Hughes Aircraft Company
(Howard Hughes Industrial Complex)
6775 Centinela Avenue
Los Angeles
Los Angeles County
California

HAER No. CA-174

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PHOTOGRAPHS

WRITTEN HISTORICAL AND DESCRIPTIVE DATA

Historic American Engineering Record
National Park Service
Western Region
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San Francisco, California 94107

HISTORIC AMERICAN ENGINEERING RECORD

HUGHES AIRCRAFT COMPANY
(Howard Hughes Industrial Complex)

HAER No. CA-174

Location:	6775 Centinela Avenue Los Angeles (Culver City), Los Angeles County, California
Dates of Construction:	1941-1953
Engineer/Builder:	Henry L. Gogerty, architect
Present Use:	Abandoned; slated for redevelopment
Significance:	Refer to historical report for statements of significance.

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INTRODUCTION

Primarily developed between 1941 and 1953 and in continuous use to the present, the subject structures of the Hughes Aircraft Company, Culver City plant, constitute a unique and remarkably intact example of one of the first large-scale aircraft production centers. It provides a physical link with the historical origin and evolution of the aviation and aerospace industry, a technological economy which has played an essential role in the development of modern southern California.

The site served as a base of operations for billionaire industrialist Howard R. Hughes, Jr., who made significant contributions to the movie industry, in addition to his accomplishments as an aviation innovator and the founder of Hughes Aircraft Company (HAC). Under Hughes, HAC grew from a small scale manufacturer of advanced racing planes into one of the country's largest electronics and aerospace firms. The buildings of the Culver City plant complex embody the various stages of the company's transformation, with structures representing all phases of the industrial process, encompassing administration, research and development, fabricating and manufacture, and support facilities. The complex contains buildings of outstanding merit in architectural design and engineering achievement, and includes the giant hangar building that was the birthplace of the Hughes H-4 Flying Boat - the renowned Spruce Goose, the world's largest all wood airplane.

Initially scattered between hangar buildings in Burbank and Glendale, the consolidation of Hughes Aircraft's operations at the expansive Culver City plant site was a direct result of Howard Hughes' desire to involve his company in the phenomenal growth of the defense industry on the eve of World War II. Preparations for war required an enormous expansion of production in the United States, driving a huge boom in construction of industrial facilities. In 1941, there was a 40 percent increase in the construction of industrial buildings (Historic Resources Group 1995:21). The Hughes Aircraft Culver City plant was part of this extraordinary mobilization.

Completed before the war's onset, the earliest of the plant structures, Buildings 5 and 6, characterized by steel and concrete construction with rooflines invigorated with sawtooth monitors, expressed Hughes' interest in providing his company the most advanced industrial facility.

> Hughes had spared no expense. There were new drafting tables, engineering lofts, blueprint and duplicating machines. There was a laboratory for testing glues and resins, and an emergency power generating plant. Shops were equipped with the most modern machine tools [Bartlett and Steele 1982:88].

Acute wartime shortages of metals necessitated development of innovative building solutions using alternative materials, wood in particular, for the construction of the additional facilities needed for the production of the HK-1 Flying Boat. After years of research and experimentation in developing the Duramold process used in wooden aircraft construction, Hughes was in the forefront of wood lamination technology. This technology enabled the construction of the Cargo Building complex, the immense arch framed hangar building that housed the fabrication and assembly of the unique Spruce Goose. The most significant structure of the Hughes plant, the Cargo Building is among the largest wood structures in the world. It was later the center of production for Hughes Helicopters. Other structures built for the project, of which Buildings 2 and 3 are most important, serving administrative and engineering functions, employ traditional wood construction.

The shift in emphasis at Hughes during the late 1940s from aircraft production to the development and manufacture of advanced electronics and guided missile technologies brought the company immediate and spectacular success, and led to a major expansion of plant facilities between 1949 and 1952. With a reputation as an innovative and forward looking concern, based largely on the accomplishments of the company's maverick founder, Hughes Aircraft attracted some of the most talented scientific minds in the country. Among them were Simon Ramo and Dean Wooldridge, who later formed TRW, and Charles (Tex) Thornton, a founder of Lytton Industries. Their work was years ahead of the industry and by 1950 Hughes had secured the bulk of government contracts for radar controlled missile systems. From the Culver City headquarters, HAC dominated the fledgling aerospace industry, later making major contributions in the areas of satellite communications and space technology, lasers, and advanced weapons.

Designed and constructed quickly to meet the pressing needs of the war in Korea and the ongoing Cold War, buildings and additions completed during the expansion program are uniformly steel framed with steel panel siding. Beginning in 1949, plant buildings were painted "Hughes green," a shade selected by Howard Hughes and closely associated with Hughes and the Culver City plant. Several buildings of the complex retain their green paint. The new buildings incorporated state-of-the-art manufacturing and laboratory facility design. Interiors of laboratories and offices typically displayed perforated acoustical tile ceilings, louvered fluorescent ceiling fixtures, asphalt tile floors, and paneled wood doors.

The most progressive business and industrial practices of the time are reflected in the planning and development of the Hughes complex during the 1940s and 1950s. Concern for employee morale is apparent in the attention given to comprehensive industrial relations facilities and a pleasant and spacious cafeteria, complete with an outdoor dining area. Worker safety concerns manifested themselves in a state-of-the-art fire station. Beginning in 1950, many of the buildings, including the administration building (Building 1), the cafeteria (Building 10), and the fire station (Building 18) were designed in the International Style, reinforcing the corporate image of Hughes Aircraft as a company committed to the forward looking and the modern.

The structures described in this document were determined in 1991 to be contributing elements of the Howard Hughes Industial Complex, eligible for inclusion on the National Register of Historic Places.

THE HUGHES AIRCRAFT COMPANY CULVER CITY PLANT DESCRIPTION AND SITE DEVELOPMENT

The former Hughes Aircraft Company Culver City Plant is situated in the western portion of the City of Los Angeles near the Pacific coast. Located immediately south of Culver City, the facility has never been within the borders of that municipality, although it has been referred to by that place name since its inception. Composed of 22 industrial buildings, the plant, which once bustled with the production of Howard Hughes' famous "Spruce Goose" and other aircraft, and later, the world's most advanced weapons, electronics, and aerospace technology, now stands largely idle. Scattered movie production crews now occupy spaces whose output was once considered essential to national defense, and the site of the world's longest private airstrip is filled with overgrown piles of earth.

The complex is part of a larger, mostly undeveloped, 1100 acre tract of land now known as Playa Vista. The contributing buildings occupy a roughly rectangular tract of approximately 55 acres. The sale of Hughes Helicopters to the McDonnell Douglas Corporation in 1984, followed by the purchase of Hughes Aircraft by General Motors in 1985, brought a steady decline in the level of activity at the plant and ultimately led to the removal of several abandoned peripheral structures. What remains is a remarkably intact core of metal clad and wood frame industrial structures representing the various phases in the physical evolution of the Hughes Aircraft Company. Sixteen of the existing buildings relate to the period of Howard Hughes' direct involvement with the facility, between 1941 and 1953, and constitute the Howard Hughes Industrial Complex, eligible to the National Register of Historic Places.

The organization of the plant may be conceptualized as consisting of three tiers of buildings aligned parallel to the east-west oriented former runway on the north, and the Westchester bluffs rising to the south. The structures are generally rectangular in plan, with long axes oriented east-west. Two north-south oriented administration buildings inaugurate the complex at the east end. The primary research and development buildings, and manufacturing buildings which are the core of the plant, are located at the center of the complex in the north and central tiers, while the irregular, southernmost tier is composed of smaller support buildings (Figure 1). The north elevations of the buildings which front on the runway (Buildings 1, 2, 5, 12, and 20) are aligned, as are the ends of larger buildings, forming regular cross streets and long east-west alleys. Ample space was left between the end of Building 15, the hangar, and the buildings to the east to allow the passage of large aircraft from the hangar to the air strip.

The Howard Hughes Industrial Complex is dominated by the immense, centrally located hangar or "Cargo Building" (Building 15), which is 740 ft long and rises to a height of 73 ft, or almost six stories. The other buildings of the plant complex do not exceed two stories. In all, the facility currently includes approximately 1.6 million sq ft of floor area (HRG 1995:2).

The plant buildings are surrounded on all sides by the expansive parking lots necessary to accommodate the vehicles of a work force which, during the peak years, exceeded 10,600 employees (George 1951:2). Shuttle buses at one time ferried workers between distant lots at the plant's extremes and their buildings. Primary circulation routes occur along the north and south sides of the complex, with the main entrance from Centinela Avenue at the east end of the plant, and a second entrance from Lincoln Boulevard to the west. A series of gates controls access to the interior of the complex, and the areas between the buildings are paved with asphalt with few areas of vegetation. Building 1, the administration building at the east end of the complex, is surrounded by lawn and shrubs, and a tree filled courtyard exists between adjacent Buildings 1, 2, and 3. Lawn also occurs in the area between Building 6 and Building 10, which includes an outdoor dining area for the cafeteria. Additional greenery is limited to planters adjoining entrances to primary buildings.

After successfully breaking the world air-speed record in 1935 with the H-1 Racer, Howard Hughes moved his team of aeronautical engineers and technicians from Grand Central Airport in Glendale to new quarters at the Union Air Terminal in Burbank. From his earliest involvement in aviation Hughes was mindful of the enormous commercial potential in this increasingly important field. In 1936, realizing that the materialization of his ambitions in the field required an organization set up on a permanent basis, the Hughes Aircraft Company (HAC) was established as a division of the parent organization, Hughes Tool Company (Stearns 1953:2).

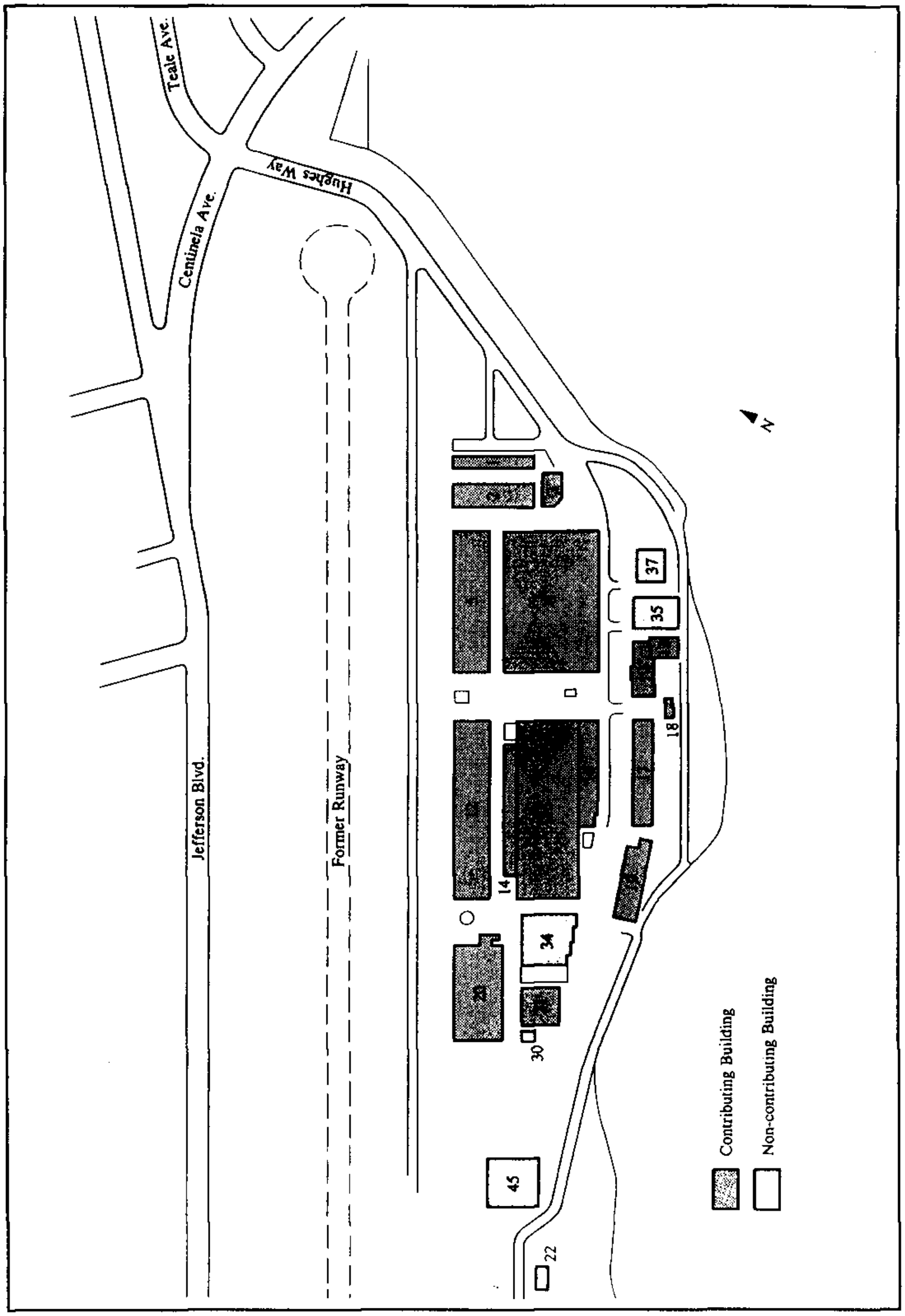

Figure 1. Hughes Aircraft Site Plan

Anxious for his firm to gain a foothold in the defense industry, Hughes next set his small crew of engineers to work on development of a twin engine interceptor aircraft. The plane was entered in an Air Corps design competition in 1937, along with designs from three larger, long established aircraft companies. While favorably impressed with Hughes Aircraft's innovative, well engineered entry, the government was reluctant to award a large contract to a firm without facilities for mass production and a Lockheed design was selected.

Preoccupied with his "Round the World" record flight for much of 1938, Hughes, sensing the imminence of war in Europe, focused once again on the development of military aircraft early in 1939. Design of an advanced fighter-bomber, designated the "D-2," was already under way when Hughes acquired rights to the Duramold process of wood lamination in March 1939, to be used in its fabrication, thus avoiding anticipated wartime shortages of light metals. Until the summer of 1939, HAC had never employed more than 50 people. The commencement of the D-2 project saw the beginning of a steady expansion of staff at the Burbank and Romaine St. facilities (Pettit 1958:6; Barton 1982:46-47).

By 1940, war was raging in Europe and Hughes Aircraft had landed its first small government contracts. Fearing that without the facilities for large scale production, he would again be passed over for major contracts, Hughes formulated plans to consolidate his various aviation activities at a single location. He was familiar with the broad, flat Ballona wetlands, which had been the site of movie filming since the 'teens, including portions of his own 1930 film "Hell's Angels" (Altschul et al. 1991:62-63). Situated near the coast southwest of downtown Los Angeles, the site was convenient to a large labor pool while being somewhat isolated and undeveloped, optimum conditions for a factory and airstrip. In mid-1940, Hughes purchased a 380 acre tract bordered on the west by Lincoln Boulevard (then Roosevelt Highway), Jefferson Boulevard (then Florence) on the north, and roughly even with Teale on the east. The Westchester bluffs rose along southern boundary. Oil rigs dotted the Pacific coast to the west and a small watercourse known as Centinela Creek flowed through the property near the base of the bluffs. The creekbed was diverted farther south prior to construction of Building 15. Celery and lima bean fields flourished on the property, and remained on the unbuilt portions long after the plant was completed.

Henry L. Gogerty, an accomplished Los Angeles architect best known as a designer of schools, was commissioned by Hughes to design the plant buildings at the Culver City site. As developed, the design placed a complex of industrial buildings at the east end of the property, between Centinela Creek and a runway which, at 9500 ft, was to be the longest private airstrip in the world. Construction of the facility began in December 1940. One of the wettest winters on record caused frequent delays in the work and turned the low lying plant site into a quagmire. Centinela Creek often threatened to overflow and required repeated dredging to prevent total inundation (*Hughesnews* 1981a:2, 1981b:3). Quantities of sand were excavated from the Ballona escarpment to fill low-lying areas of the site and to construct the roads and airstrip (*Hughesnews* 1941a:1).

Plans called for three parallel buildings. The northernmost structure, later known as Building 5, was to house processing and engineering; at the center was the Assembly Building (Building 6), with the Foundry and Drop Hammer Building (Building 9) to the south. Immediately west of the Drop Hammer Building was a fourth, wood frame, structure which housed the four diesel generators that supplied the plant's electricity until late 1943. The east facades of Buildings 5 and 6 were aligned, with Building 9 being slightly set back. A fifth building, known as Engineering III, was later moved to the site.

From an existing Pacific Electric rail spur to the north, an additional 1800 ft of track was extended onto the plant site to move the structural steel being shipped from New Orleans for construction of the buildings. The tracks, which ran along the east side of the assembly and processing buildings, and also branched along the south side of the drop hammer building, later transported raw materials into the plant and completed products out. They were removed in the late 1950s; a sidewalk presently follows their former route to Centinela (*Hughesnews* 1981a:3).

The buildings of the Howard Hughes Industrial Complex have gone by various names over time, being first referred to by their primary function and later given letter designations (Table 2). Plant planners switched to the numbers by which the buildings are presently known in early 1952. For clarity, the number designations will be used in this report.

Construction continued through the spring and summer of 1941. July 4th was set as moving day, and over that holiday weekend most of the Hughes Aircraft Company staff of approximately 400 people made the move to the Culver City site where only one structure had been completed. Building 5, the processing building, housed all plant functions until October, when Buildings 6 and 9 were completed. A fifth plant building, the wood frame Engineering III, was moved from Burbank to Culver City over the July 4 weekend as well, and placed along the north side of Building 5, only to be moved again two months later to the east of Building 6.

Design and development of the D-2 fighter bomber which had been ongoing in Burbank since 1939 continued on the mezzanine level of Building 5, while refinement of the Duramold process and fabrication of the plane's components were accomplished on the lower floor. Building 6 was reserved for assembly, and the drop hammer building housed fabrication of metal aircraft components and armaments. The Engineering III building was occupied by executive offices, accounting, purchasing, a first aid station, and the small radio department (*Hughesnews* 1981a:2; Stearns 1953:6).

Howard Hughes' involvement in the design of the earliest buildings and the layout of the plant site is not documented. Given his history of perfectionism, his high standards in all realms of personal endeavor, and what is known of his later involvement in the plant, there is no reason to believe he was not intimately involved in all aspects.

In September 1942, Hughes received a letter of intent from the Defense Plant Corporation, a government agency, formalizing an agreement with the Kaiser-Hughes partnership to develop and build three prototypes of a large cargo plane - the historic Flying Boat or "HK-1." The Flying Boat contract instigated the next phase of construction at the Culver City plant. Under the terms of the contract, the cargo plane itself, as well as all buildings erected for its production, must be constructed of non-critical materials - namely, wood. The agreement further stipulated that the project was not to generate profit for the partners, and accordingly, the manufacturing facilities were to be the property of the government. Ownership of an island of land at what was then the west end of the plant site, and the Cargo Plane Assembly Building (the Building 15 complex) built on it, was transferred to the Defense Plant Corporation and remained government property until repurchased by Hughes after the war. "To make room for the project and personnel, the plant was devoted almost entirely to development of the Cargo Plane by May 1943" and other activities of HAC were moved to various locations (*Hughesnews* 1946a, 1981a:2).

Table 1. Buildings in Howard Hughes Industrial Complex

No	Historic Name	Building Use	Old Letter Code	Other Names	Date
1	Administration	Executive offices	AA		1951
2	Engineering	Offices, engineering, mold production	A		1942
3	Mock-up	Prototype production	R		1942
5	Processing	Offices, laboratories, prototypes, manufacturing	C	Electronics, Mill Building	1941
6	Assembly	Offices, laboratories, prototypes, manufacturing	B	Incorporates 7, 8, 9, and T	1941
10	Cafeteria	Cafeteria	S		1943
11	Paint Shop	Repair shops, garage	L		c.1941-3
12	Radar	Offices, laboratories, prototype, shops, manufacturing	G		1951
14	Hull Pattern	Manufacturing, storage	D-1		1943
15	Cargo	Manufacturing, laboratories	D		1943
16	Duramold	Manufacturing	E		1943
17	Warehouse	Offices, medical center	Z		1950
18	Fire Station	Fire station and security	-		1952
19	Warehouse	Maintenance, receiving, warehouse	Z-1		1951
20	Manufacturing	Offices, laboratories, manufacturing	G-1	R & D	1951
21	Prototype Manufacturing	Laboratories, manufacturing, offices	G-2	Testing	1952
22	Raw Stock Supplies	Storage	NC		1953
27	Firing Range	Firing Range	NC*		1953
30	Storage	Storage	NC		1960
34	Warehouse	Warehouse	NC		1955
35	Processing	Processing	NC		1960
37	Storage	Storage	NC		1988
45	Hangar	Hangar, storage	NC		1954

NC=Non-contributor to District; *Demolished

Plans for the first two buildings constructed for the Flying Boat project, the Engineering Building and the Mock-up Building (Buildings 2 and 3), were drawn even before the contract was awarded and construction began in the fall of 1942 (*Hughesnews* 1942b). The new structures were sited immediately east of Buildings 5 and 6, on the opposite side of the rail spur. Building 2 was oriented north-south with its north end aligned with that of Building 5. The smaller east-west oriented Building 3 was placed to the south, on the site of the Engineering III Building, which was moved to the current site of Building 1. Its "clipped" corner responded to the curvature of the adjacent tracks. Building 2 served design, engineering and administrative functions for the Flying Boat project, while Building 3, which was connected to Building 2 with a breezeway, housed fabrication and testing of prototype components.

The Cargo Building rose quickly over the spring and summer of 1943, and fabrication of Duramold components for the Spruce Goose was occurring there by the fall of that year (Stearns 1953:8). The complex was placed with the north elevation of Building 14 roughly aligned with the north wall of Building 6, and approximately 450 ft west of the existing plant buildings. The large space between structures was, no doubt, thought necessary as a fire break and for movement of aircraft in and out of the hangar building (although the Flying Boat exited from the opposite end). This seemingly excessive expanse may also indicate that the placement of Building 15 anticipated a westward expansion of the manufacturing building, possibly if D-2 went into production.

Ground was broken for a cafeteria (Building 10) to serve the expanded Hughes workforce in the spring of 1943. The 400 seat building was the first to be constructed on the south side of the Centinela "ditch" and was connected to the other plant buildings via a wooden footbridge. It stood midway between Buildings 6 and 15 in an area notched into the base of the Westchester bluffs.

Building 4, a receiving building, now demolished, was also erected for the Flying Boat project in 1943. A narrow, east-west oriented structure, it was located south of Building 3. The current Building 11 stood to the west of the original processing building (Building 5). Initially the paint shop and plating and anodizing building, its construction may have preceded the Flying Boat project. It was later moved to the south, adjacent to the cafeteria.

The end of World War II and the completion of the Flying Boat and XF-11 projects marked a period of downsizing and consolidation of activities at Hughes' Culver City plant. During the late 1940s, the company's primary focus shifted from aircraft to development of sophisticated electronics for military and commercial applications. Hughes, in 1948, beat out several large electronics companies in securing a major contract with the Air Force for a radar-based fire control system to be used in interceptor aircraft. Additional contracts soon followed, and an extensive expansion program was initiated and completed at the Culver City facility between 1949 and 1952 (Pettit 1958:17; Stearns 1953:12).

First to be expanded in 1949 was Building 5, which was converted to offices and laboratories for the newly formed Electronics and Guided Missile Department; it was extended 60 ft to the west with a two story addition. Over the next year, Building 5 was extended westward twice more, bringing its overall length to 550 ft and more than doubling its total volume.

Next to be added was Building T, a one story manufacturing building connected to the southwest corner of Building 6 and abutting the west end of Building 9. Building 6 was extended to the west in 1950, with a south wall contiguous with Building T, and the west elevations of Buildings 6 and T were brought into alignment with the expanded Building 5. Over the next six years, a series of small extensions and additions surrounded Building 9, the drop hammer building, integrating it with Buildings 6 and T. After conversion to offices and laboratories in 1956, the entire structure, now rectangular in plan with a footprint larger than that of Building 15, was referred to as Building 6.

To serve the burgeoning Hughes work force the existing cafeteria (Building 10) was expanded in 1950 to more than twice its original capacity, with an outdoor seating area and a small second story executive dining room. Building 11 was moved from the site of the Building 5 extension to the rear of the cafeteria, where it was adapted for use as the plant garage. This initiated the use of the southern periphery of the complex - the area south of the drainage ditch - for support functions, per the expansion program master plan. Warehouse Building 17 was added west of the cafeteria in late 1950, in line with Building 16 to the north, followed by Building 19, a receiving building, erected farther to the west in 1951. The fire station (Building 18), the only building of the Howard Hughes Industrial Complex designed by the Plant Engineering Department, was added between the cafeteria and Building 17 in 1952.

In order to meet their increasing contractual obligations for electronic weapons systems and missiles, Hughes Aircraft scientists in charge of research and development and the plant planners determined that in excess of 200,000 sq ft of additional laboratory, shop, and office space would be needed by 1951 (Eaker 1950:3). To these ends, Building 12 was completed in April of that year, and was immediately filled by the Radar Department and elements of several others. Then the largest research and development facility within the Hughes complex, the scheme for the building was expanded several times. Located immediately north of the giant Cargo Building, Building 12, at 737 ft, ultimately matched that structure in length. The main entrance in the building's east end faced Building 5's newly created main entrance, allowing communication between these two primary engineering facilities, and the north elevation was aligned with that of Building 5 as well.

Building 20 was constructed along the same north alignment, 175 ft west of Building 12, in the summer of 1951 and added another 78,000 sq ft of space for guided missile engineering and development. The building's placement left 175 ft free at each end of Building 15 for a fire break, as directed by Howard Hughes. The one story structure marked the westernmost limits of plant expansion. Building 21, a two story facility housing Research and Development Department offices and testing laboratories, was completed directly south of Building 20 early in 1952. The considerable space between Building 21 and the west end of Building 15 remained vacant until filled with Building 34 in the mid-1950s. The flight line, located along the runway north of Buildings 5 and 15 prior to plant expansion, was reestablished in the area west of Buildings 20 and 21, adjacent to a hangar building (Building 45) completed in 1954 (Figure 2).

Administrative offices, primarily in the cramped Building 2, and also scattered between Buildings 5 and 6, were coalesced under one roof with the completion of the new Administration Building, Building 1, at the easternmost end of the Hughes complex in 1951. The long, narrow, north-south oriented structure, known as "Mahogany Row" for the lavish use of that rich finish in executive offices, housed the upper echelons and their support staffs. Hughes insisted that the building be immaculately maintained, and that the neat lawns and tree filled courtyard surrounding the building be mowed daily.

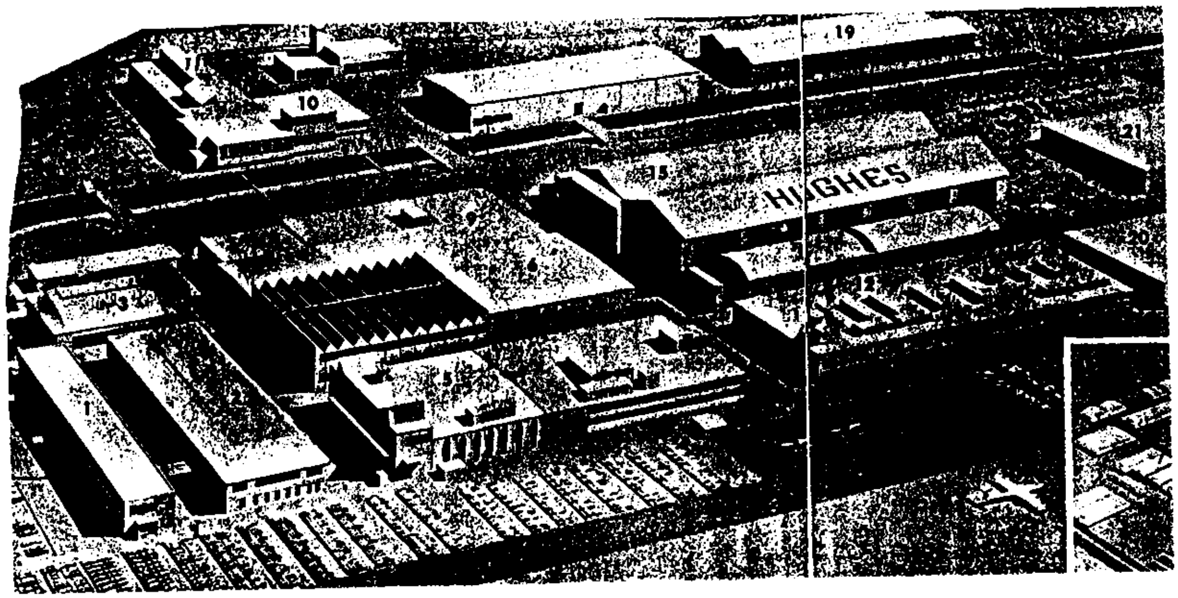

Figure 2. Bird's Eye View of Hughes Plant in 1953.
(*Hughesviews* 1953:23-24)

Toward the beginning of the expansion program, the complex took on a more unified appearance when all of the plant buildings were painted a distinctive shade of green. Opinions differ as to how the color was selected. Some say Howard Hughes had the light yellowish-green color developed by Sinclair Paints specifically for use at the plant, while others state that the color was chosen simply because it was surplus and cheap (Altschul et al. 1991:96). In any event, the shade was so closely associated with Hughes and the Culver City plant that it became known as "Hughes green." Most buildings were repainted white or light blue-grey when McDonnell Douglas took over in the mid-1980s.

Providing parking was an ongoing difficulty at the Culver City plant as it expanded. New lots were developed on all sides of the complex and in all available space between buildings. Tons of earth were removed from the bluffside south of complex, altering its appearance. The serious flooding problems which plagued the plant from its nascence were largely allayed in 1962 by channelizing and burying the drainage ditch which ran through the site (*Hughesnews* 1981b:3).

Following the Senate hearings in 1947, and the hiring of General Harold George as Hughes Aircraft's General Manager soon afterward, Howard Hughes' involvement in the day-to-day activities at Culver City waned, although he retained control of the company's finances and insisted on approving of all major capital expenditures. The success of the electronics division in attracting government contracts and the resulting need for expansion rekindled his interest. Rather than add to the Culver City facilities, as proposed by his top lieutenants, Hughes wanted to move operations to property he owned near Las Vegas known as Husite, under the pretext of the site's vulnerability to attack. Hughes resented California's income tax and realized any growth at Culver City would force him to pay more on the company's earnings while Nevada had no income tax. In the face of his staff's adamant opposition to the move, Hughes reluctantly agreed to the Culver City expansion, at the price of increased oversight:

> The feud over the laboratory site only heightened Hughes's interest in the aircraft company, which was looking a lot like a potential IBM of the space-age weapons and electronics industry. He closed in on it. Demanding approval of all architectural plans for the Culver City addition, Hughes pored over drawings for weeks, debating color schemes, moving a window here, relocating a hallway there. Not even the vending machines escaped his notice. He issued orders for an in-depth study of the sale of candy bars and soft drinks throughout the plant [Barlett and Steele 1979:163-164].

Company memos reflect Hughes' consuming interest in economy in plant construction. He felt that the cost of the original aircraft buildings was excessive and was determined that the additions to the complex conform with strict budgetary constraints (Eaker 1949a:1). All buildings and additions of the expansion period were steel frame with exteriors clad with metal panels - relatively inexpensive construction that was quick to erect. Hughes' obsession with economy seems to have brought him into conflict with top company brass, including General George and General Eaker, who had decided on a broader list of priorities, namely "the necessity of establishing a production reputation; economy; and aesthetic, utility, and other layout considerations" (Eaker 1949b:1).

While seemingly little concerned with the appearance or user friendliness of the new buildings, Hughes had strong opinions about the plant layout. The orderliness of building arrangement was important to him, and he often requested plan changes whereby adjacent structures were made to correspond in terms of length and alignment of elevations. The runway was also a point of contention with Hughes, and new buildings were not allowed to encroach on it beyond the north elevation of Building 5. During this period, several proposals were made to pave the runway to benefit jet aircraft, all of which were rejected by Hughes who insisted that such a hard surface would damage the planes' landing gear. Paving was delayed until after Hughes' departure from the company. Fire insurance ratings were also primary determining factors in building placement for the frugal Hughes. Buildings had to be located at sufficient distance apart to ensure the lowest possible insurance rates. Where this was not possible, as in the case of Building 12, adjacent to the all wood Cargo Building, measures such as windowless concrete walls and extensive roof deluge systems were specified (Eaker 1949a:2; Hopper 1950a:1-7).

With the dispersal of production facilities to newly established locations in Tucson, El Segundo, Canoga Park, and Los Angeles International Airport during the early to mid-1950s, new building construction at the Hughes Culver City plant was limited to smaller support and warehouse buildings. The only other major project was the hangar building, Building 45, at the far west end of the site, constructed in 1954 to house company planes.

Building 1 - Administration Building

The Administration Building is a two story steel frame office structure executed in the International Style which stands at the extreme eastern end of the Howard Hughes Industrial Complex. Also referred to as Building AA, Building 1 consolidated executive and administrative offices previously located in Building 2 and several other buildings.

Building 1 is a narrow rectangle in plan with a flat roof and vertical, corrugated steel panel cladding. The elevations are characterized by continuous bands of steel casement windows at the upper and lower story levels. Windows project slightly from the wall surfaces and are four horizontal lights in height, with operating awning-type sash in every other unit. The main entrance, at the center of the east facade, is framed with a rectilinear vestibule formed by stuccoed side walls and a flat roof. An aluminum framed glass double door placed off-center within the enframement is flanked by stucco piers and sheltered by an upswept cantilevered canopy formerly crowned with "Hughes" in large metal letters. There is a rectangular transom window above the canopy. Full height plate glass windows flank the doors, with Roman brick planters beneath. A secondary entrance in the north elevation also has a projecting rectilinear frame. The enframement here is sheathed with smooth finished vertical metal panels, and a glazed wooden door occurs to the west of a group of steel casement windows with a Roman brick planter below.

The western elevation opens onto a tree-filled courtyard shared with Building 2. The locations of internal stairways are expressed by breaks in the fenestration near either end of the elevation, and at the center, where there is a double-door entrance. Windows on this side are covered with external sun screens. A splice in the wall finish and a low concrete step flanked by a Roman brick planter at the center of the south elevation indicate the location of an original door. A band of casement windows presently extends across the entrance area.

A steel framed structure composed of full width, 16 x 50 ft, structural bays supported on reinforced concrete pilings, Building 1 has a reinforced concrete first floor deck and steel truss supported second floor and roof. Services are housed in the reinforced concrete basement, with mechanical equipment rooms under the central section and southeast corner of the building connected by a tunnel along the east wall.

The internal organization of the building consists of offices arranged along double-loaded corridors on the first and second floors. A portion of the first floor is open in plan with perimeter offices, and stairways occur at the center and near either end. The central lobby displays sleek wood paneled walls and reception desk, and a plaster ceiling with concave recessed incandescent ceiling fixtures. First floor offices are typified by painted or textured wall finish, suspended acoustical tile ceilings with ceiling mounted fluorescent fixtures, and carpeted floors. Floor finish in the corridors is brick-look vinyl tile and ceilings are of gridded plastic panels with integrated lighting. Ceilings in the upper floor corridor are similar, and floors are carpeted.

Second floor offices display a variety of wall treatments. Most have carpeted floors and acoustical tile ceilings with a range of fluorescent ceiling fixtures. Offices at the south end occupied by top Hughes executives and their support staff display molded panel mahogany wainscot. Walls of the southeast corner office, purportedly first used by Howard Hughes, are completely finished with mahogany, with a dado of small molded panels below and large molded panels on the upper wall. The southwest corner office and an adjoining anteroom also have walls completely finished with wood panels. Unlike the other offices, woodwork here is stained a deep red with a sleek gloss finish. The dado features raised rectangular panels. The outer room has a map case along the north wall, with sliding panels concealing hanging map racks. Some offices have a less ornate plywood panel wainscot or dado.

Noted Los Angeles architect H. L. Gogerty is responsible for the design of the Administration Building. Gogerty was involved in the development of the Culver City plant from its inception and designed all but one of its major buildings. Building 1 was among the last structures designed by his firm during the period of Hughes' leadership. It was not until after construction had commenced in June 1950 that it was recognized that, as initially conceived, Building 1 would not provide adequate space to house the diverse administrative functions of the ever expanding company. Plans were drawn for a 52 x 119 ft extension to the north end of the structure, bringing it in line with the north elevation of the existing Building A (Building 2), 60 ft to the west. The addition matched the original portion of the design detail for detail, its central double-loaded corridors following the existing space plan. A secondary lobby was designed for the north end. The Del Webb Company, a Long Beach firm that Howard Hughes used for several plant buildings, functioned as lead contractor in the building's construction (*Hughesnews* 1950f:1, 1950j:1).

Building 1 was the corporate headquarters for the Hughes Aircraft Company for 35 years. Howard Hughes and his top level executives had their offices on the second floor, and decisions that impacted the national defense and the direction of technological advancement were made there. Its richly appointed hardwood interiors earned the building the nickname "Mahogany Row." The building functioned as a reception center for senior military officers and other visiting dignitaries, in addition to initially housing Customer Relations, the Legal Department, and Planning on the second floor, and Purchasing and Industrial Relations on the ground floor (*Hughesnews* 1951a:1). Its modern design included a well-appointed lobby with a large oil painting of Howard Hughes next to his H-1 Racer, the plane in which he set the 1935 air speed record.

The upstairs executive wing featured a conference room with huge oval cherrywood table and executive dining room with an attached gourmet kitchen, staffed with a chef and two waiters, and projection equipment for film screenings. Hughes' suite of offices was at the southeast corner of the second floor. His personal office had an adjoining dressing room and bathroom, and was flanked by the offices of his two secretaries. The offices of General George, General Eaker, Alan Puckett, Pat Hyland, Noah Dietrich, and other top management of HAC and Hughes Tool Company, Aeronautical Division, were nearby. The conference room at the southwest corner was remodeled and later occupied by Jack Real, the president of Hughes Helicopters. Charlie Marcus, Hughes' patent attorney, was the only member of the senior echelon to have an office on the lower floor since he used a cane. Above Marcus' office at the northeast corner of the building were the numerous lawyers' offices and storage space for corporate documents (Altschul et al. 1991:107).

The meticulous Hughes insisted on a formal, orderly work environment. Employees were not allowed to wear their overalls inside and, "by some accounts, the fastidious Hughes was said to be so concerned about the building's appearance that, for a time, even the janitor was required to wear a tie" (Russell 1993). The building and surrounding landscaping had to be scrupulously maintained, and he required that the lawns be mowed daily. During construction, Hughes stipulated that walkways connecting Building 1 with other buildings line up, with no jogs, and that sidewalks be far enough away from the building to allow for hedges and to keep people from defacing it (Hopper 1950a:3). Despite his exacting standards for the building's appearance, and for that of its occupants, Hughes reportedly rarely used his Building 1 office.

Various alterations have been made to the interior of Building 1 since its construction; for the most part, these have been limited to alterations in room finish treatments rather than major room configuration changes. The mahogany paneling and millwork that distinguished the offices of Howard Hughes and the company officers, located primarily in the south half of the upper floor, remain largely intact, although most of the original circular, pendant-type, copper finished lighting fixtures have been replaced with fluorescents (CA-174-A-14). The conference and dining room was expanded soon after the building's completion, and remodeled once more in 1958 (Statistical Research et al. 1991). The massive conference table that formerly graced this space has recently been removed.

Building 1 retains the light "Hughes" green with dark green trim exterior paint scheme that all of the buildings of the Hughes plant displayed after 1949.

Building 2 - Engineering /Administration Building

Building 2, originally designated Engineering Building A, faces Building 1 across a narrow courtyard at the east end of the Hughes Culver City complex. Two stories in height, the structure employs conventional light member wood framing and is rectangular in plan, with a footprint measuring 338 x 100 ft. The Engineering Building is clad in false bevel drop siding with a narrow overhang delineating the articulation of the first and second floors. Horizontal smooth finished tongue and groove board siding covers the lower wall to grade, and conceals the reinforced concrete perimeter foundation. The structure has an unusual roof design consisting of two bowstring roof trusses of unequal size in side by side placement, connected at the top by a sloping tangential roof, resulting in an unusual asymmetrical profile when viewed from the north or south. Fenestration consists of double-hung sash windows placed primarily in four window groups in both the upper and lower floor, but also occurring in single placement, and in groups of two, three, and five. A large louvered bay corresponding with a mechanical (air conditioning) room occurs near the center of the second story in the west elevation, and a narrow ribbon window at the south end of the lower floor is presently boarded up, as are most of the windows in the lower story of Building 2.

The main entrance is located somewhat north of center in the east elevation. A glazed double door, originally set at the center of a full-height bay of large fixed light windows, has been moved to the south end of the bay and replaced an aluminum framed model. The entrance is sheltered by a flat wooden canopy, in deteriorated condition, suspended on diagonal tie rods. A primary entrance added to the west elevation in the early 1960s, opposite the original entrance, features an upswept canopy with pipe supports, decorative concrete block screens and low simulated stone planters. Two additional personnel entrances occur in the elevation.

Plans and historic photos indicate that a ramp along the south half of the west wall originally rose to an existing open, wood framed platform. A double door provided access to the platform and ramp from a second floor mold loft. A small, free standing frame shed stands beneath the platform. Adjacent to the platform is a circular metal stair to the basement level.

Near the north end of the west elevation, an unpainted area the full height of the wall indicates the former location of a narrow appendage. Added sometime before 1950 and removed in 1987, the structure contained a two story concrete records vault (A. Romano, personal communication 1995). Historic photos indicate that it was clad with vertical wood siding and had a shed roof (CA-174-B-23). The north elevation is unaltered and retains its original irregular fenestration pattern. Here, as in all elevations, window placement was dictated by interior uses. A band of windows extends across the upper register of the south elevation and a covered breezeway at the west end of the elevation connects Building 2 with Building 3 to the south - an original design element.

According to the original plans, an existing structure, the Telephone Building, measuring roughly 35 ft square, was to be incorporated into the first floor of the new building on the west side. The structure does not appear in photos or site plans from the period and it is not known if it was actually used. Its presence is not apparent in the existing construction.

Construction of Building 2 began in the fall of 1942, soon after the receipt of the Flying Boat contract (*Hughesnews* 1942b:1). Designed by architect H.L. Gogerty, it was conceived to house many of the non-manufacturing functions associated with the project, including engineering, research and design, and administrative services. The south half of the first floor was dominated by a large, open drafting room where design work was done. The Engineering Department was in another large open room that occupied much of the north end of the floor. Filled with desks and drafting tables, the room was shared by the stress analysis, aerodynamics, and weights sections (T. Amneus, personal communication 1995). Offices of managers and senior staff occurred around the perimeters of the large work rooms, and in the central portion of the ground floor were additional offices and smaller work rooms, the engineering files room, and a 28 ft x 26 ft reinforced concrete vault where engineering drawings and other documents were stored in floor to ceiling flat files.

In the upper floor, a large Template Mold Room corresponded with the drafting space below in the south end of the building. The north half of the floor was occupied by management and administrative offices such as cost accounting, general accounting, tabulating, and the cashier, as well as several rooms devoted to photography and reproduction. Howard Hughes is reported to have used offices in the northeast corner of the second floor even after the new administration building (Building 1) was completed in 1951 (G. P. Hall, personal communication 1995).

A 1500 sq ft reinforced concrete basement under the western portion of the building contained blueprint and duplicator rooms, as well as a darkroom, and a tunnel connected the basement of Building 2 with that of Building 6 to the west. The Mail Room was also located in Building 2, and early employees remember that mail was delivered by female staff on roller skates (J. Patton, personal communication 1995).

Original construction in the interior of Building 2 was utilitarian, with a horizontal shiplap V-grooved board wainscot in offices and corridors, and fiberboard wall and ceiling panels. In the better offices at the north end of the upper story, including one reportedly used by Hughes, molded panels were used, while in functional areas such as the large drafting and engineering rooms and stairwells, the wall finish was simple, diagonally applied, tongue and groove board. The upper floor originally had hardwood floors which were soon covered with asphalt tile (T. Amneus, personal communication 1995). Remaining original office doors are two panel with glazed upper panels. Several incandescent lighting fixtures with glass globes along the west hallway appear to be original. Rooms and corridors are lit by a variety of fluorescent fixtures, primarily the suspended, louvered type which, as in the other buildings, are indicative of early 1950s construction or remodeling. These fixtures commonly correspond with areas where perforated acoustical tile ceilings have been installed. Partition and finish changes are evident in all areas of Building 2 but, generally, the rooms of the north half of the building express the least alteration. Perimeter offices have been added in the south half of the building along the west wall, and the row of connected offices along the east wall occupied by the marketing department of Hughes Helicopter during the 1980s have been updated with rich wood dados, doors, and trim. The former template mold loft remains largely open, with ceilings to the roof. In 1954 the second floor was strengthened to allow some manufacturing to be conducted in this area. Machine gun and armament work was completed in the building in the 1960s, an industrial usage completely different from its original conception as an office building (Statistical Research et al. 1991). During the 1950s Air Force personnel associated with government contracts worked in Building 2.

Building 3 - Mock-up Building

The Mock-up Building is constructed with conventional wood framing. The structure's unique five sided plan - essentially a rectangle with the southwest corner clipped at a 45 degree angle - was executed to provide clearance for an existing rail spur. The building initially consisted of an open, high ceilinged one story shop space sheltered by a bowstring truss-framed roof. Second level loft spaces were later added at the west end of the building with the east half remaining a full height work area. The structure is clad with false bevel drop siding identical to that of Building 2, and the lower portion of the wall to grade is covered with smooth finished tongue and groove siding which covers the reinforced concrete foundation. A simple board stringcourse conceals the joint between the two materials. The structure retains its peeling Hughes green paint. A long, low frame dependency approximately 6 ft in height with a shed roof and horizontal V-board siding extends along most of the east elevation. The windowless addition holds equipment and controls associated with a testing shed to the north.

There is no formal entrance to the Building 3; access is provided by various personnel doors in the north, west, and south elevations. A covered breezeway connects Building 2 and Building 3 at the northwest corner. The breezeway door is a two panel door with a glazed upper panel and appears to be the only original exterior door. Two overhead doors added to the north elevation access the central work area. In the west elevation, a sliding door track located below the eaves and a noticeable splice in the wall cladding indicate the location of a large cargo door which originally occupied much of elevation. The site of the cargo door encompasses the present location of two windows in the upper story and a smaller plywood and glass panel cargo door in the lower story. The wall material in the in-filled area matches the surrounding walls suggesting that this was an early modification.

Fenestration of the north, east, and south elevations is placed high in the wall and consists of large wood framed casement window units, three square, single light windows high by four wide, placed in continuous bands. Each awning-type casement opens inward. In the southwest elevation, two horizontal casement window units were employed, two windows high by three wide. Windows added to the upper story in the north and west elevations are paired single light casements. A steel framed, metal panel clad prototype testing shed abuts Building 3 at the east end of the north elevation.

The interior of the Mock-up Building originally consisted of a large open work space, the only additional rooms being an office and bathroom, both triangular in plan and located along the clipped (southwest) wall. Loft space has been added above these rooms and along the south side of the building. It is connected to a loft added at the northwest corner with a catwalk along the west wall. The east half of the interior remains completely open. The original utilitarian diagonal tongue and groove board wall finish is largely intact. Suspended fluorescent lighting fixtures have replaced the original incandescents. The roofline features a rectangular louvered monitor with a flat roof. The north elevation faces Building 2 and the courtyard it shares with Buildings 1 and 2.

Designs for Building 3 and associated Building 2 were developed by architect H.L. Gogerty even before the contract for the HK-1 Flying Boat was finalized (*Hughesnews* 1942b:1). Construction of the building, to be used for production of models and component prototypes for the plane, began in the fall of 1942. The plant's first administration building stood on the site chosen for the Mock-up Building, necessitating that structure's removal to a location east of Building 2, where it remained for several years (*Hughesnews* 1981a). Building 3 was built completely of wood in compliance with the government contract stipulation that both the Flying Boat and any structures erected for its completion utilize non-essential materials. Building 3 was erected contemporaneously with Building 2, the Engineering Building, immediately to the north. The two buildings were designed as functional unit and were linked by a breezeway, allowing direct communication between the designers and engineers working in Building 2 and those giving form to their ideas in Building 3. Howard Hughes worked with his engineers for months in Building 3 designing the Flying Boat's instrumentation and working out kinks in the hydraulic system. The prototype of the plane's nose section was stored in the building's upstairs loft for years after the project was completed (*Los Angeles Times* 1990).

Early work in guided missiles at Hughes began in Building 15 and production of prototypes was transferred to Building 3 around 1950. The first model of the renowned Falcon air-to-air missile was produced there (J.Stubbs, personal communication 1995). Beginning in the late 1950s and continuing through the Vietnam War, this building was used by machinists, sheet metal fabricators and pattern makers working with the helicopter engineering department to produce prototypes. Testing of helicopter drive trains was conducted in the metal shed attached to the north side. Cannons, machine guns, and other armament were also manufactured here (J. Tweten, personal communication 1995).

Building 5 - Processing/Electronics Building

Building 5, originally referred to as the Processing Building, is a long two story structure, rectangular in plan, measuring 550 ft long by 150 ft wide. The eastern third of the structure was built first and was the first element of the Culver City plant to be completed and occupied. The building was extended three times between 1949 and 1950 to achieve its present configuration.

Recognizable as the most highly stylized of the plant facilities, the original portion of Building 5 is composed of two distinct elements: a tall, two story east bay with a roofline dominated by two symmetrically placed sawtooth monitors, and a lower, gabled main block with buttress-like wall protrusions. The body of the building is framed with rigid steel arches, with exterior walls of poured-in-place reinforced concrete. The gracefully curved shoulders and tapering legs of the seven concrete encased arches penetrate the north and south walls. The arches are attenuated as they approach the roof peak and provided a clear span work area 150 ft wide and 20 ft high at the eaves. On the north elevation, the intervals between arches are bisected by vertical strips of glass block two feet wide, added later but appropriate in the Streamline Moderne influenced design. Small horizontal vents under the eaves were likened by some early Hughes employees to gun slots (Tribbett 1941:2). The south elevation of this portion of the building is windowless but for a one bay wide strip of glass block and is further articulated by various personnel doors and large air intake grills.

The 41 ft long east bay is of concrete encased, steel post and beam construction and initially contained ground floor work areas and a mezzanine office level - the location of design, administrative, and clerical offices in the early days of the plant. The exterior walls of this portion of the building are also of reinforced concrete, and on the interior, turn-buckled steel tie rod X braces that tie the columns together are exposed. These may have been deemed necessary to stiffen the structure, the east wall of which was largely glass. The walls of the mezzanine bay are nine feet taller than those of the arch framed section. Its distinctive roofline features north and south facing glazed sawtooth monitors that rise an additional 10 feet. The monitors provided natural light to the offices and work areas below, which received additional light from broad bands of steel casement windows that extended completely across the east facade at the upper and lower story levels. A 1959 facade remodeling project designed by the original architect, H.L. Gogerty, sought to unify the appearance of Buildings 5 and 6 by applying vertical corrugated metal panels to the upper portions of their east elevations. In Building 5 a flat parapet was added to conceal the irregular roofline and the upper story windows were painted over.

A cantilevered metal canopy shelters the length of the lower facade, where the continuous band of casement windows that existed south of the centrally placed main entrance has been partially replaced with glass block. Groups of casement windows placed high in the wall occur north of the entrance. The original doors have been replaced by aluminum framed glass double doors, and the entrance is flanked by brick planters and a seating area. Shrubs and a lawn with trees extend across the front (east end) of the building. The south elevation of the end bay displays a large roll-up door in the upper story, related to a space which originally functioned as a mock-up room. An additional overhead door exists in the lower story and a tapered concrete chimney defines the joint between building sections. The north elevation has a single, canopied entrance and a band of casement windows high in the upper story wall.

Construction of the original portion of Building 5, the first building of the Culver City complex, was begun in January and completed by the weekend of July 4th, 1941, when the Hughes Aircraft Company was transferred in its entirety from the Grand Central Air Terminal in Glendale and Union Air Terminal in Burbank to the new site. The move consolidated the heretofore fractured organization of the Aircraft Division of the Hughes Tool Company. At the time of the move, Building 5 was the only structure fully completed and it housed all of the company's activities. Construction crews worked two to three eight-hour shifts per day to complete the building by the July 4th deadline imposed by Hughes. The marshy ground of the Ballona wetlands, aggravated by an extremely rainy winter, required driving 40 to 50 foot pilings to support the structure (*Hughesnews* 1941a:1, 1941b:2).

The building represents the first use by architect H.L. Gogerty of long span arch framing for the plant's industrial buildings - a method of construction revisited in the design of the Cargo Building (Buildings 15 and 16).

Also known as the Mill Building or Building C, design and development work on the Hughes D-2 fighter-bomber begun in Burbank resumed in Building 5, while Building 6 was set aside for factory work and assembly. Activities within the Processing Building were in constant flux during the first months of the new plant, as new buildings were completed and functions were shifted to locations best suited to the industrial process. In addition to shop functions, Building 5 initially housed the primary research and design functions for the plant. The ground floor held various woodworking and machine shops, a pattern shop, the chemistry laboratory, curing rooms, and the processing room. Design, engineering, managerial, and clerical offices occupied the north half of the mezzanine level, and the Mock-up Department shared its large room at the south end of the mezzanine with the Structural Test Department. A 45 x 100 ft reinforced concrete basement under the eastern portion held mechanical equipment and offices of the stress analysis and research departments, the library, and the telephone switchboard. A 10 ft wide tunnel allowed passage of personnel and materials between Buildings 5 and 6 (Horn 1941b:8; Tribbett 1941:2).

Testing and refinement of the Duramold process of wood lamination, elemental in the construction of both the D-2 and the Spruce Goose, was carried out in Building 5. The structural characteristics of numerous wood types were tested by the engineering department and experimentation with various synthetic resins was conducted in the chemistry laboratory. The Retort and Hot Room at the west end of the building housed a huge cylindrical steel chamber where the techniques for curing Duramold components were developed. The retort was pressurized with steam from a basement boiler. Ultimately, all of the D-2's Duramold assemblies were fabricated in Building 5 (Horn 1941b:8).

With the awarding of the Flying Boat contract, work at the plant shifted almost exclusively to that project. Building 5 housed the earliest design and engineering work completed for the plane and, prior to the completion of the Cargo Building, the first Duramold prototypes and components were produced there. The retort used in the thermosetting process was later moved to Building 16. Building 5 retained various woodworking, engineering, and design functions and resins testing continued in the chemistry laboratory (Stearns 1953:8; *Hughesnews* 1950j:1).

The end of World War II and the completion of the Flying Boat brought a change in direction at Hughes Aircraft, which now focused on the development and production of armaments and sophisticated electronic equipment. Early research in radar, weapons control systems, and guided missiles at Hughes was concentrated in Building 5 (Figure 3). Success led to important military contracts in 1948, necessitating an expansion of facilities to accommodate new research and an expanding staff (Pettit 1958:17-18). Building 5 underwent three expansions beginning in 1949 related to its occupation by the growing Department of Electronics and Guided Missiles. In March of 1950, the name of this department was changed to Research and Development, and with the completion of the Radar Building at the end of 1950, Building 5 was devoted primarily to missile work. At the time of the 1959 remodeling of the east facades of Building 5 and Building 6, the buildings were known collectively as the Systems Development Laboratories, producing Hughes Falcon missiles and aircraft and armament control systems. The first clean room in the aerospace industry for precision assembly of sophisticated electronic devices was established in Building 5 (*Hughesnews* 1950h:1, 1959:1; J. Patton, personal communication 1995).

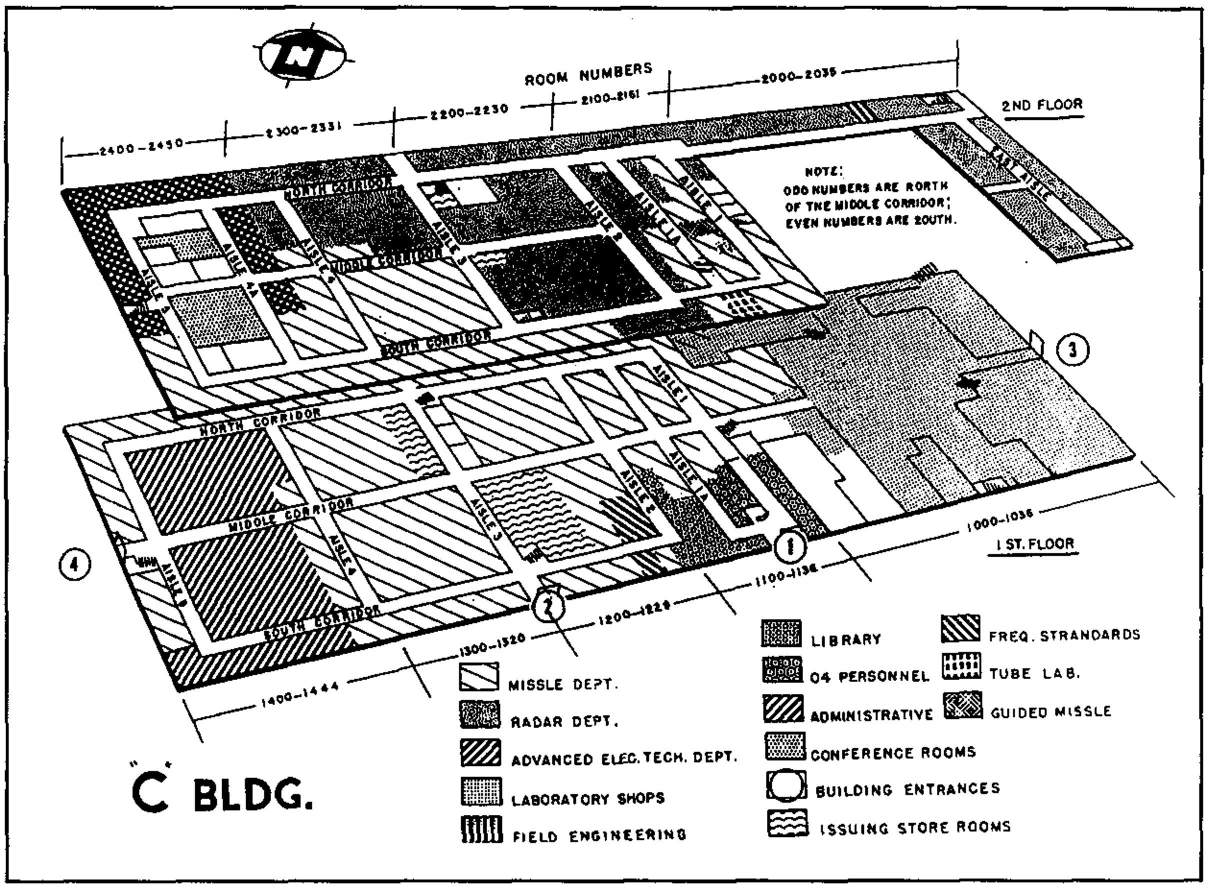

Figure 3. Building 5 Prior to Transfer of Radar Department to Building 12
(HAC Research and Development Administrative Staff and Service Activities c. 1950)

Plans were drawn by the building's original architect, H.L. Gogerty, in early 1949, for a two story addition containing offices and laboratories which would add 60 ft to the west end of the structure and "permit the location in Building C of the entire electronics research and development organization including their experimental machine shop" (Thornton 1949:1). The expansion included a 24 ft wide extension of the mezzanine of the existing building along the north wall, which contained offices and formed a connection with the second floor of the addition. T-S Construction Engineers, Inc. of Los Angeles was the contractor selected for the project, with J.T. Stafford acting as structural engineer and Pacific Iron and Steel supplying and erecting the structure's steel frame (George 1949b; Thornton 1949).

The addition had barely been completed in June 1949 when designs were developed for a second extension to the Electronics Building, as it was now called. Two hundred feet in length, it added an additional 60,000 sq ft, including 102 offices and 22 laboratories, to the west end of the building (Figure 4). A *Hughesnews* article reported that the extension was "air conditioned, has asphalt tile floors, acoustical ceilings throughout and has fluorescent lighting in the laboratories . . . the added room has allowed the (Research and Development) department to triple its library space and to add a new self service radio parts stockroom" (*Hughesnews* 1950d:1). Its construction necessitated the moving of the Paint Shop and the Plating and Anodizing Building (Building 11) to a location behind the cafeteria. A new contractor, the Simpson Construction Company, was hired for the second addition, and the company was eventually retained on a continuing basis for various work on the plant expansion (Jerman and Johnson 1950:1). By the April 1950 completion of the second extension, drawings had been made for a third and final extension of the structure which, when completed at the end of 1950, added another 76 ft, bringing the building's total length to 550 ft and causing the west end to line up with that of the expanded Building 6.

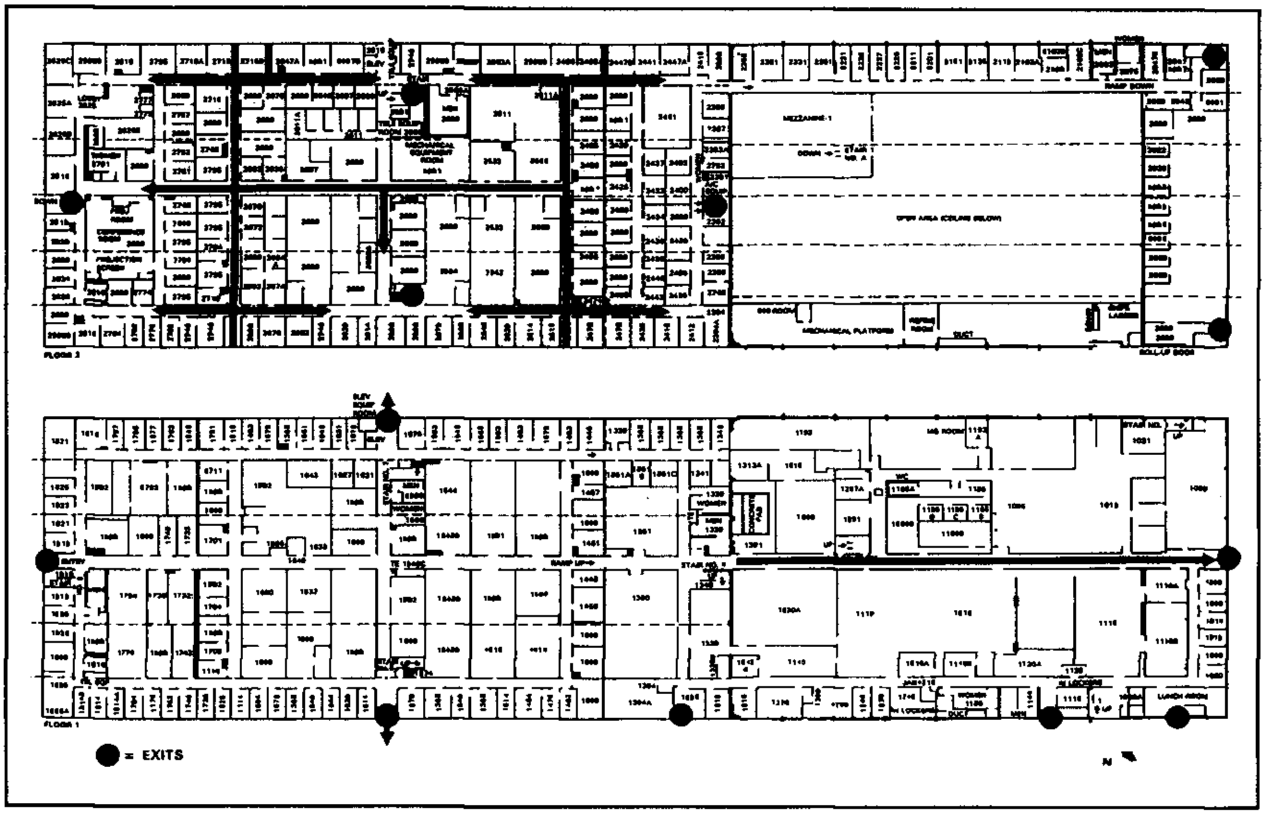

Figure 4. Building 5 Floor Plans
(Source: Wall Poster in Building 5)

Each of the extensions is of traditional steel frame construction with low-pitched gabled roofs matching that of the original structure, and Robertson smooth finish, vertical steel panel exterior wall cladding. The first addition is differentiated externally from the two later extensions by its fenestration. Banks of steel casement windows four lights high by two wide occur in the upper story of the south elevation, while a continuous band of casement windows two lights high extends across the lower story. The lower story of the north elevation is windowless. A small roll-up door occurs at the east end of the south elevation of this section.

In the two western additions, steel casements units three horizontal lights high are used in continuous ribbons across the upper and lower story. This pattern is repeated in the west elevation, with a break in the lower floor at the centrally placed main entrance. The primary entrance was switched from the east end of Building 5 to the west end at the time of Building 12's construction a short distance to the west in 1951 (*Hughesnews* 1950h:1). The entrance is defined by a rectilinear metal clad canopy and side wall and accented by low Roman brick and simulated stone planters which extend across the facade, corresponding with a similar treatment of the Building 12 entrance which it faces. A large mechanical penthouse located slightly south of the center ridge breaks the symmetry of the west elevation.

The roofline of Building 5 is further enlivened by the profusion of mechanical penthouses, ductwork, and piping necessary to serve the complex air handling system and other specialized systems within the building. Testing of radar and other electronics systems produced by Hughes was undertaken in a series of roofhouses along the north elevation.

Interior partitions, floors, and ceilings of all sections of Building 5 are primarily wood framed. The configuration of the ground floor of the original portion of the building has changed many times over the years and presently is given over largely to laboratory spaces located off of a central corridor, with some offices and support spaces located along the east and south walls. Originally open to the roof, the ceiling of the laboratory area was dropped at the time of the 1950 renovations and the attic space above is currently occupied by mechanical equipment and utilities. A concrete decked mechanical platform runs along the south wall.

The design of the 1941 mezzanine is also much altered; ceilings have been dropped in the space once lit by roof monitors and the broad expanses of glazed wall have been covered. Offices were added along the west wall of the former mock-up room, although the space remains mostly open. The offices of the 1950 mezzanine addition along the north wall are accessed from a single loaded corridor. They retain much design integrity and feature low sloping ceilings which follow the roof line, perforated acoustical tile ceilings, egg crate-type fluorescent ceiling fixtures, and narrow glass block windows. Some display the protruding flanges of steel arch structural members. The west elevation of the original building had rounded corners, and these remain discernible in the former corner rooms of this section.

The internal configuration of the western additions follows the general pattern of small perimeter offices with larger laboratories, shops, and conference rooms located in the center. Circulation is provided by a gridded system of corridors. The laboratory spaces show evidence of repeated alterations, their configurations changing with technological and programmatic requirements over time. Many offices have also been significantly altered to reflect personal tastes, function, and corporate hierarchy; however, a substantial number have received very little renovation. Offices along the south side of Building 5, and also the northeast corner of the upper floor, generally show the least change and many retain their original prefabricated panel partitions, Cellotex perforated acoustical tile ceilings, Smoot and Hoffman louvered fluorescent ceiling fixtures, reeded chair rails, and two panel wooden doors. Ceilings of the upper story offices follow the slope of the roof. The joint between the first and second additions is recognizable from metal exterior wall panels of an upper floor office partition (Room 2470), and the division of the second and third additions is apparent from a slight change in floor elevation. During the time of GM/McDonnell Douglas' occupation of the building in the 1980s, offices in the northwest corner of the upper floor were converted to executive suites.

Following completion of the third extension, no substantial alterations have been made to the exterior of Building 5 with the exception of the remodeling of the east facade.

Building 6 - Assembly/Manufacturing Building

Containing more than 400,000 square feet, Building 6 is the largest building within the Hughes complex. Located immediately south of Building 5, to which it is connected via a tunnel, Building 6 is a two story steel frame structure, essentially rectangular in plan, which has been expanded several times to achieve its present configuration.

When completed in October 1941, the original core of the Culver City plant was comprised of four structures: Building 5, the Processing Building; Building 40, a small office building no longer standing; Building 6, the Assembly Building; and Building 9, the Foundry and Power Hammer Building located a short distance north of Building 6. Building 9 was ultimately engulfed by a series of expansions which joined it to Building 6 and formed the present structure.

The original, northeast, portion of this utilitarian industrial structure is distinctive with its jagged roofline consisting of a series of 11 parallel sawtooth monitors which spanned the entire roof and provided abundant natural light to the expansive production area below. The exterior walls of the 220 x 300 ft structure were reinforced concrete, which is the existing finish of the north wall and the lower portion of the east wall. Initially painted pastel green, the building is currently white. The north elevation features continuous bands of alternating fixed steel sash and awning-type casement windows three horizontal lights high at the upper and lower story levels. The elevation is further articulated by pipe rain leaders which descend from the crotch of each sawtooth monitor, a steel personnel door, and two roll-up freight doors, one of which is in-filled.

Fenestration of the east elevation of the original building consists of continuous bands of casement windows identical to those of the north. Two large window bays five lights high with wide concrete surrounds occur immediately south of the slightly off-center main entrance. The aluminum framed glazed double door is set in multi-colored tile surround and covered by a cantilevered flat metal canopy that extends to the north to shelter a secondary entrance. In a 1959 remodeling, vertical corrugated steel panels - typical of Hughes plant buildings constructed after 1950 - were applied to the northern edge and upper portion of the east facade of the original Building 6, mirroring facade treatment added to Building 5 at that time as well. The alteration hid a third tier of windows in this elevation at the monitor level. The two added sections which comprise the south half of the east facade are clad with smooth finished vertical metal panels and have steel casement windows similar to those of the original building. The southernmost section has windows only in the ground floor.

As constructed in 1941, Building 6 featured high, one story open manufacturing and assembly areas with a unique floor composed of small wood blocks with the end grain turned upward - thought to be better for employees' feet and the machinery. A mezzanine which covered the northeast quarter of the work floor contained various design, engineering, and administrative offices, and had maple parquet floors and window walls overlooking the work area below. A basement below the mezzanine area included mechanical equipment rooms and offices. A tunnel connected the basement of Building 6 with Building 5 to the north, allowing workers and materials to pass between the two structures. A second tunnel extended to Building 2.

Hughes Aircraft's success in attracting major contracts for electronic equipment and armaments in the late 1940s created a pressing need for additional production space. Construction of Manufacturing Building T began in April 1949, roughly corresponding with the start of the first Building 5 addition (HAC 1949:1). The windowless, one story, 171 x 325 ft steel framed structure had a low-pitched, truss supported gabled roof and was clad with vertical, smooth finished Robertson 18-18 UK metal panels. A single row of columns spaced every 25 ft bisected the open manufacturing floor, and a wood framed interior structure with a mezzanine near the center of the building contained a medical room, a tool room, offices, bathrooms, mechanical equipment, and an elevator accessing a roofhouse immediately above in which radar systems were tested (A. Romano, personal communication 1995). Building T abutted the west end of the Power Hammer Building (9) and the west end of the south elevation of Building 6. Several small support structures relating to the first phase of the Culver City plant's development were removed prior to its construction, including Building 22, which initially housed the plant's diesel generators (Stearns 1953:6).

Plans were drawn by the end of 1949 for a 275 ft long, one story addition to the west end of Building 6 which would be contiguous with the north wall of Building T. Before construction had begun, the plans were modified to added another 75 ft in length to the proposed extension. An expansion of the existing mezzanine was also approved by Hughes, which added an upper level to the entire east end of the structure to contain offices for design, engineering and other functions (*Hughesnews* 1950c:1; Hopper 1950a:7).

The steel framed addition (Figure 5) completed in September 1950 has a slightly sloped gabled roof, somewhat higher than that of Building T, and is similarly windowless and clad in Robertson Smooth Steel Siding (*Hughesnews* 1950j:1). The north wall is penetrated by a single personnel door and regularly spaced louvered vents high in the wall. Two double doors and a external freight elevator door are the only openings in the addition's west elevation, to which two open steel framed vehicle sheds are attached.

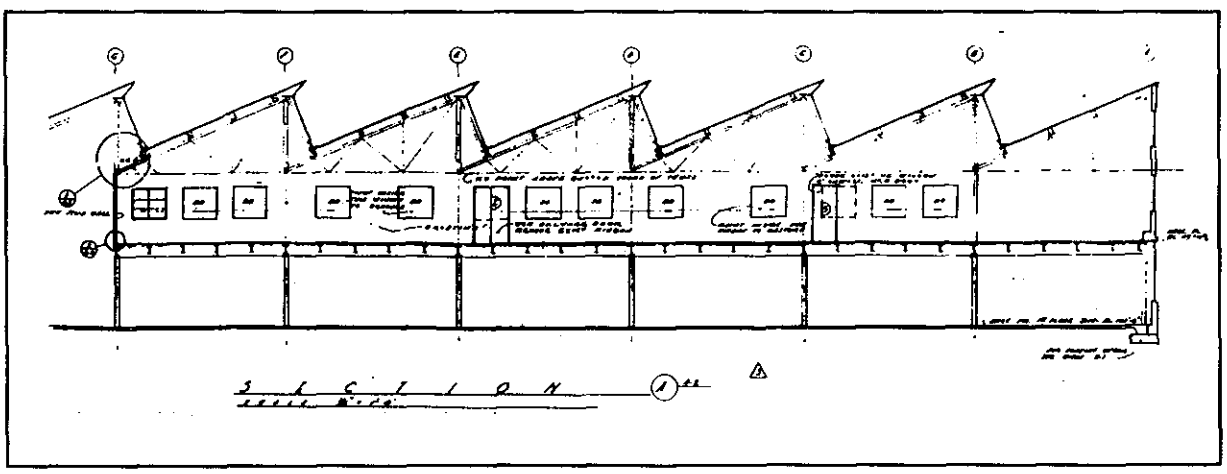

Figure 5. Section through 1950 Mezzanine Addition.
(Source: Gogerty, Henry L., June 21, 1950 Mezzanine Addition, Building 'B', Sheet A-1)

At the end of 1950 the west end of Building T was extended 75 ft. The addition matched the construction of the original structure, and brought the west elevations of Buildings T, 6, and 5 into alignment. Two groups of three large roll-up doors accessed by sunken loading ramps and separated by a seventh door at grade currently exist in this section of the west elevation of Building 6.

A single story, steel framed addition contiguous with the south elevation of Building 9, the Foundry and Power Hammer Building, begun in October 1950, was joined to the east elevation of Building T and expanded the rail spur shipping dock adjacent to manufacturing area. Aligned with the south wall of Building T, it matches that structure's roof slope and metal panel wall finish. Its fenestration consists of a narrow band of windows two lights high placed high in the south wall. A large roll-up door and two personnel doors provide access. This section now contains mechanical equipment.

Building 9, first referred to as Building H or the Foundry and Power Hammer Building, was a one story, steel frame structure with a flat roof. Encased triangular truss supports protruded from glazed curtain walls of the north and south elevation through which diagonal tie rod bracing between supports could be seen. The structure's profile replicated that of Building 5. The supports carried deep steel trusses, providing a clear span work area. The east and west walls also included large expanses of glazing and central cargo doors. Ultimately surrounded by a series of additions, the upper walls and roof of Building 9 may be seen to protrude several feet through the engulfing later construction. Traces of columns, tie rods and glazing remain at the south wall joint.

Between 1952 and 1956 the area between the original south wall of Building 6 and Building 9 was in-filled, and additions were made to the east and south, completing the rectangular overall footprint of the aggregate structure afterward known in its entirety as Building 6. The southeast corner additions are two stories, clad with smooth vertical steel panels, with a parapeted east wall matching the height of the remainder of the building's east elevation.

In 1956 radical renovations were made to the interior of Building 6. The unique wood block manufacturing floor was removed, and a new basement was excavated under the west end of the building. A second floor was added throughout the building, including the various additions, which matched the level of the existing mezzanine at the east end of the structure. Only the west end of Building T and mechanical spaces along the south wall remained a single story. The renovations were completed in phases over a period of nine months. Upper and lower stories were divided into laboratory, office, and support spaces. A lettered system of gridded corridors provided circulation within the mammoth facility. The massive and complex climate control system which serves the building was operated from a single glass enclosed booth on the first floor dubbed the "fishbowl." Howard Hughes himself reportedly contributed to the booth's innovative cockpit-like design, from which the temperature of each space could be fine tuned (A. Romano, personal communication 1995). Massive chillers, fans, and compressors of the air conditioning system were located in the basement at the west end of the structure with transformers and other mechanical equipment in the eastern section of the basement.

Design elements of the 1956 renovations are perhaps best preserved in the corridors of Building 6. In many sections the original ceilings of perforated, square acoustical tiles remain, as do the finned, wall mounted, fluorescent fixtures which line the corridors in continuous strips. Corridors also retain their painted wall finish. Office, laboratory, and support spaces of Building 6 have experienced many changes in configuration and finish treatment since their inception, and few retain any semblance of their original appearance. Dropped acoustical ceilings have replaced the original square tiles or unfinished ceilings, and recessed or surface mounted fluorescent fixtures have been installed. Office wall finishes vary greatly from space to space, reflecting personal taste, corporate hierarchy, or period of remodeling. Generally, offices along the north wall exhibit the greatest degree of change - reflecting their occupation by departmental managers. Offices along the southern portion of the east wall show the fewest modifications. They retain reeded chair rails, painted walls, and exposed concrete encased columns. Offices in the northeast and northwest corners of the second floor were remodeled last; a paneled lobby and office suites were created for General Motors/McDonnell Douglas management in 1988. Laboratory spaces were frequently altered with changing programmatic requirements. The southeast portion of the first floor contains several unique laboratories for research and production of classified equipment; these are completely steel lined and have heavy vault-like doors.

Building 6, and also Building 9, were completed by October of 1941, three months after the initial move-in at Culver City. Both were designed by H.L. Gogerty. From the time of their completion, until the contract for the HK-1 Flying Boat project brought a flurry of construction activity in 1943, the structures made up more than half of the total floor area of the plant. Following the company's move from Glendale and Burbank, design and Duramold fabrication work for the D-2 fighter-bomber continued in Building 5, while Building 6 was used for manufacture of metal components, plane assembly, and armaments work (CA-174-E-20). Metal aircraft parts and armaments were also produced in Building 9. Work on the D-2 at the Culver City facility came to a conclusion in 1943, and armament work was moved to the Romaine Street facility as activity in the manufacturing and engineering areas of Building 6 shifted to the new priority at Hughes: the HK-1 project. The various metal parts and assemblies for the plane were produced there (J. Stubbs, personal communication 1995).

The ground floor of the newly completed Building 6 was primarily taken up by elements of the manufacturing department, and at any given time work on a range of projects was ongoing. Occupants included the sheet metal, jig and fixture, welding, hydraulic, metal fittings, and mock-up sections, with space also provided for stockrooms and plant maintenance. The machine shop, comprising the heaviest milling equipment and presses, and the associated machine shop tool crib were located under the mezzanine in the northeast corner. Offices of the manufacturing department, production control, and the engineering department were located in the "glass house," as the glass-enclosed mezzanine level was known to workers. The production planning office and the company library also occupied the mezzanine, as did the loft and template department. Additional offices were located in the basement, including those of plant engineering, the photo laboratory, and *Hughesnews*, the company's weekly newsletter (Horn 1941a:8, 1941b:5).

With a series of innovations, what during World War II had been a small and relatively neglected aspect of Hughes' operation - the radio department - developed into the focus of Hughes Aircraft's post-war production. Radar and fire control systems developed by Hughes led the industry and brought a series of military contracts beginning in 1948 which placed production demands on the company which far surpassed their past projects. Manufacturing Building T was constructed to meet the expanded production loads, and additions to the west ends of Buildings 6 and T in 1950 further enhanced production capabilities. In all, the manufacturing floor area was nearly tripled, most of it devoted to the fabrication of radar and fire control systems, with the remainder used for guided missile work.

The original portion of Building 6 housed fabrication shops containing an array of milling and sheet metal forming machinery, from which components passed to radar sub-assembly areas in the extension and Building T, and then to final radar assembly areas in Building T. Assemblers in Buildings 6 and T faced each other across long double rows of specially designed work benches incorporating bins for parts and finished components, which were periodically resupplied from push carts. At the west end of Building T, assembly line production took place on small mobile work benches suspended from an overhead track that formed a circuit, with parts bins located at the center. The fabrication and assembly sections were supplied from the newly erected Stores building (Building 17) to the west (CA-174-E-21, CA-174-E-22, CA-174-E-23).

The expansion of the mezzanine along the east wall, also completed in 1950, created additional space for Equipment Engineering, Tool Planning and Design, and sections of the Radar Engineering and the Missile Production Departments. The 1949 and 1950 expansions of Building 6 were designed by H.L. Gogerty, the building's original architect (*Hughesnews* 1950j:1).

Hughes' rapid growth in the early 1950s resulted in the establishment of new facilities in Tucson, Arizona in 1951, and in El Segundo in 1954 (*Hughesnews* 1952a:1, 1981a:3). Under the Master Space Plan, the new plants were to specialize in missile and electronic systems production, while the Culver City facility would become the center of research and development activity (*Hughesnews* 1956b:1). The corporate headquarters would also remain in Culver City. To these ends, plans were drawn for the conversion of Building 6 from its manufacturing function into an engineering facility.

Work began in July 1956 on the extension of the existing mezzanine to create a full second floor which would extend through Buildings 9 and T, unifying the complex of structures into a single functional unit. The overall floor area of the renovated structure was in excess of 400,000 square feet, including a 4500 square foot basement addition at the northwest corner which contained hydraulic and electrical equipment for the laboratories, as well as air conditioning equipment for the entire building. The renovations were designed by the Plant Engineering Department, with the Del Webb Construction Company of Long Beach as primary contractor. Del Webb also built the 1949 and 1950 additions.

When work was completed in 1957, Building 6 housed the recently formulated Systems Development Laboratories, which also occupied most of Building 5, with some space on the second floor devoted to Research Laboratories. Systems Development Laboratories was responsible for the Falcon missile, one of Hughes' most acclaimed products, in addition to aircraft armament control systems. Later, laser research was conducted in Building 6. Much of the building was devoted to components and materials laboratories, where parts and components supplied to Hughes were tested to determine if they met the requirements for project applications. If appropriate components could not be secured, they were produced in the various laboratories and machine shops (*Hughesnews* 1959:1; J. Patton, personal communication 1995). The building continued to function as an engineering research and design facility for Hughes, and later for General Motors/McDonnell Douglas until its abandonment in 1994. A single story modern stucco addition containing a lobby is now attached to the north end of the eastern elevation of Building 6. Erected in 1990, it is L-shaped in plan and has a flat roof.

Building 10 - Cafeteria Building

The most ambitious interpretation of the International style within the Hughes complex, Building 10 is an asymmetrically organized structure with a small, flat roofed second story which rises from the northwest corner of the single story volume and cantilevers over the north facade. The second floor housed the executive dining room and its attached kitchen and is accessed by an external glazed stairway. The stair rises from the northwest corner and is sheltered by a series of four stepped, overhanging flat roofs. The raised, angled main entrance is inset immediately east of the stairway in the north elevation. Its glazed double door is sheltered by a flat roofed canopy. The east elevation features a corresponding entrance, also with an angled approach and a flat canopy with pipe and trellis supports. Building 11 adjoins the cafeteria at the southeast corner.

The cafeteria is primarily wood framed with steel I-beams used for major spans, and steel trusses supporting the combination of flat and low-sloped gabled roofs. The composition's volumes are finished with smooth stucco accented with simple wood trim. Window walls of 4 x 6 light steel casement units in the north elevation provide light to the large employee dining room and overlook the attractively landscaped lawn and topiary ensconced outdoor dining area between the cafeteria and Building 6 (CA-174-F-4). The glazed expanse is broken near the center of the facade by an inset secondary entrance approached by a low flight of steps. Fenestration of the overhanging upper story consists of a strip of steel casement windows four rectangular lights high across the north elevation and wrapping around the east. Shrub and flower filled planters adjacent to the entrances enhance the north elevation. A continuous wood siding clad window box trims the lower facade.

The south elevation is penetrated by a row of louvered windows, and small casements placed high in the wall light the utilitarian spaces along the east and west elevations. The east elevation has an entrance for diners at the north end with an angled approach and flat canopy, and a service entrance at the south end. An entrance added to the the rear (south side) of the cafeteria is emphasized with an ornamental concrete block screen.

The interior of the cafeteria is dominated by a large open dining area capable of seating 1000 people. The serving area is situated at the west end of this space, with the kitchen beyond. Much of the serving equipment is still present. Office, storage (including a large walk-in freezer), mechanical, and other service spaces occupy the southwest section of the building, which also contains guest and staff bathrooms. Dishwashing facilities are located at the east end of the cafeteria, and two private dining/conference rooms occur along the south wall. The former executive dining room on the second floor is accessed by a service stair from the main kitchen in addition to the exterior stairway and includes a small kitchen and washrooms for staff and diners. It was expanded in 1957 through the enclosure of a cantilevered balcony which spanned its entire north wall.

The present appearance of Building 10 reflects a major 1950 renovation and expansion of the cafeteria constructed in 1943 for employees working on the Flying Boat project. Designed to accommodate 400 people, it was a single story frame structure, rectangular in plan, with a sizable veranda on the south side for outdoor dining. Amenities also included ping pong tables, music, and "superb food and pastries." Lunch in the early days cost about 90 cents, and the 20 cent salad was described as being "so big that it should be split in two" (*Hughesnews* 1981a:3). A foot bridge spanned the drainage ditch immediately north of the cafeteria, connecting it with the rest of the complex.

H.L. Gogerty was responsible for the design of the original cafeteria, as well as the 1950 remodeling which added 8700 sq ft - more than doubling the size of the existing building. A 72 x 100 ft dining room was added to the east end, and the north side of the building was extended 13 feet. Space added at the southwest corner housed storage and support facilities and the second level executive dining room was added at the northwest corner. Company folklore maintains that Howard Hughes kept a private office in the southwest corner of Building 10, from which he could reach the executive dining room on the upper level via a stairway from the main kitchen added during renovations in 1952. The upper level contained a dining room with a balcony, restroom, and a small kitchen. It was initially available only for special uses, such as conferences and luncheon meetings, and would certainly have been at Hughes' disposal (*Hughesnews* 1950e:1; A. Romano, personal communication 1995). The balcony was enclosed in 1957, as was an outdoor patio dining area along the south side of the cafeteria for use as private dining/conference rooms.

The attractively appointed main dining room had high ceilings with exposed trusses, pendant lighting fixtures with round globes, and an asphalt tile floor (CA-174-F-13). A suspended acoustical tile ceiling with flush fluorescent fixtures was installed in 1973, at which time the floor and wall finishes were updated, the serving counter layout was changed, and accordion-type partitions were added to the dining area from the serving area and kitchen for use during special events.

Cafeteria structures were of great concern for designers of industrial sites during the 1940s and 1950s. A growing awareness of the impact of working conditions on industrial efficiency and output caused increasing interest in facilities that could improve the quality of life for workers - such as the employee cafeteria. Substantial effort was put into designing distinctive and pleasant eating environments as well as employee lounges and after work entertainment centers (HRG 1995:24). During the 1950s the cafeteria's main dining room had a movie screen for film screenings, and company functions such as awards ceremonies and the annual Red Cross blood drive were held in the facility. Original plans called for a stage for performers and orchestra, and extensive landscaping (*Hughesnews* 1950b:1). Centinela Creek, which flowed immediately north of the cafeteria, was channelized and covered in 1962 and plantings and a seating area in front of the building later added.

Building 11 - Garage and Maintenance Building

One of the earliest structures of the Hughes complex, Building 11, is a single story, high bay structure, roughly rectangular in plan, with a very slightly pitched gabled roof. Of traditional wood frame construction and clad in smooth stucco, the utilitarian design lacks any decorative embellishment.

Four roll-up doors of varying size corresponding to garage bays within dominate the west elevation. The structure's north wall abuts Building 10, the cafeteria, at the east end, and the north end of the west wall is overlapped by a cafeteria addition. Eight light, hopper-type casement windows arranged in pairs and placed high in the wall are the only features of the south elevation. Similar windows occur in the east elevation above a low shed addition that runs the length of the building. The windowless shed contains a single long room and is clad with vertical standing seam metal panels. An array of ventilators and ducts protrudes from its roof. A long, narrow penthouse extends along the ridgeline for most of the length of Building 11, culminating in a more substantial penthouse at the north end. The larger, shed roof structure is lit by groups of four-over-four double-hung sash windows in the west elevation.

Internally, the 60 x 120 ft building is organized with garage bays in the west half and smaller rooms containing specialized shops, storage and service spaces, and offices for managers along the east and north walls. The large north bay extends the full width of the building. The three bay vehicle repair shop to the south includes stations equiped with hydraulic lifts. A mezzanine level used for storage of parts and materials overlooks the north bay with narrow casement open-barred windows and a large freight door. The mezzanine has a floor of steel grating, and the rooms directly below are lined with bins for additional parts storage. Access to the penthouses is by way of an external stairway or via a stair from the north bay. The interior of the long, narrow structure is unfinished. The north penthouse most recently housed offices and has plastered walls and ceiling. Interior wall finishes elsewhere in Building 11 are painted plywood, with perforated gypsum board panels covering the ceilings.

Built between 1941 and 1943, Building 11 was designed by architect H.L. Gogerty and was one of the eight structures which formed the nucleus of the early plant. Originally known as Building L, or the Paint Shop, it also housed the Plating and Anodizing Department. The structure was first located at the west end of Building 5 and was moved to its present location behind the cafeteria in November 1949 prior to construction of the second addition to Building 5. The Donald R. Warren Company, a local engineering firm, drew the plans for the structure's relocation. Following the move, Building 11 functioned as the plant garage and contained areas for vehicle repair and washing, a welding area and carpentry shop, and tool and parts storage. The Maintenance Department also occupied space in the building *(Hughesnews* 1949d:1). Howard Hughes reportedly maintained a private apartment in the penthouse of Building 11. A rooftop walkway allowed the secretive millionaire to pass between the penthouse and the executive dining room of the adjoining cafeteria unseen by the rest of the plant (A. Romano, personal communication 1995).

The vehicle maintenance function of Building 11 remained unchanged until its abandonment in 1993. The metal-clad lean-to attached to the east side was in place by 1957 and was used by Hughes, and later McDonnell Douglas, for manufacture of helicopter components (A. Romano, personal communication 1995). Signs in an adjacent open-sided shed used for armament work bear the cryptic message "wear white gloves when handling gun barrels."

Building 12 - Radar Building

With more than 200,000 sq ft, Building 12 is by far the largest building of the Hughes complex designed specifically for research and development. It provided a huge increase in office, laboratory, and experimental shop space upon its completion in April, 1951. The two story, steel frame structure is executed in utilitarian Modernist style; rectangular in plan, it has a flat roof and walls spanned by continuous bands of steel casement windows. It was the first building to employ the vertical corrugated steel siding and smooth boxed trim used on most later plant buildings. The structure rests on reinforced concrete foundations, with columns supported on steel pilings.

The primary, north facade remains little altered from Gogerty's original symmetrical scheme. Fixed steel sash windows, three horizontal lights high, extend the full 737 ft length of the elevation in continuous bands at both the upper and lower floor levels, interrupted only by irregularly placed entrances, and two freight doors in the east half of the building that relate to shop areas. Wide, smooth metal panel surrounds enframe the recessed entrances. The steel doors have glazed upper panels and are surmounted by rectangular transoms. A central entrance adjacent to the main lobby added in the 1980s has an aluminum framed, glazed double door.

The original main entrance to Building 12 is centered in the east elevation, facing the west entrance of Building 5, and features a projecting rectilinear enframement with smooth metal panel finished side walls and flat roof. The entry protects an off-center, aluminum framed, glazed double door with transom above and flanked by a large plate glass window to the north. Planters of Roman brick and simulated stone across most of the elevation contain a variety of trees and other plantings, including palms, yucca, cypress, ficus, acacia, bird-of-paradise, and perennials. Banks of fixed steel sash windows, very similar to those of the north elevation but finished flush with the wall, fill the upper story of the originally windowless elevation. The windows were added in the late 1950s.

Freight doors associated with large shop spaces break the west elevation, which also has an inset, central, double door personnel entrance. A concrete ramp along the south half of the elevation accesses an attached one story frame shed clad with corrugated metal panels. Continuous bands of fixed steel sash windows provide natural light to spaces along this elevation as well.

Construction of the south wall of Building 12 differs from the other elevations. It is formed entirely of cast-in-place reinforced concrete panels which correspond in size with the 21 ft width of the structural bays. The elevation is completely fenestration and has few other penetrations. Ventilation ducts protrude from the first floor laboratory and shop spaces and downspouts descend at each panel joint. The original plans depict a single roll-up freight door in the south elevation; four entrances currently exist. A low, concrete block mechanical shed and a larger, one story concrete block addition with a metal roll-up door are attached near the west end of the elevation, and an additional open, steel frame shed with pipe supports and a corrugated metal shed roof is appended near mid-wall. The west end of the wall is extended at its full two story height approximately 10 ft beyond the corner, sheltering the receiving platform.

The roofline of Building 12 is articulated by a discontinuous row of shed roofed, plywood clad roofhouses along the north edge of the building. Wood sliding sash, and large fixed windows arranged in irregular groups of between two and 10 windows occur in the north elevations, facing the runway. The westernmost roof house is the least altered. It is set back and retains one paneled overhead door, wood sliding sash windows, and a plywood finished interior. A wood railing spans much of the north roof edge.

The four original roofhouses, referred to as "Observation Rooms" on the plans, were rectangular, east-west oriented structures set back slightly from the north face and connected along the north side by a boardwalk. Each roof house had a series of wood paneled overhead doors which looked out over the runway to the north. Used in the testing of radar equipment, the roofhouses were expanded in line with the original structures in 1951. The overhead doors were removed when structures were further expanded to the north parapet in the 1970s. Initially finished with painted plywood, the interiors of the roof houses are now variously finished with drywall or paneled walls and carpeting or vinyl flooring. Metal wiring chases that served electronic equipment are suspended from dropped or exposed rafter ceilings.

Howard Hughes reportedly assisted in developing and testing radar systems on the roof of Building 12. The radar equipment was tested by targeting airborne drones or fixed targets on the surrounding bluffs and at distant points, like Point Mugu Naval Air Station. An air traffic control tower was erected at the northeast corner of the roof in 1952, replacing one located on the north side of Building 5. The octagonal control room was supported on angle iron legs and a small frame shed which stood below it remains, complete with pieces of radio equipment. After years of disuse, the tower was removed in 1987 (A. Romano, personal communication 1995). The roofscape also features numerous mechanical penthouses and ventilators.

Internally, laboratory and shop spaces on both the upper and lower floors are arranged along a broad central corridor. Parallel double-loaded corridors provide circulation to office and support spaces along the north and south walls, with cross corridors at regular intervals. Stairways are located at the north ends of cross corridors, and adjacent to the east and west entrances. Freight elevators are grouped with two of the central stairways. Generally, support and storage spaces, bathrooms and conference rooms are concentrated along the windowless south wall. The north wall, which overlooks the runway, provided the most desirable office space, and offices also line the east and west walls, and some of the cross corridors. The west half of the first floor of Building 12, both south and north of the central corridor, is dominated by large, high ceilinged shop spaces which break the grid of perimeter and cross corridors.

The central corridor is lined on both sides by enclosed service chases, two feet deep, which run continuously for the length of the building, interrupted only by doors and cross corridors. The chases carry services (gas, electric, air, and chilled water supply and return lines) from the basement to laboratory and shop spaces on both floors. Removable panels along the corridor allow access to the utility lines and controls. At the basement level, a reinforced concrete tunnel lined with substantial head pipes and conduits, control boxes, pumps and other devices underlies the central corridor. Mechanical equipment rooms occur only at the east end of the building. The "most modern electrical equipment available" was installed in an electrical substation located on the south side of the tunnel which served the entire Hughes plant (*Hughesnews* 1951c:3). Basement rooms north of the tunnel contain the enormous fans, compressors, condensers, and ductwork of Building 12's extensive ventilation system, as well as minor laboratory and storage spaces.

Office spaces in Building 12 reflect varying degrees of alteration. A wholesale remodeling of interior spaces has never occurred and a high percentage of offices display a number of original design elements. Generally, offices at the east end of the building are the most altered and, not surprisingly, these were the spaces reserved for department heads and managers. The offices typically have suspended ceilings, updated fluorescent light fixtures, built-in cabinetry, and richer wall finishes.

The least altered offices in the central and west sections of the building display perforated acoustical tile ceilings, louvered "Slimline" fluorescent ceiling fixtures, painted walls with reeded chair rails, and two panel wooden doors with louvered lower panels. The configuration and finish treatments of the many laboratories of Building 12 were regularly altered throughout the functional life of the building in response to changing project requirements. Most laboratory spaces currently display suspended acoustical tile ceilings with flush mounted fluorescent lighting and carpeted or tile floors. Conference rooms and support spaces were also routinely updated. The utilitarian shop areas tended not to change and typically have unfinished ceilings with open bottomed, industrial-type fluorescent ceiling fixtures, concrete floors, and painted walls.

The corridors of Building 12 generally retain the perforated acoustical tile ceilings and brown and beige painted wall finish as originally specified. The flush mounted incandescent light fixtures have been replaced with fluorescents. Original asphalt tile floor finish has been updated throughout the building, except for several stairwells and service spaces.

A small lobby is indicated in the original plans adjacent to the main (east) entrance. It was apparently never built or quickly removed, since by 1955 only a narrow foyer existed, which was later updated with wood wall panels and pendant light fixtures. A lobby was added near the center of the north elevation in 1989.

Designed specifically to house the rapidly expanding radar section of what was then known as the Research and Development Laboratories, Building 12 was first proposed in the summer of 1950. A structure approximately one quarter of its completed size was initially called for (*Hughesnews* 1950h:1). Plans for Building G, or the "Radar Building" were soon updated by architect Gogerty, making it equal in length to Building 15 immediately to the south (*Hughesnews* 1950j:1). The two story building was to contain offices, laboratories and shops, and allow for the consolidation of radar engineering and development activities previously scattered between Buildings 5, 6, and 15.

Developed at a time when important decisions were being made about continued expansion at the Culver City plant, Howard Hughes took a particular interest in the design of Building 12. As always, economy was paramount to Hughes. He was also extremely concerned about the proximity of the proposed building to the huge, all wood Cargo Building complex directly south, and its inherent vulnerability to fire. Hughes specified that Building 12 be positioned far enough away from Building 15 to receive the lowest possible fire insurance rating, while not being placed closer to the runway than the north face of Building 5 to the east - thereby necessitating a long, linear plan. He was also adamant that the building's design be based on the most efficient fire protection system, rather than adding one as an afterthought. Windowless, solid concrete walls were to be used on the south and east wall for cost saving and fire protection reasons. He later approved a solid, metal clad seat wall. The windows on the north and west were to be kept flush with the walls and non-openable because of the deluge system. Hughes also made all final decisions for the internal layout of Building 12 (Hopper 1950a:1-6, 1950b:1).

Construction on Building 12 started in October 1950, with the Del Webb Construction Company of Long Beach as the primary contractor. Under pressure from the Hughes management to make the structure habitable as quickly as possible, the eastern quarter of the building was ready for move-in by February 1951. The remainder of Building 12 was completed by April (*Hughesnews* 1951c:3; Zimmer 1951:1). Beyond radar, many other elements of the Research and Development Laboratories were housed in the massive building when it was completed in April, 1951, including the entire Electron Tube laboratory, an important area of research in the early 1950s, the Field Engineering department, responsible for equipment testing and trouble-shooting, and sections of the R and D Fabrication department. The Microwave Laboratory researched microwave use in missile guidance and fire control system there. Also, the Advanced Electronic Techniques department was based in Building 12, working with semi-conductors, automatic data processing, communications systems, sub-miniaturization projects, and an airborne digital computer for navigation and weapons fire control. Production design and systems engineering also occurred in Building 12. The large shop spaces on the ground floor were frequently used for the manufacture of prototypes and experimental models, and for low-rate pilot production lines, which offered the opportunity to pinpoint and resolve design and fabrication problems prior to systems going into full scale production (Klass 1953; *Hughesnews* 1951c:3).

Dr. Simon Ramo and Dr. Dean Wooldridge, top scientists recruited by Hughes in the late 1940s who went on to head the guided missile department, and the radar department respectively, had their offices in the northeast corner of Building 12. Ramo and Wooldridge left Hughes in 1953 to form TRW.

Research conducted in Building 12 between 1951 and 1953 resulted in the development of both ground and aircraft based radar systems and fire control systems, which allowed guns, rockets, or missiles to lock on to targets and fire automatically. These were the most sophisticated systems being produced and were carried on all first line interceptor aircraft. The germanium diode, forerunner of modern semiconductors, was also developed in Building 12 during this period, giving Hughes an opening into the commercial electronics market (HAC c.1985).

During the early 1960s, the Hughes Aircraft Company entered the realm of space technology. Building 12 housed development of the Syncom communications satellite; the first geosynchronously orbiting communications satellite ever produced, it revolutionized the telecommunications industry and brought Hughes to preeminence in the budding field. The Surveyor unmanned lunar probes were also developed in Building 12 between 1961 and 1969. They were fabricated in the large precision assembly shop at the west end of the building.

Buildings 14-15-16 -- Cargo Building Complex

Contiguous structures built as a unit to house the fabrication and assembly of the legendary Spruce Goose, Buildings 14, 15, and 16, were often collectively referred to as the Cargo Building during the early years of the plant. With a footprint of 183,000 square feet, Building 15 is one of the largest wood frame buildings in the world. The three structures combined cover an area approximately 240,000 square feet. The Kaiser-Hughes Flying Boat contract with the Defense Plant Corporation stipulated that the plane and buildings erected to complete the project be of wood construction. Architect H.L. Gogerty had earlier experimented with the use of arch framing for industrial buildings at the Hughes plant to achieve the open free span work areas (Building 5). In the design of the Cargo Building complex he returned to the use of arch construction, this time executed with wood in accordance with the government contract. The building's program required him to work at a monumental scale never before possible. During the late 1930s, the field of wood lamination was revolutionized by the development of synthetic resinous glues far stronger and more durable than the natural resins previously used, which allowed for the practical and creative use of laminated wood members in construction. The work by Hughes with synthetic resins was at the forefront of lamination technology, and enabled laminated arches of the scale needed for the Cargo Building to be conceived (May 1951:32-33).

The giant laminated wooden arch sections, often incorrectly identified as made of the Duramold material, were fabricated in two canvas covered temporary buildings known as the "tents" located at the west end of the construction site. Summerbell Roof Structures was the contractor responsible for their manufacture (Lee 1956:2). Lengths of fir lumber were steamed or soaked and chemically treated in large vats. A synthetic resin similar to the glue used in Flying Boat construction was then applied to the pieces, which were placed in steel frames specially created for manufacture of the arches. Using a system of hydraulic jacks, the elements were gradually bent into their finished form, reinforced with bolts, and allowed to cure (J. Stubbs, personal communication 1995).

Delayed by inclement weather, construction of the Cargo Building complex began in March 1943. A ballistics pit which existed on the site was removed and the huge quantities of lumber required for buildings soon covered the area. As construction accelerated, "trusses seemed almost to grow in place over night," and the complex was rushed to completion by August 1943 (*Hughesnews* 1946b:3). *Hughesnews*, the company newspaper which diligently chronicled construction of the earlier plant buildings, was silent regarding the huge new addition, presumably for reasons of wartime security. Photos taken during construction depict barrage balloons floating above the surrounding celery fields (CA-174-J-36). When completed, the buildings' windows were blacked out and remained covered until the end of the war.

Building 14 - Hull Pattern Building

Contiguous with the north side of Building 15 and nearly as long, this narrow, single story wood frame structure is the only element of the Building 14-15-16 complex which does not employ laminated wooden arches as its primary structural members. A post and beam structure 540 ft long by 50 wide, substantial 10 x 12 inch members carry bowstring trusses which support the vaulted roof and provide clear span work spaces below. At 42 ft in height, it is considerably lower than Building 15, and the roofline is broken at midpoint by a single flat-roofed bay.

Originally an open, shed-like building, the side and end walls of Building 14 were framed and sided in 1947. It is presently clad with vertical corrugated aluminum panels and is windowless but for three recently added narrow, wood framed, single fixed light windows placed high in the wall of the east half of the north elevation. Three small, louvered openings penetrate the upper wall of the west half of the elevation. Sliding freight doors - three in the east half of the north elevation and one in the east elevation - allow movement of equipment and materials into and out of the building. There is evidence of a fifth, infilled freight door toward the west end of the long side. A single double door personnel entrance is located in the east elevation; circulation of employees into the building was primarily from Building 15. A small, open, one story, steel frame shed consisting of I-beam posts supporting a corrugated metal roof is attached near the east end of the north elevation and currently stands empty. Two low, corrugated metal panel clad, mechanical structures occur along the west half of the same elevation.

A series of sliding freight doors and solid, two panel personnel doors allow communication between Buildings 14 and 15. A wood frame mezzanine level containing a laboratory/office and bathrooms was constructed at the west end of the structure in the early 1960s, and remains relatively unaltered. An additional open mezzanine near the center of the building was added in the 1970s and functioned as a tool crib associated with laser milling equipment (J. Tweten, personal communication 1995). The remainder of Building 14 is an open, full height work area with minor encroachments from recently enclosed office spaces and a bisecting central partition. The floors are concrete. An open ceiling reveals the diagonal tongue and groove roof deck and trusses, from which open bottom fluorescent industrial fixtures are suspended. The west mezzanine has an acoustical tile ceiling with louvered fluorescent fixtures and painted wall finish. Walls of the production/shop areas are unfinished, revealing the original horizontal redwood drop siding of the exterior of Building 15 on the south wall, and diagonal tongue and groove board cladding of the exterior walls. These undifferentiated spaces remain largely unaltered.

Constructed contemporaneously with the giant Cargo Building and Building 16, Building 14 was completed by August, 1943 (*Hughesnews* 1981a:4). Designed specifically to house the two enormous wood and plaster patterns used to form the Duramold hull of the Flying Boat, the building (variously designated Building D-1 or the Hull Pattern Building) originally consisted of two independent, open sided structures - one for each pattern - separated by a single bay width at the center. The patterns were stored in the building for the duration of the project (*Hughesnews* 1946:3) and are visible in early photographs (CA-174-J-40).

In 1947, with the hull patterns removed, Building 14 was enclosed and the two sections joined. It continued to function primarily as a storage structure. Following World War II and through the end of the period of significance, the Aeronautical Division of the Hughes Tool Company, which was a separate entity from the Hughes Aircraft Company and whose activities were concentrated in the Building 14-15-16 complex, became involved in helicopter manufacture and also continued to produce armaments. Stores of sheet metal and other materials which supplied the primary production areas in Building 15 were housed there, in addition to tools and equipment (*Hughesnews* 1950j:1).

After 1953 planing and tooling machinery employed in the production of 20 mm guns was installed in the extreme east end of Building 14. A mezzanine was added at the west end in the early 1960s to provide office and laboratory space for engineers of the Specialty Metals Department who were experimenting with superhard alloys. The central mezzanine, added in the 1970s, contained a tool crib associated with laser milling machinery operating in the east half of the building. The area immediately west of the mezzanine was occupied by sheet metal presses producing helicopter body panels during that era. The structure continued to house stores and manufacturing functions through the purchase of the facility by McDonnell Douglas in 1984 (J. Tweten, personal communication 1995).

Building 15 - Cargo Building

Known to posterity as the structure where the famed "Spruce Goose" was built, the monumental Building 15 is constructed entirely of wood and consists of two parallel gabled hangar bays, designated north and south, which are joined to form a single rectangular building. With an overall length of 742 ft, a width of 248 ft, and a height of 73 ft, or six stories at the peaks of its double gabled roof, it is one of the largest all-wood structures ever built (*Hughesnews* 1981a:4; Hugh 1987:7). The primary structural components consist of two rows of 38 enormous laminated rigid wooden arches placed side by side to form identical, contiguous clear span bays. Fabricated in two pieces, the shallow pointed arches taper at the peak, creating gently pitched gables. A three story freestanding structure framed with substantial sawn timbers straddles the centerline of the building where the arches meet, physically separating the two mammoth hangar bays.

Also known as the Cargo Plane Assembly Building, or simply the Cargo Building, two long, rectangular ancillary structures, Building 14 and Building 16, are attached to the structure's north and south sides. The south elevation is characterized by huge three-part window bays, each composed of 18, six light, fixed wood sash units measuring 6 x 8 ft. The 16 ft high window bays are half of their original height, the lower portions having been infilled in 1971 when the building was sided. There are nine window groups along the length of the south elevation, now temporarily covered. The north elevation had similar fenestration, although the bays were not as high owing to the height of Building 14. The windows were covered in 1971 coincident with the application of 4 x 12 ft vertical corrugated aluminum panels over the original horizontal drop "rustic" siding. The roof was also covered with corrugated aluminum at that time. The structure received its present muted blue paint job at the time of McDonnell Douglas' acquisition in 1985. All elements of Building 15's construction were wood, including the massive overhanging eave troughs and the equally robust downspouts descending from the gable valley at the center of the east and west elevations. These are now metal clad.

The east elevation is dominated by the immense hangar door through which large aircraft were moved. With six, corrugated metal clad, sliding panels the door spans nearly the entire south bay and is sheltered by a steeply sloped pent roof. A smaller sliding door and a canopy covered roll-up door occur in the north bay end wall. The west elevation includes two metal roll-up doors in the south bay and a single roll-up door in the north bay. The east end wall of the south bay originally had two sliding doors, and a third roll-up door at the south end corresponding to the spar room. During the Flying Boat project, the west elevation had two sliding doors in each bay and was finished with 8 x 20 ft panels clad with diagonally laid redwood siding which were removable to allow passage of the fuselage and wing sub-assembly of the HK-1. In the south bay, an enlarged hangar door still exists, although it is fixed and covered with corrugated siding. Massive cooling towers which supply chilled water to much of the plant were built at the east end of the north elevation, adjacent to Building 14, in 1950.

The immense wooden arches march down the length of the cavernous interiors of the hangar bays placed 20 ft apart. The perimeter walls and ceiling are generally unfinished. Wall framing members are exposed, as is the diagonally applied redwood tongue and groove board exterior sheathing, employed to increase the building's lateral stability. Diagonal sheathing was used as an interior finish as well on the wall areas separating the huge window bays and on the exterior of the upper floors of the central bay.

As initially constructed, the center bay was two stories in height with a storage loft above. In 1950 a third floor containing office space was added to the east half of the structure. Much of the ground floor was originally unenclosed work area. Exterior walls of specialty shops, offices and stock rooms in the middle portion of the bay were clad with V-groove shiplap siding. The sided walls remain, although the open shop areas were enclosed with plywood panels as part of 1950 renovations. Numerous alterations to room configurations have occurred. The first mezzanine level, reached by four internal stairways, has likewise undergone extensive remodeling. Interior partitions have been removed to create a continuous open office space which extends nearly the full length of the building, regularly interrupted along the central axis by enclosed paired arch legs. Several modest enclosures contain restrooms, storage, and offices. Changes further include carpeted floors, plywood paneling wall finish, suspended acoustical tile ceiling, and replacement of wood sliding sash windows with fixed aluminum framed sash. A series of six external emergency stairs added along the north wall now provide egress from the mezzanine levels to the north bay and, in compliance with modern building codes, a wheelchair elevator was added at the east end. A substantial steel frame platform for helicopter parts storage was appended to the north wall in 1979. Bath and coat rooms located at the west end of the first mezzanine level remain largely unaltered, with original fixtures and wall finishes.

The second mezzanine level, a continuous open laboratory space, is more intact and displays hardwood maple floors, Cellotex perforated acoustical tile ceiling, and open bottom fluorescent ceiling fixtures. The west half of the level remains open storage loft and work space. A loft area above the third level houses elements of the massive mechanical and air handling systems. Mechanical equipment also occupies portions of the west loft area, along with several frame platforms and a small office enclosure. Catwalks slung from rafters above run the length of the building.

The "Spar Room," a narrow, one story, frame structure, abutting the south wall at the southeast corner of the hangar building during the HK-1 era, extended roughly a quarter of the length of the building. The structure was removed and replaced with offices on the same location. Several smaller one and two story structures also currently adjoin the south wall, some associated with Hughes and McDonnell Douglas production, and others related to recent movie production activity. A freestanding one story enclosure has also been built at the west end of the north bay. Floor space of the immense assembly bays, 2 ½ football fields in length, is otherwise completely open. The floors of the Cargo Building are six inch thick concrete slab-on-grade. Flush steel tracks running along the north and south sides of each assembly bay are reminders of huge steel travelling cranes which rose almost to the eave level and were capable of lifting and transporting large aircraft components like the wing assemblies of the Flying Boat or pieces of machinery (CA-174-J-41). The hoists were removed during renovations in 1971. The tracks are paralleled by covered utility trenches.

Circulation between Building 15 and the adjoining Building 14 is provided by a series of personnel doors and sliding track doors. Building 16 is likewise connected to Building 15 by personnel doors, a sliding door, and a full bay, 18 ft overhead door located near the center of the structure.

From the deck of the open mezzanine area the union of the enormous pairs of arches is clearly visible, as is the construction of the roof. The legs of the arches do not actually touch at the point of articulation, but are separated by a vertical spacer (CA-174-J-25). Rather than allow the roofline to follow the curve of the arches, a squared eaveline is framed by extending the sloped upper portion of each arch beyond the rounded shoulder to meet a vertical member rising from the springpoint forming an open spandrel. This creates greater ceiling height at the outer edges of the bays and allows for taller window groups in the north and south walls. It also creates a typical gabled roofline. Along the centerline, massive sawn beams tie the pairs of arches together at the first and second floor levels, and at the springline. A series of massive diagonal braces spans between arch pairs along the centerline, creating structural stability. The building's rigidity is further enhanced by the structure of the central bay itself. Tiers of horizontal 3 x 12 and 6 x 12 in girt beams tie the arches together and are the primary framing elements of the outer walls. They are connected to the arches with cleats and diagonal struts. The roof is framed with 4 x 12 in purlins placed 5 ft on center. Each laminated arch was fabricated in two halves; the sections are joined at the peak using bolted steel gusset plates. The arches are supported on concrete pilings and are attached to the piling caps with bolted steel angles. Lighting of the assembly bays is accomplished with high intensity incandescent fixtures suspended from the roof beams.

Building 15 was specifically designed by architect Gogerty to house the assembly of the Kaiser-Hughes Flying Boat. The incredible engineering accomplishments involved in the production of the world's largest airplane have overshadowed comparable feats involved in the design and construction of the building in which it took shape. The gigantic laminated wood arches were the first of their kind, and their production and erection tested the limits of equipment and men. Two workers fell to their deaths from the building's heights during construction (*Hughesnews* 1946b:3).

With the completion of the Building 15 complex, work on fabrication of Flying Boat components, which had already commenced in Buildings 5 and 6, immediately transferred to the new structure. Initially, the patterns and dies for the primary assemblies were created in the assembly bays, and Building 15 housed the huge quantities of raw materials - predominantly birch lumber, plus smaller quantities of spruce, maple, balsa and poplar - required for the Cargo Plane. Construction of the HK-1, or the H-4 as it was later known, was divided into two major sub-assemblies. The massive fuselage, measuring 218 ft long by 30 ft high, was fabricated in the north bay, while work on the wing section, with a span of 320 ft, proceeded in the south bay. The wing floats were also fashioned in the south bay, and the XF-11 prototype was assembled at the east end of the bay beginning in 1944. The Flying Boat's tail section, including the horizontal stabilizer which alone was more than 110 ft in length, and the 50 ft high vertical stabilizer, were assembled at the east end of the north bay. Wing spars fabricated in the spar room at the southeast corner of the south bay contained some of the largest pieces of lumber used in the plane, with unbroken spans of approximately 90 ft (Firth and Worth 1945:1-14; J. Stubbs, personal communication 1995).

Following their fabrication in the adjacent Building 16, Duramold-formed component parts were transferred to the large bays of Building 15 where they were finished and prepared for fashioning into the plane's diverse assemblies. Components manufactured with traditional woodworking techniques were also made in the hangar bays, and numerous rows of benches were laid out to hold the carefully organized and labeled pieces in various stages of completion.

Wood and other construction materials were readily accessible from stock storage rooms in the east end of the center bay's ground floor. The engine shop, along with the electrical and radio departments, foremen's offices, parts storage rooms, tool cribs, and other support spaces were located in the central section of the bay. Open shop spaces for plumbing and hydraulic work, welding, metal fitting and machining, and woodworking were situated in the western end of the bay. The mezzanine level was dominated by large unpartitioned rooms for engineering and tool design, and patterns for the Flying Boat's components were typically laid out on the open hardwood floors of this area. The main model making shop for the project was at the west end of the mezzanine, and offices for managers, secretaries, inspectors, expediters and others were located in the central section as were the mail room, conference room, and production control room. Restrooms and coat rooms to serve the hundreds who worked in the building were situated in the center, and at either end of the mezzanine. The east end was open and contained mechanical equipment.

After substantial delays, H-4 "Hercules" as the controversial flying boat was officially known, was ready for its 28 mile overland journey to the final assembly location on Terminal Island in Long Beach Harbor in June 1946. The wall panels of the west end of the Cargo Building were removed, and the hull, wings, and other large sections of the behemoth aircraft rolled away on a string of flatbed trucks.

Toward the end of the project, with most of the Flying Boat production work accomplished, space for other projects was available in Building 15, and a consolidation of Hughes' other varied contracts was undertaken. Armament manufacturing moved into the building from the Romaine St. location which had been abandoned.

With the end of the World War II, the Air Corps contract for the production of 100 twin-engine XF-11 photo reconnaissance planes was cancelled, and other government projects likewise came to a close or were cancelled. The Hughes labor force fell dramatically, and records indicate that at one point production activity in Building 15 was at only 10 percent of capacity (HAC 1948:21). For a time, the north bay housed only a promotional blimp for the Jane Russell film "The Outlaw" and miscellaneous equipment (CA-174-J-45). Like many other companies involved in military work during the war, Hughes Aircraft scrambled to find peace-time products to sustain continued operation. Various domestic and business applications for Duramold were developed, although none proved commercially successful. Modification of military aircraft for civilian use was also tried. Hughes purchased a fleet of surplus B-25 bombers which were customized in Building 15's south bay for use as executive passenger planes (Pettit 1958:13).

Research at Hughes in the field of guided missiles began in the center bay of Building 15 in 1945 with the development of the Tiamat I, "a grotesque potbellied gadget 11 ft long named after a Babylonian deity," and later the Tiamat III. Both models performed poorly in flight tests and were not accepted by the Air Force, but their development established the infrastructure for a department which eventually produced the highly successful Falcon, the nation's first air-to-air guided missile (Dwiggins 1972:57).

A significant development in Hughes' post-war evolution began with the purchase of 2000 surplus aircraft radar sets in early 1947. Conscious of a need in commercial aviation for a device to alert aircraft of a danger of collision, engineers working in the Electronics Shop in the center bay of Building 15 modified the radar equipment to create the Terrain Clearance Warning Indicator, a small unit which fit into the belly of a passenger plane and warned of mountains or other obstacles in the flight path (Rubel 1955: 3). The indicator was immediately successful, and the previously insignificant Radio Department by April 1947 had grown into the Electronics Department. In 1948 Hughes landed its first major government electronics contract for High Speed Indicating Systems for the Atomic Energy Commission. Production of these devices also occurred in the center bay of Building 15, and their success soon generated the large scale radar and fire control system contracts which became the lifeblood of Hughes Aircraft (Rubel 1955:5).

The new electronics work necessitated a plant expansion program that between 1949 and 1951 more than doubled the available laboratory, office, and manufacturing space. Building 15 was not viewed as well adapted to electronics production and was retained by the Hughes Tool Company, Aeronautical Division, for manufacture of armaments (ammunition feed chutes and boosters, gun pods) and aircraft work (Figure 6). However, by early 1950 the spatial demands of the Department of Electronics and Guided Missiles were such that plans were made to remodel the center structure to office, laboratory, and precision shop use and to add a second mezzanine level for offices and laboratories. The renovations, completed in February 1950, necessitated the relocation of Stores facilities from the center row to the north bay of Building 15 and Building 14 (*Hughesnews* 1950a:1). During the Korean War, the government established a NORAD Defense Command Office for electronics surveillance on the third level, an installation that was completely restricted and not common knowledge even within the plant. Security within the building was extremely tight during this period, and armed guards kept watch on assembly floor activity from mezzanine level catwalks (Russell 1993; J. Tweten, personal communication 1995).

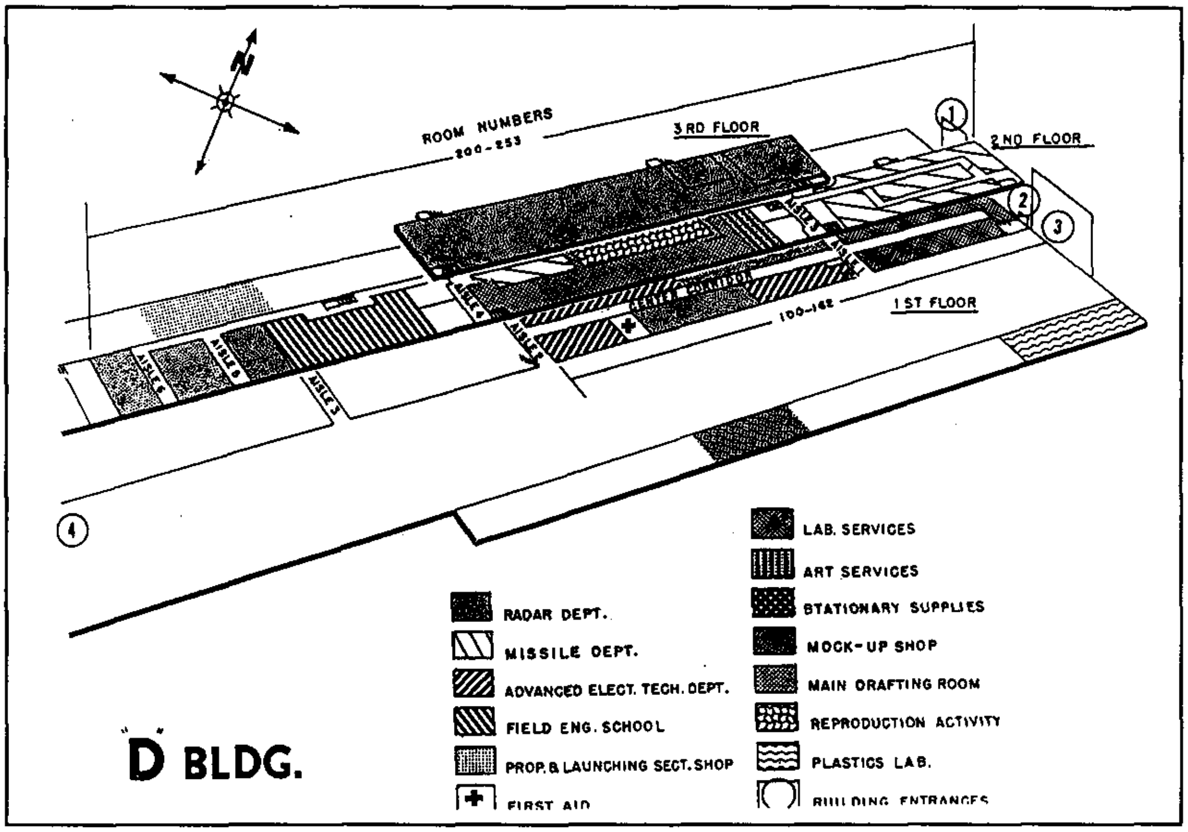

Figure 6. Diagram of Functional Areas, Building 15 Center Bay.
(HAC Research and Development Administrative Staff and Service Activities c.1950)

The search for new ideas in aircraft development brought Howard Hughes, in January 1949, to purchase the design rights for an experimental helicopter contracted by the Air Force to the Kellett Aircraft Company. Developed and fabricated in the south bay of Building 15, the innovative design evolved into the XH-17 "Flying Crane." Powered by two turbo-jet engines, with rotor blades 125 ft long and capable of transporting a 30,000 lb load, the huge XH-17 was the latest in Hughes' string of "fastest" and "largest" accomplishments. Successfully test flown in October 1952, it marked a new direction in the company's aircraft production.

Development of other helicopter models ensued, and Hughes Aircraft Company began to take on the aspect of what it had always expected to be - an airframe manufacturer. First involved in heavy helicopter design, the Model 269 Osage, forerunner of the Model 300 series, was produced in the mid-1950s. An experimental model without a transmission or tail rotor, the XV-9A "Hot Cycle," was also developed, followed by the OH-6A Cayuse, the primary Army observation helicopter for the Vietnam War, the Model 500 series, and the YH-64A Apache. Assembly work was concentrated initially in the west end of the south bay and steadily expanded as helicopter orders increased. Helicopter production reached its peak in 1968, with the south bay almost wholly devoted to their manufacture, along with sections of the north bay and Buildings 14 and 16. About 75 percent of the work was devoted to helicopters and the remaining 25 percent to helicopter armaments (J. Tweten, personal communication 1995).

Utilization of space on Building 15's huge assembly floors was on an "as needed" basis, and there were often several projects under production in the same general area. For instance, in the early 1950s, the north bay was largely devoted to the manufacture of armaments. In the western portion, flexible ammunition feed chutes for the Mark VII and Mark VIII gun programs were produced. There were also injection mold machines for the production of fiberglass tail fins for Falcon missiles, in addition to miscellaneous helicopter parts manufacture. An Experimental Shop developing a 3-D camera for the film industry was also sited there. Similarly, the south bay, in addition to housing helicopter production, was also the site of radar antenna and F-100 nose cone assembly during the late 1950s, along with various other aircraft work (J. Tweten, J. Stubbs, personal communications 1995).

The giant overhead gantry cranes in both bays were removed in the 1970s (Altschul et al. 1991:107) During the peak years, more than 6000 commercial and military helicopters passed through the hangar doors of Building 15. Hughes Helicopters, Inc. was organized as an independent division in 1969 and helicopter production continued as an important aspect of Hughes' operations well after the end of the war (Altschul et al. 1991:109). Hughes Helicopters was sold to McDonnell Douglas Corporation in January 1984, and for a short time Culver City was the headquarters of their helicopter division. Production activity in Building 15 was greatly reduced in 1985 when McDonnell Douglas Helicopters moved to new facilities in Mesa, Arizona. Production of components continued on a limited basis through 1994 (D. Richards, personal communication 1995).

Building 16 - Duramold Building

Significant as the building in which the wood for the Flying Boat was processed, Building 16 is a long rectangular structure, 65 feet wide by 441 feet long, contiguous with Building 15, with which it shares its north wall. The structure is composed of two parts: the "Boiler Room" is a tall, rectangular, reinforced concrete structure with a flat roof at the east end of the building. The western section, referred to as the "Duramold Room" on the original plans, has a low-pitched gabled roof that drops in height at the west end. It is framed with shaped laminated wood arches - smaller versions of those used in the Cargo Building. The Duramold Room is extended along the south side of the Boiler Room with a conventionally framed, shed roof section aligned with the south wall of the gabled portion. A narrow, steel framed, open shed added in 1966 spans the south elevation.

Designed of poured-in-place reinforced concrete to protect the otherwise all wood Building 14-15-16 complex from the inherent danger of fire and explosion, the boiler room is a 40 x 90 ft structure with exposed concrete interior and exterior finish. Paired, 15 pane, fixed steel sash windows inset high in the east and south walls provide light to the 38 ft high clear span space within. The structure presently contains three large, steam generating boilers, two of which are original to the building, with their extensive piping, service catwalks, feed water pumps, control panels, and a small office. Large diameter steam pipes rise from the tops of the boilers and tie into the 14 in main header pipe suspended from the roof, which branches to supply steam to the Duramold room and other areas of the plant. The boilers themselves are supported by heavy steel frames with a substantial brick housing around the burners. Rectangular brick panels in the south wall opposite each boiler could be knocked out to allow removal and maintenance of the long boiler tube units. The east wall similarly includes a large brick panel with an inset freight door that enables entire boiler units to be moved. The east wall is further articulated by a large screened panel and a hooded personnel door. A double (inner and outer), steel clad, blast proof sliding door in the west wall provides the only connection between the boiler room and the Duramold room.

The gabled portion of Building 16 is windowless but for a single four-over-four double-hung sash window near the east end of the south wall. The portions of the south elevation sheltered by the shed addition retain the original "rustic" redwood drop siding, which has elsewhere been covered with corrugated aluminum panels. The roof is also clad with corrugated panels, and displays oversized, overhanging eave troughs. Rows of turbine-type ventilators enliven the roofline. Access for personnel and materials is provided by four regularly spaced double doors and two sliding freight doors along the south wall, a sliding freight door in the east elevation, and personnel doors in the west elevation.

The 18 shaped wooden arches which are the primary structural members of the Duramold room are paired with the larger arches of the south bay of the Cargo Building, creating 20 ft wide free span structural bays. A partition in the west half of the building bisects the previously open production and shop space, which is further encroached upon by a large framed room near the center, added during the time of McDonnell Douglas' occupation. A steel framed mechanical loft occupies the southeast corner, and room partitions occur at the west end for an office and stainless steel lined steam table room. The shed roof bay south of the boiler room has been partitioned as well.

Diagonal tongue and groove board siding is used as the interior wall finish; the finish of the north wall is actually the exterior sheathing of the adjoining building. As in Building 15, the wall and roof planes are extended beyond the curvature of the arches to form the squared eaveline. Horizontal girt beams tie the arches together along the north and south walls, attached at the springpoint with cleats and diagonal braces. The roof is framed with 4 x 12 in purlins placed 4.5 ft on center. The two halves of each arch are joined at the peak with steel gusset plates, and they are attached to the piling caps on which they rest with bolted steel angles.

Rectangular patches in the concrete floor immediately west of the boiler room represent the former locations of two large cylindrical steel retorts used to heat and pressure treat wood in the Duramold process. Steel tracks made of 3/16 in steel plate extend westward from the ends of the concrete patches for a distance approximately equal to the length of the retorts. The gabled roof is higher over the retort area and immediately west of the track terminus, it drops five feet. At two locations in the western (lower) portion of the building, rectangular enclosures, 9 x 22 ft, for fan and filter equipment are suspended from the roof structure. The enclosures are finished with diagonal sheathing and have louvered panels at either end. Along the north wall at the center of the Duramold room, a 16 x 60 ft structure containing men's and women's toilet and coat rooms is similarly slung from the roof structure. It is accessed by stairs along the north wall. The rooms retain their original shiplap board wall finish, stall dividers, and fixtures. Nonstructural partitions below the bathrooms enclose office spaces. Lighting in the Duramold room is provided by continuous rows of suspended, open bottom, fluorescent fixtures which replace the original incandescent fixtures.

Begun in March 1943, Building 16, or the Duramold Building, was the first element of the Cargo Building complex to be completed. Construction began with the erection of the reinforced concrete boiler room at the east end of the structure. Truly a building that built itself, the first use of the four boiler units was to provide steam for shaping and laminating the wood used in the immense wooden arches fundamental to the design. The lack of exterior sheathing on the south wall of Building 15 where it abuts the boiler house attests to the concrete structure's earlier completion (J. Stubbs, personal communication 1995).

Building 16 was designed by project architect Gogerty as an ancillary structure to the Cargo Plane Assembly Building (Building 15) to house the manufacture of component parts for the Flying Boat using the Duramold process. Manufacturing of Duramold-formed components had begun in Building 5, and moved to Building 16 upon its completion. The Duramold process of wood lamination involved steaming and forming thin sheets of specially cut veneer into the desired shape, gluing multiple layers together using specially developed synthetic resins, and physically and chemically bonding the constituents by subjecting them to heat and pressure. Processing required a variety of specialized equipment.

Critical shortages of materials and equipment during the war years, coupled with the low priority of the project, created serious obstacles for Hughes in securing the four massive boilers needed to produce the steam required for the Duramold process. Two identical new Sterling boilers were obtained from the Hedges, Walsh, Weidner Division of the Combustion Engineering Company in Chattanooga, Tennessee, each capable of producing 300 psi of pressure. Unable to obtain additional new equipment, Hughes undertook a nationwide search for used boilers of the necessary size. After considerable delays, a massive three stage boiler nearly 30 feet high was acquired from a mid-western lumber company; a mining company supplied the fourth boiler. The four boilers, connected in series, supplied steam to the retorts and steam tables in the Duramold Room, along with providing the rest of the plant with steam for industrial processes and heating. Bunker C, a thick, crude-type fuel stored in buried tanks east of the building, was first used to fuel the boilers; this was replaced with natural gas in the 1950s. The Boiler Room also contained steam turbine fed water pumps and vacuum pumps used to pressurize the retorts. The identical No. 1 and 2 boilers remain and are still functional, supplying steam for heating purposes as needed. The easternmost No. 4 boiler was replaced with a modern unit in 1975, and the three stage No. 3 boiler was removed in 1984 (D. Richards, personal communication 1995).

Heat and pressure - two essential elements of the Duramold process - were applied to the laminated wood components and assemblies of the Flying Boat in a pair of cylindrical steel retorts or curing chambers located adjacent to the boiler room. The smaller of the two retorts (weighing 50,000 lb) was moved to Building 16 from Building 5, where it had been in use since the plant opened in 1941. A Los Angeles firm, Lacy Manufacturing Company, supplied the larger retort, which was 15 ft in diameter and 57 ft long. The massive chambers, capable of sustaining required temperatures of 300 degrees Fahrenheit and pressures of up to 250 psi, were partially sunken into the concrete floor and had full diameter, semispherical steel doors at the western end which were raised with the aid of a pivoted counterweight. Wood pieces were placed on heavy steel dollies which moved along tracks into the retorts. Vacuum pumps could be used to create negative pressure, or steam forced into the chamber for positive pressure (D. Richards, personal communication 1995).

Original plans depict a veneer storage room extending across most of the west wall of the Duramold Room, accessed directly from the exterior through a sliding door. This design was apparently abandoned in favor of a stainless steel lined refrigerated veneer storage room in the southwest corner in which sheets of birch and spruce veneer awaiting use were maintained at optimal temperature and humidity. The room later contained a steam table used in helicopter manufacturing by Hughes and McDonnell Douglas. At the northwest corner of the building was the Glue Room, where the three types of resins used in the fabrication of the plane were stored.

The largest pieces of woodworking equipment stood along the perimeter walls in the west half of the building. Automatic clippers, veneer jointers, a scarfer, and other specialized machinery used in cutting and joining pieces were adjacent to the veneer storage room, with three Deihl edge gluers and a 100 inch glue spreader to the east. Piping overhead and along the walls carried steam from the boiler room to a hot press and steam tables in the central portion of the building. Space around the major equipment was filled with benches and dollies where pieces were cut and fitted to extremely close tolerances, glued, and formed into gunite jigs. The eastern portion of the Duramold room was largely open space where components could be laid out, assembled and prepared for curing.

Expandable rubber bladders were placed within the Duramold jigs to apply uniform pressure to the complex curved shapes of the plane's assemblies during thermo-curing in the large retorts. In the case of the wing and fuselage assemblies, the jig assemblies and bladders required were immense. Smaller components were cured in rubberized bags. Following curing, completed components were moved into Building 15 through overhead doors to await sanding, final finishing, and assembly (J. Stubbs, personal communication 1995).

Processing of components for the earlier, all wood, XF-11 prototypes also occurred in Building 16. With the close of World War II and the completion of the Flying Boat, to which the Cargo Building complex was primarily dedicated for nearly three years, HAC management rushed to develop products for peacetime manufacture that would best utilize their resources and experience in wood construction. Among the items chosen for production were chairs, wood cabinets for television sets and hi-fis, garage doors, and pinball machines. Some managers believed Hughes should become a boat builder, and a 7 ½ ft dinghy was developed. Precision engineered and produced with the Duramold process, these items were, no doubt, some of the sturdiest wood products ever manufactured. The venture did not prove profitable, however, and the line was soon dropped (Pettit 1958:13; J. Stubbs, personal communication 1995).

This venture marked the end of Hughes' involvement with wood manufacture and the Duramold process, although Building 16 continued to serve as the plant Wood Shop, producing jigs, patterns, and plant furnishings. No longer needed, the smaller retort was removed in 1950 and the remaining Duramold equipment was consolidated at the east end of the building (*Hughesnews* 1950i:2). The larger retort saw limited use in the production of helicopter body panels during the 1950s and 1960s, and was eventually removed around 1984 (J. Stubbs, personal communication 1995). Building 16 was used for helicopter component manufacture beginning with the XH-17 project in 1949-1953 and it was among the last production areas in operation when McDonnell Douglas Corporation abandoned the Culver City facility in 1994. Helicopter rotor blades were being produced in the building at that time (Russell 1993).

Building 17 - Warehouse/Stores Building

Built in 1950 as part of a major plant expansion project at Hughes Aircraft, Building 17 is a long, rectangular, high bay one story structure, 442 ft long by 84 ft wide, with a mezzanine level at the east end. A spare, utilitarian design, the unadorned steel framed structure is sheltered by a very slightly pitched gabled roof supported by 10 ft deep trusses placed 20 ft on center which allow for an open, free span interior space. It is clad with the Robertson U.K. 18-18 vertical smooth steel panels typical of the plant buildings constructed during this era. It rests on a poured concrete foundation with columns set on concrete pilings, and has a concrete floor.

Fenestration occurs only at the east end of Building 17, corresponding with first and second floor offices. Bands of steel casement windows extend across the ground floor of the east elevation, interrupted by two personnel entrances and a covered steel external stairway which rises along the center of the facade. The 10 light window units have operable awning-type sash. The upper story displays a mixture of paired and single casement units of two different types. A central entrance is sheltered by the stairway, while a second entrance to the south is covered by a flat canopy with square section steel supports. Both entrances, as well as a third in the upper story, have two panel steel doors with glazed upper panels.

The north elevation faces the Cargo Building complex with a long blank wall, broken by a partially filled in band of lower story casement windows at the east end, identical to those of the end wall. A two panel door accessed by a low concrete stair occurs immediately west of the windows, and a second, double-door entrance covered by a flat canopy is located at the center of the elevation. A small mezzanine level balcony gives access to a trash chute near the east end. The elevation is divided by regularly spaced downspouts.

Somewhat less austere, the building's south face features a long concrete platform, formerly a loading dock, covered by a flat, suspended canopy, along the east half of the elevation. Mechanical equipment currently occupies much of the platform, which is protected by a chain link enclosure. Paired and single casement windows occur in the upper story, east of the platform, above a single door personnel entrance. A flat metal canopy shelters the primary public entrance to Building 17, in the west half of the elevation. The canopy is supported by a metal post at the west end and a stone veneer-clad wall at the east end. The rear wall of the entrance vestibule and low wall concealing a handicap ramp in front of the entrance are also finished with stone veneer. The glass double doors are placed off-center. Large metal roll-up doors occur at the center and west end of the elevation.

A canopied entrance comprises the only feature of the west elevation. The flat metal roof is suspended on diagonal hanger rods augmented with square section metal supports. It shelters a double sliding door and a glazed personnel door.

Offices and support spaces occupy the ground floor and mezzanine level at the east end of Building 17. The offices have recently been renovated and display suspended acoustical ceilings with flush mounted lighting fixtures, painted walls, and asphalt tile floors. Circulation consisted of a central east-west corridor and a cross corridor, with stairs to the upper level located at the north end of the mezzanine bays. From the mezzanine, broad expanses of glazing look out over a large, open work space to the west, presently occupied by a movie model fabrication shop. The steel roof trusses and tongue and groove board deck are exposed above the work area, along with abundant ductwork, mechanical equipment, and a suspended catwalk. Wall treatments include unpainted drywall or original exposed metal panels. Steel perimeter columns are also left exposed, as is diagonal bracing between structural bays. Until its latest occupation, the mezzanine level extended an additional 60 ft to the west and, curiously, cabinetry and other fixtures of former upper floor offices remain attached to the south wall. A frame partition divides the structure into two halves. Immediately west of the partition is additional recently created office space, and another large open bay (currently a sound stage) occupies the entire west end of the building. Floors in the open bays are unfinished concrete and lighting is provided by suspended, open bottom fluorescent fixtures. The original metal shaded suspended incandescent fixtures are still present, but are not functional.

Building 17, or the Warehouse, was proposed in early 1950 to supply much needed storage space for materials, parts, and components - particularly for the rapidly expanding radar and electronics production facilities in nearby Buildings 6 and T. Initially, a design more square in plan was presented by architect H.L. Gogerty, but Howard Hughes, ever involved in the planning of buildings and plant layout, insisted that the structure should be longer and narrower to correspond with the dimensions of Building 16 on the opposite side of Centinela Creek (Hopper 1950a:3).

Construction of Building 17 commenced in June 1950, and it was partially occupied even before it was fully completed at the end of September. Although early designs for the building included an 80 ft wide mezzanine across the east end, it was not constructed until several months after the shell had been completed. The upper story windows and external stairway were added at that time as well. In addition to stores, the offices of the Production Services Department were initially housed in the east end of Building 17. The finished mezzanine provided an additional 6400 sq. ft of open office space in which sections of the Planning and Tool Design Department were installed (*Hughesnews* 1950g:1, 1950j:1, 1951b:1).

Recurring problems with the flooding of the drainage ditch immediately north of Building 17 which often left the Hughes plant completely stranded, provoked construction of a three foot high concrete retaining wall along the north side of the structure in 1951. The wall was removed when the ditch was channelized and covered in 1962 (*Hughesnews* 1981b:3).

As electronics production was gradually transferred from the Culver City plant to other Hughes facilities between 1951 and 1956, production support departments left Building 17 and the demand for materials storage was greatly reduced. In 1956, the ground floor office space at the east end of the building was renovated to create a new plant medical center. The facility housed first aid, an X-ray unit, a testing laboratory, and a physical therapy room. The Personnel Department, previously housed in the so called "travelling employment office" at the corner of Centinela and Jefferson Ave., was consolidated in new offices on the first floor at the same time. Comprised of the Training and Counseling departments, Personnel Insurance, Personnel Records, the Credit Union, and Employee Services, the department was located here until the plant's closure (*Hughesnews* 1956b:1). The Plant Facilities Department was the last group to take up residence in Building 17.

In 1972, the mezzanine was extended 40 ft (two bays) to the west to supply additional office space. Sixty feet was removed from the west end of the mezzanine in 1994, adding additional space to the movie model making shop that currently occupies most of the building's east half.

Building 18 - Fire Station

The Fire Station, like the Cafeteria Building immediately to the east, is executed in the International Style and is one of the most interesting designs dating from Hughes Aircraft's plant expansion period. A clean, functional design, it is composed of two one-story rectangular volumes: a taller, larger block on the west containing garage area for fire fighting equipment, and a smaller east block containing offices and support spaces. The unequal horizontal masses are visually tied together by the slender vertical of the hose drying tower at the center of the composition.

Entirely of wood frame construction, the Fire Station has a 36 x 87 ft footprint, with a small one story appendage on the south side of the support block. The simple, unembellished lines of the building's flat roofed volumes are finished with smooth stucco. It is supported on a reinforced concrete foundation.

The west half of the primary, north, elevation is articulated by three translucent corrugated fiberglass overhead doors. They replace original wooden flush panel doors and allow filtered light into the interior. A fourth (westernmost) vehicle bay is in-filled and now contains an office. A band of steel casement windows extends across the east half of the facade. The window bay is made up of six four-light units which protrude slightly from the wall plane and have operable awning-type sash.

Entrance to the office and support wing is by way of a recessed doorway with splayed walls in the east elevation. A rectangular transom surmounts the single glazed panel door, and a two light casement window occurs immediately to the south. A second doorway at the south end of the elevation accesses the small addition. The west elevation is featureless but for a fire alarm and louvered vents along the top of the wall.

Several equipment cabinets are attached to the exterior of the south elevation, which also features a single casement window and doors to the Apparatus Room and the hose tower at the southwest corner of the support block. The 40 ft tower is rectangular in plan with horizontal louvers on all sides at the very top. Internally, the tower's structural stability is augmented by diagonal steel tie rods.

Deep wooden roof trusses span the 36 x 51 ft Apparatus Room creating an uninterrupted space for vehicle storage. One vehicle bay at the west end of the room has been enclosed with frame partitions for an office, and small free standing cubicles added along the south wall were fire crew quarters. The walls and ceiling of the Apparatus Room and other areas are painted plaster and the concrete slab floors are finished with vinyl tile. The ceiling shows considerable damage from water infiltration.

The east block of the building contains offices, and locker and restrooms for Fire Department personnel. An addition to the southeast corner constructed in 1974 provided additional space for servicing the hundreds of fire extinguisher units distributed throughout the plant. Offices for the Chief and Lieutenant and a ready room originally occupied the north side of this section. Partitions were later removed to create two offices which contained communications equipment and fire control panels which monitored the plant's alarm and sprinkler systems. Several other minor partition changes have occurred and the original lighting fixtures have been replaced by modern fluorescent ceiling units.

The Fire Station was designed in early 1952 and is attributable to the Plant Engineering Department. This was the most ambitious project yet undertaken by that department, which had previously been limited to design of minor utilitarian structures and support for lead architect H.L. Gogerty. The modest though well executed modern design was drawn by L. Rosendahl, with design work completed, at least in part, by E. Lee.

Increasing regulation by the federal government brought a heightened awareness of issues of workplace safety and security. For large facilities such as Hughes Aircraft, which were taking on the proportions of small cities, it was becoming common to provide private fire fighting equipment and staff. Building 18 is comparable in scale and design to many municipal stations of the era. Its construction relates to the plant expansion program ongoing at the time which had more than doubled the built space and correspondingly raised the need for fire protection and emergency services.

Completed by October 1952, the Fire Station initially housed three fire trucks and an ambulance, the ambulance and two trucks having been recently purchased. The facility supported a staff of 15 Hughes Aircraft Company Fire Department personnel (*Hughesnews* 1952b:3). Building 18 later served as the headquarters for the plant Security Department as well. Plans for a second story addition to the east half of the structure containing office space were drawn in 1979, but the expansion was never completed. The Hughes fire department was disbanded in 1993 (A. Romano, personal communication 1995).

Building 19 - Warehouse/Maintenance Building

A simple, utilitarian design, Building 19 is, like the Fire Station, a product of the HAC Plant Engineering Department. Roughly rectangular in plan, the one story structure is of steel frame construction clad with vertical corrugated metal panels. The ridges of its symmetrical, low-pitched, double gabled roof run east-west, and the structure's roofline mimics that of the huge Cargo Building (Building 15) immediately to the north. Fabricated steel I-section arches placed 20 ft on center frame the two bays which share common central supports. The building's overall dimensions are 94 x 260 ft, and it rests on a raised reinforced concrete foundation. The roof is also clad with corrugated metal panels, and rows of ventilators occur along the ridgelines.

The warehouse building is without fenestration but for one small window in the east elevation. Additional natural light is admitted by a series of glazed overhead doors in the north elevation. Two such doors located at the east end of the north elevation access a concrete loading dock covered by a broad shed roof on squared steel supports. Cantilevered metal-clad canopies protect single and triple freight bays toward the center of the elevation. Various ventilation fans and ductwork protrude from the top of the wall.

Preliminary plans for the building anticipated an unsheltered receiving dock spanning the full breadth of the west elevation. The design was soon altered to reflect the present configuration, in which the side walls and roof are extended beyond the end of the concrete dock with the end wall left open below the gables. Wood panel-clad frame additions have been built on top of the south half of the dock, and one room at the south end of the elevation extends to the gable end. Roll-up, sliding, and glazed overhead freight doors serve the receiving dock, with a double personnel door located at the south end of the elevation and a concrete ramp extending from the north end of the dock.

The blank plane of the south wall is broken only by two steel slab personnel doors and multiple ventilator fans along the top of the wall. The east end of the south bay has been extended and corresponds in construction and finish to the rest of the building. The end wall of the north bay includes a sliding door, a single fixed sash window, and louvered panels.

Originally consisting primarily of open warehouse space, the interior of Building 19 has been divided over the years into a variety of shop, office, and support spaces. Access to the interior is presently unavailable, but spaces typically have frame partitions with painted wall finish, concrete floors, open ceilings and industrial, open bottom fluorescent lighting fixtures.

Building 19 is part of a group of warehouses and support facilities erected along the periphery of the Culver City plant's core of manufacturing, research, and development buildings. The building functioned as the primary receiving area and it was sited adjacent to the newly established south plant entrance, Gate

17. It also housed the Maintenance, Repair, and Operations (MRO) department (*Hughesnews* 1951d). Necessitated by the increase in electronics and armaments production, Howard Hughes himself was involved in laying out the facilities and streamlining the flow of parts and materials to the various departments. Hughes specified that the warehouse should be a low cost, 25,000 sq ft structure, not attached to the recently constructed warehouse immediately to the east (Building 17).

When completed in July 1951, Building Z-1, as the structure was initially known, included a row of offices, restrooms, and small test laboratories along the west half of the north wall. The MRO department facilities occupied the northeast corner, with the remainder of the building being open storage space. The original plans depict the west half of the building containing a large receiving area, with smaller sections designated for capital equipment, holding, and outgoing items. The central portion was the Inspection and Test area, where quality control checks were performed on incoming material. The southeast corner contained rows of storage bins with a stairway for access to a second tier. Materials entered primarily from the west loading dock with distribution occurring from bays in the other elevations. A sliding door in the north elevation was aligned with a bridge over the drainage ditch which separated the warehouse from Building 15, and a ramp from the sliding door in the east end connected it with Building 17. A frame mail room was added on top of the loading dock in 1953.

As production was moved to other Hughes Aircraft facilities during the early to middle 1950s, the flow of materials through Building 17 diminished. The Maintenance Department divided the building into shop areas, including machine, plumbing, electrical, and carpentry, and also added the loading dock and overhead doors in the north elevation (Statistical Research et al. 1991). Building 19 served this function through the tenure of McDonnell Douglas Corporation.

Building 20 - Manufacturing Building

Conceived as a research and development building for the Guided Missile Department, Building 20 is a rectangular, high bay single story, steel frame post and beam structure with an L-shaped one story concrete block addition at the southeast corner. The structure has a flat roofline which is broken by a 22 x 60 ft, two story mechanical mezzanine which rises near the center of the roof plane. The roofline is further interrupted by a host of protruding ventilators, ducts, and mechanical equipment. The 200 x 390 ft building is composed of 30 x 50 ft structural bays and is clad with vertically ribbed steel siding clipped to the framing. The wall planes are enframed with smooth metal finished boxed parapets, sills and corners which carry gutters. Each wall is dissected by regularly spaced downspouts located coincident with perimeter columns. Columns are supported on concrete pilings, with exterior walls placed on reinforced concrete foundations. The structure is completely windowless.

Various personnel and freight doors give access from the south elevation of Building 20. The metal slab-type personnel doors have glazed upper panels and are protected by flat hoods. A pair of side-by-side sliding freight doors in the west half of the elevation has rectilinear metal enframement identical to the wall enframement. Each smooth metal clad freight door has an inset personnel door. The elevation has been altered from the original plans through the addition of two metal roll-up doors. A single large sliding door with projecting metal enframement has been added to the west half of the north elevation, the only other wall penetration being a double-door personnel entrance in the east half of the elevation.

The west elevation is articulated by a series of steel framed, corrugated metal roofed sheds covering low concrete platforms where various mechanical equipment was placed. One diesel generator remains in the northernmost shed. Hooded personnel entrances occur at the center and south end of the elevation, and traces of two infilled freight doors are also visible. A small, windowless dependency at the north end of the east elevation is finished identically to the main building, and a one story, high bay concrete block addition with a flat roof is attached to the south half of the elevation. The concrete structure is likewise without fenestration, and has overhead doors on the south and east sides. A modern two leaf door with a rectangular transom window and a projecting surround occurs at the center of the elevation, between the additions.

The interior of Building 20 consists of laboratory and shop spaces organized along a central east-west corridor running the full length of the structure. Large shop spaces are situated at the northeast corner of the building, while smaller specialized shops and laboratories which have changed configuration many times over the life of the building are located to the south of the corridor and at the northwest corner. One cross corridor divides the east half of the building, and it is lined with offices and support spaces. A woodworking shop presently occupies the southeast corner.

Ductwork, electrical conduits, gas and water piping, and other primary utility supply lines are visible along the length of the open ceiling central corridor. The primary electrical panels are also located along the corridor (CA-174-O-12). Corridor partitions, as well as other room partitions, are frame construction with painted drywall finish. Floors of the corridors, offices, and laboratories are asphalt tile. Shop areas have concrete floors. Industrial-type fluorescent fixtures generally light the corridors and shop areas. Some laboratory spaces in the south half of the building retain the original louvered Slimline suspended fluorescent fixtures and perforated Cellotex acoustical tile ceilings used in so many of the Hughes plant interiors of this period. Open ceilings in some of the shops leave structural members, roof deck, ductwork, and piping exposed, while suspended acoustical tile ceilings have been installed in others. The mezzanine structure is centrally located, north of the main corridor. The lower floor contains restrooms, equipment, and transformer rooms, while the upper floor houses primary ventilation equipment. The mezzanine projects one half story above the main roofline and has louvered panels on all sides.

With the receipt of new government contracts for fire control systems and armaments in early 1951, an immediate expansion of missile engineering facilities was required. Designs for Building 20 (Building G-1) were prepared by architect H.L. Gogerty, with direct input from Howard Hughes, who stipulated the size, orientation, and location of the structure, to be placed 175 ft west of Building 12 (Jerman 1951:1). Construction commenced on June 21, 1951 and was completed by August 25, one week ahead of schedule and, according to a company newspaper account:

> The speed of completion of the new building, to be used for the GM Production department's offices, shops, and laboratories, emphasizes the urgency and importance of the Company's part in the defense program (*Hughesnews* 1951e:1).

The 78,000 sq ft building initially housed more than 500 personnel of the Guided Missile Production Planning and Engineering Department. Original plans indicate that a large open shop area occupied most of the north half of the building, with an open general office area ringed by small offices and support rooms in the three easternmost bays. The south half of the building, west of the offices, contained smaller, specialized shops and laboratories with areas for shipping and receiving, assembly, testing and inspection, processing, and jig production. The central corridor did not exist and circulation to these spaces was by way of a U-shaped corridor accessed from the main shop area.

Engineers and technicians working in Building 20 participated in the design and development of the Hughes Falcon air-to-air missile, one of the most widely used missiles in the world, as well as other armament systems. Limited production lines were established in the shop and assembly areas where processes were tested and fine tuned. Never intended as a large scale production facility, designs and processes developed in Building 20 were ultimately produced at the Tucson facility, also established in 1951. Eventually, many development functions were transferred to Tucson as well, and the role of Building 20 became increasingly one of laboratory support. Electronic instruments were assembled, tested and repaired here, and personnel were also responsible for instrument purchasing, storage, and distribution (J. Patton, personal communication 1995). In December 1952, portions of the Industrial Relations Group moved to the west end of Building 20. Involved in various aspects of employee life, the group included the personnel records department, the group insurance office, the credit union, and the office of *Hughesnews*, the company newspaper. *Hughesnews* documented the life of the organization, its employees, projects, buildings, and social activities beginning in 1940. Late in Hughes' use of the facility, the helicopter division's Composites Laboratory was housed in Building 20. Helicopter transmissions were tested in the concrete east addition, built around 1981 (A. Romano, personal communication 1995). Presently, a movie set production shop occupies the concrete addition and an area in the east end of the building, with other minor film related activity in the south half. The remainder of the structure is unused.

Building 21 - Prototype Manufacturing Building

The last of the research and development buildings completed at HAC's Culver City plant, Building 21 is starkly industrial in appearance. Nearly square in plan, the 50,000 sq ft, two story structure is of steel frame construction with a flat roof. It is clad with vertical corrugated steel panels and, like the other Gogerty designed buildings from the 1951-1952 period, the wall planes are framed by broad, boxed trim at the parapet and corners, and are broken at regular intervals by pipe downspouts. The structure is built on concrete pilings, with outer walls supported on concrete foundations.

A centered entrance with a projecting rectilinear enframement is the sole wall opening in the west elevation. The entrance includes the building's only windows; an off-center, two leaf, glazed door is flanked by a large glazed panel on the south and has a rectangular transom light above. A symmetrical entrance in the east elevation is likewise the only opening in that wall. The large window and transom have been infilled and a single hollow core metal door provides access.

The north elevation features a metal roll-up door slightly east of center, and a double-door freight entrance with glazed panels placed directly above it. A monorail crane formerly projected from this opening to move large pieces of equipment directly into upper story laboratories. A single personnel entrance occurs in the west half of the elevation, and a group of louvered vents is bisected by a roof access ladder east of the freight doors.

A metal roll-up door located slightly off-center in the south elevation was added soon after the building's completion. Single personnel doors occur in the east and west half of the elevation and a small, one story, metal clad addition is attached near the east end. The elevation is further embellished with downspouts, ventilation ducts, a roof access ladder, and a stand pipe.

The interior of Building 21 is presently inaccessible due to asbestos contamination.

Demands for additional laboratory and office space for systems development during Hughes Aircraft's post-war expansion period led to the construction of Building 21, which began in September 1951. Designed by architect H.L. Gogerty, the building's interior configuration initially consisted of open work areas organized around a central service island containing restrooms and utility spaces. Laboratory spaces were arranged around the outside walls on the lower floor, while small office cubicles ringed the open general office area on the upper floor. Modifications to the floor plan of Building 21 by the Plant Engineering Department shortly after its completion divided the open work area of the lower floor into specialized laboratory spaces. Laboratories were also added to the upper story, with offices concentrated in the west half of the floor. Monorail hoists were added to both floors at this time for moving large pieces of equipment. Later, a roughly 20 ft square chase was cut in the upper floor near the north entrance, allowing equipment to be moved between floors.

Elements of the Research and Development Department moved into Building 21 in March 1952. They were joined by the Purchasing Department, which occupied office space on the upper floor. The building functioned chiefly as a testing facility for the Components Materials group. It housed highly specialized instruments and equipment used in analyzing the performance of various components and radar and weapons systems, including vibration measuring equipment, a Conrad Explosion Chamber, and a centrifuge (Statistical Research et al. 1991). Aspects of electronics manufacturing processes were also tested here through the construction of pilot production lines in the larger laboratory spaces. Building 21 has been unoccupied since 1990 (J. Patton, personal communication 1995).

Architects Associated with the Howard Hughes Industrial Complex

Henry L. Gogerty was a nationally recognized architect practicing in the Los Angeles area who was responsible for most of the original designs and alterations of structures on the Hughes Aircraft site. It is not known how or when Howard Hughes met Mr. Gogerty. Both, however, were involved in the Hollywood community, and Gogerty had designed buildings at aviation sites with which Hughes was familiar.

Gogerty began his architectural career in southern California in 1923, establishing the firm of Gogerty, Norenberg and Johnson. Later, in partnership with Jules Weyl, he designed classic Spanish Colonial Revival and Art Deco style buildings in Hollywood, several of which are listed in the National Register of Historic Places as contributors to the Hollywood Boulevard National Register Historic District. Among the structures are the Hollywood Playhouse (1926), the Baine Building (1927), the Brown Derby (1928), and the Hollywood Wax Museum (1928). The firm counted among its clients film entrepreneurs Sol Lessor, Cecil B. DeMille, and Jesse L. Lasky. Gogerty and Weyl maintained offices in the Guaranty Building on Hollywood Boulevard, home to talent agents and others associated with the film industry (HRG 1995:25-26).

Gogerty was responsible for the design of the terminal at Glendale's Grand Central Airport, where the Hughes Aircraft Company began. After ending his partnership with Weyl, he practiced under the name of H.L. Gogerty Associates until his retirement in 1968. He designed office buildings and shopping centers, in addition to projects for the U.S. Navy, and industrial structures for Hughes Aircraft, Bendix Aviation, and Union Pacific Railroad. Perhaps best known as a designer of educational facilities, Gogerty is said to have designed more than 350 schools during his career. Interested in technological innovations, he designed and developed gliding acoustical walls for schools which provided maximum flexibility for classrooms. The design helped him win a national achievement award in construction science from the American Institute of Architects (*Los Angeles Times* 1990).

Perhaps his most important industrial commission was the massive cargo plane assembly building that he designed for Hughes Aircraft to house the famous Spruce Goose. Building 15 is one of the largest wood frame buildings in the world, having a footprint of 183,000 square feet. The addition of the contiguous Buildings 14 and 16 increases the area to 274,000 square feet. A singular engineering achievement in wood framing, Gogerty utilized the most advanced lamination technology to fabricate the structure's massive wooden arches, which were the first of their kind (HRG 1995:25-26; *Los Angeles Times* 1990).

Of the 16 contributors to the Howard Hughes Industrial Complex, Gogerty designed all but one of them. Building 18, the Fire Station, was designed by the Hughes Plant Engineering Department. The most architecturally significant are the Administration Building and the Cafeteria, both excellent examples of International Style industrial architecture, and the monumental Cargo Building.

OVERVIEW OF THE AIRCRAFT INDUSTRY

Fascination with flight is rooted in the dim past, but achieving flight depended largely on scientific discovery and applied technology. Flight itself was possible as early as the late 1700s, when a lighter-than-air technology for ballooning was developed. Lighter-than-air technology appealed to hobbyists and had limited military application, but little immediate impact on the lives of most people except in the realm of the imagination. The possibilities of flight intrigued both scientists and inventors and surrounded flying with an aura of romance and danger. The idea of conquering the forces of the atmosphere through flight fit well with the Euroamerican cultural theme or belief that it is human nature and inherent right to control the natural world and its powers. The aerodynamics of birds inspired heavier-than-air craft; many potential flying machines were designed, but few of the plans were realized. Flight enthusiasts in North America and Europe began flying around the turn of the century for short flights of a few hundred feet, but this flight remained mostly soaring.

Powering a flying vehicle was the second major goal after flight itself. Steam engines were the only non-animal propulsion technology available at first, but they were too heavy and cumbersome for use with lighter-than-air craft (Ward 1953:17). The development of the gasoline engine provided motive power to control flight.

Successful flight involved solving a number of technical problems: sufficient power to get the plane aloft and support a load; a structural design that minimized aerodynamic drag or wind-resistance and maximized aerodynamic lift; a means for steering; and the ability to take off and land. Although practical flight was achieved shortly after the turn of the century, these design challenges remained and were still being addressed and refined in the 1930s and 1940s. Additional technical requirements, principally instrumentation and navigation aids, arose as the utility of commercial and military flight expanded; military uses of aircraft also required armament.

The use of aircraft by the military during World War I provided an impetus to move the industry beyond barnstorming because the war opened a market for planes and demonstrated their abilities. These planes were wooden frames, usually biplanes, with "stick and wire" struts and fabric covering, powered by gasoline engines often adapted from automobile engines and with fixed-pitch propellers. The pilot sat in an open or semi-enclosed cockpit and there was little or no accommodation for passengers (Stratford 1992:839). European-model planes were manufactured in American factories "at close to mass production rates," and American-designed experimental planes that later proved successful were also produced. Refinements to the flight process that were developed during World War I included "the high altitude engine and turbo-supercharger [to maintain power at high altitudes], gyroscopic air navigational aids, air-to-ground radiophone sets, air crew oxygen masks, electrically-heated flying clothing, automatic cameras and helium gas" (Ward 1953:91).

After World War I, the aircraft industry survived financially by producing planes for airmail contracts and passenger service (Taylor and Mondey 1983:63-73; Ward 1953:75). The federal government, although providing some support services such as navigational beacons, did not actively subsidize aircraft design or production. The 1920s were years of testing the endurance of planes and pilots, both as a means to develop new equipment and designs and to encourage public interest and support for the idea of commercial air services. The feats of Lindbergh, Earhart, and others were acclaimed.

Manufacturing, begun on the East coast by such men as Glenn Curtiss in New York and Glenn Martin in Ohio, relocated to the West coast in the 1920s, mainly in southern California. The Boeing company operated in Seattle, where it had started in 1915. Southern California offered good weather conditions for year round flying. Once the industry was established, a trained labor force and ancillary industries became available locally, which encouraged other plants to locate in the same area. Donald Douglas came to California from Martin to open his own business. The Lockheed brothers formed a company that employed John Northrop, who started his own company in the 1930s. Other companies in southern California were Vultee and Consolidated, later combined into Convair (Rae 1968:85).

More companies were organized in the 1930s: North American Aviation, Interstate, and the Hughes Aircraft Company. Like the firms of the 1920s, they were formed by entrepreneurs who believed in the potential of airplane transportation. Most of the company founders had an inventor's bent as well as a background in science and/or engineering, but not necessarily formal training in aeronautics because it was a relatively new field. Some, like Northrop, had only a high school education (Kilgore 1978). Howard Hughes fit the profile of aircraft company founder: an entrepreneur with a background in science and invention, and an interest in improving aircraft.

Technological innovations in aircraft in the 1920s and 1930s included streamlining the shape and a shift to monoplanes with enclosed cockpits and passenger/cargo space, internal bracing of the frame with an increasing use of metal in both the structure and skin of aircraft for greater durability and safety, metal instead of wooden propellers and starters that did not involve swinging the propeller by hand to start the engine, propellers with adjustable pitch, more powerful, air-cooled engines to carry heavier loads, and aerodynamic design modifications such as landing flaps. More sophisticated instruments came into use as well, such as turn-and-bank and rate-of-climb indicators (Stratford 1992:839; Ward 1953:110-111).

An aluminum alloy, principally aluminum with small amounts of copper, manganese, and magnesium, called "duraluminum" (Jordanoff 1942:143), or "dural" for short, was developed for use in propellers and other metal parts. Use of metal required different fabrication methods, and such tools as the pneumatic rivet gun were developed (Ward 1953:110). Hughes used "flush rivets" in the construction of his H-1 Racer in 1935 to improve the aerodynamics (Dwiggins 1972:12). Airframes were the most visible product, but hundreds of contributing companies manufactured items used to produce and equip aircraft.

The 1930s were also years of record-setting. Once trans-oceanic and transcontinental flight capabilities had been established, the next logical step was to attempt speed and endurance records. Hughes himself set a number of records and seemed to delight in the activity: for land plane speed of 352.388 miles per hour in the H-1 Racer in 1935; for transcontinental flight from Burbank to Newark in 9 hours, 26 minutes, 10 seconds in 1936; and around the world in 1938 in 91 hours, 14 minutes, 10 seconds (Stearns 1953:2-4). Before attempting his record-breaking flights, Hughes took an active part in modifying planes by Northrop, Lockheed, and other manufacturers to increase fuel-storage capacity, safety features, and navigational aids such as radio. According to Stearns (1953:5), modifications that Hughes made to the Lockheed 14 for his around-the-world flight were later adopted by Lockheed for use in their World War II Hudson Bomber.

In the historiography of flight, emphasis in the early years was on record-setting and in later years on airframe manufacture, with attention to the role of the military. Although little discussed, research and development (R&D) were carried on in many venues and had important ramifications for production. Each manufacturer had a staff that worked on developing and testing its models. Seemingly, industrial and national security encouraged and/or required reticence on this topic. It is the area that Hughes and his company managers exploited successfully to build Hughes Aircraft Company (HAC) into an industry giant.

Government-Industry Interactions

The United States government became involved in the aircraft industry only reluctantly, but by the 1930s was a major force in aeronautics. Before World War I there was little contact between manufacturers and the government, but during the war the government came to rely on private manufacturers for planes. At the same time, the regulation of air traffic and the management of navigation beacons and airfields came under the purview of the federal government.

Congress established the first federal research and testing laboratories in 1915, under the National Advisory Committee for Aeronautics (NACA), based at Langley Field, Virginia (Stratford 1992:835). NACA's role was basic, not operational or applied, research. By limiting its sphere of operations, Congress implied that it "expected military aviators to rely on the private sector for the production of operational aircraft" (Kucera 1974:12).

Individual companies carried out a great deal of research for their own designs, mostly applied and operational research and development. Applied research is "investigative effort aimed at the practical application of knowledge. . . . Development . . . is the translation into hardware of the results of applied-research studies. . . . Operational research is concerned with the solution of problems encountered by flight vehicles already in regular service" (Hagerty 1992:540). The Langley laboratories of NACA provided testing services for manufacturers, which were utilized by HAC for testing elements of the HK-1. After in-house weight and stress testing, the NACA laboratories tested a model of the flying boat during production to work out "the aerodynamic specifications . . . so that the folks in Culver City [would] know where to put their muscle" (Odekirk 1982:10).

The government in the 1930s continued to provide a market for military aircraft, although with many strings attached. In the post-World War I years there were extensive investigations into the aircraft industry for "procurement irregularities, mismanagement and excessively high prices," but "a wholesale condemnation of the industry or its wartime effort" was not warranted (Rutkowski 1966:18, cited in Kucera 1974:15). The tarnished image of the aircraft industry remained, however.

In the early World War II years, manufacturers bid on fixed-price contracts and had to cover design, testing, and experimental costs out of their own budgets. Failure to meet specifications was penalized financially and it was not permitted to make up for losses on one contract with profit on another. If development costs were high and/or not enough planes were ordered, a manufacturer could lose money even if awarded a contract. Furthermore, government auditors carefully scrutinized aircraft accounting, because "influential elements in Congress and the administration . . . regarded the making of profit . . . as prima facie evidence of misconduct" (Rae 1968:77-78). The contract for the Hughes flying boat was fixed-price, with the making of profit forbidden. Hughes invested several million dollars of his own money in the Flying Boat when costs exceeded the contracted sum.

Concern in Congress over perceived irregularities in wartime contracts led to investigatory hearings in 1947, instigated by Senator Owen Brewster of Maine. Hughes was singled out apparently because he had received a number of development contracts for planes that never went into production and also because Elliott Roosevelt, son of Franklin Roosevelt, had been instrumental in the contract for the XF-11. Hughes counter-charged that Brewster wished to further the merger of Pan American Airways and Trans-World Airways, owned by Hughes, and which Hughes opposed. The hearings were effectively ended when Hughes vowed to leave the United States if the HK-1 did not fly (Keats 1966:200-213; Bartlett and Steele 1979:131).

During the war years and afterward, government procurement policies changed to cost-plus contracting, which eased the financial burden on companies. In a cost-plus contract, overhead, direct, and indirect costs are billed, plus a fee, if any. Such contracts enabled manufacturers to be sure of covering at least actual expenses and not losing money in this area. The XF-11 contract in 1944 was a cost-plus-a-fixed-fee supply contract (HAC Contracts file, n.d.a). Aviation research and development (R&D) also grew during World War II. Before the war the most important R&D facility was NACA; during the war the locus of R&D shifted to individual firms, although most of the funds came from the federal government (Kucera 1974:25). HAC was one of the firms that benefitted from this change.

By the end of World War II, the federal government was inextricably tied to the aeronautics industry, which came to be called aerospace. Despite the development of commercial air travel and the concomitant market for planes and equipment, the military market for planes, missiles, and later satellites remained the financial mainstay of the industry.

Aeronautical Manufacturing

It is difficult to describe a "typical" aircraft plant. In the 1930s,

> the bulk of the aircraft industry's earnings came, not from the mass production of great numbers of virtually identical units, but from building a limited number of quite large, extremely complicated airplanes, whose total output seldom exceeded 1,000 units for any one year . . . and for which production runs of 100 or more for any given model were exceptional. . . . It was therefore out of the question for the aircraft industry to use the production methods so successfully employed by the automobile industry [Rae 1968:81].

Aircraft construction is labor-intensive; approximately 90 per cent of the aircraft labor force in the 1930s was skilled or semiskilled. "Average weekly wages ranged from $30.16 in 1931 to $25.16 in 1935 and back to $30.56 in 1939" (Rae 1968:83). The actual tasks are specific to the plane type under production, but five general spheres of activity can be used to categorize plant operations: administration, support, design, fabrication, and assembly.

Administration deals with management of the other four spheres, including contract management and planning, accounting and disbursements, human resources, facility management and support services. Administrative activities at the Culver City plant were originally conducted from Building 2, but when Building 1 was built in 1952 they moved there.

Support services aid the running of the physical plant and the everyday management. Support services include providing food, fire protection, first aid, a library, blueprints, guard services, and transportation, among others. Some support services had their own buildings, such as the Cafeteria (Building 10) and the Fire Station (Building 18). Other support services were located in Buildings 11, 17, and 19. Some support services were specific to particular design and fabrication activities. Such tasks included production control, quality control, and inspection.

Design includes engineering, drafting blueprints, testing, and writing specifications. In the case of the HK-1, stress analysis was an important part of this process. Design activities were carried out at Culver City in Buildings 2, 3, 5, 6, 8, and 21. An auxiliary part of the design sequence was the construction of prototypes, both parts and whole sections of a plane. This involved the establishment of small machine shops and other support shops to manufacture prototype parts. A significant part of design is designing the tools to make the parts required for assembly.

Fabrication is the production of all the parts that compose a plane or other product. "The particular technique selected for a given part is dependent upon a number of factors--for example, the type of basic material, the intricacy of the shape, requisite strength, and, when it becomes a part of the flight vehicle, the degree of exposure to load forces and temperatures" (Hagerty 1992: 543). Fabrication of parts is by either chipless or removal methods. Chipless operations include die-casting, molding, or pressure forming. Duramold can be grouped with the chipless techniques because it used heat and pressure to form parts. Removal operations are those that remove material to achieve a form or shape; they include "milling machines, lathes, shearing machines, borers, punch presses, knives and saws, sanders, grinders, and polishers" (Hagerty 1992: 543). At the Culver City plant, fabrication was carried out in Buildings 15 and 16. The chipless operations included molding metal at the foundry and with the drop-hammer. Removal operations were applied to metal parts and also to wooden elements of the flying boat, the D-2 fighter-bomber, and the XF-11 photo-reconnaissance plane.

Assembly is joining individual parts into larger elements, and ultimately the whole vehicle. "The most familiar method is mechanical joining by means of rivets, bolts, screws, pins, and other special-purpose fasteners. In cases in which a tighter seal is necessary or where the assembly will be subjected to great loads, manufacturers employ welding. . . . Another widely used method is adhesion bonding, or simply gluing the parts together with supercapable adhesive coatings, such as plastic resins" (Hagerty 1992:543). At the Hughes Culver City plant, the Cargo Building (Building 15) was the principal assembly area for the flying boat elements.

Airframes are not as easy to assemble as might be supposed. Some parts are rigid metal, but many more, such as the skin of the plane, are flexible and have small overlapping surfaces where they must be attached, such as where the wings meet the fuselage.

> In order to reproduce in physical form the curved surfaces designed into the airplane on paper, it is necessary to resort to the laying out of templates on metal sheets by means of a process known as 'lofting' or 'master layout.' . . . 'Loft lines' are obtained by passing sections through a portion of the airplane at uniform spacing in both horizontal and vertical planes so that a series of contours results. When these contours are cut out of sheet steel as templates and assembled in the same relationship as the sections passed through the structure, the result is a skeleton representation of the structure itself. If plaster is then filled in between the templates, and when set, worked down to the outside contours an accurate plaster 'mock-up' is obtained from which tools can be made [Lilley et al. 1947 reprinted in Simonson 1968:132].

Construction of the Flying Boat employed:

> a related method [that] consists, in effect, of building a mold surrounding the contour. If 'female' templates are cut out of the steel sheets, laid out as above, and locating points in the form of wood or steel docks are fastened in the proper positions, it is possible to develop a jig within which the desired structure can be assembled [Lilley et al. 1947 reprinted in Simonson 1968:132].

Using the Duramold process, "female" plaster dies (molds) of components were formed, then sheets of veneer and glue were "laid up" inside the dies. A rubber bladder was inserted inside the form to hold the veneer against the die. The whole mold was then cured under heat and pressure in a retort (J. Stubbs, personal communication 1995).

It takes about two years from conception to delivery of the first plane of a series. Many of the activities described above happen simultaneously, not as a strictly linear flow. For example, engineering changes can occur right up to the delivery date. Arranging the tooling to make the necessary parts can take almost as long as assembling the plane (V. Rasson, personal communication 1995).

The emphasis on research and development at HAC Culver City resulted in larger design staffs than at airframe manufacturers and an absence of large-scale fabrication and assembly areas. Production at Hughes Aircraft differed from production at plants that produced primarily airframes for sale, such as Douglas, North American, and Lockheed. At Hughes Culver City, helicopters were the only mass-produced aircraft, but not until after 1953. The only helicopter before 1953 was a prototype, the large XH-17. Radar and other electronics products were also assembled at Culver city. Production of airframes, and of missiles in the post-World War II years, was always limited to prototypes.

Production at HAC was not a linear process, as on an automobile assembly line. During the 1940s, the Flying Boat was the main project, with less work on the D-2 and XF-11. There was limited flow of materiel and personnel between areas, since some buildings were devoted to design rather than to production. In the 1950s, there were a number of separate projects (discussed below) that were not connected with each other. Security concerns were also a factor, since workers had access only to project areas for which they were cleared. In the case of parts, often a machine shop would make parts for several different projects. The work was brought to the machine rather than moving the machine to the project area because the machines were large and unwieldy to move and set up, and because they were already located near their material source, usually metal.

Work in teams, or "groups" as they are known in the industry, is a hallmark of aircraft manufacture. A group is a team composed of designers, engineers, tool-makers, and others. The origin of this practice seems to go back to the early days of aircraft production. By the late 1930s, airframe manufacturers disfavored "rigidly regulated working patterns and hours" because they argued for:

> the unique requirements of their products. These included 'precision work to a superlative degree,' . . . and 'elasticity of hours' to cope with fixed-period contracts. More importantly they insisted on the right to continuously employ the 'hands of the same men' to prevent the dilution by labor shifts of particular workers' knowledge of particular aircraft under construction. Their workers were 'specialized' not because they built aircraft but because they built particular aircraft. Each was unique, even within the same production series [Vander Meulen 1991:153].

For instance, to design the installation of an engine on an airplane, team members mount the power plant on the plane and run the wires, fuel and other feeds through the wings and fuselage. Only after this has been completed are drawings made of the configuration (V. Rasson, personal communication 1995). Aircraft production, even in commercial-scale fabrication and assembly, has an artisanal or craft flavor that differs from the mass-production of items such as automobiles.

HAC reflected the industry-wide attitude shared by management and labor. In orientation classes for new engineers on the HK-1, one lecturer admonished that, "A part, or an object being built is no better than the worst man who works on it" (*Hughesnews* 1942c).

HOWARD HUGHES

Howard Robard Hughes was born in Houston, Texas, in 1905, an only child. His father, Howard Hughes, was a free-spending Harvard graduate who engaged in various business development projects, mostly centered on oil discovery. He was interested in technology and in 1908 invented a drill bit for oil wells that made it possible to drill through shale. He held the patents, manufactured, and leased the bits out to oil companies for $30,000 per well. He and a partner formed the Sharp-Hughes Tool Company, which later became the Hughes Tool Company (Keats 1966:4-6).

Howard Hughes' mother died in 1922 and his father in 1924. He was only 19 years old, but he convinced the court that he was old enough to manage his inheritance. He took over the running of Hughes Tool Company, advised by accountant Noah Dietrich, who remained instrumental in his life until the end. Shortly after he inherited the company he married Ella Rice, a local Houston belle, and moved to California (Keats 1966:12-18). She later divorced him and he married Jean Peters (Keats 1966:197).

Hughes and his father had been in California, after the death of Howard's mother, to visit Rupert Hughes, his father's brother who was a screenwriter in Hollywood (Schwartz and Maguglin 1983:8 cited in Altschul et al. 1991:85). After his move to California he produced several movies, some more successful than others. All of his movies were silents. For his film about pilots in World War I, *Hell's Angels*, he bought period airplanes, choreographed aerial fight sequences, and flew the plane for aerial scenes himself (Keats 1966:30-36). *Hell's Angels* was one of the first movies in which action was the star, rather than the actors, but sound was introduced before the film could be released. Hughes decided to add sound to the film, which meant re-shooting a number of scenes and adding the cost of production. He introduced Jean Harlow as the actress in the sound version, which received mixed reviews but was popular at the box office. "*Hell's Angels* went on to run for twenty years in theaters throughout the world" (Keats 1966:30-45).

Hughes continued both his interest in film making and aviation, working on production of *The Outlaw* introducing actress Jane Russell in 1941, while working on the Flying Boat design at the same time. In 1948 he bought a controlling interest in RKO Pictures Corporation, sold it and bought it back again in the 1950s, but remained chairman of the board until 1957 (*Encyclopaedia Britannica* 1992 [6]:123). His aircraft and film activities seem to have been compatible, perhaps because of their creativity and entrepreneurial aspects. Both may also have appealed to Hughes' interest in detail. He was not the first to combine movies and aircraft; Cecil B. DeMille, the director, owned a small flight business in Los Angeles in 1918 (Ward 1953:115).

Hughes seems to have enjoyed the problem-solving aspects of design more than manufacturing. The financial backing of the Hughes Tool Company meant that he was unlikely to have serious shortages of funds, so he could make the effort and take the time to indulge a perfectionist streak. Hughes engendered loyalty and protectiveness in many of his associates and employees. He was a person who preferred working at night and he was apt to call his HAC designers for consultations in the middle of the night. Those who worked with him protected him by not discussing his activities with their co-workers (S. Mu, personal communication 1995).

Hughes had a genuine passion for flight and solving technical problems of flying, not just a love for the acclaim of breaking records or making an immediate profit from manufacturing. Breaking flight records gave him legitimacy beyond that of a basement inventor, however. By assembling the design and production teams for the D-2, XF-11, and the Flying Boat, Hughes was pre-positioned for R&D success after the war even though none of his wartime prototype contracts resulted in orders for mass production. Using the creative design processes common to the rest of industry, such as work groups, brainstorming, and so on, coupled with creative design leadership, the HAC team went on to other innovations in electronics and guided missiles.

ACTIVITIES AT THE CULVER CITY PLANT

The former Hughes Aircraft Company Culver City Plant is situated in the western portion of the City of Los Angeles near the Pacific coast (Figure 7). Hughes initiated construction of the Culver City plant in 1940, as discussed below in detail. At Culver City, Buildings 2, 3, 14, 15, and 16 were constructed for the HK-1 project, of wood as specified in the federal contract. At first, the buildings were identified by letters; later, numbers were used. Building 15 (D), the Cargo Building, was the largest. It was the location of fabrication of parts and assembly of the plane itself. Building 2 (A) housed the major part of the design process.

The Culver City plant in the 1940s focused on three large airframe projects: designing the HK-1 and building the first one, and assembly of the D-2 and XF-11. A minuscule Radio Department began as a subsidiary after the mid-1940s. The post-war years saw greater diversification in both activities and product lines. After a period of retrenchment in the late 1940s, the 1950s saw new Hughes facilities established in Tucson and El Segundo and projects re-assigned among all the plants. The company always had several locations, including first Glendale and then Burbank (closed when the Culver City plant opened), Hollywood, and near the Los Angeles International Airport in the 1940s. The Hollywood facility continued to work in concert with the Culver City plant, housing Duramold fabrication and armaments; HAC developed and manufactured flexible feed chutes for aerial machine guns.

During the years he was attempting record-breaking feats, Hughes became associated with a number of other aircraft enthusiasts who influenced the later course of the Hughes Aircraft Company. Among them were Charles Perrine and David Evans, radiomen who were later instrumental in initiating HAC's research and development laboratory (Stearns 1953:5). Glenn Odekirk met Hughes during the filming of *Hell's Angels* in 1928, accompanied Hughes in 1933 "to New York via Houston for a three month trip that lasted a year," and later was instrumental in the early years of HAC, where he supervised the construction of the Culver City plant and then managed it (Odekirk 1982:2).

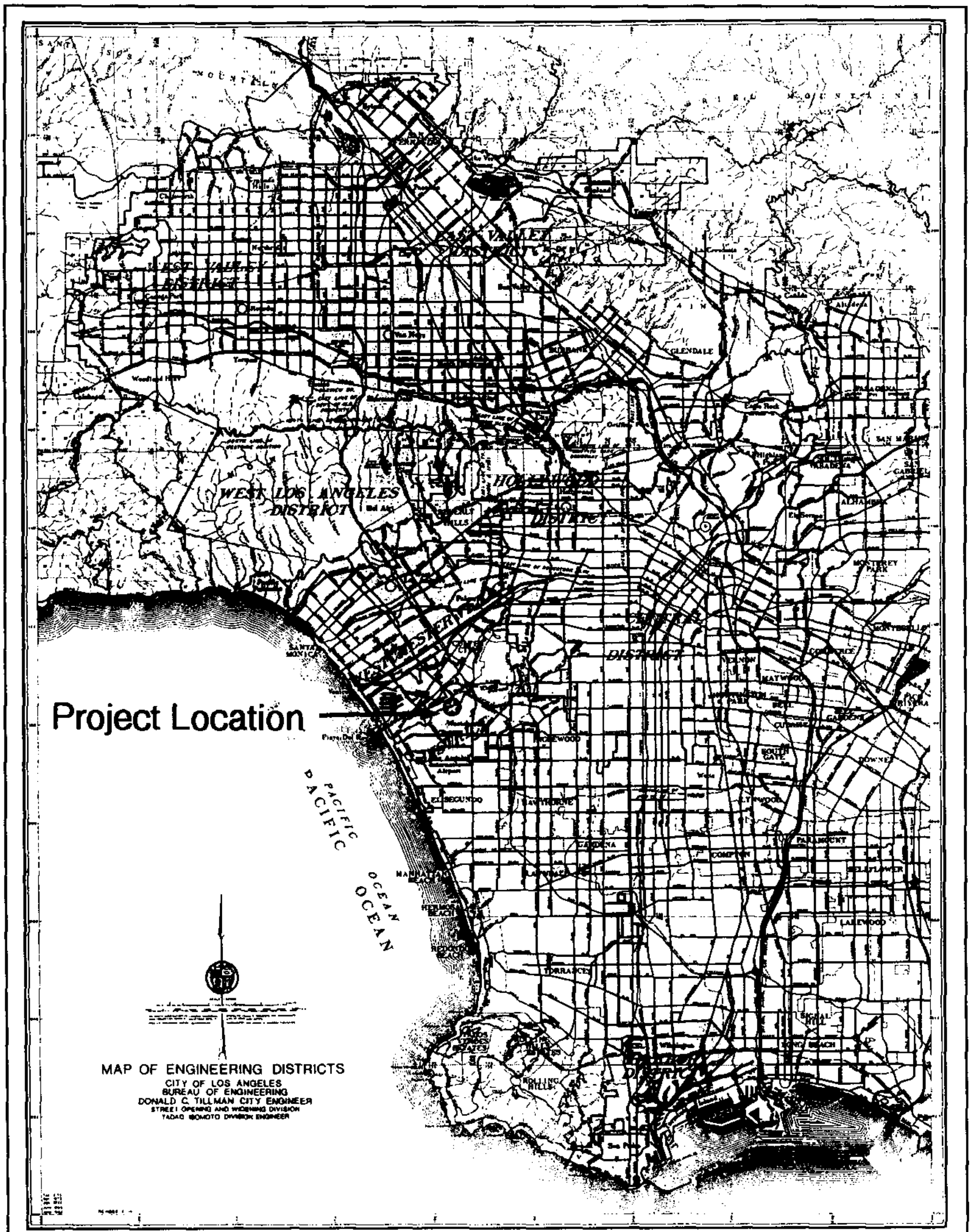

Figure 7. Vicinity Map showing location of the former Hughes Aircraft Company Culver City Plant.
(Source: Map of Engineering Districts, City of Los Angeles)

The fighter-bomber was designated the D-2, and initial design and testing were carried out in work spaces first in Glendale and then in Burbank. Additional offices for the designers were rented at the corner of La Brea Avenue and Romaine Street in Hollywood (formally known as the La Brea Avenue Division). As it became desirable to unify operations and to have room for prototype assembly and testing, and other projects, the Culver City plant site came under construction in 1940 (Altschul et al. 1993:86). The earliest buildings were 5 and 6 (initially called C and B).

The company had trouble securing engines for the D-2, which led to at least two re-designs, but by 1943 the plane underwent taxi tests and "short hops of less than 50 ft. altitude" on the Culver City runway. It was then transported to Harper Lake, a dry lake in the Mojave Desert, for flight testing, where it proved to be quite fast. Unfortunately, the hangar caught fire in 1944, the plane was destroyed, and the project ended (Stearns 1953:7).

The D-2, however, via an interim model called the D-5, left a legacy in the XF-11. Lieutenant Colonel Elliott Roosevelt, conducting a study of aerial photographic reconnaissance, was impressed with the performance of the D-2, which he saw during flight testing. He suggested that Hughes adapt the design into a fast photo reconnaissance plane (Stearns 1953:7). Hughes agreed and accepted a contract to design the XF-11 and produce a non-flying static test model and two prototypes. Successful completion and testing of the prototype was to lead to production of 100 additional planes (Stearns 1953:11).

The design and mock-ups of the XF-11 were produced at the La Brea Avenue Division, with construction of the first prototypes at the Culver City plant in 1944, in Building 15, and possibly in Building 16. In 1946, Hughes flew the first prototype from the Culver City runway (Stearns 1953:10). A variable-pitch propeller failed, and Hughes crashed in Beverly Hills while attempting an emergency landing in the only open area immediately available: the Los Angeles Country Club golf course (Keats 1966:187).

Hughes was badly injured in the crash, sustaining burns, broken ribs, and a collapsed lung among other injuries, and it seems to have been a turning point in the state of his health and in his later eccentric behavior. Hyland, general manager of HAC from 1954 to 1980, ascribes Hughes' later drug addiction to prescriptions for Valium and phenacetin made during treatment for this crash. He asserts that although the proximate cause of Hughes' death in 1972 was from kidney failure, the underlying problem was long-term phenacetin use (Hyland 1993:195).

Hughes was not deterred, however; in 1947 he successfully flew the second XF-11 prototype, after the propeller problem had been resolved. Although the prototype was delivered to the Air Force, the production phase of the contract was not implemented because the war ended (Stearns 1953:11).

The biggest project at the Culver City plant during World War II was the flying boat. Odekirk recounts that he conceived the idea for the flying boat while he was considering how to "keep over 200 engineers busy" after they finished the D-2. He heard a radio broadcast in which Henry Kaiser said, "Well, I guess we will have to put wings on my boats," and put Kaiser and Hughes in touch with each other. "In less than a week Howard Hughes and Henry Kaiser had agreed to design and build the HK-1 Flying Boat" (Odekirk 1982:2).

The 1942 government contract was for 18 million dollars. "The contracts somewhat reflected partisan government skepticism, for they were given the lowest priority rating. Furthermore, they called for two such planes to built in a matter of 2 years - a remarkably short time for an aircraft that hadn't even been designed" (Odekirk 1982:4). The contract further specified that Hughes could make no profit on the project, that a non-strategic material, e.g. wood, had to be used for both the plane and the buildings housing the project, and that no employees could be lured away from other aircraft companies (Pettit 1958:8).

The Industrial Context of the HK-1 Flying Boat

The Hughes HK-1 (or H-4) "Hercules" was not the first or the only flying boat, even if it was the largest built up to that time. A flying boat is an airplane that can take off and land from the water. "Boat-like hulls . . ., relatively rugged to sustain the pounding of waves and the impact of landings, . . . form the bottom part of their fuselages" (Luisada 1968:858). A flying boat differs from a seaplane in having this sturdier construction, while a seaplane lands on floats with the hull clear of the water. Many similar craft had been in use since World War I; one of the earliest flew in 1912 (Luisada 1968:858). Water landings were an advantage because runways long enough for large planes on land, with suitably smooth surfacing, were rare. Also, water was a better shock absorber for landing large aircraft because otherwise the landing gear had to absorb high weight loads. Taking off and landing on water made it possible to taxi a long enough distance to get a large load airborne. Safety was also a consideration; in case of difficulties over water a flying boat could land if necessary.

Flying boats of the period were bi-winged or high-wing (with the fuselage suspended below the wing) which was necessary for flotation and to lift the fuselage clear of the water. Pontoons supported the wings during landings and take offs. Some flying boats had two hulls, such as the Italian Savoia-Marchetti S-55 built in the 1920s. An early *Hughesnews* sketch of the HK-1 shows Ken Ridley (Figure 8) holding a model of a twin-hulled flying boat (B[ell] 1942b:1).

The commercial uses of flying boats were explored during the 1930s. In 1931, the German company Dornier produced the Dornier X, a flying boat with 16 engines and a wing span of 157 ft 6 in (48 m). It "set a record when it flew with 159 passengers and a crew of ten, but it was never put into regular service." Later, the company produced the Dornier 18, a flying boat designed to carry mail across the Atlantic (Luisada 1968:859). Flying boats were considered the most secure planes for passenger service over water. In 1938, Pan American Airways put the Boeing Clipper into service for the Atlantic run and later for service between California and Hong Kong. It was "the largest flying boat ever built for airline use," carrying 82 passengers (Luisada 1968:860).

Flying boats also played a role in the military arsenal, especially for the Navy. Douglas Aircraft produced a number of flying boats in the 1930s for use by the Navy, such as the all metal P3D-1, which had a wing span of 95 ft and was powered by two 1,000 horsepower Wright Cyclone engines (Maynard 1962:42). Probably the most numerous of the military flying boats was the PBY Catalina, built by Consolidated. It was slow, but reliable and had a long range. Flying boats were used during World War II for reconnaissance, antisubmarine patrols, and to carry cargo and passengers. Flying boats continued in use after the war; the last flying boat in Navy service was retired in 1988, the Martin P5M-1 Marlin (Luisada 1968:859-861).

PUBLISHED WEEKLY BY EMPLOYEES OF HUGHES AIRCRAFT CO., CULVER CITY, CALIFORNIA

KEN RIDLEY RETURNS WITH THE BACON

$18,000,000 APPROPRIATION FOR THREE HUGE PROTOTYPES

From the teeming jungles of Washington, where Senators and Dollar-per-year men (many of them considerably overpaid) feverishly squabble over rationing of noodles and priorities on bird cages, Ken Ridley returned Sunday with a large hunk of the bacon in the form of a Letter of Intent from the Defense Plant Corporation. This document appropriates the sum of $18,000,000 for the purpose of constructing two flying prototypes and one full-sized static test model similar to the designs drawn up by the Hughes Engineering Department, and for the provision of facilities for engineering and final assembly of the flying boats.

H.A.C. will be entirely responsible for the design, and as much of the actual construction as is possible will be done in our shops. Final assembly, of course, will have to be done in a location (as yet undetermined) adjacent to the water. As part of the program, work is being started here on the erection of an Engineering and Loft building, and also a Mock-up building.

We all congratulate Mr. Ridley on his most excellent performance in putting across our part of this negotiation, but Ken modestly passes on credit to the Engineering Department, which gang (he sez) has established for itself a very fine reputation. Those of us who have seen the D-2 know that it isn't just the engineers; it's the whole durned outfit that is capable of taking on this big new project and doing a swell job on it.

—*S. A. B.*

OCTOBER 2, 1942
Vol. 1 No. 26

Figure 8. Early conception of the Flying Boat. (B[ell] 1942b:1)

The Hughes flying boat was intended to carry cargo and troops, but on a much larger scale than previous planes. The wingspan was 319.92 ft, and it was powered by eight propeller engines. In comparison, the C-5 Galaxy used by the U.S. Armed Forces after the 1980s has a wingspan of 222 ft 8.5 in, powered by four jet engines. The largest cargo plane in use, since 1988, is the Russian Antonov AN-225, with a wingspan of 290 ft, powered by six jet engines.

The Hughes flying boat has been nicknamed the Spruce Goose, seemingly as a parallel to Ford's trimotor transport (not a flying boat), the Tin Goose of the 1920s (Rae 1968:14), and because of euphony, although

Hughes apparently did not like it (Keats 1966:212). Spruce actually played a small role in its construction, which was mainly of birch. The patented Duramold construction system was a far cry from ordinary "plywood," as the plane's construction is sometimes described. Duramold was a sophisticated means of laminating sheets of wood with synthetic resins under heat and pressure.

Even before the United States entered World War II, it was apparent that a military market was opening for aircraft and other products. Hughes became interested in designing and producing a fighter-bomber that could fly at high speeds. He continued in the tradition of using wood as a primary building material, as he had in the H-1 Racer. This was probably less nostalgia than a realization that aluminum would be in short supply when aircraft production was stepped up nationally.

He bought Clark Aircraft Company in 1939, securing the services of Colonel Virginius E. Clark as a consultant. The first person to earn a doctorate in aeronautics from MIT (Rae 1968:13), Clark "learned to fly [in 1913] in . . . one of the best available airplanes, but [which] lacked such modern conveniences as shock struts, fuselage, instruments and cock pit" (*Hughesnews* 1941e:3). He later developed the Duramold process for airplane construction to compensate for "the non-uniformity of wood, the unreliability of the methods which were then used for fabrication, and the difficulty of making a properly protected structural material" (*Hughesnews* 1941c:4).

Hughes worked out an exclusive agreement among HAC, the Fairchild Aviation Corporation, and the Haskelite Corporation to use Duramold to produce airplanes and other products (*Hughesnews* 1941c:4). The Duramold process "promised not only the surface cleanliness necessary to reduce the drag . . . , but to provide a material and fabrication process readily adaptable to large volume, [and] economical production" (Stearns 1953:5). At this time, Hughes intended to carry manufacture of products to full production, beyond the research and development and prototype phases. HAC used the Duramold process successfully (operating out of the Hollywood address) as a subcontractor to fabricate seats and other fittings for airframe manufacturers.

Birch was selected for the Flying Boat because by laminating sheets with the grain crossing at right angles, the finished piece could hold bolts better than other woods such as spruce. Birch also withstood stress better and made a better molded product (Barton 1982:85).

The Duramold process was cutting edge technology in the early 1940s, mainly because it was the first such process to use synthetic resins.

> Three different types of epoxy resin glues were used: phenol formaldehyde resin cured by heating to 300 degrees F., a urea formaldehyde type glue which cured at 70 degrees F. or above, and a medium-temperature resorcinal formaldehyde type glue that became available after the project was well under way [Barton 1982:82].

Advances in Duramold technology continued after the contract for the Flying Boat was signed.

> 'We built some fantastic types of Duramold plywood designed for the job it had to do--whether it was bearing or shear or tension--and developed special corner angles to replace glue blocks. We demonstrated that glue blocks were a serious problem in wood construction because of differential expansion with and across the grain. I would say that the corner angle substitute for the glue block

> was the greatest development in plywood history. We went to real thin plies, maybe a hundredths [sic] of an inch thick, and then built up angles that had maybe ten or more plies with little fillets glued in at the angle. The men wore white gloves . . . in order not to put fingerprints on the laminations when they were building them up. A fingerprint was assumed to create a bum glue joint' [Carl Babberger, personal communication quoted in Barton 1982:86].

Hindsight, sensationalist journalism, and Hughes' eccentricities in his later years have led to emphasis on the seeming oddities of the HK-1. The fact that it never went into production has added to the mystique of the plane, but many experimental projects commissioned during the war were abandoned at the prototype stage, often because the government declined to contract for them after they were developed. In the context of 1930s aviation, the Hughes HK-1 was a challenge to build because of its great size and because it was to be built of non-strategic laminated wood. The overwhelming trend after the 1930s was toward metal construction of planes. Were it not for the war contract that specified non-metal construction, it is doubtful that Hughes would have tackled the project in the same way. By the time the Hughes flying boat prototype was completed, the war was over, the supply of light metals for aircraft was adequate, and experiments with jet engines were underway. The armed forces had no need of the flying boat it had commissioned.

The Hughes Workforce in the 1940s

The employees in the 1940s (Table 2) were almost all white males of Northern European extraction; for example, wood workers tended to be "a bunch of Swedes" (Barton 1982:85). Men occupied all administrative and design positions and before the war, all the production jobs as well. Many of them were skilled machinists, cabinetmakers, and in other trades; most of the designers had attended college, even though not every one had a degree. The roots of the industry in hands-on experimentation (not to say basement tinkering) made formal credentials less important than practical experience at this period.

As men left the factory for war service, many were replaced by women, who worked at fabrication and assembly jobs requiring overalls or slacks, far different from the suits and dresses worn by female office workers (Figure 9). This was not unique to Hughes Aircraft; it happened throughout the aircraft and other industries. Cartoons from the early 1940s portray women as preserving their femininity even while learning new skills (Figure 10). HAC's policy on pregnancy was not made public; it was probably assumed that a woman would leave before or after her child was born. The airframe manufacturers and the War Labor Board ordered that "female employees who were on the payroll on July 6, 1942, and who were terminated because of pregnancy prior to March 3, 1943, shall be deemed to have been on authorized leave of absence between the date of their termination and March 3, 1943, for the purposes of computing their retroactive wage adjustments" (Southern California Aircraft Industry [SCAI] 1943:no pagination).

The prevailing attitude toward women seems to have been tolerant skepticism. This is reflected in a series of columns in the company newspaper purportedly by "Minnie the Machinist," but probably written by Chief Engineer Stanley Bell. Minnie is portrayed as a well-intentioned worker, but ignorant of the ways and language of the machine shop.

Table 2. Employment at HAC Culver City

	DIVISION		
Year	**Electronics**	**Aircraft**	**Total**
1934	0	6	6
1935	0	6	6
1936	1	44	45
1937	2	38	40
1938	3	39	42
1939	4	111	115
1940	4	246	250
1941	5	621	626
1942	6	no data available	no data available
1943	7	no data available	no data available
1944	14	1805	1819
1945	21	1225	1246
1946	45	1157	1202
1947	90	1932	2022
1948	210	968	1178
1949	826	2276	3102
1950	2085	1021*	3106
1951	3735	1643*	5378
1952	3842	1837*	5679
1953	4108	1662*	5770
1959	7259	Hughes Tool separated from Hughes Aircraft Company	7259
1962	2897		2897

* Employees of Hughes Tool Company
(Source: HAC 1958c)

Figure 9. Advertisements for Women's Work Clothing.
(Left: *Hughesnews*, 1942 3(20):7. Right: *Hughesnews*, 1942 3(16):7)

August 17

Charley, the boss, came by this morning, and asked me what I knew about filing. Thinking I was going to get a crack at one of these cushy office jobs, I started spreading it on about alphabetical order and cross references and stuff. He just said, "Can the wisecracks, sister; this is some pulley brackets that need dressing up. . . ."

So I came. He got a lot of overgrown nail files and started telling me about mill files, and double-cuts, and rat tails, and all the different kinds. I don't know why only one of them is -- well, illegitimate; they were all - - - -'s as far as I could see, after I'd worked with them awhile [B[ell] 1942a].

October 14

I was running a bunch of Dural castings through my lathe today and the boss comes over . . . and tells me to go get a carbolic tip. That one stopped me. I knew it wasn't like prop wash, so when they haven't got a carbolic tip at the stock room, I went over to First Aid.

Of course, I not only get told off for being out the shop so long, but also the merry ha-ha for showing up with a wad of cotton soaked in carbolic acid. How in the name of ----H----- would I know the boss said CARBALLOY? [B[ell] 1942c].

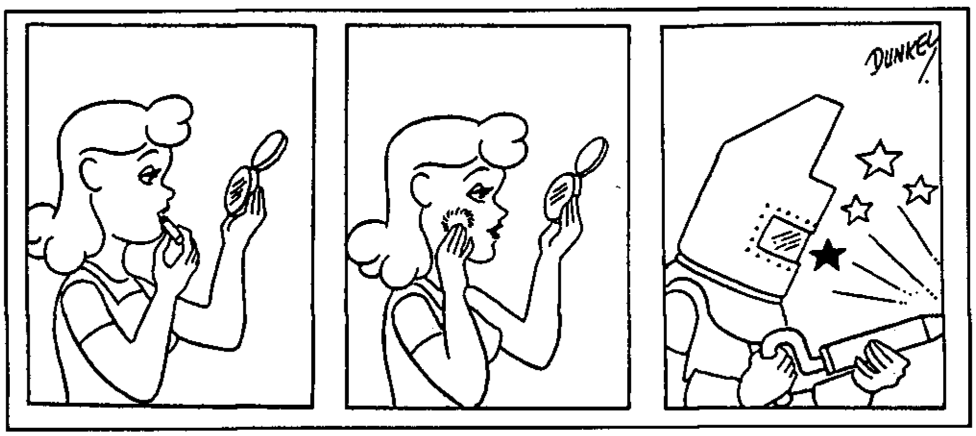

Figure 10. 'Rosie the Riveter'.
(*Hughesnews* 1942 3(31):6)

Men had a range of opinions about women's presence in the workplace; mainly cordial views were expressed in the upbeat pages of *Hughesnews*:

Nice People
We have gals that are stout,
And gals that are thin,
And others high like a tree;
But we know they are helping to win the war
So they're all swell gals to me.
Some are married, and some are not,
Some are happy and free;
But they're all in the scrap to beat the Jap,
Soon the war will be in their lap,
So they're all swell gals to me [Littell 1942].

Five men and one woman voiced their opinions in the "Speak Your Thought" column (Signor 1942b) on the question: "Do you think women in industry, earning the same wages as a man and having a voice in labor matters, will affect American homes after the war?" The responses varied, but none expected that women would remain a substantial part of the workforce after the war emergency. The men expressed the idea that women would have learned to be more sympathetic to their husbands' daily grind, but they do not seem to have considered what men could learn from women's experiences.

Lela Kiefer, Inspector	I think the majority of married women now employed in industry will be very happy to be in their own homes after this war is over. I believe they will be thankful to return to their families and resume a normal life, regardless of the money involved.
Ray Yarter, Inspection Department	. . . The women are doing fine alongside of what few men remain, but it's still almost impossible to train a girl (or even a man who is mechanically inclined) to operate and 'set-up' much of our intricate . . . machinery, inside of two or three months. Yes, a person, male or female, can 'run' a machine after it's been 'set-up' by some one, but it still takes months of training and years of experience to do both. . . . Don't get me wrong; I'm not against women in industry, but I'm just trying to point out that they can't do the things a man can MECHANICALLY. I feel that after this war, many American homes will feel the effect of women in industry, accustomed to shop manners and habits. It will be a miracle upon the opposite sex's part to restore themselves back into the vibration of a home.
Al Kornblum, Armament Engineering	This latest step in the evolution of 'equalization of the sexes' should result in a more complete understanding of the problems of earning a living on the part of the wife, and lead to a more harmonious relationship.
Wayne Anderson, Main Tool Crib	In the past, with women working, at not a great wage, they have built up a semi-ideal of being equal to a man. Now that many women are working in factories, having a voice in labor and earning the same wage as a man, they will build up a much greater ideal; whicb they will not relinquish back to the male sex, at any cost, to return back to normal life of the home.
Barney Cunningham, Manufacturing superintendent's office	. . . women . . . in industry . . . are performing a wonderful service, both to their country and themselves . . . However, for most of them I feel that this is only a temporary and necessary arrangement and that, "When the Lights go on Again,' the majority will establish and obtain the homes and bappiness which are rightfully theirs and to which they will be justly entitled. . . . The experiences which they are undergoing now will undoubtedly tend toward . . . a 'husband appreciation' and [make them] aware of some of the problems with whicb the masculine gender is confronted.
Gene Signor	. . . For the woman who has to work in order to support herself or her cbildren, I say yes, but for the woman whose husband is working . . . I say NO. We still have unemployment here in the United States . . . Women have done, and are doing, a splendid job . . . they have taken the strain off of the production question for manpower; however, even they cannot relieve the strain altogether, because it is the skilled mechanic and the trained engineer that form tbe backbone of our American production. . . . I cannot see how any woman can return to home life and try to carry on from where she left off. . . . Our greatest task after the war, is readjusting. If this readjustment can take place between husband and wife without conflict, then perhaps our American home will resume its unity; but the changed ideas of each man and woman will cause much trouble without an understanding between them. Right now, our object is Victory, but can we really call it a victory if our American home life becomes threatened, from independence?

During the war, all of southern California prepared for enemy attack. There were black-outs and a civil defense organization, among other activities. The airframe manufacturers took the situation seriously and devoted much more effort and funding to protection; for example, the Douglas Aircraft Santa Monica plant had a mock residential district on the roof as camouflage (*Douglas Airview* 1945). The Douglas plant, however, was engaged in production; the Hughes plant, engaged only in prototype production, had no camouflage. Protection from aerial attack was provided by barrage balloons moored in the vicinity, although employees who worked there at the time do not remember them. Air raid drills were held, signaled by a "horn-like" siren. There were no formal air raid shelters, as at the Douglas plant where every restroom was reinforced to double as a shelter. In case of an air raid, Hughes' employees were directed to find shelter in the "ditch [probably Centinela Creek] behind what was later Building 1" (L. Leonard, personal communication 1995).

Security was a serious matter, even before the United States' entry into the war. Security guards were stationed at the gates, and each employee had to wear a badge for entry. This concern continued into the Cold War. Awareness of the war was marked in *Hughesnews* by information about gas rationing, requirements to register place of birth and citizenship, patriotic essays, and so on. Because HAC was engaged in prototype work, it could not show its planes in action, as was common in the glossy Douglas employees' magazine *Douglas Airview*.

In typical HAC irreverent fashion, *Hughesnews* published a series of short humorous essays, "The Adventures of Little Ivan Imwayoff" dealing with current events and airplane design. The articles were accompanied by cartoons that seem to illustrate in-jokes about design concerns as well as conceptions of the Russians, who were then valued allies of the U.S. (Fleck 1941:4).

A hallmark of the aircraft industry from the 1920s through at least the 1940s was the enthusiasm of the workers. The first aeronautical engineering graduates of universities in the 1930s have been described as "optimistic and enthusiastic" (Stratford 1992:839). Despite work-weeks of far more than 40 hours and strong opposition to unionization by employers,"most workers were happy to put in long hours to be part of the excitement of building better aircraft" (Vander Meulen 1991:154).

Employees at Hughes Aircraft Company seem to have shared these sentiments. A civil engineer who conducted stress analysis of elements of the flying boat described his job at Hughes during the war years as, "the most interesting job of my life" (T. Amneus, personal communication 1995). His sentiments were echoed by an accountant who worked at Hughes during the war years and later. She said, "All the people there were hardworking. They liked to go to work, [the company] was not afraid of overtime, although salaried employees didn't get overtime" (L. Leonard, personal communication 1995).

Hughes employees could laugh at themselves, often with tongue in cheek. A test engineer was described as "a guy who gets paid for breaking things" (*Hughesnews* 1941c), and an aeronautical engineer was described as:

> one who passes as an exacting expert on the strength of being able to turn out, with prolific fortitude, strings of incomprehensible formulae calculated with micrometric precision from extremely vague assumptions which are based upon debatable figures acquired from inconclusive tests and quite incomplete experiments carried out with instruments of problematic accuracy by persons of redoubtable reliability and of rather dubious mentality with the particular anticipation of disconcerting and annoying a group of hopelessly chimerical fanatics described altogether too frequently as airplane designers [*Hughesnews* 1941f].

The employees seem to have been a lively group, judging from accounts in the company newsletter during the 1940s. The Recreation Committee was a key group in organizing activities. There was an active social life among co-workers that included dinners in private homes, fishing trips, an annual picnic, and periodic dances. There were a number of hobby and sports groups of various sizes and durations.

Bowling was the premier company sport, often accounting for as much as an entire page of the newsletter (out of six total). Different departments had teams and the scores were published regularly. Twenty-four teams competed in the Hughes Aircraft League in mid-1941, identified by department (Loft, Tool and Die, Supervisors, and so on) or other descriptor such as Wives, Girls, or Office Girls (Akerstein 1941; La Comb 1941). Different company teams competed in the Southern California Aircraft League (*Hughesnews* 1941j). Players were handicapped to adjust for varied skill levels and bowling was esteemed as an important social leveler.

> Bowling is probably the one recreation that brings together individuals from every position in the company, to match abilities on an even basis - to enable us to become acquainted, and to help forge us into the world-famous organization that is our destiny [*Hughesnews* 1941h].

At the plant, engineers and designers regularly played volleyball at lunch between Buildings 2 and 6 (T. Amneus, personal communication 1995). In the 1940s lunchtime poker games were also popular (*Hughesnews* 1941g; 1941d), although by the 1950s "gambling in any form" was forbidden by company policy (*Hughesviews* 1953:43).

In common with the rest of the industry, Hughes workers were not unionized until after the war. The National War Labor Board provided job descriptions and qualifications for the aircraft industry in 1943 as a means of wage stabilization, based on definitions drawn up by management of the major companies, although there was a provision for collective bargaining. Lockheed, North American Aviation, Douglas, Vega, and Consolidated Vultee were the only companies mentioned by name (SCAI 1943:no pagination). It is not known whether HAC had a representative on the manufacturers' committee since it was comprised mainly of airframe producers and HAC's projects were all still in the prototype stage. The wage rates at HAC were probably similar, however, since the committee's figures were arrived at by an industry-wide canvass.

Job attributes were scored according to mental capacity, skill, and the amount of responsibility for material and equipment required; they were also graded on the difficulty of job conditions, physical application required, and unavoidable hazards. Based on scores of 20 to 100 points for each attribute, grades A, B, and C were derived and used to adjust wages. Minimum wages in this system were $0.75 to $0.80 per hour; maximum wages were $1.25 to $1.50 per hour (SCAI 1943:no pagination).

The description of "unavoidable hazards" illuminates safety concerns of the day. A Grade A Jig Builder, for example, who was expected to use trigonometry and earned the maximum wage, faced noisy and dirty working conditions and the unavoidable hazard of "broken bones while climbing upon the larger jigs." A Grade A Anodizer, who only had "to follow simple written or verbal instruction" to immerse parts in chemical tanks, faced unavoidable hazards of "severe burns" because of "disagreeable working conditions" that included "soap, acid and carbon tetrachloride fumes," and occasional unavoidable "splashing of chromic acid." He earned $0.85 to $0.95 per hour (SCAI 1943:no pagination). There was little or no public awareness of hazardous materials' impacts on health. There were frequent safety warnings in *Hughesnews*, exclusively for physical injuries such as severed fingers. "It has 474 fingers, 59 hands, 43 arms, 8 backs, 4 bodies (not corpses), 25 legs, 14 feet, 6 heads, 82 eyes. . . . it IS a Monster . . . of CARELESSNESS. The above figures represent the total of injuries to different parts of your anatomy during the last month" (Signor 1942a).

The workforce in the 1940s did not have the benefit package that was available later, although a medical plan (Group Hospitalization Plan) covering both individuals and families was offered in 1941 (*Hughesnews* 1941i:2). An innovation of the 1930s, even before the move to Culver City, was the credit union. This was a New Deal institution run by a committee elected by the credit union members. It made loans and paid interest (4.5 percent in 1941) on deposits (*Hughesnews* 1942a). Workers at HAC held union membership as early as 1947 (HAC 1947). Union activities were reported in *Hughesnews*, for instance, the contract signed with the United Aircraft Welders of America, Local No. 1 (*Hughesnews* 1949c:2).

As early as 1941, HAC began a long tradition of providing educational programs for employees (*Hughesnews* 1942d, 1949e). In addition classes organized by plant management and individual sections arranged their own programs. In 1941, for instance, the Stockroom "had an extremely good discussion of 'AN' [Army-Navy specified] bolts and screws and a talk on raw materials and sheet stock." They also planned a group showing of Alcoa's technicolor film "Aluminum from Mine to Mill" and U. S. Steel's "Steel from Mine to Mill" (Wilson 1941). HAC also followed the industry practice of recognizing service to the company with lapel pins bearing the company's logo and the number of years of employment (at five-year intervals). Another company tradition was the Christmas turkey distribution. A rail spur of the Pacific Electric Railway served the plant, but early in the occupation truck deliveries replaced rail deliveries. Its subsequent use was mainly to bring in a boxcar of turkeys for distribution (*Hughesnews* 1949g; V. Olson, personal communication 1995). Many former employees remember this custom, followed by leaving the unfrozen turkey on the back seat of the car until reaching home after the departmental celebration in a nearby cocktail lounge (J. Weber, personal communication 1995).

Post-World War II Developments

Hughes' contracts during World War II were for design and construction of prototypes, which were all completed but not soon enough for wartime production. All aircraft companies faced post-war retrenchment, although both government and the industry began trying to avoid abrupt cancellations of contracts as early as 1943 (Rae 1968:173). Despite these efforts, at the end of the war the aircraft industry went into a slump.

> By the end of 1945, the Army and the Navy had canceled 18,267 contracts totaling $21,578,462,000 in value. . . . By December, 1945, only 16 airframe plants remained of the 66 that had been in the industry one year earlier [Simonson 1968:181].

"Between 1944 and 1947 the industry's sales dropped by over 90 per cent, with corresponding effects on earnings and employment" (Rae 1968:173). The entire industry was forced to regroup. Companies tried manufacturing diverse peace products from "a prototype plastic-and-aluminum packaged home" and "experimental flying autos" ("Convair History," cited in Rae 1968:181), to beer barrels and billiard tables. At HAC, the Duramold process was applied to a 7 1/2 foot fisherman's dinghy and wooden cabinets for pinball machines and televisions, among other products. "Built by precision engineers, they incorporated some of the finest workmanship ever put into a product of this type" (HAC 1958b:13).

After completing the prototypes for which there were no contracts, HAC continued along the already strong research and development trajectory initiated during the war. The company readjusted and adapted the existing physical plant (Figure 11) by not competing in the over-crowded airframe manufacturing area but instead pursuing development contracts for new products such as missiles, radar, electronics, and satellites, turning its attention to problems associated with the Cold War and the space race.

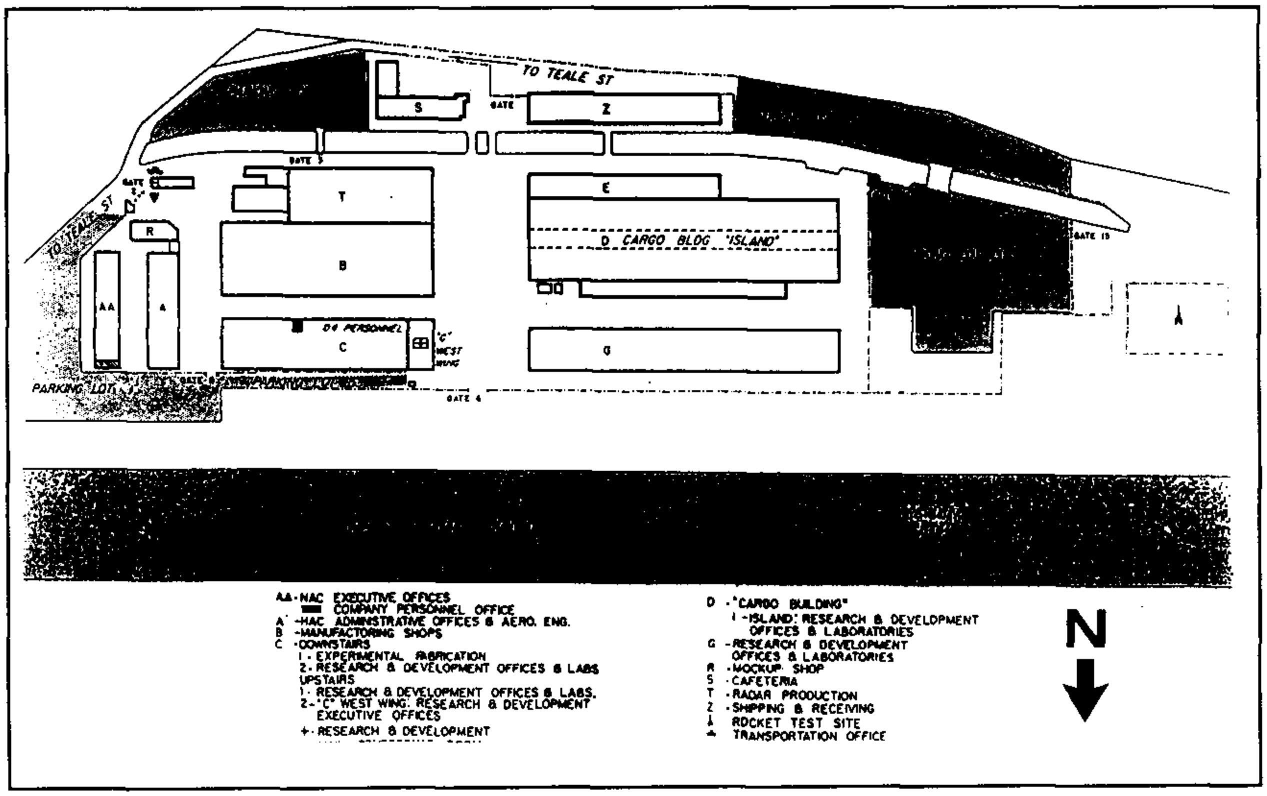

Figure 11. Hughes Plant in the 1950s.
(HAC Research and Development Administrative Staff and Service Activities c.1950:4-5)

Research and Development at HAC

Hughes' entrepreneurialism had an opportunistic streak; besides the D-2, XF-11, and HK-1, HAC had other projects under development. During his record-setting flights of the 1930s, Hughes was concerned about radio contact and worked with radio engineers to improve it. HAC included a Radio Department to develop and install radio systems in HAC planes. The department was small, consisting of three engineers, a technician, a communications specialist, and a stenographer, but by 1944 had developed a number of successful products, among them a submarine radio marker buoy (AN/CRN-1), the first interphone system for aircraft, and a walkie-talkie, "one of the first permanently sealed units of its kind"

(AN/CRC-7 and AN/URC-2). The Radio Department was first located outside the gates of the Culver City plant, but in 1945 moved to the Cargo Building (Building 15) mezzanine (Harwood 1958:no pagination).

By virtue of the Radio Department, HAC was well-positioned for electronics, or avionics (AVIation electrONICS) as it became known. By 1946, the Radio Department had moved in the direction of research and development. A half-million dollar contract with the Navy for antennas was the first impetus for growth. There were 19 employees in 1945, among them several engineers, three draftsmen, five machinists in the model shop, a laboratory technician, and two stenographers. A subsequent contract in 1946 for an Air Force navigation system led to the hiring of engineers Simon Ramo and Dean Wooldridge for "highly technical research work" and the Electronics (later Electronics and Guided Missile) Department was formed. By the end of 1948 there were 110 employees (Harwood 1958:no pagination).

Both Ramo and Wooldridge were graduates of California Institute of Technology; Ramo came to HAC from General Electric's Research Laboratory, and Wooldridge left a vice-presidency at Bell Telephone Laboratories (HAC c.1986:11). Both were highly creative and they surrounded themselves with similar staff. HAC was able to trade on the reputations of these men (Rubel 1955:7). Not only did they provide a brain-storming group to tackle design problems, together they had an impressive network of professional contacts that helped define markets and potential sources of contracts. For example, the contract for the Atomic Energy Commission high-speed indicator was initiated because a former associate of Wooldridge worked at Los Alamos and told him what they needed (Rubel 1955:4).

In 1948, the Electronics Department turned its attention to the development of non-military products. They projected the use of electronics for many items that became standard household and office equipment by the 1990s. They proposed a number of applications for magnetic recording techniques, such as an "improved home [tape] recorder," a "new electronic organ" that appears to have been like a synthesizer, a "talking book machine . . . to record entire books," machines for credit accounting, inventory control, making airline reservations, "automatic control equipment for machine tools," and "music-advertising equipment" that seems to pre-figure Muzak. They also discussed an "electronic Nim" game with lights that could play against a person. They included digital and analog computers in their list of potential products, as well as various applications of radar. They foresaw the utility of transistors as "a spectacular new device that is fated ultimately to replace many vacuum tubes that are now in use. It will be smaller, lighter, simpler and cheaper to build, and it will not wear out" (HAC Electronics Department 1948:11-12).

The Terrain Warning Indicator was one of the first radar applications produced by HAC. In the days before jet aircraft, planes needed warnings to avoid hitting obstacles. After nine DC-3s crashed into mountains in 1946, TWA contacted the Radio Department about a warning device. HAC modified war surplus radar sets and added an antenna, producing a small, light system (9 x 8 x 15 inches, weighing 15 pounds) that warned pilots of impending danger with bells and flashing lights within 2000 feet of an obstacle. HAC began commercial production of these sets in Building 15 and sold 500 of them by the time they were discontinued in 1952 (Rubel 1955:2-4).

In 1947, the Atomic Energy Commission paid for developing a high speed indicator ("a high speed precision oscilloscope with trigger sweep") and later ordered a number of them, produced at the Culver City plant in the Cargo Building. By the time the item went out of production in 1951, HAC had earned $900,000 for sales, plus the approximately $1,000,000 development contract. The significance of the project lay in the experience it provided the engineers in "designing and packaging intricate circuits for test equipment" and in production (Rubel 1955:4, 6).

This project shows some of the advantages of doing both research and development without subcontractors, a practice that became common at HAC (HAC c. 1986:27). Designing included custom-built cabinets for the project, with drawers sliding on ball-bearings for easy maintenance of equipment. "There was no clear line in the early days between the laboratories and the production shop"; the experimental production line was on the mezzanine of Building 15 (D). "Engineers often walked onto the production line and made on-the-spot changes in wiring diagrams for the girls at the work benches" (Rubel 1955:5).

Also in 1947, HAC was awarded a guided missile contract from the Air Force for the Tiamat missile, then under development (ID Study 1958b:16). Later, the Falcon "self-guided air-to-air missile" was developed (ID Study 1958c:19), incorporating their experience with both ordnance and electronics. Several generations of Falcon missiles generated income and reputation for HAC. In 1948, HAC began designing a fire control system; because

> modern bombers. . . could operate at night and in any kind of weather . . .[the] Air Force needed a system for jet interceptors which would enable pilots to locate and shoot down targets without seeing them. An important function of such a system would be the firing of a plane's weapons at exactly the right moment; thus it was called a fire control system [Byoir and Associates 1955:12].

The original contract was secured by the efforts of representatives from the Armament Laboratory, which was selling Hughes feed boosters and ammunition chutes to the Air Force (Rubel 1955:7). HAC went on to design and manufacture several generations of fire control systems (HAC c. 1986:17), which were located in the nose section of the plane. External influences impacted the development schedule for the prototype by speeding it up: a collision of jet planes in 1948 and the deterioration of the international situation "as the Communists made more evident their designs on the free world" (Rubel 1955:8). HAC cut three months off its original time estimate and managed to complete the first phase on time. In "the race to meet the . . . deadlines, . . . engineers worked round the clock and technicians slept on their work benches" (Rubel 1955:10). The second phase, flight testing, was completed two days early. This feat earned laudatory copy in the company newspaper:

> every employee played a leading role. It is not a story for the singling out of individuals nor even of departments, because every department acknowledges that it would have been helpless had it not been for another [*Hughesnews* 1949b:1].

The ability to meet the accelerated deadlines probably did much to relieve the Air Force of doubts over contracting with a small company, as Hughes was compared to the giant airframe manufacturers. The fire control systems went on to become a major earner for HAC. "By 1952, sales had climbed to $180 million, and these [fire control] systems constituted a large share of . . . business" (HAC c. 1986:17).

The postwar involvement of Wooldridge and Ramo in R&D led to changes in the physical plant not only to accommodate new projects, but to adjust to new concepts of management. Ramo took credit for giving his engineers offices, instead of desks in a shared common room.

> I was considered a great pioneer because I insisted upon giving some privacy, in ten-by-ten or ten-by-twelve cubicles, to the best scientists and engineers that we hired, so that they could think and not be continually interrupted by the telephone of their next-door neighbor. The airplane companies who didn't understand this had huge bull pen[s] with the desks against each other. It was ridiculous to think that they were saving some money in facilities. It had never entered their mind that private offices was [sic] a money-saving measure. They were simply accustomed to something where presumably everybody's working because everybody's being watched. They were Rosie-the-Riveter companies [Ramo 1985:349].

Wooldridge and Ramo made organizational changes to facilitate R&D. In a 1948 memo, they outlined a new departmental structure based on:

> many factors . . . [including] the handling of our established projects, new ones just getting under way, and still others that we expect to add . . .; the needs and aptitudes of individuals, recognizing that some individuals can contribute most in assignments with administrative and technical problems intermixed, while others should be relieved of administrative worries, or not yet burdened with them, so that they might better continue to direct the technical activities of a tough project, or to invent, or to carry through difficult experiments or analyses [Wooldridge and Ramo 1948].

The department was divided into five sections, with the section heads responsible for the activities of their area:

1. Antennas: HS Bomber Antenna, Missile Antenna, MX-904 Missile Fuze Antenna;
2. Circuit and System Development: AEC Advanced Development, AEC Production, All-weather Aircraft interceptor development, Hughes Airline radar;
3. Computers and Controls: MX-904 Missile control, antenna positioning mechanisms (MX-904 and ARTS), Seeker system simulator, celestial navigation guidance computer, magnetic memory devices, tactical bomb director;
4. Navigation and Radar Research: celestial navigation system, daylight celestial navigation, N.A. and other celestial navigation applications, high resolution radar techniques;
5. Seekers and Missile Electronics: MX-904 seeker, MX-904 launching plane radar, ARTS seeker, Boeing Gapa Seeker study, Navy counter measures [Wooldridge and Ramo 1948:1-2].

HAC was able to support creative design work because it also devised creative solutions in support of design engineering. Besides brainstorming and drawing ideals for circuitry and other electronic items, a great deal of design was hands-on, requiring various hardware items. "The Electronic Stores were the first self-service electronics store in an aerospace plant. They took the idea from the phone company. They had wide-open bins, counters, etc. with electronic components and related items. Engineers (and other people) could come in and browse. Engineers bought components at a check stand by requisition. At the end of the day the requisitions were taken to the managers of different departments for authorization" [J. Patton, personal communication 1995]. This system was quick, so engineers need not specify or wait for small items, and it was cost effective because it obviated requisitioning paperwork. Stanley Mu (personal communication 1995), an engineer who worked with early transistor applications, related that sometimes he used petty cash to buy a transistor (at between $30 and $40) outside the plant when he needed one.

Because HAC was in the forefront of electronic R&D engineering, they also had to create new components and parts. "In the 1950s electronics was the big thing for radar and missiles, it had to do its job, had to be precise. They knew what they wanted, but maybe it didn't exist or it wasn't precise enough, or needed to be a different type of metal. New parts had to be developed and refined" (J. Patton, personal communication 1995).

Testing components to see if they met the specifications or qualifications for the product went on in Building 6 in the 1950s. "A good portion of the building was occupied by Components and Materials labs, rooms, and machine shops. They tested anything that might go into electronic gear: liquids, machine screws, nuts, bolts, etc. If the product didn't meet Hughes' needs, they re-designed it and made specifications and paid more for manufacturers to produce the item to their specifications" (J. Patton, personal communication 1995).

The success of electronic research and development precipitated a confrontation between Howard Hughes and his top managers. Upper management felt the company was not being well run and wanted part ownership of HAC, but Hughes did not want to relinquish control. The managers (Ramo, Wooldridge, General Manager General Harold George and his assistant Charles "Tex" Thornton) threatened to resign (Ramo 1985:262-282; HAC 1958:3). Both sides to the dispute were immoveable; finally, management resigned and formed its own company, first Ramo-Wooldridge Corporation, later TRW (Thornton-Ramo-Wooldridge).

In 1954, Hughes transferred ownership of the company to the Howard Hughes Medical Institute, a non-profit organization, "to prevent the possibility of future ownership demands by HAC management" (HAC 1958:1). This change was apparently precipitated by the demand of the Air Force, fearing disruption of production during the Korean War, for reorganization "in such a way that . . . [Hughes] personally would not be actively involved in its management" (HAC c. 1986:11). The Korean War created a market for military electronic applications, the first profitable operation of HAC (HAC 1958a:3). HAC rode this wave of prosperity until 1959, when cancellation of Air Force contracts for fire control systems resulted in the "first major layoff" (HAC c. 1986:17).

The Hughes Workforce in the 1950s

By 1951, HAC workers represented a fair proportion of aircraft employees. "Of the Los Angeles manufacturing employment totaling 483,000, more than 110,000 (about 1 out of 4) work in the aircraft industry. Of these aircraft employees, 1 out of 10 work at Hughes Aircraft Co." (HAC 1951:10). The impact of HAC on the local economy is reflected in its business with 2862 subcontractors and vendors in Los Angeles, 75 percent of them small businesses, employing 182,320 people (HAC 1951:17). Employees lived in the vicinity of the plant, contributing their spending power to the regional economy: 4,085 in Los Angeles, 1,026 in Culver City, 877 in Venice, 653 in Santa Monica, and 521 in Inglewood (HAC 1951:14).

In the 1950s, the HAC corporate culture became more formal. This is seen in the increasing sophistication of and professional input into *Hughesnews* and in such items as employee handbooks. The industrial relations policy of the 1950s included the assurance that employees would have opportunity to advance within the company and that vacancies would be filled by promotions if there were qualified replacements available, that employees would be treated "without discrimination," and that "safe, healthful, and harmonious working conditions" would be provided. Labor relations were acknowledged when the company asserted that it would "live up to the spirit--as well as the letter--of all agreements with labor organizations, and promote a better mutual understanding and relationship by fair and considerate dealings with their representatives" (*Hughesviews* 1953). The company offered life and health insurance plans, a retirement plan, a Red Cross blood bank, and a U. S. Savings Bond purchasing program in addition to the credit union (*Hughesviews* 1953).

HAC provided facilities for its employees beyond their work stations. The original Cafeteria Building constructed in 1943 was expanded in 1950. It offered both indoor and outdoor dining areas and an assembly point for company-wide announcements on special occasions (J. Patton, personal communication, 1995). The cafeteria served meals on plain white modern dinnerware. Dinner plates (10" in diameter) had a coupe shape (with no brim or well), decorated with a brown rim band. Two types of undecorated small bowls of the same manufacture were used, one conical (2 3/4") and one shallow (4 1/2" in diameter). They were backstamped "Pyroceram Tableware by Corning." The ware is described as "tile-like" and the earliest date as 1962 (Kovel and Kovel 1986:50). Small salad or dessert plates (6 5/8" in diameter) also had a coupe shape, but no decorative band. They were marked "Pyroceram Tableware by Corning/No Stovetop/No Microwave." Another type of small bowl with straight flaring sides (5 1/4" in diameter) was also used. These were marked "Syralite by Syracuse, 100-I, U.S.A." The Syracuse China Company filed the name Syralite on November 6, 1964. The date code (100) indicates 1971 and the letter code (I) indicates September 4 (Lehner 1988:63-64, 455). The rounded, modern shapes were congruent with the International Style cafeteria building. Their simplicity had the added advantage that the company could refill the service from any maker.

During the Cold War, security continued to be of concern to HAC. Employees were screened for possible subversive tendencies before they were allowed to work. Investigations before employment included checking with the "Subversive Squads" of the Los Angeles Police and Sheriff's Departments, also with the police in Long Beach and other cities, with other aircraft plants, the FBI, and also checking Communist Party membership, voter registration and subscription to Communist publications as well as "other informers" (HAC n.d.b:[1]). Badges were required for entry to the plant. Interviewees for jobs were escorted to the interview and then back to the Personnel Office. Sensitive work was carried out in Buildings C, D, and T (Buildings 5, 15, and part of Building 6) and they were restricted. Anyone not working in these restricted areas needed special permission to go there (Brown 1950:1).

Women continued to form a substantial proportion of the workforce. Beside secretarial work, they most often performed electronic assembly, seemingly because they were assumed to have nimble fingers. "This work calls for deft skill," captions a photograph showing instruction in wiring a harness board with a male instructor and four women students (*Hughesnews* 1949e:4).

Until the late 1950s the engineering staff was exclusively male. In 1952, the R&D staff was highly qualified by virtue of both education and experience; many had won awards and a number also held patents. The Advisory Council consisted of 46 men, 17 holding Ph.D.s, eight with Master's degrees, and all the rest but one with at least a Bachelor's degree. Of 75 other staff members, 13 held doctorates, 14 held Master's, and all the rest except 8 held Bachelor's degrees. Those without degrees had extensive experience and often worked in technical support jobs, such as Head of the Instrumentation Laboratory (HAC 1952).

Howard Hughes' Contributions to Aviation

Hughes' personal contribution to aviation was to set flight records, but this was not as important as the technological innovations that he sponsored and/or designed. Despite his rather unorthodox management style, he fostered creativity in engineering design and production. A number of "firsts" are associated with Hughes and HAC. With the Flying Boat, in addition to the application of Duramold technology to sizable objects, the project added to the body of knowledge on the performance of large aircraft. Further experimentation that continued after the HK-1 was built was applied to massive commercial and military planes.

In the electronics field HAC, but perhaps not Hughes himself, pioneered critical defense systems such as fire control, radar, guided missiles, and satellites. Pursuing products in these spheres led to numerous innovations in design, the design process itself, experimentation, assembly, and testing. In terms of development of the electronics industry, HAC brought together a number of innovative thinkers, most notably Simon Ramo, Dean Wooldridge and Tex Thornton, who went on to form their own companies. When these three left HAC, Ramo and Wooldridge formed the Ramo-Wooldridge Corporation and Thornton and others formed Lytton Industries. Later, they joined to form TRW (Thornton-Ramo-Wooldridge), a major electronics firm.

PROJECT INFORMATION STATEMENT

This document has been prepared as one of several mitigation measures undertaken in anticipation of potential impacts which may affect the HAC District. The Determination of Eligibility in 1991 concluded that 15 of the 22 buildings on the site were eligible as a unified entity of historically and functionally related properties, with one of them (Building 15, the Cargo Building) being individually eligible for its exceptional engineering values. Seven structures were assessed at that time as noncontributing because of construction after 1953, the period of significance, or distance from the concentration of the contributing cluster. One structure, Building 12, was later added to the list of contributors, after the date of its construction was corrected.

The initial review under Section 106 led to a Programmatic Agreement among the U. S. Army Corps of Engineers, the California State Historic Preservation Officer, the Advisory Council on Historic Preservation, and other concurring parties. As the project proponent, Maguire Thomas Partners - Playa Vista has proposed the creation of an entertainment, media, and technology district on 56.9 acres of the HAC plant site. Of the 16 contributing buildings, 11 are to be preserved and resued for offices and studio support; five (Buildings 5, 6, 12, 19, and 20) will be demolished. Building 2 will be reoriented. Construction will add sound stages, studios, and entertainment office facilities (HRG 1995:2).

With appropriate safeguards that modifications and new construction will be compatible; the existing circulation grids will maintain the relationship between structures; that the cafeteria, fire station, administrative and office buildings will be preserved, along with selected examples of the research and development facilities, manufacturing, and support property types; an interpretive program will be developed; and that this documentation be prepared to record the historical and current appearance of these structures, a subsequent Determination of Eligibility submitted by the Corps of Engineers in 1995 concluded that proposed mitigating measures will protect the integrity of the District.

Greenwood and Associates has prepared this document in partial fulfillment of the stipulations of the Programmatic Agreement. Under the supervision of Roberta S. Greenwood as Principal Investigator, this has been a cooperative effort by David De Vries for the photography and duplication of historical photos and drawings; Judith R. Rasson, Ph. D., who accomplished the background research; and Dana N. Slawson, M. A., who wrote the physical description of all the structures.

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Plans and Drawings

(All drawing sets on file, Hughes Aircraft Facilites and Design Layout Drawing File Room)

Gogerty, Henry L.

1941 February 3. Construction Drawings. Processing Building [Building 5], Hughes Aircraft Company.

1941 February 20. Construction Drawings. Assembly Building [Building 6], Hughes Aircraft Company.

1942 October 30. Construction Drawings. Engineering and Mock-Up Building [Building 2], Hughes Aircraft Company.

1942 December 15. Construction Drawings. Engineering and Mock-Up Building [Building No. 2], Hughes Aircraft Company.

1943 September 9. Construction Drawings. Cargo Plane Assembly Building [Building No. 14, 15, 16], Hughes Aircraft Company.

1949 April 12. Construction Drawings. Addition to Electronics Building 'C' [Building No. 5], Hughes Aircraft Company.

1949 May 3. Construction Drawings. Storage Room and Shipping Platform [Building 8], Hughes Aircraft Company.

1949 May 18. Construction Drawings. Manufacturing Building 'T' [Building 6], Hughes Aircraft Company.

1949 December 12. Construction Drawings. Relocation of Building 'L' [Building No. 11], Hughes Aircraft Company.

1950 January 23. Construction Drawings. Tower, Cargo Plane Assembly Building 'D' [Building No. 15], Hughes Aircraft Company.

1950 March 23. Construction Drawings. Electronic Offices and Laboratories, Cargo Plane Assembly Building 'D' [Building No. 15], Hughes Aircraft Company.

1950 March 27. Construction Drawings. Mezzanine Extensions, Cargo Plane Assembly Building 'D' [Building No. 15], Hughes Aircraft Company.

1950 August 5. Construction Drawings. Mezzanine Addition--Building 'B' [Building 6], Hughes Aircraft Company.

1950 August 5. Construction Drawings. Building 1, Administration Building [Building 'AA'], Hughes Aircraft Company.

1950 December 5. Construction Drawings. Extension Number One--Building 'B' [Building 6], Hughes Aircraft Company.

1950 December 28. Construction Drawings. Interior finishes, Administration Building 'A-A', Hughes Aircraft Company.

1950 December 28. Construction Drawings. Extension Number Three, Building 'C' [Building No. 5], Hughes Aircraft Company.

1951 Office and Laboratory Building G-2 [Building No. 21], Hughes Aircraft Company.

1951 January 6. Construction Drawings. Warehouse Building 'Z' [Building 17], Hughes Aircraft Company.

1951 January 28. Construction Drawings. Manufacturing Building 'G-1' [Building 20], Hughes Aircraft Company.

1951 February 28. Construction Drawings. Remodelling of Cafeteria--Building 'S' [Building No. 10], Hughes Aircraft Company.

1951 April 11. Construction Drawings. Extension No. 1 to Administration Building 'AA', Hughes Aircraft Company.

1951 April 11. Construction Drawings. Extension No. 1 to Manufacturing Building 'T' [Building No. 6], Hughes Aircraft Company.

1951 April 13. Construction Drawings. Modernized Machine Shop, Building 'C' [Building No. 5], Hughes Aircraft Company.

1951 May 1. Construction Drawings. Alterations to Electronics Building 'C', [Building 5], Hughes Aircraft Company.

1952 Construction Drawings. Building No. 19, Hughes Aircraft Company.

Hughes Aircraft Company, Plant Engineering Department

1952 February 19. Construction Drawings. Fire Station [Building No. 18], Hughes Aircraft Company.

1952 June 6. Additional Facilities, Building 21 (G-2), Hughes Aircraft Company.

1953 January 2. Construction Drawings. Building No. 19 Addition, New Mail Room on Dock. Hughes Aircraft Company.

1953 June 11. Record Drawings, Building 1, Hughes Aircraft Company.

1956 May 25. Construction Drawings. Medical Center Facility [Building No. 17], Hughes Aircraft Company.

1963 August 8. Record Drawings. Building 1, Hughes Aircraft Company.

1972 August 4. Construction Drawings. Mezzanine Extension [Building No. 17], Hughes Aircraft Company.

Hughes Tool Company, Aircraft Division, Plant Engineering
1966 January 10. Construction Drawings. Storage Lean-to Shed [Building 16], Hughes Aircraft Company.

Integrated Facilities Incorporated
1990 March 28. Construction Drawings. Addiiton, Phase II Retrofit Lobby, (Building No. 6), Hughes Aircraft Company.

Norman Engineering Company
1973 November 21. Construction Drawings. Interior Alterations, Modifications to Cafeteria Building No. 10.

Informants

Amneus, Thomas, Hughes employee, 1941-1946.

Greenwood, Roberta S., Principal Investigator.

Hall, G. Peyton, Director of Architecture, Historic Resources Group.

Leonard, Hugh, Hughes employee, 1944-1981.

Leonard, Laura (Pesola), Hughes employee, 1948, 1952-1985.

Mu, Stanley, Hughes employee, 1950-1968.

Olson, Vernon, Hughes employee, 1952-present (1995).

Patton, John W., Hughes employee, 1951-1984.

Rasson, Victor U., Douglas Aircraft employee, 1936-1973.

Richards, Doug, Chief Operating Engineer, ABM Engineering Services.

Romano, Al, Hughes employee 1987-present (1995); Assistant Operations Manager, Maguire Thomas Partners.

Stubbs, Jack, Hughes employee, 1945-1988.

Tweten, John F., Hughes employee, 1952-1985.

Weber, Jack, Hughes employee, 1949-1986.

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ADDENDUM TO:
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FIELD RECORDS

HISTORIC AMERICAN ENGINEERING RECORD
National Park Service
U.S. Department of the Interior
1849 C Street NW
Washington, DC 20240-0001