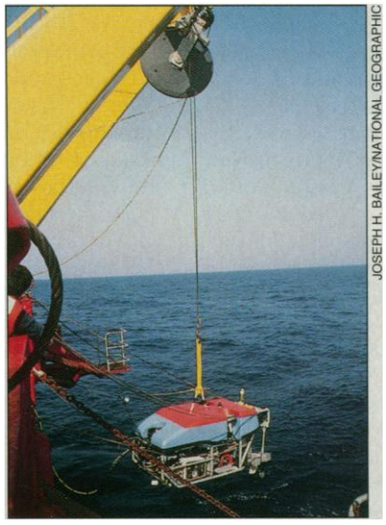
Deep-Sea Debate Pits Alvin Against Jason

An aging explorer gone to pieces, the deep-sea research submersible Alvin recently sat high and dry in a garage at Cape Cod's Woods Hole Oceanographic Institution (WHOI). In for its traditional 3-year strip-down and renovation, Alvin's state of disassembly was just temporary—it just went to sea to get recertified by the Navy and to begin a busy year of research. But the image of a dismantled and useless Alvin is all too real for many oceanographers.



JOSEPH H. BAILEY/NATIONAL GEOGRAPHIC

Wave of the future? Unmanned Jason is lowered into the ocean.

They contend that the Navy would like to replace the elderly manned submersible, which in its historic three-decade career has taken crews of scientists on trips to the mid-ocean ridges and the sunken *Titanic*, with the newer, remotely operated Jason system developed by WHOI's Robert Ballard. "My own impression is [the Navy] is trying...to shove Jason down the throats of the scientific community," says Bruce Robison of the Monterey Bay Research Aquarium Institute (MBARI). Unless something is done, contends one of the sub's pilots, "Alvin will die a slow death."

Alvin's plight is symbolic of a larger issue now confronting marine scientists, who are asking a question strikingly similar to one that has bedeviled the space program for decades: Are manned or unmanned vehicles the way to go to study the ocean and its floor? To a small but growing band of enthusiasts the answer is clear: Remotely operated vehicles (ROVs), like Jason, are the wave of the future. The ROV advocates contend that their instruments are cheaper, safer, and more efficient research tools. Not so, say Alvin's champions, who quickly counter that Jason and its kin are still an immature technology that may complement manned submersibles but will never completely duplicate their capabilities, especially those guided by human hands and eyes. But the ROVs aren't Alvin's only competition on the unmanned front.

Marine engineers are also developing untethered, and thus more mobile, autonomous underwater vehicles (AUVs) that can survey various ocean depths for days, weeks, and even months at a time (see sidebar). The debate over these technologies is one of the hottest topics in ocean science today. One indication of its prominence: the National Research Council's (NRC) marine board is in the midst of a 2-year study titled "Undersea Vehicles and National Needs."

A forced marriage

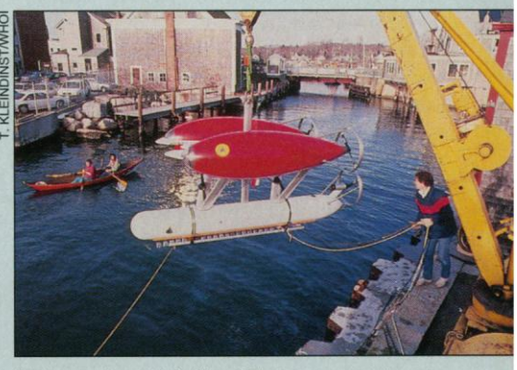
But nothing illustrates the issue like the war of words that characterizes the tussle between Alvin, Jason, and their respective champions. "The paradigm shift has begun. I just don't believe manned systems are competitive with ROVs," says Ballard, a former Alvin devotee who predicts that manned submersibles will be obsolete within a decade. Indeed, the Navy has shown some support for Ballard's view by funding the development of Jason to the tune of more than $3 million since the late-1980s. And now, in a move the Navy hopes will encourage researchers to use Jason, they are merging the ROV's operation with that of Alvin, a change that's raising the hackles of Alvin supporters.

Since 1974, the Navy, which owns Alvin, has operated it jointly with the National Science Foundation and the National Oceanic and Atmospheric Administration (NOAA) as a so-called national facility based at WHOI. Scientists planning Alvin missions merely had to pass peer review and obtain money to cover their salaries and specific instruments. The relevant funding agency would pick up the tab for the operational costs of Alvin and its dedicated mother ship, typically ranging from $21,000 to $28,000 a day. But the agreement under which Alvin has been operating expired last year and the new 3-year memorandum, which is still awaiting final approval at NOAA, has a significant change: It specifies both Alvin and "designated ROVs"—most notably Jason—as part of the national facility.

Economics are a driving force behind the union. For instance, last year was disastrous for Alvin, says Barrie Walden, WHOI's manager of submersible engineering and operations. Many of its planned missions didn't make it through peer review, limiting the submersible to fewer than 100 days at sea. Operating Alvin at that level was simply not cost-effective and there was talk of suspending operations for a year, but WHOI might then have lost to industry or other jobs the highly trained personnel it takes to operate the vessel. Merging the operational aspects of Jason and Alvin should increase efficiency by keeping the crews busier and reducing the danger of slow years, says the Navy. The Navy also contends that the merger will allow researchers to choose more easily the instrument best suited for their research, or some-

ABE and Odyssey: AUVs Test the Waters

While oceanographers debate the relative merits of manned submersibles such as Alvin and unmanned remotely operated vehicles (ROVs), such as Jason, for doing deep-ocean research, a new technology is emerging on the horizon—and it may soon compete for the dollars now devoted to the Jasons and Alvins (see main story). In pools, lakes, and bays, institutions such as the University of New Hampshire, the Massachusetts Institute of Technology, Woods Hole Oceanographic Institution (WHOI), and the Monterey Bay Aquarium Research Institute have been experimenting with a novel class of deep-sea explorers, the autonomous underwater vehicle or AUV.



T. KLEINDINST/WHOI

Going solo. AUVs like ABE can roam alone beneath the sea.

These instruments combine robotics, thrusters, sonar, and sensors with artificial intelligence. Because AUVs aren't tethered to a mother ship, the way ROVs are, they have a much greater range of movement. And if they judiciously use power, AUVs can wander under the waves for days to months, far surpassing the ability of energy-intensive research submersibles like Alvin, which can make no more than a mere 12-hour voyage

day make use of them both on the same mission. "It's not so much a replacement for Alvin as putting another tool in the toolkit," argues Steve Ramberg, director of the ocean engineering division at the Office of Naval Research (ONR).

Others aren't so sure about that. The move may have been prompted, some suggest, by the fact that the Navy already independently operates two manned research submersibles of its own and doesn't have much use for Alvin. They worry that if Jason does become as popular as Ballard expects, it will crowd Alvin off the scene. Those concerns are further buttressed by another fact: Since the merger cut total staff, there isn't sufficient personnel to operate both vessels simultaneously, although that is a hope for the future. "Financially, the possibility is that one might have to replace the other. I'm not sure we can do both," worries Walden.

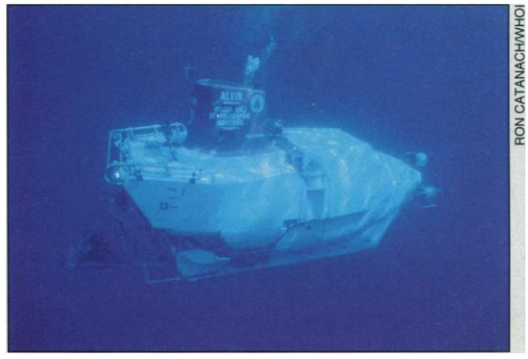
Jeffrey Fox of the University of Rhode Island (URI), who chairs the committee that decides which researchers can use Alvin and Jason, says, however, that the ROV, rather than Alvin, is at risk of being greatly underutilized. Jason only has a few missions for this year, while Alvin's schedule is packed. Scientists have so far displayed what he calls a "knee-jerk resistance" to the unmanned tool. Indeed, another major concern is that many believe that merging operations was premature. "Some scientists feel the [Navy] is forcing this change before the unmanned system has proven its practicality," says Larry Clark, NSF's program director for ocean technologies.

Whether premature or not, the Navy's decision has stimulated a new look at the relative merits of manned and unmanned research into the deep sea. One unavoidable concern of crewed dives is safety, since researchers and pilots are diving to depths where the pressure would easily crush them and a leak in the hull could be fatal. "The minute you put people in vessels going to the sea floor, you have enormous problems," says the Massachusetts Institute of Technology's Carl Wunsch, the chairman of NRC's ocean studies board, explaining that the need to protect its occupants drives up the cost of a crewed research vessel considerably.

Another major drawback for Alvin and other research submersibles is their short "bottom time." Power and oxygen requirements typically limit an Alvin voyage to 12 hours, eight of which can easily be spent going down to and coming up from the deep ocean floor. As a result, says NSF's Clark, Alvin's dive time is precious and best utilized in goal-oriented research, not the exploration that marked the vessel's early years.

But when there is an identifiable research target, say a hydrothermal vent or sunken ship, a submersible is at its best. Even just looking through small portals, a crew can provide a three-dimensional viewing experience that an ROV's two-dimensional cameras cannot match. And while stereovision technology is progressing rapidly, remarks Fox, "there's no substitute for the human eye." Furthermore, Alvin's superior manipulator arms and its ability to provide a completely stable environment by settling directly on the sea floor make it far better than Jason at obtaining samples and performing experiments. "Right now, the submersible is still better at carrying out delicate manipulative experiments on the sea floor," says Fox. And, as Clark points out, the biggest argument for putting humans miles below the surface is still the ability of a human crew to react to surprises and perhaps improvise an experiment.

For their part, ROV advocates contend that these advantages don't warrant either the increased safety risk, or what they maintain are the higher costs, of manned ocean research. Indeed, says Ballard, the advantages are overrated. He particularly takes issue with the notion that humans need to be on site to react quickly to events, pointing out that they must still work manipulator arms and can only see out through a few small windows. "Unlike going to the moon, when you get to the bottom of the sea, you don't get out. Manned submersibles don't create a manned presence. It's all a question of where you put the window," he says.



RON CATANACH/WHOI

That sinking feeling. Is manned submersible Alvin on the way out?

Ballard and his ROV allies are also trying to improve Jason's capabilities, adding a new manipulator arm and better sampling capabilities, for example, and devising what he and others call "telepresence," which might allow researchers to operate Jason from their own lab instead of a ship above. An important test of those improvements came last week when researchers working out of the URI Graduate School of Oceanography successfully operated Jason in the Gulf of California, collecting data and samples.

Eyeballs with thrusters

The skeptics may still take some convincing, however. "The Alvin group has a fantastic record of making dives as scheduled and delivering the product to scientists. Jason doesn't have that dependability. It doesn't have that track record yet," admits ONR's Ramberg. Because of that lack of experience, oceanographers are openly skeptical of Ballard's claims that Jason can do Alvin-like science. "The idea is still pervasive throughout the community that [ROVs] are just eyeballs with thrusters," says the University of Connecticut's

because of battery limitations. "AUVs have a lot of promise. There are simple projects for which they are ready today," says James Bellingham, manager of the MIT Sea Grant Underwater Vehicles Laboratory, which developed Odyssey, a prototype AUV capable of roaming 170 miles before being picked up. A recent test run in the waters of Antarctica, for example, was the first step in plans to let Odyssey traverse large distances beneath ice floes and collect data, which researchers can analyze after retrieving the AUV.

While problems such as underwater navigation and battery limitations have slowed AUV development, there are considerable signs of progress. Also making its debut this year is WHOI's Autonomous Benthic Explorer (ABE), a much larger instrument that derived some of its technology from Odyssey. This summer, researchers plan to program ABE to follow a preplanned course around a beacon they've placed at a deep-sea hydrothermal vent in the Atlantic. ABE will run its daily route in about 15 minutes, monitoring ocean currents, taking pictures, temperature measurements, and other data, and then return to a mooring platform on the sea floor, where it will go into a "sleep" mode to conserve energy. If all goes well, ABE should function for nearly a year.

Although AUVs are still an immature technology, some researchers have high hopes for their eventual contribution to climate research, especially if they can be mass-produced relatively cheaply. The need for understanding the ocean's role in global climate change demands the larger-scale, more continuous monitoring that AUVs could provide, rather than the in-and-out missions that manned and remotely operated vehicles appear best suited for, notes MIT's Carl Wunsch, who heads the National Research Council's ocean studies board. If he's right, the names Odyssey and ABE may one day be as familiar as Alvin and Jason.

–J.T.

Peter Auster, editor of the Marine Technology Society's latest journal issue, which was devoted to "ROVs for science" and the dialogue over manned versus unmanned research. Such skepticism infuriates Ballard. "The point is they haven't used an ROV system. What's their credibility? I've used both," he says.

What's more, he argues, manned research is simply not cost-effective, and he points out that ROVs can literally work 24 hours a day since the ships they're tethered to can provide continuous power through the cables in its tether. Beyond that, he says, the amount of data gathered from a manned mission cannot compare to that from an ROV like Jason, since the ROVs' link to the surface ship also includes fiber optic cables that provide scientists with an unending flow of numbers and images.

But while manned research supporters concede that ROVs offer more bang for the buck, they question whether ROVs actually save much money. Alvin's costs are relatively well established, operating on an annual budget of around $2 million, but since Jason hasn't operated as a research vehicle full-time, its overall costs are more murky. WHOI's Walden points out, for instance, that Jason requires more manpower to operate—12 people compared to Alvin's eight—and manpower represents a significant fraction of operating costs. "There's really no great savings. I think the financial argument is a lot of smoke," he says. "It's about a wash [in overall cost]," agrees Dick Pittinger, WHOI's associate director of marine operations and one who monitors the accounts of both vehicles.

A final consideration attached to the debate, and one that researchers suggest cannot be easily dismissed, is the emotional appeal of manned missions. "These scientists just want to go down in subs," says Drew Michel, chairman of the Marine Technology Society's ROV committee. A small number even argue for a new manned vessel, one making use of the incredible advances in composite materials and able to go deeper than current submersibles like Alvin. But does the ocean science community really need manned submersibles, a growing fleet of ROVs, and the oncoming autonomous vehicles, and is there enough good research projects to keep them all busy? Some oceanographers think so. "In the future, I can't see anything except widespread use of all three," says MBARI's Robison, who recently called the whole debate a "bogus issue." He and others argue that the goal-oriented research capabilities of subs like Alvin are the perfect complement to the superior surveying powers of AUVs and ROVs like Jason. Says URI's Lynne Carter Hanson, a member of NRC's marine board, "We are dividing the community unnecessarily when we look at ROVs or AUVs versus submersibles." Those concerned about the fates of Alvin and Jason, at least most of them, certainly agree with that opinion.

–John Travis

SWEDISH SCIENCE

Funding Bonanza Splits Biologists

Every so often, some section of the scientific community gets an unexpected windfall that banishes—for a while, at least—the usual complaints about underfunding. Last year, British biomedical researchers struck it lucky when the charitable Wellcome Trust sold billions of dollars worth of drug company shares and doubled its annual budget (*Science*, 22 May 1992, p. 1132). Now it's the turn of the Swedish research community.

Late last month, the Swedish government set aside some $1.3 billion to launch three new research foundations, which should mean a boost of up to $125 million a year for Swedish research over the foundations' intended 15-year life. That's almost as much as the total amount now spent by Sweden's three main government research councils. Most of the money is destined for projects that could eventually help Swedish industry, but academic researchers will get the lion's share of the sudden cash injection. Gustav Rickerts, a senior official in the Swedish Education and Science Ministry, expects university-based "directed basic research" in biotechnology, computing, and materials science to dominate the new investment.

Three new research foundations will spend almost as much as Sweden's three leading research councils.

The euphoria hasn't lasted long, however: Swedish biomedical researchers are already engaged in a bitter dispute over the division of the spoils, and the research community is holding its collective breath, hoping that the planned foundations will not be torpedoed by a dispute between the country's major political parties over the source of the funds.

Both the ruling center-right coalition and the left-leaning Social Democrats—who held power until 1991—claim to be strong supporters of research. But the Social Democrats are incensed that Science Minister Per Unckel intends to finance the new foundations from the so-called wage earner fund—money levied from industry that the Social Democrats had intended to use to buy shares in companies on behalf of the public. Although the Social Democrats have reluctantly accepted that their fund is to be dismantled, some researchers are worried that they may try to convince minority parties that more of the money should be used on schemes that would directly help ordinary workers, and that this will cut into the allocations for the three foundations.

But the looming parliamentary debate may be tame compared with the spat that has already split the biomedical community—pitting the Swedish Medical Research Council (MRC) against such elder statesmen of Swedish science as tumor biologist George Klein of Stockholm's Karolinska Institute and University of Gothenberg pharmacologist Arvid Carlsson. The problem? A proposal the MRC sent to the government last summer, after it was asked for advice on how to spend the money.

"The whole issue was dealt with by a dozen people on the MRC itself," says Carlsson, who contends that the council should have first consulted its network of peer-review committees. When the contents of the proposal leaked out, says Carlsson, many researchers thought it was slanted toward the research interests of council members. Worse, he says, it included an addendum with more than 30 names of scientists suggested as possible candidates to perform the work—at least five of whom were close colleagues of members of the MRC. "That was rather shocking," says Carlsson, who has since collected 550 signatures for a petition denouncing the MRC's behavior.

MRC secretary Tore Scherstén responds that the council's traditional peer-review committees were not well equipped to draw up the interdisciplinary research proposals that the government was looking for. And although Scherstén now regrets that the controversial addendum was attached to the proposal, he says the point was simply to show that Sweden had competent researchers in the priority areas identified by the MRC. The critics have now taken the issue to the Swedish government's judicial chancellor, however, who will rule in the spring on whether the council fell afoul of a conflict of interest.

A big fear among biomedical scientists is that the affair has so badly damaged the public image of Swedish biomedicine that medical research could end up getting less than its fair share of the wage earner fund money. "Maybe we will get nothing," laments brain researcher David Ingvar, of the University of Lund, an outspoken critic of the MRC's handling of the issue. "The whole thing is tragic."

–Peter Aldhous