MICHOUD ASSEMBLY FACILITY
13800 Old Gentilly Road
New Orleans
Orleans Parish
Louisiana

HAER LA-24
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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

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FIELD RECORDS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
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1849 C Street NW
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HISTORIC AMERICAN ENGINEERING RECORD

THE MICHOUD ASSEMBLY FACILITY

(Building No. 103, Manufacturing Building and Adjoining Structures: Building No. 101, Administration Building, Building No. 102, Engineering Building, and Building No. 110, Vertical Assembly Building)

Location:	13800 Old Gentilly Road, New Orleans, Louisiana
Date of Construction:	Building Nos. 101, 102, 103: 1943 Building No. 110: 1964
Builder/Fabricator	Building Nos. 101, 102, 103: Higgins Aircraft Company Building No. 110: N.A.S.A.
Present Owner:	N.A.S.A.
Present Use:	Rocket Development
Significance:	The significance of the Michoud Assembly Complex lies in its architectural heritage, as a structure designed by Albert Kahn, Architects and Engineers, Inc., the foremost factory architectural firm of the twentieth century. Second, The National Aeronautics and Space Administration (NASA) used the Michoud Complex to manufacture the S-1C booster stage of the Saturn V rocket, and to manufacture the S-IB booster stage of the Saturn I rocket during the Apollo program. NASA employed the Michoud Assembly Facility as an element in an integrated system to engineer, manufacture, and operate spacecraft.

The manufacturing facility was later used to manufacture the External Tank of Space Transportation System (the Space Shuttle). With the retirement of the orbiters and the end of the Space Transportation System, the facilities at Michoud are again being retooled for the manufacturing of the core stage of the Space Launch System booster and the Orion Multipurpose Crew Vehicle.

Project Information

Documentation of the Michoud Assembly Facility's manufacturing works is part of the Historic American Engineering Record (HAER), a long-range program to document historically significant engineering, industrial, and maritime works in the United States. The HAER program is administered by the National Park Service, U.S. Department of the Interior. The Michoud Assembly Facility recording project was cosponsored during 2013 by Marshall Space Flight Center with the guidance and assistance of Ernest Graham, Michoud Assembly Facility, Jennifer Groman, Federal Preservation Officer, NASA Headquarters and Joseph King and Melvin Mckinstry from the Planning Office at Marshall Space Flight Center. The field work, measured drawings and the historical report were prepared under the general direction of Richard O'Connor, Chief, Heritage Documentation Programs, National Park Service. The project was managed by Thomas Behrens, HAER Architect and Project Leader. The Michoud Assembly Facility Recording Project consisted of team leader, John Wachtel, HAER Architect and architectural delineators Rick Linan, Arizona State University and Alda Harris-Copeland. Written historical and descriptive data was produced by Douglas Jerolimov and large-format photographs were produced by Jet Lowe, HAER photographer.

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We also acknowledge the help of those at the Michoud Assembly Facility who gave their time to help with this project: Ernest Graham, Project Engineer, Malcolm Wood, Deputy Chief Operating Officer, Patrick Whipps, Aerospace Flight Systems Manager, and Matt Wallo, Senior Manager of the Lockheed Martin Corporation.

Douglas Jerolimov
Project Historian
July 2013

The Michoud Assembly Facility and NASA

Born during the Second World War, the design of the Michoud plant exhibited the characteristic strategies of the Second Industrial Revolution, a time when many corporations became national in scope, developing their techniques of mass production and marketing to address mass consumer markets. The Michoud Assembly Facility, however, grew to be associated with the new large systems approach that the National Aeronautics and Space Administration (NASA) employed to design, manufacture, and operate its spacecraft.

Located 15 miles east of downtown New Orleans, the Michoud complex (pronounced Mee-shoo) was originally designed by the foremost factory architectural firm of the twentieth century, Albert Kahn, Inc., Architects and Engineers of Detroit. The enormous and dominating manufacturing structure of the facility—43 acres under a single roof—was built upon the remains of an aborted shipyard construction project, a shipyard that Frederick Higgins conceived as an assembly line factory to build Liberty Ships. Wartime officials decided against following through with the plan to build the shipyard, despite spending $11 million of the planned $29 million on its construction. Only months after stopping construction of the shipyard, however, wartime officials granted another contract to Frederick Higgins' for the production of military cargo planes, which led to the construction of Michoud's manufacturing complex. But changing wartime priorities again stalled this effort, and only a single cargo plane was built at the facility. The facility would not actually be used until the Korean War of the early 1950s, and then to build engines for Patton and Sherman Tanks.

Again empty after the Korean War, Michoud would gain prominence in the 1960s as a manufacturing facility for NASA's Apollo program, when most of the features of this complex, and the outlines of arrangements among its tenants, first took shape. Beginning in the 1970s, the facility would be used manufacturing facility for NASA's Space Transportation System, also known as the Space Shuttle program.

Albert Kahn, Inc., Architects and Engineers, Detroit, typically subordinated the architectures of their factories to the design of the manufacturing processes taking place within them; the Michoud Assembly Facility (MAF) was designed originally to accommodate the production of aircraft. Few aircraft were actually built (though the Higgins Aircraft factory did produce a number of wing panels for aircraft of the Curtiss-Wright Corporation[1]); what remained standing was an enormous shell of a factory, a flexible space that could accommodate many different manufacturing goals, but one best suited to the manufacture of large artifacts, such as ships and large aircraft. NASA's administrators believed the site to be ideal for the manufacture of enormous launch stages for the Apollo program.

[1] Jerry E. Strahan, *Andrew Jackson Higgins and the Boats that Won World War II* (Baton Rouge: Louisiana State University Press, 1994), 190.

Kahn's architectural designs were tailored to fit the manufacturing processes occurring within his structures, but NASA incorporated and tailored the Michoud Assembly Facility to fit within a broader system designed to engineer, build, and operate spacecraft, a system that would encompass facilities and transportation arrangements spanning the nation. The development of the Michoud Assembly Facility (MAF) during and after the 1960s is as much about the facility's role in NASA's system of developing and operating spacecraft as it is about the efforts and participation of people whose efforts at MAF helped to achieve the goals of NASA. The facility was created as a satellite of the George C. Marshall Space Flight Center (MSFC) in Huntsville, Alabama, its "manufacturing arm", and remains its satellite.[2] Although officials and engineers at MSFC used the MAF to accomplish their goals of designing and manufacturing propulsive vehicles for space travel during the Apollo and "Space Shuttle" programs, the contractors at Michoud developed autonomy over the course of each program, and made substantial contributions to each program.

Organization of Report

This report for the Historic American Engineering Record (HAER) will explore the emergence and development of the Michoud Assembly Facility, beginning with a discussion of the facility's place in the context of NASA's efforts to landing Americans on the moon. It will next describe the origins of the Michoud Assembly Facility as a factory complex, explaining the goals of its designer, Albert Kahn and Associates of Detroit, and the context of the factory's original design, as well as the historical roots of the site upon which the Michoud Assembly Facility rests.

Discussion will then turn to NASA's work to prepare, to renovate and rebuild, the Michoud Assembly Facility to suit their broader goal of engineering, manufacturing, and operating space vehicles for the Apollo program. This section will describe in greater detail the individual buildings of the Michoud Assembly Facility, and the operation of the Facility, including the arrangements among contractors and NASA's civil servants at Michoud during the Apollo program.

The report's next section will briefly examine arrangements during its transition to building the External Tank for the Space Transportation System (the Space Shuttle Program) and arrangements during the Space Shuttle program. This final section of the report will conclude with an examination of the events and challenges of the Michoud Assembly Facility during the Space Shuttle Program, and will look ahead to the facility's future as a NASA facility.

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[2] Malcolm Wood, Interviewed by author, 15 March 2013. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

The Context of NASA's Emerging System of Spacecraft Development and Operation

In response to the successes of the Soviet Union's space program, President John F. Kennedy challenged the American people on September 12th, 1962, to land astronauts on the moon and return them home safely—"in this decade."[3] Nine months earlier, Kennedy had already presented his case in an address to a Joint Session of Congress, and planning for the project had already begun.[4] Nevertheless, engineers of the National Aeronautics and Space Administration (NASA), which itself was created only in 1960, had little more than eight years to accomplish the task. To achieve the goal, the United States committed more than $25 billion to this federally-funded project, an enormous amount of money in the 1960s.

Kennedy understood that money alone would not solve the problem of landing Americans on the moon, and he argued that the problem was one that "new money cannot solve unless every scientist, every engineer, every serviceman, every technician, contractor, and civil servant gives his personal pledge that this nation will move forward, with the full speed of freedom, in the exciting adventure of space."[5] One way in which the President motivated Americans to commit to the task was to appeal to their noble aspirations: "We choose to go to moon and do the other things," said Kennedy at Rice University, "not because they are easy, but because they are hard."[6] But still more than money, good intentions and commitment were needed land Americans on the moon—Americans needed a new and more efficient way of organizing the engineering, development and operation of space vehicles.

There were precedents for NASA to draw upon. Military contractors, collaborating with the federal government of the United States, had developed a "systems" approach to weapons development, one that took into consideration the complexity of engineering and that of the management of large projects. The most widely known of projects of the 1950s included the SAGE project, the "Semiautomatic Ground Environment" project centered at the Massachusetts Institute of Technology (MIT) that brought computing and radar equipment together into a system of air defense. In this project, MIT worked closely with the military to "[synthesize] organizational and technical innovation," creating "transdisciplinary committees…mission-oriented laboratories, government agencies, private corporations, and systems-engineering organizations" to accomplish the task.[7]

A second project, more relevant to NASA's task, was the Atlas Project of the Air Force during the 1950s, which created the nation's first working intercontinental ballistic missile. In this project was introduced the strategy of working on different stages of a weapons system's

[3] John F. Kennedy, "We Choose to go to the Moon…" (speech given at Rice University, Houston, Texas, 12 September 1962).
[4] John F. Kennedy, "Urgent National Needs" (speech to Joint Session of Congress, 25 May 1961).
[5] Kennedy, "Urgent National Needs" (speech to Joint Session of Congress, 25 May 1961).
[6] Kennedy, "We Choose to go to the Moon…" (speech given at Rice University, 12 September 1962).
[7] Thomas P. Hughes, *Rescuing Prometheus* (New York: Pantheon Books, 1998), 15-16.

development "concurrently."[8] The approach was important in that it shortened the duration of a large-scale engineering effort which, in turn, decreased and controlled the cost of large and complicated projects. The "concurrent" approach, however, forced engineers and scientists to depart from the sequential approach to managing a weapons system design, instead pushing program and project managers to coordinate the overlapping tasks of a weapons system design, testing, and manufacture (see Figure 1).

"Concurrent engineering" overlapped research and development; production and operation—in order to "cut red tape" collapse the development and manufacture weapons and aircraft.[9] Coordinating the efforts of vast numbers of contractors and engineers who were often geographically far-flung, however, created unique problems of management—both in logistics and in technical development—and required new methods of program management and systems engineering to ensure that a "concurrent engineering" approach would not result in "a massive concurrent failure."[10]

Thomas Parke Hughes characterizes postwar "system builders" as individuals who "preside[d] over technological projects from concept and preliminary design through research, development, and deployment." To do so, he continues, they often "cross[ed] disciplinary and functional boundaries."[11] For the system builders of NASA who sought to create space vehicles for the Apollo program, and later for the Space Transportation System (also known as the Space Shuttle program), this also meant creating new infrastructure of development, of production, and of transportation. Apollo's infrastructure of transport, for instance, entailed specially built or modified aircraft, tractor-trailers, and barges, and docks, for use in transporting its rocket engines and rocket stages.

Such system builders, according to Hughes, were creators of a "human-built world," a world built "according to their own blueprints."[12] In the case of NASA, this world was likely to be represented by maps featuring its various centers and sites of operation (see Figures 2 and 3), including the Michoud Assembly Facility. The "world" that NASA built was as much about

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[8] Ibid., 105-108.
[9] See Stephen B. Johnson, *The United States Air Force and the Culture of Innovation, 1945-1965* (Washington, D.C.: Air Force History and Museums Program, 2002).
[10] Ibid., 108. For more on concurrent design, see Stephen B. Johnson, *The Secret of Apollo: Systems Management in American and European Space Programs* (Baltimore: Johns Hopkins University Press, 2002), and also Howard E. McCurdy, *Inside NASA: High Technology and Organizational Change in the U.S. Space Program* (Baltimore: Johns Hopkins University Press, 1993), Joan Lisa Bromberg, *NASA and the Space Industry* (Baltimore: Johns Hopkins University Press, 1999), W. Henry Lambright, *Powering Apollo: James E. Webb of NASA* (Baltimore: Johns Hopkins University Press, 1993), Phillip K. Tompkins, *Organizational Communication Imperatives: Lessons of the Space Program* (Los Angeles: Roxbury, 1992), Irving Brinton Holley Jr., *Buying Aircraft: Materiel Procurement for the Army Air Forces*, vol. 7 of Stetson Conn, ed., *United States Army in World War II* (Washington, D.C.: Dept. of the Army, 1964).
[11] Hughes, *Rescuing Prometheus*, 7.
[12] Thomas P. Hughes, *Human Built World: How to Think about Technology and Culture* (Chicago: University of Chicago Press, 2004), 11.

creating a new built environment and infrastructure to facilitate the research and development, production and operation of spacecraft, as it was about creating new technologies of space vehicles. Representations of the system that NASA built were as likely to appear as organizational charts, as charts of interfaces among technical systems, and as the representations of the space vehicles that NASA designed and produced, as they were to appear as geographical maps. The variety of representations were a consequence of the system's heterogeneous elements—including disciplinary and transdisciplinary groups, technologies of every kind, ideas, and natural elements, such as waterways—that composed NASA's system of developing and operating spacecraft. From the beginning, the system of elements that NASA's officials and engineers created included explicit geographical and spatial dimensions—that extended into Space.

NASA provides us with an important example of human built social, technical, and natural arrangements that were brought together and conceived as a large technological system. As with other efforts dedicated to developing and nurturing such systems during the postwar period, the system builders at NASA, engineers and scientists, were motivated in some important measure by a fear of losing the Cold War, the United States' struggle with the Soviet Union to gain influence among the remainder of world not yet within either nation's sphere of influence. The systematic thinking needed to design and develop the spacecraft of the Apollo program was also facilitated by an explicit and narrow goal of landing Americans on the moon as quickly as was possible, which demanded cooperation among many actors of different interests—the systematic approach, which depended upon clear goals and demanded hierarchical control, allowed those in charge to measure their progress and to measure the cost effectiveness of constituent groups and efforts. The emergence of NASA's Michoud Assembly Facility can be explained as a necessary element of a system designed to land astronauts on the moon. But this is certainly not the whole story, however, as actors (contractors) at Michoud exercised increasing agency in achieving this goal, and by the Apollo program's end acted as full participants who shaped the system, rather than as passive agents who were shaped by it. The same can be said of Michoud's contractors engaged in the External Tank production for the Space Shuttle program.

As with many such systems created during the postwar period, NASA's system of engineering, manufacturing, and operating spacecraft was built upon the conceptions, materials, and people at hand, often drawn from an earlier period that had different goals and priorities.

Albert Kahn and Factory Architecture

As historian Grant Hildebrand has noted, the factory architectures of Albert Khan—including Michoud's enormous factory structure and facilities—has its roots in the ideas of Frederick Winslow Taylor, who sought to "systematize" the organization of manufacturing.[13] The father of management theory in the United States, Taylor is associated with the idea that one may apply "scientific management" techniques to learn the "one best way" to accomplish tasks of production.[14] To do so, Taylor broke down production processes into their constituent elements, and reassembled these elements in a way that optimized production. His analyses and design examined both the management of tools and factory workers. Taylor's work, and those of his followers, generally focused on batch-manufacturing processes, and his ideas would be extended to mass production, epitomized by the automobile factories of Henry Ford, especially Highland Park and then the River Rouge factory, which provide idealized expressions of manufacturing during the period of the Second Industrial Revolution in the United States, generally dated between 1870 and the Great Depression.

Albert Kahn's work is associated with the architectural development of these ideas—most famously the River Rouge Complex for Henry Ford and his Ford Motor Company—he designed factory structures which, in design, dimensions, and details, facilitated the steps of particular manufacturing processes to be contained within his structures. Moreover, Kahn also rationalized the process of creating architectural designs; his architectural firms featured an extensive division of labor among his subordinate architects and engineers, allowing him to increase the scale and throughput of designs produced by his firm.

Doing so allowed Kahn his own firm's efficiency, and allowed his firm's clients to engage mass markets, hallmarks of the second industrial revolution of Europe and North America. Kahn oversaw the design of more than 2000 factories in his lifetime and achieved greater prominence as a factory architect toward the end of his career—in 1938 he was responsible for 19 per cent of "all architect-designed U.S. industrial building," wrote George Nelson.[15] Grant Hildebrand has written that Kahn's architecture "encouraged, served, and to a considerable degree made possible

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[13] Grant Hildebrand, *Designing for Industry: The Architecture of Albert Kahn* (Cambridge, Massachusetts: MIT Press, 1974). Other historians have noted characteristics that would support Hildebrand's assertion. Terry Smith emphasizes the "functionalism" of Kahn's factories, and George Nelson noted the "accumulated influence of the machine environment" on Kahn's factory designs. Terry Smith, "High Modernism and Actual Functionalism," in Brian Carter, Grant Hildebrand, and Terry Smith, *Albert Kahn: Inspiration for the Modern* (Ann Arbor: University of Michigan Museum of Art, 2001), 29-41; George Nelson, *Industrial Architecture of Albert Kahn, Inc.* (New York: Architectural Book Publishing Company, Inc., 1939), 9.

[14] Frederick Winslow Taylor, *The Principles of Scientific Management* (New York: W. W. Norton & Company, 1967).

[15] Grant Hildebrand, "Albert Kahn: The Second Industrial Revolution," Backgrounds for an American Architecture, *Perspecta, 15* (1975), 37; George Nelson, *Industrial Architecture of Albert Kahn, Inc.* (New York: Architectural Book Publishing Company, Inc., 1939), 15.

the leap in the efficiency and economy of mass production that occurred in those early years of the twentieth century" and, he wrote, "it would not be stretching the point that it marks a second industrial revolution" in architectural practice.[16]

Kahn's industrial architecture is most associated with the automobile industry and, perhaps, best expressed and known for the design of, first, Highland Park factory for Henry Ford's Ford Motor Company, and later the company's sprawling River Rouge Complex, for which construction began in 1917, ending in 1928 as the world's largest integrated factory. The dominant factory building of the sprawling Rouge complex is "a third of a mile long, of one story with lighting through roof monitors and clerestories"[17] and remains a testament to what George Nelson claims was "one of [Kahn's] favorite remarks," that "architecture is 90 per cent business and 10 per cent art."[18]

Indeed, Kahn's designs functioned as elements of the manufacturing process, and only began after the design of the manufacturing process to be contained within the architectural structure. This approach suited officials at the Ford Motor Company who, according to Lindy Biggs, had "fully developed" their philosophy regarding the role of the architect in designing factory structures: production engineers should first "lay out the work of the factory," only after which came the architect's work.[19] Moritz Kahn, Albert Kahn's brother and senior engineer for Albert Kahn, Inc., articulated the complementary philosophy of Albert Kahn's architectural firm: "the manufacturer … should never be called upon to accommodate the process of manufacture to the layout of the building." Continuing, Moritz Kahn wrote that "An architect is not qualified to make process layouts. Only the works management can do this… the architect should be able to plan a factory which is properly built around the scheme of operation."[20]

Kahn's architectural approach grew out of his experiences working with industrialists like Henry Ford. Nelson writes that Kahn grew to believe that businessmen were "profoundly suspicious of artists; they wanted fast work, no mistakes and flexibility to provide for the inevitable changes in production."[21] Ironically, the River Rouge plant became an icon of the modernist aesthetic, one made popular by photographer and painter Charles Sheeler.[22] Moreover, "leading modernist architects and designers such as Gropius and Le Corbusier cited Kahn as an influence," writes

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[16] Hildebrand, "Second Industrial Revolution," 37.
[17] Hildebrand, "Second Industrial Revolution," 34.
[18] Nelson, *Industrial Architecture of Albert Kahn, Inc.*, 17; David Leatherbarrow and Mohsen Mostafavi, *Surface Architecture* (Cambridge, Massachusetts: MIT Press, 2002); W. Hawkins Ferry, *The Legacy of Albert Kahn* (Detroit, Michigan: Wayne State University Press, 1970), 27.
[19] Lindy Biggs, *The Rational Factory: Architecture, Technology, and Work in America's Age of Mass Production* (Baltimore: Johns Hopkins University Press, 1996), 143.
[20] Moritz Kahn, "Plan the Plant for the Job," *Factory and Industrial Management 75* (February 1928): 316.
[21] Nelson, *Industrial Architecture of Albert Kahn, Inc.*, 16.
[22] Terry Smith, *Making the Modern: Industry, Art, and Design in America* (Chicago: University of Chicago Press, 1993), 109-135.

James Christen Steward.[23] Grant Hildebrand writes that Water Gropius's "widely accepted cornerstone of Modernism, the *Faguswerk* [shoe-last factory] of 1911 at Alfeld-an-der-Leine" was influenced by Kahn's recently completed Highland Park Facory for the Ford Motor Company.[24] And Hildebrand argues that the River Rouge plant was admired by the Moholy-Nagy of the Bauhaus, who "included a photograph of it, without mentioning the architect, in his *Von Material zu Architektur* of 1929." Le Corbusier "also used photographs of American factory buildings" in arriving at his designs.[25]

Terry Smith places industrial architects like Albert Kahn among other "industrial engineers and architects who pioneered the displacement of the eighteenth-century British multi-story mill as the basic industrial form." Albert Kahn and his associates, writes Smith, did so in their "constant adaptation..of the Ford plants at Highland Park, Detroit, and River Rouge, Dearborn."[26] The growing complexity and diversity of operations associated with mass production, "their separation yet interdependence," writes Smith, "demanded a new form": "the single-story shed, internally open to a variety of usages and tied to external service systems." Smith writes that this form "was the factory conceived as a machine itself, a shell for the shaping of production."[27]

The description proves apt for the Michoud Assembly Facility, which is an enormous space of flexible configuration within which to shape production. Thinking of the Michoud Assembly Facility in these terms leads one to recall that the site itself, the land upon which the facility rests, saw many different uses. The site of the Michoud Assembly Facility was shaped by different agents, for many different purposes, long before the Kahn-designed facility allowed for such flexibility in manufacturing production.

Michoud Before Apollo

The Michoud Assembly Facility (MAF) was built on a cypress swamp on the western outskirts of New Orleans. The swamp immediately south of the facility eventually gives way to Lake Borgne. Jean Baptiste leMoyne, Sieur de Bienville founded New Orleans in 1718, as part of a larger region claimed by France. As a colonial settlement, the New Orleans became the capital of the region, and a trade center for plantations created on the banks of the Mississippi River.[28]

In 1763, the site upon which the MAF now stands and the 34,500 surrounding acres were granted to Gilbert Antoine de St. Maxent. St. Maxent was able to maintain control over the land when the

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[23] James Christen Steward, "Director's Forward," in Brian Carter, ed., *Albert Kahn: Inspiration for the Modern* (Ann Arbor, Michigan: University of Michigan Museum of Art, 2001), 8-9.
[24] Grant Hildebrand, "Beautiful Factories," in Brian Carter, ed., *Albert Kahn: Inspiration for the Modern* (Ann Arbor, Michigan: University of Michigan Museum of Art, 2001), 16-27.
[25] Laszlo Moholy-Nagy, *The New Vision*, translated by Daphne M. Hoffman (New York: George Wittenborn, 1946), 64; Hildbrand, *Designing for Industry*, 121.
[26] Smith, "Albert Kahn: High Modernism and Actual Functionalism," 31.
[27] Smith, "High Modernism and Actual Functionalism," 31-32.
[28] M. Todd Cleveland, Mark D. Chancellor, and Jeffrey L. Holland, *Architectural Survey of the NASA Michoud Assembly Facility: Final Report, New Orleans, Louisiana* (Atlanta, Georgia: TRC Garrow Associates, 2000), 3.

Spanish gained control over the colony in 1764, in some way helped because his daughter married Don Bernardo de Galvez, son of the chief advisor to the king of Spain. St. Maxent thrived under the new regime, and with his partner received exclusive trading rights to the Missouri River valley's Native Americans. He died a wealthy man in 1794, residing on a large estate on "Gentilly Ridge" near one of his three plantations maintained by his 209 slaves. The tract of land was sold to Lieutenant Louis Brognier deClouet, a Frenchman who served in the Spanish army, and who would himself sell the land and its plantation in 1801, to the Frenchman Bartolomey Lafon, who added tracts of land to the plantation.[29]

Lafon died in 1820 a bachelor, bequeathing his house to his "paramour," Modeste Foucher, who was a free black, and with whom he fathered at least two children.[30] A substantial portion of the land, after tracts were sold to creditors, went to his brother in France, Jean Pierre Lafon, who came to New Orleans but died soon afterward.[31] Jean Pierre Lafon's children held a public sale of the tracts in 1827, and sold the land to Antoine Michoud, another Frenchman. Michoud, who had come to New Orleans in 1817, had then gone about purchasing lands that reassembled the original tracts owned by St. Maxent, and maintained a plantation on the land which produced sugar and molasses, selling it from his shop in the Vieux Carré of New Orleans.[32]

Michoud maintained a large sugar plantation as late as 1860, when he was listed in a census of the Sixth Ward of New Orleans. Michoud died in 1862, during the Civil War, and the estate was passed on to his nephew, Jean Bapiste Michoud, who would never see the estate, as the property was sold via an attorney in New Orleans who, in 1870, gave up a right-of-way through the land to the New Orleans, Mobile, and Chattanooga Railroad. The railroad became the Louisville & Nashville line and a station called Michoud was established on the line where it crossed Gentilly Road, "apparently for the benefit of hunters and fishermen, rather than for the plantation."[33] Tenants may have worked the land after Michoud's death, but the plantation's Sugar House "was in ruins" by 1883 for, as historians Castille and Reeves noted, a property map mentioned "chimneys of the old sugar house."[34] The chimneys stood during the Apollo program, and still stand today (Figure 4).

The land would fall to Marie Alphonse Michoud who, in 1910, sold the property to the New Orleans Drainage Company. After the company defaulted on bonds they issued for its purchase, R. E. E. de Montluzin purchased it, and granted rights-of-way to the Intracoastal Waterway and to utilities, with plans to create a residential and commercial development upon the site.[35]

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[29] Ibid., 3-6.
[30] Ibid.
[31] Ibid.
[32] Ibid.
[33] Ibid., 9.
[34] Castille and Reeves, 1981, p. 12, cited in Cleveland et al, *Architectural Survey*, 9,
[35] Cleveland et al, *Architectural Survey*, 9.

In the early years of the World War II, the United States government purchased 1,000 acres of the site, south of Gentilly Road, according to Cleveland, Chancellor and Holland, to build a factory for wooden Liberty Ships.[36] The Higgins Corporation, which had gained a good reputation building military LCP Boats (Landing Craft, Personnel), LCPLs (Landing Craft, Personnel, Large), LCMs (Landing Craft, Mechanized), PT Boats (Patrol Torpedo Boats), and LCVPs (Landing Craft Vehicle, Personnel). The company's president, Andrew Jackson Higgins, had proven that such vehicles could be built using assembly line techniques, and the US Government was intrigued about his claim that the vastly larger Liberty Ships could also be built using the assembly line technique, using "movable ways" to convey ships under construction from one station to the next.[37] According to Jerry E. Strahan, Higgins had been first contacted about the Liberty Ship project in February 1942.[38] The contract had been finalized on 13 March 1942.[39] Higgins facilities were insufficient to construct Liberty Ships, and thus the "[c]onstruction of a new plant was required, which he could not finance."[40] Higgins expected to roll out a Liberty Ship each day from the Michoud facility.[41]

However, the US Government cancelled the shipbuilding project at Michoud on 18 July 1942; the shipyard, under construction, was estimated to be 35 per cent complete at the time. The shipbuilding contract was cancelled because of an alleged shortage of steel, however, argues Strahan, the reason had more to do with the increasing productivity among the other shipyards engaged in producing Liberty Ships. When the contract had been finalized with Higgins, President Franklin Delano Roosevelt sought a combined additional 24 million tons of capacity in cargo vessels to be produced in 1942-1943, only 448,000 deadweight tons had been constructed. In March of 1942, it took 138.6 days on average to construct and launch a Liberty Ship, but by June 1942 the other shipyards had lowered the number of days required to 77.9 days on average, with one shipyard producing Liberty Ships at the rate of one per 40.9 days. The other shipyards, therefore, proved capable of producing the required ships before Higgins' Michoud facility had begun operation—and the cost of the shipyard had been estimated to more than double, from $29 Million to $59 million. So, given the rising costs of creating a shipbuilding facility in New Orleans, and the ability of the other shipbuilders to produce the required number of ships, it was recommended that a cancellation of the contract for the Michoud facility would be prudent, and

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[36] Ibid., 9. Cleveland, Chancellor, and Holland cite unidentified and undated NASA documents to substantiate their claim that he US Government purchased Michoud in 1940, but this year may be inaccurate, as the first public mention of a factory came in March 1942.
[37] Strahan, *Andrew Jackson Higgins and the Boats that Won World War II,* 100.
[38] Strahan, *Higgins*, 99. The documents cited to support this assertions include *House Documents*, 77th Cong., 2nd Session, No. 281, p. 20. In relation to the contracts for Liberty Ship production, Strahan also cites Fredrick C. Lane, *Ships for Victory: A History of Shipbuilding Under the U.S. Maritime Commission in World War II* (Baltimore, Maryland: Johns Hopkins University Press, 1951), 185-86.
[39] Strahan, *Higgins*, 114.
[40] Ibid., 99.
[41] Ibid., 100.

President Roosevelt agreed.[42] The cancellation proved devastating, of course, to all who had counted on the shipbuilding operation.

Higgins himself blamed the political pressure exerted by owners of the shipyards based in the East Coast who, he claimed, feared his revolutionary methods of ship production. “The Maritime Commission knows that its excuses are mere pretexts,” he said to a *New York Times* reporter, “I guess the real reason is that we can build ships faster and cheaper than any plant and place in the world.”[43] And while East Coast shipbuilders may have exerted political pressures to thwart the construction of Liberty Ships at Michoud, it was the East Coast shipbuilders’ rising productivity that placed much more pressure on Washington to reconsider the necessity of adding another shipyard at Michoud.[44]

Soon after Higgens was awarded (temporarily) the contract to produce Liberty Ships on 13 March 1942, the ambitious Andrew Jackson Higgens had purchased the Tucker Aircraft Company of Detroit, on 21 March 1942. The company held government contracts totaling $250 million. In the agreement between the two companies, Preston Tucker agreed to move his company to New Orleans and to serve as the new Vice President in charge of the new Higgins division of aircraft production.[45] Immediately after the contract to build Liberty Ships was cancelled, the ambitious Higgins was already seeking a contract to build cargo aircraft from the US Army, proposing to build “70-ton flying boats at his shipyard” for the Army.[46] Higgins would soon win a contract from the US government to produce 1200 plywood cargo C-76 aircraft for the Army Air Corps. The letter of intent from the War Department had arrived on 29 October 1942, only 3 months after Higgins had lost the Liberty Ship Building contract.

The new contract led to the construction of a factory to replace the one that had not been built at Michoud; Higgins received $30 million for the redesign and completion of an aircraft factory at Michoud and created the new Higgins Aircraft Company, choosing Colonel John H. Jouett as its President, a man who was currently serving as President of the Aeronautical Chamber of Commerce of America.[47] On 7 November 1942, the *New York Times* reported that the partially completed ship facilities at Michoud were being razed to build the new aircraft production facility. The new program “will be started,” said Higgins, “as soon as the Maritime Commission

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[42] Ibid., 112-114.
[43] “Shipyard closing Protested in South: Maritime Commission Order a ‘Staggering Blow’ to New Orleans, Says Mayor,” *New York Times*, 19 July 1942, p. 7. Strahan, *Higgins*, 110.
[44] Strahan, *Higgins*, 114.
[45] Ibid., 102.
[46] “Army Bids Airlines Expand Transport: General George Calls for More Transport Planes Carrying Troops and Supplies,” *New York Times*, 21 June 1942, p. 7.
[47] Ibid., 147.

finishes tearing down more than $11,000,000 worth of shipbuilding facilities erected for construction under the revoked cargo vessel contract."[48]

Higgins had stated that two of the four planned assembly lines for the Liberty Ships would be manned by Blacks, which drew the support of the Black community in New Orleans, who protested the cancellation and "planned to send an appeal to President Roosevelt on the grounds that the cancellation has destroyed one of the biggest industrial opportunities ever given the Negro race."[49] Higgins maintained a similar planned composition of the workforce for the aircraft production. "Eighty per cent of the workers will be women … and 40 per cent of the working force will be Negroes," he said to *New York Times* reporter Frederick Barkeley. "And that won't raise any race problem, as some people, even in New Orleans, have suggested," he said. "Negroes always have worked for Andrew J. Higgins and at the same rate of pay that white workers get for the same work. We are going to provide the same kind of housing for them that we will for the white workers, but the two groups will be separated, just as they are in the plants."[50] For his time and place, Higgins held progressive notions of race relations.

As reported by the New York Times on 25 October 1943, Higgins celebrated that the newly constructed plant "was kept within the original estimate of $27,000,000"—something to be proud of, as the shipyard originally planned for the Michoud site was expected to double its estimated cost, from $29 million to $59 million. The plant was now ready "to supply Curtiss-Wright C-46 Commando cargo planes," with "[c]onstruction of subassembly parts," begun "several weeks ago," reported the *New York Times*.[51] The C-46 Commando cargo planes were actually made of aluminum, a result of a government restructuring of the contract on 3 August 1943. Rather than build the C-76 plywood cargo planes, Higgins Aircraft Company would build the larger C-46 Commando aluminum cargo planes.[52]

Strahan writes that "it had taken creativity and determination to salvage what could have been an enormous waste of manpower and material" directed toward the shipbuilding facility, adding that "[t]he converted facility served as an example of the flexibility of American industry."[53] But, notes Strahan, the crowds at the dedication were most impressed by the "enormous size of the plant that left them in awe."[54] The sources do not make apparent, however, how much of the

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[48] Frederick R. Barkeley, "Higgins Outlines Big Plane Program: Besides 1,200 Plywood Cargo Craft for Army, He will Make Gasoline Engines," *New York Times*, 7 November 1942, p. 9.
[49] "Shipyard Closing Protested in South," *New York Times*, 20 July 1942, p.7.
[50] Ibid.
[51] "New Higgins Plant Dedicated," *New York Times*, 25 October 1943, p. 8.
[52] Strahan, *Higgins*, 182-83, 230. The C-46 suddenly appeared in higher demand, and the main maker of the aircraft, Curtiss-Wright, apparently could meet the production requirements. "Buffalo Work 'To Expand': Curtiss Head Defends P-40s, Cites Orders for C-46's," *New York Times*, 11 July 1943, p. 24; "Large Crowd Attends Higgins Aircraft Plant Dedication," *Eureka News Bulletin*, II (November, 1943), 3.
[53] Strahan, *Higgins*, 191.
[54] Ibid.

cancelled shipyard facility was incorporated into the aircraft facility, such as whether the foundation for the plant had already been laid for the cancelled shipyard.

The retooling to produce C-46 Commandos rather than the C-76s would continue for a year, while the Higgins Aircraft Company also produced wing panels for the Curtis-Wright factories in Louisville and St. Louis.[55] On 10 August 1944, as the US prepared a major offensive in the Pacific, the US military *again* announced a change in strategy which placed emphasis on "superbombers" and "long-range troop transports." This change in strategy meant "cut-backs" in the production of B-24 Liberator bombers, in the production of P-47 Thunderbolt fighters and, significantly for Michoud, cut-backs in the production of C-46 cargo planes.[56] The change in military strategy, wrote the *New York Times* on 11 August 1944, meant "cancellation of the contract for the C-46 cargo plane at Higgins Aircraft, Inc., New Orleans, which is not yet in production."[57] Only one C-46 Commando cargo plane had been built at the Michoud factory of Higgins Aircraft, Inc.[58] On 10 November 1945, the plant closed and was transferred to the War Assets Administration.[59]

The New Orleans Dock Board arrived at a 15-year rental-purchase agreement with the US Government, and at the close of which they would have gained title to the site. However, with the Korean War beginning in 1950, the US Army Ordnance Corps chose the Michoud facility to manufacture tank engines.[60] The US Government awarded a contract to Chrysler Corporation in 1951 to manufacture Patton and Sherman tank engines, and the plant was officially reopened on 28 November 1951. After hostilities ceased in July 1953, the Army decided that the property would be valuable to retain, "in view of the cost of rehabilitating the facility" for tank production, and the facility remained under the control of the US Army until 7 September 1961, when it was transferred to the National Aeronautics and Space Administration.[61]

Structures Still Standing From World War II Period

Important structures exist from the World War II period of the Michoud Assembly Facility, all built for Higgins Aircraft, Inc., and designed by Albert Kahn, Associated Architects & Engineers, Inc. The three most important structures were inhabited by managers, engineers, and production workers. Officials of the facility inhabited Building 101, the Administration Building. Engineers and designers inhabited Building 102, the Engineering Building. Perhaps most

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[55] Strahan, *Higgins*, 230.
[56] Strahan, *Higgins*, 230. "Orders Increase in Superbombers: Army's Drastically Revised Aircraft Program Indicates Big Attacks on Japan," *New York Times*, 11 August 1944, p. 6.
[57] Strahan, *Higgins*, 230. "Orders Increase in Superbombers," *New York Times*, 11 August 1944, p. 6.
[58] Strahan, *Higgins*, 250.
[59] Cleveland et al, *Architectural Survey*, 11. George J. Castille and Sally K. Evans Reeves, *Cultural Resources Survey of the Almonaster-Michoud Industrial District*. Baton Rouge, Louisiana: Coastal Environments, Inc., 1981., S-5.
[60] Ibid., S-6.
[61] Ibid.

important, from an historical standpoint, is Building 103, the Manufacturing Building, the focal structure of the complex. These three buildings are adjacent to one another, with the Administration building facing north, alongside Old Gentilly Road, and providing a façade for the manufacturing facility (Building 103), with the Engineering Building (Building 102) wedged between the two structures and engineers with direct access to both the officials in the Administration building, as well as to the production site of the manufacturing facility. A Systems Engineering building (Building 130) also survives from the period, standing near the southwest corner of the building.

Administration Building (Building 101)

The Administration Building is a two story-structure, of brick construction, and stands before two chimney ruins of the plantation that once operated on the Michoud site (See Figures 4 and 5). The building was constructed in 1943 as an office building of 90,012 square feet. As described in an architectural survey in the year 2000, the building "features a flat roof with raised penthouses; continuous concrete sills and lintels; an aluminum cornice; and long rows of two-over-two, horizontal wood sash windows."[62] Some of the windows have been infilled.

Similarly to other office structures produced by Albert Kahn and his Associates, it reveals a conservative design for the façade. Eight squared pilasters frame the building's main entrance and its windows, the entrance itself between the central two pilasters. As described in Architectural Survey of Cleveland et al in 2000, "The façade (north side) … exhibits a center section that projects in two planes; eight pilasters with a curved, molded, cornice; windows and spandrels between the pilasters." Large lettering above the pilasters reads,

MICHOUD ASSEMBLY FACILITY
GEORGE C. MARSHALL SPACE FLIGHT CENTER – NATIONAL AERONAUTICS & SPACE ADMINISTRATION

A semi-oval driveway separates the structure from Old Gentilly Road, allowing drivers to maneuver vehicles off Old Gentilly Road, and providing off-street parking.

Engineering Building (Building 102)

Resting between the Administrative building (Building 101), and attached to the Manufacturing Structure (Building 103), stands the Engineering Building. The structure was built by Higgins Aircraft, Inc., and also designed by Albert Kahn, Associated Architects & Engineers, Inc.[63] It shares features with Building 101, the Administration Building, such as "a flat roof with raised penthouses; continuous concrete sills and lintels; an aluminum cornice; and long rows of two-over-two, horizontal, wood sash windows."[64] Interestingly, the building reveals three second-

[62] Cleveland et al, *Architectural Survey*, 25.
[63] Cleveland et al, *Architectural Survey*, 27.
[64] Ibid., 25.

story enclosed bridges that connect and provide passageways between the Engineering Building and Building 101, the Administration Building.[65]

Some changes have been made to the Engineering Building in the years after the Second World War, altering the structure's outward appearance. Just as for the Administrative Building, some windows have since been infilled, and other windows "have been removed and replaced with single and double metal doors."[66]

Manufacturing Building (Building 103)

In 1943, this structure opened to a great celebration in the City of New Orleans, for it was projected to be an employer of twenty thousand.[67] But what most impressed those attending opening ceremonies was the structure's size. "The plant," writes Jerry E. Strahan, "had more floor space under a single roof than any other manufacturing facility in the nation except Ford's plant at Willow Run [for B-24 Liberator Bombers]." It housed 43 acres under a single roof, 1,981,614 square feet, according to the architectural survey by Todd Cleveland, Mark Chancellor, and Jeffrey Holland.[68]

The structure shares features with another wartime manufacturing structure for Curtiss-Wright Corporation designed by Alfred Kahn, Associated Architects & Engineers, Inc., the Curtiss-Wright Corporation Airport Plant of Buffalo, New York. This structure was built in 1941 and produced the P-36 Hawk and the SB2C Helldiver fighter planes of World War II.[69] Both, for instance, featured spare white exterior walls with multiple ribbon windows, and vast unblocked expanses inside, the ceilings supported with cantilever structures.[70] The description that Cleveland, Chancellor, and Holland offer for the Michoud plant, that it "features a slightly gabled roof; asbestos shingle siding; a large loading dock; large canopy doors; and multi-light, steel sash windows," also aptly verbalizes the main features of the Curtiss-Wright facility at Buffalo, New York.[71]

The Michoud plant has undergone some alterations since the World War II period. Cleveland, Chancellor and Holland write that "Asbestos shingles have covered over the original ribbon windows located on the upper floor of the resource," and that the structure "evidences modern doors, small shed additions, and later garage and door openings." While the structure continues to feature "supports that are set far apart" in order to maintain the vast unblocked expanses, they

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[65] Ibid.
[66] Ibid.
[67] Strahan, *Higgins*, 191.
[68] Cleveland et al, *Architectural Survey*, 28.
[69] See especially the images of Figures 95, 96, and 97 of Grant Hildebrand, *Designing for Industry: The Architecture of Albert Kahn* (Cambridge, Massachusetts: MIT Press, 1974), 207-209.
[70] Ibid.
[71] Cleveland et al, *Architectural Survey*, 28.

write that there exist "vertical boards at the upper walls, and several modern partition walls that rise up to the ceiling."[72] Partitions still exist within the structure.

Supporting Structures

A number of surviving buildings from the Second World War are associated with the facility's infrastructures and that surround the manufacturing structure, Building 103: the Battery Charging and Maintenance Building (Building 104), the Waste Incinerator (Building 105), Emergency Power for Pumping Station #4 (Building 106), Pumping Station #4 (Building 143), a potable water tank (Structure 206) and a Boiler House (Building 207). There also exist a number of maintenance-focused buildings, beginning with the three Maintenance Shop structures (Buildings 107, 108, 109), an Office Machine Maintenance Building (Building 140). And there survives a Reclamation Storage building (Building 203). Other additional support structures also originated in the Second World War, and survive: the East Master Substation (Building 121), and a Guardhouse Building at Gate #11, Building 123.[73]

* * *

These structures described above were among the more important ones associated with the facility during the Second World War. But the facility would be transformed again when NASA took possession of the facility in 1961. NASA would transform the site for its own purposes, and the transformation of the Michoud Assembly Facility would reflect an entirely new context of engineering and manufacturing, and an entirely new understanding of the facility itself as an element of a larger system of designing, producing and operating aircraft. The re-conception of the Michoud facility as an element of a larger system, rather than as an independent site of the design and manufacture of artifacts taking place within the facility's structures, is associated with the facility's transfer to the National Aeronautics and Space Administration.

Siting the Michoud Assembly Facility; Siting a Rocket Development System

Had not the Soviet Union enjoyed successes with Sputnik I (1957) and Sputnik II (1958), the Eisenhower administration would not have been likely to create a long-term plan for space exploration. These successes of the Soviet Space Program, and especially the first spaceflight by a human, Yuri Gagarin's flight and orbit of earth on 12 April 1961, during the subsequent Kennedy Administration, led the United States to pursue spacefaring with fervor. Americans believed the Soviet successes had changed the circumstances of the "Cold War," the war of

[72] Ibid.
[73] Michoud Assembly Facility drawing repository. Historic maps, job number 1931 et.al.

words and symbols that Americans waged with Soviets for allegiance of the unaligned world—and Americans felt they needed to respond strongly or risk losing this "war."

In 1958, President Eisenhower's answer to the Soviet Union's successful space launches was a bill to Congress to create a "National Aeronautic and Space Agency." Congressional committees were formed to explore the matter, reworking the bill and on 16 July 1958 gaining passage of the National Aeronautics and Space Act.[74] The act established the National Aeronautics and Space Administration (NASA), placing at its nucleus the National Advisory Committee for Aeronautics (NACA), a civilian government agency that had long (since 1915) engaged in research into air and space flight. On the morning of 1 October 1958, NACA employees returned to their desks and became NASA employees.[75]

NASA would soon be buttressed by a group of rocket expert expatriates from Germany, led by Wernher von Braun, who had extensive experience developing liquid propelled rocket engines for Germany during the Second World War. The German rocket engineers were employed at the Army Ballistic Missiles Agency (ABMA), and were called upon to develop large booster stages and rocket engines for both the military and for the emerging space program. A memorandum, which President Eisenhower approved on 2 November 1959, directed NASA to continue to assist in the Department of Defense's ICBM and Intermediate Range Ballistic Missile (IRBM) programs. But since "no clear military requirement for super boosters" yet existed, and because there *was* a "definite need for super boosters for civilian space exploration purposes, both manned and unmanned," Wernher von Braun and his team were transferred to NASA, joining the researchers from NACA and forming the core of the American space program.[76]

With their unparalleled expertise in developing rockets, they soon gained a new home to develop rockets for the space program when, by Presidential executive order on 15 March 1960, the space complex located within the Redstone Arsenal became the George C. Marshall Space Flight Center (MSFC). On 1 July 1960, the missions, personnel, and facilities, were officially transferred to the new Director of the MSFC, Wernher von Braun. The transfer came with complete responsibility to achieve the goals of the United States' space program, and President Kennedy would add a sense of urgency to the work of NASA when he publicly challenged the United States to put its astronauts on the moon by the end of the decade. The public challenge added a new managerial challenge to the technical challenge of a lunar landing. How was the United States to supervise and coordinate the efforts of engineers and scientists to accomplish this goal in the time allotted?

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[74] Roger E. Bilstein, *Stages to Saturn: A Technological History of the Apollo/Saturn Launch Vehicles* (Washington, D.C.: NASA History Office, 1980), 32.
[75] Joan Lisa Bromberg, *NASA and the Space Industry* (Baltimore: Johns Hopkins University Press, 1999), 30-31; Bilstein, *Stages to Saturn*, 33.
[76] Ibid., 41.

Program Management and Systems engineering at NASA

The personnel from NACA may have solidified NASA's claims to excellence in scientific research, but NASA had little experience developing large-scale engineering projects like for the Apollo program. At the ABMA, Von Braun's rocket engineers relied on informal methods, on face-to-face relationships, and on a close collaboration to understand and coordinate the different tasks of their projects. Much as for weapons systems, the Saturn project would require more formal and hierarchical control of engineering in order to monitor and control costs, schedules, and to ensure the reliability of complicated and emerging systems. Such requirements demanded a new "systems engineering and systems management," one characterized by "a set of organizational structures and processes to rapidly produce a novel but dependable technological artifact within a predictable budget."[77] In the years after the Second World War, the innovations and expertise that Americans developed in the management of complicated technological projects has become "a hallmark of American management and engineering," writes Thomas P. Hughes, one that has "generated a managerial revolution comparable to that brought about earlier by Taylor's scientific management."[78] NASA's management of the engineering, production and operation of space vehicles provides among the most important examples of the managerial revolution Hughes describes.

Engineers and managers of the Apollo program went about the task of management very consciously, employing new program management and systems engineering approaches. Many references in managerial reports to Wernher von Braun make manifest the need for and use of an emerging form of program management that employed the new Program Evaluation and Review Technique (PERT).[79] The importance of "block" or configuration control in Saturn program, for instance, also attests to the need to control "interfaces" in the design of the constituent systems that composed the Saturn rocket, such as those "between stages, between payload and the vehicle, and between the vehicle and the launch facilities"—as well as among engineering groups themselves behind the designs.[80] New approaches of program management and systems engineering often emphasizes those interfaces between human and machine, at the level of the components and devices, but NASA also established an overarching system of designing,

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[77] Stephen B. Johnson, *The Secret of Apollo: Systems Management in American and European Space Programs* (Baltimore: Johns Hopkins University Press, 2002), 17. See also Stephen B. Johnson, "From Concurrency to Phased Planning: An Episode in the History of Systems Management," in Agatha C. Hughes and Thomas P. Hughes, eds., *The Systems Approach in Management and Engineering, World War II and After* (Cambridge, Massachusetts: MIT Press, 2000), 93-112.
[78] Hughes, *Rescuing Prometheus*, 9.
[79] For references to the proliferation of training in PERT at MSFC, see Hans Maus, "Weekly Notes to Wernher von Braun," 5 August 1963, NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama. Also R.G. Smith, "Weekly Notes to Wernher von Braun," 30 October 1961, 6 November 1961, 4 December 1961, 18 December 1961, NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama. Arthur Rudolph, "Weekly Notes to Wernher von Braun," 25 May 1964, NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
[80] Bilstein, *Stages to Saturn*, 274.

producing, and operating its space vehicles. It was a system that incorporated natural elements as well as humans, institutions, and the artifacts of space travel.

Choosing the Sites of NASA's System of Developing, Producing and Operating Spacecraft

Creating a system to engineer, produce, and operate spacecraft entailed decisions of geography as much as it entailed decisions about the performance of the components, devices, and subsystems that together composed the Apollo program's Saturn rocket. NASA's Marshall Space Flight Center lacked key capacities that led NASA's officials to add three new sites for the newly created administration: (1) a site to conduct operations during mission flights, (2) a manufacturing facility, and (3) a rocket stage test-fire facility. In all, the additional sites would complete the overarching system that NASA administrators sought to create for the engineering, manufacture, and operation of manned space vehicles.

Given the amount of funding granted NASA, and the number of jobs associated with the creation of a new NASA center, members of Congress and state governors made efforts to lure NASA into their district or state. Historian Henry C. Dethloff, for instance, has described the "particularly strong political pressure" exerted by State Governors and members of Congress on NASA to win the site of the new "manned spaceflight laboratory" that would become the Manned Spacecraft Center in Houston.[81] Just as for the other sites to be created, however, in August 1961 NASA established widely publicized criteria for a manufacturing facility that included, "water transportation by large barges, a moderate climate, availability of all-weather commercial jet service, a well-established industrial complex with supporting technical facilities and labor, close proximity to a culturally attractive community in the vicinity of an institution of higher education, a strong electric utility and water supply, at least 1000 acres of land."[82] The description was as detailed as it was evocative of a culturally and technologically thriving site of industrial America.

With so little time to achieve their goal of a moon landing, NASA officials moved very quickly to decide on the locations of the agency's additional sites. Site visits for the site that would become the Manned Spacecraft Center took place between August 21 and September 7, and the decision was made on 14 Sepbember 1961 and conveyed to President Kennedy.[83] On 4 August 1961, NASA officials established similar criteria for selection of a site for its manufacturing facility and began its search, setting as a major criterion that the site be "available to NASA on or before 15 September 1961."[84] The selection criteria for a manufacturing facility were drawn

[81] Henry C. Dethloff, *Suddenly, Tomorrow Came…A History of the Johnson Space Center* (Washington, D.C.: National Aeronautics and Space Administration, 1993), 39.
[82] Ibid., 38.
[83] Ibid., 39.
[84] General List, "Criteria for a Manufacturing Plant for Saturn S-I and S-IB Stages," circa 4 August 1961, NASA Historical Archives, reproduced in William Ziglar, *The Fertile Southern Crescent: Bayou Country and the American Race Into Space* (Washington, D.C.: NASA Historical Office, 1972), 25.

up, writes historian William Zigler, “despite the solid foundation of evidence pointing to a choice of Michoud.”[85]

Because the desired site was a manufacturing facility to be integrated within a broader system, infrastructural requirements would become especially important. The criteria emphasized “accessibility,” especially rail and water transportation. Perhaps the most significant requirement of transportation infrastructure was that the plant needed to be “on a navigable waterway, either coastal or inland, with a minimum width of 150 feet and a minimum depth of 12 feet,” in order to facilitate the barges that would be used to move the rocket stages among NASA’s sites.[86] The site also needed to be accessible on a year-round basis. The criteria stated that “The plant shall be accessible all year round from a weather standpoint except for acts of God such as hurricanes and floods. Areas of high snowfall and freezing are not acceptable.”[87] Interestingly, while snow and freezing temperatures were not acceptable, the explicitly mentioned exceptions to the condition of year-round accessibility, “hurricanes and floods,” made sites on the Gulf Coast of the United States look quite favorable.

The enormous size of the rocket stages that NASA planned to build demanded an appropriately vast and rugged manufacturing floor space, for the assemblies to be built were not only extraordinarily large, but also very heavy. NASA’s called for extraordinary size requirements, requiring a plant that “must have a minimum of one million square feet of manufacturing space,” a “High Bay Area” of at least 400,000 square feet with overhead clearance below crane hook height of at least 35 feet.” To bear the great weight of the rocket stages and manufacturing equipment, the criteria established that “the plant must have a sub-surface soil strata or artificial foundations capable of supporting machinery such as heavy presses and forming equipment,” while the structure itself also was required to be “capable of supporting ten-ton traveling cranes.”[88]

To function well, manufacturing spaces need infrastructural support, and they require closely adjoining spaces for administrative and engineering staff, as well as social spaces on site for employees, and off-site living spaces for employees’ families. The criteria for the manufacturing site included requirements for at least 35,000 kVA (kilovolt amperes) of electrical power, “plus an appropriate power distribution system,” as well as for “a supply of potable water sufficient for a working force of 3,000 people” and an additional “supply of 100,000 gallons per day of industrial water” for uses in production. The facility was expected to produce mechanical structures that were characteristically highly precise. To achieve dimensional stability of the

[85] Ziglar, *Fertile Southern Crescent*, 22.
[86] Ibid.
[87] Ibid.
[88] Ibid.

assemblies produced—and to provide a comfortable place of work for employees—the criteria stated that "The plant must be air conditioned."[89]

Habitable spaces were necessary for workers at the site, administrators, and engineers, as well as off-site for the families of those employed. On-site, the manufacturing facility was expected to include a cafeteria and a "hospital space" of 15,000 square feet. At least "One hundred thousand square feet of engineering space must be available," stated the criteria, and eighty-five thousand square feet of "office space." There were requirements of habitation off-site, as well: "The plant must be near an urban area capable of supporting 3,000 persons and their families." NASA clarified the word "support" in this last instance, stating that "The plant should be near an urban area with adequate shopping, educational, religious, recreational and cultural facilities."[90]

There were other requirements of communication and interconnection to be met for the site. It was desired to locate the site "within a reasonable distance of a commercial airport from which high speed connections can be made to Washington, Huntsville, AMR [Atlantic Missile Range] and the West Coast."[91] The site needed to be near an "available labor market." And proximity to the Marshall Space Flight Center and a location for a new test site were key requirements. The criteria stated that "The plant should be located so that water travel of stages to either Marshall or AMR will require less than three weeks," and that "an area suitable for a new test site should be available within two days' barge travel."[92]

The Michoud plant remained the obvious choice, but NASA established an "ad hoc site selection committee" on 4 August 1961 and brought them together for the first time at MSFC on 7 August. They revised only a few of the criteria above, changing the availability date to 30 September 1961. The committee also relaxed waterway standards from 150 to 100 feet in width and from 12 to 10 feet in depth. They increased other requirements, however, requiring 200,000 square feet of engineering and administration space (from 185,000), and increased electrical power requirements from 35,000 kVA to 50,000 kVA. To meet the availability requirement and keep costs under control, NASA's committee eliminated more than 50 sites owned by contractors, restricting their search to available government-owned facilities.[93]

Unlike the site selection committee tasked with choosing the site that would become the Manned Spacecraft Center, the "Ad Hoc Site Selection Committee" conducted few site visits before choosing a manufacturing site for NASA. They began with information from three sources to make their decision: the General Services Administration regional offices, the Army Corps of Engineers district offices, and the Defense Department's reports on military properties. Ultimately, writes historian William Ziglar, the "committee was in agreement that the criteria

[89] Ibid.
[90] Ibid.
[91] Ibid., 26.
[92] Ibid.
[93] Ibid., 31.

used by these three groups did not fit their own."[94] To speed the decision making process, the committee boiled down the criteria to five categories, 1. accessibility, 2. date of availability; 3. size, 4. proximity to MSFC and AMR, and 5. the site's capacity for expansion.[95] The committee considered 52 sites on both coasts, and along major waterways.

In a memorandum of 31 August 1961 to Robert Seamans, NASA's Associate Administrator, Milton W. Rosen of the Ad Hoc Site Selection Committee wrote that their "evaluation indicated that the Michoud Ordnance Plant at New Orleans, Louisiana, is substantially superior to all other alternatives." Rosen was moved to "recommend selection of the Michoud Plant and immediate action to acquire the plant for NASA use."[96] The decision came less than one month after creation of Ad Hoc Site Selection Committee.

The process was a fair one, and after examining minutes of the Committee's meetings, Zigler reports that the decision had been unanimous.[97] As Table 1 reveals, Michoud was the only site that could meet all the requirements the Ad Hoc Committee established. But Michoud also far outstripped the requirements that the Site Selection Committee had established. For instance, the Michoud plant provided 1.9 million square feet of manufacturing space, nearly double the requirement. It was also ideally located on a waterway between Huntsville's MSFC and the launch facilities at The Atlantic Missile Range's Cape Canaveral. To the committee, Michoud was unquestionably ideal was for the purposes of NASA—and immediately available.

So ideal was Michoud as a manufacturing facility for NASA that its selection seemed to have been expected among both member of the Ad Hoc Committee and among bidders who hoped to win the impending contract to manufacture the S-I launch stage. In a memorandum dated 13 July 1961, more than two weeks before the Ad Hoc Committee had been formed, Major General Donald R. Ostrander, Director of Office Launch Vehicle Programs, wrote to Robert Seamans that

> it is becoming increasingly apparent that our interest in the Michoud Plant is known to almost every potential bidder for production of the SATURN first stages. It has come to our attention in the last few weeks that many of these companies have made independent studies of the Michoud Plant, and most of them have reached conclusions similar to ours…In my opinion, all that we have

[94] Ibid., 29.
[95] Ibid., 31.
[96] Memorandum, Milton W. Rosen, Acting Director, Launch Vehicle Program to Robert Seamans, Associate Administrator, "Report of the Ad Hoc Site Selection Committee," 31 August 1961. NASA History Office, Marshall Space Flight Center, Huntsville, Alabama.
[97] Zigler, *Fertile Southern Crescent*, 35.

> heard gives strong support to the Michoud Plant as the best available site for production of SATURN first stages.[98]

The thorough comparison of other potential sites made it clear that Michoud offered the best choice. "This plant emerged as a <u>unique solution</u> to the established criteria from a hundred government and contractors facilities examined," wrote the committee.[99]

The committee also explored sites for the new Test Facility that was to be closely associated with the manufacturing facility. Zigler reports that the Committee traveled to New Orleans from Huntsville on 9 August 1961 to visit Michoud but that, in the days that followed, "the committee or various representatives of it conducted on site or aerial inspections of several sites but most of the time was spent searching for testing areas."[100]

Rosen recommended to Seamans on 31 August 1961 that the Michoud plant become NASA's own manufacturing facility. The following day, on 1 September 1961 Milton Rosen authored another memorandum selecting the Pearl River Site as NASA's rocket production test-fire facility. The Pearl River Site, he wrote, "is principally in the State of Mississippi at the Louisiana border," noting that it "is approximately 40 miles from the Michoud plant."[101] Other sites nearby were also considered; the second choice was a "Delta site, under the heading of New Orleans," despite "construction hazards" that seemed "formidable" to the committee, and also Corpus Christi in Texas.[102] "I recommend," wrote Rosen, "that the Pearl River site be selected as a future test area for NASA large liquid stages, and that action be taken leading to land acquisition."[103] It seemed that, in their visit to the Michoud site, the question of Michoud's suitability as NASA's manufacturing facility was decided quickly, and the Ad Hoc Site Selection Committee had used their visit to begin answering the question of where to locate the test facility.

Transfer of the Michoud Plant to NASA occurred very quickly; more was required to take control over the Pearl River site where NASA wanted to establish a test-fire site. On 7 September 1961, NASA formally announced its selection of the Michoud Ordnance Plant "for

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[98] Copy of Memorandum, General Donald R. Ostrander to Robert Seamans "Planning for Utilization of Michoud Facility," 13 July 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
[99] "National Aeronautics and Space Administration Launch Vehicle Manufacturing Site Selection by Ad Hoc Site Selection Committee, August 23, 1961," NASA Historical Archives, Washington, D.C. Quoted from Zigler, *Fertile Southern Crescent*, 35. Underlining in original.
[100] Ziglar, *Fertile Southern Cresent*, 29-30. Ziglar cites Office of Programs, Action Sheet, "Policy Guidelines re Central Point for Consideration of Facility Sites." 20 June 1961 to 18 August 1961. NASA Historical Archives, Washington, D.C.
[101] Copy of Memorandum, Milton W. Rosen, Acting Director, Launch Vehicle Program to Robert Seamans, Associate Administrator, "Report of the Ad Hoc Site Selection Committee," 1 September 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
[102] Ibid.
[103] Ibid.

fabrication of large launch vehicle stages."[104] On 25 October 1961, NASA announced that they "moved to acquire some 13,500 acres in southwest Mississippi as the site of a static test facility for Saturn and Nova class launch vehicles." The news release noted that the area is "located about 35 miles from NASA's Michoud Plant in New Orleans," and would have "deep-water access for booster transport to the Michoud Plant via the Pearl River and Intra-coastal Waterway." The site, called the "Pearl River area" in the news release, cost approximately $13.5 million to acquire, and required that 85 families relocate from within the area itself and that another 575 relocate from a 128,000-acre "buffer area." The families would have 2 and ½ years to relocate.[105]

* * *

Although the Michoud plant seemed the best and obvious choice for NASA's system of development, production, and operation of spacecraft, it was not a perfect site. Wernher von Braun, Director of the Marshall Space Flight Center, remained concerned about two potential problems. He was most concerned about the extent of corrosion that could result from exposure to the high levels of humidity and the salt air of the nearby Gulf of Mexico. And Von Braun was also concerned about the possibility that a Hurricane might flood the manufacturing facility, and wrote to NASA's Director of Manned Space Flight Brainerd Holmes to with the MSFC's tests in progress that were "exposing typical material test samples, both inside and outside the plant facility." Von Braun engineers planned the test results at Michoud "to be compared with similar tests presently being conducted at Huntsville and at the Atlantic Missile Range," in order to make "a more exact evaluation of the corrosive effects."[106]

In his reply, Holmes praised Von Braun for "undertaking a program to expose typical material test samples to the environmental conditions to be expected at the Michoud operation," in which engineers at MSFC "will compare the results of these tests with similar experiments being conducted at Huntsville and at the Atlantic Missile Range." Holmes echoed von Braun's concern about environmental conditions, writing, "I believe it is extremely important that we assure ourselves that we have controlled environment within all manufacturing and assembly areas at Michoud. We believe that the modernization and renovation of the building air conditioning system is a 'must'."[107]

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[104] News Release, Public Information Office, George C. Marshall Space Flight Center, 7 September 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
[105] News Release, Public Information Office, George C. Marshall Space Flight Center, 25 October 1961.
[106] Wernher von Braun, Huntsville, to D. Brainerd Holmes, Washington, D.C., 19 February 1962. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
[107] D. Brainerd Holmes, Washington, D.C., to Wernher von Braun, Huntsville, 27 February 1962. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Von Braun also explored the history of hurricanes at the site, providing Holmes with a "tabulation of hurricanes of record and the climatological data in the area," and showing that significant hurricanes struck Michoud in 1893, 1901, 1909, 1915, 1947, and 1956.[108] Von Braun presented a report produced by the U.S. Army Engineer District "showing the location and grade elevation of existing protective levees or embankments and the desirable future grade elevations," which "would prevent flooding from hurricanes with a return period of about 10 years."[109] Holmes responded with concern in his letter, writing that "we ought to take all steps necessary to assure ourselves that the flooding of this plant because of [a] hurricane would be a most remote possibility. When one considers the setback to our space program which could result from such a catastrophe," he wrote, "it would seem prudent to be extremely conservative in providing protection against such flooding through dikes and pumping facilities, as appropriate."[110] NASA would ensure that the facility remained safe from the possible damage resulting from a hurricane.

Developing NASA's system of engineering, producing, and operating spacecraft, entailed geographical decisions as much as it entailed decisions about arrangements among technologies, people, and institutions. Given the lack of time to construct a manufacturing facility, for instance, the Marshall Space Flight Center found a facility at the Michoud Factory, which is in New Orleans and along the Mississippi River. The site was the best choice for the attributes of the facility (its ability to house the production of the massive launch states of the Apollo Program), but it was also nearly perfect for its proximity to Huntsville's Marshall Space Flight Center and to the Atlantic Missile Range's Cape Canaveral. And, very important, the site was sought after for its access to waterways, because barges were virtually the only way to transport the enormous launch stages between Huntsville, New Orleans, and Cape Canaveral. The "system" came first, despite political pressure exerted by state and local interests.

It is not surprising that NASA often used images of maps to represent itself as an organization and to represent the work that needed to be done. NASA used maps to convey the location of its vendors (Figure 3), the sites of its major centers (Figures 2 and 3), and to convey the transportation routes and methods of transport (Figure 6). Representation of NASA by maps was also provided clues to the manner in which NASA organized and controlled the processes of developing, producing, and operating spacecraft. Michoud, in particular, began as a satellite of NASA's Marshall Space Flight Center, and was shaped to a large extent by the decisions and actions of administrators and engineers at Marshall, who integrated the facility among the many different sites that developed and produced propulsion systems and rocket stages, and their components, for the Saturn V and Saturn I rockets. Long after the Apollo program, and even

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[108] Chart, "Hurricanes of Record: Michoud, LA.," included in Von Braun to Holmes, 19 February 1962; quotation from Holmes to Von Braun, 27 February 1962.
[109] Von Braun to Holmes, 19 February 1962.
[110] Holmes to Von Braun, 27 February 1962.

after the Space Shuttle program, the Michoud Assembly Facility continues to as a satellite of the Marshall Space Flight Center.

The First Inhabitants of NASA's Michoud Assembly Facility

NASA acted quickly on the recommendation and began to prepare on 26 September 1961, MSFC's Director, Wernher von Braun, named George N. Constan as "acting manager" of the Marshall Space Flight Center's "New Orleans operations."[111] The official news release announcing Constan's appointment noted that "Michoud is a former defense plant which has been inactive for about eight years," which suggested that much work needed to be done to prepare the facility.[112] On 10 October 1961, MSFC entered into an agreement with Gurtler, Hebert, and Co., Inc. of New Orleans for "inspecting, repairing, and returning to useable condition the huge manufacturing building … and an adjoining office building, plus certain work on the grounds."[113] NASA planned for the work of renovating and preparing the plant to occur in tandem with the preparations made by site's eventual tenants, the contractors who would establish their own arrangements for the facility in order to manufacture boosters for the Apollo program.

On 14 September 1961, MSFC announced a "pre-proposal conference" to be held on 26 September "for firms interested in submitting bids on a contract to produce the booster (S-I) stage of the Saturn space vehicle," the booster that would become the Saturn V's S-IC launch stage. The news release stated that "The contractor selected will operate in a government-owned facility 15 miles east of New Orleans, formerly known as the Michoud Ordnance Plant," though "Saturn boosters are presently fabricated at the Marshall Center in Huntsville."[114] Interested bidders, followed the news release, "will have until October 16 to enter their proposals at the Marshall Center."[115] NASA released a request for proposals for the S-IB "advanced Saturn booster," on 7 October 1961, inviting 27 firms to provide proposals by 8 November 1961.[116]

Marshall also planned to award a separate contract to maintain the Michoud site and to support the site's contractors engaged in production of the two boosters. On 30 October 1961, MSFC submitted a request for quotations for a contract "to provide support services" for the "Michoud Operations." A news release stated that the "firm receiving the support services contract will provide personnel, equipment and materials for the provision of transportation, security, fire protection, photographic, medical, food supply, communications, custodial, plant maintenance and repair, engineering messenger and mail, refuse, reproduction and utilities services at the

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[111] News Release, Public Information Office, George C. Marshall Space Flight Center, 26 September 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
[112] Ibid.
[113] News Release, Public Information Office, George C. Marshall Space Flight Center, 11 October 1961.
[114] News Release, Public Information Office, George C. Marshall Space Flight Center, 14 September 1961.
[115] Ibid.
[116] News Release, Public Information Office, George C. Marshall Space Flight Center, 7 October 1961.

Michoud facility."[117] The "housekeeping" services contract, as the procurement plan called it, was meant "as a corollary procurement to the approved Procurement Plan on SATURN SI and S-IB Stages," and was presented as a "comprehensive service support requirement by management, operation, and maintenance." The contract was apparently meant to free the manufacturing contractors of these responsibilities, as the "housekeeping" procurement plan explicitly "excludes management of the total engineering and production services of the prime SI and S-IB efforts and the distinct separate plant renovation."[118]

On 8 December 1961, NASA selected Mason-Rust to provide support services at MSFC's Michoud Operations. Mason-Rust was a joint venture of Rust Engineering Company of Pittsburgh and Mason & Hangar-Silas Mason Company of Lexington, Kentucky, according to the news release.[119] In the same news release, NASA selected The Chrysler Corporation "to produce the Saturn S-I booster at Michoud."[120] Soon after, on 15 December 1961, NASA announced that it would "negotiate with the Boeing Co., Seattle, Wash., for a contract to develop the first stage of the advanced Saturn launch vehicle," and expected that the contract would be "worth more than $300 million" and "run through 1966," calling for "development, construction, and test of 24 flight boosters plus several ground test versions."[121]

Preparation of the Michoud plant as a manufacturing facility for NASA during the Apollo program revealed the hierarchies of NASA's system of developing, producing, and operating spacecraft. With widely varying degrees of success, officials and engineers at Marshall sought to exert very close and systematic control over the design and production of the S-IC and S-IB launch stages, and over the movements of production and test units among NASA's sites. Although Boeing and Chrysler produced the boosters of the Apollo program, for instance, officials and engineers at NASA's Marshall Space Flight Center strongly controlled the modifications to the facility itself to manufacture the launch stages, as well as the manufacturing processes employed.

Officials at Marshall, for instance, established and tested the manufacturing processes while developing prototype S-IC launch stages in Huntsville, and then exerted strong influence over the manufacturing arrangement that Boeing and Chrysler employed at Michoud. The decisions of officials and engineers at NASA were also extraordinarily important in shaping the dimensions and characteristics of the newly-built "Vertical Assembly Building" (VAB), Building 110, a facility constructed adjacent to Building 103, where Boeing employed assembled the major components of the S-IC launch stage. Second, officials at NASA required that the planning and

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[117] News Release, Public Information Office, George C. Marshall Space Flight Center, 30 October 1961.
[118] Wernher von Braun, Director, Marshall Space Flight Center to B. R. Brackett, 27 September 1961, National Aeronautics and Space Administration, "Procurement plan for 'Housekeeping' Services at Michoud Plant," 1, Marshall-Michoud file. NASA History Office, Washington, D.C.
[119] News Release, Public Information Office, George C. Marshall Space Flight Center, 8 December 1961.
[120] Ibid.
[121] News Release, Public Information Office, George C. Marshall Space Flight Center, 15 December 1961.

accounting of work were integrated with the planning offices at Marshall through links between a newly created computing center at Slidell, Louisiana (about 10 miles from Michoud). And planners at Marshall Space Flight Center also embedded the Michoud Assembly Facility within water transportation network that tied together the Michoud Plant with the facilities at the Marshall Space Flight Center, with the newly-created Mississippi Test Facility at Pearl River (where testing of production stages would take place), and with the Cape Canaveral launch site of the Atlantic Missile Range.

Preparing Michoud for the Production of Apollo's S-IC and S-IB Launch Stages

Renovation at Michoud began before MSFC had selected contractors. The roof of the Administration Buildings (Building 101) needed repair, and work was begun. On 30 October 1961, George Constan reported that the "roofing contractor has begun," and that "work is 15% - 20% complete."[122] Work had also begun on "fitting/repairing screens and painting window trim," to "test interior water pipes." And for the "manufacturing building," work had begun "toward removal of partitions in shop area."[123] While contractors began working to reawaken the Michoud complex from its eight-year slumber, MSFC was busy "evaluating" seven proposals for the S-I contract (this launch stage would soon be called the S-IC launch stage), with more proposals to come by the 7 November deadline. Similarly, proposals were due from contractors on 8 November for the S-IB contract.[124]

By the end of November 1961, the "roofing work" on the Administration Building was complete. There remained much more to do to prepare the two office buildings and the manufacturing structure for occupancy: "testing of transformer banks," "electrical work," "testing of boilers" (which needed "minor repairs"), "painting of office building (inside)," and the repair of "outside screens," of which installation awaited the completion of painting on 1 December.[125] More work followed to renovate the Engineering Building, Building 102.

Work to renovate the Administration and Engineering buildings continued through 1961 and well into 1962. During the month of April, for instance, contractors were still "repairing electrical circuits and lighting" on the Engineering Building's first floor. Work on the "main electrical sub-station," wrote Constan, had been nearly completed.[126] On 4 June 1962, Constan reported that "Initial renovations to the office and engineering building are completed," but added that the buildings' "sprinkler system is completely rusted and should be replaced."[127] Contractors continued their seemingly endless renovations on the Office Building and

[122] George N. Constan, "Weekly Notes to Wernher von Braun," 30 October 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
[123] Ibid. See also Constan, 4
[124] Ibid.
[125] Constan, "Weekly Notes," 20 November 1961. See also Constan's "Weekly Notes" of 4 December 1961.
[126] Constan, "Weekly Notes," 23 April 1962.
[127] Constan, "Weekly Notes, 4 June 1962.

Engineering Building.[128] Work on the manufacturing building also continued, as Boeing and Chrysler prepared their manufacturing layouts and began to construct their assembly and manufacturing stations.

By the end of December 1961, the removal of "partitions" in the manufacturing structure had been completed.[129] The "painting of the asbestos shingles" on the outside of the structure began 22 January 1962.[130] The replacement of its roof proved to be a surprise for George Constan, who planned the maintenance for 1964. Constan wrote in his Weekly Report to Von Braun of 13 August 1962, however, that a new roof for the manufacturing structure was needed in 1963, "as soon as possible due to poor conditions."[131] The money for the repair was not forthcoming, even though the repairs on the roof became "more critical each day."[132] The ongoing delays elicited remarkable concern from Wernher von Braun, "What the h… is holding it up?" he wrote on Constan's report.[133]

Other engineers and officials besides George Constan participated little in the details of renovating existing office structures at Michoud, but they did closely monitor and, at times, attempt to influence the layouts of Boeing and Chrysler within the manufacturing building at Michoud. (Constan may have been Director of Michoud Operations but he reported directly to Wernher von Braun at MSFC.) The relationship between MSFC and Chrysler Corporation Space Division at Michoud Operations, for instance, illustrates the extent to which engineers and officials at MSFC sought to control and integrate and manufacturing at the Michoud site within the structure they created for developing and manufacturing propulsive stages for the Apollo program's rockets. The relationship between Marshall and Chrysler seemed to begin inauspiciously; Constan reported that Chrysler complained that "the space assigned to them at Michoud is insufficient."[134] But the complaint about the lack of space within the manufacturing facility turned on a question of the roles of the MSFC and that of Chrysler in producing the S-IB launch stage. And, as for the other examples that follow, Marshall could only control the roles of its participating groups in varying degrees—just as Marshall's officials and engineers had difficulty controlling the circumstances they would encounter in the process of designing and building launch stages.

On 5 February 1962, Constan (again) reported that Chrysler protested the "space allotted to them was too small." However, when "MSFC personnel" examined Chrysler's "detailed layout of the production area," wrote Constan, they found "a number of departures from what we understand

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[128] Constan, "Weekly Notes," 11 June 1962.
[129] Constan, "Weekly Notes," 18 December 1961.
[130] Constan, "Weekly Notes, 22 January 1962.
[131] Constan, "Weekly Notes, 13 August 1962.
[132] Constan, "Weekly Notes, 27 August 1962.
[133] Ibid.
[134] Constan, "Weekly Notes, 29 January 1962.

to be the basic Chrysler assignment."[135] Chrysler's layout revealed facilities for "fabrication of nearly all items in Michoud instead of using MSFC developed vendors and sources." And Chrysler's manufacturing floor layout also revealed "Extensive R&D activities as evidenced by layout of specialized laboratories (such as spectrographic labs.) and environmental test facilities." The layout suggested that Chrysler viewed their role as more than assemblers of the designs and parts that MSFC engineers specified, Chrysler expected to be full participants in the design process. The report of additional laboratories in Chrysler's layout provoked an annoyed handwritten response from MSFC Director Wernher von Braun, who wrote, "Let's stop this nonsense. No wonder we're short of funds!! Please let me know what corrective action has been taken."[136]

"Preliminary meetings" were quickly held between "interested MSFC elements" and "a unified position for MSFC has been established," wrote George Constan on 12 February 1962.[137] A meeting was planned for the following week "between MSFC and Chrysler to evaluate Chrysler's production layout."[138] At the meeting, it "was determined that Chrysler should proceed with their detailed layout using six bays within the Michoud facility," and another meeting was scheduled between MSFC and Chrysler on 26 February, "to review the detailed layout and the make-or-buy plan."[139] MSFC and Chrysler reconciled their differences. Constan reported that Chrysler "presented their initial make or buy plan to Michoud Operations and MSFC Division representatives" and "with a few minor exceptions," he wrote that the plan was "satisfactory," and that "approval actions are underway."[140] As well, Chrysler's revised plant layout found "verbal acceptance of functional locations" although, noted Constan, "some minor changes were agreed upon" along with "MSFC requests [for] more detailed information and functions supported by some laboratory areas."[141]

MSFC engineers may have compromised on some points at the meeting—accepting a "make-or-buy" plan reveals that MSFC softened their requirement that Chrysler use "MSFC developed vendors and sources." However, the episode revealed that MSFC exerted a remarkable effort to control the manufacturing and design process, a pattern that would recur in the design and production of the S-IC and S-IB stages.

It became clearer that Chrysler wanted to do and be more than simply a manufacturing contractor for the Apollo program. In a meeting of 9 May 1962, according to a report by Harry Gorman, Deputy Director for Administration, Chrysler representatives "expressed concern" that the company "may not be able to participate in furnishing engineering support to MSFC beyond

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[135] Constan, "Weekly Notes, 5 February 1962.
[136] Constan, "Weekly Notes, 5 February 1962.
[137] Constan, "Weekly Notes, 12 February 1962.
[138] Constan, "Weekly Notes, 12 February 1962.
[139] Constan, "Weekly Notes, 19 February and 26 February 1962.
[140] Constan, "Weekly Notes, 5 March 1962.
[141] Ibid.

September 30, at which time the work now being performed under the Chrysler level of effort contract will be phased into the definitive contract."[142] Gorman wrote that his answer to Chrysler representatives expressed the position "that Marshall intended to hold Chrysler responsible for the scope of work identified in the request for proposal and to be identified in the final contract and that we have no commitment to Chrysler for any work that would fall outside the S-I scope."[143] To placate representatives of the Chrysler Corporation Space Division, Gorman also told the corporate representatives that, "while Chrysler is free to propose on any requirement for which they qualify, from a policy view we do not favor stage contractors providing engineering support except as required under the mission contracts."[144]

The answer was a good one, thought Von Braun, who responded that it "Seems to be the only sound & correct position for us to take. Suggest..that we make sure all MSFC divisions involved understand this clearly."[145] But while the answer revealed the extent to which Marshall used contracts, as well as their own manufacturing sites, to carefully define and circumscribe the roles of their contractors—both for contractual reasons and to maintain control over the design and production process—Marshall also depended on their contractors, and sought to maintain their loyalty and goodwill. This may be why Wernher von Braun also added that "They [Chrysler] should be given a chance (in fact: they should be specifically invited to) identify all remaining engineering support in the S-1 plus C-1 systems work area for inclusion in the definitized contract. Unless we do that, I expect a full-fledged fire alarm in September [1962]."[146] Ultimately, it seems, it was important to keep contractors happy in order to achieve the best possible results, and this meant that sometimes Marshall's engineers and officials needed to delegate portions of the closely-controlled design process to contractors such as Chrysler and Boeing.

Indeed, a year later, Ernst Geissler, Director of Aeroballistics Division at Marshall, reported that Chrysler was trying to establish an "Aeroballistics Section" at Michoud. Geissler reported that "Chrysler has made some progress in establishing an Aeroballistics Section at Michoud, in spite of their problems in obtaining qualified personnel and the fact that they have few people on board from the 'old Chrysler team.'"[147] Geissler's tone was different, suggesting approval of Chrysler's efforts. "It will take some time for their team to become completely familiar with our programs and operating techniques," he wrote, "but they are working hard to accomplish this." Geissler comments seemed to exhibit confidence in Chrysler's abilities, and encouragement that there would be uses for their abilities around MSFC. "Chrysler will continue to build up this

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[142] Harry Gorman, "Weekly Notes to Wernher von Braun," 14 May 1962. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
[143] Ibid.
[144] Ibid.
[145] Ibid.
[146] Ibid. Underlining in original.
[147] Ernst Geissler, Director of Aeroballistics Division, "Weekly Notes to Wernher von Braun," 28 October 1963. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

section, broaden their skills and demonstrate their competence. We hope to be able to assign them Aeroballistics system responsibility by early 1966."[148] Despite Marshall's initial reluctance, Chrysler was able to expand its role to include more engineering, and MSFC grew to embrace the Company's efforts.

The S-IC contract was little different in that MSFC's engineers maintained substantial control over the design and manufacturing process. Immediately after an initial contract was finalized on 12 February between MSFC and Boeing, Oswald H. Lange, Chief of Saturn Systems Office, reported that "The Boeing Co. will send approximately 30 technical representatives to MSFC on 2-19-62, to familiarize themselves with the S-IC activities at MSFC and to develop technical contacts."[149] A month after Chrysler Corporation Space Division submitted its proposed plant layout to MSFC, Boeing submitted its own layout, on 5 March 1962.[150]

The Boeing manufacturing plan for Michoud gained the attention of many engineers at MSFC, and Werner Kuers, who was Deputy Director of the Fabrication and Assembly Engineering Division at MSFC, characterized the review process as "a heavy burden, requiring continuous attention of key people."[151] He wrote that "several items would merit more serious investigation, but we can only make a cursory review due to the time element."[152] Marshall's engineers would make much more than a cursory review of Boeing's manufacturing plans over the course of the Apollo program, because the manufacture of the S-IC launch stage would require expensive tooling, and plant modifications to the Michoud manufacturing facility.

At this early stage of the design, however, Boeing could not provide many details for investigation, for many important underlying decisions were out of their hands. The reason was that Marshall had not yet arrived at enough of the design of the S-IC launch stage to warrant a manufacturing plan. On 16 April 1962, H. R. Palaoro, Chief of the Vehicle Systems Integrations Office, wrote to William A. Mrazek, Director of the Vehicle and Propulsion Engineering Division, "In the S-IC area, we have a problem…Boeing is required to furnish a number of plans, among others a Model Spec and Test Requirements Plan." But, wrote Palaoro, "Since Boeing doesn't really know what the stage will look like since we are designing it, they have a hard time to come up with sensible documents, which will be acceptable to us."[153]

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[148] Ibid.
[149] Oswald H. Lange, Director of Saturn Systems Office, "Weekly Notes to Wernher von Braun," 19 February 1962. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
[150] Constan, "Weekly Notes," 5 March 1962.
[151] Werner Kuers, Deputy Director Fabrication and Engineering Division, "Weekly Notes to Wernher von Braun," 19 March 1962.
[152] Ibid.
[153] H. R. Palaoro, Chief of Vehicle System Integration Office to William A. Mrazek, Director of Propulsion and Vehicle Engineering Division, "System Integration Activities," 16 April 1962. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

If Marshall's engineers closely guarded the design of the S-IC launch stage itself, they were willing to compromise in the design of the manufacturing processes. When it came to the "Preliminary concept," recalled MSFC's Manager for the S-IC Stage, Matthew Urlaub, "why did you choose this diameter, factor of safety, pressure requirements, general layout—that's all Marshall." But he continued, "When you talk about converting an idea to a producible item, the detail drawings that you can contract on and specifications that you can contract on, and assembly techniques that are repeatable, give you repeatable results … that was all Boeing." Urlaub celebrated Boeing's contribution in the design of manufacturing tooling, saying, "They did a tremendous job in an area where they had the expertise and we didn't. You get in to building airplanes…and the whole process, of drawing generation, quality, tool design, and how you make the parts come together in a repeatable fashion"—these aspects of the producing the S-IC launch stage were Boeing's contribution.[154] Nevertheless, Marshall's engineers remained the "principal" engineers in both the effort to design the S-IC launch stage and to initially manufacture it. Marshall often had the last word in manufacturing decisions and processes undertaken at the Michoud facility though, as shown below, the manufacturing expertise of Boeing's engineers lent them an authority which caused Marshall's engineers to make compromises.

The tooling required for the big components of the S-IC Launch Stage—bulkheads, tanks, the tunneling through the tanks—required big, precise, and expensive tools and fixtures. Boeing's manufacturing plan included plans and designs for tooling that seemed as important as the design of the launch stage itself, at least in terms of the time it took to produce, build, and debug. The "pacing item in this plan," wrote Lange, "is the bulkhead assembly fixture which will costs $200-300,000, and approximately 32 weeks will be needed to complete the first <u>four</u> bulkheads because of this fixture."[155]

On 14 May 1962, H. R. Paloaro seemed to present the relationship between Marshall and Boeing as more collaborative than he described earlier, one that exhibited greater division labor and, perhaps, took better advantage of each group's expertise. "On the S-IC stage," he wrote to William Mrazek, "we are making progress in establishing schedules and data toward this combined development approach with Boeing. It came up in discussions with the Boeing representatives again, that we have divided up the hardware problem areas pretty well for this task."[156]

The shift toward a more collaborative relationship was reinforced by the reports of Werner Kuers, Deputy Director of the Fabrication and Assembly Engineering Division at MSFC, at least

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[154] Matthew Urlaub, Interviewed by Roger E. Bilstein, 29 July 1975.
[155] Oswald H. Lange, Chief, Saturn Systems Office, "Weekly Notes to Wernher von Braun," 12 March 1962. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
[156] H. R. Palaoro, Chief of Vehicle System Integration Office to William A. Mrazek, Director of Propulsion and Vehicle Engineering Division, "System Integration Activities,"14 May 1962. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

in the area of tooling for the S-IC launch stage. In his weekly report to Von Braun of 23 July 19962, Kuers wrote that "A complete listing of 157 assembly and sub-assembly tools has been established jointly with Boeing. An agreement on the split of tool design responsibility as been reached whereby the design for the major tools for the tanks and the thrust structure will be carried out in-house and Boeing will take over responsibility for inter-tank structure, forward skirt and fins."[157] Indeed, Boeing shouldered much of the responsibility for the manufacturing tooling for the first articles, which were produced at Marshall under the direction of Kuers. He wrote that "Boeing will, of course, fabricate all the tools for us. They will also install them in our shops and be responsible for necessary modifications during try-out period."[158] However, Kuers left no question about the control that MSFC engineers would exercise in the process, which MSFC defined carefully in the coming contract. "The Boeing work for tool design and fabrication will be controlled by written task order assignments by us," wrote Kuers, "under item 2 of the follow-on contract."[159]

Welding Problems

Problems appeared that MSFC engineers could not solve alone, such as in the welding of the bulkheads, and in welding of the pressure vessels, with their "y" rings (specially welded and machined "rings" that were shaped like a "y" in cross-section, and used to join together the domes at the ends of the lox and fuel tanks to the tanks' cylindrical walls).[160] When such welding problems arose, MSFC and Boeing collaborated more and more, with the work finally falling to Boeing's manufacturing engineers. At the end of 1962, fo instance, Kuers complained that "Multipass welding of 5" thick plates for Y-Ring fabrication by Boeing at Michoud seemed for some time to become a critical item because Boeing was not able to produce a single sample weld which was acceptable to Quality Assurance Division."[161] Meanwhile, at Kuers own parallel manufacturing facility at MSFC, engineers had difficulty with their own "meridian weld station," which was used to tie together the sections of the dome to tanks. They were hindered, Kuers wrote, "due to problems pertaining to the gore trimming."[162] The domes were composed of narrow curved pie-shaped sections called "gores," each welded together and converging at points at the top of the pressure vessel's domes, like the spaces between longitudinal lines on globe as they approach the North or South Pole.[163] Boeing made the ½ inch thick and "sculptured" gores.

In many cases, MSFC engineers directed Boeing to make changes. In the case of the gores, MSFC called upon Boeing "to form these segments unmachined and ship them to Ryan [a

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[157] Kuers, "Weekly Notes," 23 July 1962.
[158] Ibid.
[159] Ibid.
[160] See Bilstein, *Stages to Saturn*, 206.
[161] Kuers, "Weekly Notes," 10 December 1962.
[162] Ibid.
[163] Kuers, "Weekly Notes," 25 March 1963.

fabrication company] for chemical milling."[164] Kuers also noted in his report that MSFC, "after modification of our Gore Trim Fixture and Meridian Weld Fixture," had "succeeded in making the first meridian weld on the bulkhead." However, he noted, "X-ray evaluation of the weld revealed some porosity requiring repairs." MSFC also pushed Boeing to "change their planning in the area of optical alignment of the structure and in the method of laying the structure down from the vertical to the horizontal position." Boeing's practice of laying down the structure before assembly required an expensive optical alignment, and still risked creating an adverse tolerance "stack-up." Kuers proudly stated that "Quality Division is in complete agreement with us," and that "we [MSFC] eliminated a special fixture [at Boeing], called the skate dolly, which is estimated to cost between $200,000 and $300,000."[165] The discussion revealed the ongoing difficulties that both MSFC and Boeing confronted in perfecting the welds that brought together tanks and bukheads of the S-IC launch stage.

But the welding problems increasingly became the problems of Boeing's engineers at Michoud as the S-IC-T, the testing prototype that Marshall had been building, neared completion. On 21 September 1964, for instance, the "meridian welding equipment" seemed to be firmly in place and making production welds at Michoud, but was exhibiting "unpredictable oscillation or hunting of the head"—the point of contact for the welder. Constan reported that, "Since this station is loaded end-to-end for the next several vehicles, we anticipate more slippage in weld station certification and resultant vehicle fabrication."[166] Michoud's engineers had the benefit of learning with MSFC engineers, however, and by 26 October 1964, Boeing seemed to be closer to a solution on the meridian welding. Constan again reported that "The weld station has improved with the last two welds[,] having one and six defects, respectively. The Boeing task force, headed by Mr. McCellan, has provided a much more systematic approach to welding problems and a concentrated system of follow-up to insure permanent resolution to this problem."[167]

The problems persisted for other welds, however, as Kuers related in his report of 2 November 1964. He stated in the report that "The fabrication of bulkheads by Boeing is not successful at the present time. The Boeing Company has [yet] to deliver three complete bulkheads to MSFC, one each for -S, -1, and -2," with the -1 and -2 denoting bulkheads for S-IC stages destined for Apollo's first flights of the Saturn V rocket, *Apollo 4* and *Apollo 6*, nearly two years away. "The quality of the first two bulkheads (-S and -1)," wrote Kuers, "was such that they could not be accepted or repaired and had to be scrapped."[168] The welding problems were ongoing and also revealed that that MSFC manufacturing engineers would not stand pat and wait for Boeing to resolve them.

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[164] Ibid.
[165] Kuers, "Weekly Notes," 15 April 1963.
[166] Constan, "Weekly Notes," 21 September 1964.
[167] Constan, "Weekly Notes," 26 October 1964.
[168] Kuers, "Weekly Notes," 2 November 1964.

Kuers continued about the bulkhead welding problems, stating that "Several factors contributed to this unsatisfactory result." Kuers seemed to regret that MSFC engineers did not have more authority in shaping Boeing's manufacturing processes. "We do not direct the Boeing Company to copy our welding processes and techniques," he went on,

> they selected to develop their own techniques, and they have capable people in their methods development organization. However, they failed to make sufficient use of experience gained at MSFC. In spite of all training and help we have given them, the skill of their crews at Michoud is not yet the level required. I have agreed with Mr. Coenen [Boeing's liaison to the MSFC] to provide in the future more direct help and advice in Michoud.[169]

Bulkhead welding of the S-IC launch stage improved, finally, reported Constan nearly a month later, and MSFC engineers of the Manufacturing Engineering Laboratory were important in helping. "The quality of the last few welds appears greatly improved," wrote Constan, "and it appears that considerable progress in improving weld techniques has been made. [MSFC's] ME Lab [Manufacturing Engineering Lab] assistance has been substantial."[170] The ongoing welding problems revealed the extent to which MSFC engineers continued to oversee the process, but it also revealed a general transfer of responsibility for manufacturing processes to The Boeing Company.

S-IC Documentation System

Marshall's engineers also imposed a documentation system upon The Boeing Company that revealed their desire for overarching control over the design of the S-IC Launch Stage. Whilst engaged with Boeing in contract negotiations, H. R. Palaoro, sought to ensure that the documentation was tightly controlled by MSFC. He noted that "We [MSFC] want only one design for our static test booster [S-IC-T] and the Boeing flight booster. Since we make ours first," wrote Palaoro,

> this is also the design for Boeing and they help make the drawings and specifications. We will probably permit Boeing to change the letter M in our drawing numbers to B , (example: 10M0005 to 10B0005), but otherwise use exactly the same drawing and we will probably control all changes thru the Configuration Control Board as we do with Chrysler at least thru SA-505 [the fifth Saturn V expected to fly]. Boeing may not like this, but this is the basis on which they will prepare a counter proposal within the next 4 weeks.[171]

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[169] Ibid.
[170] Constan, "Weekly Notes," 30 November 1964.
[171] H. R. Palaoro, Chief of Vehicle System Integration Office to William A. Mrazek, Director of Propulsion and Vehicle Engineering Division, "System Integration Activities," 02 April 1962. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Palaoro received support from Wernher von Braun in this regard, who responded, "Sounds good to me. Please keep me posted on Boeing's reaction."[172]

And yet, the documentation changes that MSFC imposed on Boeing could backfire. Kuers lamented that "The Boeing Company has been required by MSFC to change the Engineering Release System," and "The new release comes now to us in a mechanized computer print-out system," wrote Kuers. But "[t]he manual operation for all receiving elements … does not match the mechanized flood of paper." For a program that placed extreme emphasis on each part's identification and traceability, Kuers noted that "[p]arts identification at sub-vendors and stock rooms has become a problem.[173] Unfortunately, wrote Kuers, "The new system has been introduced and cannot be changed again now, but the wisdom of introducing such a system, in the design effort being more than 50% complete, is questionable. It will have a retarding effect on all manufacturing operations."[174] Arthur Rudolph, the Saturn V Program Manager at MSFC, noted the greater inefficiencies, which required "special training sessions on the new system within Boeing and MSFC, special assistance to ME Lab to resolve specific problems." He expected "All 'bugs' … to be out of the new system release by mid-December 1964."[175]

The "Arsenal System" and the Marshall Space Flight Center

Housing their contractor's manufacturing facilities within NASA's own facility gave the officials and engineers at MSFC greater leverage to control the manner in which their stage contractors manufactured the S-IC and S-IB stages. This greater ability to control manufacturing decisions would become most apparent in decisions about the size of the Vertical Assembly Building at Michoud. From the first, NASA's engineers at MSFC shaped the decisions concerning the structure of the Vertical Assembly Building, its basic dimensions, as well as the operations that occurred within it.

From its inception, engineers and officials of the Marshall Space Flight Center have been well known for both their expertise and for their advocacy of the "Arsenal System," in which the government civil-servants take a "hands-on" role in the design, testing, manufacture, and operation of its own systems and equipment. The tradition dates back to the U.S. Army in the early-nineteenth century.[176] The approach has often been contrasted with the "Air Force System," which gives contractors freedom to both propose and evaluate the merits of technical projects, rather than the administrators of a program. Rather than maintain the technical expertise

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[172] Ibid.
[173] Kuers, "Weekly Notes," 28 September 1964.
[174] Ibid.
[175] Arthur Rudolph, Saturn V Program Manager, "Weekly Notes to Wernher von Bruan," 19 October 1964. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
[176] See for instance, Merritt Roe Smith, *Harpers Ferry Armory and the New Technology: The Challenger of Change* (Ithaca, New York: Cornell University Press, 1977). See Roe Smith's dissertation, also. Merritt Roe Smith, "The Harper Ferry Armory and the 'New Technology' in America, 1794-1854." Ph.D. Dissertation: Pennsylvania State University, 1971.

to evaluate proposals received, administrators who employ the "Air Force System" instead depend on competition among contractors to improve the quality of proposals and deliverables.

Those who believed in the Arsenal System, as did Marshall's engineers, argued maintaining in-house expertise to evaluate contractors' work served to reduce costs, maintain schedules and improve quality.[177] Marshall's espousal of the Arsenal System was certainly evident in the case of the S-IC launch stage for its engineers took leading roles in the design, manufacture, and testing of the vehicle. As Georg F. von Tiesenhausen, recalled, "Boeing knew exactly what they were doing, but they watched and then we turned over the specifications and drawings, blueprints, and they made theirs exactly like ours." Von Tiesenhausen acknowledged Boeing's contribution, however: "That doesn't mean that they did not later improve here and there." Citing the arguments associated with the Arsenal System, Von Tiesenhausen argued that MSFC's engineering control was legitimately based on their expertise and their experience with the project under way. "[W]e could afford to do that," he said, "because we had a 'hands-on' approach in-house." Von Tiesenhausen regretted, however, that MSFC's engineers were "maybe authoritarian."[178]

Designing and Constructing Michoud's Vertical Assembly Building (VAB)

In the construction of Michoud's Vertical Assembly Building, Marshall's "hands-on" approach was evidenced by the MSFC's parallel construction of its own Vertical Assembly Building in Huntsville. When, according to Kuers, "Boeing originally proposed an additional 120,000 square feet of high bay area at Michoud," he recoiled, stating "There is no justification for this proposal because many of the operations planned in this facility could be performed adequately in the main Michoud building." Kuers could point to the Vertical Assembly building at MSFC and say that "our area has 10,000 square feet, is 140 feet in height, and will cost 1.4 million." Successfully challenging Boeing's design, Kuers bragged that MSFC engineers "reduced, with their [Boeing's] concurrence, the requirement to approximately 50,000 square feet, of which only 20,000 square feet would be 200 feet in height. The remaining area would be 100 feet high."[179]

However, Boeing "still included the large 200 ft. high building in their proposal as an alternate to our proposal," reported Kuers on 16 April 1962.[180] In his steady refusal to accept the alternate proposal, Kuers found support from Von Braun, who wrote, "W.K., It's entirely up to us to reject the alternate and pick what we think is in the best interest of the govt."[181] The plans for the "high bay facility" at Michoud were finalized in late May 1962, reported Kuers, "The two level

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[177] Andrew J. Dunar and Stephen P. Waring, *Power to Explore: A History of the Marshall Space Flight Center, 1960-1990*. Washington, D.C.: National Aeronautics and Space Administration, 1999, 42.
[178] Georg F. von Tiesenhausen Interview, 29 November 1988.
[179] Kuers, "Weekly Notes," 9 April 1962.
[180] Kuers, "Weekly Notes," 16 April 1962.
[181] Ibid.

structure as proposed by the ME [Manufacturing Engineering] Division has been basically accepted. The total square foot area was reduced from 120,000 to 34,300 of which only 9,860 sq. ft. is 200 ft. high."[182] The Marshall Space Flight Center seemed to have the final word on the dimensions of the Vertical Assembly Building at Michoud. It "meets all requirements agreed upon with M-ME, M-QUAL, and M-MICH," wrote Constan on 18 June 1962, as the design package was finalized and, he noted, "the revised cost estimate for the facility falls within the budget."[183]

But Marshall's influence would not stop there, they would also influence the manner in which Boeing used the VAB. While noting that Boeing's S-IC Manufacturing Plan "differs in many respects from our MSFC plans because of differences in facilities and because of higher production rates at Michoud," William Kuers nevertheless complained about the differences in the ways that Boeing planned to use its Vertical Assembly Building.[184] "During the last 6 months," he wrote, "it became more and more apparent that Boeing had developed different concepts for utilization of their Vertical Assembly Building (VAB), which required different and additional tooling which did not meet our approval."[185] Kuers himself became "gravely concerned about this divergency of our concepts because of the obvious flaws in the Boeing plans."[186]

The influence that MSFC exerted managed to sway Boeing's engineers again. "In a meeting last Friday," wrote Kuers, "we succeeded finally to come to an agreement. Mr. Coenen and his tooling and facilities engineers presented a new plan in which they had adopted our principles. This new plan will be effective for the -F vehicle without any schedule impact. One basic advantage of this plan is that it does not require the activation of a third assembly station in the VAB, thus saving the big turntable and equipment for this station." In the end, Kuers characterized Boeing's compromises as un-coerced. "We are glad," he wrote, "having reached this decision voluntarily by Boeing without [Marshall's engineers] being forced to give them a directive."[187]

The Vertical Assembly Building (VAB), Building 110, was completed on 15 December 1964.[188] David Akens report that "Boeing completed the equipping and instrumentating of this facility

[182] Kuers, "Weekly Notes," 21 May 1962; Constan, "Weekly Notes," 21 May 1962.
[183] Constan, "Weekly Notes," 18 June 1962.
[184] Kuers, "Weekly Notes," 21 September 1964.
[185] Ibid.
[186] Ibid.
[187] Kuers, "Weekly Notes to Wernher von Braun," 21 September 1964. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
[188] David S. Akens, Leo L. Jones, A. Ruth Jarrell, *History of the George C. Marshall Space Flight Center from July 1 Through December 31, 1964, Volume One*. MSFC Historical Monograph No. 10 (MHM-10). Huntsville, Alabama: MSFC Historical Office, 1966., 144. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

and occupied it during the period," however, "the tank repair station was still under design" at year's end.[189]

Building 110 stands approximately 203 feet high, measuring 195 feet by 215.25 feet with over 8.5 million cubic feet of interior volume. The building features a flat roof "with a heavy cornice, walls of corrugated asbestos, and low brick walls at the base."[190] The Building 110 is attached to the main manufacturing building (Building 103) on its east and north sides, and on the building's east side there is an intermediate stepped rectangular section approximately 100 feet below the roof of Building 110's highest point, and 50 feet above the roof of the manufacturing building. A band of corrugated fiberglass beneath the cornice of the Building allows natural light to enter the structure. At the building's corners are steel piers, which provide support for the building's walls and structural elements. The white exterior is populated with rectangular vents, which are arranged in rows. Exterior light fixtures are attached to each side of the building. A large NASA logo is affixed to the north side of the building, and a metal pipe travels vertically and extends above the cornice. On the west side, facing away from the manufacturing facility, are two enormous sliding doors, 90 feet in height and 60 feet in width, the frame from which the two doors hang measure approximately 90 feet in height by 120 feet in width.[191] (see Figure 7)

Constructing a New Office and Engineering Building

The Michoud Assembly Facility may have been large enough to house the manufacturing of two different launch stages by the Boeing Corporation and Chrysler Corporation Space Division, but it did not include sufficient office space for the two contractors' administrative and engineering personnel. At the end of January 1962, Constan wrote that "Office space at the Michoud Facility will be inadequate about August 1962," and planned to undertake a "survey to determine the availability of office space in the New Orleans Area."[192] The two contractors would begin looking for space in downtown New Orleans, while officials at MSFC and NASA headquarters considered plans to bring them closer to the Michoud site.

With so little space in the Administrative and Engineering Buildings on site, by 14 May 1962 Chrysler planned to relocate from Michoud temporarily, and then to "invite firms to propose an office and engineering building" to accommodate the company's needs, thus leaving Boeing and MSFC personnel to "occupy available engineering and office space in the Michoud plant."[193] But this would not be enough, and both Boeing and Chrysler began looking for temporary office

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[189] Ibid.
[190] M. Todd Cleveland, et al, *Architectural Survey of the NASA Michoud Assembly Facility*, 74.

[191] Ibid.; Public Affairs Office, "Fact Sheet, Michoud Operations," 20 April 1965, Michoud Operations, George C. Marshall Space Flight Center. NASA History Office, George C. Marshal Space Flight Center.
[192] Constan, "Weekly Notes," 29 January 1962.
[193] Gorman, "Weekly Notes," 14 May 1962. Von Braun annotated Gorman's report, writing "Sounds like a very good solution!" The following week, Gorman wrote that "Chrysler was directed to proceed with plans for their own office building near Michoud." Gorman, "Weekly Notes," 21 May 1962.

space on the order of 100,000 square feet for their individual administrative and engineering sections. By July 1962 it became clear that Boeing alone needed "somewhere between 300,000 and 400,000 sq. ft. of office space."[194]

Both companies rented office space in downtown New Orleans as a stopgap measure, and each company made plans to build a structure near Michoud Operations. By 13 August 1962, Constan reported that "Boeing presently is leasing about 40,000 sq. ft. in Claiborne Towers down town."[195] A few weeks later Constan reported that "Boeing and Chrysler are preparing to lease office space in the 225 Baronne Building (downtown New Orleans) for about one year," he wrote, "Chrysler to lease about 85,000 sq. ft. and Boeing about 100,000 sq. ft."[196]

But, ultimately, the lack of office space threatened production schedules and George Constan, Manager of Michoud Operations, acted quickly to resolve the problem. In July, Constan had completed a study "to determine the exact amount of square footage and the time phasing that such footage will be needed by the Boeing Company."[197] By 10 December 1962, Constan reported that "MSFC has prepared and forwarded to NASA Headquarters a report on office space deficiency at Michoud. The report outlined several alternative ways to solve the deficiency of office space and outlined costs and funding comparison of the alternatives."[198]

He requested an "early decision" from NASA Headquarters on the matter.[199] By 4 March 1963, Constan had engaged the architectural firm of August Perez and Associates, and contracted the firm "to perform design and construction management of the $9 M engineering and office building to be built at Michoud Operations"—overcoming an initial disagreement with the firm over what constituted a "reasonable fee."[200] The "500,000 sq. ft. engineering and office building," a "two-story, H-shaped" structure that "also includes a cafeteria and parking lot," would become Building 350 of Michoud Operations.[201] (see Figures 8)

Michoud's Engineering and Office Building was "beneficially occupied" on 1 September 1964, and completed on 15 October. The structure cost $6.7 million. Boeing and Chrysler, as well as NASA personnel removed from their offices in downtown New Orleans, and from other temporary sites, into the new structure during the months of October and November 1964, ending their move on 10 November.[202] It was planned as a "giant" transfer, according to a NASA

[194] Constan, "Weekly Notes," 30 July 1962.
[195] Constan, "Weekly Notes," 13 August 1962.
[196] Constan, "Weekly Notes," 4 September 1962.
[197] Constan, "Weekly Notes," 30 July 1962.
[198] Constan, "Weekly Notes," 10 December 1962.
[199] Ibid.
[200] Constan, "Weekly Notes," 4 March 1963; Gorman, "Weekly Notes," 18 February 1963.
[201] Constan, "Weekly Notes," 8 April 1963; Public Affairs Ofice, "Michoud Operations Today Begins a Mass Movement," 1 September 1964. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama; Public Affairs Office, "Fact Sheet, Michoud Operations," 1 January 1965, Michoud Operations, George C. Marshall Space Flight Center. NASA History Office, George C. Marshal Space Flight Center.
[202] Akens et al, *History of MSFC, July 1 Through December 31, 1964, Volume One*, 144.

News Release of September 1964.[203] Approximately 4,400 employees of Chrysler Corporation Space Division, and from The Boeing Company's Large Systems Branch, were moved from their temporary site the Allan Towers and Claiborne Towers in downtown New Orleans. 3,800 of these employees were moved to the new Engineering and Office Building (Building 350) at Michoud, while 600 were moved to the existing administration and engineering buildings, Buildings 101 and 102, respectively.[204] The move was facilitated, according to the News Release, by the Mason-Rust service contractor at Michoud, which moved "10 to 15 van-loads of equipment nightly."[205] Employees prepared and left their desks "at the close of business one day," the News Release stated, and moved to their "same desks in the new offices the following workday."[206]

Controlling and Monitoring the Movement Data and Launch Stages

Marshall would attempt to integrate the program management transactions of Chrysler and Boeing at Michoud Operations through an integrated computing system, although it would do so for reasons of the cost efficiency of the system rather than for reasons of greater control. Helmut Hoelzer, Director of the Computation Division, reported that his division had "furnished Mr. Constan [with] a draft of a proposed manner in which computation and data reduction facilities be set up at Michoud." Hoelzer wrote that, "essentially we feel that there should be one centralizing facility servicing the various contract efforts and furnishing essential management and control data back to MSFC." Hoelzer recommended that his division set up this facility.[207] Further meetings supported Hoelzer's recommendations, mainly because there was a lack of funds to create more than a single computing facility.

The plan was that "A data link will be established between Michoud and Computational Division, MSFC, for transmitting data between the two installations. Initially the system will be used for transmission of supply data with the phasing in of financial and other data reporting."[208] The data link, therefore, would entail all transactions regarding engineering as well as program management, including financial data of costs, presumably. Constan wrote on 16 March 1962, that "it has been decided that because of lack of funds, that initially no choice other than centralizing computer and data processing exists."[209]

Boeing and Chrysler immediately took umbrage at the idea, reported Constan, who wrote that the two companies "have registered written disagreement with a centralized computer facility,

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[203] "Michoud Operations Today Begins a Mass Movement," 1 September 1964.
[204] Ibid.
[205] Ibid.
[206] Ibid.
[207] Helmut Hoelzer, Director of Computation Division, "Weekly Notes to Wernher von Braun," 12 February 1962.
[208] Constan, "Weekly Notes, 19 February 1962.
[209] Constan, "Weekly Notes," 16 March 1962.

[though] our opinion is that only one facility is justified in the immediate future." Von Braun thought that "it would appear that once we are committed to this 'centralized' approach, it'll be forever." He wondered, "What's the reason for CC's [Chrysler Corporation's] and Boeing's opposition?"[210]

In response, Chrysler and Boeing submitted a joint statement of opposition, explaining their positions. J.C. McCall, Assistant to the Director (Werner von Braun) at MSFC complained that "the only valid arguments these companies have is that certain financial data is proprietary and should not be done on a computer belonging to some other company." McCall debunked this position, however, writing that "Even this argument is weak, however, because the IBM Service Bureau, among others, does a nationwide business of keeping books on computers for other companies." But it didn't seem worth pursuing, suggested McCall, "Hoelzer does not want the headache of arguing with them, so his attitude is, 'Give them what they want.'"[211] Hoelzer would not need to because, McCall revealed, "Constan has agreed with Comp Division to take on these headaches himself and is proceeding in that direction."[212] In many instances, it seems that MSFC personnel sought to control or centralize the power of decision-making or, in this case, computing, because they believed the course of action the best action to accomplish the goals at hand.

On 5 April 1962, Boeing and Chrysler did indeed register written objections to the requirement that a "Single Central Computing facility" be employed at Michoud "to furnish computational services to Michoud Operations and its contractors"—and they submitted a joint statement.[213] The reasons that the contractors cited in opposition to the "Central facility concept," as summarized in a memorandum of 16 April 1962 attached to Constan's weekly report to Wernher von Brain, were "proprietary data such as payroll, personnel, management reports and certain scientific data over which corporate policy of both companies requires restrictive control."[214] These may be seen in the statement, "Under no circumstances will employees of another company be permitted to transmit data, process data, operate computers which are processing data, or otherwise had access to data which may be considered of a proprietary nature."[215] However, in addition to the points that gained Constan's attention, Chrysler and Boeing also appeared concerned to maintain independence in carrying out their efforts at Michoud. For

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[210] Constan, "Weekly Notes," 2 April 1962.
[211] J. C. McCall, Assistant to the Director, MSFC, "Weekly Notes to Wernher von Braun," 9 April 1962. NASA History Office, George C. Marshall Space Flight Center.
[212] Ibid. Wernher von Braun, ever the consensus builder, responded to "Mac" in writing on his report, saying "I think I agree with your convincing arguments. But don't you think we should invite Boeing and CC to give us their reasons <u>in writing</u> and <u>invalidate (or disprove) them</u> point by point, so as to really and permanently '<u>bury</u> the issue'?" (Underlining in original.)
[213] Constan, "Weekly Notes," 16 April 1962.
[214] Ibid.
[215] "Joint Boeing-Chrysler Statement Regarding Central Computing Facility and its Proposed Operation," 5 April 1962, Attachment in George N. Constan, Director of Michoud Operations, to Michoud Computer Steering Committee, "Establishment of Computer Facilities Michoud Operations," 23 March 1962. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

instance, they were concerned that "Computer scheduling and priorities are problems peculiar to each program and must be subject to control of the responsible contractor in his own best Management judgement <sic>. It cannot be delegated to a second party."[216]

Boeing's and Chrysler's counter proposal was that Boeing would "negotiate rental agreements for such equipment necessary to meet immediate and short term requirements." Chrysler would rely on their computing facilities in Detroit until such time as they required the use of the Boeing-operated computer, and at that time Chrysler "will operate the computer during the processing of any of their proprietary data." The statement of Boeing and Chrysler then turned the tables on MSFC, stating that "Mason-Rust and NASA have not stated any proprietary requirements but adequate safeguards will be provided." The joint statement proposed that "the mode of operation will continue until such time as Chrysler requirements require additional equipment." When Chrysler will "require additional equipment," the counter proposal stated, "Each will then be responsible for its own equipment and system."

MSFC prevailed again in this negotiation, at least initially. MSFC went ahead and created a central facility in nearby Slidell, Louisiana, for both Chrysler and Boeing. The site at Slidell was a former FAA (Federal Aviation Administration) building, one that required much modification to suit its new purpose as a computing facility (see Figure 9).

Constan obtained "Favorable comments" from Boeing and Chrysler, he wrote in his report of 14 May 1962, and "it was decided that MSFC should use this facility for the Central Computer Center."[217] MSFC selected an operations contractor, Telecomputing Services, Inc. of Panorama City, California, to operate the facility, according to Hoelzer's weekly report of 7 January 1967.[218] However, six months later, Hoelzer would complain that Boeing's utilization of the Slidell facility was "less than 25% of their original projections." Hoelzer would also note positively that "use by Chrysler is limited at this time but definitely increasing.[219] Hoelzer and MSFC would continue to upgrade the computing installation, connected by data cable to both Michoud and to MSFC, but would sadly again report on 1 July 1963 that Boeing continues to use "less than 25% of their projections" of computer usage at Slidell. Hoelzer was also troubled that "In spite of this situation, Boeing is obtaining bids from computer manufacturers on an analog installation which would essentially duplicate the Slidell facility in Huntsville."[220] Boeing and Chrysler successfully resisted MSDC's centralization of computing transactions.

Establishing a Water-Transportation Network

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[216] Ibid.
[217] Constan, "Weekly Notes," 14 May 1962.
[218] Hoelzer, "Weekly Notes," 7 January 1963.
[219] Hoelzer, "Weely Notes," 3 June 1963.
[220] Hoelzer, "Weekly Notes," 7 July 1963.

Michoud was created as an element within NASA's system of centers, also subordinated to that of the Marshall Space Flight Center, functioning as MSFC's manufacturing site. Much as Albert Kahn designed factory structures to facilitate the systematic flow of material undergoing processes within a factory structure (the flows imagined spatially as well as from a process standpoint), so NASA and MSFC during the Apollo program systematically organized its centers for the flow of rocket stages and engines among its sites, as part of the broader system of developing, producing and operating space vehicles. Although NASA's charter included scientific activities—a legacy of the National Advisory Committee for Aeronautics (NACA), which formed the original core of NASA on 1 October 1958—during the Apollo program NASA primarily engaged in the design, production, and operation of spacefaring vehicles directed toward the goal of landing an astronaut on the moon.

The efforts of MSFC, specifically, during the period of the Apollo program were mainly directed toward the design and production of rocket propulsive stages, such as the various propulsive stages of the Saturn V and the Saturn I rockets. To do so, the systematic organization of rocket design, production, and testing, also required careful control of the transport of vehicles and their assemblies among NASA's sites (and those of their contractors who were engaged in design, production, and testing of rocket stages and engines).

NASA reported in October 1961 that the S-I launch stage would be "too large to be moved by conventional rail, highway or air transport." Instead, NASA planned to move this launch stage by barge from Huntsville to launch facilities in Florida. "The route includes," according to the news release, "the Tennessee, Ohio and Mississippi rivers, the Gulf of Mexico, and inter-coastal waterways to Cape Canaveral on the east coast of Florida" for a distance of "more than 2,000 miles."[221] Consequently, in addition to operating spacefaring vehicles, NASA also necessarily operated seafaring vehicles. And the emerging sub-system of moving assemblies and rocket stages among NASA's design, development, and testing facilities—as well as to the launch pad at the American Missile Range's Cape Canaveral—was perhaps best represented in a map (see Figure 6), for NASA's "systems" characteristically and prominently included a geographic and spatial dimension.

Karl Heimburg, Director of the Test Laboratory at MSFC, was given the task of purchasing the appropriate barges and other vehicles for both rocket stages, as well as for the transport of cryogenic liquids, such as liquid hydrogen and liquid oxygen for both test fires and launches. It was a system that demanded careful attention to both the capacities and to the design of the barges, tractor trailers, and aircraft, which each needed to protect the space vehicles and rocket engines between manufacturing steps, or to safely convey cryogenic liquids they carried. The task of creating a transport system also demanded careful attention to the interfaces where the transfer of vehicles or liquids occurred from one site to another, or from one mode of transport to

[221] Public Information Office, George C. Marshall Space Flight Center, News Release, 15 October 1961, 2-5. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

another, such as the location and design of docks, and in the design of transfer vehicles to move rocket stages between manufacturing floor or test site and docks, and so forth.

Heimburg's work often began with the purchase and modification of barges. For instance, the Karl Heimburg reported on 2 October 1961 that he "initiated a contract to modify barge 'Compromise' in time to meet SA-2 shipment," which was referring to the launch stage slated for the rocket of the second Apollo Saturn I launch (SA-2), which would take place on 25 April 1962.[222] The *Compromise* underwent significant changes in this instance. A New Release indicated that its "arched cover, resembling that of the Saturn barge *Palaemon*, will provide a protective housing for Saturn boosters and upper stages during transportation to the Cape. Addition of a pilot house will allow the towboat, which literally pushes the Compromise, to be steered and operated from the forward end of the barge."[223]

But sometimes the modification of barges could be more superficial. For instance, Heimburg asked Von Braun whether the name 'Compromise' should "be retained or changed at this time" and then proceeded to suggest that a "Change of name to 'Promise' would be most economical – only have to erase 'Com.'"[224] Ever the promoter of all things NASA, Wernher von Braun saw another opportunity here, and replied to Heimburg, "Good idea. Suggest to publicize it in a suitable way… ("Money-conscious MSFC" or so)."[225] The *Compromise* appears in the record as the *Promise* in Heimburg's managerial report of 5 February 1962.[226]

The emerging system of transport also concerned a system of docks, as well, and here Karl Heimburg had the help of the Deputy Director for Administration at Marshall, Harry H. Gorman. At the Michoud itself, for instance, Heimburg sought a dock on the East Pearl River. Heimburg noted on 23 April 1962 that "Michoud waterfront facilities were inspected and a study is underway at MSFC for pier site selection." The East Pearl River seemed promising a site for a pier he thought, because "The river may be easily and safely used by vessels of the "PROMISE" class," although "Some dredging will be required in the way of three sharp turns."[227]

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[222] Heimburg, "Weekly Notes," 2 October 1961. In a News Release of 13 December 1961, MSFC's Public Information Office reported that that the barge Compromise was worked on, "sporting a new cargo cover and pilot house." The news release reported that "the converted U. S. Navy barge, which carried the first Saturn flight vehicle to Cape Canaveral, Fla., for its successful launching Oct. 27, has been undergoing modification at Houston since Dec. 3. It is scheduled to arrive at Wilson Dec. 22." Hence the *Compromise* had also carried the first SA-1 to Cape Canaveral. Public Information Office, "Barge *Compromise* undergoing modification," 13 December 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

[223] Public Information Office, "Barge *Compromise* undergoing modification," 13 December 1961.
[224] Heimburg, "Weekly Notes," 6 November 1961.
[225] Ibid.
[226] Heimburg, "Weekly Notes," 5 February 1962.
[227] Heimburg, "Weekly Notes," 23 April 1962.

But first Heimburg and Gorman sought a pier on the Michoud Canal, which also ran adjacent to the facility. Gorman wrote that the "Industrial Canal connecting the Michoud plant with the intra-coastal system is privately owned by the New Orleans East Corporation." MSFC officials tried to work out a leasing arrangement with them, according to Gorman, who wrote that "We have been in contact with officials of the New Orleans East and are confident we can work out a satisfactory lease arrangement for nominal cost."[228] Unfortunately, however, after "a number of meetings with the officials of the New Orleans East," NASA could only negotiate what they believed to be unfavorable terms. "In short," wrote Gorman, "Marshall is being asked to bear the cost of a dredging operation estimated from $150,000 to $250,000."

Gorman was more optimistic about his efforts to "explore the availability of the Army Transportation Company Dock Area, located at the Northwest corner of the Michoud property," which he believed to be "even more desirable from an operational point of view than the Michoud Canal."[229] All that stood in the way, according to Gorman, was the Department of Defense. "Our problem here is to convince the Department of Defense of NASA's needs. The Washington office [NASA's Headquarters] is on board and we are asking them to contact the Department of Defense with the idea of transferring the dock area to NASA."[230]

The Manager of Michoud Operations, George Constan, reported to Von Braun on 24 September 1962 that "The Army signed and submitted to NASA Headquarters on September 21, 1962, a proposed agreement between the NASA and the Army for the joint use of the Army Michoud Storage Area (located adjacent to the western boundry <sic> of MSFC Michoud Operations.)…The MSFC Michoud Operations docking facility will be constructed in this area."[231]

Heimburg, an engineer at MSFC who exhibited the typical design conservatism of the German engineers who headed many of the Center's laboratories, tested the water routes to wring out all possible "bugs." The barge *Promise*, reported Heimburg on 25 February 1963, "is enroute to New Orleans with the SA-5 'mock-up'. It is due in New Orleans Saturday, 3/2/63." Heimburg conducted numerous tests of the effectiveness of the water transportation routes and technologies, which was consistent with the approach of Marshall's engineers and, perhaps, what one might expect of the Director the Test Laboratory at Marshall. "Slosh tanks" (anti-roll) tanks were needed to minimize the "high roll tendency" of some barges when in the open sea which threatened the S-IC during transport.[232] For instance, the barge *Promise* was scheduled to arrive in drydock in New Orleans on 14 May 1963 "to be equipped with anti-roll tanks," wrote

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228 Gorman, "Weekly Notes," 30 April 1962. Gorman held out hope for "a lease which would permit NASA barge movement in the Industrial Canal on a non-interference basis. This simply means that we would have the authority to stop other traffic in the canal if disturbed or interfered with our own barge operations."
229 Gorman, "Weekly Notes," 30 July 1962.
230 Ibid.
231 Constan, "Weekly Notes," 24 September 1962.
232 Heimburg, "Weekly Notes," 27 May 1963.

Heimburg. Wernher von Braun quipped in response, referring to the current practice of equipping transatlantic ocean liners with anti-rolling tanks, "Why not go first class, eh?" Nothing was too good for the S-IC Launch Stage.[233]

The efforts to create transportation infrastructure required the support of various other agencies and institutions, as well as their assistance. For instance, in order to transport cryogenic barges carrying LOX (liquid oxygen) and LH_2 (liquid hydrogen) MSFC needed to meet the requirements of the Coast Guard's officers, who "indicated that they cannot accept presently proposed design for modification of these barges" to carry the two liquids, stating that "LOX and LH_2 should be considered 'most hazardous' as a commodity although current Coast Guard classifications do not classify them as such."[234] "If the Coast Guard succeeds in making the 'most hazardous' classification stick," wrote Heimburg, "will require additional compartments in order to comply with the rules," increasing the "cost per barge $12,000.00."[235] Heimburg engaged in negotiations with the Coast Guard over design modifications to the barges, and gained approval. He reported on 7 October 1963 that "U. S. Coast Guard approval has been received on the cryogenic barge designs as proposed by Test Laboratory."[236] The transport of assemblies and stages was not limited to water transportation, although barges were the only vehicles suitable for transport of the massive S-IC and S-IB stages.

NASA also used specially modified aircraft to transport rocket stages. Among the better known vehicles was named the "Pregnant Guppy," a severely modified Boeing B-377 Stratocruiser prepared by John M. Conroy and his company, Aero Spacelines, Inc.[237] Conroy's design directly targeted MSFC's transport network, but his initial proposal was rejected "unacceptable to this Center both in cost and technical aspects," reported Gorman.[238] Conroy persevered. A month later Gorman reported that the "Pregnant Guppy was flown from Van Nuys, California, to Edwards Air Force Base, by Mr. Conway on May 16, 1963," and that "FAA personnel stated the Pregnant Guppy made a normal flight with no incidents."[239] The Pregnant Guppy (see Figure 10) promised a better and faster way to transport the S-IV stage, the second stage of the Saturn S-I rocket, from manufacturer Douglas Aircraft in Sacramento, California to Kennedy Space Center at Cape Canaveral, Florida. MSFC had established barges to undertake the transport of the stages, but this took too long, approximately 15 days at best.[240] So Von Braun listened and, after certification of the vehicle, MSFC entered into contract with Conroy's Aero Spacelines, Inc., "to

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[233] Heimburg, "Weekly Notes, 14 May 1963.
[234] Heimburg, "Weekly Notes," 5 August 1963.
[235] Ibid.
[236] Heimburg, "Weekly Notes," 7 October 1963. See also Heimburg, "Weekly Notes," 18 November 1963.
[237] Robert S. Tripp, "Guppy: The Strange Epic of the Ugly Airplane That Got Us To the Moon," *Invention & Technology 17*(4) (Spring 2002), 21-31.
[238] Gorman, "Weekly Notes," 15 April 1963.
[239] Ibid.
[240] Ibid.

furnish transportation for the S-IV Stage, Saturn, and other priority cargo, for the period of September 1963, through June 1964."[241] The estimated cost of the service was $995,884.[242]

The infrastructure that Heimburg developed had been proven by the testing that he had undertaken, and had been expanded to include air transport. On 10 February 1964, Chief of the Test Laboratory Karl Heimburg reported that "The last barge trip (SA-6) under Test Laboratory's jurisdiction, from MSFC to the Cape, started at 4 p.m. on 2/7."[243] "From now on," wrote Heimburg, "operation of the barge will be under the jurisdiction of the Project Logistics Office."[244] Wernher von Braun congratulated Heimburg for a job well done. "Test deserves a bit pat on the back for setting up and running a very efficient transportation system all these years," wrote Von Braun.[245]

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NASA and the Marshall Space Flight Center would succeed in their efforts to land American astronauts on the moon and return them home safely, and manufacturing at Michoud would be essential to that effort. As a satellite of the Marshall Space Flight Center, the story of Michoud as it developed during the Apollo period was one in which the engineers and officials of MSFC attempted to systematize and tightly control the design, development, and manufacture of propulsive rocket stages for the Apollo program.

Engineers and officials at the Marshall Space Flight Center quite consciously went about constructing a system to control the flows of information, knowledge, and artifacts. Doing so was essential to developing, producing and operating space vehicles of the Apollo program. The control was generally hierarchical, concentrating power in the hands of engineering laboratories. In the case of the water and air transportation system, the systematic control achieved a high degree of reliability and engineers at Marshall were able to maintain precise control of the movements of their vehicles. The same may be said of the control that Marshall exhibited over the design of the S-IC and S-IB launch stages. However, in the task of designing and maintaining manufacturing processes to produce the two launch stages, that control was shifted to the contractors, Chrysler Corporation Space Division and The Boeing Company. Other instances, however, such as the efforts of MSFC to centralize data processing at Slidell, did not work as well.

As the examples above show, the intent to closely control the process did not always result in close control, and Chrysler and Boeing at the Michoud facility, were able to carve out autonomy in manufacturing operations. The uncertain times at Michoud at the end of the Apollo program,

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241 W. S. Davis, Chief of Procurement and Contracts Office, "Weekly Notes to Wernher von Braun," 9 September 1963. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
242 Ibid.
243 Heimburg, "Weekly Notes," 10 February 1964.
244 Ibid.
245 Ibid.

and the development of the site for manufacture of the External Tank seemed to provide additional examples of the varying degrees of success of MSFC engineers of officials to closely control manufacturing operations at Michoud Assembly Facility.

The Space Shuttle Decision

As the Apollo program came to a close, and NASA struggled with the question of what to do next, administrators arrived at the idea of a National Space Transportation System (STS), more popularly known as the "Space Shuttle." Officials at NASA initially conceived of STS as a large technological system that included ground control and tracking, reusable spacecraft, launch facilities, and a space station. Budgetary goals of the first administration of President Richard Nixon (1969-1973), however, pushed NASA to decide between a "space plane" and a space station, and then to phase out all other expendable rockets and make the Space Transportation System into NASA's *sole* payload-carrying platform. NASA would continue to pursue the goal of a space station for use with Shuttle flights, joining international ventures in the Spacelab program during the 1980s and 1990s, and the International Space Station (ISS) in the late 1990s until the end of the Space Shuttle program in 2011.

To gain the support of Congress and the President necessary for funding its Space Shuttle, NASA presented STS as a transportation infrastructure, one that featured reusable spacecraft to improve cost-effectiveness. This program, argued administrators, would serve many different clients: agencies of the United States Government, including the Department of Defense (and in particular, the Air Force), telecommunications corporations seeking to launch communications satellites, and allied national governments that also sought to launch satellites. To achieve the economies of scale that would make the Shuttle financially feasible to the President's Office of Management and Budget, and to spur the development of satellites and other payloads for space, the goal was to create something approximating commercial airline, with weekly service.[246] The President's Office of Management and Budget (OMB) was divided over whether to fund the Space Transportation System, but OMB Head George Shultz championed the cause, and persuaded President Nixon that the Space Shuttle was needed to develop a national capacity to deliver large commercial and government payloads in space, and to "reduce substantially the cost of space operations."[247]

The success of Apollo raised expectations among Americans, making the idea of such a frequent, reliable, and low-cost shuttle service seem feasible. Matters of propulsion seemed to be less a

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[246] T. A. Heppenheimer, *The History of the Space Shuttle, Volume 1: The Space Shuttle Decision, 1965-1972* (Washington, D. C.: Smithsonian Institution Press, 2002), 257-259.
[247]Richard M. Nixon, "Statement about the Future of the United States Space Program," John T. Woolley and Gerhard Peters, *The American Presidency Project* [online]. Santa Barbara, CA. Available at http://www.presidency.ucsb.edu/ws/?pid=2903, cited in Heppenheimer, *History of the Space Shuttle,* 391-392.

concern than questions of how to reliably automate an improved "checkout and control system" which would "provide autonomous operation by the [spacecraft's flight] crew, without major support from the ground," and which would "allow low cost of maintenance and repair."[248]

In planning the Shuttle's "Orbiter," the reusable passenger vehicle with a 15 by 60 foot cargo bay, its designers provided it with sophisticated systems that eclipsed those of Apollo's spacecraft. But it was decisions about the Space Shuttle's "launch stack" that were celebrated at NASA's Michoud Plant. The "launch stack" would include the orbiter, solid rocket boosters, and an expendable liquid propellant tank—one that would be manufactured at Michoud. On 27 July 1972, 3 months after Apollo 16 landed American astronauts on the moon for the fifth time, and a little more than 3 months before Apollo 17 would land American astronauts on the moon for the sixth time, James C. Fletcher, NASA administrator, "announced that the external tanks for the multi-billion dollar Space Shuttle program will be built at the Michoud Assembly Facility here."[249]

The expectation of frequent flights also meant that many tanks would be required, making it an enormous contract. "The exact number of jobs the program will create in the New Orleans area is undetermined," reported the *Times-Picayune*, "but both Chrysler Corporation's Space Division and the Boeing Co. said the 'drop tank' contract would have a significant economic impact on the area." According to the United States Senator Allen J. Ellender, reported the newspaper, "it is estimated that 40 to 50 tanks a year will be built, creating long-term employment for up to 2,000 workers at the government-owned facility."[250] The newspaper reported that Douglas Lowrey, President of Chrysler's space division, said that "originally 445 flights were proposed."[251] In fact, the Michoud Assembly Facility would build 136 tanks, of which 135 would be used on missions between 1981 and 2011. Not what was expected, but a tremendous achievement nonetheless.

But if the manufacturing project was new, the manner in which NASA's Marshall Space Flight Center conducted the External Tank's design and production proved familiar. The system of water transport, for instance, remained in place, with barges used to transport the External Tank, just as they had for the S-IC launch stage, to the Cape for final assembly and launch. And just as for the S-IC design and manufacture, engineers at Marshall initially maintained a tight grip over the design of the External Tank and the manufacturing processes, although they did not work as closely with the tank's manufacturer, Martin Marietta as they did with Boeing's engineers on the S-IC manufacture. And, just as for the S-IC project, they relinquished control over the manufacturing of the project later in the program's life. As the program matured, the tightly

[248] George Mueller, "Opening Remarks," Proceedings, NASA Space Shuttle Symposium, October 16-17, 1969, 3-8, cited in T. A. Heppenheimer, 246.
[249] "Work for Michoud Announced by NASA," *Times-Picayune, New Orleans*, 27 July 1972.
[250] Ibid.
[251] Ibid.

controlled system of design and development changed to something more akin to a collaboration between MSFC's engineers and the recently merged Lockheed Martin.

Preparing for Manufacture of the External Tank

In the year after the first moon landing, 1970, NASA headquarters announced that it would be granting an easement to allow improvements to be made to protect the Michoud Assembly Facility from floods, which usually accompanying hurricanes. The improvements undertaken were part of the Pontchartrain Barrier Plan begun in 1968. An easement across the Michoud Complex was built, the surrounding levee was enlarged, the construction of a floodwall was undertaken, also a relocation of the access road to the barge dock.[252]

When beginning to design and build the External Tank at Michoud, Michoud was reintroduced to an old friend. Eberhard Rees, Director of the Marshall Space Flight Center, reappointed George N. Constan as Manager of the Michoud Assembly Facility on 5 January 1973, returning him to his familiar post.[253] And, much as NASA operated the Michoud Assembly Facility through a services contractor (Mason-Rust) during the Apollo program, they continued to do the same in the period of the Space Shuttle, engaging Boeing Services International (BSI) to "provide facility operating services."[254]

Before the Shuttle's first flight, however, there would be important changes in the management of Michoud. From the beginning of NASA's ownership of the facility, Michoud had been a Government-Owned, Government-Operated facility. But in 1977, MSFC moved to create a Government-Owned, Contractor-Operated (GOCO) facility. Officials at MSFC made the change because they believed there was "potential for improved facilities support of the External Tank program[,] since the External Tank contractor [Martin Marietta] would be self-supporting without the need for interfaces now required."[255]

Designing and Building the External Tank

Much as for the S-IC launch stage, Marshall's engineers retained control over the design of the External Tank (ET) (See Figure 11), and also established much of the manufacturing processes before turning over the project for manufacture to Martin Marietta. At Marshall, the Manufacturing Engineering division built the S-IC-T and the S-IC-1 and S-IC-2, "debugging"

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[252] Eberhard Rees, Director of Marshall Space Flight Center, to NASA Headquarters, "Easement across MICHOUD complex for enlargement of a levee, construction of a floodwall and relocation of barge dock access road," 26 May 1970. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
[253] Eberhard Rees, "MSFC Key Personnel Announcement," 5 January 1973. NASA History Office, George C. Marshal Space Flight Center, Huntsville Alabama.
[254] W. R. Lucas, Director of Marshall Space Flight Center, to NASA Headquarters, "Facility Management at the Michoud Assembly Facility," 17 May 1977, 1. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.
[255] Ibid., 3.

both the rocket design and the manufacturing design before relinquishing control of manufacturing to Boeing.

Both MSFC and Martin Marietta attempted to reduce the weight of the tank, but it was engineers at Marshall who took the lead in the original "Standard Weight Tank" (SWT), which served for the first six flight tanks of the Shuttle.[256] Marshall's engineers initiated the change to eliminate the white paint overlaying the ET, a change that saved nearly a thousand pounds.[257] It was the engineers of Marshall who revised their original design, arriving at the Light Weight Tank (LWT), a "two-year redesign" effort that "trimmed 7,000 pounds from the 71,000-pound tank used in the first Shuttle flight."[258]

Marshall engineers also created the initial tooling for the ET, just as they did for the S-IC Launch Stage. James Odom recalled that he sought to ensure that "the Tanks I qualified were built on the same tooling that I was going to build the flight tanks on. I took the risk and put a $200 or $300 million investment into tooling up front that normally gets invested later in the program."[259] Like the MSFC engineers of the Apollo program, MSFC engineers pressured Martin Marietta into making changes in their manufacturing arrangements; in the case of the ET, MSFC pressured Martin Marietta to make a distinct company division responsible for the ET production, and to establish a dedicated project manager as well as an improved organizational plan.[260]

And, just as did Marshall's engineers in the early 1960s, the MSFC's engineers of the Space Shuttle program employed the S-IC test stand to thoroughly engage in a structural test of the ET to verify its design. The S-IC test stand was substantially modified to fit the comparably-sized External Tank. Test manager Chuck Vershooretest recalled that engineers at Marshall took many more measurements of the tanks structure when fully loaded (with water) than were possible in earlier days. "On the intertank alone, we had close to 2,000 measurements," he recalled, "on the hydrogen tank we had 4,000, and on the LOX tank, we had another 2,000."[261]

There were also similarities in the trajectory of responsibilities for contractors at Michoud. Just as The Boeing Company undertook greater responsibility for the production of the S-IC Launch Stage, so did the contractor responsible for production of the External Tank of the Space Shuttle program. After Martin Marietta and Lockheed merged to form Lockheed Martin in 1995, the newly formed company applied its engineering expertise in a thorough redesign of the External

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[256] Andrew Dunar and Stephen P. Waring, *Power to Explore: A History of Marshall Space Flight Center, 1960-1990* (Washington, D.C.: National Aeronautics and Space Administration, 1999), 320.
[257] James B. Odom, Interviewed by Jessie Whalen, 9 February 1988. Transcript at NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama, 8.
[258] Dunar and Waring, *Power to Explore*, 320.
[259] James B. Odom interview, 14-15.
[260] Dunar and Waring, *Power to Explore*, 305.
[261] Chuck Verschoore, interviewed by Sarah McKinley, 27 June 1988. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama, 5.

Tank, reducing the weight from approximately 63,000 lbs. to 58,500 lbs by 1998.[262] The new tank would be called the Super Light Weight Tank (SLWT). In the aftermath of the Columbia tragedy of 2003, Lockheed Martin would take the lead in investigating and changing the process of applying insulation to the External Tank.

The Space Shuttle flew 135 missions, its last on 21 July 2011, thirty years after its first flight. By any measure, the Space Shuttle has been tremendously successful, recently supporting the International Space Station—a goal of Wernher von Braun. NASA has moved to replace the Space Shuttle with a new program, called the Space Launch System, after the aborted effort of the Constellation program, which was cancelled in 2010. At the time of this report's writing, the tooling is currently being created and installed at Michoud for the Space Launch System program.

Conclusion

Albert Kahn conceived of the design of his factory architectures as an element in a manufacturing processes taking place within the factory architecture; NASA understood the Michoud Assembly Facility as an element of a broader infrastructure that encompassed the design, manufacture, and operation of its rockets for the Apollo program—they conceived of the factory as an element of broader system to develop and operate spacecraft. Yet the changing roles of contractors at the Michoud Assembly Facility have shown that such systemic top-down control of design and manufacturing would not be maintained over the course of the Apollo program's production of the S-IC and S-IB launch stages, nor in the production of the External Tank for the Space Shuttle program.

The challenges of the engineering and manufacturing tasks allotted to contractors at Michoud—The Boeing Company and the Chrysler Corporation Space Division during the Apollo program, and the Martin Marietta/Lockheed Martin during the production of the External Tank for the Space Transportation System—led to an ongoing renegotiation between MSFC and its contractors over who should control manufacturing designs and processes. Sometimes it worked like a "hand-off" between Marshall's engineers and those of its contractors, and at other times contractors' expertise lent them an authority that resulted in the redistribution of responsibility over manufacturing processes that emphasized the contractor's authority.

The Apollo and STS programs were beholden to the original systems that MSFC created for the design, production, and delivery of launch vehicles in the early years of the Apollo program. But contractors who engaged in the production of these launch vehicles, such as Boeing and

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[262] Press Release, Lockheed Martin, "Lockheed Martin Ends External Tank Production at NASA Michoud Assembly Facility," 30 September 2010. Retrieved from http://www.lockheedmartin.com/us/news/press-releases/2010/september/LockheedMartinEndsExterna.html.

Chrysler, and Lockheed Martin, seemed to make those projects their own as each program matured. Each of the contractors at Michoud, working together with engineers at Marshall, may be credited for the tremendous achievement of designing and producing rockets of extraordinary reliability. Together, they made the United States a spacefaring nation.

Table 1: Government-owned Facilities[263]

		Criteria				
Facility Name	Location	1. Accessibility	2. Availability	3. Size	4. Proximity	5. Expansion
Naval Industrial Reserve Shipyard	Alameda, California	x				x
Maritime Alameda Reserve Shipyard	Alameda, California	x				x
Benicia Arsenal	Benicia, California	x		x		xx
Naval Industrial Forge Plant	Berkeley, California	x				
Fort Mason	San Francisco, California	x		x		x
Marine Corps Supply Forwarding Annex	San Francisco, California	x	x			
Bethlehem Steel Shipyard	South San Francisco, California	x		x		x
Pacific Ordnance Steel Foundry	Pittsburg, California	x				x
Cheli Air Force Station	Bell, California		x			x
Riverbank Ordnance Plant	Riverbank, California	x	x			
Lenape Ordnance Plant	Newark Delaware		x		x	x
MacDill Air Force Base	Tampa, Florida		x	x	x	x
Army Reserve Armory	Savannah, Georgia	x	x		x	
Kings Bay Army Terminal	St. Mary's Georgia	x	x		x	x
Indiana Arsenal Plant #2	Charlestown, Indiana		x		x	x
Topeka Air Force Depot	Topeka, Kansas		x		x	x
Michoud Ordnance Plant	New Orleans, Louisiana	x	x	x	x	x
Louisiana Ordnance Depot	Shreveport, Louisiana		x		x	x
Curtis Bay Storage Activity Letterkenny OD	Baltimore, Maryland	x	x		x	x
Naval Industrial Reserve Aircraft Plant	Bengies, Maryland		x		x	x

[263] Table, "Government Facilities," from William Ziglar, *History of NASA, MTF, and Michoud. The Fertile Southern Crescent: Bayou Country and the American Race Into Space* (Washington, D.C.: NASA Historical Office, 1972), 23-24.

Naval Industrial Reserve Shipyard	Hingham, Massachusetts	x	x		x	x
Naval Weapons Industrial Reserve Plant	Kansas City, Missouri		x			x
St. Louis Ordnance Plant	St. Louis, Missouri		x			x
St. Louis Ordnance Street Foundry	St. Louis, Missouri		x			x
Caven Point Army Terminal	Jersey City, New Jersey	x	x			x
Raritan Arsenal	Metuchen, New Jersey	x	x		x	x
Air Force Plant #3	Wood-ridge, New Jersey	x	x			
Cold Spring Battery Plant	Cold Spring, New York		x			
Air Force Plant #59	Johnson City, New York	x	xx			
Air Force Plant #69	Lewiston, New York		x			
Malta Test Station	Malta, New York		x			
Fitzgibbons Boiler Co. Inc.	Oswego, New York		x			
U. S. Maritime Shipyard	Wilmington, North Carolina	x	x		x	x
U. S. Naval Air Station	Harvey's Point, Edenton, North Carolina	x	x		x	x
Cincinnati Ordnance District Industrial Storage Activity	Kings Mills, Ohio		x			
Marion Engineer Depot	Marion, Ohio	x		x	x	x
Plum Brook Ordnance Works	Sandusky, Ohio	x		x	x	xx
Wilins Air Force Station	Shelby, Ohio	x		x	x	x
Rossford Ordnance Depot	Toledo, Ohio			x	x	x
Astoria Naval Station	Tongue Point, Astoria, Oregon	x	x			x
Monaca AF POL Retail District Station	Monaca, Pennsylvania	x	x		x	x
Philadelphia Army Supply Base	Philadelphia, Pennsylvania	x	x		x	x
U. S. Naval Torpedo Station	Goat Island, New Port Rhode Island	x			x	
Cramet Titanium Plant	Chattanooga, Tennessee	x	x			x
Volunteer Ordnance Works	Chattanooga, Tennessee	x	xx		x	x
Holston Ordnance Works	Kingsport, Tennessee	x	x		x	x
Milan Arsenal	Milan, Tennessee			x	x	x
Cabaniss & Cuddihy Naval Aux, Airfields	Corpus Christi, Texas		x	x	x	x
Former Fire Fight School, Manchester Fuel Annex	Bremerton, Washington		x			x
U.S. Maritime Community Shipyards	Vancouver, Washington	x	x	x	x	x
Mt. Rainier Ordnance Depot	Pierce County, Washington			x		x
Morgantown Ordnance Works	Morgantown, West Virginia		x	x		

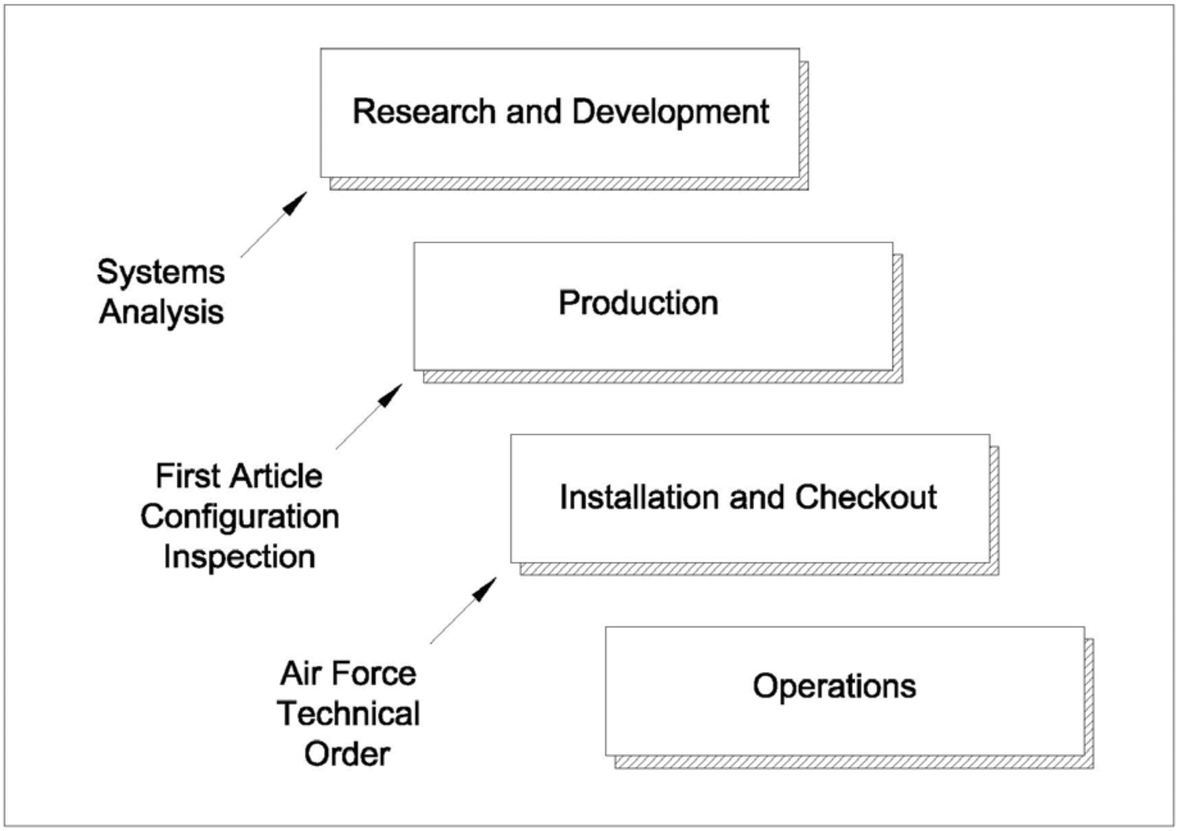


Figure 1: Concurrency. *Source*: Adapted from Stephen B. Johnson, *The Secret of Apollo: Systems Management in American and European Space Programs* (Baltimore: Johns Hopkins University Press, 2002), 42, and Benjamin Bellis, L/Col USAF Office DCS/Systems, "The Requirements for Configuration Management During Concurrency," AFSC Management Conference, May 1962, Air Force Systems Command, Andrews Air Force Base, Washington, D.C., 5-24-3.

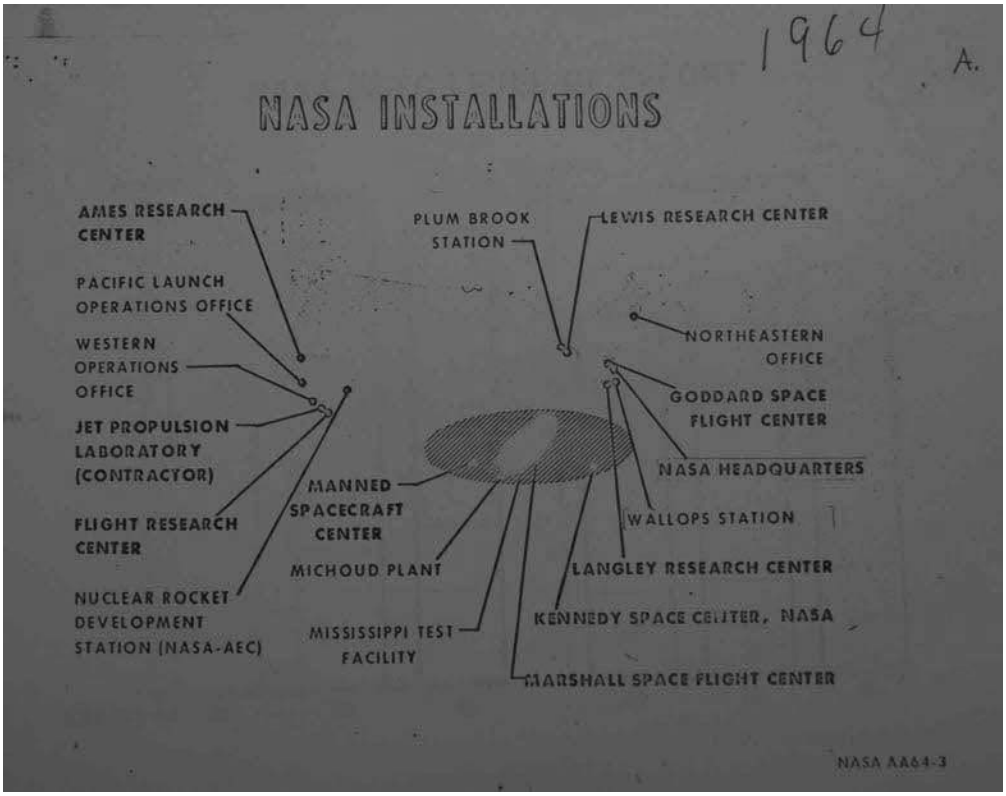


Figure 2: NASA Installations, ca. 1964 (Note Faint Outline of US Map). *Source*: NASA Installations, 1964 A., NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

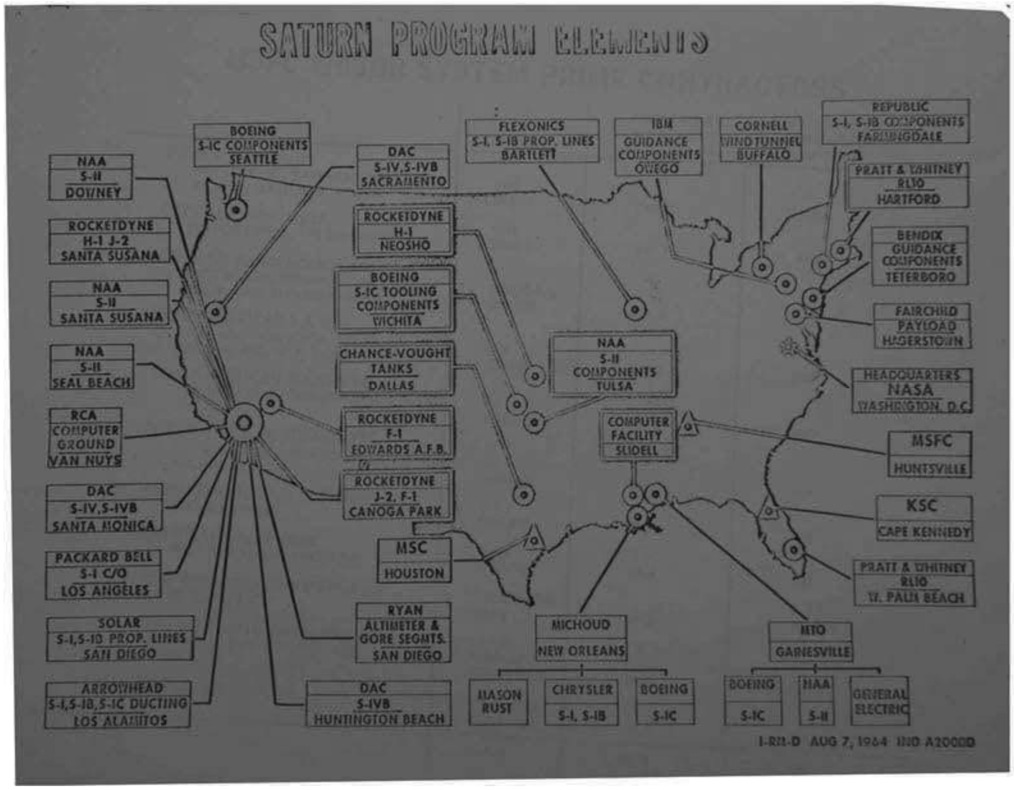
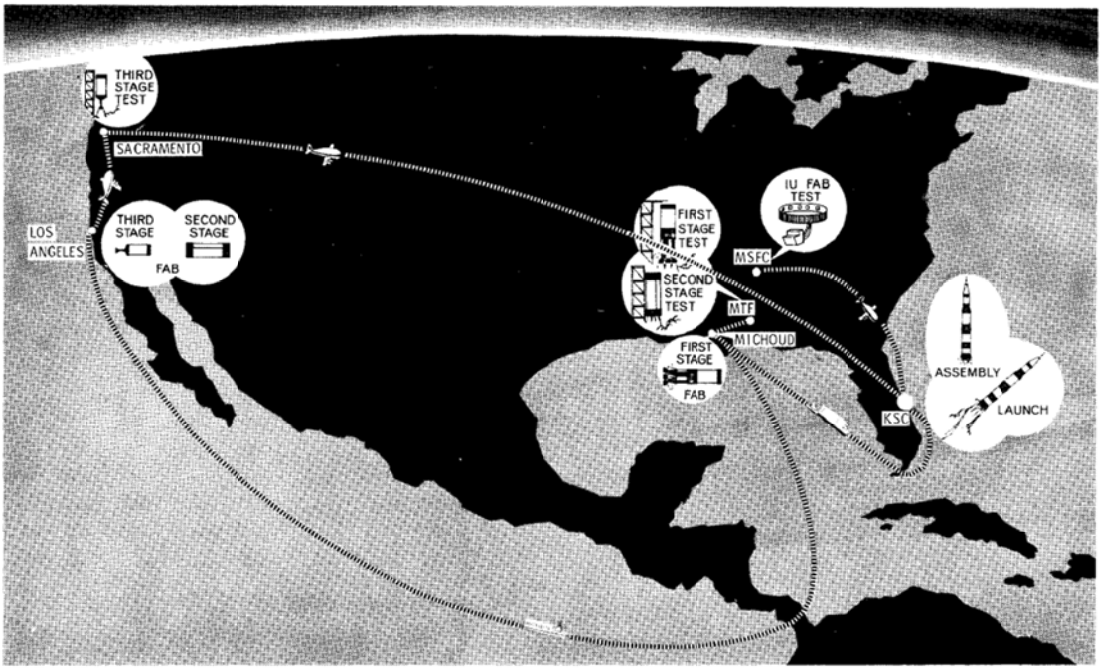


Figure 3: Saturn Program Elements, August 7, 1964. *Source*: Saturn Program Elements, August 7, 1964, NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Figure 4: Chimneys at Michoud. *Source*: Image “5-20489 Michoud Progress Comparison 1915 & 1968,” NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Figure 5: Administrative Building, Michoud Assembly Facility. *Source*: Image “16650-7 Michoud Administration Building,” NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.



Traveling Saturn– This depicts the Saturn V assembly and test sequence and the transportation routes of rocket-carrying craft.

Figure 6: Traveling Saturn. *Source*: The Boeing Company, Douglas Aircraft Company, International Business Machines Corporation, North American Aviation, Inc., *Saturn V News Reference* (Huntsville, Alabama, 1967). NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

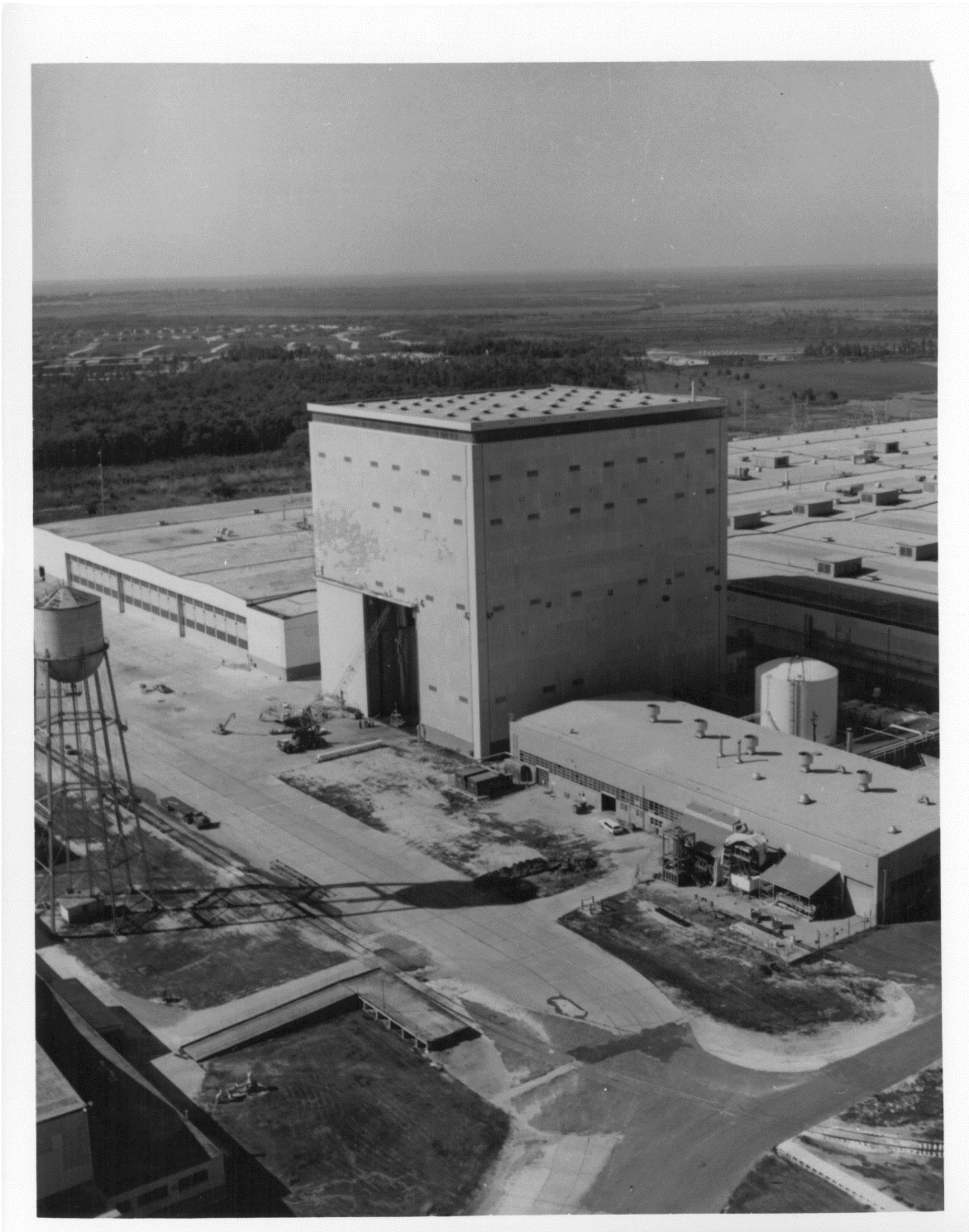


Figure 7: Vertical Assembly Building Under Construction, with Open Doors, ca. 1964. *Source*: Image "8-64886, Michoud Vertical Assembly Building 8-7-1968."History Office, George C. Marshall Space Flight Center. Huntsville, Alabama.

Figure 8: Engineering and Office Building (Building 350). *Source*: Image "8-64888 Michoud Administration Complex 8-7-1968." History Office, George C. Marshall Space Flight Center. Huntsville, Alabama.

Figure 9: Computer Operations Office, Slidell, Louisiana. *Source*: NASA, *From Michoud to the Moon* (New Orleans: Michoud Assembly Facility, George C. Marshall Space Flight Center, 1966), 7. History Office, George C. Marshall Space Flight Center. Huntsville, Alabama.

Figure 10: Pregnant Guppy in Flight. *Source*: History Office, George C. Marshall Space Flight Center. Huntsville, Alabama, retrieved from http://mix.msfc.nasa.gov/IMAGES/HIGH/9801783.jpg .
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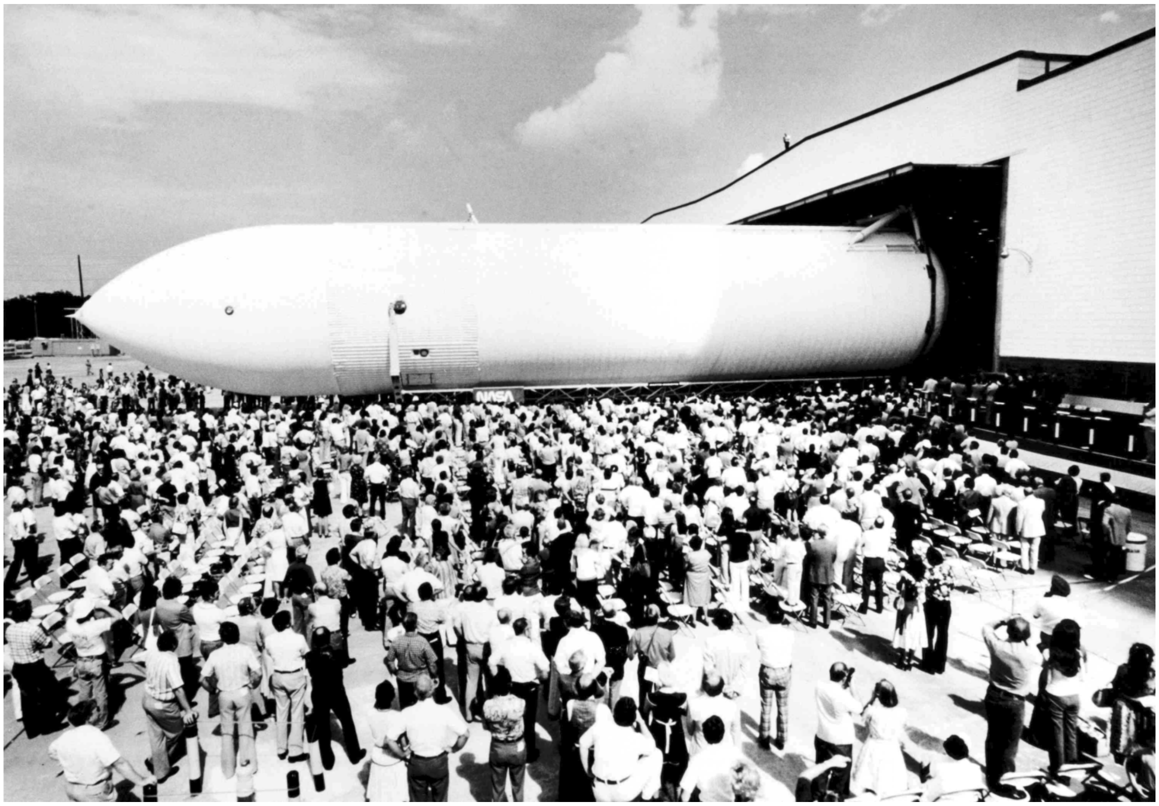

Figure 11: Roll Out of First External Tank. *Source*: History Office, George C. Marshall Space Flight Center. Huntsville, Alabama, retrieved from http://mix.msfc.nasa.gov/IMAGES/HIGH/7783349.jpg.

Bibliography

Primary Sources

Interviews:

Odom, James B. Interview by Jessie Whalen, 9 February 1988. Transcript at NASA History Office, Marshall Space Flight Center, Huntsville, Alabama.

Tiesenhausen, Georg von. Interview by A. Dunar and S. Waring, 29 November 1988. MSFC History Project, transcript. NASA History Office, Marshall Space Flight Center, Huntsville, Alabama.

Urlaub, Matthew. Interview by Roger E. Bilstein, 29 July 1975. NASA History Office, transcript. Marshall Space Flight Center, Huntsville, Alabama.

Verschoore, Chuck. Interview by Sarah McKinley, 27 June 1988. NASA History Office, transcript. Marshall Space Flight Center, Huntsville, Alabama.

Wood, Malcolm. Interviewed by Douglas Jerolimov, 15 March 2013. Recording at NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Speeches:

Mueller, George. "Opening Remarks," Proceedings, NASA Space Shuttle Symposium, October 16-17, 1969.

Nixon, Richard M. "Statement about the Future of the United States Space Program," John T. Woolley and Gerhard Peters, *The American Presidency Project* [online]. Santa Barbara, CA. Available at http://www.presidency.ucsb.edu/ws/?pid=2903

Kennedy, President John F., "We Choose to Go to the Moon..," Speech Given at Rice University, Houston, Texas, 12 September 1962.

__________, "Urgent National Needs," Speech Given to Joint Session of Congress, Washington, DC, 25 May 1961. Available at http://www.jfklibrary.org/Asset-Viewer/xzw1gaeeTES6khED14P1Iw.aspx.

Newspapers:

Eureka News Bulletin (Higgins Industries, New Orleans, Louisiana)

Marshall Star (Huntsville, Alabama)

New York Times (New York, New York)

Times-Picayune, New Orleans (New Orleans, Louisiana)

Letters and Memoranda:

Ad Hoc Site Selection Committee, "National Aeronautics and Space Administration Launch Vehicle Manufacturing Site Selection by Ad Hoc Site Selection Committee, August 23, 1961," NASA Historical Archives, Washington, D.C.

Boeing Corporation and Chrysler Corporation Space Division, "Joint Boeing-Chrysler Statement Regarding Central Computing Facility and its Proposed Operation," 5 April 1962, NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Wible, M. Keith [MICH-X] to David S. Akens [M-MS], Memorandum, "Historical Report for Michoud Operations, September 1961 to July 1, 1962," 23 August 1962. MSFC Annual Chronologies (1960-1990), Series 102 Chronologies, History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Holmes, D. Brainerd., Washington, D.C., to Wernher von Braun, Huntsville, 27 February 1962. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Lucas, W. R. Director of Marshall Space Flight Center, to NASA Headquarters, "Facility Management at the Michoud Assembly Facility," 17 May 1977, 1. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Office of Programs, Action Sheet, "Policy Guidelines re Central Point for Consideration of Facility Sites." 20 June 1961 to 18 August 1961. NASA Historical Archives, Washington, D.C.

Ostrander, Donald R. to Robert Seamans "Planning for Utilization of Michoud Facility," 13 July 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Rees, Eberhard. Director of Marshall Space Flight Center, to NASA Headquarters, "Easement across MICHOUD complex for enlargement of a levee, construction of a floodwall and relocation of barge dock access road," 26 May 1970. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Rees, Eberhard. "MSFC Key Personnel Announcement," 5 January 1973. NASA History Office, George C. Marshal Space Flight Center, Huntsville Alabama.

Rosen, Milton W. Acting Director, Launch Vehicle Program to Robert Seamans, Associate Administrator, "Report of the Ad Hoc Site Selection Committee," 31 August 1961. NASA History Office, Marshall Space Flight Center, Huntsville, Alabama.

Rosen, Milton W., Acting Director, Launch Vehicle Program to Robert Seamans, Associate Administrator, "Report of the Ad Hoc Site Selection Committee," 1 September 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Palaoro, H. R., Chief of Vehicle System Integration Office to William A. Mrazek, Director of Propulsion and Vehicle Engineering Division, "System Integration Activities," 16 April 1962. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Palaoro, H. R., Chief of Vehicle System Integration Office to William A. Mrazek, Director of Propulsion and Vehicle Engineering Division, "System Integration Activities," 02 April 1962. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Von Braun, Wernher, Huntsville, to D. Brainerd Holmes, Washington, D.C., 19 February 1962. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Von Braun, Wernher, Director, Marshall Space Flight Center to B. R. Brackett, 27 September 1961, National Aeronautics and Space Administration, "Procurement plan for 'Housekeeping' Services at Michoud Plant," 1, Marshall-Michoud file. NASA History Office, Washington, D.C.

Management Sources:

Constan, George N. "Weekly Notes to Wernher von Braun," NASA History Office, Marshall Space Flight Center. Huntsville, Alabama.

Davis, W. S. "Weekly Notes to Wernher von Braun," NASA History Office, Marshall Space Flight Center. Huntsville, Alabama.

Geissler, Ernst, "Weekly Notes to Wernher von Braun," NASA History Office, Marshall Space Flight Center. Huntsville, Alabama.

Gorman, Harry. "Weekly Notes to Wernher von Braun," NASA History Office, Marshall Space Flight Center. Huntsville, Alabama.

Heimburg, Karl. "Weekly Notes to Wernher von Braun," NASA History Office, Marshall Space Flight Center. Huntsville, Alabama.

Hoelzer, Helmut. "Weekly Notes to Wernher von Braun," NASA History Office, Marshall Space Flight Center. Huntsville, Alabama.

Kuers, Werner. "Weekly Notes to Wernher von Braun," NASA History Office, Marshall Space Flight Center. Huntsville, Alabama.

Lange, Oswald H. "Weekly Notes to Wernher von Braun," NASA History Office, Marshall Space Flight Center. Huntsville, Alabama.

Maus, Hans. "Weekly Notes to Wernher von Braun," NASA History Office, Marshall Space Flight Center. Huntsville, Alabama.

McCall, J. C. "Weekly Notes to Wernher von Braun," NASA History Office, Marshall Space Flight Center. Huntsville, Alabama.

Mrazek, William A. "Weekly Notes to Wernher von Braun," NASA History Office, Marshall Space Flight Center. Huntsville, Alabama.

Rudolph, Arthur. "Weekly Notes to Wernher von Braun," NASA History Office, Marshall Space Flight Center. Huntsville, Alabama.

Smith, R.G. "Weekly Notes to Wernher von Braun," NASA History Office, Marshall Space Flight Center. Huntsville, Alabama.

Reports

Castille, George J., and Sally K. Evans Reeves, *Cultural Resources Survey of the Almonaster-Michoud Industrial District*. Baton Rouge, Louisiana: Coastal Environments, Inc., 1981.

Cleveland, M. Todd, Mark D. Chancellor, and Jeffrey L. Holland, *Architectural Survey of the NASA Michoud Assembly Facility: Final Report, New Orleans, Louisiana*. Atlanta, Georgia: TRC Garrow Associates, 2000.

NASA, *Apollo Systems Equipment Interfaces: SA-5 Mission*, NASA-CR-116651, Prepared for NASA, Directorate of Integration & Checkout, Office of Manned Space Flight, Washington, D.C., by General Electric Company, 19 November 1962. Retrieved from http://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/19750069247_1975069247.pdf on 8 June 2012.

NASA Installations, 1964 A., NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Saturn Program Elements, August 7, 1964, NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

The Boeing Company, Douglas Aircraft Company, International Business Machines Corporation, North American Aviation, Inc., *Saturn V News Reference* (Huntsville, Alabama, 1967). NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Other Primary Sources

"Criteria for a Manufacturing Plant for Saturn S-I and S-IB Stages," circa 4 August 1961, NASA Historical Archives, reproduced in William Ziglar, *The Fertile Southern Crescent: Bayou Country and the American Race Into Space*. Washington, D.C.: NASA Historical Office, 1972), 25.

Kahn, Moritz. Plan the Plant for the Job. *Factory and Industrial Management 75* (February 1928): 316-318.

"Michoud Progress Comparison 1915 & 1968," Image 5-20489, NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

"Michoud Administration Building," Image 16650-7, NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

"Michoud Vertical Assembly Building 8-7-1968." Image 8-64886, History Office, George C. Marshall Space Flight Center. Huntsville, Alabama.

"Michoud Administration Complex 8-7-1968." Image 8-64888, History Office, George C. Marshall Space Flight Center. Huntsville, Alabama.

NASA, *From Michoud to the Moon*. New Orleans: Michoud Assembly Facility, George C. Marshall Space Flight Center, 1966. History Office, George C. Marshall Space Flight Center. Huntsville, Alabama.

"Pregnant Guppy in Flight." History Office, George C. Marshall Space Flight Center. Huntsville, Alabama, retrieved from http://mix.msfc.nasa.gov/IMAGES/HIGH/9801783.jpg

"Roll Out of First External Tank." History Office, George C. Marshall Space Flight Center. Huntsville, Alabama, retrieved from http://mix.msfc.nasa.gov/IMAGES/HIGH/7783349.jpg.

News Releases

National Aeronautics and Space Administration, News Release, "The National Aeronautics and Space Administration will negotiate with the Boeing Co., Seattle, Wash.," December 15, 1961, History Office, Marshall Space Flight Center, Huntsville, Alabama.

News Release, Public Information Office, George C. Marshall Space Flight Center, 7 September 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

News Release, Public Information Office, George C. Marshall Space Flight Center, 14 September 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

News Release, Public Information Office, George C. Marshall Space Flight Center, 26 September 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

News Release, Public Information Office, George C. Marshall Space Flight Center, 7 October 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

News Release, Public Information Office, George C. Marshall Space Flight Center, 11 October 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

News Release, Public Information Office, George C. Marshall Space Flight Center, 15 October 1961, 2-5. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

News Release, Public Information Office, George C. Marshall Space Flight Center, 25 October 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

News Release, Public Information Office, George C. Marshall Space Flight Center, 30 October 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

News Release, Public Information Office, George C. Marshall Space Flight Center, 8 December 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

News Release, Public Information Office, "Barge *Compromise* undergoing modification," George C. Marshall Space Flight Center, 13 December 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

News Release, Public Information Office, George C. Marshall Space Flight Center, 15 December 1961. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Public Information Office, George C. Marshall Space Flight Center, "NASA … placed in force a $15,954,096 supplemental agreement to the contract with the Boeing Company, Seattle, for preparatory work leading to the design, development, fabrication and test of the first stage (S-IC) for the Saturn C5 vehicle," August 2, 1962, History Office, Marshall Space Flight Center, Huntsville, Alabama.

Public Affairs Office, "Fact Sheet, Michoud Operations," 20 April 1965, Michoud Operations, George C. Marshall Space Flight Center. NASA History Office, George C. Marshal Space Flight Center.

Public Affairs Office, "Michoud Operations Today Begins a Mass Movement," 1 September 1964. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Press Release, Lockheed Martin, "Lockheed Martin Ends External Tank Production at NASA Michoud Assembly Facility," 30 September 2010. Retrieved from http://www.lockheedmartin.com/us/news/press-releases/2010/september/LockheedMartinEndsExterna.html.

Secondary Literature

Akens, David S., Leo L. Jones, A. Ruth Jarrell, *History of the George C. Marshall Space Flight Center from July 1 Through December 31, 1964, Volume One*. MSFC Historical Monograph No. 10 (MHM-10). Huntsville, Alabama: MSFC Historical Office, 1966., 144. NASA History Office, George C. Marshall Space Flight Center, Huntsville, Alabama.

Akens, David S., *Saturn Illustrated Chronology, MSFC MHR-5*. Huntsville, Alabama: MSFC Historical Office, National Aeronautics and Space Administration, 20 January 1971. NASA History Office, Marshall Space Flight Center, Huntsville, Alabama.

Bellis, Benjamin, L/Col USAF Office DCS/Systems, “The Requirements for Configuration Management During Concurrency,” AFSC Management Conference, May 1962, Air Force Systems Command, Andrews Air Force Base, Washington, D.C. 5.24.1 – 5.24.14.

Biggs, Lindy. *The Rational Factory: Architecture, Technology, and Work in America’s Age of Mass Production*. Baltimore: Johns Hopkins University Press, 1996.

Bilstein, Roger E. *Stages to Saturn: A Technological History of the Apollo/Saturn Launch Vehicles*. Washington, D.C.: NASA History Office, 1980.

Bromberg, Joan Lisa. *NASA and the Space Industry*. Baltimore: Johns Hopkins University Press, 1999.

Carter, Brian, Grant Hildebrand, and Terry Smith, *Albert Kahn: Inspiration for the Modern*. Ann Arbor: University of Michigan Museum of Art, 2001.

Cortright, Edgar M., Ed. Apollo Expeditions to the Moon. Washington, D.C.: U.S. Government Printing Office, 1975.

Dethloff, Henry C. *Suddenly, Tomorrow Came…A History of the Johnson Space Center*. Washington, D.C.: National Aeronautics and Space Administration, 1993.

Dunar, Andrew J. and Stephen P. Waring, *Power to Explore: A History of the Marshall Space Flight Center, 1960-1990*. Washington, D.C.: National Aeronautics and Space Administration, 1999.

Ferry, W. Hawkins. *The Legacy of Albert Kahn*. Detroit, Michigan: Wayne State University Press, 1970.

Heppenheimer, T. A. *The Space Shuttle Decision: NASA’s Search for a Reusable Space Vehicle*. NASA SP-4221.Washington, D.C.: National Aeronautics and Space Administration, 1999.

__________. *History of the Space Shuttle, Volume 2: Development of the Shuttle, 1972-1981*. Washington, D.C.: Smithsonian Institution Press, 2002.

Hildebrand, Grant. *Designing for Industry: The Architecture of Albert Kahn*. Cambridge, Massachusetts: MIT Press, 1974.

__________. “Albert Kahn: The Second Industrial Revolution,” Backgrounds for an American Architecture, *Perspecta*, *15* (1975), 31-40.

__________. "Beautiful Factories." In Brian Carter, Grant Hildebrand, and Terry Smith (Eds.), *Albert Kahn: Inspiration for the modern* (pp. 16-27). Ann Arbor, Michigan: University of Michigan Museum of Art, 2001.

Holley, Irving Brinton, Jr. *Buying Aircraft: Materiel Procurement for the Army Air Forces*, Volume 7 of Stetson Conn, ed., *United States Army in World War II*. Washington, D.C.: Dept. of the Army, 1964.

Hughes, Thomas P. *Human Built World: How to Think about Technology and Culture*. Chicago: University of Chicago Press, 2004.

Hughes, Thomas P. *Rescuing Prometheus*. New York: Pantheon Books, 1998.

Johnson, Stephen B. *The Secret of Apollo: Systems Management in American and European Space Programs*. Baltimore: Johns Hopkins University Press, 2002.

_________. The United States Air Force and the Culture of Innovation, 1945-1965. Washington, D.C.: Air Force History and Museums Program, 2002.

_________. "Samuel Phillips and the Taming of Apollo," *Technology and Culture* 42, no. 4 (2001): 685-709.

_________. "From Concurrency to Phased Planning: An Episode in the History of Systems Management," pp. 93-112. In Agatha C. Hughes and Thomas P. Hughes, eds., *The Systems Approach in Management and Engineering, World War II and After*. Cambridge, Massachusetts: MIT Press, 2000.

Lambright, W. Henry. *Powering Apollo: James E. Webb of NASA*. Baltimore: Johns Hopkins University Press, 1993.

Lane, Fredrick C. *Ships for Victory: A History of Shipbuilding Under the U.S. Maritime Commission in World War II*. Baltimore, Maryland: Johns Hopkins University Press, 1951.

Leatherbarrow, David, and Mohsen Mostafavi. *Surface Architecture*. Cambridge, Massachusetts: The MIT Press, 2002.

Logsdon, John M., "Selecting the Way to the Moon: The Choice of the Lunar Orbital Rendezvous Mode," *Aerospace Historian 18*, June 1971, 63-70.

McCurdy, Howard E. *Inside NASA: High Technology and Organizational Change in the U.S. Space Program*. Baltimore: Johns Hopkins University Press, 1993.

Moholy-Nagy, Laszlo. *The New Vision*, translated by Daphne M. Hoffman. New York: George Wittenborn, 1946.

Nelson, George. *Industrial Architecture of Albert Kahn, Inc.* New York: Architectural Book Publishing Company, Inc., 1939.

Smith, Merritt Roe, "The Harper Ferry Armory and the 'New Technology' in America, 1794-1854." Ph.D. Dissertation: Pennsylvania State University, 1971.

____________. *Harpers Ferry Armory and the New Technology: The Challenger of Change*. Ithaca, New York: Cornell University Press, 1977.

Smith, Terry. *Making the Modern: Industry, Art, and Design in America*. Chicago: University of Chicago Press, 1993.

Smith, Terry. "Albert Kahn: High Modernism and Actual Functionalism." In Brian Carter, Grant Hildebrand, and Terry Smith (Eds.), *Albert Kahn: Inspiration for the modern* (pp. 29-41). Ann Arbor, Michigan: University of Michigan Museum of Art, 2001.

Strahan, Jerry E. *Andrew Jackson Higgins and the Boats that Won World War II*. Baton Rouge: Louisiana State University Press, 1994.

Steward, James Christen. "Director's Forward." In Brian Carter, Grant Hildebrand, and Terry Smith (Eds.), *Albert Kahn: Inspiration for the modern* (pp. 8-9). Ann Arbor, Michigan: University of Michigan Museum of Art, 2001.

Taylor, Frederick Winslow. *The Principles of Scientific Management*. New York: W. W. Norton & Company, 1967.

Tompkins, Phillip K. *Organizational Communication Imperatives: Lessons of the Space Program*. Los Angeles: Roxbury, 1992.

Tripp, Robert S. "Guppy: The Strange Epic of the Ugly Airplane That Got Us To the Moon," *Invention & Technology 17*(4) (Spring 2002), 21-31.

Von Braun, Wernher. "Saturn the Giant," pp. 41-58, In Edgar M. Cortright, ed. Apollo Expeditions to the Moon. Washington, D.C.: U.S. Government Printing Office, 1975.

Ziglar, William. *The Fertile Southern Crescent: Bayou Country and the American Race Into Space*. Washington, D.C.: NASA Historical Office, 1972.