Beam Us Out Of This Death Trap, Scotty

5 ... 4 ... 3 ... 2 ... 1 ... Goodbye, Columbia

By Gregg Easterbrook (In *Washington Monthly - April 1980)*

The most expensive flying machine ever constructed sputtered and smacked through the low waves, kicking up spray, straining mightily to take flight. It had been bobbing by the dock in Long Beach harbor for two days that November of 1947. Now the Spruce Goose was trying to fly. People couldn't take their eyes off it. Who could comprehend its size ! Three hundred-foot wingspan, seven-story tail, 200 tons of plane with room for 700 soldiers. It upstaged even the ocean liners lounging nearby. There it was, $25 million worth of prototype seaplane, skating along toward take-off, engines cackling and fuming. Howard Hughes, America's most publicized aviator, designed it, swore by it, and was at the controls. "If it doesn't fly, I'll leave the country forever," he had promised. Now his Spruce Goose was churning through the water, trying to lurch skyward, better get up soon or we'll run out of harbor ....

And... it's aloft ! The beast flies ! Four hundred thousand pounds of wood and wires break the bonds ! Alas, not for long it splashes right back down, hull groaning. The flight crew hears the sound of cracks here and there. Crawling out the hatch back at the dock, the engineers look slightly pale. Can't call the flight an unqualified success. The Spruce Goose had flown about a mile, rising to the tree trimming height of 70 feet.

The crowds cheered, however, and the next day The New York Times pleaded for more federal money to continue the project. "Had our armed forces had a fleet of such planes during World War II," it explained, "many battles might have been won sooner, and many lives saved."

A fleet ? A fleet of these sorry pelicans ? Hadn't it occurred to anyone that the Spruce Goose--with throttles thrown wide open, no cargo, and only a few tons of fuel where dozens would be needed--had managed to make 70 feet for 45 seconds ? That it was so badly damaged by this sortie it would never fly again ? How would we win battles with this plane--make the enemy die laughing ? Couldn't anybody see the aviator's new clothes were not clothes at all ?

The Spruce Goose remains today in the hangar where it came to rest 33 years ago. The record for most expensive flying machine has long since been surpassed. There's something heavier, too. Down at Cape Kennedy the National Aeronautics and Space Administration is tinkering with the champion, the $1 billion, 2,300 ton space shuttle Columbia. Columbia is the first of at least four space shuttles. It will blast into space like a rocket, and sail back like an airplane. It isn't a "capsule," as they called the Mercury orbiters, or a "module," as they called the Apollo moon machine. It's a spaceship, designed to be used over and over again, instead of thrown away like a rocket. Much cheaper than rockets, much more versatile, it is the key to the next phase of space exploration. The space shuttle is to the Apollo module what the DC-3 was to Wright's flyer. With a fleet of these ....

But something doesn't look right about the astronaut's new clothes, either. The Columbia has yet to fly. It's several years behind schedule, with no imminent prospect, despite official assurances, that it will fly at all. But more important, if it does fly, it won't do anything those old throw-away rockets couldn't do. You've probably heard, for instance, that the space shuttle will retrieve damaged satellites and return them to earth for repair.

Not so. It can't. Simply and flatly, can't. And, according to The Washington Monthly's sources, flying the shuttle will cost more, not less, than flying those old disposable rockets.

If you haven't heard this, don't be surprised. After all, reporters clustered around Howard Hughes for years, begging to know when the Spruce Goose would fly and scribbling down the predicted dates. Nobody spent much time asking what it would do once it got up there. Getting it up there was the drama. What it would do was... well, there must be a reason or they wouldn't build it, would they ?

Waning Moon

Even as the Apollo 11 moonship was being primed for what President Nixon called "the most important event since Creation"--the August 1969 moon landing--plans for a space shuttle were being drafted. By spring of 1969, Apollo's impending success seemed assured. The technological precision of Apollo was nothing short of remarkable ; its builders and astronauts accomplished more than even the most optimistic among them predicted. But even NASA officials had to admit that being on the moon didn't amount to much. Getting there was all the fun. Some space venture had to be found to succeed Apollo.

A special White House "task group" was formed to select the next program. Roy Day, now a top official for the shuttle program, was pulled off Apollo to help NASA order its options. "It was assumed from the start that we needed some sort of manned mission," Day explains. "The progress of high technology and national prestige demanded it." After summarily dismissing less-expensive but less-glamorous mechanized space exploration (see "Battlestar Bureauctica" on page 42), NASA devised these possibilities : a manned landing on Mars ; a manned fly-by (approach without landing) of Mars or Venus ; a permanent moonbase ; a permanent orbiting space station, with a shuttle vehicle to supply it; or, at last resort, the shuttle only.

Planetary missions were rejected as technically feasible but absurdly expensive. (A single Mars flight, requiring a nuclear-propelled spaceship traveling for years, was pegged at $100 billion. Apollo cost $20 billion.) The moonbase was nixed as useless. The space station sparked a lot of interest, but it too was overwhelmingly expensive. Its components would be so heavy, NASA's entire budget would be required to pay for the launch rockets--to say nothing, as space proponents are wont to do, of building or servicing it. The task group members reasoned that a reusable space shuttle would be the logical first step to prepare for a space station. Only the economy of a reusable shuttle could make the space station affordable.

The shuttle was to be nothing more than that--a space truck to lug things back and forth to orbit. The craft itself would have no scientific function. It was assumed by task group members that, once the shuttle was approved, somebody, could devise some missions for it. "First you have to get the horse," said Dr. Jerry Gray, former NASA scientist and now public policy director of the American Institute of Aeronautics and Astronautics, "then you decide where to ride him."

A Horse By Committee

NASA longed to abandon the familiar one-shot rocket-whose stages, once fired, went tumbling into the sea or burned up, taking their titanium castings and navigational computers with them. The Saturn V moon rocket, for example, weighed 3,050 tons at blast-off, and you got exactly seven tons back--that dinky little "command module" the men rode in. "We wanted to have only miniscule involvement with the rocket concept in the future," Day says.

At first NASA asked for an all-reusable shuttle. Grumman and McDonnell-Douglas came up with a plan that called for two huge winged ships, each with its own pilots and engines, mated piggyback. They would blast off together, with the larger ship-the booster-spitting fire for the first 10 to 20 miles of altitude. Then, fuel spent, it would circle back to land like an airplane. The smaller ship would continue into orbit, drop its cargo, reenter the atmosphere, and also land like a plane : NASA believed this system would be economical to operate, but would cost $10 billion to build. The Office of Management and Budget balked. Ten billion, it gasped --out of the question !

What could you do, OMB asked, for $5 billion ? Design of the horse was referred to committee, where a compromise was found. A partially reusable shuttle was conceived.

In this plan, the shuttle's main part would be the "orbiter." That's the section that gets a name, like Columbia. It would be a winged rocket-powered flying machine about the size and weight of a DC-9 airliner. This orbiter would carry 65,000 pounds of cargo into a low orbit, stashing the goods in a 60-by-15-foot bay. It would be flown by a crew of two to seven astronauts. Not ridden by strapped-down guinea pigs like those capsules and modules, but, down by pilots. Flown during landing, at least ; the rest of the time they would pretty much watch the instruments. But there would be people in control--a concept popular with people, who seem to be less in control of things with every passing day.

The shuttle ship would be mounted piggyback on a cavernous 150-foot long fuel tank carrying the frigid liquid gases to power the shuttle's main engines. Strapped to it would be two booster rockets, powered by reliable solid fuel. Their motors would be the fiercest ever imagined generating 2.5 million pounds of thrust each, as opposed to 470,000 pounds for each of the shuttle's three main engines. Those insatiable trolls would burn through their fuel in scarcely a moment.

Bolts and hoses fastened, the shuttle spaceship, its fuel tank, and the boosters would blast off together from Cape Kennedy, a tremendous troika of power. At an altitude of 20 miles, the spent boosters would fall away, floating down on parachutes. They would be fished out of the sea and used again. The shuttle's own engines would keep firing until, nine minutes after launch, their fuel was exhausted. Then the empty fuel tank would tumble away, to burn up in the atmosphere. (Since it's only a tank, NASA reasoned, it's cheaper to let it fry than bolt on all the navigational and heat-shielding hardware needed to get it back.).

The shuttle would go about its business in orbit. Lacking main-engine fuel, it would employ two small reaction rockets for maneuverability and to slow it down for reentry. Once back in the air, it would glide toward a landing field, setting down like an airplane but "dead stick"--without any power to compensate for miscalculations. After landing it would be refitted, mated to a new tank, strapped to two refilled boosters, and blasted off again.

Estimating a cost of $5 billion to $6 billion, NASA got its launch-commit for this design in 1972. The agency explained that having a crew of pilots aboard would add "flexibility" and "new dimensions" to space flight, but otherwise NASA wasn't terribly specific about what the astronauts would do. It was assumed that with the horse under construction some carriage maker would build something for it to pull--a space mission only a shuttle could handle. Meanwhile, petting the animal became an obsession. It would be "the dawn of a new age" (Nixon), a "breakthrough" (Ford), the first "commuting to space" (Carter).

James Gehrig, staff director of the Senate Commerce Committee's space and science subcommittee, sums up the two features that shuttle backers have cited again and again : its "wonderful advantages of higher payloads and lower costs." NASA planned the first launch for 1977. Didn't quite make it that year, and won't this year. NASA officials won't be too upset if it doesn't fly next year either because when you're not launching them, you don't have to explain awkward things like higher costs and lower payloads.

Pole Sitting

Down at Cape Kennedy, Columbia lies in an assembly hangar, imprisoned in scaffolding. Arc lights gleam off its impossibly smooth surface. They shine round-the-clock, as 500 technicians work double ten-hour shifts, six days a week, trying to make the shuttle spaceworthy. Columbia was supposed to be finished last March, when it was transferred from the factory of the prime contractor, Rockwell International. Instead, it arrived at the Cape only 75 percent complete, according to NASA. No one is certain when--or even if--the remaining work will be finished.

The drydocked Columbia represents at once all the shuttle program's problems. They are: delays; cost overruns; performance underruns; and lack of work for the horse to do. Delays, the least important problem, are the easiest to understand. "People don't appreciate that the shuttle, as a technical goal, is much more ambitious than the moon program," says Eugene Covert, an MIT professor and rocket-propulsion expert. "The schedule couldn't possibly have been met."

Considering what the Columbia is supposed to do, it's no surprise that it didn't fly in 1977, or in 1978, or in 1979, and can't fly now. The rockets it is supposed to replace have always been throw-away affairs for very pragmatic engineering reasons : the fiendish forces of space flight twist and sizzle machines into scrap. Rocket engines are essentially explosions with a hole at one end. Exploding gases roar out the hole, shoving the rocket in the opposite direction. The act of firing does such violence to the rocket engine, immolating and warping its components, it's impractical to use again even if you can get it back. Yet the shuttle's main engines will have internal pressures three times greater than those of any previous large engine, NASA says and the goal is to use them on 55 flights before an overhaul.

To truly grasp the challenge of building a space shuttle, think about its flight. The ship includes a 60-by-15-foot open space, narrow wings, and a large cabin where men must be provided that delicately slender range of temperatures and pressures they can endure. During ascent, the shuttle must withstand 3 Gs of stress--inertial drag equivalent to three times its own weight. While all five engines are screaming, there will be acoustic vibrations reaching 167 decibels, enough to kill an unprotected person. In orbit, the shuttle will drift through -250°F. vacuum, what engineers call the "cold soak." It's cold enough to embrittle and shatter most materials. During reentry, the ship's skin goes from cold soak to 2,700°F., hot enough to transform many metals into Silly Putty. Then the shuttle must glide along, under control, at speeds up to Mach 25, three times faster than any other piloted aircraft has ever flown. After reentry, it cascades through the air without power ; finally thunking down onto the runway at 220 m.p.h. The like-sized DC-9 lands, with power, at 130 m.p.h. Rockets are throwaway contraptions in part so that no one piece ever has to endure such a wild variety of conditions. The shuttle's design goal is to take this nightmare ride 100 times.

The main cause of delay is currently the shuttle's refractory tiles, which disperse the heat of reentry from the ship's nose and fuselage. Columbia must be fitted out with 33,000 of these tiles, each to be applied individually, each unique in shape. The inch-thick tiles, made of pyrolized carbon, are amazing in two respects. They can be several hundred degrees hot on one side while remaining cool to the touch on the other. They do not boil away like the ablative heat shieldings of capsules and modules ; they can be used indefinitely. But they're also a bit of a letdown in another respect--they're so fragile you can hardly touch them without shattering them.

"The tiles are the long pole holding up the tent," says Mike Malkin, NASA's shuttle project director. Fixing them to the Columbia without breaking them is like trying to eat a bar of Bonomo Turkish Taffy without cracking it. Most of the technicians swarming over Columbia are trying to glue down tiles. The tiles break so often, and must be remolded so painstakingly, the installation rate is currently one tile per technician per week. All this mounting was supposed to be finished before Columbia left Rockwell's factory. When it wasn't, the work had to be resumed at the Cape. "We've had to put up what amounts to a manufacturing facility there," says Walter Kapryan, who retired as the Cape's shuttle project director last spring. "The most we ever did for Apollo was a little patch-wiring." NASA sources privately acknowledge that Columbia was taken to the Cape in unfinished condition partly for public-relations value--to make it appear that preparations were accelerating. The move also allows computer testing to proceed while the tiles are being mounted. This exercise may have been practical, but it was staggering in cost : $50 million extra to attach the tiles at the Cape, according to congressional sources.

Some suspect the tile mounting is the least of Columbia's difficulties. "I don't think anybody appreciates the depths of the problems," Kapryan says. The tiles are the most important system NASA has ever designed as "safe life." That means there is no back-up for them. If they fail, the shuttle burns on reentry. If enough fall off, the shuttle may become unstable during landing, and thus un-pilotable. The worry runs deep enough that NASA investigated installing a crane assembly in Columbia so the crew could inspect and repair damaged tiles in space. (Verdict : Can't be done. You can hardly do it on the ground.)

According to the computers, as long as you can bring the shuttle back into the atmosphere, you can fly it to the airfield even if the tiles are damaged. Former Apollo astronaut Richard Cooper doubts the computers know what they're meeping about. Many of the projections are based on the magnificent accuracy of the Apollo landings. Apollo went to the moon, came back, and dropped all its little manned modules into a target area about the size of Los Angeles International Airport. But Apollo modules were ballistic projectiles. They were slightly asymmetrical and thus had a little lift for control, but basically they fell like well-aimed stones. The science of ballistics is much more precise and predictable than the art of flying. To assume that experience with one is the same as experience with the other is to confuse a slingshot with a seagull. The only way to find out about something as big and balky as Columbia, Cooper says, is to launch the thing and see what happens. Computers have never flown with the unpredictable combination of damaged tiles that a shuttle may experience. They've never been whacked by a sudden, nonprogrammed gust of jetstream wind. They've never flounced like a twig on the crazy rapids of "bias"--the bland physics term for unexplained variations in the earth's gravitational and magnetic fields. These are the wild, uncharted rivers of space. Unknown ; unknowable ; beyond programming. To find out if your ship can cope with them, you have to take it up there.

One Year And Holding

The people struggling with the tiles serve a useful function. They make the rest of the project look good by comparison. "You have to keep your pole a little shorter than everybody else's," says a NASA engineer. "That's why everybody likes to be under the tent of tile delays." The Air Force, a partner in the shuttle project, is happy to be there under the tent. It's supposed to build a small rocket booster, the Inertial Upper Stage (IUS), to ride in the shuttle bay. IUS, will float away from the shuttle and fire satellites into the high altitudes that shuttles can't reach. It's based on conventional throw-away technology and should be the easiest part of the project, but it's two years behind schedule and $144 million over budget. Yet Secretary of Defense Harold Brown recently assured Congress that IUS is not a problem--because of "revised operational requirements and shuttle program delays."

The shuttle's main engine is also lurking under the tent. Columbia is to be powered by the first large, high-performance "cryogenic" rocket engine, burning liquid hydrogen for fuel instead of kerosene. Cryogenie engines can achieve the impossible dream-combustion efficiency of 99 percent. But the shuttle's cryogenic engines have the annoying habit of blowing up. Not conducive to 55 reuses.

The failures, of course, are taking place on the test stand. During development, it's assumed that some engines will blow up ; pushing them to the limit is part of testing. But the shuttle engines often start flaming under normal operational conditions. And then there was this embarrassing snag that made checking their reliability all but impossible. Although the engines must fire for 520 seconds during a shuttle flight, Rockwell's test stand held only enough fuel for 300 seconds.

For a time, engine progress looked so bleak that Congress convened a panel of National Academy of Science members to decide if the motors would ever work. Just after the engineers managed to get single engines to fire properly for the full duration, for instance, they tried to fire three simultaneously, as would be required during a launch. All three blew up ; acoustic vibrations from one would destroy the next.

Meanwhile, down at the Johnson Space enter in Houston, astronaut preparation was months behind even the short-pole schedule. The reason ? Computer-simulators, used to stage mock failures in the flight trainer, weren't working. This was a triumph of accurate simulation, but otherwise not amusing.

Despite these problems--which have been widely discussed in the trade press since as early as 1977-NASA made routine announcements that a launch was right around the corner. The day the corner would be turned was never specified. "You'll notice that NASA always says the first shuttle will launch within the year," says Dr. Marshall Kaplan, a Penn State physicist. "I call this a 'one year and holding' countdown." The routine came close to slapstick comedy in March 1979. A cluster of three shuttle engines had just caught fire at NASA's test stand, a scant nine seconds into a test. The partially finished Columbia was mounted on the back of its 747 ferry plane for the flight to Cape Kennedy. The instant the 747 nosed off the field, Columbia began to rattle itself to pieces. Tiles flew off ; tape and electrical connections began flapping everywhere. The big jet hastily banked back to the field and rolled to a stop. There was so much damage to Columbia after 17 minutes in the air-- a Sunday afternoon stroll disabling a spaceship ! --that it took a week to get her ready to go up again.

So on a fine morning m March 1979 with engines blowing up, pilots playing parcheesi to pass the time, Columbia melting like an icicle in routine flight NASA announced that the first shuttle launch would be December 1979. History will record that there were no rolled eyes in Congress, no catcalls and guffaws at press conferences, no panic on the floor at Lloyd's of London. December 1979 ? Right. Sounds fine. Everybody wrote it down.

Since then the outlook has brightened considerably. The engines have been fired in unison several times. If it turns out they work, they will take their rightful place among the premier achievements of modern engineering (see "Because Out There is There" on page 49). Problems involving tiles continue, with residual doubt about "whether they can be relied on at all," according to the General Accounting Office. Countdown is back to minus one year and holding. NASA administrator Robert Frosch says Columbia will fly "between late 1980 and the first quarter of 1981." Cape Kennedy observers say the "back end" of that schedule is "possible."

A Flooded Basement

There's good and there's bad to being stuck under the tent. The good part is that Congress throws you money, hoping you will come out.

Until recently, the shuttle program had an admirable record for cost control. But NASA had made its $5 billion to $6 billion projection based on "success-oriented planning." That means it assumed everything would work the first time. Budgets were drawn as if redesigns would never be needed, as if no contingencies would arise, as if 520-second engine tests could be conducted with 300-second tanks.

Of course, NASA planners knew everything would not work the first time. In a complex technological project, very little works at first ; delays and failures are perfectly normal. But to help the shuttle win budget approval, NASA estimated costs as if there would be no problems, according to Dan Cassidy of the House subcommittee that oversees space projects.

To be "success-oriented," NASA decided to test shuttle components only after assembling them together, instead of individually as had been the case with all previous spacecraft. If the bundle worked, great. But if it didn't, the damn thing had to be torn down and tested from scratch. NASA budgeted for only a couple of backup engines. When they started blowing up, as every engineer knew they would--wanted them to ! --the scheduling went berserk. Sitting around waiting for new engine parts to be built can cost the program up to $7.5 million a day in idle facilities and personnel, Cassidy says much more than what would have been spent had the costs been predicted honestly in the first place. "So now we're throwing money at it," former NASA official Gray declared.

In 1979 NASA asked for, and got, a $220 million supplemental appropriation for Columbia. Then it asked for another $185 million, and got that. This January it asked for still another $300 million extra. Money is also being shifted from other NASA projects, mainly planetary probes that are interesting but lack immediacy, and from construction of the other three shuttles, into patching Columbia. In all, shuttle construction is budgeted at $1.8 billion in fiscal 1981--$800 million more than NASA said it would need, according to the Congressional Research Service.

By the time all four shuttles are built, the bill for development and manufacture will come to $13 billion, GAO estimates. It'll hit $16.5 billion if you figure in NASA salaries and construction of a second shuttle launch base for the military at Vandenberg Air Force Base in California. Asked about the supposed bargain basement approach of "success-oriented" planning, Richard Cooper observes "Some basements get flooded."

Considering the ambitious nature of the shuttle program, the overruns are not unspeakable. The promised $5 billion inflates to about $8 billion today. If it really costs $13 billion, that's within reason. And NASA wants you to remember all the money we'll save when Columbia flies. No more throw-away hardware ! No more zillion-dollar towers of power crumbling into ashes downrange over the Azores ! The shuttle's promise of cheap "commuting to space" will finally be realized. That's what they say. Fine--if you don't mind paying more for a "cheap" launch than for rockets you throw away.

Economy At Any Price

Walk into NASA headquarters with a long enough line of credit, and you can buy yourself the top floor of a rocket. For $23 million, for instance, you can buy the services of a Delta, a rocket that will toss 2,750 pounds of whatever you have into the 22,000-mile geosynchronous orbit used by communications satellites. For $33 million, you can get the more powerful Atlas-Centaur, which could kick a small payload out of earth orbit altogether. If you plunk down $50 million or more, you could probably arrange to get a Titan III, the rocket the Air Force uses to launch military satellites. A Titan III, the Clydesdale of space horses, will heave 29,000 pounds into due-east, low orbit.

The money you pay is "total cost incurred"--NASA's price for everything associated with the launch, covering the rocket itself, the fuel, the command personnel to fire it, and the guys who sweep up the pad afterwards. Commercial rocket launches, by law, must be financially self-supporting.

If you want one of these rides, sign up now, because NASA plans to terminate all throw-away rocket launches as soon as the shuttle is working.

"The shuttle will be able to carry three Delta-class payloads," says Chet Lee, the shuttle pricing director. That means, for instance, three communications satellites and the extra boosters needed to push them to high orbits. To launch three Delta-class payloads on Deltas would cost three times $23 million--$69 million.

Compared to this, the shuttle looks like a fire sale. You can book Columbia for $22.4 million, Lee says. That's all you pay. A third the price of those wasteful old throw-away rockets. This is the official rationalization of the official contention that the shuttle will be cheaper.

Let's take a closer look at the numbers. NASA is using the conventional business technique of a loss-leader. For the first three years of shuttle flights, Lee says, "We'll make no attempt to recover all of our direct operational costs." This is necessary, he maintains, to attract customers away from disposable rockets and into the shuttle. Seems odd, since NASA would only be stealing customers from itself. So how was $22.4 million arrived at ?

Back in 1972, when shuttle designs were still on the table, a consulting company called Mathematica did some cost-benefit studies for the project. Mathematica estimated that, under certain conditions, an individual shuttle flight would have a direct cost (fuel, command salaries, sweeping the pad) of $22.4 million. In 1975, NASA froze that number. It started selling contracts for shuttle launches at $22.4 million per, for the first three years of flight--a guaranteed price with no escalator for inflation.

The spirit of '75 is great for satellite customers, since the cost of regular rockets is inflating right along with the rest of reality. The 1975 estimate inflates to about $32 million today--still cheaper than our three Deltas.

What happens to the cost of shuttle flights at the end of three years ? "Then our direct-launch price will go up to reflect true costs," Lee says. All the evidence is that "true" costs will be high indeed. Flying and refitting the shuttle--even assuming all goes well--will be more expensive than predicted. All the things that you used to throw away and forget about now must be returned to earth, fixed, and cobbled together for another launch. Lee says the "true cost" of a launch is "about 25 percent" more than will be charged in the first three years. The "true cost" of one flight of the shuttle thus approaches $40 million. Costs keep rising, like a rocket gushing flame and trembling to get off the pad. But NASA says the shuttle is still a bargain, payload for payload. Better keep a close eye on that cost-rocket. Once those things get moving, they really pick up speed fast ....

Turn Down the Volume

What was the basis of Mathematica's cost projections ? The analysts assumed that the shuttle fleet would stage at least 50 flights a year. With each vehicle having a 10-year life, that meant at least 500 flights over a 10-to-12-year period. (At one point in 1976, NASA was projecting 75 flights a year. The number has been dropping steadily since, and now stands at "around 40 to 50 flights a year," Lee says.) As with any volume merchandising, the more flights there are, the lower the cost of each individual flight. So it was important to project lots of flights. These are "safe life" numbers.

Fifty flights a year ? For what ? Mathematica assumed there would be 20 flights a year for something called Spacelab. Spacelab is a little workshop that rides in the shuttle bay. The shuttle goes up and opens its doors ; scientists crawl from the cabin into Spacelab ; they sail around doing experiments ; then the shuttle snaps closed and brings the whole package back, to be outfitted for another flight. Spacelab is being built by the European Space Agency. ESA is paying for its first flight. (NASA likes to give the impression ESA is paying for all its flights. It is not. NASA will pay for everything after the second Spacelab cruise, Doug Lord, the Spacelab director, notes.)

Will Spacelab be used 20 times a year ? "I can't imagine what for," says Albert Cameron, a Harvard physicist who is chairman of the Space Science Board of the National Academy of Science. "The duration of the flight is so short," he explained, pointing out that it will ordinarily last only four to seven days, "there's way too little time to carry out any meaningful experiments." Even Lord acknowledges that the applications of Spacelab are limited : "It's really an interim step, to demonstrate to the world that a permanent space station is a worthwhile idea." Meanwhile, will the interim step fly 20 times a year--a total of 200 times ? "Not a chance," says an informed NASA source.

Also listed in the calculation are six flights a year for communications satellites, like those made famous by Comsat, Inc. Communications satellites fit Columbia just perfectly ; NASA says three of them could go up on one shuttle ride.

How many communications satellites are now being launched ? Two a year. Intelsat, the international consortium that is the largest private space user (Comsat is part of it), plans to send up two satellites in the next three years, a spokesman says. The satellite communications business is expanding, with RCA, Western Union, AT&T and SBS (a venture of IBM, Aetna, and Comsat) planning to enter. But to require six shuttle launches a year, there would have to be 18 satellites. "Barring some extraordinary breakthrough in technology," says an informed communications industry source, "that's inconceivable."

So how many shuttle flights a year seem reasonable ? Maybe 20, insiders say, with the largest share devoted to launching defense satellites.

Suddenly, like a rocket veering off course, NASA's numbers are shaking. If there aren't 50 flights a year, the cost of each flight shoots up from the projected "true" cost of $40 million. It's getting closer and closer to the $69-million cost of using three Deltas, the throw-away equivalent of a shuttle.

Take A Walk

But we all know there's something the shuttle can do that rockets can't. The shuttle can recover damaged satellites. This is a widely publicized aspect of shuttle mythology--grabbing and returning to earth a satellite that has worn out or broken down, so that it can be repaired and returned to orbit later. According to a GAO study, fully 75 percent of the shuttle program cost savings are based on Mathematica's assumptions about how much we will benefit from recovering crippled satellites.

The only problems are :

- (a) The shuttle can't retrieve satellites ;
- (b) Nobody wants them back in the first place.

More than two thirds of the satellites being launched are sent out to geosynchronous orbits--22,000 miles up, where, relative to a spot on the rotating earth, they hang in the same place all the time. Others are sent to nearly-as-high sun-synchronous orbits, where they follow the movements of the sun.

The shuttle, on the other hand, orbits at 200 miles. The highest it could reach, unloaded, would be 600 miles. Routinely, the shuttle will fly to 200 miles and release a satellite mounted on the LUS booster, or a smaller booster called a SUS (for Spinning Upper Stage). The booster then blasts the satellite out to its final destination. Once there, it is beyond the shuttle's reach. Period. When something is 22,000 miles away, getting 200 miles closer isn't much of a help.

Cassidy of the House space subcommittee acknowledges this is "a flaw in the system."

Like most mythology, the "retrieve and return" business has a basis in fact. When the shuttle was being planned, there was supposed to be a "space tug." This was to be a robot rocket vehicle of some kind, assembled in space and left there. The shuttle would bring it fuel and satellites to move around : The tug would take a new satellite out to high orbit, then go find a damaged one and tow it back down to the shuttle.

The tug proposal has been killed. Every year NASA sticks it back in the budget under a different name, and every year it gets killed again. It gets killed because people don't want their satellites back. "A communications satellite has absolutely no salvage value," says Larry Weekly, spokesman for SBS, Inc. "They almost never fail, and by the time they wear out, after seven to ten years, they're obsolete. It's much cheaper to build a new one." Especially, Weekly adds, since the cost of a new satellite--now running $20 million to $40 million--is likely, to be less than the cost of sending a repairman after an old one.

Some satellites are parked in low orbits, within Columbia's reach. But even then they may exceed its grasp. A shuttle has little maneuvering power ; basically, it can only intercept things in its launch path. Few existing satellites are in orbital inclinations the shuttle uses. NASA is adjusting for this by launching satellites worth recovering--$90-million spy-eyes and telescope-observatory satellites--into paths the shuttle will cross. But this doesn't guarantee that Columbia will be able to cope with them. When satellites get into trouble, they often suffer loss of stabilit--the gyros fail and the little robot starts tumbling wildly. NASA acknowledges that the shuttle wouldn't even try to recover an unstable satellite. How could it ? What could it grab hold of ? Would you pull a billion-dollar spaceship under a rumbling stellar bowling ball that might come caroming into your ice-fragile tiles ?

Warp Speed

NASA has been casting about for other reasons to stage shuttle flights. The agency hoped that companies would sign up for space manufacturing tests--the search for the fabled flawless ball bearing. But so far, according to Ed Fritz of GAO, only one American firm has shown any interest. And, in order to entice it, NASA has promised to foot the bill for the full cost of the test flight, Fritz says. In return for accepting this fiscal hardship, the company gets the patent rights to anything it might develop.

The price per flight keeps climbing beyond $40 million, as the number of plausible missions decreases. But it's still less than $69 million for those three Deltas. Less, that is, until you remember that the Deltas were already around. You didn't have to spend $13 billion to develop them. NASA has repeatedly noted that there will be no attempt to recover--amortize, you might say--the development cost of the "cheaper" shuttle.

Suppose the shuttles fly 500 sorties, as predicted, and cost $13 billion to build. That works out to an investment cost of $26 million per flight. Add that to the $40 million "true cost" of a launch. Suddenly a shuttle launch costs $66 million just about the same as three Deltas. Now, suppose the shuttles fly only the pessimistic 200 flights. The investment cost leaps to $65 million per flight. Suddenly the total cost of a shuttle flight becomes $105 million--almost twice the cost of three of those wasteful Delta rockets.

Of course, it once cost money to develop the Delta and the Titan and what all, and that money is not amortized to each flight. But those rockets are already developed. That money's already spent.

"Oh, the shuttle will definitely cost more than equivalent expendable rockets," said Kaplan plainly. "The payoff is not in dollars, but in flexibility and expanded horizons."

Weight A Minute

They didn't talk much about "expanded horizons" back in 1972 when NASA was selling the shuttle as an economy move. They did talk about flexibility, though, because the shuttle payload would, be greater than the other rockets'. It was supposed to be able to carry 65,000 pounds into a low orbit, launching due-east. (Because the earth spins west to east, rockets launching east get a boost from the earth's own momentum. Launching north or south to reach polar orbits bucks the spin. Nobody launches west.)

Here the "economy" calculations reach escape velocity. The 65,000-pound payload is being quietly dropped, too. "We'll be lucky if we hit 30,000 due-east," says Kaplan. Columbia and Challenger, the second shuttle, are turning out to weigh much more than planned. Every pound added to the shuttle is a pound subtracted from the payload.

The external fuel tank, for instance, is full of oxygen and hydrogen cooled to -400°F. to make the gases flow as liquids. Ice will form on the tank. When Columbia's tiles started popping off in a stiff breeze, it occurred to engineers that ice chunks from the tank would crash into the tiles during the sonic chaos of launch : Goodbye, Columbia. So insulation was added to the tank. But while thermal cladding solves the ice problem, it adds weight. The entire vehicle, loaded, weighs 4.5 million pounds. Say you add one percent. Doesn't sound like much. One percent comes to 45,000 pounds. That's almost all of the payload.

Discovery and Atlantis, the third and fourth shuttles, are slated to have stronger tiles and lighter components. They may be able to lift 65,000 pounds. Meanwhile, remember the Titan III, lifting 29,000 pounds for about $50 million ? "Getting only a 30,000 payload from the shuttle is a giant step backward, compared to the Titan," says Albert Cameron. "But it's a moot point now to argue about the practical virtues of the rocket. NASA has eliminated it. You have no choice but to launch on the shuttle, do you ?" Indeed, NASA has even eliminated the word "rocket." Jack Mahon, NASA's Expendable Launch Director, says they are now called "ELVs"--Expendable Launch Vehicles. Surely you remember that fabled day in 1926 when Robert Goddard, father of modern rocketry, lit off the first liquid fueled rocket engine, sending a device the size and shape of a coat tree screaming into the low clouds over Auburn, Massachusetts ? Remember how he called to his wife, "Come quick, dear, I've invented the expendable launch vehicle !"

Spyless Sky

The original reason the shuttle was supposed to lift 65,000 pounds was to satisfy not commerce or science, but the Defense Department. DOD plans to launch all its military spy satellites on the shuttle, using NASA tracking facilities and astronauts. "DOD was brought into the shuttle planning because they wanted something big with a lot of payload," Doug Lord explains. "Without DOD, there would have been no reason to make the shuttle so big."

DOD's chief concern was being able to launch south over the poles, where sun synchronous orbits are available. In such orbits, a spy satellite's cameras see the same sun conditions every day. A shuttle launching 65,000 pounds due-east was supposed to have enough energy to lift 40,000 pounds over the poles. But as time went on, DOD began to perceive that Columbia couldn't even come close. So DOD got funds to build a "thrust augmentation package"--yet another set of engines to be strapped to the shuttle conglomeration.

The "thrust package" will be an abbreviated first stage of a Titan rocket-two motors and four fuel tanks. Fitting under the shuttle's fuel tank, it will generate enough thrust to lift an extra 10,000 to 20,000 pounds. The cost is $10 million a shot, NASA says--there go those costs, picking up speed again--and it will not be reusable. Tumbles into the ocean like those despised old rockets.

This doesn't dampen DOD's enthusiasm for the shuttle project. Air Force Secretary Hans Mark recently told Congress : "It is important to exploit the shuttle... because as far as we know, the Russians have nothing like it." (It is believed the Klingons have nothing like it, either.) DOD campaigned long and hard to get its own shuttle launchers, at Vandenberg Air Force Base in California. Since Cape Kennedy could already accommodate more shuttle flights than were planned, it was hard for DOD to justify $4 billion to build and operate another base. But the Joint Chiefs of Staff pointed out that, after a polar launch from Cape Kennedy, the empty fuel tank would tumble away and burn up in the skies over Russia. After a polar launch from Vandenberg, it would not. Russia might interpret a burning fuel tank as a nuclear attack, the Chiefs warned : The fact that Russian instruments would immediately identify the launch as that of an unarmed shuttle--or that we could notify them of the launch via Mailgram, at a fraction of the cost of a telegram or a Vandenberg base--was discounted. The Chiefs prevailed.

Because of the delays, DOD has ordered six more Titan IIIs to ensure launch capacity for the next two years' worth of spy satellites. Beyond that, however, no more Titan production is planned, according to Jack Boyd of Martin-Marietta, the rocket's builder. "By the mid-1980s," says Defense Secretary Brown, "we will be almost totally dependent on the shuttle for our national security space missions." No alternative but to rely on an untested system. Wonder if the Russians have one of those ?

Scotty, Beam Us Out

Technical problems are just that : technical. Much of what's wrong with the shuttle will someday be fixed. If money is no object, as it usually isn't in space launches, we can pay more for reusable shuttles than for throw-away rockets if we have to. But the question never answered is--what will the shuttle do that rockets couldn't do ?

It can't launch more than they can ; sometimes, it can't launch as much. (Even the 65,000-pound target pales compared to the 250,000 pounds a Saturn V could hoist.) It can't bring back satellites. It can't keep a space station aloft even a fraction as long as Skylab stayed up there. It has no scientific value. It just has men in the front seats ... and an enormous amount of weight and equipment devoted to bringing them, and an empty cargo bay, back in one piece.

There is something noteworthy a rocket can do that the shuttle cannot. A rocket can be permitted to fail. What if a billion dollar spaceship wipes out on a "routine" mission "commuting" to space with some puny little satellite ? Cooper fears it might drive a stake through the heart of the manned space program. Would the public stand to lose a quarter of the fleet in a single day ? Would it fork over another billion dollars to build a replacement ? Would it stand for spending millions to train astronauts to be truck drivers, only to lose truck and drivers both ? The prospect makes the old rockets seem kind of nice. One of the old throw-away jobs could go haywire, and spiral down into the ocean off the Bahamas, and everybody would feel miserable and millions would be wasted and everybody would go back to work. Lost it, dammit--but then nobody ever expected it back.

You Only Go Around Once

The shuttle is the first space vehicle that can't be test-fired unmanned, Cooper points out. Pilots have to crawl in and light the candle and go. A couple of guys who ought to know better have to wrestle with that stick and call out the numbers and write when they get there. Then we'll know.

It goes like this. During blast-off, unlike those capsules and modules with escape rockets to pull the pilots free in case of trouble, there is no way out of the shuttle. Columbia has ejection seats like a jet fighter, but they're useless during take-off. Punching out at several thousand m.p.h. doesn't work. If the slab of rushing air doesn't kill you, the engine exhaust flames will.

Here's the plan. Suppose one of the solid-fueled boosters fails. The plan is, you die. Solid rockets can fail in two ways. They can explode ; enough said. Or they can shut down spontaneously. If a booster shuts down, there will be 2.5 million pounds of thrust on one side battling zero pounds on the other. Even a split second of this imbalance will send the ship twisting into oblivion, overriding any application of pilot skill.

Suppose one of the shuttle's three main engines fails. You have a fighting chance. You blow the boosters off. Then, using the throttles on the remaining engines, you try to turn the beast around. It's screaming and trembling, a vicious wounded animal. There's that damn fuel tank hanging there, and it has all the aerodynamic grace of the Temple of Karnak. But it's got the fuel. Ditch it and you've got no engines.

If you get twisted back around toward the Cape, you blow the fuel tank off and glide home. If the beast is too badly wounded to land, but you can slow it down to a few hundred m.p.h. before you splat into the water, you're okay. At that speed you can eject.

But you're in luck--the launch goes fine. Once you get into space, you check to see if any tiles are damaged. If enough are, you have a choice between Plan A and Plan B. Plan A is hope they can get a rescue shuttle up in time. Plan B is burn up coming back.

But let's not worry about the tiles. The tiles should be okay. They're certainly spending enough time on them. So once you get back into the atmosphere, the mad joyride begins. You have no power now, the engines are spent and switched out. You get one shot at a landing. Originally the plans called for a couple of regular jet engines to give you enough power to maneuver, or maybe go around for a second approach if the first one doesn't line upright. But jet engines got killed in the cost-cutting. A billion-dollar ship, and this is how they were cutting costs ....

The shuttle starts rubbing air at Mach 25--25 times the speed of sound. At 250,000 feet, you have a little control with the reaction thrusters. By 80,000 feet, they've shut off, and you're gliding. It's silent in the ship. Just the air rushing by and the computers meeping to each other. Biting into the denser air, your elevators and speed brakes lend some control. You can still maneuver "cross range"--several hundred miles north or south relative to your approach from the west. But there are only 15 runways and lake beds in the world where you can land, so don't get carried away.

Cross-range maneuvering is no longer possible by 50,000 feet. You're locked in, wherever you're going. Now you have company. Fighter planes--"chase planes"--have picked you up. They're swarming all around you, snooping around the hull for damage. Eighteen miles from the runway, you finally slow to subsonic speed. Now you really have some options. At this low speed and altitude, you could punch out safely.

At 12,000 feet, the plummeting begins. Nose down at 24 degrees to the horizon, 30 degrees in some flights. Feels like a dive bomber. That DC-9, the one that makes your knuckles white on commercial flights, comes in at three degrees. Thirty seconds out, you can raise the nose back up. Now you have one and only one chance to lower the landing gear. No time to cycle them. If the gear don't lock, that's it. The chase planes are coming right down to the strip with you, following your every move like baby ducks. They snoop around the landing gear. Locked ? If not, the chase pilots have a couple seconds to tell you to bail out.

Only a few more seconds. The ground isn't coming up ; some prankster from Hell is throwing it at you. Whack ! Down at 220 m.p.h. Hope the rubber in those tires didn't blow from that long cold soak. Crack ! You bounce along, you roll to a stop.

Good thing you didn't have to punch out. Only Columbia will have ejection seats. "The whole philosophy is that the shuttle is like a commercial airliner," Day explains. "You test everything like mad, but once it's checked out, you take your chances."

Now, let's check. Is the hull intact ? Better be. NASA says it will turn this ship around and have it flying again in two weeks--only 96 of those hours for "safing" and refitting. Did all that stress--stress that would have twisted any other flying machine into a croissant--pop off any of your tiles ? Let's hope not. The cost-cutting plan says NASA will have to replace only 1.4 percent of them after each flight. It's right here in the cost-cutting plan, right under "C"--"Commuting to space."