formation of ice crystals in the atmosphere. Ronald Reagan was also working as a flack for GE back then. What a time to be alive!

KURT VONNEGUT
New York, New York
6/86

Shuttle program

In the aftermath of the shuttle failure it has become rather popular to point out, as Thomas Donahue does in his editorial (July, page 112), how "obvious" it is that the US made a drastic mistake in trying to rely on a single system (the shuttle) for transportation to orbit.

In the presence of unlimited amounts of funding, development of a wide spectrum of launch vehicles is clearly a good idea. Given limited funding, however, it was and is very reasonable to focus effort on a single launch technology rather than spread the same money over a large number of different technologies. One good reason to do this is to achieve economies of scale. Another is that as experience—that is, the number of launches on a specific type of vehicle—increases, efficiency rises and costs decrease. To get maximum use out of the learning curve, it is again preferable to pick one particular technology and use it to the maximum extent possible.

It is clear that NASA's management procedures had been allowed to become disastrously flawed. However, Congress and the Office of Management and Budget must also shoulder blame for the failure because of their continuous whittling away of the development and operations budget for the space shuttle, their deleting funding for quality-control and inspection personnel, their eliminating the needed fifth orbiter (thus putting a larger launch-schedule burden on the remaining vehicles) and their decreasing operations funding for the program to the point where sufficient spare parts are not even available to make all of the existing shuttles operational at the same time.

Advocates of unmanned space science often advance the argument that if funding for manned spaceflight is cut, the money saved will be used for unmanned missions. I think that this point of view is naive, and that money saved from cuts in one scientific program very rarely ends up actually being used for another. In fact, one can make a very good case that long-term funding for space science *increases* with the budget for manned spaceflight. Space science will be best served when routine access to space is guaranteed not only to astronauts, but to working physicists, technicians and even grad students.

We should not forget that the space shuttle, despite its failures, has still proven to be by far the most reliable transportation to low Earth orbit in its payload class, with a considerably better record than the Titan or Ariane vehicles (whose failures do not normally attract as much publicity), and at a cost that, if not the $600/kg once promised (for a fully reusable shuttle considerably different from the "bargain basement" version finally funded), is nevertheless competitive with unmanned vehicles.

Finally, I would like to take specific issue with Donahue's final two sentences, where he states that "the Soviet approach [of incremental improvements] . . . has been much more productive since the 1960s than the American propensity for grandiose technological quantum leaps." The American approach has resulted in detailed geological information on the Moon and Mars; probes to Mercury, Venus, Jupiter, Saturn and Uranus; and exciting results in space-based astronomy in spectral ranges from the infrared (IRAS) through the ultraviolet, all the way up to x-ray and gamma-ray astronomy (Einstein). It is unclear to me which results Donahue is referring to when he calls the Soviet approach "much more productive."

The obvious next step for space science is to move to a fully reusable, air-breathing "next generation" aerospace transport capable of carrying payloads to orbit for a realistically low cost. However, such a vehicle will likely not become operational until at least the late 1990s. In the interim, the space shuttle is the best, most reliable transportation to orbit currently available. It is important that a single, well-publicized failure not blind us to the fact that the program is worthwhile. A replacement for Challenger—and even a fifth shuttle to relieve some of the launch pressure on the existing fleet—would be a wise investment.

GEOFFREY A. LANDIS
Brown University
Providence, Rhode Island
8/86

DONAHUE REPLIES: The undoing of American space science was the decision to stop using expendable launch vehicles as launchers of scientific spacecraft before the space shuttle became a proven, routine system to replace them. Space scientists, particularly planetary scientists, protested this policy when it was effected, and the Space Science Board is on record as being opposed long before the Challenger accident. What has changed since the accident is not that people like me have begun to talk about the problem, but that some people have

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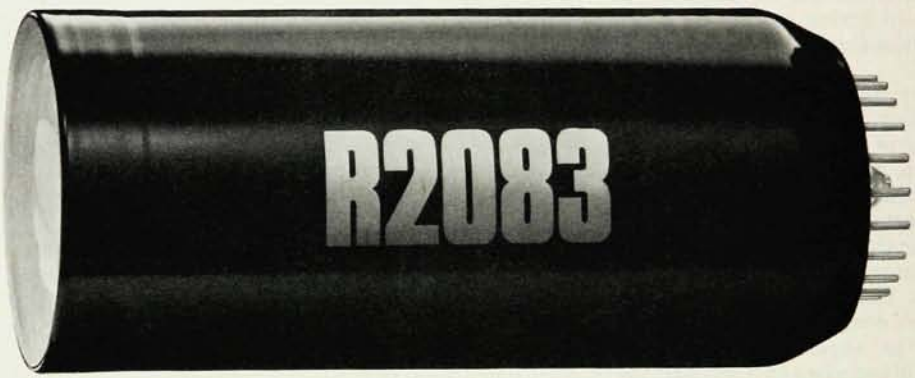

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begun to listen. The last major US scientific spacecraft were launched in 1978 by Atlas–Centaur rockets. Since then space science has been on hold, waiting for the shuttle to become usable. The only rational way out of this trap is to make ELVs available until the shuttle proves itself—whenever and if ever that may be. In the case of launches that can be made only during limited windows in time, constraints imposed on shuttle launches by safety considerations will probably forever keep the shuttle from serving as a suitable launcher. Failures of ELVs destroy hardware, not people, so one can afford a higher failure rate with unmanned launch systems. To procure a variety of ELVs and still retain the rest of the space program will require more resources than are presently at hand. I certainly do not disagree with Geoffrey A. Landis when he asserts that the resources that have been made available to NASA since the 1960s have been inadequate to support the kind of program it has tried to maintain.

If, by implication, Landis is attributing to me the "naive" position that to cut funding for the manned space program will free funds for unmanned space science, then he is attributing to me a position I do not hold. There is nothing in the fourth paragraph of his letter, dealing with the issue of funding, with which I would seriously disagree. On the other hand, there is nothing in the paragraph that is relevant to the issue of the suitability of the shuttle as a launch vehicle.

Landis provides a long list of the grand achievements of the United States space-science program. There is no question that the US was once peerless in space science. But all of the spacecraft that produced the magnificent results he lists were launched on ELVs, and all except IRAS were launched in the 1960s and 70s. The USSR has moved ahead of us now because they are launching scientific spacecraft, using proven reliable launchers such as Proton, while we have been launching nothing at all. Venera landers, balloons and radar imagers, Vega missions to Venus and comet Halley, and Phobos missions to Mars are certainly more productive of scientific results than are Space Telescope, Galileo and Ulysses stored in warehouses.

THOMAS M. DONAHUE
Space Science Board
Washington, DC

9/86

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The recent tragic loss of the space shuttle Challenger has reopened many basic issues regarding our national space program. Many mildly enthusiastic supporters of the shuttle, and even some opponents, have been so moved by the loss as to advocate building a replacement shuttle to continue the original shuttle program. However, if we seek a suitable memorial to the brave individuals who perished in the shuttle accident, then we should learn from this disaster and not repeat previous mistakes.

The place to start is with the design of the shuttle itself. NASA has recently released film of the shuttle launch that indicates signs of trouble some 15 seconds before Challenger exploded. Most discussions of this issue have focused on the decision not to monitor more closely the performance of the solid-fuel boosters. This misses the essential point. Even if the shuttle crew had known at the instant of launch that the shuttle was going to explode in little more than a minute they would still have died. The shuttle has no safety margin at launch. Either everything works right or the crew goes down with the ship.

The space shuttle is the first manned US space vehicle that has no provision for emergency escape during launch. The Mercury, Gemini and Apollo programs all recognized the great dangers and uncertainties in any propulsion system capable of boosting man into space and made explicit provision for the type of accident that blew Challenger apart. The decision was made, early in the shutle design, to remove these safety precautions to meet payload, crew size and mission length requirements. Given the nature of both solid- and liquid-fuel rockets, the laws of probability guarantee that something would eventually go wrong either at the launchpad or during the boost phase. And given the rather incredible design choices made, it was inevitable that astronauts would die in either of these cases.

It is possible to obtain a reasonable safety margin by returning to the equipment used in the first few shuttle launches. There the crew was limited to two astronauts to allow the installation of ejection mechanisms. Of course, this sacrifices one of the major goals of the shuttle, the ability to take payloads and mission specialists into orbit.

Unfortunately, there is another safety problem that has no easy remedy. The problems with the insulating tiles are well known, and the potential for disaster if a tile is lost over a critical area of the shuttle reentry is obvious. What is not so well known is that such a disaster has almost occurred. One shuttle on reentry came within seconds of burning through a main wing support due to the loss of tiles. The failure of this support would have caused the

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shuttle to crash, killing all on board.

Given the size of the shuttle, it is not feasible to return to the proven heat-resistant alloys used on previous manned space vehicles. Given the problems with keeping the tiles attached during launch and reentry, it is inevitable that despite NASA's best efforts a critical tile will someday fall off and another shuttle crew will go up in flames with their shuttle.

If the shuttle were a reliable and economical way to get into space, then it might make sense to try to live with its inherently poor safety margins. Unfortunately the reliability and economic records of the shuttle are dismal. Its reliability is so questionable that even before the Challenger loss the Air Force was developing an expendable launch vehicle to supplement the balky shuttle. Another of the major goals of the shuttle was very rapid turnaround time. As for economics, the shuttle will never fly again without massive subsidies—once again in stark contrast to the original NASA promise.

The nation's space program has three alternatives. It can continue the shuttle program with whatever "quick fixes" are deemed necessary, it can develop alternatives to the shuttle, or it can leave the launch business altogether. Continuing with the shuttle means future disasters like the Challenger explosion. The price in precious lives and in replacement shuttles will be much too great. Letting NASA develop alternatives is equally unpalatable. The shuttle's performance compared with NASA's promises about its performance creates a very serious credibility problem for NASA. To entrust this group with the responsibility for finding a replacement for the shuttle is to risk another piece of aborted technology ruined by bureaucratic and political intrigue.

Getting NASA out of the space-launch business is not as naive a proposal as it might seem. There are many ways of getting into space. Expendable launch vehicles, air-breathing ramjets and sane shuttle designs are only three possible options. It is impossible to predict which method will prove the most reliable or economical. If we are to cut the expense of space travel dramatically, we must free the space-launch business from bureaucratic management and put it squarely into the innovative, cost-competitive environment of the free market. Launching payloads into space is a service that market forces can provide, just as they provide automobiles, computers and clean laundry. There is no rational justification for US taxpayers to subsidize the expense of rocket

letters

development and rocket launches. Let those who directly benefit pay the bill, and let the rest of us spend our money on items we deem important.

Market forces are no panacea. Space exploration will continue to be the domain of brave, intelligent and courageous men and women who are willing to risk their lives pushing technology to its limits. There is no shortage of such people and there is also no shortage of space entrepreneurs willing to push our people and technology to their limits to create a reliable, cheap and safe space transportation system. All we need do is get government out of the way and let them do it. If we learn this lesson from the Challenger loss, then we will have created the most suitable memorial to the individuals who died on that flight.

JOHN BARTEL
TOM COUGHLIN
2/86 *Charlestown, Massachusetts*

SDI: The debate continues

The "debate" between Richard Garwin and Robert Jastrow in your Letters section has elicited a letter I feel is of great importance, that from Lieutenant General James A. Abrahamson, director of the Strategic Defense Initiative Organization (March, page 11). In this letter Abrahamson comments on the question of payload reduction of the Soviet SS-18 due to the addition of eight tons of laser shielding. He says:

> Jastrow's book states that all ten warheads would be lost. I asked our systems-analysis contractors to check these calculations. They concluded that Jastrow's calculations, reported in *How To Make Nuclear Weapons Obsolete*, are correct. Quite simply, Garwin is wrong.

In his reply Garwin supplied a calculation showing that the payload need be reduced by only about two warheads. The calculation is a simple one and can be understood by students of freshman physics. There is only one correct answer to such a straightforward calculation and it is Garwin's.

Are the contractors selected by Abrahamson really that incompetent? If so, they should be replaced. Knowing where to turn for correct advice is an especially important function for any director, and especially for the director of the SDI Organization. Perhaps Abrahamson should also be replaced. I fear that at a higher level there is a similar problem. Leading American physicists have been unable to get their message through to President Reagan. I have reason to believe that the members of the council of The American Physical Society personally agree that no amount of effort and cost could provide a defense of population so efficient and reliable that it would make nuclear weapons impotent and obsolete.

A foolproof argument against Reagan's "space shield" is that there are delivery systems that would be unaffected by any space shield. One of the several delivery systems that would be unaffected by space weapons is the diplomatic pouch. In a similar vein, nuclear weapons could be smuggled in as successfully as marijuana by wrapping each bomb in marijuana. In fact the pursuit of SDI on our part will encourage this kind of response.

The world now seems to have its first real chance to reduce nuclear weapons swiftly by 50%. If our President continues to listen to Abrahamson, or to the kind of people Abrahamson listens to, rather than to the established scientific community (such as The American Physical Society), he will continue to believe that his dream of making nuclear weapons obsolete may work. He will then continue to refuse to give up SDI and thereby lose this precious and fleeting chance for a real arms reduction.

JAY OREAR
Cornell University
7/86 *Ithaca, New York*

JASTROW REPLIES: Jay Orear apparently failed to notice the sleight of hand in Garwin's analysis that struck me and Albert Petschek, as well as two MIT students (PHYSICS TODAY, July, page 15). To wit, Garwin did a different calculation from the one Abrahamson was writing about.

I had said in my book that eight tons of mass spread over the skin of an SS-18 would force the Soviets to offload the ICBM's entire complement of warheads. Abrahamson's SDI contractors checked this statement and found it to be correct. Garwin calculated the number of warheads lost if eight tons are spread *over the first stage only*. That number is, of course, considerably smaller. Garwin presented his result as if the two calculations were the same—and seems to have misled Orear thereby—but in fact they lead to entirely different results.

Once you notice that Garwin has switched calculations and do the calculation over with Garwin's own formulas, but for the problem Abrahamson and I described, you get, of course, the result we obtained.

Orear suggests that SDI contractors are incompetent and that Abrahamson should perhaps be replaced because he does not know "where to turn for correct advice." The shoe may be on the other foot; perhaps the Union of Concerned Scientists should turn else-