VIII.1

SPACE VEHICLE TEST STANDS

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INTRODUCTION

One of the pacing items in this Nation's accelerated space program is the construction of facilities for the manufacture, development, testing, check-out, transportation and launching of space vehicles. Behind each successful launching are countless hours of effort in development, quality and reliability checks and tests of engines, components, boosters, and stacked stages; including pressure tests, cold-flow tests and hot firing (or static) tests; all to assure the safest possible trip for the men or instrumentation in the space craft.

Today, in the time available, we will discuss typical facilities required for one important phase of testing, specifically, the facilities in the Test Division of NASA's Marshall Space Flight Center used to perform experimental and development testing of rocket engines, launch vehicle stages, and their components. These facilities are for the testing of liquid fueled engines and stages. As we discuss engines, stages and vehicles, it will be helpful to refer to Figure 1 "Saturn Configurations".

FUNCTIONS OF TEST STANDS

Test stands serve many important and essential functions. They help confirm or refute design conclusions by actual tests, suggest improvements, find and help eliminate "bugs" in space vehicle engines, components and stages, and check out actual flight vehicles. Such test stands are widely used in two major, often overlapping, areas-for development testing and for acceptance testing.

Development testing is essential in securing the required performance and reliability in a new engine, booster or stage, and space vehicles of new or untried combinations of stages. Acceptance testing is to assure that a particular piece of equipment from a valve to a complete multi-engine stage will perform as required.

The information from these tests is obtained by the use of many hundreds of channels of instrumentation measuring pressures, temperatures, forces, flows, vibrations and other parameters. The use of test stands permits testing on the ground with, in most cases, the object being tested still intact at the completion of the test and available for inspection, analysis, modification , and still further testing of the same object. Since most test items are at least as expensive as the test facility, it is easy to see that such testing is much more economical than to stack up an unproven group of stages and attempting to launch such a vehicle.

TYPES OF TEST STANDS

It is to be noted that many tests are made during the development and manufacture of each part of a space vehicle. This area of testing preceeds the testing now under discussion.

Many and varied types of test stands and facilities are required for experimental and development testing of engines, major components, stages and configurations of space vehicles. They include:

1. Model Test Facilities - used to study new concepts and configurations and to aid in the design and development of promising arrangements of engines, stages, etc., as well as studies in areas where the size of the actual object makes full scale testing impractical. In this connection, some of the models of future boosters will develop thrusts greater than some of the stages presently being developed as flight vehicles.

2. Components Test Facilities - to assure that valves, lines, tanks, etc., will function properly at the extremely low temperatures encountered with liquid hydrogen and liquid oxygen.

3. Engine and Engine Systems Test Stands - for actural firing of the individual rocket engines. Engine test stands are necessary to assure that a particular engine will receive the proper quantities of propellants and develop the required thrust as well as swing, or gimbal, to give the proper direction to the stage. Engine systems testing goes one essential step further and simulates the propellant flow conditions that exist on the booster.

4. Stage Static Test Facilities - permit the actual firing of all engines of a tied down stage or booster.

5. Dynamic Test Facilities - permit the stacking of stages to form a complete vehicle to assure that the stages will match, determine centers of gravity, and for certain vibration studies.

6. Altitude Simulation Facilities - permit the study of components and actual items at simulated altitudes to assure proper functioning. A further step is to better simulate the actual enviroment by not only reduced pressures but also by simulating temperature conditions.

TEST FACILITIES AT MARSHALL SPACE FLIGHT CENTER

The Test Division at Marshall has the facilities used for the testing of the S-1 booster that has successfully flown twice to date. These existing facilities include a power plant test stand for engine testing, components test facilities, the largest known operating static booster test stand for the S-1 stage, and a dynamic test stand for the C-1 vehicle. The S-1 stage develops 1,500,000 pounds of thrust.

Now in various stages of design and construction are four new major facilities for experimental and development testing in support of the Advanced Saturn C-5 space vehicle. The S-1C stage will be the first stage of this vehicle and will be powered by 5 F-1 engines, each developing 1,500,000 pounds of thrust for a total of 7,500,000 pounds of thrust. This stage will be 5 times as powerful as the first stage of the C-1 Saturn that has been flown.

New components test facilities are now being designed to check out piping, valves, pumps and other components for this large vehicle. Because of the drastically increased size of the components for this new vehicle and the continued use of existing facilities in support of the C-1 program, these new facilities are required.

An F-1 engine systems test stand (SEE Figure 2) has been designed and will soon be under construction. This stand will be over 200 feet tall and will be used to prove out engine systems including the flight type piping connecting the engine to the booster propellant tanks.

The Advanced Saturn Static Test Facility (SEE Figure 3) is now under construction and will be used for developmental testing of the S-1C booster. The test stand will be over 400 feet tall.

An Advanced Saturn Dynamic Test Facility (SEE Figure 4) is being designed for mechanicah and structural testing of the C-5 stacked space vehicle. This facility will have the tallest structure in the group. It will be approximately 450 feet tall.

COMPOSITION OF A TYPICAL STATIC TEST FACILITY

A "typical" test facility for static firing tests consist of several major parts. A heavily reinforced blockhouse or control center houses the personnel conducting the tests, instrumentation and control systems, and observation ports, periscopes and TV viewing systems. The blockhouse is placed as close as feasible to the test stand, say 700 to 1,000 feet away, to provide more reliable instrumentation readings. It must be designed to resist the effects of a possible blast at the test stand. Walls are frequently 18" thick and of reinforced concrete.

Connecting the blockhouse to the test stand is an instrumentation and control tunnel filled with many miles of instrumentation and control cables. The tunnels also provide a safe route from the test stand for personnel, if necessary.

The test stand proper must be sufficiently strong and rigid to resist the tremendous reversible loads imposed upon it almost instantaneously during firings. Because of the necessity to have very rigid test stands, most of the larger stands are being constructed of reinforced concrete up to the tie down, or load platform, level. Beneath the load platform is a water cooled deflector to divert the flames from the engine or engines and reduce the overall height of the stand. A superstructure above the load platform provides for handling the booster or engine and provides access for inspecting, servicing, minor modifications, and the attachement of controls and instrumentation devices. On an engine test stand, the superstructure also may support the propellant run tanks. The stand also contains a fire protection system, pressurization piping, propellant fill and dump lines, lighting, TV viewing cameras, and lightning protection. Because of the greath height of planned stands, an elevator normally is provided as well as access stairs. Obstruction lighting on the test stands warn aircraft of the presence of the tall structure.

Support items for the facility include propellant storage tanks, high pressure air, inert gasses, and often liquid nitrogen. Great quantities of water are required to cool the deflector and to be available in the event of a fire. For example, the F-1 engine stand will require 125,000 gallons of water per minute at 150 pounds per square inch pressure while the S-1C stand will require 320,000 gallons per minute at the same pressure.

A reinforced concrete observation bunker is normally provided at the side of the test stand for observation of the stand during tests. The observer can cut off the test if abnormal conditions develop. The bunker normally has its own air supply for emergency use.

A support building is frequently provided in the test stand vicinity. This building houses equipment and tools for quick repairs and similar operations.

Access roads are required in the area for movement of personnel and equipment. A wide heavy duty road is also needed for movement of the booster to and from the test stand. The one at MSFC will be about 45 feet wide and suitable for a 25,000 pound wheel load. The traffic will be infrequent and slow moving on this road and thus will not require design for fast, frequent loads.

In addition to the above, and normal utilities, the test facility requires a detention pond to keep spillage of propellants from contaminating normal run off water. After decontaminating, generally by burning on the pond, the water remaining is released.

ENGINEERING FOR SPACE VEHICLE TEST STANDS

The objective of engineering for space vehicle test facilities is to secure a properly designed, usable facility within the time and funds available. This is a normal requirement in any field of engineering, however, as usual, there are some complications.

Because of the two to three years required for the design and construction of the unusual, unique and mammoth test facilities needed for the present and future space vehicles, criteria development, design and construction of various portions of a test facility frequently are being done simultaneously. For a new space vehicle such as the C-5 Saturn, facilities work starts during the early stages of vehicle development. Firm requirements are often not available. Changes are numerous and occur through all stages of evolution of the facility. It seems that this situation is normal for facilities work in this field.

Good engineering design practices are essential. As in any facility, agreement between design concepts and the constructed facility are necessary. It does no good for a designer to come up with the best possible solution to a problem unless the results shown in his calculations are translated to the construction plans and specifications and then are followed in the construction of the facility. It helps if the solution is clearly delineated and is easily understood by all concerned. Agreement between different portions of the drawings also is essential. If there is lack of agreement, time and money are generally required to straighten the matter out.

The best of construction practices are also required. Careful scheduling and coordination of work is mandatory under accelerated schedules. Good workmanship is called for in this field. For example, because of the tremendous dynamic loads, structural integrety of the test stands is of utmost importance.

SPECIAL PROBLEMS

One area requiring particular attention is the natural resonant frequency of the test stand. If the stand's natural frequency is in the range of the normal gimbal frequency of the engines, it is difficult to secure valid measurements and, in the extreme case, can result in damage to the test stand and to the vehicle or engine being tested. This problem is becoming more acute with larger vehicles and engines.

Special provisions and precautions must be taken with liquid oxygen and liquid hydrogen. Special materials must be used at the very low temperatures encountered. Vessels and lines must be surgically clean to prevent contamination and possible explosions. Vents and insulation also present special problems.

Safety must be carefully considered during all phases of design, construction and operation. Calculations must be made of the blast that can occur and the resulting effects evaluated. Warning devices are required to alert personnel in or near the area. Safety showers and shelters must be provided.

Because of the physical size of the program to provide the needed facilities in the bare minimum of time, many individuals, firms and agencies are involved. This requires close coordination and cooperation by all concerned.

Another special problem requiring more and more attention as engines and vehicles mushroom in size is the noise generated during static firings This feature will probably require remote locations for future test stands unless some suitable means of sound suppression is developed. I might add that more and more study is going into this problem.

As might be gathered by the preceeding remarks concerning the size and special provisions required in these facilities, considerable cost is involved, both for vehicles and for facilities. For example, the four C-5 facilities discussed will cost approximately $50,000,000 to design and construct.

CONTRIBUTIONS OF CIVIL ENGINEERS

It is evident that all branches of engineering have vital parts to play in the design and construction of facilities for space vehicles. It is also evident that the civil engineer is deeply involved in much of the design and construction activities mentioned. The civil engineer's contributions are particularly evident in the structural, hydraulic, utilities and highway fields.

The civil engineer, as the others involved in these facilities, must rely on basic engineering principles to guide him in many areas of his work. Much of this work is without specific precedence.

SUMMARY

It is hoped that this brief discussion has better acquainted you with the functions and types of test stands and facilities used in the development of space vehicles, especially those now being designed for construction at the Marshall Space Flight Center, and that it has covered some of the major considerations necessary during the design and the construction of such facilities. I thank you.

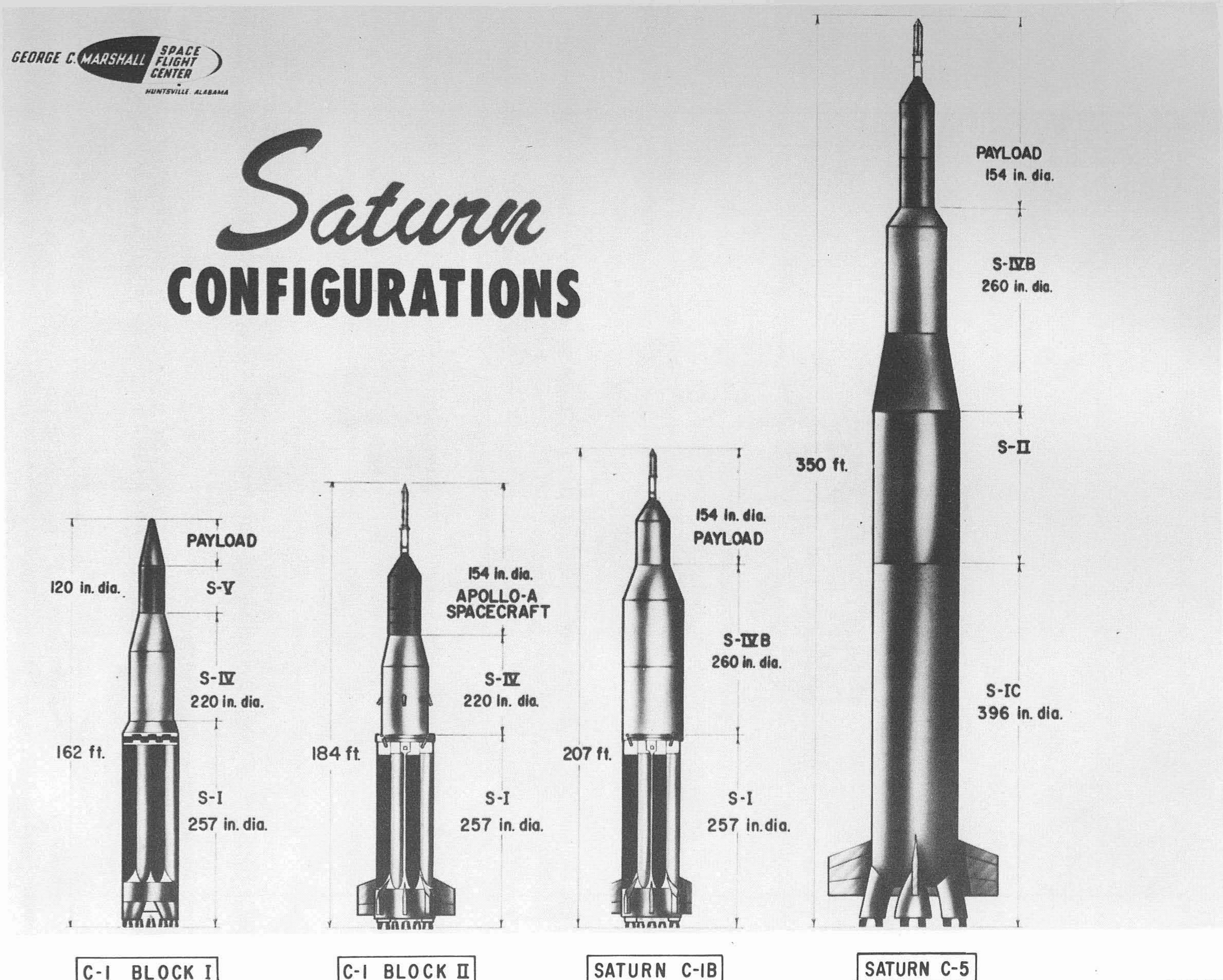
GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA
Saturn
CONFIGURATIONS
PAYLOAD
120 in. dia.
S-V
S-IV
220 in. dia.
162 ft.
S-I
257 in. dia.
154 in. dia.
APOLLO-A
SPACECRAFT
S-IV
220 in. dia.
184 ft.
S-I
257 in. dia.
154 in. dia.
PAYLOAD
S-IVB
260 in. dia.
207 ft.
S-I
257 in. dia.
PAYLOAD
154 in. dia.
S-IVB
260 in. dia.
S-II
350 ft.
S-IC
396 in. dia.
C-I BLOCK I
C-I BLOCK II
SATURN C-IB
SATURN C-5

FIGURE 1

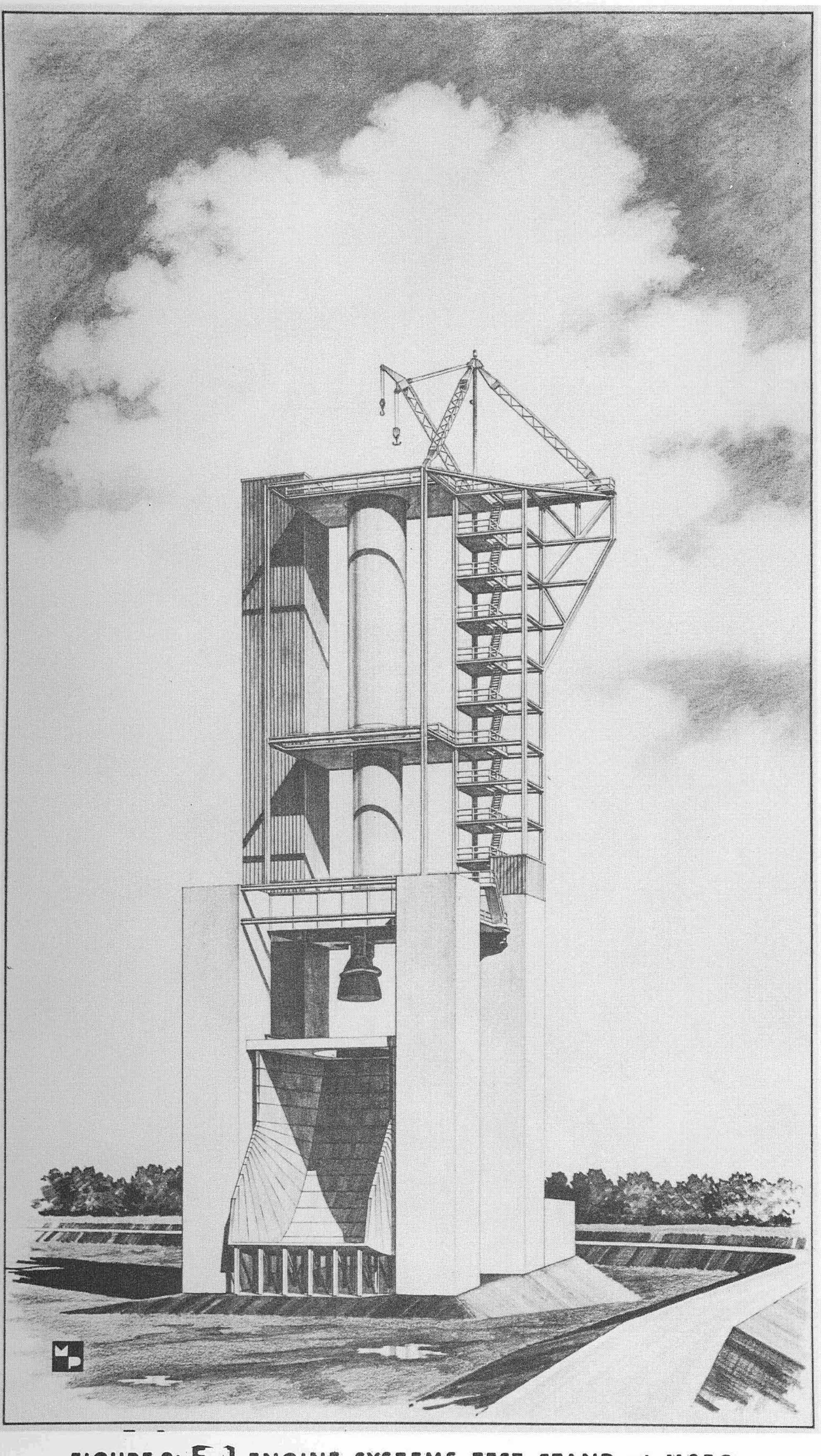

FIGURE 2: F-1 ENGINE SYSTEMS TEST STAND at MSFC

FIGURE 3: SATURN C-5 FIRST STAGE TEST FACILITY at MSFC

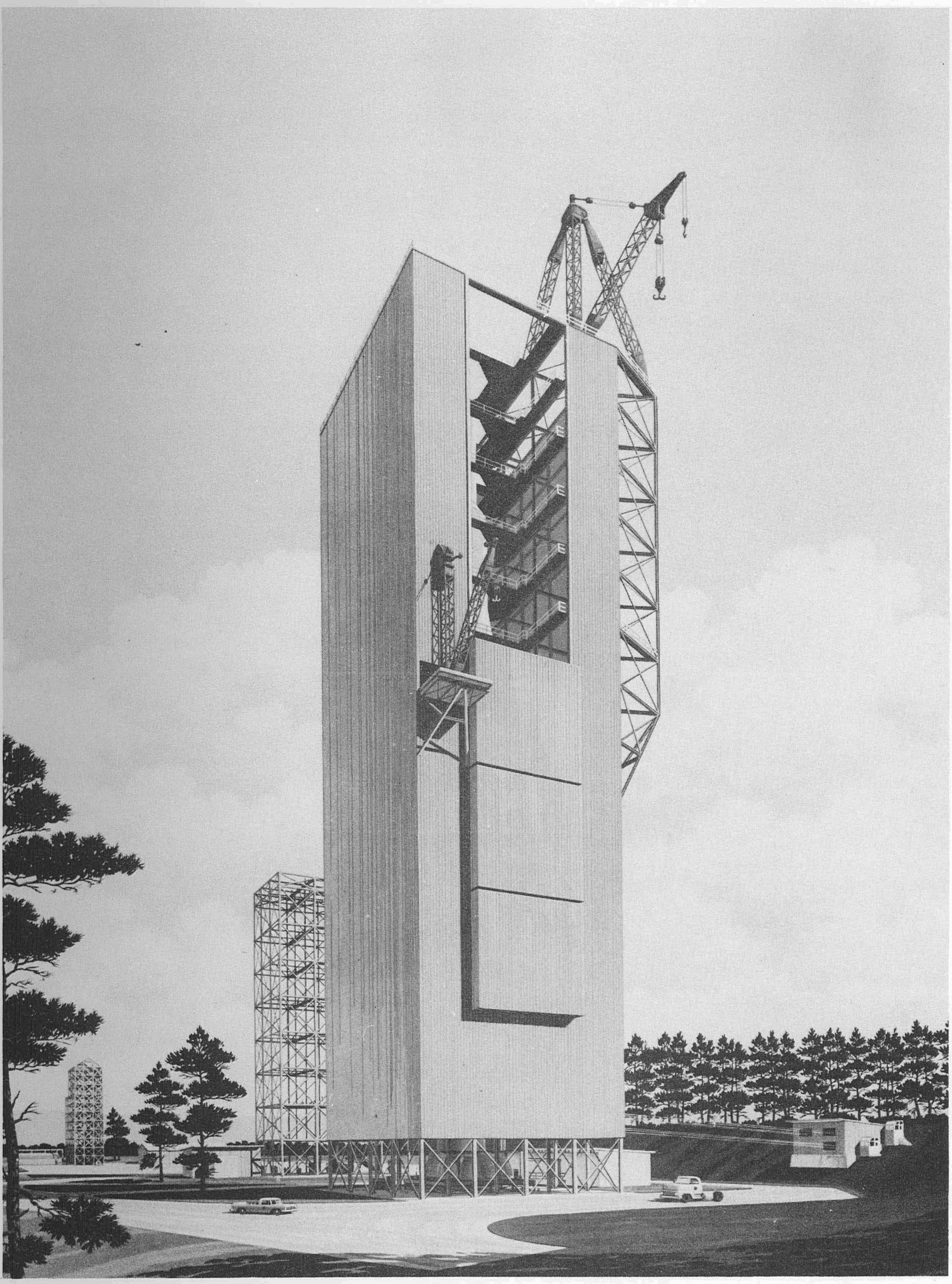

FIGURE 4: ADVANCED SATURN C-5 DYNAMIC TEST FACILITY at MSFC