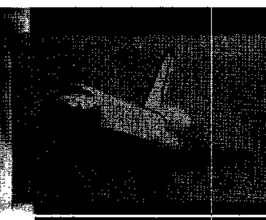
NASA
National Aeronautics and Space Administration
Lyndon B. Johnson Space Center
Houston, Texas



Charting a decade

The space shuttle fleet's statistics are impressive when added up over 10 years of flying. Chart on Page 3.

From ... where?

Leon... ...n and Dan Germany tell wha... of the shuttle in the years to com... Page 4.

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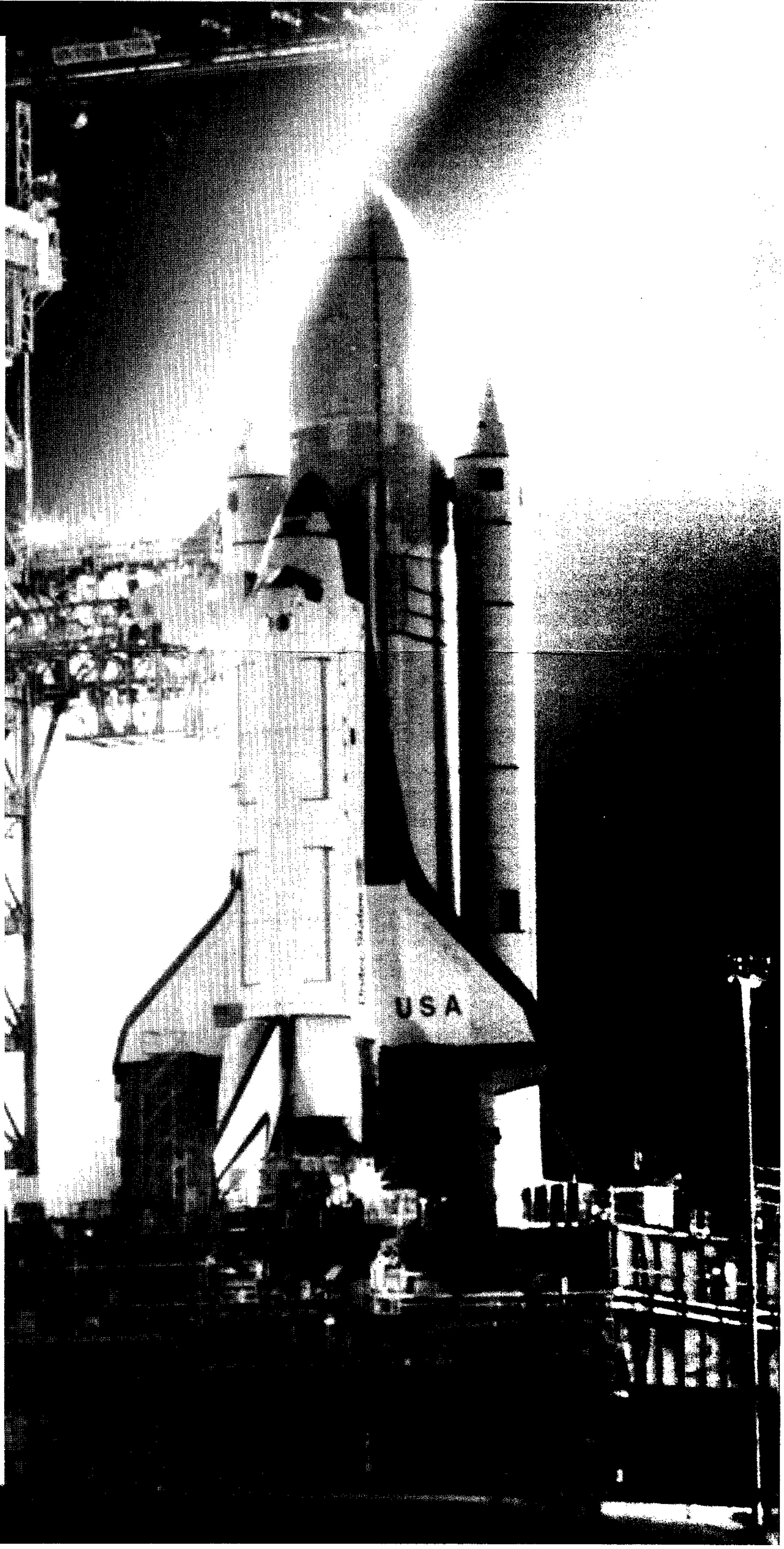

The Amazing All-Electric Flying Machine

By Brian Welch

There were a quarter-of-a-million people on the lakebed that morning, awash in a sea of Winnebagos, blue bunting, American flags and network anchormen, but most of the half-million eyes were trained on the sky.

Although they couldn't see the spacecraft just yet — *Columbia* was still far out over the Pacific — they had been able to hear the exchanges between Mission Control and the two astronauts thanks to loudspeakers out on the desert floor. "Okay, understand Go for the deorbit burn," Commander John Young had said when the time came to fall out of orbit. "Thank you now."

Clad in bright orange pressure suits, sitting atop ejection seats, Young and Pilot Robert Crippen were about to exercise the one capability that made their spacecraft truly revolutionary: they were about to bring it back in one piece. All of it. And they were going to land it on a runway. But first, there was EI to get past. Entry Interface, it was called, the point at which the spacecraft began to plunge through denser and denser folds of the atmosphere, trailing heat and a plasma sheath as it went. Because this had never been done before with this kind of machine, because the avionics were new and highly challenged by what was to come, because of fragile heat shield tiles and predictions of a "zipper effect," millions of people on the planet below were watching and waiting.

If even one tile came loose from the underside, so the conventional wisdom said, then the flow of hot gases would work around and under the next tile downstream and then the next one, in short order stripping an area bare of heat protection like yanking on a zipper. "The two major technology problems we had to solve in the orbiter program," JSC Director Aaron Cohen remembers, "were the avionics system and the tiles." Now both elements were about to be tested. It was an edge-of-the-seat kind of moment.

"Nice and easy does it John," CapCom Joe Allen radioed from Mission Control, "we're all riding with you. We'll see you about Mach 12." And then the crackling transmissions receded, it grew quiet on the airwaves, and the spectators out on the lakebed talked about how this must be the radio blackout from reentry. The blackout dragged on, the landing convoy's engines were idling, and the anticipation became palpable. The spectators were about to witness an event unique to history; no one knew what to expect next.

Still out over the ocean, *Columbia* was tripping down through the high Mach numbers, nose high, in a state of equipoise amidst the fireball, while the avionics bays hummed with automatic flight controls at work, firing off jets and steering through regimes of flight never before navigated by a vessel with wings. Until now, it had all been theory. It was still a realm of vast uncertainty for a flying machine and its designers, this business of balancing opposing forces along a sliding scale of altitudes, velocities and pressures, where every tenth of a Mach number you passed through was a distinct and separate place, a different aerodynamic address.

Now at last the technical heritage of American high-speed flight research and the practical experience of sending men to the Moon had joined to create the granddaddy of all plane rides. It really was happening. And when the moment finally came, the engineers

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The Amazing All-Electric Flying Machine

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and operators who had slogged through the lean times of Reductions in Force and program stretchouts to build this machine could only stand and wait, just like everybody else.

Henry Pohl was one of them, and he still marvels at how rocketry and aeronautics came together that day in the shuttle program. "Most people can't appreciate that the shuttle, when it's in orbit up there, is going eight times faster than a bullet when it leaves the muzzle of a 30.06," said Pohl, JSC's Director of Engineering. "It's an airplane. But we launch it like a rocket. We kick it out of orbit halfway around the world, dead stick, no engines. It flies like a rock, yet we set it down on the runway, and we do it time and time again."

It comes down like a rock for good reason, explains Max Faget, who had Pohl's job during the long years of shuttle development. "There never was a machine imagined like the shuttle before there was a shuttle," Faget said. "Embodied in that one machine you have a launch vehicle, you've got a spacecraft, and you've got a reentry airplane, not a reentry vehicle. Prior to the shuttle, when the Apollo came down, it just fell down. They didn't fly down, they fell down. There was no way it could support itself in the air on wings, so it fell. And everybody knows that if you fall down, you're *going* to get down. So it was a much easier maneuver. There was nothing tricky about it."

The shuttle, on the other hand, must remain perfectly balanced on its wings throughout the long steep drop to Earth, said Chris Kraft, former JSC Director and an engineer with some experience in the world of flight control systems. "The way you balance something is with pure force," he said, "and those forces are totally known because there are no aerodynamic forces (on the orbiter) above about Mach 10. The real problem was between 8 and 1."

And it was that region of the entry profile which required a tool of the trade called a Monte Carlo analysis. In that procedure, Kraft explained, aerodynamic parameters were plotted against different Mach numbers in random combinations. The idea was to first fashion an aerodynamic curve along which the shuttle would fly, a corridor where the flight control system would be designed to guide the ship through precise forces at specific velocities, compensating for changing conditions all the way down. Then they expanded that envelope above and below the curve by adding variations to the flight control settings.

"There are about 40 major aerodynamic parameters, give or take a few," Kraft said, "and within this envelope, at any given Mach number, we took all 40 of these parameters and ran them in a totally random way, 1,000 times for each Mach number until there were zero, zero failures. Zero."

They even went so far as to break the Mach numbers down into tenths of Mach numbers, threw all the parameters back into the hopper, and then ran it until they could go a thousand times without a glitch. "If we had a single failure we went back and made a correction to the system until we got 1,000 runs without a failure for every Mach number," Kraft said.

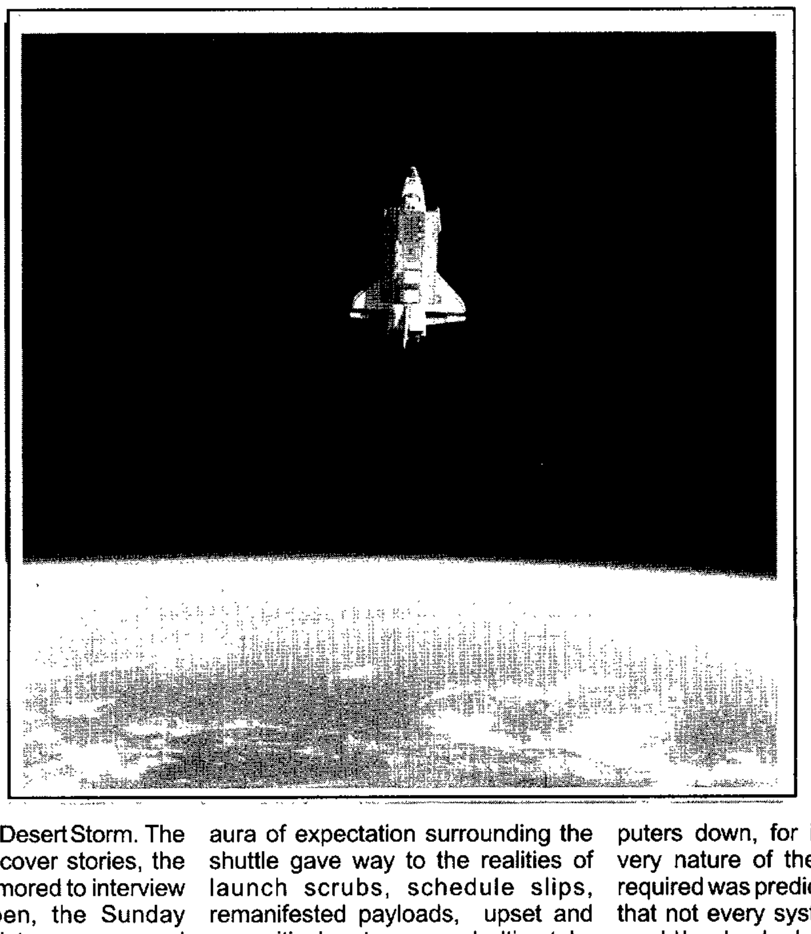
They used wind tunnels to predict what the parameters would be along the corridor, measured their ability to predict these phenomena, and pored over flight data from research aircraft such as the X-15 and the YF-12. Not yet satisfied, they tweaked the responsiveness of the controls by adding gains to the system, damped out and tight in one place, high and loose in another. They varied the gains all through those Mach numbers, Kraft said, adjusting the flight path angle here, the angle of attack there, until the aerodynamic factors, the thermal constraints and the structural integrity of the vehicle were all harmoniously balanced.

There was nothing harmonious about the waiting, however, as *Columbia* took the hypersonic toboggan ride back to Earth. "Even with all of that testing," Kraft said, "I still wasn't sure this sonofabitch was gonna fly." He and Faget were sitting at the management console in the back of Flight Control Room-1 with Gene Kranz, then Deputy Director of Flight Operations.

At last the telemetry started coming back after more than 16 minutes with no data from the orbiter, S-Band through the Western Test Range at first, then through the Buckhorn station, showing the *Columbia* to be doing Mach 10.3 at 180,000 feet, "exactly nominal," the flight dynamics officer noted.

At 151,000 feet, traveling more than 8 times the speed of sound, Crippen saw coastline ahead. "What a way to come to California!" he called. The worst of the waiting was over. Theory was becoming reality.

Even though still hypersonic at Mach 6, heading down toward Mach 5, the *Columbia* was now in the familiar territory of flight regimes first pioneered by the X-15. "It was a question of getting this flying machine down from orbit and into flight conditions that we understood something about," Kranz remembers. "We had been there before."



And that was when Kraft turned to Faget, even before the twin sonic booms were heard over California, and said, "We have just become infinitely smarter."

There was plenty of enthusiastic agreement on that point, and not just in Nassau Bay, where they blocked off the streets and had a landing party, just like the splashdown celebrations of Apollo. All over the country, pride ran deep after STS-1. It was the same sort of dynamic, although on a smaller scale, as the one at work in America today in the euphoria following Operation Desert Storm. The newsweeklies ran cover stories, the morning shows clamored to interview Young and Crippen, the Sunday supplements ran picture pages, and people generally felt good about the country's very visible leap forward in space exploration.

TIME said the flight was "a much needed reaffirmation of U.S. technological prowess. It came at a moment when many Americans, and much of the world as well, were questioning that very capability." TIME said we were troubled a decade ago by Viet Nam, Japanese cars, Three Mile Island and the failed hostage rescue at a place called Desert One. Newsweek said, "All Americans had the right stuff again: and it turned out to be Nomex felt insulation and heat-resistant silica tiles, 31,000 of them fitting together as seamlessly as Arizona and New Mexico."

Looking back on it now across a gulf of memories 10 years wide, such sentiments seem quaint. Over the past decade, the shuttle has become the aerospace world's most visible lightning rod, a waste to some, an art form to others, a machine with wings that flies not only in outer space and the Earth's atmosphere, but also plies the murky realm where budgets, science and politics all meet.

But then, diversity of opinion has always been one of the common threads in the space shuttle tapestry. It was President Nixon himself who, having just announced that the U.S. would proceed to build the shuttle, alluded to the controversies of this next step when he quoted Oliver Wendell Holmes: "We must sail sometimes with the wind and sometimes against it, but we must sail, and not drift, nor lie at anchor." That was January 5, 1972. Fifteen years later — to the day — the headwinds were blowing as work crews opened an abandoned Minuteman test silo in Florida and began interring the 20,000 cubic feet of debris recovered after the *Challenger* accident. Point, counterpoint. Glowing praise and harsh criticism, success and failure, triumph and tragedy. That's been the way of it over the course of the whole program.

Even in the afterglow of STS-1 at the very inception of the flight program, the shuttle was already being seen as too much of one thing and not enough of another, depending on the viewer's perspective. "All but forgotten amid America's sudden love affair with the shuttle," TIME said as only TIME can, "were its $9.9 billion price tag, all those loose tiles, the exploding engines, even the last-minute computer failure, to say nothing of the inevitable jokes about America's 'space lemon,' and 'flying brickyard.' Could past scorn actually have increased the passion of this new embrace? The shuttle had become a kind of technological Rocky, the bum who perseveres to the end, the underdog who finally wins."

And this was after only one flight. Over the decade that followed, the aura of expectation surrounding the shuttle gave way to the realities of launch scrubs, schedule slips, remanifested payloads, upset and very critical customers and, ultimately, the cauterizing spectacle of the *Challenger* accident. "There was an aura of expectation," said Joe Loftus, assistant director for plans, "and the failure to meet some of those expectations has totally obfuscated anybody's actually looking at what's been accomplished. So the disparity between the expectation and the reality creates the sense that it's a debacle, while in fact the achievement has been impressive."

Another problem for the shuttle, Pohl said, is the finite size of the research and development pie from which all pieces must be cut and served. "The way our environment is set up, everybody that wants to sell something has to go knock something else," he said. "There's always somebody that can gain something from this other program, and they can show you just how cheaply their new widget can be made. Paper airplanes never have problems with hydrogen leaks."

But many believe the shuttle's problems of perception go well beyond schedule slips or hydrogen leaks. The problems, some say, go all the way back to the beginning of the program to what one space reporter, Morton Dean of ABC News, called "original sin." And that was the promise that the shuttle would drastically reduce the cost of getting a pound of cargo into orbit by flying 60 times a year, along the lines of a spacegoing airline. When that didn't pan out in the '80s — when it didn't even come close to happening — the critics lit into NASA for overselling the program.

To understand why those promises were made, one has to return to the heady days of Apollo. "You could not have built the shuttle without the Apollo heritage," Loftus said. "You couldn't have done it with another team." Pohl agrees: "A lot of the people that worked on the orbiter worked on the X-15," he said. "Then they worked on Apollo. So they had the knowledge of how to build airplanes, they had the knowledge of how to build rockets, and the kinds of things that you had to be concerned about when operating in the space environment."

The designers of the shuttle, in other words, had just sent people back and forth to the Moon in one of history's great adventures. They thought expansively in those days. In that sense, their plans for operating the shuttle fleet and their baseline assumptions about how we would do the job, and what tools would be required, were at least a generation ahead of the hardware. Back then, they thought in terms of a rough and ready, rugged and robust 4-wheel drive of a spacecraft, capable of bouncing around the back roads of space with a vast array of redundant systems, four deep in many cases, to provide defense in depth against hardware problems and ground processing headaches.

That defense in depth, known as quad redundancy, had an odd sounding acronym (even for NASA) to express its method of operation: FO/FO/FS. That stood for Fail-Operational/ Fail-Operational/ Fail-Safe. Safe enough to get you home even if three strings cratered, and for anything short of that, you just kept on operating. And launching. Strange as it may seem today, the original design intent of the program was to be able to absorb hardware problems and keep the missions going. People intended to launch with one out of five computers down, for instance, and the very nature of the processing time required was predicated on the notion that not every system or subsystem would be checked out between flights. The redundancy in the hardware, it was thought, would preclude that necessity.

So the shuttle was styled as something of a space truck, fitting enough since the design team was based in Texas, but there was more to it than that. The people of Apollo had seen all sorts of heavy duty adventure take place eight light seconds away on the Moon's near side. There was no reason to suppose that would be different in the future. "I think what we are finding difficult is that since the '60s, society has become far more risk averse than was the case previously," Loftus noted.

All of this helps explain how it was, in the days before Saigon fell, in the years before Watergate took its toll, in the first half of the '70s before disco strangled rock 'n roll and infected a decade, that NASA went forward with plans for a space station and for a reusable vehicle to get people there. And back.

"Very early on in our discussions with the Office of Management and Budget," Kraft said, "we found out that we couldn't build what we wanted to build. And we had to compromise greatly in order to get the program to fit into the budget that people were allowing us to have. We estimated $15 billion to build a totally reusable machine and they said, 'You can have five.' And we ended up compromising at a fixed price contract of about $6.5 billion with a billion dollar overrun possibility."

It never got any easier after that. A slowdown hit the aerospace industry, thousands of engineers lost their jobs. Reductions in Force swept NASA, and the civil service complement at JSC had to be reduced in those years from 4,800 to 3,200. All while trying to bring a revolutionary space vehicle on line. There was more. "From the very start, they never gave us the money we asked for," Loftus said. "So it was a constant struggle to develop the system and it's been a constant struggle to get adequate funding for spares and for all the kinds of things that are productivity enhancing."

For the person running the Orbiter Project at the time, the budget situation was "very severe and very hard." But Aaron Cohen is quick to point out that when the budget axe had to fall, it generally fell on the schedule, not on quality and not on safety. "I don't think we made any shortcuts in that sense," he recalls, "but when I had a problem, I couldn't solve it as rapidly because I couldn't go with parallel approaches. I had to pick an approach and then hope it was right, rather than go down two or three paths at the same time, as we did in the Apollo program. We had to be much more accurate on the solution we picked before going forward in the shuttle program, and it did slow us down somewhat."

Pohl remembers the technical horsetrading that went on in those days, such as the time when his old Propulsion and Power Division deleted a fourth fuel cell and auxiliary power unit during a weight reduction exercise. He still speaks of it as if the division had to offer up a kidney and a lung, and remembers how tough the choices were. "And I don't think a person can give Aaron Cohen too much credit," he says next. "His tenacity and just being hard-nosed and being able to deal with an enormous number of problems simultaneously early in the program, not caving in to the whims of everybody, was one of the major contributions to the success of it."

In the end, they couldn't do it all, however, they couldn't make the shuttle all things to all people and somehow also manage to achieve every one of the enormous promises that were made. It is illuminating, in 1991, to consider just some of the elements that were a part of the list of things that said, "here's how you can launch 60 shuttle flights each year." The list included a baseline of seven orbiters, three launch pads, two orbiter processing facilities, adequate spare parts, regular Florida landings and a large percentage of highly standardized commercial satellite deployment missions. In one way or another, for one reason or another, none of those baseline assumptions was met, yet the expectations placed on the shuttle scarcely lessened.

Despite all of those things, work on the shuttle program continued, and now the fleet is flying. The tenth anniversary of STS-1 is a good time to reflect on just how capable the vehicles have turned out to be, despite the shuttle's bad press.

There are very few Americans who realize, for example, that the space shuttle is one of the most reliable launch vehicles the world has ever known, with a success-to-failure ratio of .974, with 1 being perfect. Moreover, most Americans do not realize that this number is made even more impressive by the fact that, Loftus will tell you, launch vehicles usually experience more failures in the early years of operation, before they hit a stride of design maturity after 100 or so flights. But the shuttle, with 38 flights, has a higher reliability rating than any other U.S. booster. Ariane, the only other vehicle designed in the '70s and operated in the '80s, had five failures in the first 40 flights.

How many Americans are aware, as another example, that the shuttle has launched almost half of all the mass that the United States has ever deployed to space? Most of what they see and read tells them only that one launch or another has been delayed, or that one mission or another has moved into or out of a given calendar year. It's like trying to assess how the railroads shaped westward expansion and America's manifest destiny in the 19th Century by fixating on whether the 3:10 to Yuma actually got to Yuma at 3:10 p.m. on Aug. 21, 1889. Historically speaking, it doesn't matter if the train was late on

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STS-1 Crew Remembers Pride, Satisfaction of First Flight

By James Hartsfield

Columbia launched the space shuttle program a decade ago, but for the two men who flew it, some of the strongest memories came later.

"Right about then, everybody was down on the United States. Two weeks before we launched, they (news reports) said the space shuttle was a lemon," STS-1 Commander John Young said recently. "But after we launched, it really changed everything. And after the flight, when we went all over the country and talked to everybody — we made about 400 appearances in about three months — you could see a lot of good spirit coming back. It was a shot in the arm to the patriotic spirit and to the get up and go spirit that's inherent in the people in this country."

For STS-1 Pilot Robert Crippen, one of the strongest memories of the mission also comes not from space but from Earth.

"One thing that has really stuck in my mind wasn't during the flight or even right after the flight. It was the travels that John and I made," the Navy captain said. "Everywhere we went, we felt the sense of pride the country had. People everywhere felt they were a real part in it, not just in this country, but abroad as well, from Europe to Australia. It was out there, from small towns to big cities. When you see people react to something like that, it gives you a very good feeling, a good feeling of satisfaction."

Young had flown three different spacecraft and walked on the Moon before he flew the shuttle, yet the beginning of the space shuttle was surprisingly different.

"We had parades in Apollo where nobody came except the people who were in the parade," he said. "But we had parades all over the country after STS-1 and there were all kinds of people there."

The biggest surprise for those aboard *Columbia* during its baptismal trip was the simple fact that there were no surprises during the first flight.

"We prepared for so many disaster scripts in simulations where everything went wrong. And so little went wrong, in terms of start to finish, that that is probably the most memorable thing, "Young explained. "The whole mission was just like we planned it. We didn't run into anything we didn't expect. We did lose some tiles on the OMS pod, but that was about all we could see onboard."

Although there were few problems apparent on board, the test flight did find unanticipated events. But the events were not seen until after landing. The fact that they posed no problems during the flight was testament to the forgiving qualities designed into the shuttle.

"There were a lot of things that people could see when we got back and looked at the data. On ascent, it pitched up and solid rocket booster staging was about 10,000 feet high, and, on entry,we had a big side slip," Young said. "That's what we were supposed to be doing with the first mission, looking at those kinds of things. Fortunately, the control system was set so that you could do that kind of stuff and get away with it. It was very tolerant of not having to know the exact aerodynamics to fly properly."

For many of the shuttle's designers, the reentry of STS-1 was the most intense period of the flight. But on board, confidence was high.

"Don't ask me why I knew reentry would work. I just had a feeling when we started reentering that it was going to go great," Young said. "But the shuttle was working so well, I wanted to stay up there another two or three days and see how it really worked. But before we flew, there were ones who wanted to go around a rev and then land. So we thought we were very lucky to be up for two days or so. We could have done it (orbited longer), but nobody would let us."

"Entry was a big unknown," added Crippen. "But I didn't find it tense. In fact, one of the hardest things to do was to keep your mind on the job and not spend time sightseeing out the windows, because it was really spectacular."

Crippen also would have liked a longer first flight. "Honestly, I was so busy all the time, that I didn't get a chance to sit back and enjoy it like I wanted to. I didn't get to do that until my subsequent flights," he said.

After 10 years, the commander and pilot of STS-1 are both at the top levels of management of the shuttle program — Crippen directs the program and Young serves as a special assistant to JSC Director Aaron Cohen — and both are still inspired. "I've always thought that the shuttle was the real way to find out how to use space," Crippen explained. "I believe that it has proved itself to be a fantastic flying machine. Working on it is very satisfying to me personally. I'm proud of what the shuttle has done, but I think it can do better."

"I think the shuttle program is still new," Young added. "And there's great opportunity to improve the shuttle. You could improve it tremendously from what we know now. There's a whole new suite of avionics out there that's been developed. It's a lot of fun to still be involved in the program. You learn something new every day. Each mission does have special contributions it's making to science and technology in the country. All of these things are really going to change the way that we live and it's really hard for people to see that."

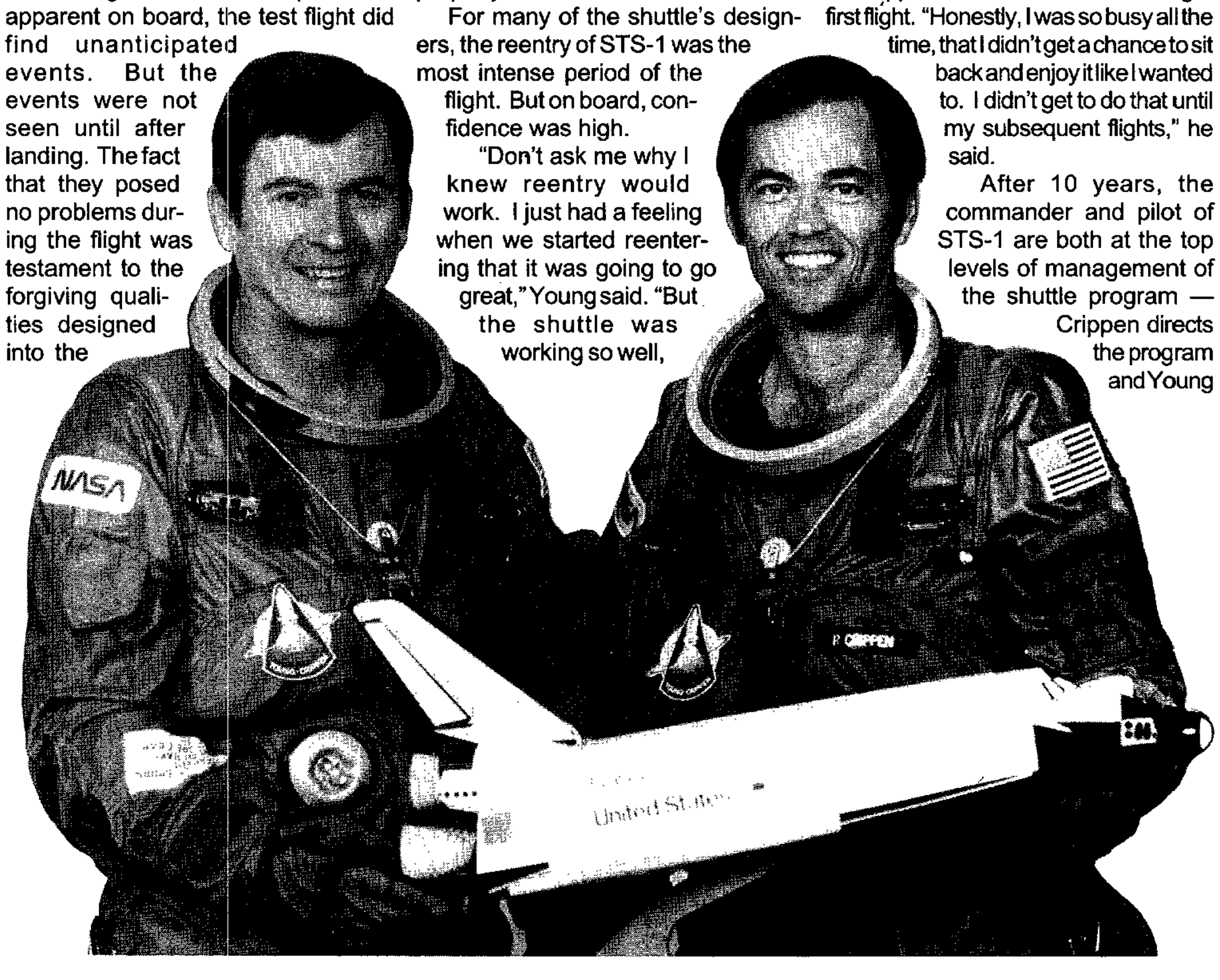
Although the shuttle program has had setbacks, they are simply the work involved with operating such a vehicle, Young said, and the future is bright.

"There are no slick management schemes in working the space shuttle. There just aren't," Young said. "You've got to figure out a way to do it and then just do it. It's plain old engineering.

"I think the people, the maternal care and the attention to detail that everybody has to give to this program to make it work right are hanging in there and doing it. There isn't anything magic about it. New technologies that allow you to do things lighter, and better engines, are really the keys to the future."

The spirit and dedication of those involved with the shuttle made STS-1 work, and they also are the key to its successes to come, Crippen said.

"The amount of teamwork that went into it then and now is exceptional. It is a marvelous flying machine, and it is a terrific team that built it. And it is a terrific team that flies it," he added. □

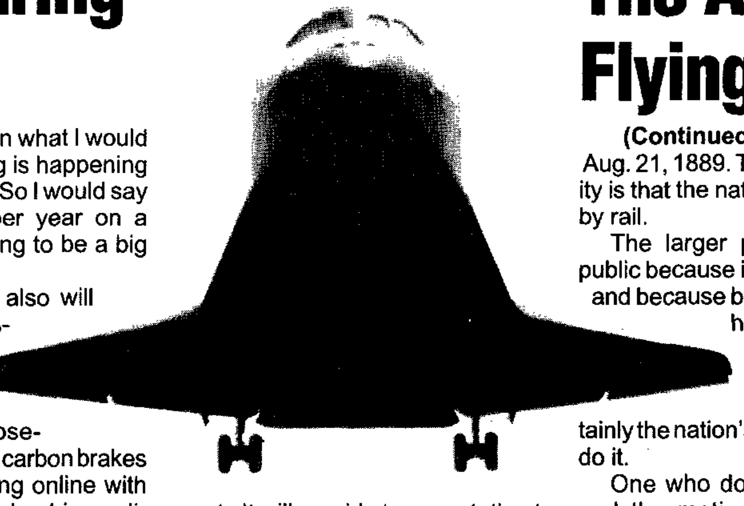


Decade of Accomplishments: Space Shuttle Statistics 1981-1991

Mission	Orbiter	Launch/ Landing Dates	Times Orbiter Flown	People Flown*	Days in Orbit	Man-Hours in Orbit	Orbits	Maximum Altitude, n. mi.	Statute Miles Flown**	Total No. Payloads	Orbiter Weight at Lift-off, lbs	Pounds to Orbit (not including Orbiter)	Payload Deployed, lbs	Payload Returned to Earth, lbs	EVA Man-Hours
STS-1	*Columbia*	4/12-14/81	1	2	2.25	108	37	145	1,074,567	1	219,441	10,823	0	10,823	0
STS-2	*Columbia*	11/12-14/81	2	2	2.25	108	37	137	1,074,567	6	230,939	18,778	0	18,778	0
STS-3	*Columbia*	3/22-30/82	3	2	8	384	130	128	4,400,000	7	235,556	22,710	334	22,710	0
STS-4	*Columbia*	6/27-7/4/82	4	2	7.04	338	113	172	3,300,000	8	241,772	24,492	816	24,492	0
STS-5	*Columbia*	11/11-16/82	5	4	5.1	490	82	160	2,110,849	9	247,113	32,080	14,585	17,495	0
STS-6	*Challenger*	4/4-9/83	1	4	5.04	484	81	155	2,094,293	9	256,928	46,971	37,546	9,425	7.08
STS-7	*Challenger*	6/18-24/83	2	5	6.13	735	98	170	2,530,567	15	249,363	37,124	18,122	22,175	0
STS-8	*Challenger*	8/30-9/6/83	3	5	6.04	725	98	166	2,514,478	16	242,912	30,076	7,445	22,631	0
STS-9	*Columbia*	11/28-12/8/83	6	6	10.33	1,488	167	135	4,295,853	1	247,807	33,264	0	33,264	0
STS-41B	*Challenger*	2/3-11/84	4	5	7.96	955	128	176	3,311,379	18	250,483	33,868	14,863	19,005	23.22
STS-41C	*Challenger*	4/6-13/84	5	5	6.96	835	108	272	2,870,000	7	254,555	38,266	26,396	16,870	20.20
STS-41D	*Discovery*	8/30-9/5/84	1	6	7	1,008	97	179	2,490,000	11	263,477	47,516	30,080	17,530	0
STS-41G	*Challenger*	10/5-13/84	6	7	8.23	1,382	133	190	3,434,444	23	242,791	23,465	4,949	18,516	6.96
STS-51A	*Discovery*	11/8-16/84	2	5	7.98	958	127	195	3,289,406	3	263,325	45,306	22,764	24,853	24.48
STS-51C	*Discovery*	1/24-27/85	3	5	3.9	468	49	185	1,276,303	DOD					
STS-51D	*Discovery*	4/12-19/85	4	7	6.98	1,173	110	251	2,889,755	11	250,892	35,824	22,576	13,248	6.34
STS-51B	*Challenger*	4/26-5/6/85	7	7	7	1,176	111	193	2,890,383	4	247,291	31,407	105	31,302	0
STS-51G	*Discovery*	6/17-24/85	5	7	7.07	1,187	112	209	2,916,127	14	256,422	44,477	25,049	21,645	0
STS-51F	*Challenger*	7/29-8/6/85	8	7	7.94	1,334	127	173	3,283,543	7	252,629	34,400	628	34,400	0
STS-51I	*Discovery*	8/27-9/3/85	6	5	7.10	851	112	242	2,919,576	4	262,310	43,988	30,546	13,542	23.70
STS-51J	*Atlantis*	10/3-7/85	1	5	4.07	488	64	278	1,704,406	DOD					
STS-61A	*Challenger*	10/30-11/6/85	9	8	7.03	1,349	112	180	2,909,352	2	243,763	31,861	150	31,711	0
STS-61B	*Atlantis*	11/26-12/3/85	2	7	6.88	1,155	109	209	2,838,972	12	261,610	48,041	27,577	20,464	24.68
STS-61C	*Columbia*	1/12-18/86	7	7	6.08	1,022	98	185	2,528,658	25	256,003	32,462	12,351	20,111	0
STS-51L	*Challenger*	1/28/86	10	7						12	268,830				
STS-26	*Discovery*	9/29-10/3/88	7	5	4.04	485	64	178	1,680,000	13	254,607	46,478	37,514	8,964	0
STS-27	*Atlantis*	12/2-6/88	3	5	4.38	525	70	244	1,849,240	DOD	240,861				
STS-29	*Discovery*	3/13-18/89	8	5	4.98	598	80	163	2,000,000	9	256,358	38,097	37,546	551	0
STS-30	*Atlantis*	5/4-8/89	4	5	4.04	485	65	161	1,681,997	4	261,119	45,930	45,799	131	0
STS-28	*Columbia*	8/8-13/89	8	5	5.04	605	81	166	2,100,138	DOD	245,160				
STS-34	*Atlantis*	10/18-23/89	5	5	4.98	598	80	177	2,000,000	9	257,569	48,643	38,323	10,320	0
STS-33	*Discovery*	11/12-27/89	9	5	5	600	79	302	2,115,789	DOD	266,578				
STS-32	*Columbia*	1/9-20/90	9	5	10.86	1,305	172	178	4,509,972	9	255,994	26,488	15,316	21,393	0
STS-36	*Atlantis*	2/28-3/4/90	6	5	4.44	533	72	132	1,851,408	DOD	246,129				
STS-31	*Discovery*	4/24-29/90	10	5	5.05	606	80	330	2,068,213	9	249,109	28,673	23,905	4,768	0
STS-41	*Discovery*	10/6-10/90	11	5	4.02	482	66	160	1,707,445	10	259,594	44,107	38,603	5,504	0
STS-38	*Atlantis*	11/15-20/90	7	5	4.92	590	79	142	2,033,639	DOD	265,922				
STS-35	*Columbia*	12/2-11/90	10	7	8.96	1,075	144	190	3,755,293	4	256,447	29,806	0	29,806	0
TOTALS				199	225.07	28,688	3,572	189 Avg	94,300,612	292	9,061,659	1,055,421	533,898	546,427	136.66

SOURCE: JSC FLIGHT DATA AND EVALUATION OFFICE
*Uses number in crew; total individuals who have flown, not including reflights, is 119.
**Source: Rockwell International

Future Bright for Maturing Space Shuttle Fleet



By Kari Fluegel

As the Space Shuttle Program begins its second decade, *Columbia*, *Discovery*, *Atlantis* and *Endeavour*, will shed their training wheels and shift into a new era of operational accomplishment.

"I think we're on the verge in the next year or two of demonstrating, yea verily, this vehicle will do what we say it will do and that we have laid in place all the right plans to make it a robust, varied program with a high degree of confidence," said Leonard Nicholson, deputy director of the Space Shuttle Program.

Delivery of *Endeavour*, OV-105, expected later this month, will round out the orbiter fleet and will be the next major milestone for the shuttle program.

"By having another vehicle we won't be as hardware poor, so to speak, which is where we've been ever since we lost the *Challenger*," said Dan Germany, manager of the Orbiter Projects Office.

Endeavour, the first new orbiter in six years, will fly its maiden voyage on STS-49 in May 1992 to rendezvous with and repair a disabled INTELSAT communications satellite.

"We will for the first time be in a posture where we have margin to make our manifest," Nicholson said. "We'll have sufficient number of orbiters and, along with *Endeavour*, a new processing facility at the Kennedy Space Center. We will be in, for the first time, what I call an operational posture."

A fifth orbiter could come into the fleet in late 1990s,Nicholson said, but national priorities as described by the Advisory Committee on the Future of the U.S. Space Program now call for the development of a new heavy-lift launch vehicle.

In May, *Columbia* will drop from the manifest for a few months as it undergoes structural inspections and several modifications as part of the standard orbiter maintenance plan.

Discovery will follow *Columbia* to Palmdale in February of next year as will *Atlantis* in July 1992.

Modifications to the orbiters over the next decade will gradually upgrade the fleet, Germany said.

"The technology the shuttle was built on was like 1970, so we're about 20 years behind the times," he said, "It's very difficult now to replace the hardware and to make replacement (parts) because no one is using that technology in the aircraft industry."

Cockpit instrumentation upgrades, new auxiliary power units and a new drag chute system eventually will be installed in all the orbiters.

"There are an awful lot of smaller things," Nicholson said. "The list is pages long that folks have been working on that will be incorporated into the system. Many of them are enhancements to the system to allow the turnaround at KSC to be shortened."

Improving orbiter turnaround at Kennedy is the key to meeting manifest requirements, Nicholson and Germany agreed.

"The experience that we've had is that it takes us longer to process than we'd like for it to," Germany said. "That comes about for a variety of reasons. The mechanics of processing are very labor intensive. Some of that is due to the complexity of the hardware and some of it is due to the checks and balances laid in place."

Currently the shuttle manifest calls for six flights this year and eight in 1992. An average year's manifest will provide for 10 flights per year. Both Nicholson and Germany agreed that launching 10 times a year is well within the grasp of the program's capabilities.

"I think 10 flights per year is certainly doable," Nicholson said. "It's within the capacity of the system and our challenge is to make the flight rate on a year-in year-out basis even with the kind of problems we're going to have."

Occasionally, unforeseen problems like last year's hydrogen leaks on *Columbia* and the current hinge lug cracks on *Discovery* affect the flow.

"Those things seem to be happening to us a lot more than what I would call smooth processing is happening to us," Germany said. "So I would say to get to 10 flights per year on a consistent basis is going to be a big job for us."

Orbiter processing also will be enhanced when missions routinely land at KSC. A series of improvements including redundant nosewheel steering, the new carbon brakes and drag chutes coming online with *Endeavour* and the *Columbia* modifications have increased the comfort level for landing at KSC.

"We just recently polled the community and I think everybody is to the point of saying if we can meet our flight rules, we're ready to start going back to the Cape very shortly." Nicholson said.

Still, the fast-changing weather in Florida will remain a concern, he said.

While being checked out at Palmdale this year, *Columbia* also will be outfitted as the fleet's extended duration orbiter. It will then have the capability to remain in orbit for 16 days and will demonstrate the capability during a 13-day flight on STS-50 now manifested for June 1992.

And staying on orbit longer will be the next frontier crossed by the Space Shuttle Program.

"I think the tendency to use the EDO capability will grow," Nicholson said. "We're also putting the basic provisions in OV105 *(Endeavour)* to allow it to be an EDO. I intuitively believe that that capability is going to be something that people find very useful and will be requesting more and more of."

No matter what the flight rate, the Space Shuttle Program will continue to challenge the limits of mankind's ingenuity. More and more frequently, the shuttle will provide a laboratory in the micro-gravity environment. It will provide transportation to retrieve and repair satellites. It also will provide the platform for construction of Space Station *Freedom*.

"The shuttle is a workhorse," Germany said. "It's the way you get to zero-G and get home. It's the way you take crews up there and get them back. It's the way you take payloads up there and bring them back. Right now there is no other manned space hardware capable of doing that in the stable of the USA. This is it, and we plan to use it for the next 30 years."

Whereas the first 10 years have been a decade of development, the next 10 will be a decade of growing operations.

"I think the next 10 years are going to be the proof of the pudding, so to speak," Germany said. "The first 10 years have been 'Let's get our sea legs under us,' or 'Let's get used to the training wheels on the bicycle.' We're ready to take training wheels off and get on with more of an operational program as much as this program can ever be operational.

"I'm looking forward to the next 10 years. I think we're going to start showing a much better return on the investment, for all the money the country has put into this program and it's going to be very exciting." □

The Amazing All-Electric Flying Machine

(Continued from Page 2B)

Aug. 21, 1889. The fundamental reality is that the nation moved westward by rail.

The larger picture escapes the public because it is very complicated, and because by and large the public has neither the means nor the motivation to add up all the numbers, and certainly the nation's news media doesn't do it.

One who does have the means and the motivation to add up the numbers and assess the big picture is Loftus. "I'll give you a chart," he will say, "that shows for all intents and purposes we've launched 1,200 tons of payload every decade. It took us 215 launches in the '60s, 152 launches in the '70s and 102 launches in the '80s. The shuttle,with 41 percent of all U.S. launches, has launched 41percent of all the mass. Not including the orbiter."

During Apollo, the measure of mass deployed to space included the Command and Service Module and the Lunar Module. Imagine how the numbers would change today if NASA included the launch of a winged vessel of exploration in the measure of mass sent to space! Beyond that point, however, is the spectre of another "truism" that critics trot out with some regularity whenever it's time to bash the shuttle again. The Saturn V, they say, was far more reliable than the shuttle is today, able to send up far more cargo, and would be much cheaper and less complicated to operate than the orbiter fleet. It was a gross mistake, they say, to replace it with the shuttle.

"The truth of the matter is," Pohl said, "if you go back and look at the number of people that worked on building those stages for every launch, and you translate that into today's labor rates, it'll cost you three times as much to launch one of those as it costs you to launch a shuttle. And yet they say the shuttle is too expensive."

But how does that square with the generally accepted notion that the shuttle has siphoned off vast sums of money from science programs, wrecking a golden age of planetary reconnaissance in the process?

The easy answer is, it doesn't, because none of that was ever true. "Contrary to general belief," Loftus said, "the agency spent less money on transportation in the '80s than it spent in the '60s, and more money on the operations of science, TDRS and all the data networks."

Another shuttle strength not generally recognized is that its 20-year-old design is still state-of-the-art in many areas, including computerized flight control, air frame design, the electrical power system, the thermal protection system and the main propulsion system. It is the one vehicle flying that offers any sort of meaningful capability to return payloads to the Earth, and has, in fact, brought more than half-a-million pounds of cargo back to the planet. And it also is the only man-rated vehicle type now being emulated by all of the other major spacefaring powers.

In the end comes the question of how the shuttle will rank in the vast pantheon of flying vehicles. Faget offered the perspective of an experienced aerospace designer: "When we first broke the speed of sound, we did this in a research airplane. After we flew that airplane a dozen times we discarded it, put it into a museum, and then got to work on designing airplanes based on the knowledge we gained from it. When we flew up to Mach 3, then Mach 6, none of these machines was used operationally. The shuttle is the first one that. . . flew this tremendous Mach number range but it also did the job of a launch vehicle and a spacecraft that could stay in orbit for days or weeks at a time. If it is a little bit wanting in some of its operational features, I think it's excusable. What I'm trying to say is, maybe the second and third generation shuttle could be really good, but I don't know how you can make the third generation shuttle without having the first and second generation shuttle. We are still learning."

The shuttle is a stunning expression of the art of engineering. It was the very finest that could be done with the tools at hand, and no other nation could have reached as far and achieved as much. The space shuttle can't do everything perfectly, it can't even do some things as well as other vehicles. But anybody who really does expect it to perform at such an exotic level of perfection isn't firing on all thrusters anyway, and certainly doesn't understand the true challenge of space flight. To the engineers who built it, the shuttle will always be a miracle.

Chris Kraft tells the story of wanting to design automobile engines before airplanes lured him to aeronautics, and how his high school physics teacher back in Hampton, Va., gave him an early insight into the profession. "He always said, 'Young man, if you really get to be that kind of engineer, when you see that automobile drive down the street, you will not see that automobile at all. What you will see are those pistons going up and down, and the camshaft going around and the spark plugs going off and the flame burning inside that cylinder.' And he was right," Kraft said.

After a decade of flight, with experience both triumphant and tragic to guide our perceptions, it's easy to get bogged down and lose sight of that same kind of magic. Perhaps it was Bob Crippen who summed it up best as *Columbia* rolled out across the desert lakebed for the first time. He could see, in his mind's eye, the hundreds of valves, the miles of wiring and the sheer, raw power this machine had just spent with an easy grace. "The shuttle is," he said, "the world's greatest all-electric flying machine." □

NASA-JSC

DEDICATION—This special issue of Space News Roundup is dedicated to all of the men and women who have given of themselves to create and fly America's space shuttle, the worlds first reusable spacecraft. Their dedication and sacrifice has, stone by stone, built a new highway to the heavens. It goes out to the family members who encouraged, supported, endured and rejoiced in their efforts and accomplishments. It especially honors the memory of those who have died building or traveling that highway, including the STS-51L crew—Dick Scobee, Mike Smith, Judy Resnik, El Onizuka, Ron McNair, Greg Jarvis and Christa McAuliffe.

Ingenious Piggyback Concept Born at JSC

By Pam Alloway

While many engineers were working on various aspects of the shuttle in flight, one JSC engineer was concentrating on getting the shuttle from its landing site, generally Edwards Air Force Base in California, to its launch site at Kennedy Space Center.

J.W. Kiker, a longtime aircraft model builder and aviation enthusiast, was a branch chief in the Engineering Directorate's Mechanical Systems Division in the late 1970s. He'd seen a lot of airplanes as a boy working at a North Carolina airport and as a flight instructor for the Air Force. While others were talking about strapping several jet engines under the orbiter's belly and making numerous stops on its way back to KSC, Kiker was doing what he usually did, tinkering with models. But this latest model project would have a far-reaching effect. Kiker developed a design, proposed it to NASA management and, despite numerous roadblocks, built a miniature orbiter that could ride piggyback on a Boeing 747 scale model. He did it on his own time, in his own garage, mostly at his own expense.

"No one thought it would work," said Kiker, who retired from NASA in 1980 but now is an engineering consultant for Lockheed. "But it was an attempt to show the center and the world that this was the way to do it."

So on a warm day in 1977 Kiker, fellow JSC engineer Kirby Hinson, and dozens of others gathered in a JSC field and watched Kiker's 1/40th scale radio-controlled 747 and orbiter models take off, separate in mid-air and glide to a successful landing.

"It was great to see it work," Kiker said. "But we crashed a lot of models."

Kiker narrated a historic NASA film clip that recorded his model's flight. Kiker talked about some problems encountered with the experiment.

"One thing we did learn was that our orbiter models, which of course had no stability or orientation, weren't flying well with the tail cone installed," Kiker said. "We tried flight after flight and had many crashes. So we talked to our aerodynamics people and asked what we should do."

Aerodynamics engineers recommended Kiker partially deploy the models' speed brakes and body flap, which helped.

Getting the orbiter to land smoothly continued to plague the experimenters but a new tail cone configuration enabled the model to glide to a nearly flawless landing on its last flight in 1977–minus one wheel that popped off on impact with the ground. That flight was the precursor for a successful set of tests with the space shuttle *Enterprise*, and a long history of safe cross-country ferry flights. □