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Lear Siegler Instrument Division's Manned Spaceflight Systems

An Interview with John H. Glenn Jr: Godspeed

The NASA Art Program: Technology, Art, and Contested Visions of Progress

The Short Life of Akjuit Aerospace and SpacePort Canada

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Features

Oral History

Front Cover Caption

The late Ohio Senator John Glenn is shown enjoying a tour of the flight deck in the orbiter *Columbia* at the Orbiter Processing Facility 3 at Kennedy Space Center.

He is pointing to one of the Shuttle's attitude-director indicators (ADI) whose historical development is covered in this issue. Glenn, who made history in 1962 as the first American to orbit the Earth, completing three orbits in a five-hour flight aboard *Friendship 7*, would go on to fly his second space mission aboard Space Shuttle *Discovery* in October 1998. Glenn died on 6 December 2016 at age 95.

Credit: NASA

Museums and Archives

Book Reviews

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On Course to Tomorrow: A History of Lear Siegler Instrument Division's Manned Spaceflight Systems 1958-1981

By Glen E. Swanson

Abstract

This article examines the historical development of human space systems at Lear Siegler Inc., Instrument Division (LSI-ID) in Grand Rapids, Michigan (now GE Aviation Systems). Specifically, it explores those systems built at LSI-ID and used in the X-15, X-20 Dyna-Soar, Gemini, Gemini B/MOL, Apollo, and Space Shuttle. In addition to the products developed, the author explores reasons why LSI-ID first entered into the business of developing human spaceflight systems in the late- 1950s only to distance itself entirely from this product area by the mid-1980s.

Introduction

The legacy of the Lear Siegler Inc. Instrument Division of Grand Rapids, Michigan, began in 1930 when aviation pioneer and inventor William P. Lear developed a reliable automobile radio. Generally acknowledged as the best car radio then on the market, the entrepreneurial Lear poured the profits from his first successful business venture back into his company, then known as Lear-Wuerful Corporation. Out of this investment emerged Lear's first aviation-related products—a series of low-cost, reliable, lightweight aircraft radio equipment designed for both commercial and general aviation.

By 1931, the name of the company changed to Lear Developments, Inc., followed by a move to New York City three years later when the company established a small laboratory and manufacturing plant on Long Island to focus on the design, development, and manufacturing of airborne radio transmitters, receivers, and direction finders. At this time the "Lear-O-Scope Radio Direction Finder" was developed, further advancing the fledging new arena of radio-electronic aerial navigation. By 1939, the new Lear Avia, Inc., developed the first practical commercial automatic direction finder. Its great accuracy, combined with small size and price, "took off" with aircraft manufacturers, leading to record worldwide sales.

In 1940, the company continued to grow, relocating to Vandalia, Ohio, near Wright Field. It was during this time that the "Learmatic Navigator" was developed, an instrument that provided pilots with straight-track navigation utilizing available radio station frequencies. This invention proved to be so successful that the company was given the annual Frank H. Hawks Award in honor of the most outstanding contribution to aircraft navigation for that year.

What eventually emerged as the modern Lear operations began in 1941 when the company relocated to Piqua, Ohio. This move helped increase both the manufacturing and engineering capabilities of the company. Because of high production demands brought on by World War II, it became necessary to develop another branch manufacturing facility. In 1943, a plant was established in Grand Rapids, Michigan. The following year, the company's name changed to Lear, Inc., and in 1945, its headquarters moved to Grand Rapids. By 1946 all activities were transferred from Piqua to Grand Rapids.

The principal product line of the Grand Rapids division—aircraft instruments and automatic flight control systems—began with a five-year research program conducted in coordination with the Air Force to develop an automatic pilot and approach coupler for jet aircraft. In 1949, Lear developed the F-5 Automatic Pilot with Approach Control Coupler System, which proved to be so successful that it won Bill Lear the coveted Collier Trophy in 1950 for that year's "greatest aviation achievement in America."

As an outgrowth of the F-5 autopilot, Lear began producing small commercial autopilots suitable in size, weight, and price for use in executive aircraft. During the development of the F-5 autopilot, Lear became involved in the manufacture of gyroscopes, leading to the company's emergence as a world leader in the design and production of advanced vehicle reference systems.

In 1962 Lear, Inc., and the Siegler Corporation merged to form Lear Siegler Inc. (LSI). As a result of the new merger, the Grand Rapids facility became the Instrument Division (ID), and cor-

porate headquarters moved to California. The Instrument Division (LSI-ID) became the largest LSI division, and over the next 20 years, demonstrated progressive leadership in the development of precision electronic instruments for aircraft, missile guidance systems, and space vehicles.

As part of the massive restructuring and downsizing that the aerospace industry as a whole underwent in the 1980s, LSI-ID, like many other companies, changed ownership and became part of Smiths Industries (SI), a multinational corporation based in the United Kingdom.*

The rich heritage that founded LSI-ID's work in the area of precision instrumentation did not go unnoticed during the rise of the US space program. What follows is the story of the Instrument Division's role in America's human space program, how it entered into this great adventure, the products that it created and flew into space, and why it decided to withdraw from the space business by the mid-1980s.

The X-15 Program

The year 1957 brought the United States into the Space Age following the launching of *Sputnik*. Lear became a part of the nation's collective interest in human spaceflight through its early work with the X-15 research program. The following year, the Wright Air Development Center (WADC) approached the Grand Rapids division to supply a three-axis flight director-attitude indicator for installation in each of the three X-15 vehicles being designed and built by North American Aviation under a project sponsored jointly by the United States Air Force (USAF), the National Aeronautics and Space Administration (NASA) and the United States Navy (USN).[1] Lear received the WADC contract as a result of its previous contributions in the field of flight indicator development.

"The WADC had worked with LSI-ID quite a bit in the area of attitude indicators,"[2] said John Kearns, former project engineer with the USAF program for Control and Display. Kearns spoke in retirement about Lear's early involvement with the X-15 program in the late 1950s and how this work led to the Instrument Division's securing its first space-related contracts.

"Colonel John Martin, who was head of the Flight Control Laboratory at WADC, decided to put forth a major push toward the development of flight instruments and cockpit improvements. He wanted to pursue a contract for a complete cockpit development program, which led to Lear getting one of the first contracts for the X-15.[3]

Lear had previously been chosen to work with the Air Force to develop an attitude-director indicator for the F-102. "At the time, the F-102 was a very state-of-the-art high-performance jet aircraft," explained Kearns. "Aircraft maneuverability improved during this time period, and we began to have severe problems with attitude displays. The F-102 could turn upward and climb at a fairly steep angle such that it exceeded the display capabilities of the onboard attitude-director indicators."[4] The solution to this problem was found at Lear with an attitude-director indicator that allowed pilots to pitch at severe angles without affecting their readings. This unique instrument included a two-gyro platform that was separate from the cockpit instrument. The gyro platform would not get into a gyro-lock condition, allowing the pilot to fly directly vertical while still having the indicator respond properly.

The Lear attitude-director indicator built for the X-15 was a modified version of the same model used on the F-102 program. Like those that flew the F-102, the X-15 pilots relied on the Lear indicator to assure them that the longitudinal axis of the vehicle remained perfectly aligned with its flight path as they returned from the edge of space.

The Lear indicator supplied several different types of information to the pilot. The pictorial sphere gave the pilot the attitude of his vehicle with respect to the earth in terms of pitch, roll, and yaw. A vertical needle showed the side slip of the aircraft, and a horizontal pointer indicated the angle of attack. Yaw and pitch angles

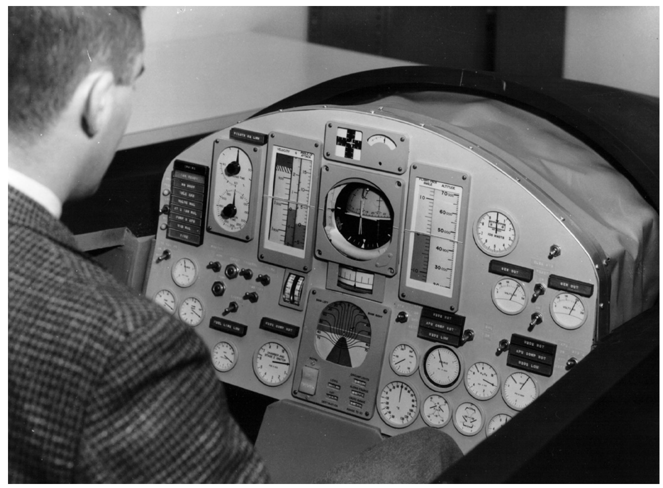
* On 15 January 2007, the Smiths Group, which included the Grand Rapids-based Smiths Industries Aerospace, was sold to General Electric for $4.8 billion. Smiths Industries Aerospace thus became an operating subsidiary of GE Aviation. Because of the numerous name changes that have occurred over the course of the company's history along with the fact that all but the Shuttle ADI were created prior to the acquisition of this division by Smiths Industries, the author has decided to keep the Lear name and use the following derivatives interchangeably throughout this article when referring to the Grand Rapids Division: Instrument Division, ID, Lear or LSI-ID. (Sources: "GE To Acquire Smiths Aerospace, Extending Aviation Offers; Plans JV with Smiths Group to Build Global Detection Business," GE Aviation official press release, 15 January 2007; "Smiths To Sell Aerospace Ops to GE for $4.5B," Smiths Aerospace press release, 4 May 2007)

revealed the displacement between the direction toward which the vehicle pointed and the direction in which it moved. A horizontal needle indicated the desired angle of attack for the moving vehicle.[5] A turn and bank indicator located at the bottom of the sphere warned the pilot of any deviation from his flight path at high speeds and helped him make coordinated turns at low speeds.[6]

As a follow-on to the work being done by Lear on the X-15, in August 1962, the Instrument Division began participating in a USAF Advanced Technology Program to develop an integrated flight control system concept for an orbital space mission. One phase of this Air Force program involved the flight test and evaluation of the flight control system in the No. 3 X-15 research aircraft. Both engineering and flight personnel at Lear and NASA's Ames Flight Research Center were responsible for design inputs and flight operations. In addition, LSI implemented an X-15 simulator both for use in control-display system development and pilot familiarization. The Instrument Division designed the primary flight instruments, in-flight guidance and control systems. Although the control-display elements in the simulator did not possess all of the features of the actual system, it presented all of the flight control parameters.[7]

Because of the Lear X-15 simulator program, the division played host to many of the pilots that flew the actual vehicle. In January 1963, NASA's chief pilot for the X-15 program, Joe Walker, visited the Instrument Division, followed by Air Force pilots Major Robert Rushworth and Major Robert White.[8] In September of that same year, Lear briefed USAF pilot Joe Engle on the simulator, and a few days later briefed NASA pilots Milt Thompson and Jack McKay.[9]

By participating in the X-15 program, the Instrument Division gained valuable experience and exposure along with respectability in the field of custom-made attitude-director indicators for high-performance aircraft. In summarizing Lear's role in this program, Kearns explains that "the X-15 was a one-of-a-kind experimental program that used the same basic instrumentation that was developed for the F-102. Lear focused on the engineering for putting these instruments into the X-15 and was very successful." Kearns pointed out that "the modified 4060 Attitude-Director Indicator built for the X-15 worked so well that versions of this same model went on to be used in the Gemini through Apollo spacecraft."[10]



Top: Bill Lear (seated) inspects the X-15 cockpit simulator. To his left is Jerry Snider, manager of Control Display Operations; Hahns Thiry, vice president of Engineering; and Joe Walsh, Instrument Division president.
Credit: Lear Instrument Division Archives

Bottom: A close-up of one of the mockup X-15 control panels built by Lear. Prominently shown in the center of the image is the attitude-director indicator, which was built at the Grand Rapids Division.
Credit: Lear Instrument Division Archives

Advance Engineering Division Control-Display Systems Group

It was during the early work in the X-15 program that a group of engineers, scientists, and systems analysts organized a separate operating division at LSI-ID. Known as the Advance Engineering Division, it consisted of two departments: Instrument Development and Advance Systems Research.

The primary purpose of Advance Engineering was to formulate and develop new concepts for use in the

X-15 Attitude-Director Indicator Design Team: Pictured are some of the original Lear Instrument Division's "Learites" responsible for the X-15 attitude-director indicator (ADI). In the first row, left to right, Frank Breiner (mechanical design) holding the indicator's pitch angle set unit; Stan Gustafson (mechanical design) holding the director control; Ward Goodrich (electrical design engineer) holding the indicator itself; and Dick Schulmeyer (X-15 project engineer) holding the rate gyro. In the second row are Ed Yalacky (lab tester), Dennis Boyd (instrument technician on the director control), Mat Calsbeck (instrument technician on the rate gyro), Robert Vanderbei (model shop planner for the project), and Bob Schroeder (mechanical designer on the indicator). In the last row are Bob Miller (lab supervisor), Pete Lindemulder (instrument technician on the indicator), Walt Redington (instrument technician on the pitch angle set unit), and Harold Saphouse (instrument technician on the amplifier). Source: December 1958 *LearLog*.

design of Lear's future products. While the regular Engineering Division shared this goal, management felt that a separate organization could more easily devote its full energies to the strategic use of Engineering, concentrating on meeting the challenges and problems posed by complex future systems.

As one of the "older" and larger operating groups of the division, the Control-Display Systems Group acquired extensive experience in its particular field and achieved wide recognition among both the military and industry as a responsible, progressive, and creative organization. This group specialized in the integration and design of instrumentation systems. Working on the assumption that complex electromechanical and electronic systems must be planned around and include the human as the controlling element, the group applied human factor principles in establishing an efficient and effective "whole system" operation to instrumentation system development and design.

Overall, the state of cockpit design in conventional aircraft lagged far behind that of aerodynamics, propulsion, and structural design. "We sought to develop a systematic approach to cockpit design," said Ed Krug, associate manager of Lear's Advance Engineering Division. Lear built up a special group of people within the Control-Display Systems Group including psychologists, industrial engineers, designers, aeronautical and electrical engineers. "We formed a Whole Panel Study Group," explained Krug "whose purpose was to develop a systematic approach to cockpit design. Prior to this, most cockpits were loosely thrown together assemblages without a lot of thought given to their design."[11]

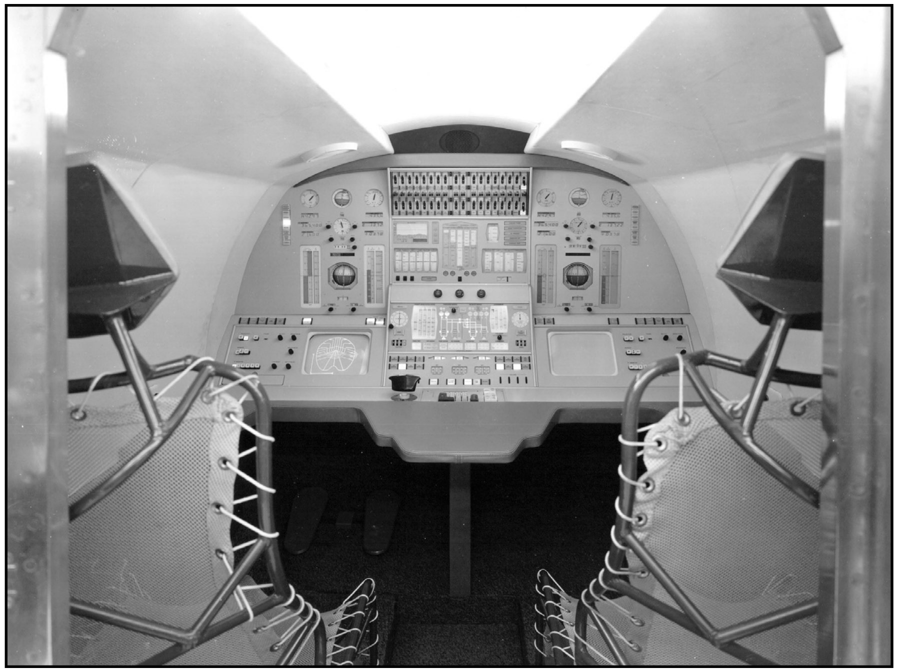
Many safety engineers thought that a number of accidents commonly credited to pilot error actually were caused by the inability of the cockpit to support pilots with essential and interpretable data during critical periods of flight. They reasoned that the instrumentation problems experienced in conventional aircraft would be multiplied many times in spaceflight.[12] As a result, beginning in the late 1950s, this group devoted a large share of its effort to the instrumentation problems of a variety of man-machine systems, including space weapons systems.

One of the earlier projects assigned to this group involved the development of a new approach to the design of aircraft instrument panels and controls under a contract with the Flight Control Laboratory at WADC. In addition to the submittal of a formal technical report, Lear-produced 11-minute movie titled "Maximum Performance through Cockpit Design" narrated by entertainer Bob Cummings, who presented the results of the program. The final report contained a summary of the work performed and conclusions reached during the period of 1 July 1957 through 1 July 1958.[13]

Following this report, Lear was asked by Colonel John Martin of WADC's Flight Control Laboratory to assist in the development of a new approach to instrument panel and cockpit design that used the USAF Whole Panel Concept. After considerable study and examination of cockpit organization theories, the concept of a pilot-manager emerged, with the pilot's tasks outlined according to this concept. Individual instrumentation, illustrative artwork, and background material provided support for the approaches and ideas used

along with assembled mockups showing the completion of different phases of the study program. Under this program, the group developed—and exemplified by the mockup technique—a series of progressively refined instrument panels, reflecting the principles generated under the Air Force Whole Panel Control-Display Integration Program. Since this program was an advancement in state-of-the-art instrument panel and cockpit designs for the Air Force, under this contract Lear studied various types of planned weapons systems along with finding new approaches to their display problems.

On 1 July 1958, the Whole Panel Study Group, under another Air Force contract, began work on an extension of the earlier program. Completed in July 1960, this program studied space vehicle instrumentation and crew station design for a hypothetical weapons system. Program tasks included a review of future weapons systems and other systems necessary to achieve space flight and a systematic review of present and future operational trends and tactics to predict probable mission profiles, including semi-orbital and orbital space vehicles. The program examined requirements for human control and spaceflight training, with engineers constructing a full-size crew station mockup. The mockup incorporated certain operational instruments as examples of these new concepts and was delivered to the Flight Control Laboratory at Wright Patterson. Upon conclusion of this program and at the Air Force's request, Lear continued exploring and refining methods of cockpit design for use in future spaceflight display development.[14]



Full-scale Mark IV cockpit interior built by Lear for the USAF Wright Air Development Center Whole Panel Study. Credit: Lear Instrument Division Archives.

Space Vehicle Crew Capsule Study

The Wright Air Development Center awarded Lear a contract to study the requirements for human spaceflight and, on the basis of that research, design and build a crew capsule for a space vehicle. The Lear Advance Engineering Division conducted the project in support of the Air Force's Instrumentation Integration Program. The contract covered a crew capsule either for an orbit-to-orbit space vehicle to be launched and recovered from a space station or for a space vehicle capable of taking off and landing on another planet. The function of the space station would be equivalent to that of a landing strip or aircraft carrier in that it would serve as a base of operations for a defense or reconnaissance vehicle. In plotting the layout of the capsule, Lear applied the pilot-manager design concept previously used in arranging the whole panel cockpit. The idea behind the pilot-manager cockpit was that it freed the pilot from routine tasks best performed by automatic devices, allowing him instead to use his intelligence to manage the vehicle and to cope with unforeseen situations. The new space capsule project was an extension of the Lear Whole Panel Study and Development Program for the Wright Air Development Center.

The program first covered special problems of spaceflight, including spatial translation, vehicle mechanics and crew station environment; and second, the design and development of the crew area, complete with instrument displays, control knobs and switches. Also included in this space study were weapons system definition, mission prediction, space navigation, orientation, propulsion, power generation, the creation of a livable artificial atmosphere, and food, water and oxygen requirements.[15]

Mark III Cockpit

Another contract with the Wright Air Development Center in

support of the USAF-WADC Whole Panel Study and Development Program involved the research and development of a full-size cockpit mockup designed by Lear for a hypothetical aircraft of the next decade.[16] Designated the Mark III, the model represented the third and final phase of a year-long study that began in 1957 with the Lear Advance Engineering Division goal to design and build a cockpit suitable for hypersonic aircraft capable of operating at Mach 5.

The pilot-manager design influenced the Mark III cockpit as Instrument Division engineers felt that maximum performance of an aircraft can be realized only with a logical and well-defined division of labor among the pilot, crew and automatic aircraft devices. Engineers arranged each display according to the pilot's needs. The center panel displayed vital information directly in front of the pilot, with less-frequently used indicators, dials and switches to the right and left. Related information was grouped together for quick assimilation by the pilot.[17]

The purpose of the study was to investigate the shortcomings of current cockpits and to anticipate any problems that might exist in future aircraft. The study further revealed that weapon system efficiency increased when the cockpit was an integral part of the machine rather than a tacked-on appendage.[18]

Mark IV Cockpit

The final and most complex application of the WADC-defined methodology for whole panel control-display design completed by the Advance Engineering Division at Lear was the Mark IV orbital bomber control-display subsystem mock-up. The Air Force contract had two major objectives. One was to explore, expand, and refine the methodology while the other was to apply the procedure in a practical test case, both to establish its validity and to provide an example of its application.

The weapons system selected for this application represented the first detailed analysis of displays and controls required for an Earth-orbiting, missile-launching system. It was to be operated by a four-man crew in a 300-mile high orbit for periods up to 30 days and with five onboard missiles.[19] It is not clear that the work done on this mock-up was in any way related to the X-20 Dyna-Soar, which was also under development by the Air Force at this time. During a Lear briefing covering the results of the 17-month study, conflicting opinions were provided by Lear project managers and Air Force officials about a possible relationship between the Mark I-IV cockpit studies and the X-20 Dyna-Soar. One USAF official stated that further discussions were classified while another said that the weapon system application was purely hypothetical.[20] However, Kearns mentioned that Charles Snyder, an Air Force employee, was a branch chief for the organization developing advanced instrument displays (including the USAF-Lear programs). When the Dyna-Soar System Project Office (SPO) was formed, Snyder was assigned to that office to deal with the instrument/cockpit programs. According to Kearns, Snyder's experience with the Lear Mark I-IV efforts greatly helped him in his new responsibilities.[21]

Semi-operational instruments dominated the Mark IV display system. Because of the vehicle's orbital mission parameters, Lear developed several new instruments in the mock-up. These include a rate indicator, displaying rate of rotation of the vehicle about each of its axis, and a temperature indicator, showing body and nose temperature during reentry.

"They also looked at using three-dimensional displays in the mockup," said Kearns. "One idea came from Max Olinger at Lear. He used a glass container, which turned out to be nothing more than a fishbowl. You could shoot a beam of light into it, but in order to make the beam visible you had to have some particles floating around inside. In order to keep these particles floating around, Olinger threw a few goldfish into the bowl. This was an example of the type of innovation that was common back then."[22]

A set of unique handgrips served as the primary controls for maneuvering the vehicle. Padded rests supporting the pilot's and copilot's arms made up these controls along with grips oriented so that the palm angled downward, inward and toward the pilot. The right-hand grip controlled all three axes, with maneuvers generated by the application of force about the appropriate axis without actually rotating or moving the grip. This unique right-hand grip controller may have been influential in the design of the side arm flight controller that was to be used in the X-20 Dyna-Soar cockpit. The left hand grip provided switches for critical vehicle controls.[23] "This was the first control unit for fly by wire," said John Kearns.[24]

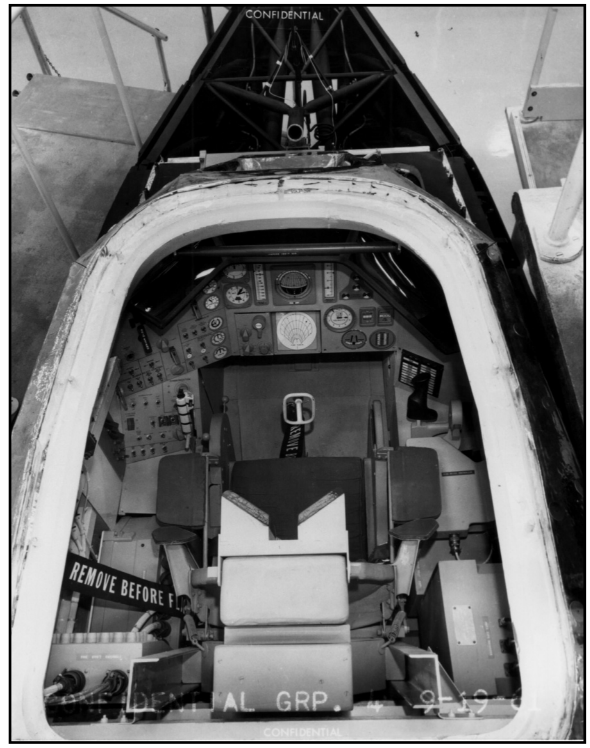
Ed Krug explained that, "in designing the Mark IV cockpit control and display system for an orbital bomber, we were able to work without the usual constraints

forced upon designers of conventional airplane cockpits who could not depart too radically from long-used cockpit configurations and instruments."[25] Krug, worked on B-58 cockpit instrumentation at Convair before joining Lear. He retired from LSI-ID in 1986 after serving as associate manager of Advance Engineering Division.

"Because of its shape, the Mark IV cockpit was also affectionately called the "beer can," recalls Kearns. "Lear had the finished cockpit simulator delivered to WADC and mounted it on a motion-base for simulator operation so that people could actually sit inside and fly it."[26] Advance Engineering personnel "flew" numerous reentry routes to evaluate the finished Mark IV cockpit. The main viewing screen interfaced with a computer to display to the pilot the parameters of a typical hypersonic glide vehicle during reentry. With this display information, pilots made corrections by moving the hand control. The simulator covered the period at 60 miles in altitude —when most critical control problems occurred. At this point, a vehicle travels five miles per second down to an altitude of 20 miles, when velocity drops to less than one mile per second. Dissipating this enormous amount of kinetic energy while avoiding burning up was a challenge for most test pilots.

Watching the displays, "pilots" controlled the simulated reentry vehicle using the unique force-control hand grip. First action at the beginning of the reentry flight is to elevate the nose to a high angle, "mushing" into the outer fringes of the atmosphere underbody first, producing a rapidly rising underbody temperature. If the pilot pushed the nose down too soon, he would not slow down sufficiently to prevent the nose from burning up as he encountered denser air. If he kept the nose up too long, the underbody would burn. This is the first of several critical up-down maneuvers that the pilot must control with precision and timing in order to successfully complete his mission and land at the chosen landing field. Two or three of these "skips" may have to be made before enough speed is lost to make a final safe reentry. As long as the pilot's instruments show he is in a safe reentry corridor, he can continue "flying" down to an altitude where heat is no longer a problem (about 20 miles up), and the test is finished. If the pilot's maneuvering is wrong and he "burns-up," warnings on the displays show his error and the computer automatically terminates the program.[27]

The Control-Display Systems Group and the work they produced at Lear were not without their critics. "I don't know of anything that they worked on in the Advance Engineering Department that ever resulted in a



A carryover from the LSI proposed Mark IV cockpit can be seen in this X-20 Dyna-Soar cockpit photo. Shown is a variation of the Model 844-2050 X-20 cockpit revealing a set of unique handgrips that served as the primary controls for maneuvering the Dyna-Soar vehicle. Like those proposed for the LSI designed Mark IV, we can see the same padded rests supporting the pilot's arms along with the side arm flight controller (to the right) that would not only have controlled the flight surfaces, but would have also been used to control the on-orbit reaction control system of the vehicle. Photo courtesy Roy Houchin via Al Misenko at the history office/Aeronautical Systems Division, Wright Patterson AFB, Dayton, Ohio and Terry Smith, "Dyna-Soar X-20: A Look at Hardware and Technology," *Quest*, Vol. 3, No. 4, Winter 1994, 26, 31.

manufacturing job," said Tom Hekker, Instrument Systems manager at LSI-ID.[28] In spite of such criticisms, the various studies and resulting cockpit mockups that were produced was, in retrospect, important in that it embodied the new "systems" methodology to derive design requirements for vehicle control problems.

Through the work done at Lear, the Air Force sought to eliminate the "cart before the horse" type of design prevalent in many aircraft programs at that time. Lear first established the weapons system's specific requirements— in this case the orbital bomber—from which they arrived at an analytical description of the

vehicle's mission and then a description of the vehicle itself. Rather than designing the cockpit as an afterthought, the Air Force initiated the work at Lear in the preliminary stages of the program, thus establishing essential integration between hardware and its human operators at the outset.

Much of the activity in this area at Lear diminished shortly after General Bernard Schriever became commander of the Air Force Space Systems Command. "When they [NASA] had the first manned spaceshots with Mercury and later Gemini, there was no similarity between what they [NASA] were doing and in what we did," said Kearns. "Our work was more future oriented but it was eventually picked up and used by NASA. They used the engineering and methodologies that we developed on later programs."

X-20 Dyna-Soar

Paralleling the development of NASA's civilian human space program, the Air Force embarked upon its own goal of developing a reusable human spacecraft. The end result produced a series of detailed studies and full-scale mockups of what became known as the X-20 Dyna-Soar. The Dyna-Soar program sought to develop a crewed orbital satellite reconnaissance / interceptor / bomber that allowed pilots immediate access to space for intelligence gathering exercises, to destroy enemy satellites, and engage in orbital bombing. Dyna-Soar was designed to be rocketed into space, where it would orbit at nearly 18,000-miles per hour, then re-enter the earth's atmosphere to make a pilot-controlled landing on a predetermined landing strip.

LSI Instrument Division engineers built an attitude-director indicator for installation aboard the X-20 Dyna-Soar. One of the few flight instruments designed for use by the space pilot during all phases of flight—launch, orbit, re-entry and landing—the device provided an artificial horizon for controlling the vehicle under both spaceflight and atmospheric flight conditions. The LSI attitude-director indicator presented the vehicle's elevation, roll, and yaw on a three-axis sphere and flight director information on crosspointer needles superimposed on the sphere. The indicator was one of the critical instruments that the pilot relied upon during reentry to assure a safe approach through the atmosphere.[29] In addition to the attitude-director indicator, LSI provided a rate-of-climb instrument display showing the rate of climb or rate of descent from 0-2,600 feet per second. These specially developed units were built under contract with Boeing, the prime system contractor for the Dyna-Soar program, and developed by the Air Force's Aeronautical Systems Division in cooperation with NASA.

When the United States and the Soviet Union accepted mutual satellite overflights in 1963, Dyna-Soar became a hindrance, threatening to unbalance international stability. Ultimately, Air Force leaders placed military requirements ahead of political necessity and lost Dyna-Soar, and the "high ground" of space, to a peace initiative. The diplomatic quest for safe passage of American satellites outpaced military efforts to protect them.[30] As a result, on 10 December 1963 the Dyna-Soar program was cancelled, and all work done at LSI-ID on this program ceased. Prior to the cancellation, all design and development was completed on both Lear instruments. Lear built one engineering prototype of the rate-of-climb instrument along with constructing two engineering prototypes of the attitude-director indicator; one unit shipped to Boeing for simulation studies while the second unit was subjected to design integrity tests at Lear, which successfully met all environmental requirements.[31]

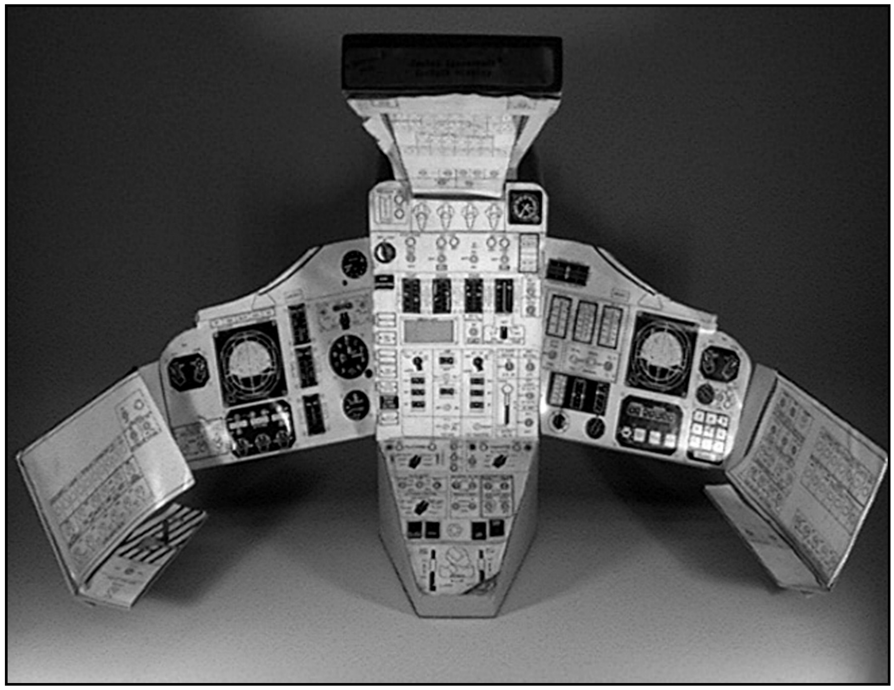
The Gemini Program

One of the Instrument Division's largest contributions to the human exploration of space came during the Gemini program. Lear provided 11 instruments as part of the cockpit instrument panel that flew aboard each crewed Gemini mission.[32]

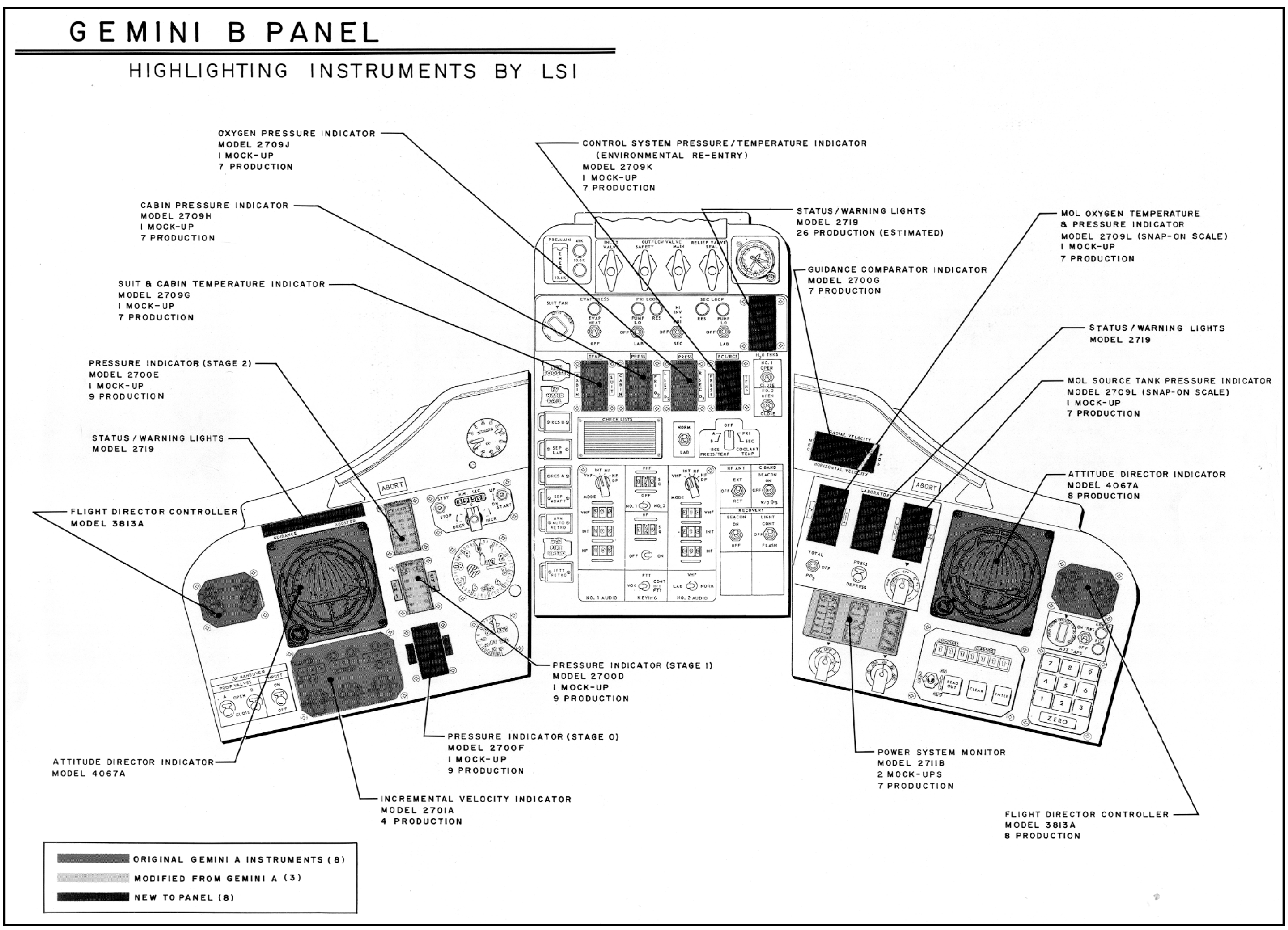
"I think it was because the spacecraft interior was most like that of an aircraft," commented Tom Hekker when asked why so many instruments were bid upon and won by LSI-ID for the Gemini program. "We were among the foremost aircraft instrument suppliers for many years, and it seemed natural that NASA should turn to us as a supplier of cockpit instruments for their space program," added Hekker.[33] The Instrument Division developed seven instruments for the McDonnell Aircraft Corporation, prime contractor for the Gemini spacecraft, along with one instrument built for IBM as part of their work in the program.

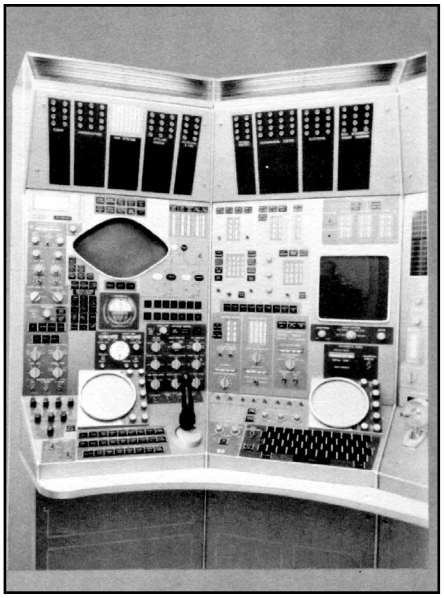
"This was the first time that the Instrument Division became involved in the development of manned spaceflight instrumentation [other than the X-15]," said former ID president Joe Parini, "and there was a great deal of technical challenge to this." In explaining why we pursued contracts for the Gemini program, Parini states, "We sat

down with several of the engineers from McDonnell Douglas and, during the course of our meetings, our group realized that this could become a very exciting project from a technical point of view. We would be pushing the state of the art in trying to make the attitude-director indicator lighter and more rugged. By getting into the manned spacecraft hardware business, we could



The Gemini B-MOL cockpit control panel. The bottom image shows details of the instruments while the above is a 1/4-scale model built by the Instrument Division. Instruments outlined in black are those built by the LSI Instrument Division.
Credit: Lear Instrument Division Archives.





In February 1964, the Air Force awarded additional study contracts to Douglas Aircraft, General Electric and Martin for its Manned Orbiting Laboratory (MOL) Program. Under the GE study contract, Lear functioned as the total control-display subsystem manager. In support of this study contract, LSI completed several detailed definition studies which included these full-scale instrument panel mockups of basic station consoles. These were delivered to GE for integration with their MOL mockup. Astronaut L. Gordon Cooper (center) inspects a smaller desktop model of one of the MOL instrument panels during an October 7, 1964 visit to the Instrument Division in Grand Rapids. To the left of Cooper is then US Representative Gerald R. Ford. Credit: Lear Instrument Division Archives

begin to push the state of the art and increase the excellence level of this whole set of instrumentation."[34]

Dominating the center panel of both the commander and pilot's seat of the Gemini spacecraft were Lear-built attitude-director indicators. These specially modified indicators (one on each side) featured low power consumption along with minimum weight, providing an all-attitude unambiguous display of the spacecraft's attitude along with displaying roll, pitch, and yaw command information via director needles.

The Instrument Division submitted its first Gemini proposal, for the attitude display system, in January 1962. A contract was awarded by McDonnell in June of that same year with two mock-up units shipped the following month. Three engineering prototypes—two for McDonnell and one for IBM—shipped on 1 October 1962, followed by two McDonnell production systems shipped on 12 February 1963 for testing prior to final modifications. Also provided were two flight director controllers. These instruments provided the switches and necessary electronics to allow selection of command information for display on the attitude-director indicator. After the first successfully crewed Gemini mission was underway, other contract awards for hardware soon followed.

Many people at the Instrument Division had an important part in the Gemini program, but one man in particular stood out for his unique role. Harry Markus, former LSI section head for Indicators and Air Data Instruments, not only worked on designing and building the instruments for the Gemini program, but was fortunate enough to view the first crewed Gemini launch live at Cape Kennedy. On 23 March 1965 Markus along with Hal Walton, Instrument Division product information manager, were on hand at the launch of *Gemini 3* to tell the story to the assembled press of the Instrument Division's contributions to the Gemini program.

Among the news coverage highlights during the mission was a live network television interview in which Jim Bell, an Instrument Division representative at McDonnell Aircraft, explained the operation of the Lear-built attitude-director indicator to a nationwide audience while astronauts John Young and Gus Grissom flew overhead using one of the Lear indicators for navigation. Over the ABC-TV network, science correspondent Jules Bergman and astronaut Scott Carpenter were doing the same thing, except that Bergman had a complete Gemini control panel built, with the Lear instruments receiving feature coverage. At the request of the Grand Rapids Press and three local radio stations, Hal Walton telephoned colorful reports

Under subcontract to IBM, The Instrument Division designed and built an electroluminescent alphanumeric computer output display panel for the MOL program. This unique device had the capability of displaying both numbers and letters on a solid-state flat panel that could easily be read by astronauts. Credit: Lear Instrument Division Archives.

of the activities surrounding the launch and mission back to Grand Rapids.[35]

In recalling the events surrounding the Gemini program, Markus said, "To have a front row seat to history in the making—not many people have that opportunity. It's exhilarating to know that you were a part of something like this."[36]

Gemini B/MOL

The concept of an Air Force human spaceflight program using Gemini-type spacecraft to develop rendezvous, docking, and transfer techniques began during congressional hearings in February 1962.[37] By June of that year, the concept included using Gemini spacecraft as ferry vehicles for the Manned Orbital Development System (MODS)—a military space station designed for sustained operations in space.[38] The four-man MODS featured a variety of equipment and carried a cargo supply module with provisions for propulsion.[39] The name "Blue Gemini" first surfaced in August of that same year in a proposal to fly six Gemini missions with all-Air Force crews as a preliminary orientation and training phase of MODS.[40]

In late 1962, Defense Secretary Robert S. McNamara dropped Blue Gemini and MODS arguing that they "duplicated existing NASA projects."[41] McNamara believed that cooperation would ensure the most effective use of existing resources and sought to eliminate duplication of efforts while at the same time pressuring the Department of Defense to mesh their space projects with those of NASA.[42]

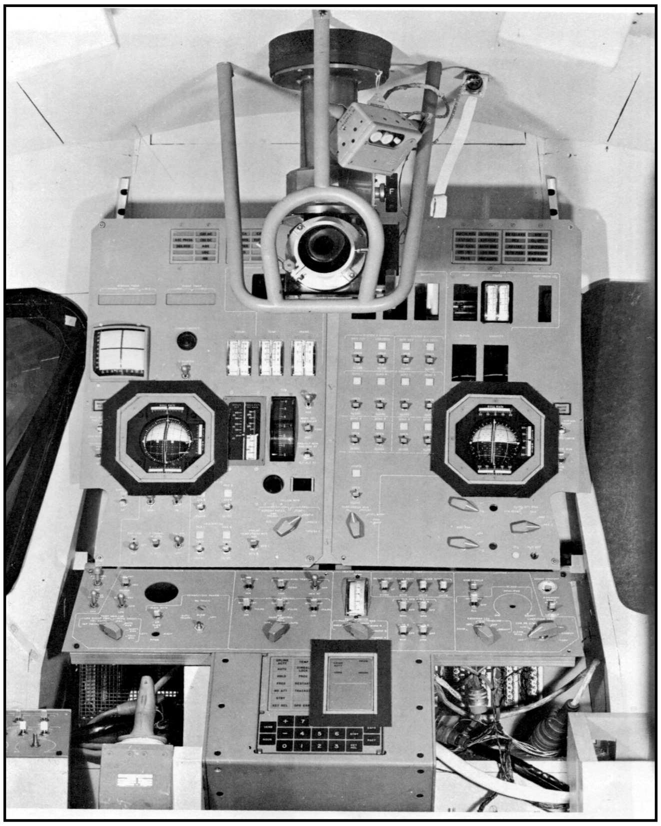
In September 1963, the Air Force began conceptual studies that eventually lead to the Manned Orbiting Laboratory (MOL) Program. MOL replaced the X-20 Dyna-Soar as the Air Force's major human spaceflight effort. As interest shifted from experimental programs emphasizing the means to control man's return from space to those focusing on man's use of space, MOL gathered significant support both within the Department of Defense and the White House.[43]

By January 1964, the initial objectives of MOL were outlined. These goals included the development of technology to improve military space capability (both human and robotic), the development and demonstration of human assembly of large structures with potential for military applications, and in-orbit servicing along with experiments designed to cover the spectrum of potential military applications including maintenance, repair, operation, reconnaissance, surveillance, and nuclear test detection.

MOL was designed to use a modified human Gemini spacecraft, called Gemini B, with a unique through-the-heat-shield access hatch. A Titan IIIC would launch both spacecraft and laboratory module as one unit. Project engineers reasoned that a combined launch helped minimize cost and maximize safety. Crewmembers sat in the Gemini B during launch, and once in orbit, transferred through the rear hatch to the laboratory module to perform military experiments. After completion of their mission, the astronauts returned to the Gemini B, separated from the laboratory module and returned to Earth. The labo-

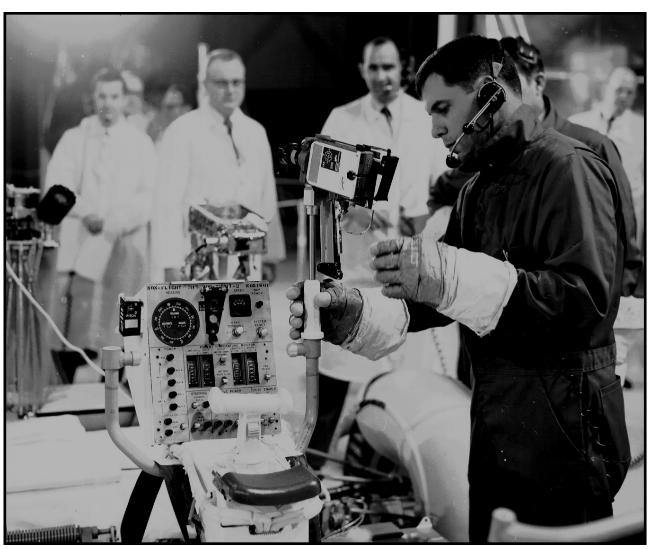
Astronaut Alan B. Shepard, Jr., left, chief of the Astronaut Office, NASA Manned Spacecraft Center in Houston, Texas, paid a visit to the Instrument Division in March 1969. Joseph Parini, right, assistant manager of Engineering, shows Shepard an LSI-built Model 4068E attitude-director indicator which was aboard both the Apollo command and lunar modules. Ed Krug, center, Computer Systems Division manager, also accompanied Shepard on a tour of the LSI facilities.

Credit: Lear Instrument Division Archives.



Top: The lunar module has two LSI Model 4068E attitude-director indicators, and a Model 8704A guidance and navigation computer display. The other six LSI instruments cannot be seen in this panel display. The attitude indicators were used to furnish the astronauts with pitch, roll, and yaw rate information. Credit: Lear Instrument Division Archives

Bottom: Lear provided directional gyros that were used onboard the Apollo lunar rover's navigational system shown here. Credit: NASA 71-H-490



ratory module remained in orbit awaiting ground command to deorbit for its fiery demise. A second Gemini B carrying a relief crew could rendezvous and dock with the laboratory module if extended operations were needed.[44]

Prior to the issuance of a formal Air Force contract, Lear participated on an unfunded basis with General Electric Missile and Space Division to develop a preliminary control-display subsystem for the MOL program. The Instrument Division had responsibility as control-display subsystem manager for both the basic station and experiment consoles. The results of the study produced a preliminary control-display panel design.[45]

In February 1964, the Air Force awarded additional study contracts to Douglas Aircraft, General Electric, and Martin. Under the GE study contract, Lear again functioned as the total control-display subsystem manager. In support of this study contract, the Instrument Division completed further system definition studies and, with updated requirements from the Air Force, refined their original control-display panel design, layout and mechanization techniques. LSI-ID built several full-scale instrument panel mockups of the basic station consoles, delivering them to GE for integration with their MOL mockup.[46] In addition, as a subcontractor to McDonnell Aircraft Corporation, Lear built 19 MOL cockpit display instruments for use in the modified Gemini B spacecraft.

One of the more unique pieces of hardware to emerge from Lear's work on the MOL program, and later applied to the Apollo Program, involved a state-of-the art technology called electroluminescence (EL). Electroluminescence produced an even light over large areas without the use of bulbs, tubes, or light fixtures. Its effect is similar to that of glow-in-the-dark paint used to illuminate clock faces. Electroluminescence involves the production of light through an electric field. A non-conductive sheet of material containing a phosphor is sandwiched between two sheets of electrically conducting material; the back sheet is opaque and the front sheet transparent. When electric current is run through the two outside sheets, the encased phosphor glows with a uniform light through the transparent sheet.[47]

Under subcontract to IBM, the Instrument Division designed and built an EL alpha-numeric computer output display for the MOL program. This unique device had the capability of displaying both numbers and letters on a solid-state flat panel that could easily

The late *Apollo 1* astronaut Roger B. Chaffee is shown shaking hands with his old boss, Charlie Hall, during a visit to the Lear Instrument Division in Grand Rapids on 18 December 1963. Hall was Chaffee's supervisor of the White Room at the Ionia Building during the summer of 1953, when Roger, a recent graduate of Central High School, worked for him pulling blueprints. Credit: Lear Instrument Division Archives.

be read by the astronauts.

As Bob Kurti, a technician at Lear and later project engineer for EL displays during the MOL program, explained, "We were the first to pioneer the use of electroluminescent technology in aircraft, and it was through this work that we were able to first apply EL displays in the MOL program. We were the leaders in the field." EL displays use very little power, produce very little heat, have a very long lifespan compared to traditional incandescent, gas tube or fluorescent display lighting, and can survive tremendous shock and vibrational forces.[48] "EL was the perfect solution for the rigorous environment of space," said Kurti.

Unfortunately, Lear could not fully demonstrate this technology's capabilities in the area of spaceflight until winning a contract with the Apollo program. On 10 June 1969, Defense Secretary Melvin Laird announced the cancellation of the MOL program.[49] As a result, an orderly phasedown of all MOL-related contracts and activities began with some developed technology and hardware transferred to NASA.[50] In a last-ditch effort, McDonnell Douglas made an attempt to interest NASA in MOL technology through a proposal entitled "Big G." Big G was essentially a ferry/resupply vehicle for the proposed post-Apollo Orbital Workshop. However, interest in space vehicle technology shifted from a capsule approach to a winged reusable lifting body, similar to Dyna-Soar, which later become known as the space shuttle. The Big G proposal was eventually abandoned, and the remaining artifacts of MOL became solemn reminders of what might have been.[51]

The late Shuttle astronaut Navy Captain Manley Lanier "Sonny" Carter Jr., (center) is shown holding the Lear-built Shuttle attitude-director indicator during an April 1988 visit to Smith's Industries Aerospace (formerly LSI). To his left is SI employee Dennis Boyd, senior engineering technician and at his right is Tom Larkin of purchasing. Both were awarded NASA's prestigious Snoopy award for outstanding and superior quality on space-borne projects.

Credit: SI Archives

The Apollo Program

Paralleling the natural progression of increasingly ambitious human space missions, in an effort to fulfill the nation's goal of landing a man on the Moon before the end of the decade, Lear continued building space hardware as the space agency advanced from the Gemini to Apollo programs.

"Who would not want to be in the Apollo program?" asked former Instrument Division project engineer manager Tom Hekker. "Everybody identifies with going to the Moon. We could not have turned this down."[52] Lear's previous experience in providing hardware for the Gemini program allowed it to successfully bid upon and receive contracts that contributed a total of 19 instruments and components to the Apollo program.[53]

As part of the Apollo guidance and navigation computer, a Lear-built digital electroluminescent display used on the display and keyboard (DSKY) assembly of both the command and lunar module guidance systems gave the astronauts a coded readout of what they were programming into the computer and a digital readout of flight information.[54] This particular instrument played a crucial role during the ill-fated *Apollo 13* mission when the crew had to manually enter critical data using the Lear-built display. This had to be done in order to force a quick return back from the Moon after the service module became critically damaged due to an onboard explosion of one of the liquid oxygen tanks. Joe Parini remembers the accident well. "The weekend that the accident occurred, we had an open line to Houston allowing us to give them information on our system's power

LSI-ID SPACE PRODUCTS 1958-1981

Model No.	Description	Units per System	Prime Contractor	Total Quantity
X-15				
4060	Flight Director-Attitude Indicator	---	North American	---
Gemini				
4067A	Attitude-Director Indicator	2	McDonnell	36
3813A	Flight Director Controller	2	McDonnell	33
2701A	Delta Velocity Indicator	1	IBM	20
2700B	Pressure Indicator (First Stage)	1	McDonnell	38
2700C	Pressure Indicator (Second Stage)	1	McDonnell	38
2709A	Indicator, Suit & Cabin Temperatures	1	McDonnell	65
2709B	Indicator, Cabin Pressure	1	McDonnell	65
2709C	Indicator, Oxygen Quantity	1	McDonnell	65
2711A	Power System Monitor	1	McDonnell	---
	Contract Type: Cost Plus Fixed Fee Contract Amount (Original): $3,500,000 Contract Amount (Final) $3,500,000			
Gemini B / MOL				
4067A	Attitude-Director Indicator	2		8
3813A	Flight Director Controller	2		8
2701A	Delta Velocity Indicator	1		4
2700D	Pressure Indicator (Stage 1)	1		32
2700E	Pressure Indicator (Stage 2)	1		32
2700F	Pressure Indicator (Stage 0)	1		32
2700G	Guidance Comparator Indicator	1		32
2709G	Suit & Cabin Temperature Indicator	1		32
2709H	Cabin Pressure Indicator	1		32
2709J	Oxygen Pressure Indicator	1		32
2709K	Control System Pressure/Temperature Indicator (Environmental ReEntry)	1		32
2709L	MOL Oxygen Temperature & Pressure Indicator (Snap-On Scale)	1		24
2706L	MOL Source Tank Pressure Indicator (Snap-On Scale)	1		24
2719A	Status/Warning Lights	2		26
2719B	Status/Warning LIghts	1		26
2711B	Power System Monitor	1		7
MOL				
8705A	Electro-Luminescent Alpha-Numeric Computer Output Display - Assembly	1	IBM	15

requirements which they needed in order to get back home."[55]

When the crew of *Apollo 11* landed on the surface of the Moon on 20 July 1969, the people at Lear took great pride in knowing that they helped bring them there and get them back safely. In the months following the completion of the mission, congratulatory letters arrived from all of the principal contractors, praising the work done by all the Instrument Division's employees in helping America successfully fulfill the historic goal of landing men on the Moon.

The Apollo Lunar Rover

The last major piece of Apollo hardware to be designed and flown in the human lunar program was the lunar roving vehicle (LRV). Designed and built by the Boeing Company and NASA's Marshall Space Flight Center, the LRV was a lightweight vehicle, weighing only 462 terrestrial pounds empty—70 pounds on the Moon. Battery-powered, it had a range of approximately 30 miles with a top speed of 8 miles per hour.

The "problem" of getting back to the LM from some distant geology station on the lunar surface was actually a trivial one. There were outbound LRV tracks to follow and, even if the astronauts weren't retracing their outbound course, there were plenty of landmarks to lead them close enough to see the 23-foot-tall lunar module on the surface. Because even the "flat country" on the Moon is rolling and everything but the LM is shades of gray, the problem of finding anything else—say a specific crater—could be challenging. As an example, during *Apollo 14* astronauts Alan

LSI-ID SPACE PRODUCTS 1958-1981

Model No.	Description	Units per System	Prime Contractor	Total Quantity
APOLLO				
8704A	CM Guidance & Navigation Computer Display	2	Raytheon	52
8701C	CM Delta Velocity Display	1	Autonetics	26
4068E	LM Attitude-Director Indicator	2	Grumman, Link, NASA	78
5841E	LM Gimbal Angle Sequence Transformation Assembly (GASTA)	1	Grumman	29
2464E	LM Time Delay Helium Pressurization	2	Grumman	43
8704A	LM Guidance & Navigation Computer Display	1	Raytheon	--
8701D	LM Radiation & Radiation Rate Display	1	American Scientific & Engineering	1
8702B	LM Abort Guidance Display	1	TRW	39
8702A	LM Propellant Quantity Indicator	2	Kearfott	79
8701B	LM Helium Temperature/Pressure Indicator	1	Kearfott	--
1903C	LM Integrating Rate Gyro - Floated	4	RCA	125
9010	Directional Gyro for Lunar Rover	1		--
	Contract Type: Cost Plus Incentive Fee (CPIF) Contract Amount (Original): $4,152,120 Contract Amount (Final): $4,495,445 Final Cost: $4,411,508.43 Target Fee: $297,540,000 Final Fee: $263,207.46			
SPACE SHUTTLE				
4069C	Attitude Direction Indicator	3	Rockwell	23

Shepard and Ed Mitchell walked to within 65 feet of the rim of Cone Crater and then, after a tiring climb and a fruitless search, eventually had to head back toward the LM without ever having actually looked into the crater.[56] With the LRV, the problem of finding geology stops was much less dramatic.

A "spacecraft on wheels," the LRV contained a sophisticated navigation system employing the use of wheel rotation counts and an internal gyro to measure distance, range, and bearing. The navigation system consisted of three major components: a directional gyro built by Lear,[57] odometers on each traction drive assembly that provided distance and speed information, and a small solid state computer called a signal processing unit (SPU). The navigation system worked on the principle that, when starting a sortie from a known point, entering speed, direction and distance traveled into the onboard computer allows the vehicle's position to be determined. Inputs to the navigation subsystem came from changes in the LRV direction with respect to lunar north (obtained from the directional gyro) and odometer pulses obtained from the wheel rotation of the third fastest wheel. For each increment of distance measured by the odometer circuitry, the SPU calculated the east-west and north-south distances traveled based on vehicle heading data from the gyro. The end results gave range and bearing to the LM as displayed on the control and display console.

The Apollo program came to a close with *Apollo 17*—the last human lunar landing—in December 1972. When the crew safely splashed down in the Pacific, it marked the end of Lear's major space activities. "Though not big in dollar volume," commented former Instrument Division President Ronald V. Paolucci, "our part in the space program has been of tremendous importance, not only to us, but for the technical advancements we have made possible. And add to that the wonderful amount of pleasure and pride there is in just being a part of this momentous time in the history of mankind."[58]

LSI–ID Space Studies 1958-1981

Program	Date	Type	Customer/Contract
X-15 Attitude Director Indicator	1958	Hardware	Unknown
Mark IV Whole Panel C-D Study	1958-60	System Study	USAF (ASD) AF-33(616)-5901
Flight Data Display System	1960	System Study	USAF (ASD) AF-33(616)-5901 SA/I-(60-1153)
Apollo C-D Study and Mock-up	1961	System Study	GE, Grumman
Apollo C-D Study	1961	System Study	Martin / LSI Sponsored
Apollo C-D Study and Mock-up	1961	System Study	GD/A
Apollo C-D Study	1961	System Study	MAC
Military Test Satellite System C-D Study	1961	System Study	GD/A
Space Guidance & Control Studies	1961-64	System Study & Technique Development	Lsi Sponsored
Rotating Space Station Stability & Control Subsystem Study	1962	System Study	NAA/LSI Sponsored
Selected C-D Problems for Manned Aerospace Vehicles	1962	System Study	USAF (ASD) AF-33(616)-8070
LEM C-D Study	1962	System Study	OD/A/LSI Sponsored
LEM C-D Study	1962	System Study	LAC/LSI Sponsored
LEM C-D Study & Mockup	1962	System Study	Northrop/LSI Sponsored
LEM C-D Study	1962	System Study	CVA/LSI Sponsored
Rocket Propulsion System Measurement & C-D Investigations	1962-63	System Study	Rocketdyne/ USAF AF 33 (657)-8739
X-20 Displays	1962-64	Hardware	Boeing/AF-33 (657)-7132
Gemini	1962-65	Hardware	IBM/NAS9-170
Gemini Displays and Controls Engine Pressure Indicators ADI & Flight Director Controller ECS Indicators Power System Monitor	1962-65	Hardware	MAC-NAS9-170
MODS C-D Study	1963	System Study	GE/LSI Sponsored
Manned Satellite Surveillance System Study	1963	System Study	USAF (SSD) / LSI Sponsored
MORL C-D	1963	System Study	GE / LSI Sponsored
X-15 C-D Panel Study	1963	System Study	NASA (FRC) / NAS 4-280
ACDS C-D Systems Study, Development, and Flight Test Program	1963-66	System Study Hardware Technical Development	USAF (RTD)/AF-33(657-9341
Procedures for Determining Operator Info. Req. Study	1963-64	System Study	USAF (RTD)/AF-33(657)10972
Apollo Display techniques, EL, Taps Instruments, Fluid Filled Meters	1964	Technique Development	LSI Sponsored
Rendezvous Vehicle Range & Range Rate Indicator Study	1964	System Study	LSI Sponsored
MOSS C-D Study	1964	System Study	LSI Sponsored
Spacecraft Digital Stability & Control System	1964-65	System Study Hardware	NASA (OART)/NASWW 1004
Crew Station Design Guide	1964-65	System Study	NASA (MSC)/NAS9-3671
LEM ADI & GASTA	1964	Hardware	GAEC/NAS 9-1100
MOL C-D System Study and Mockup	1965	System Study	GE/AF 04(695)778
Range & Range Rate Simulator Indicators	1965	Hardware	NASA (MSC) /NAS9-4121
Spacecraft Meter Investigation	1965	Technique Development	LSI Sponsored
High Contrast EL Display Study	1965-66	Technique Development	USAF(RTD)/AF 33(616)2841

Former Lear section head of Indictors and Air Data Instruments, Harry Markus, also agreed that it was well worth the time and effort to be a part of the space program. "Through the years," he said, "we have made a viable, comprehensive contribution. And it's a great feeling to know that it all worked." There are many ways to express reliability, Markus said, "but the best way is when the astronauts returned safely using your equipment."[59]

The Space Shuttle Program

The attitude-director indicator became the first piece of hardware built by the Instrument Division for America's human spaceflight program; over time, it eventually evolved to become the last. In 1974, Rockwell International Space Systems Division awarded Lear a $2.6 million contract to design, develop and produce the Attitude-Director Indicator (ADI) for the Space Shuttle. Even though the Instrument Division was awarded the contract, it was initially difficult to convince management to go ahead with development.

"We didn't want the job," said LSI-ID Technical Director Tom Hekker. "We were asked by Rockwell to do the Shuttle ADI after NASA told them that Lear was to build it." In part, NASA's decision to give the job to Lear as a non-competitive bid was based on the Division's past performance in developing similar instruments for the Gemini and Apollo programs. "They went with us because they knew what we were doing and that we had supported NASA's past manned space initiatives from Gemini through Apollo," said Hekker.[60]

After the Instrument Division won the contract, it initially had a problem in producing the Shuttle ADIs since manufacturing would not touch the job. Even though a majority of previous human space-rated instruments built by Lear were produced in engineering rather than in manufacturing, since the last days of Apollo and by the time of the Shuttle contract, management philosophies had changed. "We weren't going to get into the space hardware business anymore," said Hahns Thiry, chief engineer at LSI. "Space products brought new technologies (solid state techniques and reliability engineering plus a lot of green money) but no big production."[61]

"Engineering was afraid that this piece of hardware would not get the attention that it might need and deserve because it is on the space program," said Joe Parini. "I remember arguing about this program in my office since I was president of the division at this time. I supported the program because of the engineer in me. If I was a purely financial business person, I would have said 'forget the program.' But I believe that the business that we were in was an engineering business and engineers love a challenge...the Shuttle ADI program was a challenge."[62]

"They did not want this item in their area contaminating the rest of the production items," said Hekker. By contaminated, Hekker explained that "you have a whole bunch of people that have been taught to do certain things to certain procedures. With the Shuttle ADI, you had people required to do traceability, additional controls on the drawings, etc. Why would you need more people that you would have to pay extra to be overly cautious?"[63] LSI-ID finally got permission to do the whole job in Engineering. A total of a dozen units were made—four flight items and their spares along with several test units used in trainers on the ground.

In reflecting on the work done on the Space Shuttle through the ADI program, Parini commented in 1998 that, "I think we should be with the Space Shuttle today. By working on the Shuttle, you obtain a level of excellence that you have to achieve in order to be effective on the program and retain your reputation. It is programs like this that set the bar for the rest of your organization."[64] Lear chose not to pursue additional follow-on contracts for replacement avionics for the Shuttle fleet. By 1998, the Multi-function Display Systems (MEDS) or "glass cockpit" contract went to the Instrument Division's main competitor, Honeywell. Lear was out of the space systems business.

Conclusions

In looking back at the work done by Lear during the space program, it became clear why Lear got into the space hardware business; what was less apparent were those reasons why the company decided to get out. However, while interviewing many retired department managers, who included one company ex-president, a common answer emerged. The Instrument Division distanced itself from future space-related activity primarily in response to a shift in management philosophy from that of an engineering, research, and development facility to a financially driven company. This change in attitude also seemed to reflect a growing sense of risk aversion on the part of the customer. "The customer was willing to have companies take risks during the space program,"

said Parini. "Today we seem to be living in a risk averse society, and I don't know how you can find what the limits of any new technological frontier is without taking risks."[65]

Risk was at the heart of new engineering, and the people at Lear were accustomed to taking such risks for the sake of developing new products. Once a new product was developed and marketed, LSI worked with the customer to improve that product even further. The fact that one contract followed another was not unusual in that many of the Lear systems built for the Gemini program were essential instruments needed by the astronauts to fly the spacecraft. As pointed out earlier, one of the key instruments that saw use in the Gemini through Shuttle programs was the attitude-director indicator. Every aircraft requires such an instrument in order for the pilot to fly; the same holds true for spacecraft. "Our series of attitude-director indicators were our bread and butter in the spacecraft business," commented Joe Parini. "Every pilot needs one whether flying on Earth or off into space, and we built them."[66]

When it came to finding a reliable, low-power lighting system to help illuminate the instruments that went aboard the Apollo spacecraft, the primary contractors turned to Lear for answers. "I remember the guys that were working on the Apollo Command Module came to us and said 'We've looked at what we have to build and we know that no matter what we do, we're going to get into a lot of trouble, and we decided we'd rather be in trouble with Lear than we would with anybody else,'" said Glenn VanWinkle who worked on electroluminescent (EL) displays at the Instrument Division until his retirement in 1976. For the space program, EL displays gave them what they wanted once the right people knew that the technology was available for use. "We did a lot of missionary work to get the EL contracts for Apollo," said VanWinkle. "People went out, shook hands and had lunches with the right people, which helped secure our work in this area with NASA."[67]

In addition to having good rapport with the customers, LSI had superb testing facilities and a contracts department that knew how to handle the paperwork within NASA. "In doing business with the government, it is almost impossible to get the first contract because nobody wants to change," said VanWinkle. "But once you start working with them, no matter how stupid you are, they will not get rid of you. They just keep giving you more business because it's too hard to change. I think that this was the case with the work that we were doing on Apollo. They just kept giving us more contracts."[68] In addition, the administrative costs were also very high but if LSI-ID did a lot of similar work for the same customer, corners could be cut due to replication of tasks, which also helped in securing more contracts.

The Apollo program was the United States' largest and most prestigious entry into the propaganda war with the Soviet Union. Apollo was a massive undertaking second only to that of the Manhattan Project in scope and cost. Costing $19,349,000,000 through the first Moon landing, it employed 300,000 individuals working for 20,000 contractors and 200 universities in 80 countries at its peak.[69] As one of the contractors, Lear was swept up by the challenge of building space hardware.

"We got into this business, in part, for the technical challenge," said Parini. "The space hardware that we built was an engineering-driven program as opposed to a market-driven program. Since there was no production involved in any of these programs, there was very little money to be made."[70] The type of contracts that were available were cost-plus incentive fee (CPIF) as opposed to fixed price, which made a huge difference in the amount of risk a company was willing to take. "There was no financial risk with the space program," said Hekker in commenting upon the differences between now and the days of Apollo in bidding on space-related projects. "In many cases the contractors did this because there was enough risk such that you could not get many people to even bid on them. Why on these small quantities would you take a risk where you could possibly lose your shirt?"[71] Since that time, management has become more cautious in how they spend their resources.

There was a risk that in taking on such projects; you might not succeed, and your name would be "mud" within the industry. This was a motivator to succeed. There were a lot of people watching the space program. Because the space program was such a high profile business for anyone who contributed to it, managers argued that through such an association with a space contract, other work would follow. "There is a certain amount of cross pollination in this business," said Parini. "We may not have made any significant profit from the space program, but we got other business because of what we did. Some products in any business don't make money, but because you had

the product, you get other contracts that do make money. This is a difficult concept for the financially-driven managers that dominate the business today."[72]

"People started to manage more with their heads than with their hearts," said Thiry when asked about the management style differences that characterize today's aerospace industry as opposed to the Apollo-era industry.[73] A company can be managed from many points of view, including a technical point of view, a distribution point of view, a financial point of view and a product point of view. "Lear, at that time," said Parini, "recognized ourselves as an engineering company, and we managed ourselves from an engineering point of view. The engineering challenges brought on by the space program raised the bar in technical excellence and quality for the whole division."

After the attitude-director indicator was built for the space shuttle, Lear distanced itself from the space products business. This was due, in part, to the fact that as the company matured, it became more of a financially managed company. As a result, the company began to look at each and every piece of business on its own rather than how it might be used to attract other business. "In 1962, a group of people from Siegler came in and bought out Lear. The Siegler people were all financial. They left us [LSI-ID] alone for a good period of time but by the time of the shuttle contract, you could see more and more financially-oriented decisions being made within the company," said Parini. "They looked at the top line, the costs and the bottom line, and to them, it did not matter whether you were making an instrument for the space shuttle or golf carts. If they could make more money making golf carts than in the space program or any other high technology program, they would rather make golf carts."[74]

"Building space hardware was a real introduction into reliability and statistics," explained Hekker. "There was a whole new set of disciplines. People worked almost continuously with an understanding of reliability in quality control and traceability. Whereas before, this was not so great a concern. Even before you ever start bending metal you have to go through various analysis to prove longevity, likelihood of failure, failure mode and effects analysis. In addition, everything that went into the space program either had a lot number or a serial number on it. A lot number means that an item could come from a lot of parts. If you had any failures in the field you could trace that part back to see how many other units had parts from that same lot. These were areas that we did not have a lot of previous experience in and became something very valuable that we took with us from the space program and applied to other areas."[75]

"I'm sure that the work that we did in the space program made a big difference in work habits and in the way that people were used to doing things," said VanWinkle. "Standards were a lot higher in the space program than they had been before, and I think that this gave people a reason for doing things better. It is one thing to have an indicator fail on an airplane and the guy only has to limp home 100 miles. But when you are a quarter of a million miles away, it better not fail."[76]

The legacy of the Instrument Division's contributions to America's human space program is a previously unwritten chapter in history of space exploration. "In looking back," reflected VanWinkle, "it was a hell of a lot of work involving an awful lot of hours, but it was probably the most exciting time of our lives because you were dealing with things that nobody had ever done before and you knew that what you were doing was going to make a difference in the whole project. The work that the Instrument Division did seemed insignificant when compared to rocket engines or the spacecraft itself, but what we did was important because it was the interface between man and the machine, so you knew that what you were doing made a difference. As a result, there was a tremendous amount of pressure on everyone to get the job done right."[77]

Acknowledgments

Graduate students often end up publishing a book from their research. In my case, I ended up publishing a paper in the course of researching a book.

Back in the late 1990s when I worked for LSI, then called Smiths Industries Aerospace, I learned of a project to research, write, and publish a formal history of our division (see *Fifty-five Trips Around the Sun: The History of Smiths Industries Information Management Systems in Grand Rapids, Michigan* by Ray J. Abraczinskas, Donald J. Barkel, Gordon L. Olson, and Glen E. Swanson). Having grown up only a few miles from the company, I embraced this project as my research took me into their corporate archives, where I discovered the critical role that the company played in supplying instrumenta-

tion to the nation's human space program.

The wealth of information that I found convinced me that, in addition to providing material for their corporate history I could also apply this research to my graduate studies. The end result is what turned into this, my master's thesis.

There were many who made it possible for me to complete this work. I owe a debt of thanks to many, including those members of the book committee—Ray Abraczinskas, Don Barkel and Jennifer Villarreal—who got me started. In addition, I owe much to the patience of my coworkers, who endured my historical muses during the many months in which I was absorbed in this topic. Appreciation must also be extended to past employees of this division whose interviews proved invaluable in the course of my research. Those interviewed include Bob Kurti, Don Haadsma, Tom Hekker, Ed Krug, Hans Thiry, Edmund Hakeem, Glenn VanWinkle, John Kearns, Bob Wierenga, and Joe Parini. For grammar and stylistic coherence, I thank the late Bob Fry along with others who reviewed numerous draft copies and offered valuable input. I also thank my department manager, Earl Iseler, whose patience and interest in the project allowed me the time to find the answers that made the company's history more complete. Finally, I must thank my UND graduate advisor, Stephen Johnson, whose constructive criticisms were invaluable in helping me become a better historian.

About the Author

A native of Grand Rapids, Glen Swanson has held a fascination for space exploration since childhood. After several years of teaching, he founded CSPACE Press, an aerospace publishing firm during which time he founded *Quest*. After obtaining a graduate degree in Space Studies from UND in 1998 he served as an historian at NASA's Johnson Space Center. After returning to Grand Rapids, he began work at Grand Valley State University, where he has been a physics laboratory instructor for the past ten years. Glen and his wife have an eight-year-old named Luke after their favorite Star Wars character.

Notes

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61 Author interview with Hahns Thiry, 3 April 1998. It should be noted that "green money" is that money offered by the government for Internal Research and Development (IR&D). It is a percentage of the contract value that a company can use to further develop/improve the product requested under contract. "Red money" is simply that money spent by the company (out of pocket) to do essentially the same thing. Those products or portions thereof resulting from red money are proprietary to the company whereas any products or portions thereof resulting from green money are owned by the government.

62 Author interview with Joseph A. Parini, 26 May 1998.

63 Author interview with Tom Hekker, 2 April 1998.

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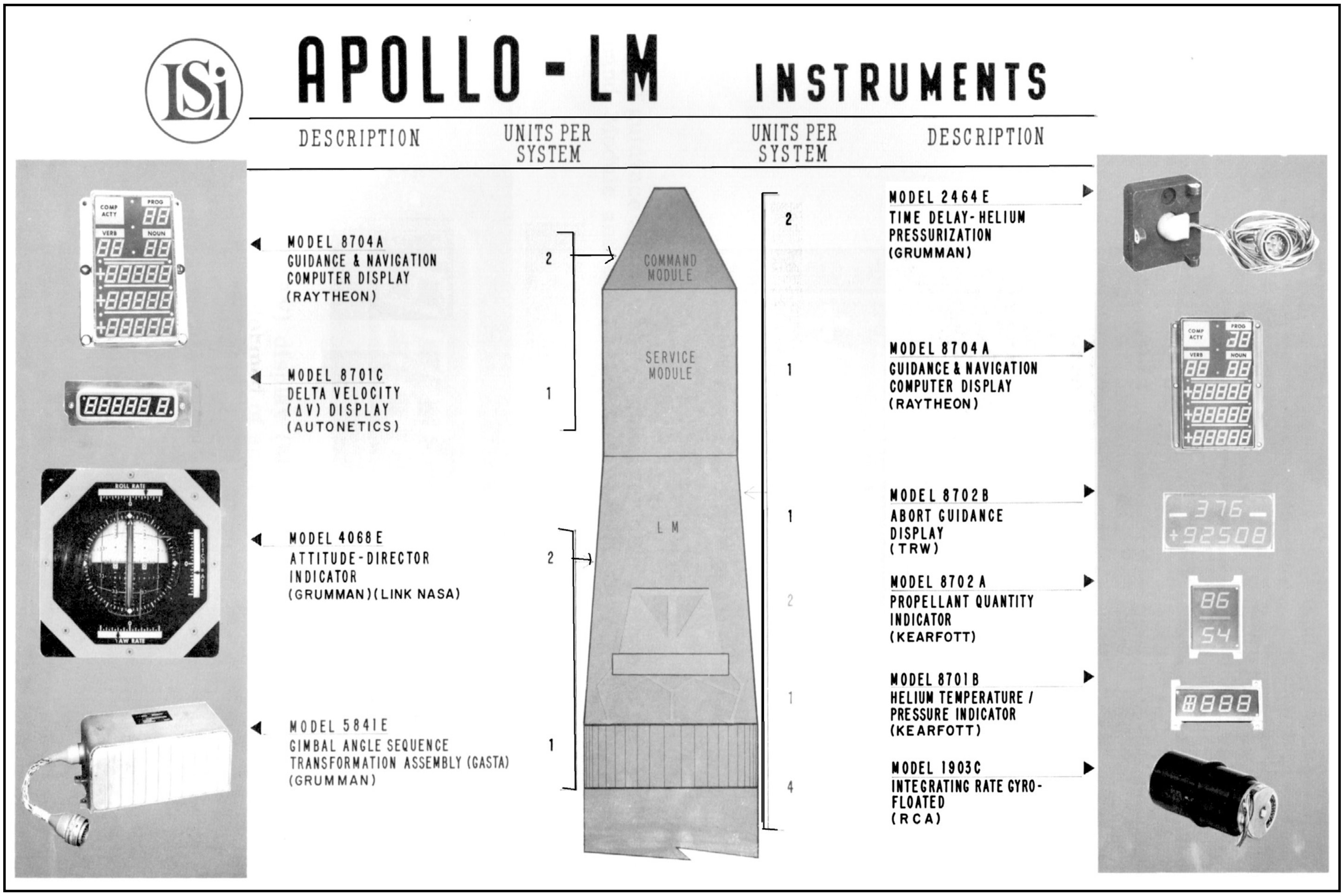

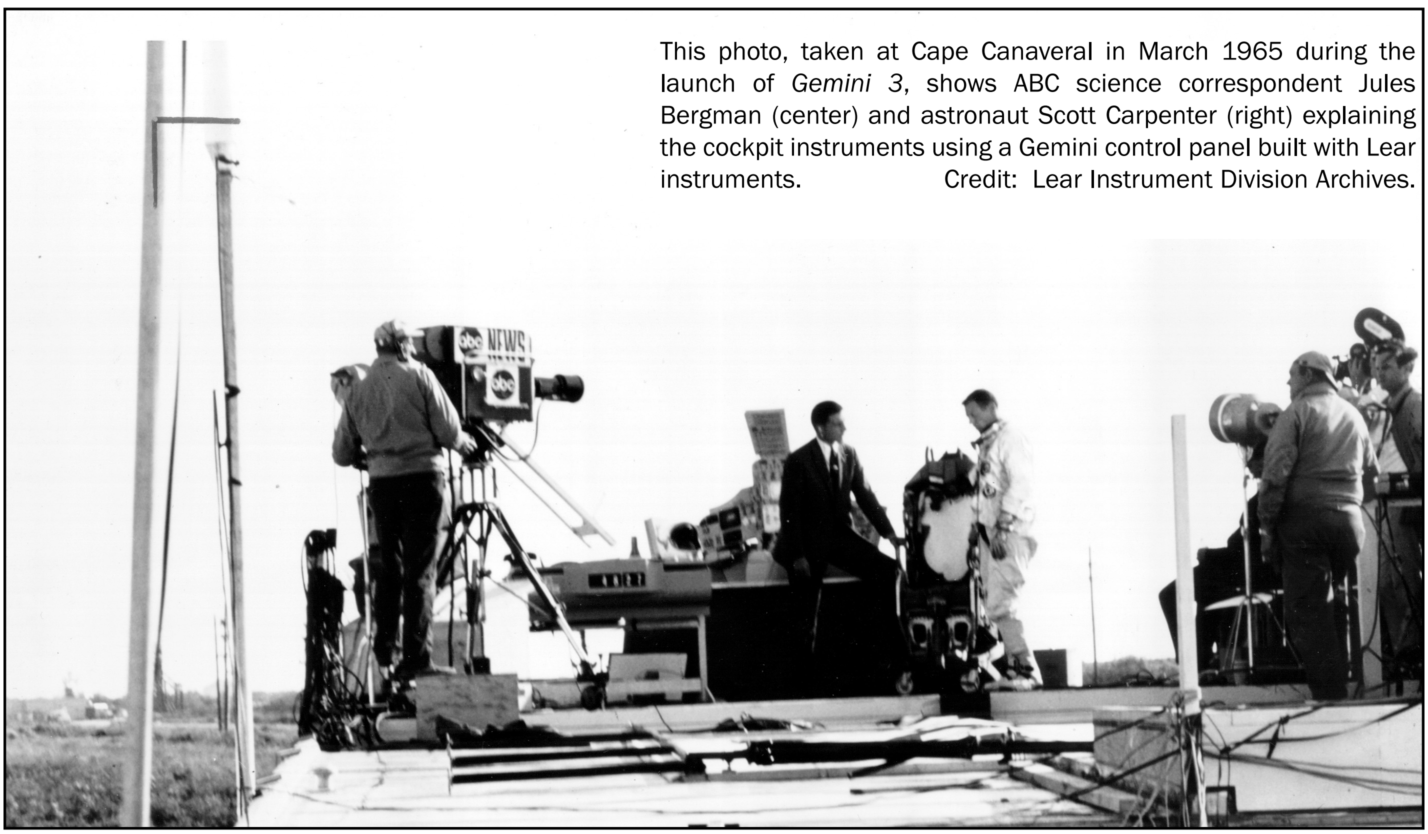

This photo, taken at Cape Canaveral in March 1965 during the launch of *Gemini 3*, shows ABC science correspondent Jules Bergman (center) and astronaut Scott Carpenter (right) explaining the cockpit instruments using a Gemini control panel built with Lear instruments. Credit: Lear Instrument Division Archives.

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