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TRANSPORTATION OF DOUGLAS SATURN S-IVB STAGES

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ABSTRACT

This paper describes the significant events and equipment associated with transporting the Douglas Aircraft Company, Inc., built Saturn S-IVB stage from stage fabrication at Huntington Beach, California, to the Sacramento Test Center and to the Kennedy Space Center. Descriptions and illustrations of the transportation vehicles and major ground support and instrumentation equipment are presented for a more comprehensive understanding of the transportation problem.

TRANSPORTATION OF DOUGLAS SATURN S-IVB STAGES

As our nation's space vehicles increase in size and complexity, the manufacturers of these space giants face a new and increasingly difficult problem; that of how to transport these celestial covered wagons while they are still on the ground. The Douglas Aircraft Company, Inc., Missile and Space Systems Division was confronted with this challenge in transporting the S-IV and S-IVB stages of the Saturn space vehicle. How Douglas and the National Aeronautics and Space Administration have solved this problem, plus future Douglas plans, are the subjects of this paper.

The Saturn vehicle will pass through three design and mission changes before it evolves to its planned destiny; that of taking man to the moon. Figure 1 illustrates the design and comparative size of these vehicles. Douglas is the only space vehicle contractor participating in all three of the vital Saturn missions. Saturn I, the initial vehicle design, placed in Earth orbit the test versions of the Apollo Command and Service modules. The Douglas-built second stage, S-IV booster, provided the final velocity to place an 11-ton payload into low Earth orbit. The Saturn I vehicle completed its flight program with its 10th successful launch on 30 July 1965. Saturn IB, the intermediate design, will boost Apollo into Earth orbit manned tests. Douglas is building the second stage, S-IVB, that provides the final velocity needed to place a 17 1/2-ton vehicle, with its three astronaut occupants, in Earth orbit.

Saturn V, the final configuration, will place Apollo in Earth orbit, then boost the lunar landing module on its way to the moon. Douglas will build the S-IVB stage that will inject the 47 1/2-ton vehicle with its three man crew into lunar transfer trajectory.

A cursory glance at the problems of moving just one stage of the space vehicle may seem relatively simple, but how large is this one stage and what is there about its design that proves a problem in transporting it? The S-IV stage, figure 2, of the Saturn I vehicle, is 18 feet, 4 inches in diameter and 41 feet long, and weighs approximately 14,000 pounds. As shown in figure 2 the stage has two large propellant tanks, which are empty when in transit. Mounted at the aft end of the stage are six rocket engines weighing

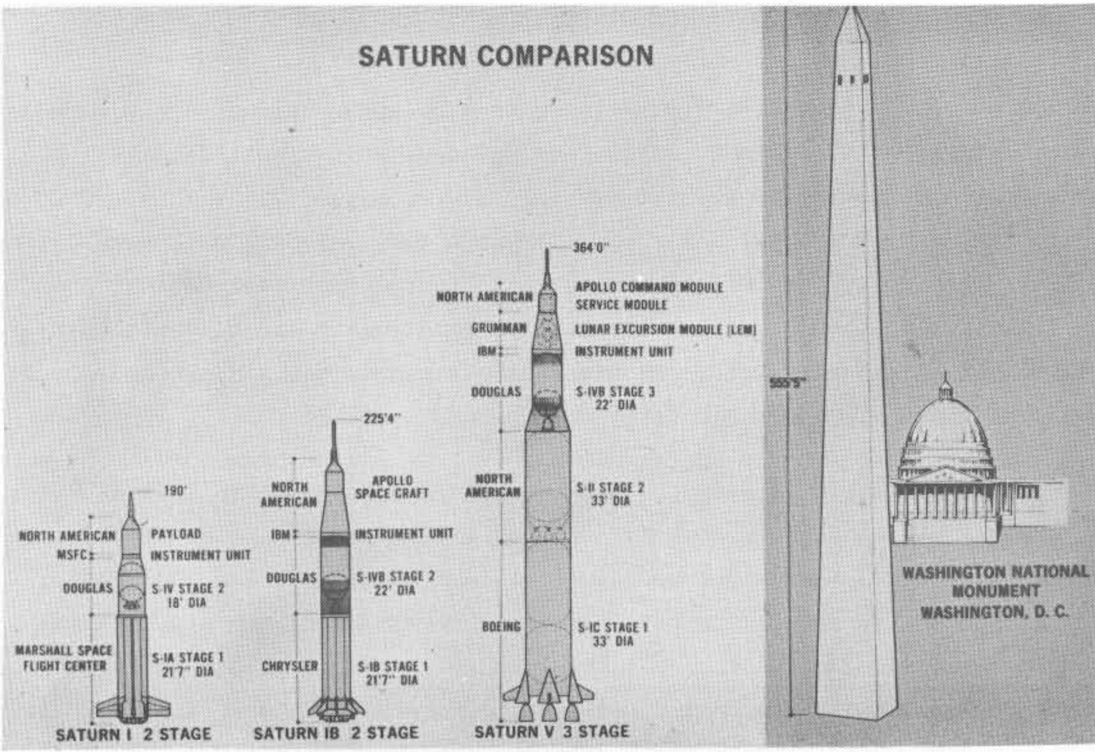

Figure 1. Saturn Comparison

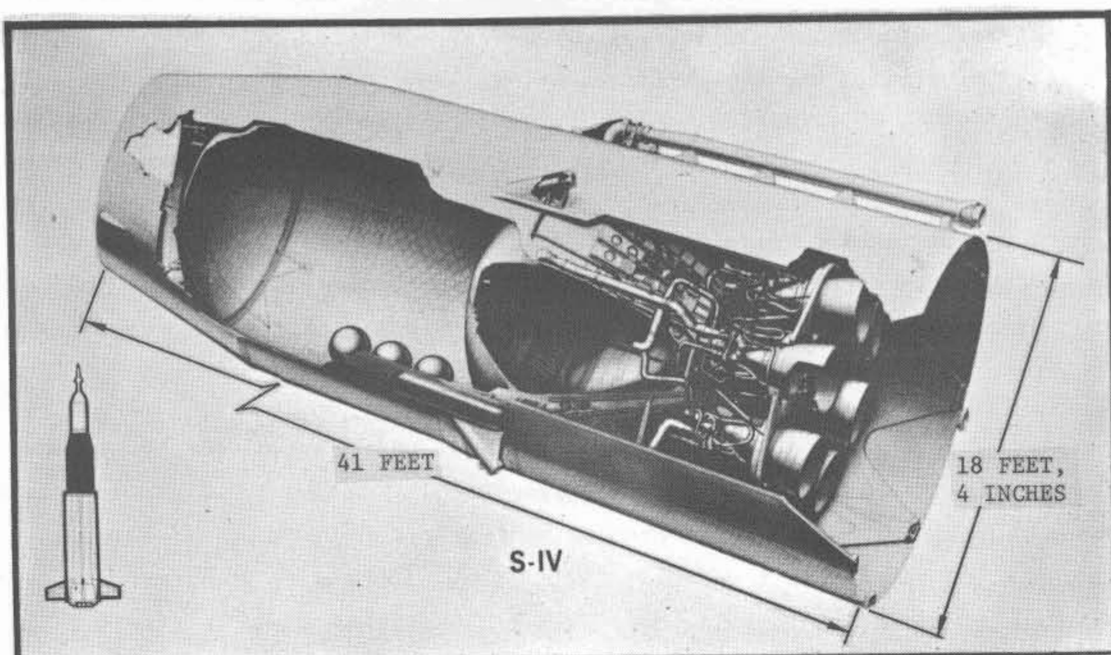

Figure 2. S-IV Stage

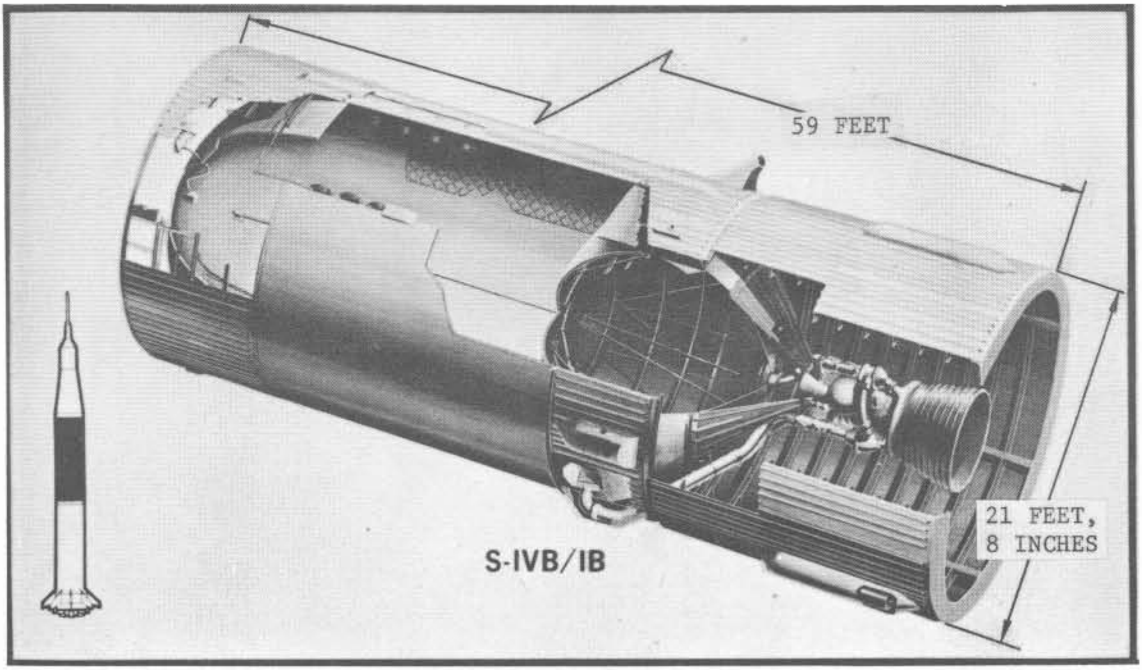

Figure 3. S-IVB/IB Stage

approximately 500 pounds each. The S-IVB/IB stage, figure 3, is 21 feet, 8 inches in diameter, and 59 feet in length, with a dry weight of 25,000 pounds. Like the S-IV stage, the S-IVB has two large propellant tanks, but rather than six rocket engines, it has only one weighing approximately 3,500 pounds. The S-IVB/IB stage is essentially the same configuration as the S-IVB/V, figure 4, with the only significant difference being the S-IVB/V flared aft interstage which has a maximum diameter of 33 feet. The S-IVB aft interstages are shipped separately from the parent stage.

Ordinary modes of transport can only be used with difficulty, if at all. The use of the nation's roads for long distance moving has serious restrictions because of the size of the S-IVB stage. At least two highway lanes, figure 5, would be required. On two-lane roads, the transporter would hang over the edge of the pavement on both sides. Highway transport of the S-IVB stage is comparable to moving a three-story barn. Other difficulties include legal maximum size and weight limits, moving time restrictions, the enormous cost of permanently repositioning utility and power lines, and detouring underpasses and bridges, figure 6, that cannot accept the size of the S-IVB stage and transporter.

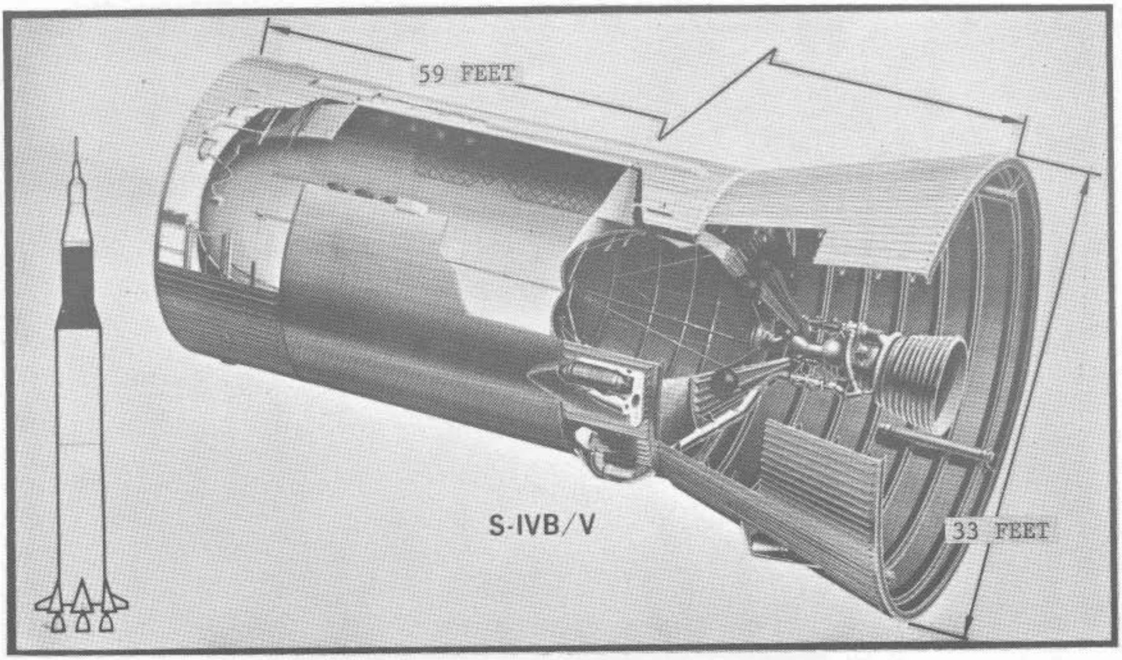

Figure 4. S-IVB/V Stage

Figure 5. Highway Movement

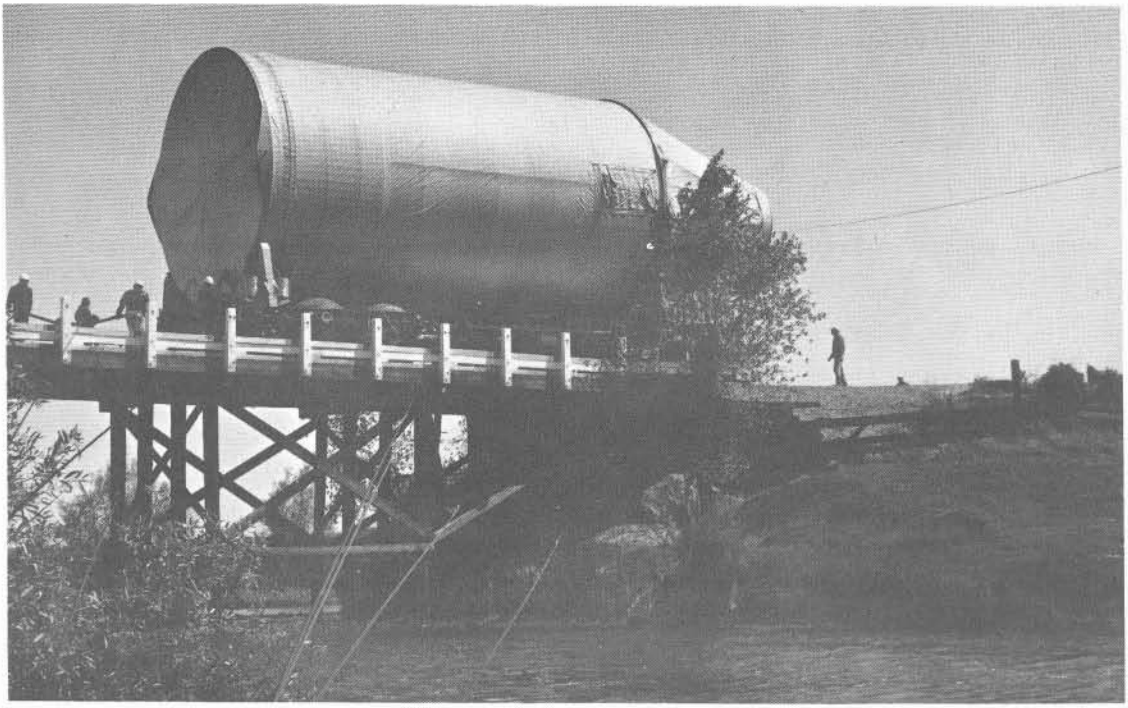

Figure 6. Bridge Crossing

Clearly, the use of highways for *long* distance transportation is out of the question.

Railroads cannot be used since railroad routes are designed to a width limit considerably less than the dimensions of the S-IVB stage.

Because of its size, the S-IVB was not air transportable in the cargo compartment of any aircraft existing at the time of its design. Its weight precludes the use of existing helicopters. Lighter-than-air cargo craft offer intriguing possibilities for long-range transport; however, these craft will receive consideration in future designs encompassing even larger vehicles.

Water transport is limited by the extent to which navigable bodies of water adjoin the fabrication, testing and launching facilities. Fortunately, all terminal areas for the S-IVB stage are reasonably close to such bodies of water. Several types of vessels are acceptable for transport of the S-IVB stage. Barges can be used for short hauls, on rivers, where draft is limited. Conventional freighters or cargo vessels can be used for long ocean trips, such as from San Francisco to Kennedy Space Center.

The present transportation concept had its inception in the movement of the S-IV stages during 1960 through 1962. The planning and implementation of the various activities necessary to move S-IV hardware from Santa Monica, California, to the various test facilities and launch sites laid the ground work for the transportation of the S-IVB stages.

It should be emphasized that during the development of the Saturn Transportation system, special care was given to the retention of the high reliability required by the vehicles. The Saturn-Apollo vehicle is scheduled to be used in a program in which men will risk their lives. For this reason, it is not possible to downgrade transportation at the expense of stage reliability.

The studies by Douglas, during the initial design phases, determined that water transportation, together with a special highway transporter for use at terminal areas, offered the most readily available solution for transport of the S-IV and S-IVB stages.

The S-IVB stage transporter, figure 7, provides support, mobility, and shock isolation for the S-IVB stage during all normal land and sea travel. The transporter is also capable of transporting necessary stage hardware, with the

Figure 7. S-IVB Stage Transporter

exception of the aft interstage. The transporter is a built up base frame, mounted on a four-wheeled under carriage at the rear end and two sets of drop legs at the forward end. The dimensions of the unloaded transporter are 46 feet long, 22 feet wide, and it weighs approximately 22,500 pounds. With the S-IVB stage installed, the loaded transporter is approximately 30 feet high, 58 feet long, 26 feet wide, and weighs approximately 60,000 pounds. The transporter is capable of traveling at speeds of 10 to 15 miles per hour over paved roads, and is fitted with all safety devices in accordance with Interstage Commerce Commission regulations.

The Stage Handling Kit, figure 8, provides segmented metal rings which are bolted to the forward and aft skirt of the stage. The stage handling kit is utilized when hoisting and mounting the stage in order that the induced handling loads will be transmitted safely into the stage structure.

S-IVB Stage Cradles, figure 8, are attached to the transporter to provide support for the stage during ground and sea transportation. The cradles are designed to attach to forward and aft stage handling kit rings.

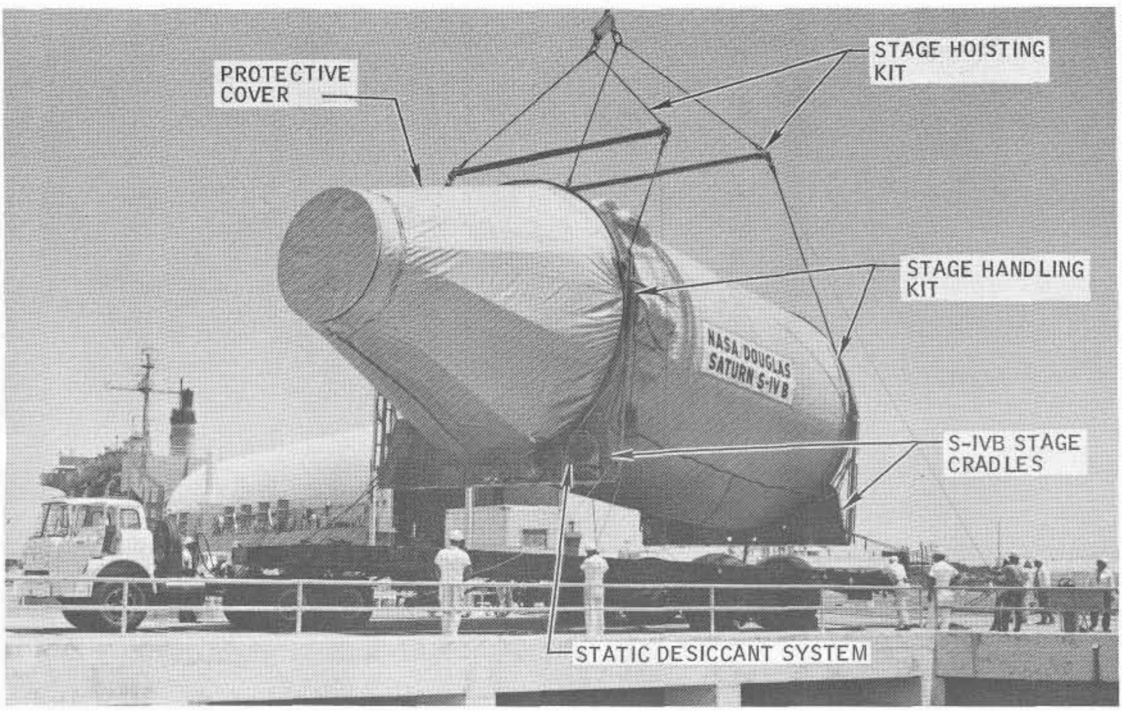

Figure 8. S-IVB Stage Handling and Transporting Equipment

A Stage Hoisting Kit, figure 8, is provided to lift the stage onto the transporter and to lift the stage from the transporter to a ground or water carrier.

To establish environmental protection for the stage during ground and sea transportation, protective and tiedown transport kits, figure 8, are provided. These kits include a neoprene coated nylon cover assembly which, when installed on the stage, forms a weather-tight protective cover. A sponge rubber pad is placed between the protective cover and the stage to protect the stage from falling objects. A static desiccant system, using a series of commercial silica gel desiccators, attaches to the protective cover to control humidity within the cover and the stage. Environmental controls are installed on the stage to monitor temperature and humidity, together with any shock and vibration loads that might be encountered during transit.

During ground and sea transporting of the S-IVB stage, a NASA-furnished Mobile Instrumentation System Trailer, figure 9, and a Power Supply Trailer is connected to the stage and towed behind the transporter. The umbilical that connects the instrumentation trailer to the stage is not disconnected at any time while in transit. All loads experienced en route, which include effects

Figure 9. Mobile Instrumentation System Trailer and Power

of vibration, differential pressures, humidity, and temperatures, are recorded on tape.

When the S-IVB stage is being transported on water, the Dynamic Desiccant System Trailer, figure 10, provides constant low humidity control of the S-IVB stage by circulating warm dry air through the stage and a dehydrator bed of silica gel. The system also maintains a constant low pressure on the environmental protective cover, keeping the cover from laying on the stage surface. The dynamic desiccant system consists of a commercial type, self-generating desiccator unit and gasoline-engine-driven generator to provide ac voltage for the operation of the desiccator when ship power is not available or inoperative.

As previously mentioned, the interstages and skirt sections are transported separately from the stage itself. Handling kits are provided for these items which include dollies for transporting the sections for short distances, and neoprene-coated nylon protective covers to protect the sections from the elements while in transit. Hoisting beams are also included and are attached to the forward end of the sections to provide a means of lifting the section when it is attached to the dolly. Figure 11 illustrates the aft interstage

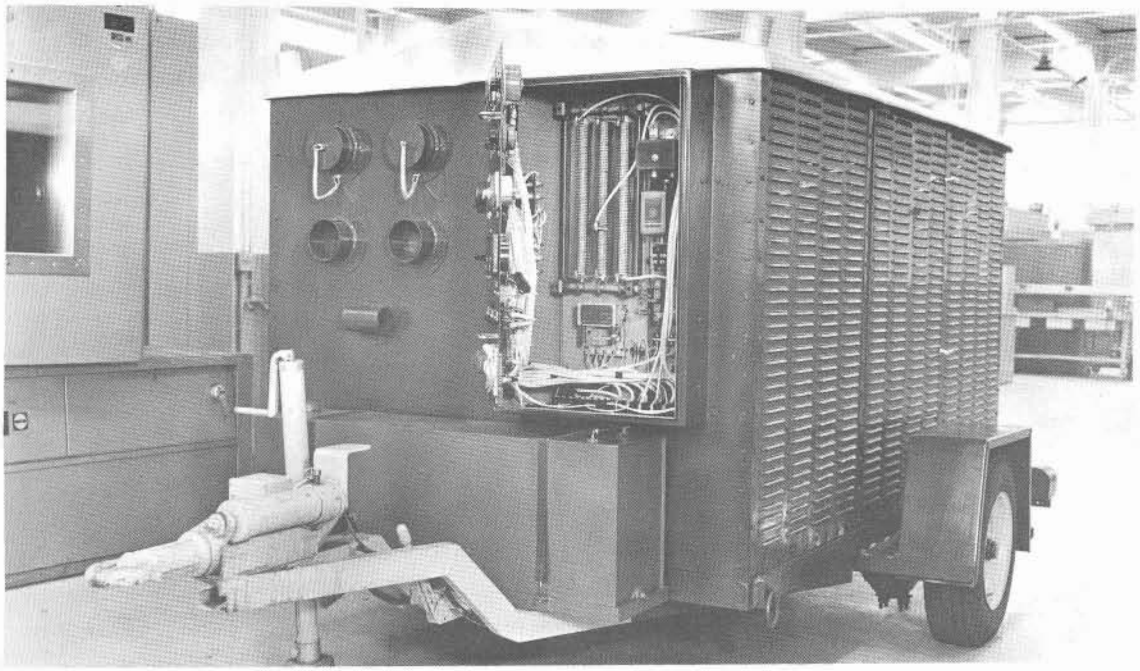

Figure 10. Dynamic Desiccant System Trailer

Figure 11. Interstage and Skirt Sections

section, forward interstage section and aft skirt section waiting to be transported to Kennedy Space Center.

The initial S-IV stages that were delivered to the test and launch facilities were shipped by commercial ship and barge following a transportation flow as shown in figure 12. Consider, for a moment, some of the aspects of transporting an oversized stage such as the S-IVB. Following a transportation flow such as shown in figure 12, the S-IVB stage on its transporter, figure 13, with the towing instrumentation trailer and power supply attached, are transported from the Douglas Space Systems Center at Huntington Beach, California, on the first leg of its long trip to Kennedy Space Center. From the Space Systems Center it is seven miles to Seal Beach Weapons Station Harbor.

At the Seal Beach harbor, the stage and transporter are rolled onto the NASA furnished sea-going barge, Orion, figure 14. The barge is towed along the California coast to San Francisco and up the Sacramento River, figure 15, to Courtland, a dock site just below the city of Sacramento. Then, the S-IVB and transporter are unloaded, figure 16, and towed to the Douglas Sacramento

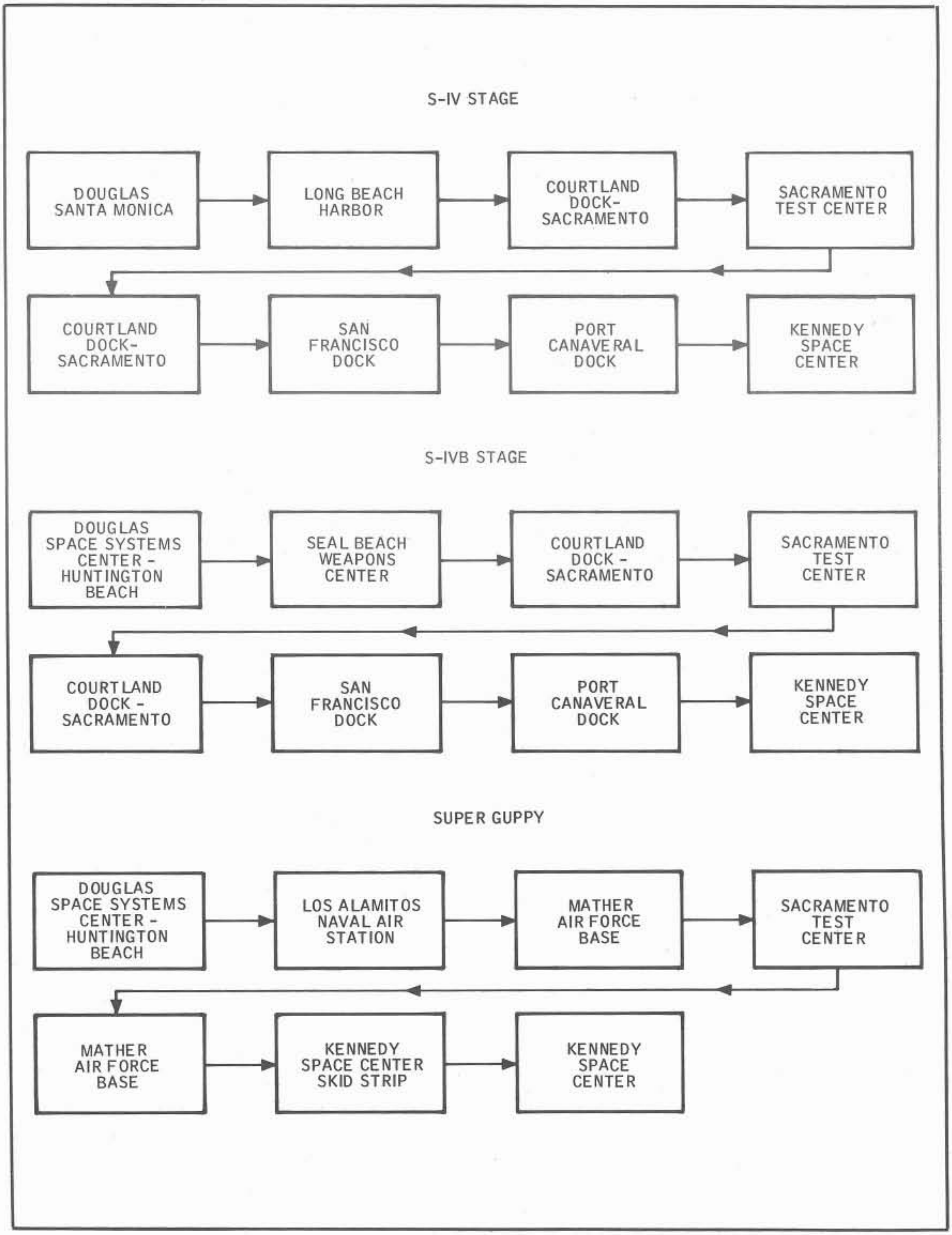

Figure 12. Transportation Flow Charts

Figure 13. S-IVB Stage--Space Systems Center

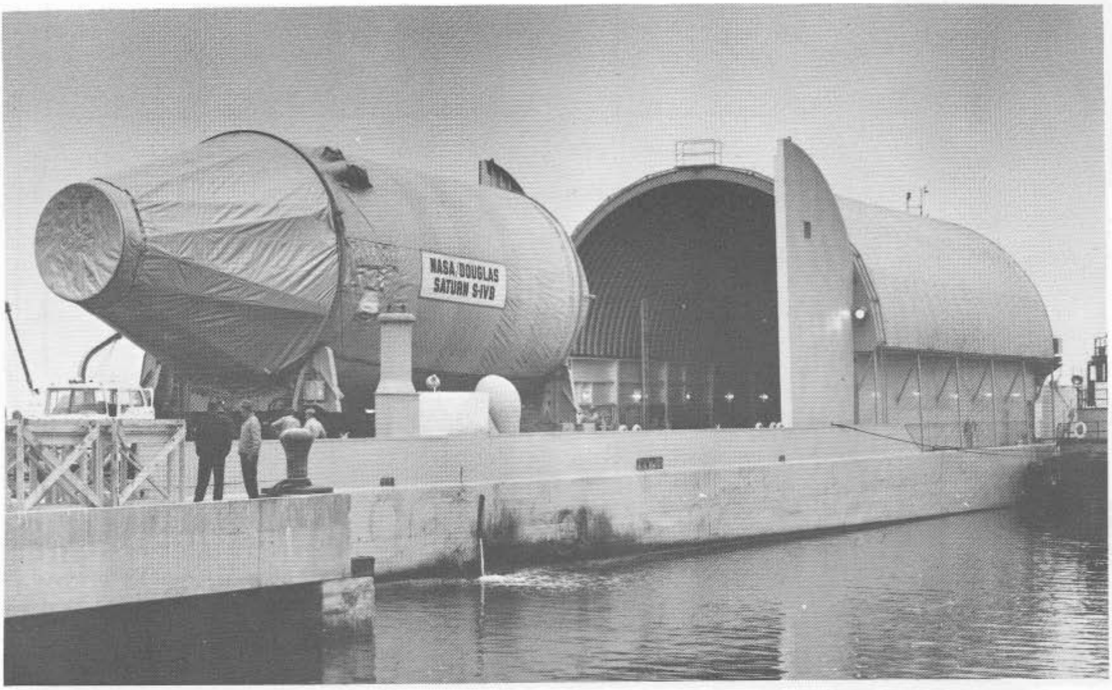

Figure 14. S-IVB Stage--Loading at Seal Beach

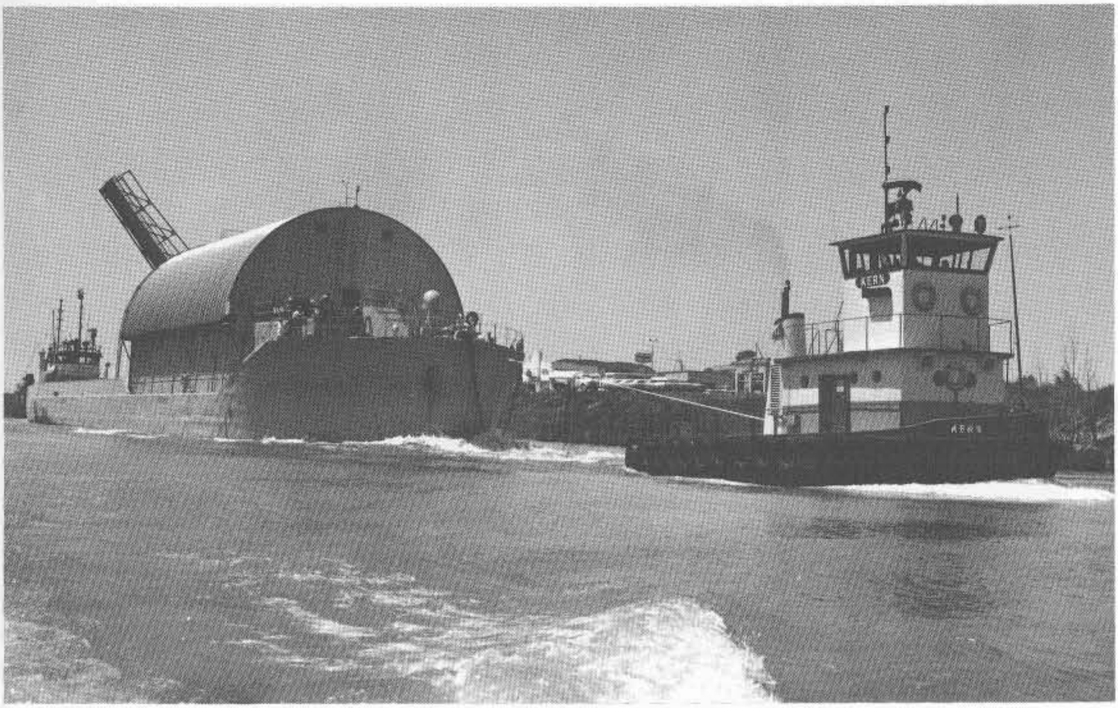

Figure 15. Barge Orion--Sacramento River

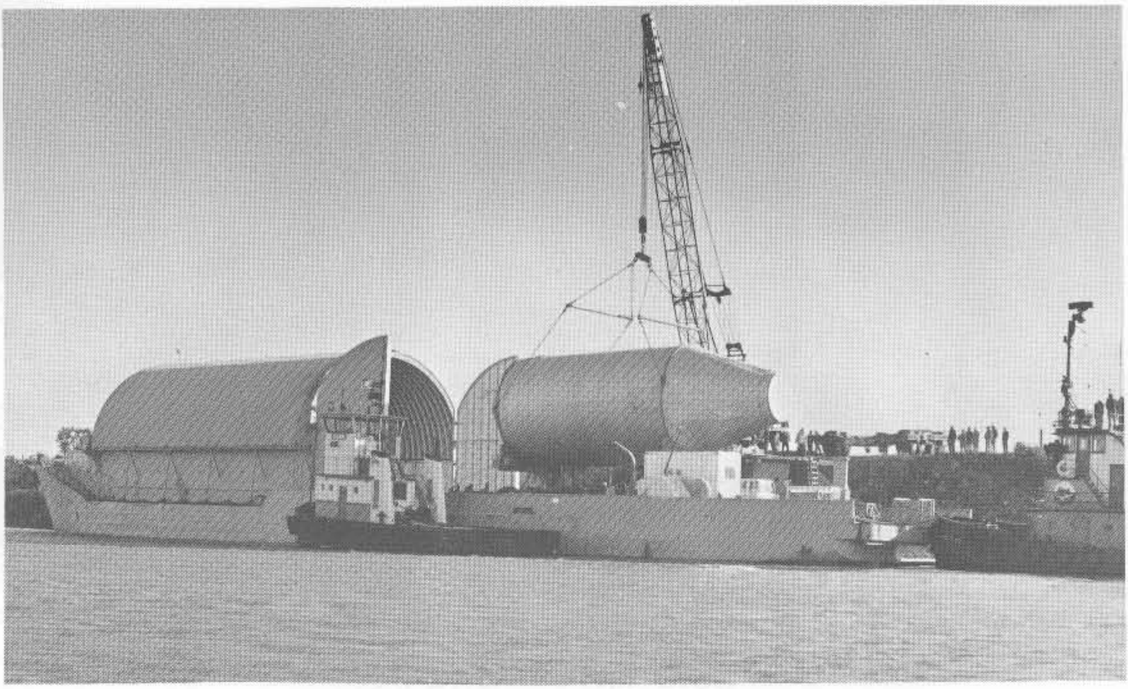

Figure 16. S-IVB Stage--Unloading at Courtland

Test Center over existing roads. A total transit time of four or five days is required for the Seal Beach to Sacramento Test Center move. When departing Sacramento, the transporter and barge are used to transport the stage to San Francisco Bay where the S-IVB stage and transporter are transferred to the ocean freighter, the Point Barrow, figure 17. The stage is shipped via the Panama Canal to Port Canaveral, figure 18, at Kennedy Space Center. Transit time from San Francisco to the Kennedy Space Center is approximately 17 days.

The Orion, figure 14, a modified YFNB class barge, was turned over to the Marshall Space Flight Center which was turned over to them by the Navy. It is 264 feet long and 48 feet wide.

The Point Barrow, figure 17, has a speed of approximately 15 knots and is 465 feet long, 74 feet wide, with a 19 foot maximum draft. It is self-propelled and is owned and operated by the Military Sea Transportation Service for the National Aeronautics and Space Adminstration.

During the early delivery of S-IV flight stages, it was clear that program requirements dictated a need for faster stage deliveries. Consequently,

Figure 17. Point Barrow

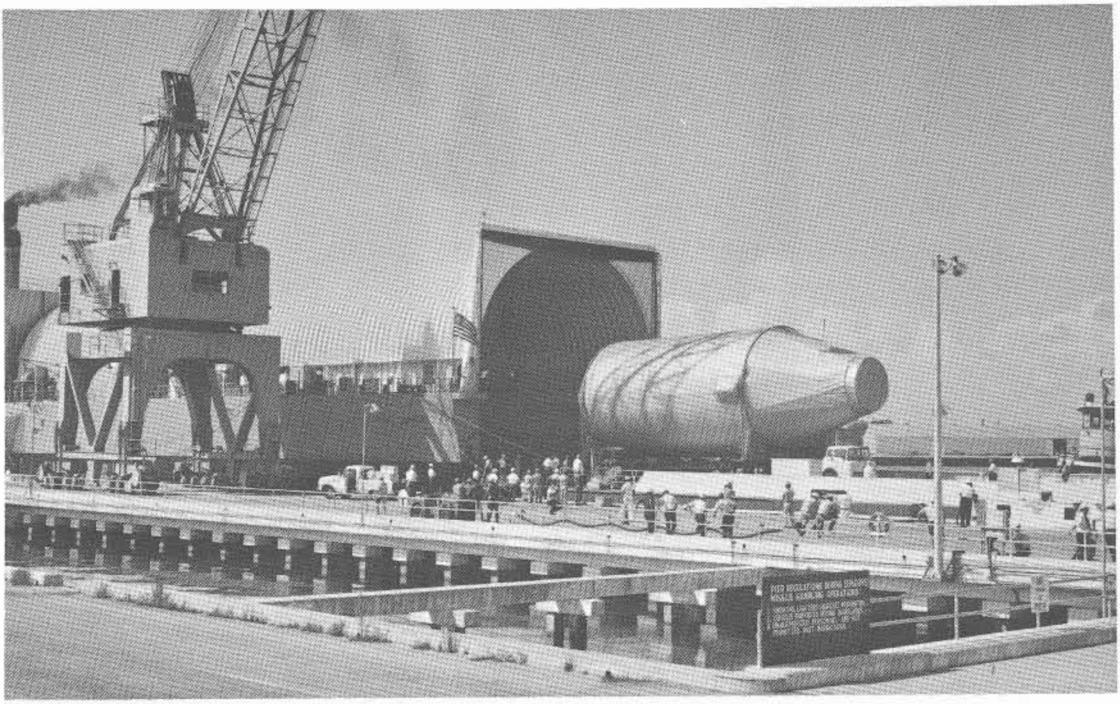

Figure 18. S-IVB Stage--Unloading at Port Canaveral

preliminary planning for air transportation of S-IV stages was initiated. In 1962, Aero Spacelines of Van Nuys, California, modified a Boeing B-377 commercial aircraft to carry S-IV stages. This 25,000 pound payload aircraft, nicknamed the *Pregnant Guppy*, figure 19, was operated under the direction of the National Aeronautics and Space Administration. In 1963 the first S-IV stage was flown to the Kennedy Space Center setting the pattern for air transporting the remaining S-IV stages, and the future S-IVB stages. A NASA/MSFC furnished Cargo Lift Trailer, figure 19, is utilized to lift the stage to the proper aircraft cargo floor height. This trailer can be used also to tow the stage from the manufacturing or test facilities to the loading sites. The cargo lift trailer is a scissor lift, dual railed trailer.

Special ground support equipment had to be designed to accommodate the S-IV stages for air transit. This equipment is being modified for the S-IVB stages.

A Roller Transfer Kit, figure 20, is mounted on the transporter when the stage is to be transported by air. The two longitudinal beams of the roller kit are topped with a series of small rollers which provide the capability of

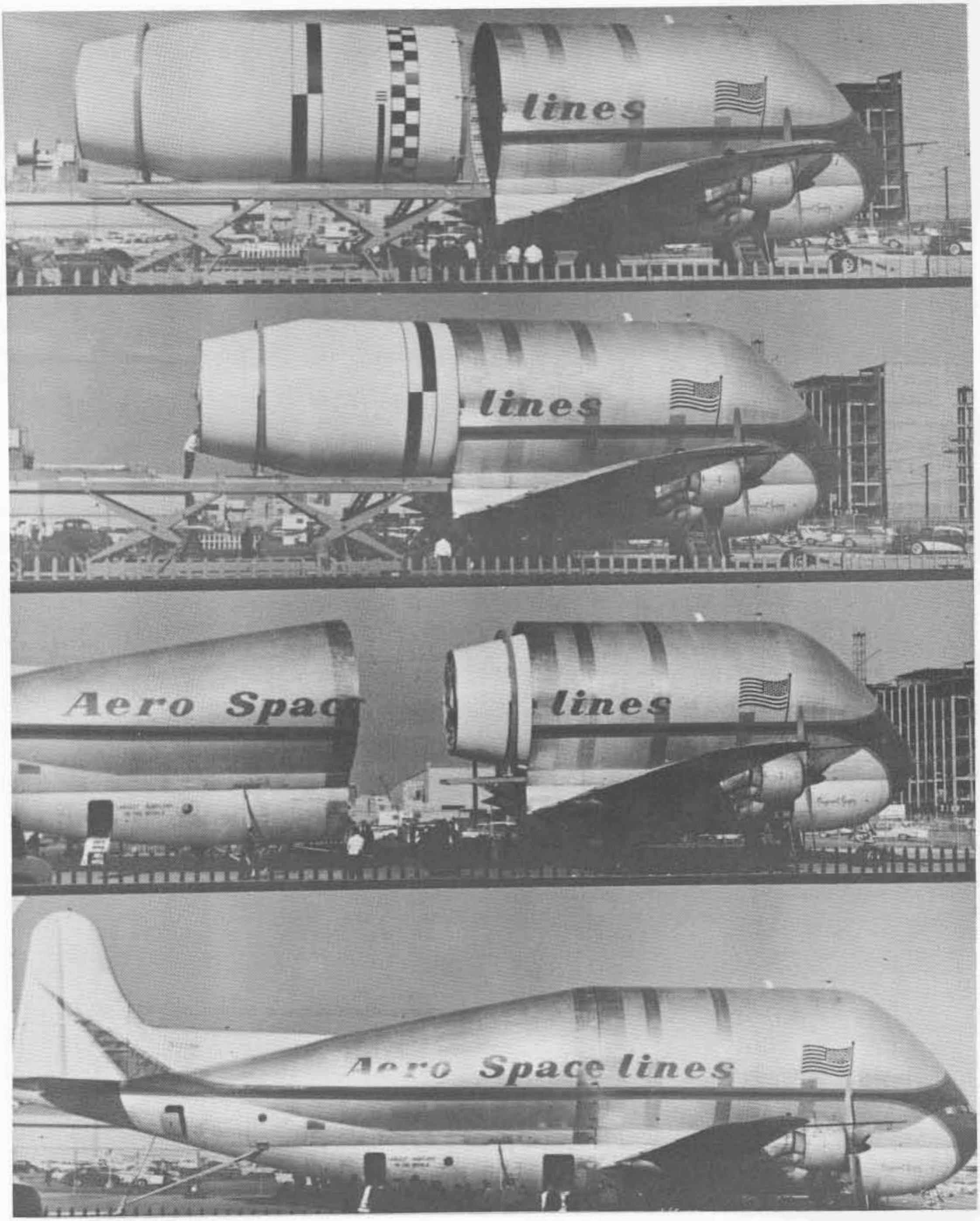

Figure 19. Pregnant Guppy

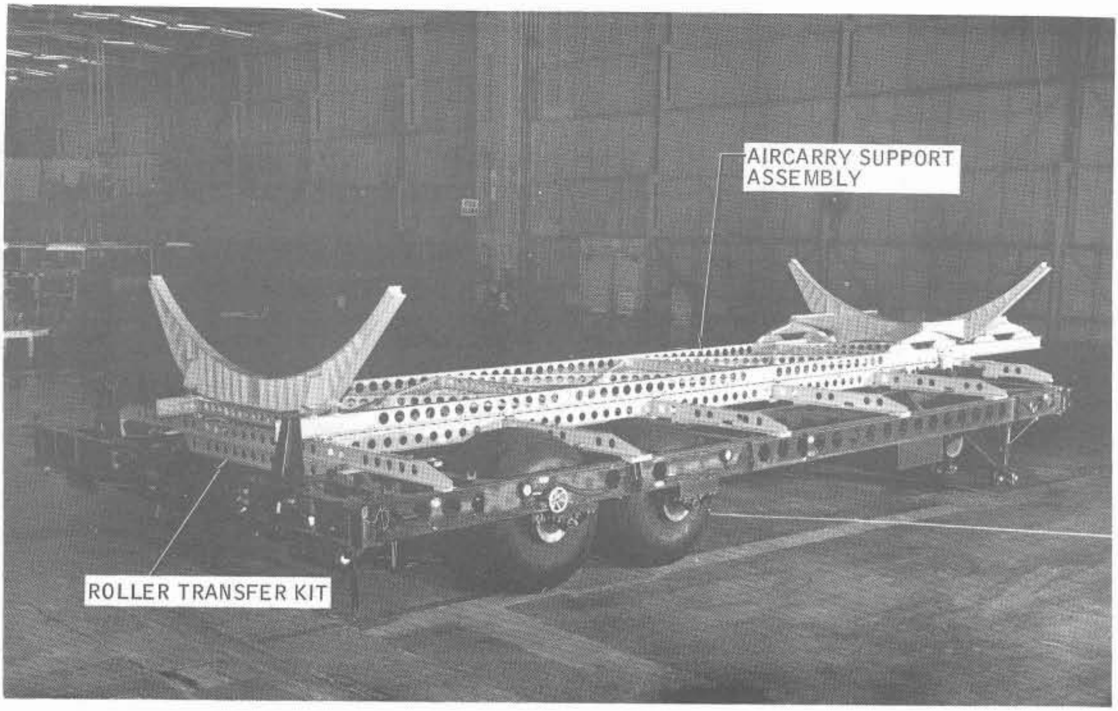

Figure 20. S-IVB Stage Aircarry Handling Equipment

moving the stage mounted on an aircarry support assembly from the transporter to a cargo lift trailer.

For air transit an Aircarry Support Assembly, figure 20, replaces the stage cradles. The support assembly is similar to a pallet and provides a support cradle for the stage when in transit for rolling the stage off the roller transfer kit onto a cargo lift trailer.

When the stage is to be transported by aircarrier, a light weight protective cover is placed over the forward and aft end of the stage. Five static desiccators are connected through the protective cover into the propellant tanks. The desiccators enable free flow of clean dry air and are mounted on the support assembly. These items comprise the aircarrier environmental control system.

The aircarrier instrumentation system is comprised of GSE that will be permanently installed within the aircarrier. This equipment will monitor and record the effects of vibration, differential pressure, humidity, and temperature variations within the stage.

Early in 1965, Aero Spacelines again started modification of several B-377 aircraft, together with components for two C-97J airplanes (turboprop military versions of the commercial 377). This aircraft, nicknamed the *Super Guppy*, figures 21 and 22, can transport a payload of approximately 45,000 pounds and is specifically designed to carry the S-IVB stage, as well as similar space components. This aircraft initially flew in late August 1965. When the Super Guppy is fully operational, all S-IVB stage deliveries will be performed by Marshall Space Flight Center utilizing this aircarry method.

Following the transportation flow in figure 12, the S-IVB stage will be transported from the Space Systems Center, overland 5 miles to the Los Alamitos Naval Air Station. At Los Alamitos, the stage and its support assembly will be rolled from the transporter onto the cargo lift trailer which will raise the stage to the cargo level of the aircarrier. When the cargo lift trailer is raised to the proper height, the stage will be rolled onto the parallel rails within the Super Guppy. The stage will then be flown to Mather Air Force Base which is east of Sacramento and nearly adjacent to the Sacramento Test Center. The stage will be unloaded from the aircarrier at the Mather Air Force Base, placed on a transporter, and towed overland the

Figure 21. Super Guppy--Artist's Conception

Figure 22. Super Guppy

short distance to the Sacramento Test Center. After the stage has been tested, it will be towed back to the Mather Air Force Base and placed on the aircarrier to continue its journey to the Kennedy Space Center. The Super Guppy will land at the Kennedy Space Center skid strip. The stage will receive its final unloading from the aircarrier and be taken to a launch area at the Kennedy Space Center when it will be readied for its flight into outer space.

Now that the major problem of how to transport the S-IVB stage has been solved, let us reflect on some of the numerous and seemingly insignificant little details that have to be resolved in order to move this 3-story space age giant. Weeks of searching and investigating the various possible overland transportation routes are required. Then, when the one route with the best advantages has been chosen, the right-of-way must be cleared and obstacles removed. When a stage is ready for transit, land transportation carriers must be arranged and coordinated by Douglas, and schedules established and met. Douglas notifies NASA who arranges for sea or air transportation. The destination agencies must be notified of the expected time and means of arrival, so that receiving facilities can be made available. State, county, and city permits must be obtained to move overloaded and oversized equipment through their jurisdiction. The utility companies must be notified and requested to lower or raise any lines that might present an obstacle. The local law enforcement agencies must be notified; the railroad must be informed and provide a flagman wherever the stage crosses the tracks. Even the local school districts and commercial bus lines must be notified in advance so that they can reroute the bus pickups during the time the stage is in transit on their route. These are just a few of the many complex last minute items of coordination that must be completed for the benefit of the Nation's Space program, and the convenience of its people.

Transportation is a vital part of the space program and is daily growing more complex. Even longer periods of planning will be required in the future because of the size, complexities, and sensitive nature of the cargo. Today, the primary mission to outer space is truly transportation oriented.

NOTES

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