arguing that the future of space commercialization lies in the shuttle. "We would not have entered the shuttle program if we had thought that the expendable was the way to go," says Beggs.

Further down the road, Europe has plans for competing here as well. Already on the drawing board are ideas for a much larger Ariane 5. So far, ESA has made no commitment to the new version, whose future depends on the outcome of a current study of the size and shape of future markets.

CNES, however, is continuing development of the cryogenic engines, two of which might be used on Ariane 5 in contrast to the single cryogenic engine in the current series.

One possible use for the larger rocket would be to launch a small two-person space vehicle—the current version is known as Hermes—which would subsequently glide back to the earth like the shuttle. "There could be all sorts of scope for intermediate vehicles, such as retrieving satellites from orbit, perhaps from orbits that the shuttle cannot get to economically very often," says Christopher Nicholas of Britain's Department of Industry.

Defining the boundary line between useful competition and unnecessary duplication of effort is a task that now faces space policy-makers on both sides of the Atlantic. Each seems to have taken up the gauntlet that has been thrown down by Ariane; "monopoly is usually damaging, one way or another," says Nicholas.

ESA's Quistgaard, however, warns that too much competition between commercial operators in space could become counterproductive and suggests a possible international division of labor. "We should make sure that we do not end up in the same situation as, for example, shipbuilding, where everyone tried to get into the market and it proved to be disastrous," he says. "Some form of constraint on the countries that work with this should be maintained, because there is no point in every country trying to do everything. I personally feel that it makes sense to use our worldwide technical capability in the most intelligent way and not to saturate each other with things that are already there."

—DAVID DICKSON

Centaur Wars

A straightforward technical decision on space shuttle upper stages has dissolved into a political free-for-all

Even as the Europeans are moving aggressively forward with their Ariane rocket (p. 1010), Washington has once again bogged down in bickering over the one tool that would do the most to keep the space shuttle competitive.

That tool is the high energy upper stage, or HEUS, a booster that would carry heavy payloads from the shuttle's maximum orbit of 1000 kilometers to the geosynchronous orbit at 35,900 kilometers, or even into interplanetary space. A long-simmering controversy has reemerged in recent weeks: Should the National Aeronautics and Space Administration (NASA) go ahead now and adapt an existing rocket, the Centaur? Or should the agency wait and build a totally new vehicle later, when the budget crunch has eased?

Arcane though it sounds, the issue has ignited a free-for-all between feuding congressional committees, the aerospace lobby, the Reagan White House, the Air Force, and NASA, with the latter caught mostly in the middle. At stake is the shuttle's viability as a launch vehicle for the massive new communications satellites being developed for the latter half of the decade—as well as the viability of any new NASA plans to send spacecraft into remote parts of the solar system.

Also at stake is the sanity of the scientists and engineers in charge of the Galileo orbiter/probe mission to Jupiter: the $850-million Galileo, currently NASA's only approved planetary mission, is once again being whipsawed from one launch configuration to another, and its scientific productivity is once again under a cloud.

The problem goes back to the original plan for upper stages, formulated in the mid-1970's. The idea was to use solid-fueled devices because of their convenience and safety. The Air Force agreed to build a two-stage, solid-fueled booster for launching moderate-sized payloads.

Representative Ronnie G. Flippo

This booster came to be known as the Inertial Upper Stage, or IUS. NASA agreed to develop a third solid-fueled stage to be added on for occasional high-energy missions such as Galileo or the International Solar Polar Mission.

Unfortunately, developing that third stage turned out to be more difficult than anyone had imagined. By 1980 it was becoming clear that the IUS contractor, Boeing, would not be able to deliver a vehicle powerful enough to launch Galileo to Jupiter. So the mission was reconfigured: instead of a single launch in 1982 there would be a dual launch in 1984, with the orbiter and probe traveling separately.

Even so, when Boeing still had not resolved the third stage problems by the beginning of 1981, NASA terminated the third stage and announced that henceforth the agency's HEUS needs would be met with the Centaur.

It was a popular move: the liquid oxygen/liquid hydrogen burning Centaur had been a reliable NASA workhorse for more than a decade. It was far more powerful than the IUS, and at the same time more gentle. Its slowly building thrust would be kinder to spacecraft than the instant jolt of a solid rocket. Best of all, as a liquid fueled rocket the Centaur could be turned on and off as needed; once ignited, the IUS, like all solid boosters, would have to burn out like a skyrocket.

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The planetary science community liked Centaur because it would allow Galileo to get to Jupiter faster and carry more fuel to encounter more satellites. The mission was quickly reconfigured for a single Centaur launch in 1985. NASA's advanced planners, meanwhile, liked Centaur because of its legacy for future planetary missions. "Our biggest problem is always getting there," says one. "IUS is spotty, but Centaur has more than enough power to go anywhere but the far outer solar system."

The communications industry liked Centaur because of its lifting ability to geosynchronous orbit (GEO). Orbital communications traffic is expected to grow 30-fold by the end of the century, and the trend in the industry is to centralize more and more equipment on bigger and bigger satellites. The combination of the shuttle plus the two-stage IUS will lift only some 3000-kilograms to GEO, however, whereas the Centaur would increase that limit to between 5000 and 7000 kilograms.

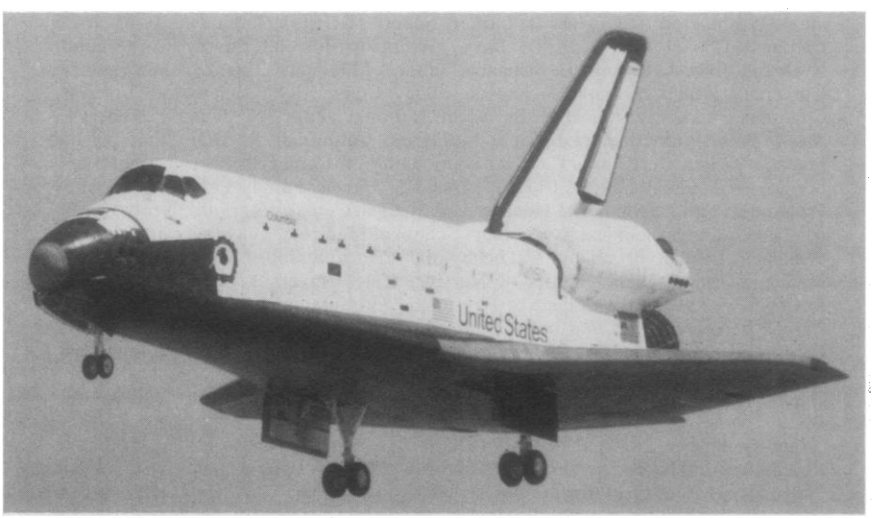
The NASA front office liked Centaur because it could be ready by 1986, when Europe's Ariane series is expected to surpass the 3000-kilogram IUS limit. Without a HEUS of some sort, the shuttle could be shut out of a very lucrative market.

The Air Force, although irritated at NASA's withdrawal from the IUS project, at least had a foreseeable need for Centaur. In the late 1980's and the 1990's, Soviet antisatellite technology is expected to advance to the point that the Pentagon's own geosynchronous communications satellites will have to be "survivable." Among other things this means having a large propellant reserve for evasive maneuvers, which means weight, which means a HEUS of some sort to get the things up there.

But the White House Office of Management and Budget (OMB) did not like Centaur. It had nothing to do with the vehicle's merits, it was simply that extensive modifications would have to be made in the shuttle and its launch pad to handle Centaur's cryogenic fuel. Moreover, the booster's own fuel tank would have to be shortened and widened to fit it into the shuttle's payload bay. All this meant that money would have to be added to NASA's upcoming budgets, and in the budget-slashing frenzy of 1981, OMB was not about to do it.

Thus, NASA was ordered to drop Centaur from its fiscal year 1983 budget request, which went to Congress in February 1982. Galileo was reconfigured for a 1985 launch on a two-stage IUS, using a trajectory that would delay its arrival at Jupiter until 1989, and allow enough fuel for only half as many satellite encounters when it did arrive.

First, however, Congress had to approve the budget. Senator Harrison H. Schmitt (R–N.M.), chairman of the Senate's subcommittee on science, technology, and space, was outraged at the Centaur decision and said so often. Both the House and Senate Appropriations Committees, although quieter, were equally convinced that the need for a HEUS was real, and that dropping the Centaur now would be false economy. But Representative Ronnie G. Flippo (D–Ala.), chairman of the House subcommittee on space science and applications, sided with the White House. And there matters stood for 6 months: three of the relevant committees for Centaur, one against.



The space shuttle: can it compete?

In July, however, the Centaur proponents made an end run. In the Emergency Supplemental Appropriations Bill, signed by President Reagan on 18 July, there appeared language restoring $140 million for Centaur development in NASA's 1982 budget, and ordering both NASA and Boeing to stop work on the two-stage IUS's for Galileo and the International Solar Polar Mission. (The Air Force IUS program, of course, continues unchanged.)

The scientists were overjoyed. The two missions were reconfigured for 1986 launches aboard Centaur.

In late August, however, the opposing side counterattacked. When the FY 1983 NASA appropriations came up to a vote on the House floor (as part of the HUD-Independent Agencies Bill), Flippo and Representative Don Fuqua (D–Fla.), chairman of the full Science and Technology Committee, offered an amendment that would kill Centaur and order NASA back to the IUS. The vote was promptly postponed until after Labor Day, but the showdown could come anytime after 8 September.

Flippo and Fuqua explained themselves in a letter to their House colleagues, dated 16 August. They cited the cost of the Centaur modifications ($140 million this year and a total of $634 million), the limited usefulness of the vehicle (just two NASA missions), and the poor example of sole source procurement (presumably the modified Centaurs would be purchased from the traditional Centaur contractor, General Dynamics, instead of being put out for competitive bidding). Far better, they said, to go with the IUS now and let the Air Force and NASA build a new HEUS later.

That same day Fuqua received a supporting letter from Secretary of the Air Force Verne Orr. It would cost still another $200 million to $350 million to modify the Centaur for (classified) Air Force needs, he said. Besides, he too was uncomfortable with sole source procurement.

Centaur supporters, however, find the explanations unconvincing. A planetary scientist within NASA, who prefers not to be quoted by name, pointed out to *Science* that Flippo and Fuqua did not include the cost savings to NASA that accrue from having Galileo spend less time in space. Ground operations will cost roughly $40 million per year. Moreover, all the cost of launch pad and shuttle modifications for cryogenics handling are charged to Centaur, even though similar modifications would be required for any liquid-fueled HEUS. "The net cost of Centaur over IUS would be closer to $50 million or $100 million," he says. "And for that you get more science on Galileo, the legacy for

future planetary missions, and the potential for commercial uses."

He also points out that the Centaur engines are already very close to the theoretical maximum efficiency of a liquid hydrogen/liquid oxygen rocket; moreover, that fuel combination is about the most potent one available. Any new HEUS would just be a repackaging. It certainly would not be any cheaper. (In fact, the cost of a new HEUS has been estimated at about $1.5 billion.)

Besides, he says, the Air Force indulges in sole-source procurement all the time. And if Orr does not want to use Centaur, nobody is forcing him. The Air Force still has its IUS's.

So what is going on? It must be said that Flippo's district includes NASA's Marshall Space Flight Center in Huntsville, Alabama. Marshall is the lead center for the IUS work, and will be the lead center for any new HEUS. However, the Centaur would continue to be handled out of NASA's Lewis center in Cleveland, as it has been for 20 years. Thus, there are jobs involved for Marshall.

It is also true that every aerospace company except General Dynamics has been lobbying hard against Centaur. "If they shoot down Centaur now, they all get a shot at a new HEUS," says a staffer in the office of Representative Bill Lowery (R–Calif.). Since General Dynamics assembles the Centaurs in Lowery's San Diego district, he has been in the thick of the fight. The Air Force, Lowery's assistant suggests, has a similar reason for opposing Centaur: "If Centaur is defeated, I guarantee you that a year from now the Air Force will be back asking for HEUS studies of its own—without having to share it with NASA." That is why the Air Force has been trying to whip up support for its position on the Armed Services committees, he says.

NASA, meanwhile, is split on the issue. In the late 1980's or 1990's the agency would like to build a reusable orbital transfer vehicle (OTV) that would ferry spacecraft from low earth orbit to GEO and back again. Eventually the vehicle might even be manned. From that point of view the Centaur is a dead end, because modifying it to be an OTV would cost more than starting from scratch. On the other hand, the Centaur would be an excellent HEUS in the interim.

The Galileo team could live with either an IUS launch or the Centaur, but they want a final decision on something. The endless flip-flops have been agonizing, wasteful, and demoralizing. Besides, work on the Galileo IUS ceased in July. If the Centaur is canceled now, the whole program will be months behind schedule.

NASA headquarters has managed to stay fairly neutral in all this (perhaps in part because administrator James M. Beggs was formerly a vice president of General Dynamics). Soon however, the agency will officially come out in favor of Centaur on the basis of its usefulness in scientific missions and the need to compete with Ariane. The various divisions are now drawing up lists of specific missions that could utilize Centaur, and the agency is talking to the Air Force about ways of sharing the cost.

Given the forces arrayed against Centaur, however, it seems unlikely that its fate will be decided anytime soon.

—M. MITCHELL WALDROP

IOM Elects New Members

Forty-nine new members have been elected to the Institute of Medicine, raising the total active membership to 453 when their terms begin on 1 January 1983. In addition, six persons were elected to senior membership, bringing that roll to a total of 159.

Lawrence K. Altman, *The New York Times*; **Ralph L. Andreano**, economics, University of Wisconsin, Madison; **H. David Banta**, Office of Technology Assessment, Washington, D.C.; **Ben D. Barker**, School of Dentistry, University of North Carolina, Chapel Hill; **Karl D. Bays**, American Hospital Supply Corporation, Evanston, Illinois; **Richard E. Behrman**, School of Medicine, Case Western Reserve University; **Henrik H. Bendixen**, anesthesiology, College of Physicians and Surgeons, Columbia University; **Lionel M. Bernstein**, National Library of Medicine; **Robert L. Black**, private practice, pediatrics, Monterey, California; **R. Don Blim**, private practice, pediatrics, Kansas City, Missouri; **James A. Campbell**, Rush-Presbyterian–St. Luke's Medical Center, Chicago; **David S. Citron**, Family Practice Residency Program, Charlotte Memorial Hospital and Medical Center, Charlotte, North Carolina; **John J. Conger**, clinical psychology, School of Medicine, University of Colorado; **William C. Dement**, psychiatry and behavioral science, Stanford University School of Medicine; **Donna Diers**, School of Nursing, Yale University, New Haven; **I. S. Edelman**, biochemistry, College of Physicians and Surgeons, Columbia University; **Carroll L. Estes**, social and behavioral sciences, School of Nursing, University of California, San Francisco; **Richard G. Farmer**, The Cleveland Clinic Foundation; **Harvey V. Fineberg**, health policy and management, Harvard School of Public Health, Boston; **William D. Fullerton**, Health Policy Alternatives, Inc., Washington, D.C.

Paul Goldhaber, Harvard School of Dental Medicine; **Avram Goldstein**, Addiction Research Foundation, Palo Alto, California; **Morris Green**, pediatrics, Indiana University School of Medicine; **Joseph Hamburg**, College of Allied Health Professions, University of Kentucky, Lexington; **Margaret C. Heagarty**, pediatrics, Harlem Hospital Center, Columbia University; **Robert W. Jamplis**, Palo Alto Medical Foundation; **Ruth L. Kirschstein**, National Institute of General Medical Sciences; **Arthur Kleinman**, medical anthropology, Harvard Medical School; **Carl Kupfer**, National Eye Institute; **Lester B. Lave**, economic studies program, The Brookings Institution, Washington, D.C.; **Philip Leder**, genetics, Harvard Medical School; **Mark H. Lepper**, Rush-Presbyterian–St. Luke's Medical Center; **Thomas E. Malone**, National Institutes of Health; **Donald N. Medearis, Jr.**, pediatrics, Harvard Medical School; **Duncan Neuhauser**, epidemiology and community health and medicine; Case Western Reserve University; **Dominick P. Purpura**, School of Medicine, Stanford University Medical Center; **Richard D. Remington**, public health, School of Public Health, University of Michigan, Ann Arbor; **Leon E. Rosenberg**, human genetics, Yale University School of Medicine; **Steven A. Schroeder**, general internal medicine, University of California, San Francisco; **William Silen** surgery, Harvard Medical School; **Eliot Stellar**, physiological psychology in anatomy, School of Medicine, University of Pennsylvania, Philadelphia; **George H. Taber**, Richard King Mellon Foundation, Pittsburgh; **Robert E. Tranquada**, Medical School, University of Massachusetts, Worcester; **Ralph O. Wallerstein**, private practice, internal medicine, San Francisco, California; **Lewis W. Wannamaker**, pediatrics, University of Minnesota, Minneapolis; **Virginia V. Weldon**, medical affairs, Washington University, School of Medicine, St. Louis, Missouri; **M. Donald Whorton**, Environmental Health Associates, Inc., Berkeley, California; **Linda S. Wilson**, University of Illinois, Urbana/Champaign; **Michael Zubkoff**, community family medicine, Dartmouth Medical School.

Elected to senior membership: **Kenneth E. Boulding**, Institute of Behavioral Science, University of Colorado, Boulder; **George L. Engel**, psychiatry and medicine, School of Medicine and Dentistry, University of Rochester Medical Center; **Alfred Gellhorn**, School for Biomedical Education, City College of New York; **Neal E. Miller**, psychology, Rockefeller University; **David D. Rutstein**, preventive medicine and clinical epidemiology, Harvard Medical School; **Jonas Salk**, The Salk Institute for Biological Studies, San Diego, California.

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