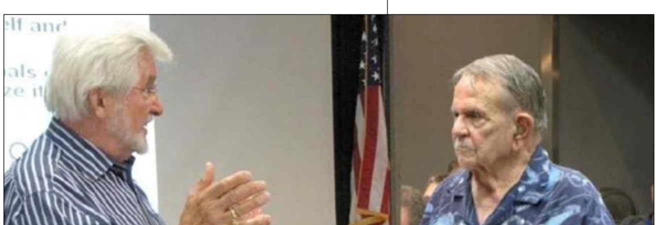
Dinner Meeting Featuring Wayne Hale

DOUGLAS YAZELL, EDITOR

This popular dinner meeting took place at the NASA / JSC Gilruth Center Alamo Ballroom on March 28, 2013, with an audience of more than 50 people. Some of the information is not available to the press, so starting below we present a somewhat similar address given by AIAA Houston Section Member Guy Thibodaux back in 1966. Guy was our Section's 1969-1970 Chair. We can find an oral history and biography here.



Above: Guy Thibodaux (right) at an AIAA Houston Section dinner meeting of May 26, 2010. At left is the featured dinner speaker Mr. Bohdan (Bo) Bejmuk, a member of the Augustine Committee whose human spaceflight review report was released in 2009. Image credit: Douglas Yazell. Image source: Horizons, July 2010, dinner meeting article starting on page 8.

SYSTEMS TESTING IN THE SPACE AGE

AN ADDRESS BY

JOSEPH G. THIBODAUX

TO THE

AEROSPACE PROPULSION TESTING ASSOCIATION
NASA MANNED SPACECRAFT CENTER
WHITE SANDS TEST FACILITY
DECEMBER 7, 1966

Completion of the Gemini Program last month marked NASA's sixteenth consecutive successful manned venture into Space. While every system and component did not work perfectly, the major mission objectives were accomplished and all crews were successfully recovered. Gemini paves the way for Apollo and inspires confidence that we can successfully land man on the moon and return them safely to earth.

The Apollo Program is the most complex engineering task men have ever attempted. Each discipline has exercised all the imagination and ingenuity it can muster to cram the most performance into the least volume and weight. All components and systems must function in ranges of environmental conditions not normally found on earth. The multitude of components and Subsystems has many interactions and interfaces with other components and systems. Many thousands of people are involved in all aspects of the program. All of this creates an unusual degree of complexity.

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The program requires that we develop this complex system to a high degree of maturity and confidence in a reasonable time and at a reasonable cost. We cannot afford to build thousands, or hundreds, or even tens of boosters and spacecraft and fly them to get the statistical confidence we would like to have. This is in real contrast to the practice of other industries. It is even in sharp contrast to past space industry practice. I have a friend who was a production engineer in an automatic transmission plant. He told me he could build and throw away ten thousand transmissions a year if it was necessary to set up his line properly and keep it turning out quality products. He also said that a complete transmission cost less than 40 dollars. At about$1,000.00 a pound or more, we can't afford to throw that much spacecraft hardware away.

We are being required to change our philosophy a bit. We are being required to show that the Government-Industry team has learned some lessons from all of the missile-space programs of the past and that these lessons can be applied to the Apollo Program.
The keystone in the arch of success in the program is test, test, and more tests. A thorough, comprehensive ground test program is the only way we can develop mature systems which will succeed in early flights. We are well down the road toward successful qualification of most of the major subsystems; I would like to review for you some of my impressions of the past pertaining to the Apollo test programs and philosophy.
Before discussing the Apollo test program and philosophy, I'd like to tell you something I learned about testing last week. Usually, when I'm asked to address a group, I consult my favorite reference authority "Webster's Dictionary" to bone up on the subject. How many of you in the audience know that the word "test" is derived from earlier words in English, French, and Sanskrit meaning cup, or a piece of burned clay pottery. The clay cups were used in assaying or refining precious metals in ancient times. For those of you who speak French, Spanish, Italian, or German, the words tasse, taza, tazza or tasse all mean cup and sound much like the English word test. Incidentally, the definition of test in the context we are here today is an examination, or trial to prove the value, or ascertain the nature of something and the method, or process for making such an examination.

In the Apollo Program, the general philosophy is to provide the maximum confidence for crew safety and in a secondary sense, provide reasonable confidence for mission success. The Program is designed to avoid loss of mission or crew as a result of single point failures. Where possible, redundant components are provided, and in many instances redundant systems are provided. For example, all primary propulsion systems have redundant valves in the engine and pressurization system. The reaction controls have two complete systems, either of which can successfully perform its required function. While we do not have redundant primary propulsion systems, each backs the other up. In the event of failure of the descent engine, the ascent engine is used in an abort mode. Likewise, in the failure of the Service Propulsion System, the descent engine can be used for a free return trajectory to Earth. Since the primary propulsion systems are non-redundant, successful completion of the mission requires their satisfactory operation — crew safety is not affected unless a failure is catastrophic; i.e., a large explosion, or that two primary propulsion systems fail on a single flight.

The objectives of our test program are first — to demonstrate that hardware design and manufacturing is satisfactory for operation under all normal conditions encountered in a lunar mission. Second to characterize the limits within which the system performs as a result of varying environmental conditions and manufacturing tolerances. And finally, to determine off-limits operating characteristics which result from a failure of one or more redundant components. An added feature of the test program is to verify satisfactory operation of servicing equipment and procedures, and the training of personnel, the fact that men fly the spacecraft propulsion systems makes the job more complicated. Booster engines always operate under preplanned conditions; i.e., fixed thrust programmed attitude and minor variations in duration. Spacecraft engines must operate on any mission duty cycle which can be flown within the limits of total propellant consumption and this is responsible for much of the complication in planning tests as well as designing and building hardware.

Above: Gemini 11 Maintenance. The Gemini 11 spacecraft is lowered onto a dolly for preflight maintenance before stacking on the Titan rocket at the Kennedy Space Center. Dick Gordon and Pete Conrad would liftoff in this spacecraft on September 12, 1966 for a mission lasting almost three days. The crew practiced docking with the Agena unmanned docking craft, and Gordon also performed two spacewalks during the mission. Image credits: Great Images in NASA (GRIN) for 1966.

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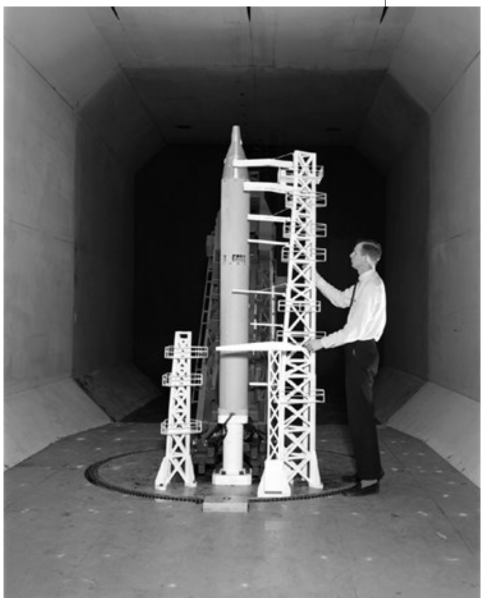

Above: Titan with Gemini capsule in the Transonic Dynamics Tunnel. Langley wind tunnel. Image credit: Great Images in NASA (GRIN). 1964.

A test program is usually composed of the following elements - hardware, facilities, software, paperwork and people. People are the most important part of the program as the other items are their creations. Let's discuss people first. Some of the key words relating people and test are philosophy, competence, rigor, discipline, planning, honesty, integrity, organizational motivation and teamwork. That's a big mouthful of words. We assume that people are competent, honest, and motivated; however, we still must recognize that each of us has a bad day. We also recognize that with such a large number of people participating in the program, even with excellent screening, a few who are not up to the required standards are hired. These inherent human failings are the most difficult to admit, and they are the ones which are most likely to cause troubles.

People in test are required to find not only the design or manufacturing mistakes made by others; they must also help ferret out their own weaknesses. This requires an unusual amount of honesty and integrity. A single unreported, or unadmitted mistake committed by a test specialist can destroy millions of dollars worth of hardware, cause unsafe hardware to be flown, or even cause major redesign of a system or component that was more than adequate With a program Costing $l0, 000,000 a day to run, such unnecessary redesign lengthens the program and results in the loss of many times the cost of a test or value of the hardware. We should give medals and awards for admission of honest mistakes committed in a test program, I would say that errors Committed in Apollo testing which were not surfaced have been a substantial cause of program slippage and increased program costs.

Motivation is another problem. Test people perform a service and often feel like frustrated designers who are not allowed to be very creative. Occasionally their attitude is "let's show those damned design engineers and manufacturing type that their designs and products are no good and proceed to tell them how it should have been designed or built in the first place". This is the "test specialist's backlash". We have experienced this attitude at some installations — White Sands is not one of them, This is not a healthy attitude.

We all perform a service for someone else and at times our role is dominant and at other times subservient Each of us must recognize when to be dominant or subservient - the proper times are different for different disciplines it is the job of management to make each group or organization feel like an equal member on the team, and to equally recognize creativity whether it be in test activities or design, or management, or operation, or manufacturing. When this is accomplished, motivation and the pride of accomplishment which is attendant with motivation will follow despite some of the hardships which I will touch on later.

We said people make honest mistakes, and we regretfully admitted that all people are not necessarily honest, in the consumer industry when this happens, someone is at the complaint window returning an article, or he complains bitterly to his friends and neighbors and stops payment on his account. Statistically, the number of poor articles a reputable manufacturer turns out is low; however, it is too high to accept in a manned space program. I cannot picture three astronauts returning an engine which failed to start. For this reason, planning, rigor, and discipline are important if we are to learn what is wrong with hardware and eliminate human error.

Good planning is always the first step. In a good organization, planning is accomplished through teamwork; the basic requirements are set up by engineering who designed the article to operate to a given set of specifications. Data requirements are also the responsibility of engineering. Manufacturing should be consulted on handling, assembly, disassembly and potential repair or modification of the test article. Operations should participate in servicing procedures and GSE performance. Test should be responsible for all facility—test article interfaces, data acquisition and processing and overall test planning and finally, the actual conduct of the test. This teamwork and communication is not always evident; in fact, it is sometimes nonexistent and is replaced with parochial or provincial

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attitudes and interest which cause jurisdictional disputes that result in inefficiency, foot dragging and buck passing. This is one of the things you can least tolerate or forgive in an organization because it is caused by pettiness, poor organization and poor management, and has nothing to do with individuals technical competence or honesty. This has been responsible for a considerable loss in efficiency on Apollo.

The continued coordination throughout the program is a must. The loop must repeatedly be closed between all parts of an organization all the way through the last segment of the organization until completion of the program.

Rigor and discipline are important. In qualification testing, each step must be defined and rigorously adhered to. This is extremely necessary where many people are involved in testing complex hardware in an equally complex facility. It provides the only opportunity to learn exactly what was wrong with the article, the facility, the procedure, or the planning and an opportunity to verify what was wrong. We insure rigor and discipline by inspection and quality assurance.

This is an affront to the test specialist's dignity to have someone checking upon his every move. If he participated in the detailed planning, is it unreasonable to expect him to do what he said in the order he said he was going to do it? People check drawings for mistakes, calculations for mathematical errors, contracts for legal loopholes, manufacturing for discrepancies in materials or tolerances, audit money handlers for honesty, edit reports and documents - which is really exempt? And yet I know of games people play with millions of dollars worth of hardware just to see if an inspector can catch someone's willful mistake, Remember ,inspectors aren't perfect either. A successful program requires everyone's best effort and cooperation.

Hardware and the facility which tests it can present many difficult problems, Often management dictates that old facilities be used because they are available and have not returned their capital investment this is certainly permissible if they can accomplish the job efficiently and above all on time. Remember, if a test causes a system to pace a launch - we lose $10,000,000 a day for each day of delay.

With new, complex hardware, often new complex facilities are required. Generally, they can be planned, constructed, and shaken down while the spacecraft system is being designed and manufactured. The facilities-hardware interfaces must be thoroughly studied and test procedures and other necessary paperwork planned well in advance, Teamwork and participation of the test organization, the program, cannot occur too early, Lack of proper planning, paperwork, and shakedown of facility-test article interfaces can result in catastrophes or near catastrophes, we always hope for the latter. It is our Policy to run a formal acceptance inspection of all test articles at the plant, and all facilities prior to operation The inspection team is empowered to require any obvious discrepancies to be corrected before operation In the case of the test facility inspection — we call these Operational Readiness inspections — not only the actual physical facility is considered, but the state of readiness and training of personnel, and their organization is considered.

Usually one mandatory requirement is a detailed failure modes and effects analysis, this is an analysis which assumes failures of critical items in the facility and evaluates its effect on the safety of personnel or potential damage to test article or facility. Some of the results are quite interesting. Often, we do not catch all potential failure modes in the analysis - they show up in testing. Again, we hope none are catastrophic or result in injury to people. In general, despite all of the complexity, rigor, discipline and frustration, the qualification programs on Apollo are proceeding well and at this time are not pacing the program. We have had many spectacular failures, and I cannot say with all honesty that we could not have accomplished more with less effort. I must say that as one who has been in some facet of the business of testing during my entire professional career, I understand the frustrations of the business. I know it seems that test hardware deliveries are always late -That the hardware is never shipped complete - and that supporting GSE never operates properly, I also know that the test organization is usually the last one to be called into the program and the last one to be advised of the test requirements. I also know that all schedule slippages are to be made up by the test organization. I've seen for myself the long hours worked each day seven days a week for months at a time.

Above: Apollo Block II Saturn I aerodynamic integrity. Langley wind tunnel. Image credit: Great Images in NASA (GRIN).

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Likewise, I have talked to many people who changed jobs and wound up in a test organization. Many have told me they have never had such a challenging, interesting and

rewarding job. I consider the early apprenticeship I served in a test organization the most valuable experience I have received, and as a matter of policy, I require cooperative students assigned to my organization to spend part of their on-the-job training in our Thermochemical Test Branch. The contributions of testing to the Mercury, Gemini and Apollo Programs are quite evident. I'm sure many in the audience were outstanding contributors to the success of these programs, I hope your deliberations here today and tomorrow am fruitful and enlightening, and will contribute to even more efficient test operations in the future. Test hardware, facilities, manpower, and time are the major items of expense in the development of spacecraft and boosters. We need all the talent and help we can get.

Above: Vacuum instrumentation research at Lewis Research Center, now John H. Glenn Research Center. Image credit: Great Images in NASA (GRIN). 1960. Aeronautical research.

Above: Image credit: Copied from an earlier page in this issue, four pages before this page.

Right: Excepts from the Thibodaux biography on the NASA oral history web site.

NASA Johnson Space Center Oral History Project
Biographical Data Sheet

NAME: Joseph Guy Thibodaux, Jr.

EDUCATIONAL BACKGROUND:
BS in Chemical Engineering, Louisiana State University, Baton Rouge, Louisiana 1942

MILITARY EXPERIENCE: Officer, United States Army (1943-1946)

PRE-NASA CAREER:
Officer, United States Army Corps of Engineers, Burma, Pacific Theater of Operations (1943-1946)

National Advisory Committee for Aeronautics (NACA) Langley Memorial Aeronautical Laboratory/Langley Research Center, Langley Field, Virginia
Propulsion Engineer, Pilotless Aircraft Research Division (PARD) (1946-1949)
Head, Model Propulsion Section, PARD (1949-1955)
Head, High Temperature Materials Section (1955-1958)

NASA CAREER:
NASA Langley Research Center, Langley Field, Virginia
Chief, High Temperature Materials Branch (1958-1964)
Consultant to Space Task Group (STG) Director (1958-1964)

Chief, Propulsion and Power Division, NASA Manned Spacecraft Center/Lyndon B. Johnson Space Center, Houston, Texas (1964-1980)

PROFESSIONAL & HONORARY SOCIETIES:
- Fellow, American Institute of Aeronautics and Astronautics (AIAA)
- Chairman, Houston Section AIAA
- Member, AIAA Technical Committee on Solid Rockets
- Member, NASA Research Advisory Committee on Chemical Propulsion
- Member, Interagency Chemical Rocket Propulsion Group

AWARDS & CITATIONS:
- NASA Exceptional Service Medal (twice in 1969)
- AIAA James H. Wyld Propulsion Award (1970)