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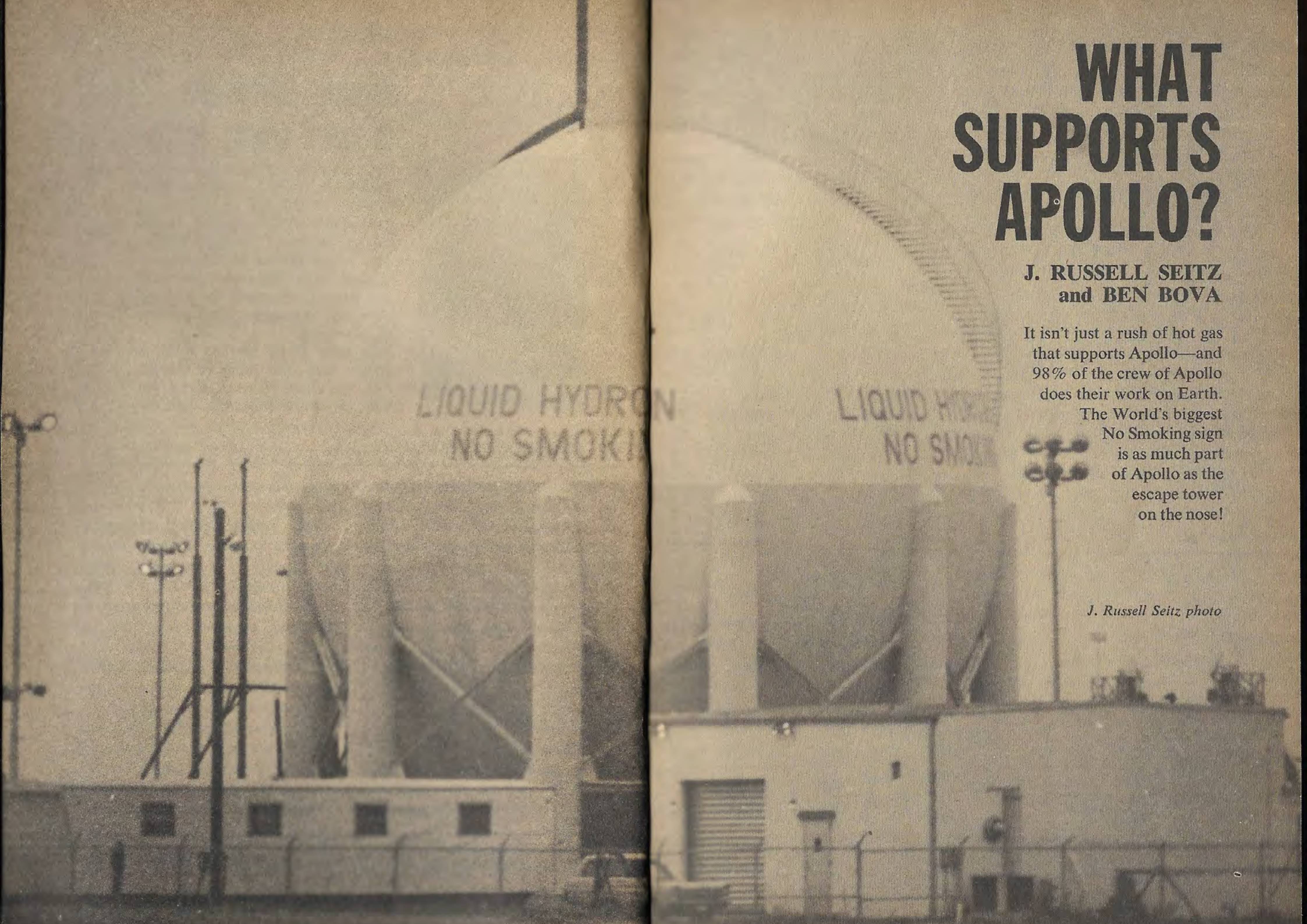

WHAT SUPPORTS APOLLO?

J. RUSSELL SEITZ
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It isn't just a rush of hot gas that supports Apollo—and 98% of the crew of Apollo does their work on Earth. The World's biggest No Smoking sign is as much part of Apollo as the escape tower on the nose!

J. Russell Seitz photo

The world's largest NO SMOKING signs—easily ten feet high by 100 feet long—adorn a pair of huge spherical tanks at Launch Complex 39, Kennedy Space Center, the world's first Moonport.

The tanks are 200 feet in diameter. They hold 3,410,000 liters of liquid oxygen and 3,200,000 liters of liquid hydrogen, respectively. That's 8,550,000 pounds of liquid oxygen; 4,275 tons of it at −297.4°F (−183°C). Hydrogen, of course, weighs much less. There's only 476,000 pounds of it in its tank. But its temperature must be kept much lower: −423°F, or −252.8°C, only 20.3°C above absolute zero.

Big numbers are seldom impressive in themselves, especially when they come as often as they do around Launch Complex 39. But the sheer immensity of the Apollo mission is something you really can't appreciate until you've stared at the Brobdingnagian proportions of the hardware this side of Tranquility Base.

Kennedy Space Center, Fla. The mobile service structure, atop the transporter at right, slowly moves down ramp at Launch Complex 39A, leaving the Apollo 11 Saturn V space vehicle and its mobile launcher alone during a recent Countdown Demonstration Test or dress rehearsal for launch. In the foreground is the 900,000 gallon liquid oxygen storage tank which services the launch vehicle.

NASA

This is something that even the best science-fiction stories have seldom conveyed: the *size* of everything. Putting a pair of men on the Moon takes not only a giant rocket booster, it requires enough ground-based hardware, plumbing, concrete and steel to produce a fair-sized city. And despite all the years of gabble about micro-miniaturized electronics, nothing about Moonport is small. Launch Complex 39 is truly the Land of the Giants.

The Complex starts with the Vehicle Assembly Building (VAB), which is nothing less than the world's largest structure. The VAB is 716 feet long and 518 feet wide, with a total floor space of 343,500 square feet. It's divided into two main working spaces, called the "high bay" area and the "low bay" area: 525 feet and 210 feet high, respectively. Its total volume is 129,482,000 cubic feet. No enclosed space built by man is larger.

You could slide the *Queen Mary* into the VAB and stand her crossways from one corner of the floor to the diagonally opposite corner of the ceiling. And still have plenty of room for stacking three more ocean liners into the remaining three sets of corners. You could fit half a dozen Pan American Buildings into the VAB, or a squadron of *Hindenburg* dirigibles. You could play two football games comfortably side by side on its floor, and if you put up a few more floors at various heights, you could probably squeeze the entire National Football League's weekly schedule of games into the VAB, with all the teams playing simultaneously.

What NASA really does in the VAB is exactly what the name implies: here the three stages of the Saturn V launch vehicle are brought together and mated with the Apollo modules. The high bay can easily accommodate two complete, 363-foot-tall Saturn/Apollo vehicles. In the low bay area, single stages are checked out and prepared for mating, then moved out to the high bay area.

On Tuesday, July 15th, the day before the Apollo 11 launch, engineers and technicians were working in the low bay area on the rocket stages of the Saturn V boosters for the Apollo 12 and 13 missions. A half-dozen technicians were standing inside the mammoth bell of a single rocket nozzle at one point in the day.

The high bay area was almost empty. Nothing but fifty house trailers and a hundred or so automobiles parked on its floor, and a few thousand visitors gawking around. All these occupied maybe five percent of the floor space.

NASA had spotted various pieces of hardware here and there for the benefit of the tourists. One of them was a hold-down clamp, 6 x 9 feet at the base and 10 feet long. Made of a single casting of maraging steel—tensile strength 300,009, psi—the clamp weighs 20 tons. Its job is to keep the Saturn V booster securely tied to the launch stand despite her 7.6 million pounds of thrust, until the exact moment for liftoff arrives. Needless to say, there is more than one hold-down clamp on the launch pad. The clamps are the largest single castings of maraging steel ever made.

It takes about a half hour to walk the complete circuit around the floor of the VAB. Then you start your way upstairs.

There are five work platform levels in the high bay area. Each of them is three stories tall. They can be extended to wrap completely around the rocket booster at various levels. When you get to the highest level, you feel that you could stage parachute-jumping contests in the VAB. Certainly you could spend an afternoon of stunt flying in a light plane inside the building.

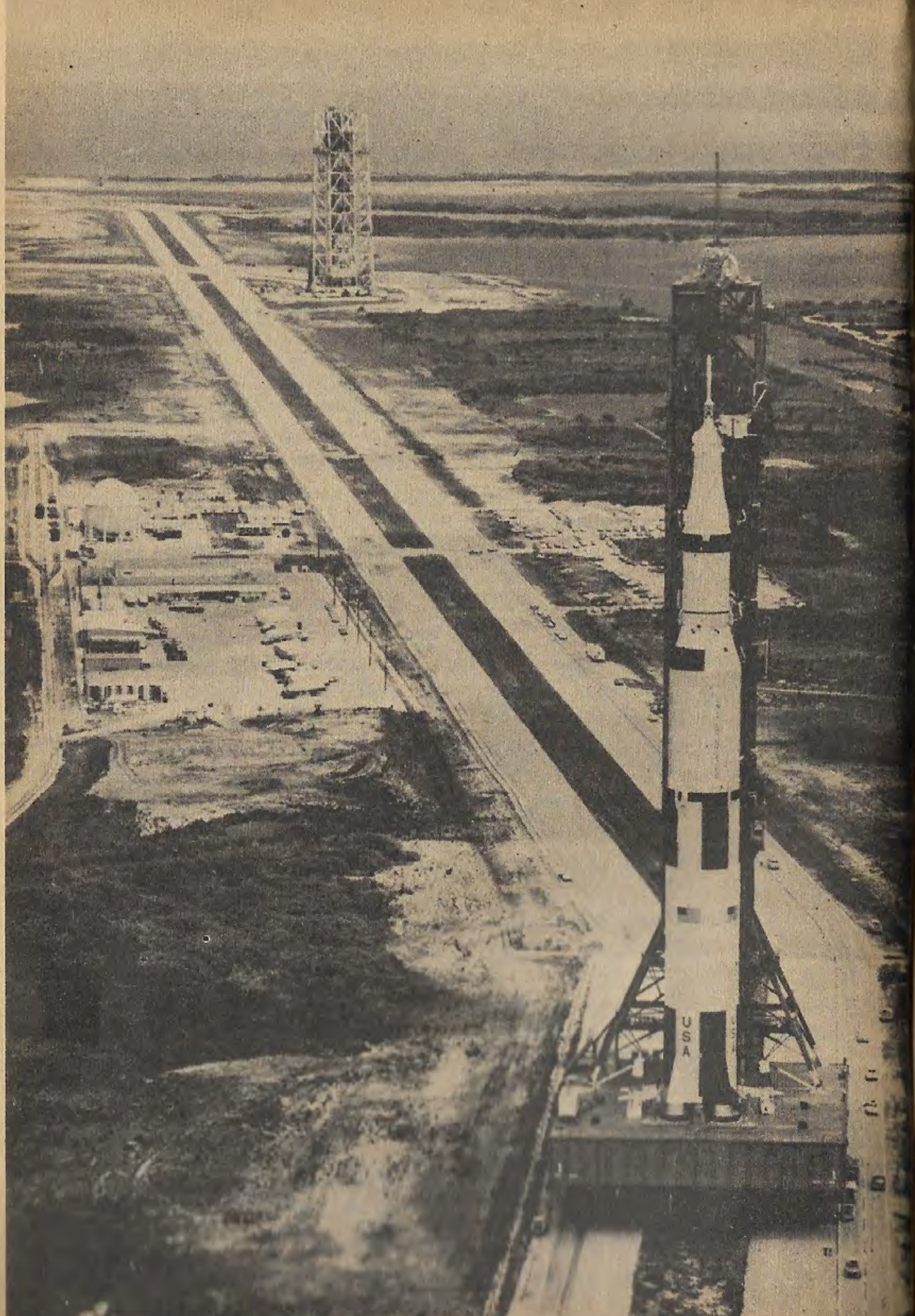
The various offices, laboratories, workshops and platforms of the VAB are cooled by an air-conditioning system that handles more than 10,000 tons of air, more than enough for 3,000 homes. And the building consumes enough electrical power to light up almost any town in the United States.

The VAB structure weighs more than 60,000 tons. Empty. To keep this building from sinking into the Florida sands—which are seldom more than a foot or so above sea level—the VAB was built on an underpinning of 4,225 steel pilings, each sixteen inches in diameter, which were sunk some 150 feet down to bedrock.

Adjacent to the VAB is the Launch Control Center (LCC), where the Apollo launches are directed. There are actually three separate launch control rooms, each equipped with some 450 consoles that control the final checkout and countdown of the Saturn V booster and its Apollo spacecraft. More information flows through these consoles through the twenty-eight hours of countdown than was amassed by all the scientists of the last century.

Sixty television cameras are spotted around the launch pad, transmitting pictures to the LCC and the men who work there. Some of their views were shown on commercial television broadcasts during the actual launch of Apollo 11.

When the Saturn/Apollo is assembled in the high bay area of the VAB, the vehicle is actually standing on its launching platform. This is a two-story-high steel structure called the Mobile Launcher, which is the base that carries the rocket vehicle and the 398-foot-tall umbilical tower. The Mobile Launcher is carried out to the launch pad with the rocket and tower on it.



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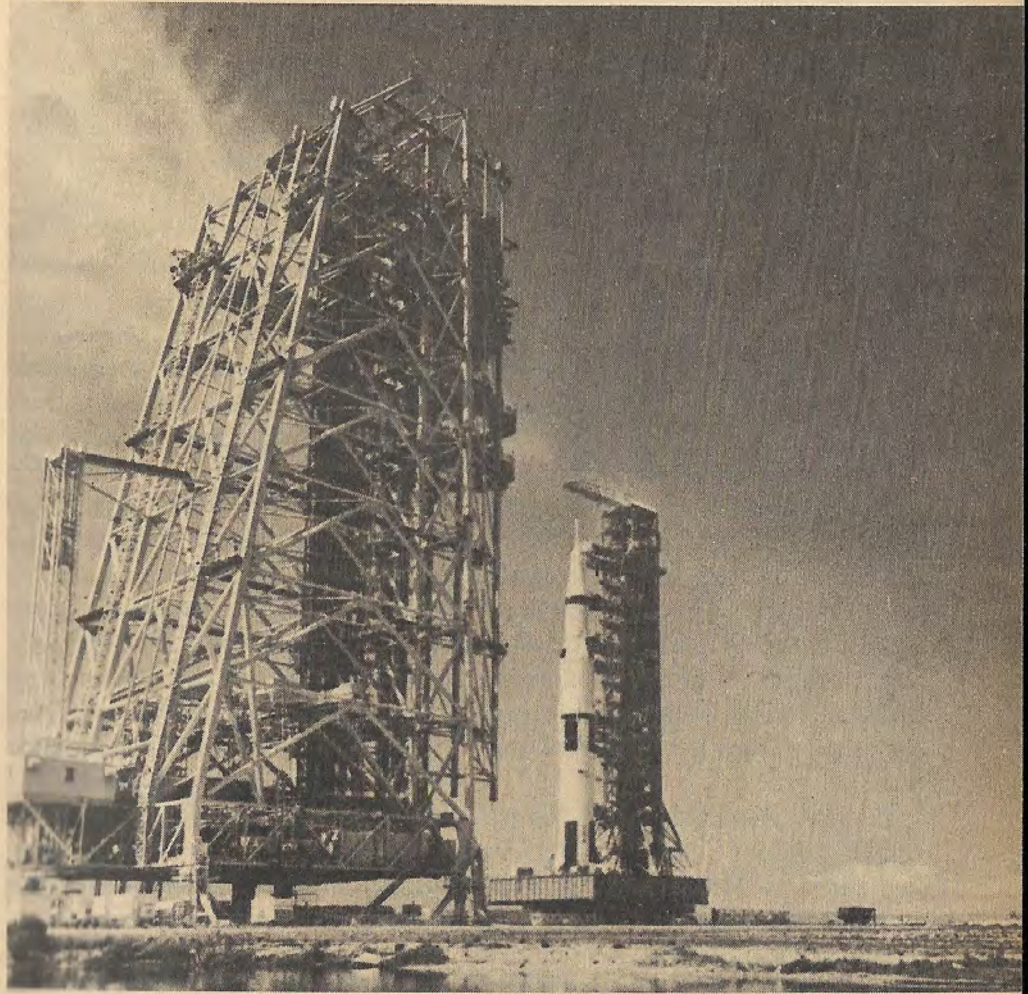

The Mobile Launcher is roughly the size of the main building of the White House. Its base covers half an acre. Built of 6,000 tons of steel, it must bear not only the weight of the fully-fueled Saturn V but must stand up to its takeoff

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Kennedy Space Center, Fla. The Apollo 11 space vehicle is shown on the Crawlerway on its way to Launch Complex 39A in preparation for the National Aeronautics and Space Administration's Lunar Landing Mission. The transporter started the rollout of the Saturn V/Apollo and mobile launcher at 12:30 p.m., and at a snail's pace of one mile per hour arrived atop the launch complex at 6:30 p.m. with the 363 feet tall space vehicle.

blast as well. Even more: the launcher is designed to withstand the force of the Saturn falling back onto it, if the engines are shut off before the rocket vehicle clears the launch stand.

In the middle of the Launcher is a 45-foot-square opening, through which the Saturn V's rocket engines bellow their flames. The opening is lined with a replaceable steel blast shield (and it needs to be replaced after each shot) and cooled by tons of water spray.

The umbilical tower has nine service platforms that enwrap the Saturn/Apollo at various levels and allow the technicians to work on the vehicle. The topmost arm, at the 320-foot altitude, provides access to the Apollo Command Module for the three-man crew and their support technicians and medical men.

If the usually-flawless Saturn rocket should develop troubles just prior to launch, the crew of astronauts can get to safety fast in a pair of 600-foot-per-minute elevators and a slide-wire and cab. Buried beneath the launch pad is a blast shelter. There are also armored personnel carriers standing beside the Launcher, ready to zip away to a bunker 2,200 feet from the launch site.

To carry the rocket vehicle and its Mobile Launcher from the VAB to the launch pad, a distance of 3.5 miles, the world's unlikeliest and ungainliest-looking vehicle is used. This is the 3,000-ton Transporter.

The Transporter is 131 feet long and 114 feet wide at its base. Its top, where it mates with the bottom of the Mobile Launcher, is big enough to handle a baseball infield. It moves on four double-decked caterpiller-type treads; each set on a bogey assembly that's 10 feet high and 40 feet long. Each shoe of the tread is more than seven feet long and weighs a ton.

This squat, square, solid beast is straight out of the Mesozoic Age, a mammoth steel dinosaur that lumbers up and down the road between the VAB and the launch pad at a maximum speed of two miles per hour. When fully loaded with the empty Saturn/Apollo and Mobile Launcher, top speed goes down to one mile per hour.

To carry more than 6,000 tons of dead weight—twice its own weight, incidentally—the Transporter is driven by 16 electrical motors, which in turn are powered by four 1,000-kilowatt diesel-electric generators. Two additional 750-kilowatt diesel-electrics power the cranes, jacks, steering, lighting, ventilating and electronic gear aboard. There are two completely-enclosed operator's compartments, one fore and one aft. The Transporter does *not* make U-turns.

It took about six hours for the Transporter to lug Apollo 11 and its Saturn V booster and the Mobile Launcher out to Pad A of Complex 39. That's considerably less than top speed, even for the Transporter. But with such a precious cargo aboard, nobody wanted to risk daredevil driving.

The Transporter has to come in under the Mobile Launcher's platform, in the VAB, lift the whole assembly off the ground, carry it 3.5 miles to the launch area, up a five-percent slope to the launch pad itself, and then lower it gently onto the pad's waiting pedestals. It has a leveling system built into it so that it can do all this without tilting the tall Saturn or the umbilical tower more than 10 arc-minutes from true vertical. That's a sixth of a degree, or about the diameter of a basketball, measured at the top of the rocket vehicle.

Once it has deposited this 6,000-ton load onto the launch pad, the Transporter backs away down the road about 7,000 feet and picks up the 402-foot-tall Mobile Service Tower. This weighs only 4,900 tons, so it's a relatively easy job for the Transporter.

The Tower has five work platforms, all of which can be adjusted to various heights for work on the launch rocket or spacecraft. About 11 hours before launch, the Transporter carries the Mobile Tower back to its parking area. All further work on the Saturn/Apollo must be done from the umbilical tower from that time on. Finally the Transporter lumbers back to its own parking area—a lot big enough to handle nearly 500 cars.

The road between the VAB and the launch pad is called the crawlerway, for obvious reasons. It's about as wide as an eight-lane superhighway—131 feet across—and even has a dividing strip down the middle. But it's strictly a one-way, one vehicle road. And the speed limit is two miles per hour, tops. Part of the material that was used to make the crawlerway was scooped from the ground nearby, leaving a fair-sized lake. On the far side of this lake stand the special stands built for visitors and newsmen who witnessed the launch.

For all its size and the enormous loads it carries, the Transporter leaves no visible tracks on the crawlerway road. Its caterpillar treads distribute the load so well that it does less damage to the road than an Army light tank would do.

Launch Complex 39 has two launch pads, poetically named Pad A and Pad B. Each is roughly octagonal in shape and covers about a quarter of a square mile. Pad A was used for the Apollo 11 launch.

At the center of the pad is the hardstand, atop a 48-foot-high man-made hill. On this stand rests the Mobile Launcher, the umbilical tower, the Mobile Service Tower—and, oh yes, the Saturn/Apollo. By launch time this comes to a total weight somewhere in the neighborhood of 10,000 tons.

Remember those 200-foot-diameter LOX and liquid hydrogen storage tanks? Together with the first-stage fuel storage tanks they're spotted along the perimeter of the launch pads. The first-stage fuel is RP-1, a high grade of kerosene. It's stored in three 325,000 liter tanks.

Stainless steel vacuum-jacketed pipes are used to carry the liquid oxygen from the storage tanks to the waiting rocket. Driven by a 320 psi pump, the LOX can be delivered at rates up to 37,500 liters per minute.

The RP-1 is pumped aboard the Saturn's first stage at 7,600 liters per minute, maximum. The liquid hydrogen used in the second and third stage engines goes through 1,500 feet of 10-inch vaccum-jacketed invar pipe at a maximum rate of 37,500 liters per minute. A conventional pump wouldn't be able to handle the ultra-cold cryogenic hydrogen, so a vaporizing heat exchanger pressurizes the storage tank to drive the liquid hydrogen through the pipe.

The various pneumatic and purging systems around the pad use 90,000 kg of liquid nitrogen and 30,000 kg of helium. That's merely to flush out the storage tanks and piping during and after the propellant loading operations. There's also a good-sized town's worth of electrical equipment, pumps, motors, and plumbing scattered around the pad.

Leading from the center of the hardstand is a 58-foot-wide trench that's been flame-blackened to the point where not even the stubborn Florida scrub tries to take root. A half-mile away from the pad stands the perimeter wire fence. All along that path, up to the fence and past it, the ground is permanently scorched. The fence itself is blackened on the side that faces Saturn's fierce exhaust.

Connecting the flame trench to the hardstand is the elbow-shaped rocket flame deflector. It is built of steel, covered with a 4.5-inch-thick layer of refractory concrete mixed with volcanic ash. When Saturn's engines roar, about three-quarters of an inch of this heat-resistant stuff is boiled away within a few seconds. The flame deflector weighs 6,500 tons.

To prevent the hot breath of those rocket engines from melting most of Complex 39 during launch, 3,750,000 liters of water—about 4,000 tons—is sprayed over the Mobile Launcher, the umbilical tower, the flame deflector and the flame trench. On the Mobile Launcher, for example, 29 water nozzles start spraying at a rate of 200 tons per minute immediately after lift-off. After 30 seconds the flow is decreased to 80 tons/min. Still, the tower, launcher deck and flame deflector must be refurbished after each launch.

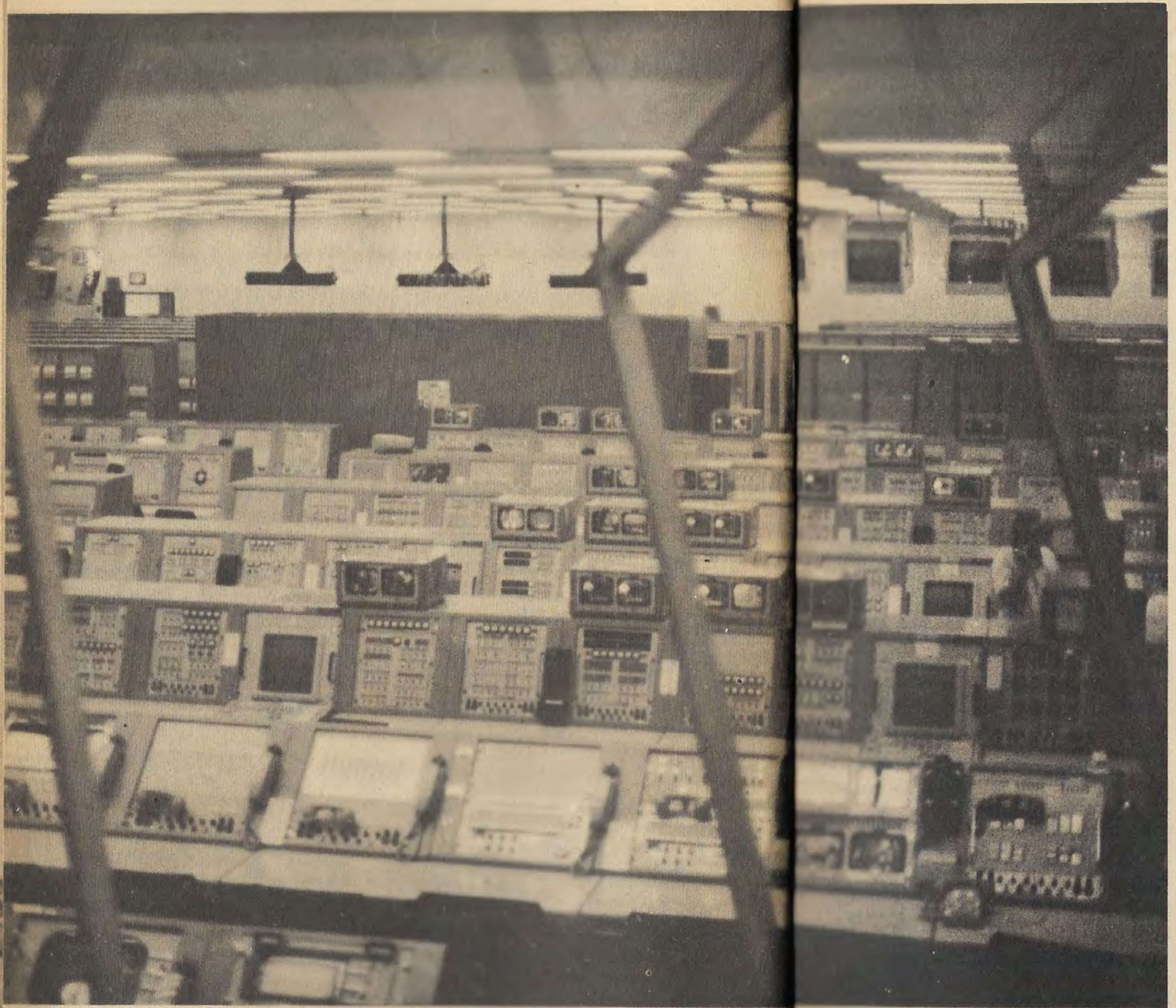
There's also a special water spray system that deluges the emergency escape routes that the astronauts would take in case of trouble.

Launch activity actually begins five days before the real countdown. By the time the countdown is started, at T-28 hours, the Saturn/Apollo is standing on the pad surrounded by the umbilical and service towers.

At T-8 hours, 15 minutes, propellant loading begins. It takes nearly five hours to complete the job of pumping the RP-1, LOX, and liquid hydrogen into the Saturn's three stages. The first stage takes 1.3 million liters of liquid oxygen. Even pumping at full capacity of 37,500 liters per minute it would take more than a half hour to fill those mammoth tanks. And pumping cryogenic propellants is seldom done at anything approaching full speed.

The crawler en route to pick up another few kilotons of equipment.

J. Russell Seitz photo



J. Russell Seitz photo

The sizes, weights, propellants and thrust ratings for the three Saturn stages are as follows:

First Stage (S-IC)
Height: 138 feet
Diameter: 33 feet
Empty Weight: 288,750 lbs.
Fueled Weight: 5,022,674 lbs.
Propellants: Liquid oxygen, 3,-307,855 lbs. (346,374 gals.) RP-1, 1,426,069 lbs. (212,846 gals.)
Engines: five F-1
Thrust: 7,653,854 lbs. at liftoff

Second Stage (S-II)
Height: 81.5 feet
Diameter: 33 feet
Empty Weight: 79,918 lbs.
Fueled Weight: 1,059,171 lbs.
Propellants: liquid oxygen, 821,-022 lbs. (85,973 gals.) liquid hydrogen, 158,221 lbs. (282,-555 gals.)
Engines: five J-2
Thrust: 1,120,216 to 1,157,707 lbs.

Third Stage (S-IVB)
Height: 58.3 feet
Diameter: 21.7 feet
Empty Weight: 25,000 lbs.
Fueled Weight 260,523 lbs.
Propellants: liquid oxygen, 192,-023 lbs. (20,107 gals.) liquid hydrogen, 43,500 lbs. (77,680 gals.)

Launch control at Cape Kennedy. Every possible function is monitored by engineers. There are only three trained experts aboard Apollo—but the rest of the crew of Apollo sits here!

Engine: one J-2
Thrust: 178,161 to 203,779 lbs.

The rocket booster, the launch complex, the VAB, these are only some of the things that support Apollo. The obvious, gigantic chunks of hardware that strike the eye when you visit the Kennedy Space Center. Nobody's had the nerve—or time—to calculate how many thousands of miles of wiring weave Complex 39 together. Or how many miles of plumbing, how many pumps, air conditioners, motors, trucks, hard hats, et cetera.

Then there's the Mission Control Center, linked electronically to Complex 39 from Houston. And the world-wide tracking network, including four ocean-going Apollo instrumentation ships named, appropriately, the *Vanguard, Redstone, Mercury* and *Huntsville.* And eight Apollo instrumentation aircraft, specially-modified KC-135's, which help to track and communicate with the spacecraft. And the recovery task force.

Nor have we talked about how Apollo has changed the Cape Kennedy area of Florida, the Huntsville area of Alabama, Houston, Boston, and many other parts of the country. During the week of the Apollo 11 launch, towns like Cocoa Beach looked like goldrush boomtowns, with cheeseburger plates going for $4.00 and up, fifteen people sleeping in a room, rental cars being obtained by bribing the girls behind the counter with an early bottle of celebration champagne, cars and trailers parked solid for dozens of miles around the Kennedy Space Center, with three million visitors from senators to science-fiction writers pouring in to watch mankind's finest moment.

But before we get too self-congratulatory, we should remember a calculation that Arthur C. Clarke made several years ago.

The actual cost of taking a man to the Moon, Clarke figured, is $20. That is, it takes about 1,000 kilowatt-hours of energy to lift an average-sized man out of the Earth's gravitational field. A 60-horsepower motor could produce that much in twenty-four hours' running time. One thousand kilowatt-hours, at today's prices for electrical energy, costs roughly $20.

So, Clarke pointed out, the fact that it cost us more like $20 *billion* is an indication of how much room we have for improvement in efficiency!

Those improvements will come. Already the Rover nuclear rocket engine has passed its first series of ground tests. But, for a long time to come, the mammoth hardware that supports Apollo is going to be the order of the day, and space exploration will continue to be a realm of giants. ■