WISHING FOR THE STARS

US astronomers are renowned for getting together and choosing their projects as a group. But just as these tactics are catching on in other fields, some say the astronomy process is grinding to a halt. **Geoff Brumfiel** investigates.

Some of us are impulse buyers, some chaotic shoppers, and some of us head out with a carefully thought through list of what we want. Collectively, US astronomers fit in that last category. Since the 1960s, a who's who of the field has gathered together every ten years to draw up a table of what instruments they want to buy — or rather, to have bought for them. Their reports, known as decadal surveys, cram radio dishes, ground-based telescopes and ambitious satellite observatories into a tidy, page-long, prioritized list.

Compiled through the US National Academy of Sciences, these surveys can do much to set the field's agenda, especially when they prioritize a ground-breaking instrument. The 1964 recommendation to build the 27-dish array that went on to become the Very Large Array in New Mexico led to an explosion in radio astronomy. A 1972 recommendation for research towards the goal of a large space telescope did not, in itself, bring about the birth of the Hubble Space Telescope, but it helped show the community's support during the early years of the project. Cosmic-ray facilities in the 1980s and infrared astronomy in the 1990s both received fruitful bursts of interest and investment thanks in part to earlier decadal surveys.

The astronomers' orderly and concise sorting of their needs has won them the praise of Washington politicians and the imitation of their peers in other disciplines. In recent years, space physics, high-energy physics, atomic and molecular physics, and planetary science have all compiled their own decadal surveys in the hope of galvanizing researchers and winning funding from agencies. Even Earth scientists and botanists have taken a stab at the process. Meanwhile, across the Atlantic, European astronomers are trying to develop a Europe-wide set of priorities (see 'Continental drift', overleaf).

Cloudy skies

But at precisely the time others are rushing to emulate them, the astronomers have run into trouble. It is now five years since the publication of the most recent report, and not one of the instruments it recommended is yet operational. That is not unusual: none of the 1991 report's recommendations was up and running in 1996. And if all goes well, the first of 2001's list — the Gamma-ray Large Area Space Telescope — will launch on 7 October. But in stark contrast with previous surveys, many of 2001's other recommendations have yet to leave the starting blocks and are a long way from being launched or built (see 'Where are they now?', overleaf). Only one other space mission from the survey is likely to fly this decade. The really large space missions are all deferred to the 2010s, as are most of the ground-based projects.

As telescopes and satellites languish in the queue, the designs to which the 2001 report gave its blessing run an increasing risk of becoming technologically outdated. And the survey's price estimates are proving to be a long way wide of the mark. The cost of its chief priority, a successor to Hubble known as the James Webb Space Telescope (JWST), has gone from $1 billion to $4.5 billion (see *Nature* **440,** 140–143; 2006); and the Constellation-X quartet of X-ray telescopes has risen from $800 million to $1.6 billion. "I think the last decadal survey for astronomy was a failure," says Webster Cash, an astronomer at the University of Colorado, Boulder. "We basically just have the JWST seven years from now, and until then we're surviving on existing missions. Space astronomy is grinding to a halt."

"The last decadal survey for astronomy was a failure." — Webster Cash

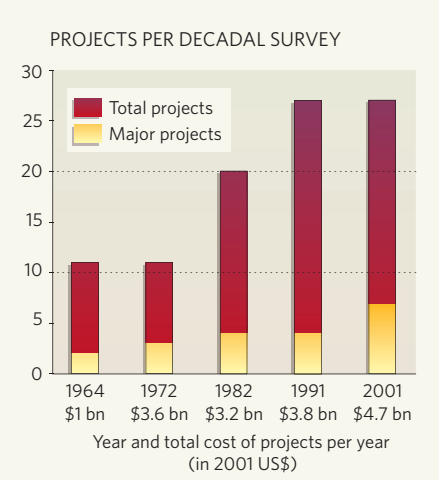
Get back on track

It is against this background of minimal success that the community will begin work on the next decadal review this winter. And as it discusses what should go into the report, it will also be assessing how the surveys can be made to work as they once did. Michael Turner, a cosmologist at the University of Chicago, was until recently head of the National Science Foundation's Mathematical and Physical Sciences Directorate, in which capacity he set up a decadal review for particle physics. "The philosophy of the astronomical decadal survey was 'one blessing with holy water' — you touch a project and by the end of a decade it should be done," he says. In today's environment "that philosophy really doesn't make sense", he adds. Turner is one of several scientists calling for reform of the decadal-review process. He wants to see the survey focus on scientific goals rather than equipment and to give the projects realistic price tags.

Astronomy has always been an easier discipline to organize than most. "We're all building experiments that go either in space or on the ground, look at the sky and make measurements of distant objects," says Steven Kahn, deputy director of the Kavli Institute for Particle Astrophysics and Cosmology at Stanford University, California. "Most astronomers have some comprehension of what other astronomers are doing. You feel like you can make comparisons or make rankings."

But the surveys are rooted as much in political economy as in epistemology. The first survey was completed in 1964, following efforts to gain a lead in the space race with the Soviet Union. The eight-member panel was convened to work out how best to channel a flood of new funding into ambitious projects that might be beyond individual universities and foundations. Confined to ground-based projects, its priciest recommendation was for a $40-million 'pencil-beam array' of radio dishes, which eventually became the Very Large Array.

The next review also considered instruments in space, with its 23 authors recommending 11 space-based and ground-based facilities in a growing number of fields, including infrared and high-energy gamma-ray research. Unlike



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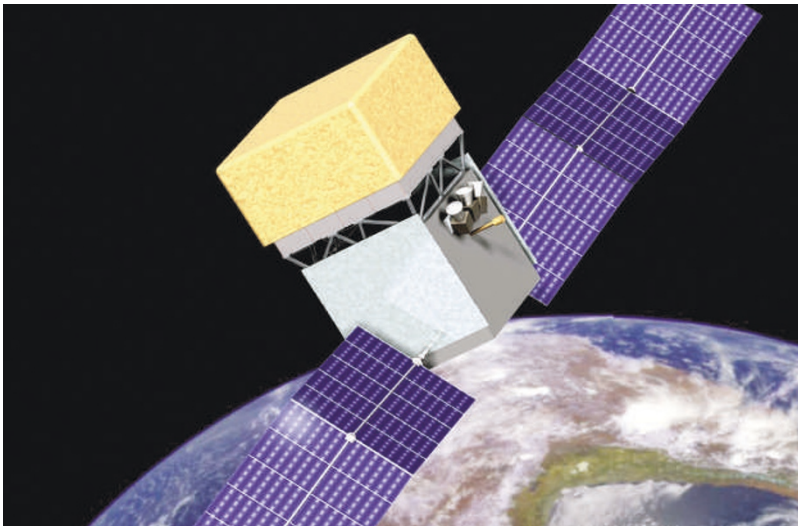
NASA



The GLAST telescope is the only project from the last decadal review that is ready for launch.

the 1964 survey, the 1972 panel ranked the projects. NASA, which funds most space-based projects, has its own planning process that runs in parallel with the decadal reviews, but their priorities often coincide.

Over subsequent decades, the size of the committee grew further, as did the number of projects it recommended (see graph). The most recent survey, completed in 2001, involved more than 100 individuals and was drawn up by a central committee of 15, flanked by 9 subcommittees, each devoted to a separate field of astronomy. It recommended a total of 27 projects, including 7 'major initiatives' — more big ones than any previous decadal review.

Inflation from all angles

The increasing size of the panel reflects the growth of astronomy, says Stephen Strom, an astronomer at the National Optical Astronomy Observatory in Tucson, Arizona, who has served on four of the five decadal reviews. "Astronomy was not a terribly large field when the first of these came out, and it was possible to more or less name the leaders," he says. The process now includes panels, public meetings and white papers from subdisciplines.

The fortunes of subdisciplines can be determined by a nod from a decadal-review committee. For example, the 1991 report chaired by John Bahcall endorsed several major infrared projects. According to Harley Thronson, a chief scientist for exploration at NASA's Goddard Space Flight Center in Greenbelt, Maryland, infrared astronomy was "a respectable field" before the 1991 report, but progress was slow. The Infrared Astronomical Satellite, a joint programme between the United States, the Netherlands and Britain, had provided a tantalizing look at long infrared wavelengths in the Galaxy in the early 1980s; but plans for the next US space-based observatory, known today as the Spitzer Space Telescope, were caught up in NASA's bureaucracy. Then the Bahcall committee gave it high marks. "The Bahcall committee gave it the official, highest-level imprimatur," says Thronson. This endorsement, he says "established the credibility, the substance, the importance of observations at long wavelengths".

"There was a tremendous amount of undercosting going on." — Chris Reynolds

Making the grade

It's that kind of power that has left astronomers enamoured of the decadal review. "It builds a consensus in the field and it prioritizes," says Turner. "Any group of scientists can produce a wish list that exceeds the GNP of the Milky Way," adds Roger Blandford, director of the Kavli Institute for Particle Astrophysics and Cosmology. The decadal-review process helps astronomers to whittle the list down to a realistic level and "make tough calls".

If the surveys appealed only to scientists they would be of limited value, but they appeal to Washington too. Agencies such as NASA and the National Science Foundation often depend on the survey to help them determine which programmes to back. And the tidy list of priorities makes it a favourite with the White House Office of Management and Budget, which recommends yearly spending for those agencies. It also steadies the United States' famously chaotic congressional budget process, according to David Goldston, chief of staff for the House Committee on Science. "In general, on real science questions, Congress tends to defer to the community," he says. "It's an area where Congress really recognizes that it doesn't have the expertise to make a decision on its own."

The survey's popularity in Washington has led other disciplines to copy it. "A babble of voices is not useful," says Berrien Moore, a climatologist at the University of New Hampshire in Durham, who is co-chairing the Earth science community's first decadal survey. "The community has got to come together and decadal surveys force that." Not all of the surveys are carried out the same way, or necessarily with quite the same ends in mind. The broad field of atomic, molecular and optical science shunned specific projects in favour of endorsing research areas such as physics at ultra-short time periods or ultra-high temperatures. The survey for high-energy physicists, which Turner helped to organize, on the other hand, was geared towards

Continental drift

The popularity of the decadal review extends well beyond the United States, and many European astronomers have their own national survey processes. But these national reviews have yet to be combined into a continental consensus, says Catherine Cesarsky, director-general of the European Southern Observatory (ESO). "We are not yet a united states of Europe."

A consortium of 11 science agencies is trying to do something about that. Known as Astronet (www.astronet-eu.org), the group wants to build a pan-European list of space missions and telescopes, says Anne-Marie Lagrange, head of the astronomy directorate at the CNRS, France's basic research agency, based in Paris. Unlike the US decadal review, which is coordinated by the community, Astronet has been convened by funding agencies, which frequently collaborate to build European projects. "We felt there was a strong need for a shared science vision for astronomy at the European level," Lagrange says. "Astronomy tools are getting more and more complex and expensive."

Over the next three years, the group will set up advisory committees and hold public meetings to try to draw up its list. The task may not be as complex as it first seems. The two main funding bodies for much of astronomy — the ESO and the European Space Agency — are already Europe-wide, and many of the national decadal surveys share similar priorities.

But it is nevertheless important to create a master list, especially as the European Union (EU) develops new pan-European funding bodies such as the European Research Council, says Reinhard Genzel, a director of the Max Planck Institute for Extraterrestrial Physics in Garching, Germany.

"The EU doesn't have a formal role in the funding of basic research, but that may be coming," says Genzel. "We had better be ready with a view of what should be funded." **G.B.**

convincing outsiders that the discipline was worth investment, says its chair, Harold Shapiro, an economist at Princeton University in New Jersey. "They felt the field badly needed an assessment from the outside, to find out if the day of the accelerator is really over," he says. Shapiro and his colleagues concluded it wasn't, which may be of some help to US physicists when they ask for money to host the Next Linear Collider.

This imitation may give astronomers a warm glow, but it doesn't get their mirrors mounted, their balloons inflated or their spacecraft launched. The lack of progress on the 2001 committee's recommendations has become a source of anxiety, and any agreement on what to do differently in the upcoming survey depends on working out what went wrong last time.

Christopher McKee of the University of California, Berkeley, one of the co-chairs of the 2001 survey, believes that the current impasse has nothing to do with the survey process. "There have been two things that occurred in this decade that did not occur in the previous ones," he says. First, the 2003 crash of the space shuttle Columbia put a heavy financial strain on NASA. Second, President George W. Bush's redirection of the space agency towards manned exploration of the Moon and Mars drastically and unexpectedly cut its science budget. "We did not make the assumption that somehow NASA funding would increase, but we very definitely did make the assumption, at least in constant dollars, that there would be no cut in support for astrophysics," McKee says. Instead, the budget for astrophysics in 2010 is projected to be substantially below the funding level in 2000. "That is having some very major effects," McKee says. This all comes at a time when the National Science Foundation is also over-extended. Blandford is chairing a committee with the rather more challenging task of reaching agreement on which of the National Science Foundation's ground-based facilities to close down.

Others believe that the 2001 survey has to take some share of the blame itself. It's true that the budget outlook was considerably rosier during 2000, when the survey committee was finalizing its plans, says Cash. But that still doesn't explain what he describes as "a severe low-balling" of mission costs. "There was a tremendous amount of undercosting going on," agrees Chris Reynolds, an astrophysicist at the University of Maryland in College Park. "And some of it was completely apparent at the time." McKee defends the committee's choices, noting that it was wholly dependent on NASA estimates of mission costs. "We did not have any separate funding to do an independent cost analysis," he says.

Future tense

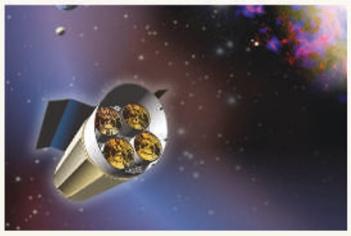
Whatever the reason for the problems, they mean that the survey that gets under way this winter will be setting a different kind of agenda, because it will have to deal with the large number of incomplete projects in the previous survey, says McKee. "I think that the survey will have to explicitly prioritize projects that have already been recommended," he says. "And it's quite possible that it will have to recommend termination of some projects."

More care must also be taken to ensure that costs are accurate, adds Strom. After the dramatic price hikes of projects in the last survey, the committee must learn to be more sceptical, he says, or it is likely to lose political credibility in Washington. "A key element of trust is a reliable cost estimate and good management tools," Strom says. "I'm not sure that kind of culture has been sufficiently inculcated by the community."

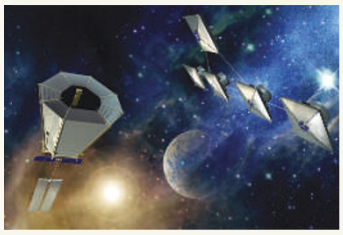
WHERE ARE THEY NOW?

The class of 2001 has had mixed fortunes.

Deferred indefinitely



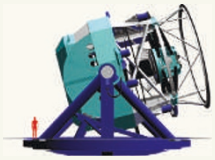
Terrestrial Planet Finder



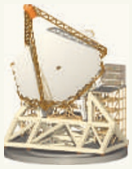
Constellation-X Observatory

NASA/ESA

Lacking construction funds



Large-aperture Synoptic Survey Telescope

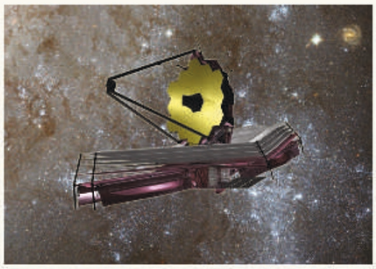


Giant Segmented Mirror Telescope

Expanded Very Large Array

Delayed launches

Single Aperture Far Infrared Observatory
Postponed to 2015–20



James Webb Space Telescope
Launching 2013

But should there be more radical changes to the way the survey is done? Some scientists think so. Reynolds believes that part of the problem is that the review depends on senior members of the community, and they may have outdated scientific viewpoints. "Those views can drive basic decisions on missions," he says. He thinks that the review should hold more public forums to get community-wide opinion and that there should be a clear and direct process for submitting project proposals. These steps would give a voice to younger researchers at the beginning of their careers.

Others criticize ranking. "I feel it's a terrible mistake to rank missions," says Cash. "If you implement it right away it's fine, but if everything sits on hold for more than three or four years, it freezes in one approach to one piece of science." Both equipment and scientific knowledge itself are changing rapidly, Cash adds. Instead of listing missions with specific costs, the survey should list the science goals of each decade, and allow missions to be chosen independently. "For example, instead of saying our number two priority is Constellation-X, we should say our number two priority is to watch blobs of plasma fall into black holes," Cash says.

But Kahn and many others continue to stand by the traditional decadal survey. "The perception within the community, which is backed by what the agencies tell us, is that the reason we've had such success is that we made hard decisions and made a list," Kahn says. "The alternative is just chaos." ■

A. RAE

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