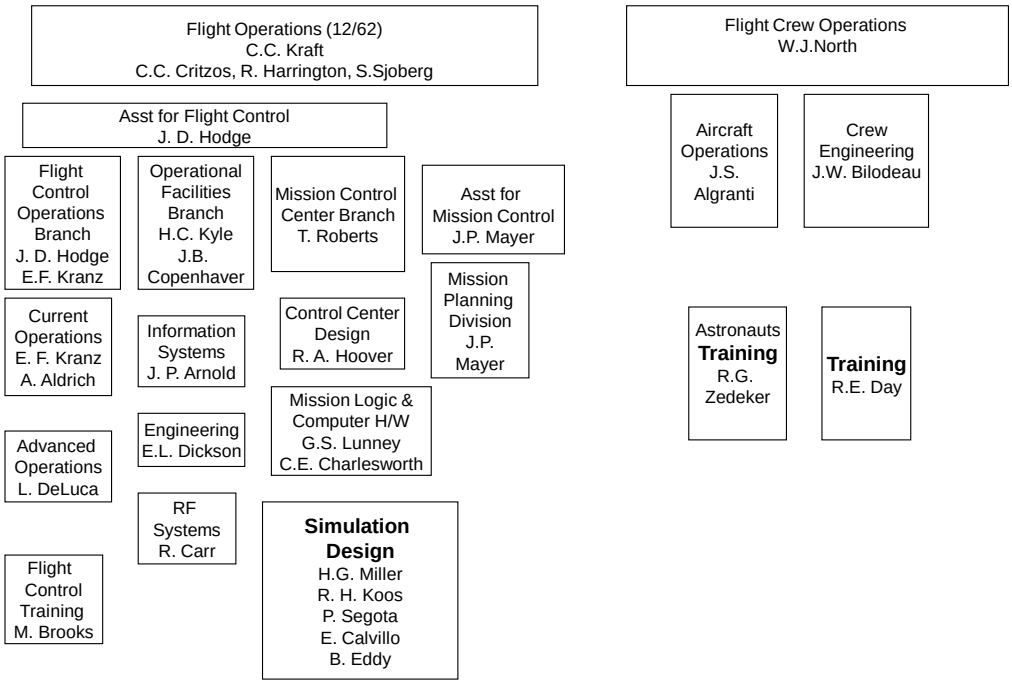
The day after MA-7 flew, May 25, 1962; I left Cape Canaveral, Florida, for Houston, Texas, with a pregnant wife in a white 1959 Ford convertible that was not air conditioned. We were about to experience the heat of Texas. After a few days in a motel, we found a place to stay in the Lawndale Village Apartments where several of the NASA personnel were quartered. I reported to Tecwyn Roberts on the second floor of the Stahl and Meyers building. The second floor had no windows and when we occasionally had a power shortage it was totally black. It was just as well, for the next few months hardly any of us saw any daylight.

The typical day was likely 12 hours long, most worked Saturday and half days on Sunday. Overtime, what was that? The paperwork for the official organization reassignments had not caught up with the verbal assignments. After a few days in Houston, I was told to report to the HPC [Houston Petroleum Center, first Manned Spaceflight Center Headquarters location in Houston] building to have my picture taken as part of John Mayer's Division.

Things were moving fast in 1962, paperwork, not so. Pete Segota, Dick Koos (after MA-8 and a brief organizational assignment to another office) and Bob Eddy reported. I also hired Efren Calvillo, and Miles Springfield. In 1962 I could interview a prospective candidate and have them on board within a week. The support we received from personnel and administrative people was fantastic. The two organization charts illustrated how dynamic the organizations were in 1962. Sometime the charts were a work in progress.

Assistant to Director for Operations
W.C. Williams 5/62





The responsibility for the next Mercury simulations was assigned to Mel Brooks and Gordon Ferguson after we moved to Houston. The Philco support personnel who had helped Dick Koos put together the sims for MA 7/8 were reassigned to Mel also.

The Simulation Design Section, which I was the head of, was responsible for the design and implementation of the system for integrated flight crew and flight controller training. By late 1962 the section had laid out the major simulation system functions and identified which organizations were responsible for their implementation. This included the simulation system for both Gemini and Apollo at Houston and the Cape.

Chris Kraft, head of operations, called me and said he wanted to go over the proposed simulation system that was to be included in the Mission Control Center-Houston SOW [statement of work] that was to be released September 7, 1962. Betsy (his secretary) set me up with a full afternoon the following week. With flip charts I went to explain what we were proposing to do. The only people in the meeting were Chris Kraft and I. He grilled me for over three hours on the charts I had prepared and then said that the proposed approach was okay and to go ahead.

I could never forget that afternoon. Once Kraft gave someone the go-ahead he expected you to get the job done without excuses. This was his style. He would also back you to the hilt. I have never seen him do anything but give his people full support. Rarely did our bosses interfere with the negotiations of functions between the organizations or in our approach to "getting the job done." John Hodge was also especially good at supporting his people.

In preparation for the simulation portion of the statement of work for the MCC-H we had to have a clear definition of how we were to conduct integrated (flight controller and flight crew) and standalone (controllers only) simulations for both Gemini and Apollo. This included number

and types of consoles for the sim instructors, software and display requirements, voice loops, etc. Also basic agreements had to be reached with other organizations about functional allocation of simulation responsibilities. These organizations included Marshall Space Flight Center for simulation of the Saturn, and the Flight Crew Support Division that was responsible for the development and implementation of all the crew training devices.

We also needed agreements with the network people in the Goddard Space Flight Center who would install the equipment to transfer simulation data between the simulation system in the MCC-H and Cape Canaveral (the future Kennedy Space Center). These data lines would transfer data at 40.8k bits per second. This was advanced at the time. The final decisions concerning where or how some function were allocated was mostly made based on capability (computing power) and necessity (location near crew facilities).

The interfaces between the crew trainers and the MCC-H were driven by these agreements. Pete Segota was a key to these decisions since the most difficult interfaces would be between computers. One of the most critical decisions was the agreement to simulate the Agena digitally. At the time (in late 1962) there had not, to our knowledge, been a real time digital simulation of a dynamic spacecraft like the Agena. Another key decision was the decision to simulate the Saturn in the GSSC (Ground Support Simulation Computer). Once these decisions were made, the contractors were able to develop the technical details of the many interfaces and the algorithms for simulating the environment and systems necessary providing realistic data for the flight controllers and crew.

Goddard, as part of their network support, was providing the remote sites for both Apollo and Gemini. We negotiated with them for two sites to be located inside the MCC-H for Gemini and one site located in a building apart from the MCC-H for the support of the Apollo Missions.

At this time it was unclear if it would be possible to transmit Apollo data from the remote sites directly to Houston or if we would have to locate flight controllers at remote sites like we were doing for Mercury and Gemini. We did know we would have to train the Gemini remote site personnel.

Training preparation had to proceed as if there were going to be Apollo remote site controllers. As it turned out, Goddard was able to remote the Apollo data and the remote site at the Manned Spacecraft Center was never used as a training facility. As an aside, I reviewed the Apollo Mission schedule and it looked pretty clear, not certain however, that the remote site facility for Apollo would not be required. I discussed this with Kraft and he decided to go ahead with the implementation as a backup in case the manned remote sites were necessary.

In late 1962, in addition to the ongoing Mercury simulations, two major activities were occurring in the simulation world. The first was to define the interfaces between the Apollo Mission Simulator, the Gemini Mission Simulator, and the MCC-H. This documentation was included in the MCC-H SOW. Also at the same time we were setting up the interface of the Gemini Trainer at the Cape with the Cape Control Center for the final missions that were to be controlled from the original (Mercury) Mission Control Center. These requirements were documented in the "Gemini Orbital Simulation Plan" signed by Chris Kraft.

IBM had been a subcontractor to Western Electric during Project Mercury for the development of the Manned Space Flight Network and the Cape Mission Control Center. On October 15, 1962, IBM was awarded a contract for computers and software in the MCC-H. Shortly after the IBM award, the question of how to simulate the Agena arose. I considered it of utmost importance that we do the Agena simulation digitally because that was the only way I

could see us ever keeping a configuration similar to what the flight controllers would be seeing in the real mission.

We were scheduled to fly Gemini Missions on a two month schedule and to keep a hardware/analog simulator up to date would have been an almost impossible task and possibly improperly train the flight controllers and crew**.** The battle over how to simulate the Agena was a rather bitterly fought battle between Mel Brooks and me. This went on for several months in the Stahl-Meyers building. Mel argued strongly for actual Agena hardware the flight controllers could use as hands-on training and also as the data source for the simulations. I felt that this was unrealistic since we would need to physically modify the highly classified Agena for each flight and the systems data such as temperatures and pressures would be hard to generate and interface with an analog type of trainer.

The argument finally came to a head in John Hodge's office where IBM presented the arguments for a digital simulation. Mel argued for the analog version. In what I considered, at the time, a real leap forward, Hodge agreed to let IBM simulate the Agena's trajectory and systems in the GSSC in the MCC-H. The Atlas launch vehicle and its trajectory were also to be simulated in the GSSC.

I decided, and it was approved, to have the simulation control room located next to each Mission Operations Control Room (MOCR) with a viewing window. This put the sim guys in close contact with the controllers and helped coordinate our activities, especially the debriefing of each of the simulations. In each sim room consoles were placed that allowed the sim controllers to monitor and inject failures into both ground and spacecraft to the devilment of the flight controllers and crew. There were consoles for the sim sup, systems (Gemini, Agena, Apollo Command and Service Module (CSM), Lunar Excursion Module (LEM), and boosters.

We could also introduce failures in the ground equipment. The first thing a controller had to do when he detected a failure was to determine if it was an actual spacecraft failure or an instrument problem. This was one of the main reasons it was so important to bring into play the technical support personnel (John Hatcher's guys). These guys often played a dual role where they would aid the sim controllers introducing failures to the front room guys, i.e., Dave Reed's console failure. James (Jim) Miller wanted to put a console in the sim room to coordinate these back room sim activities. Brooks, I and Ferg were dead set against it. There was a meeting in Hodge's office and each side presented their case. Hodge listened to both sides and then decided that the addition console in the sim room was not necessary. This saved me quite an effort since I would have had to have it killed anyway.

Organization of the Mission Simulation Branch evolved so that each of the section heads except Ferg would be the sim sup for assigned missions. However, section duties precluded the head from doing the day to day duties necessary to get ready for a set of mission simulations; therefore, I set up under Carl the function of "sim coordinator." The sim coordinators were generally responsible for documentation of the simulation cases and for any requirements to modify the simulation system prior to start of the simulations. Software and hardware requirement were due approximately nine months before flight. This would cover unusual cases for software simulation of the various simulation vehicles (Agena, Gemini and Saturn).

Most of the vehicles were dynamically simulated making a wide range of cases possible and thus reduced the necessity for case-specific requirements. The sim coordinators were to work with the assigned sim sup to generate and document the sim cases. The sim sups were Jerry Griffith, Dick Koos and Carl Shelly. Ferg was a section head but he took care of the classroom training and wasn't a sim sup after the first Gemini Missions in MCC-H.

The sim coordinators were essential to the preparation of the sims. For instance the sim coordinator's duty was to develop a working schedule for requirements development which sometimes (depending on how complicated) ran several months. We had to have major changes identified nine months before simulations started. The sim coordinators were the right hand man for the assigned sim sup. Without these guys we would never have been able to run the number and quality of sims that we did for each mission.

I was able to obtain six to eight Air Force guys to help in addition to the contractor support. These guys were top flight and served in different sections. We would have the Air Force guys for two year tours. I found that they could pick up and be useful in very short order and considered myself lucky to have such bright people. However, other branches didn't view the Air Force guys as well, and some said that since they were not permanent they were not given very responsible jobs. Two year was an eternity in manned spaceflight at that time. I had a lot to learn about military evaluations when I gave what appeared to me an excellent rating. He wanted to know where he had gone wrong and said the evaluation would not let him get promoted. I did some checking and found that any military personnel that didn't get top marks were passed over for promotion. The guy was tops so I re-rated him.

Since remote site flight controllers were utilized for the Gemini missions, we decided to train them in the control center so that we could run the network simulations closed loop if a remote site sent a command that would be reflected in the spacecraft (simulator) hardware. We had two functioning remote sites to support all the remote site flight controllers. Each team would be cycled through the site shortly before AOS (acquisition of the signal) of the spacecraft and would interface with the MCC-H controllers in real time.

This was not an optimum situation and the flight controllers hated it. They were crowded in small waiting rooms with limited equipment, like cattle waiting their turn in the active simulation site. One controller told me he would do anything to get out of having to do network sims in the MCC-H. The same controller later told me he really appreciated the sims even though they were tough. The impact of trying to coordinate in real time the transfer of remote site teams into the live sites caused me to ask IBM if they could develop a unique display system for the sim guys. They came up with a screen display that had the top showing the progression of the spacecraft around the globe and when we would need to have remote site controllers in position.

The sim controllers also had access to all the MOCR communications and displays. We could watch what the controllers were doing. This got me in trouble with John Hodge again because he wanted to know why I could get special displays for the sim guys and the front room guys didn't have that capability. The answer was of course that if we screwed up a simulation it was not big deal however the mission system must be rock solid.

The flight controllers were by nature a conservative group and as a result were reluctant to alter procedures or methods of monitoring spacecraft and booster information. Nowhere did this show up as much as in the display of systems data for the spacecraft. The definition and implementation of displays turned out to be a carryover from the display system used at the Cape. These were analog meters with calibration strips and strip charts. The new control center was to have CRT [cathode ray tube] displays. The decision to use CRTs was a directed decision by the upper management. The resolution to this problem was of course to have pictures of meters on the CRTs for the flight controllers to use.

The simulation guys were not so constrained and used digital numbers directly. The sim guys were able to develop some unique displays, such as a partitioned display, that had, for instance, remote site coverage as a fixed display and the more dynamic data to be shown on the same CRT. IBM and Philco, I believe, used the simulation system to test and advance displays and to develop confidence in them for the flight controllers. As an aside, John Hodge used the fact that we had "advanced" display system and argued that the flight controllers should also make changes more quickly. The answer of course was simple. If we blew a simulation no damage was done. It was not so with the operational systems.

The description of the trajectory interfaces is described below by Pete Segota.

The Gemini Mission Simulator (GMS) simulated the Titan during integrated simulations. The GSSC simulated the Burroughs Guidance Computer (BCS) which sent guidance commands to the Titan to steer it to the proper orbit. The GMS sent a T minus 3 minute message to the GSSC—this was used by the simulated BCS in the GSSC to determine the required launch azimuth. The GMS simulated the Titan launch trajectory and sent vectors to the GSSC. It took many hours of GSSC/FCS testing to get the GMS to correctly receive the GSSC commands and execute a yaw trajectory into the proper orbit. In the actual mission the BCS and another computer (I forget its name) sent canonical vector trajectory data to the mission computer. In a simulation the GSSC simulated this data from both computers and sent the data to the mission computer. I remember spending many hours nailing down the definition of the canonical units, which were different for the two computers. I am not sure how the GMS routed their trajectory vectors to the GMS. But I do remember that I allowed IBM to modify a Burroughs box, which caused Lunney and [Cliff] Charlesworth some consternation.

As an aside, apparently the GMS was not training astronauts in the yaw maneuver during GMS training. During the first integrated simulation the astronauts were surprised at the yaw maneuver and thought an abort would be required – they were informed that the yaw maneuver was normal. During Agena simulations, I think the simulated BCS in the GSSC would somehow know the parameters of the Agena orbit. Then at T minus 3 minutes to Titan launch it would establish the guidance commands needed to send to the simulated Titan in the GMS to steer it into the proper orbit to rendezvous with the Gemini (Agena) spacecraft.

In the Apollo integrated simulations, the GSSC did simulate the Saturn and sent trajectory data to the Apollo Mission Simulator (AMS) to get the Apollo spacecraft into orbit and then into a translunar trajectory. When the simulated Apollo spacecraft was separated from the simulated Saturn, the GSSC sent trajectory data to the AMS to assure that the AMS would reflect realistic data to the astronauts. The AMS would simulate spacecraft trajectory burn data to the GSSC so that the GSSC could update its trajectory. The GSSC was prime on orbital, translunar and lunar trajectory data because it had an Earth and lunar model and could better reflect a realistic trajectory (via radar data) to the mission computer. (The GSSC also was prime for orbital trajectory during Gemini simulations.)

(Note: Shortly after Pete Segota wrote this e-mail to Harold Miller he suffered cardiac arrest and died September 1, 2011.)

While preparation was ongoing for getting the MCC-H built, GT-1 [Gemini 1] flew April 8, 1964. The Cape Control Center was to remain the main control center until the MCC-H was operational.

In June 1964 I was made Chief of the Mission Simulation Branch (MSB). Jim Miller's section was moved from the development organization to the MSB. Gordon Ferguson's group

was moved from Mel Brooks's organization also. Feguson's section was busy with GT-2, which left the rest of the branch to sort out the interfaces and develop the simulation systems for supporting both the Gemini and Apollo missions.

Jim Miller was assigned to me to oversee the implementation of the simulation system in the MCC-H. He was the head of the Systems Support Section and it was staffed by Segota, Calvillo, James R. Smith, Miles G. Springfield and Richard L. Brown. I have never understood the rational for moving the simulation development organization under Jim Miller and Lee Roots to the Operations organization but that is what happened. Koos was excellent at negotiation of schedules with the crew for the integrated sims. Ferg turned out to be an excellent section head of a group to provide class room training. In situations where Ferg had to interface with engineers, he could become abrasive and rather difficult to deal with. I was able to persuade him to go to school and get a degree and this smoothed some of the edges. Ferg wound up one the most productive and one of my favorite people.

About the time the branch moved to Clear Lake in 1964, Jim Miller and his section was transferred back to the MCC-H implementation group under Pete Clements. I was now again in charge of just the simulations operations. I did not consider it a great loss to lose the implementation task since it was a distraction to the development of training operations for the flight controllers and astronauts. Plus, although Jim was a hard driving effective section head, he was difficult to work with. It was interesting to observe the dynamics of the interpersonal relationships. For instance, if I really needed some change implemented in the simulation system, I would send Carl B. Shelley, who seemed to always have the upper hand with Jim. No one else could get their way with Jim like Carl.

My branch evolved into four sections with Ferg in charge of class room training, Shelley in charge of sim ops, Koos in charge of systems, and the rock-solid Jerry Griffith running the vehicle dynamics section. Jerry was able to interface with the flight dynamics groups and the trainer personnel to establish some of the most challenging trajectory cases for the flight controllers and crew.

GT-2 had slipped almost a year and was putting the simulation guys in somewhat of a bind since the network tapes that Ferg had cut for GT-2 were rapidly becoming obsolete because of changes being made in the spacecraft systems. The sim guys had to have the documentation and tapes ready to hand the remote site controllers when they departed for their individual sites around the world. We had about three weeks to send Ferg and crew to the Cape to cut new tapes and document the cases. I asked Ferg if he could get it done, and if he thought so, I would get him the support ready. We had just moved into Building 30 at Clear Lake. Hodge, my division chief, thought I had bit off more than I could chew. Ferg was able to get the cases taped and documented and we were able to hand the flight controllers much better simulation material. Close call. GT-2 flew January 19, 1965, unmanned.

January 29, 1963, Philco awarded the contract for MCC-H, and the building of the simulation system got underway.

When Ferg's group of people was transferred to me I found that his classroom training group was really the contract managers for all the people in the Flight Control Division. To get anything done, Ferg had to go through four levels of contract management to get training tasks performed. I, needless to say, found this intolerable. I sat down with Ferg and we outlined a plan for classroom training where he would direct a group of four to six people, and they would

lay out the training plans for each console position and obtain classroom teaching material from our spacecraft contractors, i.e., systems data from Lockheed, Rockwell, McDonnell, etc.

As part of the reorganization, I had Ferg place more emphasis on providing classroom training. I was able to get written into the spacecraft contracts a provision for training support. Ferg organized and ran this activity. Classroom instructors would be a combination of Ferg's guys and the various contractors. Philco, our contractor at the time, moved the managers to different locations and left Ferg with a group which he used to develop training plans. This became a full time effort and he was relieved of the sim sup duties. Ferg did the Gemini simulations at the cape and the initial sims at the MCC-H.

In late 1964 or early 1965 the Russians were supposedly about to conduct a rendezvous mission in their preparation for a lunar attempt. I, of course, had no real idea as to how or when this would happen. All the NASA branch chiefs and section heads were called to a large conference room in Building 2 where Kraft gave an impassioned speech to his managers and to the Philco and IBM contractors about getting the MCC-H ready for the manned Gemini missions, especially GT-4 in June 1965. He asked the contractors opinion regarding having the control center ready for the Gemini mission in preparation of the rendezvous missions.

Philco demurred on the readiness and IBM understanding Kraft's desire said they would be ready somehow. This placed extra pressure on the simulation personnel at the time to have the simulation system ready and to develop the cases and learn how to run the simulations so training could start two months prior to launch of GT-4. The training sequence for flight controllers, excluding classroom training, generally started two to four months prior to each flight. The sequence of exercises were tailored to the specific mission and usually started with launch aborts and then went to network sims.

The first simulations run in the MCC-H were Gemini launch aborts. I was acting as the sim sup and remember running nine cases on the first day. The most launch aborts we had ever run in a day at the Cape were four. It was quite a good feeling being able for the first time to run that many simulations with a brand new complex. As Chief of the Mission Simulation Branch, I was often the sim sup for simulations where it was the first time, such as the Gemini rendezvous simulations, which almost caused a launch slip. The assigned sim sup usually, with help from the sim coordinators, was also responsible for coordination of the integrated flight controller and flight crew training schedules. The crew would participate in their trainers either at MSC or as the flight approached from the Cape. To facilitate data exchange between the simulation systems, 40.8 kb data channels were set up between the trainers and the control center.

Looking back at the sims run over the years, we were extremely fortunate in our selection of cases for the simulations. Cliff Charlesworth would, after some simulations, tell me that was the most unrealistic simulation he had ever seen. Invariably that specific problem would occur in the mission and he would have to eat crow. That didn't seem to stop him from griping about a sim. A lot of it was good natured just to give me some grief.

I remember one case where we had calculated the size of a hole in an Agena pressure tank so that the flight controllers had to take action before the pressure dropped below a critical value. Cliff gave me grief about the case, and in the next mission the exact same problem occurred. The pressure curves from the actual mission and the simulation were almost identical.

Another case we simulated was the loose heat shield in John Glenn's flight. It was a network sim so Glenn wasn't a part of the exercise. The reaction by the flight controllers was quite different in the real case. The two engines out S-II case got us a lot of grief from the MSFC booster group. They said it could never happen. But it did. A backup cutoff signal was

wired to a good engine and shut a perfectly good engine down. The bird was thrusting hard as it went over the horizon. MSFC built really rugged vehicles. The mission was a success. Apollo 13 was simulated, not to the extent of the actual flight, but in a more limited way.

Rarely would we run long duration sims. The mission to be simulated would be broken up into segments and simulations were set up for those cases. The lunar landing mission was handled by sever sim sups. As I remember Dick Koos was the lead sim sup and Jay Honeycutt handled the lunar landing. He was the sim sup that ran the simulation showing the computer failure light. It got so that the flight controllers didn't complain about a particular system failure because in so many cases the problem occurred in flight. Remember of course the purpose of the Sims was not to teach the controllers how the systems worked, but to teach them how to handle most any problem that occurred.

The first Gemini rendezvous simulation – three days in the control center. The only time that a mission was almost slipped for simulation was the first Gemini rendezvous. The simulation was set up such that the Gemini launch trajectory was generated from the trainer at the Cape. The trajectory information was then transferred to the simulation computer (GSSC) in the MCC-H. The computer (in the MCC-H) then simulated the launch of the Agena, which was to rendezvous with the Gemini spacecraft in 3 orbits or M=3.

Because of an error in the data transmitted from the trainer at the Cape, the simulations resulted in a rendezvous 24 revolutions later (M=24). Because of the importance of the rendezvous mission, Kraft was in the control center. After our third failure on consecutive days to have a simulation of M=3 he (Kraft) came into the sim room and leaned over the sim sup's console and in a very quiet way told me that I could have the control center and any help I need, but not to call him back until we could run a M=3 rendezvous and that if he couldn't practice the

rendezvous he would have to slip the mission until he could. For the next three days I stayed in the control center watching the activities of the hardware and software people try to find the problem. An engineer from McDonnell Douglas was shipped from St. Louis and found the problem. A sign on the launch azimuth was backward resulting in the M=24 rendezvous. Sunday afternoon we were able to test at least three practice sims and so I called Chris Kraft and told him we were go for Monday morning. Whew!

For Apollo trajectories, the training of the booster system controller, the Saturn boosters were simulated in the simulation computer (GSSC) in the MCC-H. To do this we needed to get information from MSFC to enable IBM to generate the appropriate trajectory and systems data for the booster flight controllers. A joint panel was set up between MSFC and Houston for the coordination of data transfer and to determine how the simulations would be run. I was co-chair with Fred Hammers.

MSFC was a very exacting organization and did not like the idea of failures that they thought were rather low probability. They argued for the use of FMA (failure mode analysis) as the basis of faults for the simulations. This was very restrictive because of any failures that could be considered likely would be fixed, and of course would no longer be a realistic failure. The Houston approach (mine at the time) was to have the sim guys introduce failures that would excise procedures and ground rules and exercise communication between the flight controllers. To say the least there was a bit of tension. We needed the data to permit simulations and we didn't want MSFC to control the faults that were introduced. This process went along for a year or so until one IBMer teed off some of the MSFC folks. The meetings stopped; however, we had established the data channels and had enough data to build the simulation model.

One of the more interesting simulations was the two engine out on the S-II. MSFC was adamant that this was an unrealistic simulation. It however gave the simulation guy the trajectory that made the flight controllers exercise their procedures and ground rules. As it turned out, in the very next mission the S-II had a two engine failure, and that was the last time I got grief from MSFC for running an unrealistic simulation.

The simulations in the MCC-H opened a new area in training since we were able to introduce failures that the flight controllers could take action on. The launch aborts were the most intensive training. I have had flight controllers say to me that flying a mission was a lot less stressful than a simulation because they knew someone was going to have a problem and that Kraft and the other flight directors would be watching. If they screwed up they could get pulled off a console. The primary data for the simulations were from the Gemini and Apollo trainers at the Cape. We did have in-house (MCC-H) simulation that could duplicate the Gemini and Apollo spacecraft.

For the trajectory simulation, the launch trajectory was generated by the Gemini trainer and shipped to the MCC-H. If the crew aborted the data would reflect this new trajectory. By adjusting the thrust parameters we were able to play games with the V/Gamma plot and cause all kinds of mischief. For example, any new FIDO would get an apogee kick run where the controllers would have to wait until half of an orbit before having the crew thrust to bring the perigee high enough so reentry would not occur. Ed Pavelka was the first FIDO to get caught by this simulation. He had the crew immediately thrust which only raised the apogee. To some extent the trajectory from the trainers were preplanned because the Gemini trainers could not calculate a launch trajectory in real time. So trajectory cases (thank you Jerry) were planned several months ahead of the start of the simulation. This I believe was not true for Apollo.

The philosophy of the simulations remained the same as originally laid out for the Mercury Missions; however, we were able to much better execute the implementation of simulations that would stress the flight controllers to the max. Some of our guys said that we should never give the flight controllers an even break. The competition between the simulation guys and the flight controllers, I believe, was a good thing. Controllers would say that the simulations were more stressful than the real mission, which of course was our (the simulation guys) objective. There was an inherent pride in the sim guys when the flight controllers would handle successfully difficult missions, and there were many of these.

For instance we had simulated an Apollo 13-type mission similar to the actual flight. The flight controllers had, of course, worked out some of the procedures used during that mishap. Another very visible example was the simulation of the computer overload light coming on during lunar landing. Gene Kranz took a bunch of controllers and spent several days identifying what would cause the onboard computer fail light and if it was serious or could be ignored. Many other examples exist where the simulation failures preempted the actual failure and helped enable procedures to be developed to handle the contingencies. Most of these cases are well known and documented. A detailed analysis of each flight should not be complete without a history of the simulations run in preparations of the mission. After MA-7 the simulations were documented much better, but I do not know if the material has been saved.

Somehow there developed a routine/custom of simulation guys celebrating after the last simulation before each mission. This was just the sim guys. Of course all the sim guys went to the splash down parties. I never knew who started, but suspect that it was Ferguson. In Dickinson there was a German restaurant where all the sim guys would meet after the last simulation and relax. One of our members was especially prone to going to sleep after a few

beers – never passed out, just went to sleep. On more than one occasion I sprung for a hotel room in the T&C Motel just across the road from the restaurant. No one thought anything about it and without fail next morning the sim guy would show up bright and early at work, as did all the other sim guys ready for the next mission.

Other

I would be remiss if I didn't mention the social aspects of the NASA teams. We were rather young and most newly married with small kids. We didn't have much money since we were mostly low lever government employees and this circumvented our social life. In many case the office interfaces continued through community activities, church, swimming pool, bridge clubs, poker clubs, golf, little theater, and other activities that were sort of a carryover of the work day. In my newly minted neighborhood, most of the families were either NASA directly or one of the contractor's personnel.

I think it is fair to say that we as a group worked hard and partied harder. Gene Kranz lived one street over from me and was known to host some serious parties. Our party season started about Thanksgiving and went through New Year's. Baby sitters were scarce and highly coveted since our nightly activities were frequent. I remember in the mid-'60s checking my calendar and finding that I had one night free over the next two months, and I was not unique. Close friends would come over with kids so we didn't have to get sitters. Sometime it was so busy it all seems just a blur now.

The Apollo missions were like a giant jigsaw puzzle where every piece, no matter how small or large, had its place. My role in the puzzle, although small, was a necessary activity. If I personally had not filled that role, someone would have stepped up and taken on the duties I was handed. I consider myself fortunate to have been part of a very large activity that accomplished

a stellar mission. I am sure others feel as I do that we just happened to be at the right place at the right time.

After John Hodge left the Flight Control Division and Gene Kranz was placed in charge, I joined Gene's staff and left the simulation world to take on the task of managing the Flight Control Division contractor staff and develop for Gene a manpower tracking system, a very unpopular activity that the flight controllers knew as the Green Sheets. On Gene's staff were Mel Brooks, Jones Roach, and myself. We were known as the three blind mice. Dealing with the contracts was my first look at government contracting. I and my small staff served in this capacity until I left MSC (later the Johnson Space Center, JSC) in August 1970.

I returned to NASA Headquarters (HQ) in 1983 to work for John Hodge, who at the time was leading the effort to establish a Space Station Program. My instructions from Hodge when I hired on was to make sure that operations and utilization were visible in the Station Development.

I found NASA had changed drastically over the 12 years I had been gone. Program managers were in large part controlled by the budget people and told what they could and could not do. Promotions were accorded to people because of the size of the contracts they could develop and bore little relationship to capability. However, throughout this time Flight Operation remained a can do, hands on organization. I was pleased to have been a part of the organization. I labored in Station serving at HQ and moving to the engineering office in Reston [Virginia]. When the Reston offices were closed I returned to HQ in the Office of Manned Spaceflight and was placed in the Chief Engineer's office and tracked Shuttle performance.