Saturn 5 only a beginning

The giant space bird launch at Cape Kennedy is a forerunner of more muscular rockets; the technology already exists

by Jonathan Eberhart

The first hint of the big bird's hatching was a little rocket development program tentatively labeled Juno 5 by the Advanced Research Projects Agency some three years before President Kennedy announced in 1961 that America was going to the moon. Because it followed the development of the Jupiter missile, the booster's name was changed to Saturn, the next planet out from the sun.

The latest member of the Saturn family has been on launch pad 39 at Cape Kennedy, ready for this month's first of several practice shots before launching three men toward the moon. The Saturn 5, all 363 feet and 3,000 tons of it, so far is the most powerful rocket ever flown, and the biggest man-made object ever lifted off the ground.

Spectacular though it will be—it will carry a load equal to the weight of a Boeing 707 transport complete with passengers—there are already bigger, stronger versions in the works. Although the Saturn 5 was designed for a single task—the Apollo lunar landing—engineers were at work almost before it had left the drawing boards to fit it for even bigger tasks such as supplying lunar colonies or taking men to the planets.

There are five basic muscle-building, or uprating, techniques for big space boosters. One of these, engine uprating, is constantly being applied to the Saturn family. The others—propellant additives, thrust augmentation, additional stages and reconfiguration—either have been or are being pursued with the aid of test stands, lab benches and computers, against the day when a few thousand extra pounds of thrust will make the difference between being able to use the Saturn 5 and having to develop an entirely new booster.

The two most important quantities in uprating an engine are thrust—the strength of the engine in pounds of push—and specific impulse. Specific impulse is a sort of miles-per-gallon efficiency rating that describes how much thrust the engine produces for a given rate of fuel consumption.

The Saturn 5 has 91 individual engines, ranging from tiny attitude control motors up to the giants that power the booster's three stages; only 11—the five first-stage F-1s and six upper-stage J-2s—actually provide push into space.

The F-1 engines, three times as tall as a man, will produce the total of 7.5 million pounds of thrust needed to get the big bird into the air and on its way.

Each of the F-1s in the Saturn 5's present version has a thrust of 1.5 million pounds. But they were delivered to the National Aeronautics and Space Administration two years ago. North American Aviation's Rocketdyne division, which builds both the F-1s and the J-2s, already has fully qualified F-1s that have been uprated to produce an additional 22,000 pounds of thrust each. These will be used on later Saturn flights. And to keep ahead of the game, Rocketdyne, about three months ago, fired an F-1 at 1.8 million pounds, a boost of 20 percent over the ones NASA is presently using. The difference in thrust alone would lift 100 automobiles into the air.

The techniques that yield such increases are relatively simple: The basic method is to forcefeed more fuel into the engine's thrust chamber, upping the chamber pressure; the thrust goes up at roughly the same rate as the chamber pressure. Even uprating the engine to 1.8 million pounds required few physical modifications.

Among the uprating ideas being investigated by Rocketdyne and NASA is one based on the fact that the thrust of a rocket engine goes up as it gets higher in the atmosphere. An F-1 that produces 1,522,000 pounds of thrust when it leaves the ground, for example, will be churning out 1.8 million pounds by the time it burns out, 38 miles up.

With this in mind, engine designers are investigating an engine that would start out at 1.57 million pounds, to give some extra lift for getting off the ground, then be throttled back so that its thrust would develop like a 1.5-million-pounder, burning out at 1.8 million pounds and thereby saving precious fuel.

The J-2 engine is another story. Five J-2s drive the second stage of the Saturn 5; another powers the booster's topmost section. The J-2 burns liquid

hydrogen, one of the most efficient chemical propellants known, instead of the kerosene that fuels the F-1. It also can vary the ratio between the fuel and the liquid oxygen (LOX) that enables it to burn. A special motor-driven valve allows the oxidizer-to-fuel ratio to vary from 4.5-to-1 up to 5.5-to-1, which in turn varies the thrust from 175,000 to 225,000 pounds.

Little use is presently made of this variable feature, however, though it will be exploited later; as of now the J-2s in this first Saturn 5 are generally considered simply as 225,000-pound-thrust-engines.

By the third Saturn 5 flight the engine on the third stage will be rated at 230,000 pounds; on the flight after that so will the ones on the second stage. Beyond that, Rocketdyne has a 235,000-pounder in the bank and a 245,000-pound version has already been test fired continuously for 500 seconds, almost 50 percent longer than required by a lunar mission.

In contrast to the kerosene-burning F-1s and its specific impulse or efficiency rating, of about 261, the J-2 burns the much more efficient liquid hydrogen and has a specific impulse of more than 420. If the J-2s that power the upper stages ran on kerosene instead of liquid hydrogen, the rocket would have to be so big just to hold enough fuel for the mission that it would never get off the ground.

There are other ways than choice of fuel by which a designer can manipulate specific impulse. One is to increase the ratio between the diameter of the exit end of the rocket nozzle and that of the nozzle throat.

The area ratio in the already-efficient J-2 is 27.5-to-1, but another 20 seconds of specific impulse would be available, says Rocketdyne's assistant general manager for liquid propulsion, Norman C. Reuel, if physical size and shape limitations would let it be upped to 80-to-1. This is equivalent to changing the nozzle from the shape of a bell to that of a salad bowl, and would add several tons to the payload of each upper stage.

The engine that powers the Centaur rocket used to send Surveyors to the moon uses the same liquid hydrogen that fuels the J-2, but because of a wider, 57-to-1 expansion ratio, it gets an extra 13 to 18 seconds of specific impulse.

A third source of extra seconds is the propellant oxidizer. Since the oxidizer makes up more than seven-tenths of the Saturn 5's propellant weight, it would be a natural place to try some uprating. The likeliest technique seems to be the addition of fluorine—a superactive substance that unfortunately poses handling problems—to the regular LOX oxidizer, forming FLOX. FLOX research has been limited because of lack of funds, but the need for more power—either for more speed or greater payload capability—could start things going again.

In 1965, General Dynamics predicted that FLOX could enable its Atlas booster to put 88 percent more payload into orbit 100 miles above the earth. If the Centaur used a 70-percent FLOX mixture instead of pure LOX, says the company, it could take two Surveyors at a time to the moon. Rocketdyne went the full route and tried using pure fluorine for the oxidizer in a J-2, and found that the specific impulse shot up to a record-breaking 460 seconds. No actual rocket flights, however, have been made with the system.

Besides handling problems, fluorine poses the hazard of highly toxic fumes. Since the rocket exhaust from fluorine-oxidized fuel is poisonous, the substance could be used only for upper-stage boosters.

A different technique is the use of thrust augmentors, or strap-on rockets, so-called because they would be attached to the sides of an existing booster. Solid-propellant strap-ons, such as converted Minuteman missiles, could do wonders even for Saturn 5. Today's big bird can put about 250,000 pounds into earth orbit. Strap-ons could raise that to as much as 427,000 pounds. Various combinations of 120-inch, 156-inch and 260-inch solids could enable boosters to be tailored to a wide variety of missions as could extra F-1s.

Additional stages are another source of bigger muscles. A nuclear or chemically powered fourth stage could be added on top of the Saturn's present three. A Centaur-like fourth stage has been suggested for such missions as sending a 10-ton probe to the asteroid Ceres or a 15-ton version to intercept Comet Encke.

About the only thing left to change —after the propellants, the engines and the number of stages and strap-ons—is the original booster itself. A team of NASA engineers reports that the present stages of the Saturn 5 could be greatly extended even with today's hardware and manufacturing facilities. The giant booster, they conclude, could be stretched from its present 363 feet to a towering 410 feet, with almost all of the increase being used to hold extra fuel that would feed voracious uprated engines.

Budget troubles have slowed up some of NASA's more expansive plans for bigger and better launching rockets. But the technology already exists to uprate and update Saturn 5 into a virtually new vehicle any time the need —and the budget—comes along. ◈