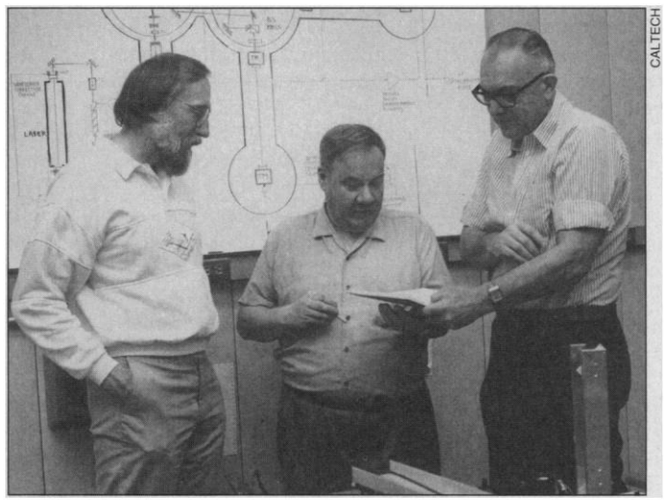
# LIGO: A $250 Million Gamble

The potential prize would be great: the first glimpses of gravitational waves. But a messy dispute at Caltech has again raised the question of whether it's too long a shot

In February 1992, then National Science Foundation (NSF) director Walter Massey called in the press to announce that his agency had selected areas in Hanford, Washington, and Livingston, Louisiana, as the two sites for an ambitious physics facility: the Laser Interferometer Gravitational-Wave Observatory, otherwise known as LIGO. Later that summer, Congress dramatically stepped up LIGO's budget, approving $38 million in construction startup funds to scale up from a 40-meter prototype detector to two 4-kilometer behemoths—big enough, supporters claimed, to have a good chance of snaring the first direct evidence of the gravitational waves predicted by Einstein's theory of general relativity. LIGO seemed well on its way, and it was a proud time for its director Rochus Vogt, NSF, and the rest of the scientists that made up the joint MIT-Caltech project.




**Odd man out.** Ronald Drever *(center)* has been shut out of the project. Team members Kip Thorne *(left)* and Rochus Vogt.

The euphoria was short lived, however. For more than a year, LIGO has been under siege from inside and outside. In the latest chapter in a bitter internal battle that many say has paralyzed the endeavor, a committee of Caltech faculty members recently concluded that Vogt and LIGO's management had unfairly fired one of the project's chief scientists. The battle is more than a personality clash, for it revolves around the crucial issue of whether the current LIGO effort offers the best chance of success in what all admit is an incredibly difficult task—a question that is reverberating among researchers outside the LIGO community as well. Adding to the acrimony is LIGO's $250 million price tag, which some hold responsible for NSF's recent funding woes. Since 1991, a number of astronomers and physicists have attacked the decision to proceed with the scale up, expressing concerns about whether LIGO will be able to detect gravitational waves, let alone fulfill its promise of being an observatory.

Now, even as bulldozers prepare to move land at each site, the level of discord is rising. "I think LIGO could come back to greatly haunt the scientific community if we spend $250 million and see nothing," warns one astronomer who, like many of the officials and scientists interviewed for this article, requested anonymity. "There's been so much unhappiness out there about all this that I don't think we will be able to easily forget it," adds University of California, Los Angeles, space plasma physicist Charles Kenel, who chairs the National Research Council's (NRC) board on physics and astronomy.

To LIGO's supporters, however, much of the latest criticism smacks of sour grapes. They argue that the technical concerns being raised are nothing new and have all been thoroughly investigated. The project is risky, they concede, but the return could be enormous. By using lasers to measure, for the first time, the exquisitely small ripples in space that passing gravitational waves from astronomical sources produce, researchers believe they can greatly improve their understanding of general relativity. More stirring is the hope that a series of gravitational wave detectors around the world will usher in a new day in astronomy, providing a novel way of watching supernovae, colliding neutron stars, and perhaps offering definitive proof for the existence of black holes. Says Kip Thorne, Caltech theoretical physicist and member of the LIGO team: "The payoff, when it comes, is so exciting that it's worth the risk."

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### A pink slip from LIGO

Part of the debate over LIGO has been played out in the pages of technical journals and the general media. But one key aspect has remained hidden from public view: the ongoing troubles between Caltech experimental physicist Ronald Drever and the rest of the LIGO team, specifically director Vogt. For the past 2 years or so, Drever has been, in the words of one Caltech faculty member, "frozen out of LIGO" in a messy feud that peaked last year on 6 July, when Drever was fired from the project apparently without explanation. "He was thrown off the project, forced to turn in his keys, kicked out of the lab, and told he was persona non grata," says one Caltech faculty member familiar with the events. (*Newsday* also reported some of these events earlier this week.) Within hours of the dismissal, Vogt sent out an e-mail letter to the LIGO community saying that Drever was no longer associated with the project, would be allowed to remove his personal possessions from the LIGO offices only under staff supervision, and had been instructed not to enter LIGO premises or disturb project scientists. (Vogt was traveling last week, but he declined through a spokesman to discuss details of the rift with Drever; Drever also declined to speak with *Science*. Colleagues of Vogt and Drever provided accounts of the dispute.)

Drever is not somebody to be taken lightly: Brilliant is the description most often given of him, and he is viewed by almost all as one of the key physicists whose research in the 1980s transformed LIGO from a dream into a realistic undertaking. Caltech imported Drever from the University of Glasgow in Scotland specifically to work on the detection of gravitational waves, and when NSF merged the parallel efforts at MIT and Caltech into a single project in 1984, Drever's design was chosen over another proposal from MIT physicist Rainer Weiss. Furthermore, from

1984 to 1987, Drever, along with Weiss and Thorne, made up the steering committee that managed LIGO, a task Vogt subsequently took over.

The root of the current conflict, supporters of both camps say, is a personality clash between Vogt and Drever, exacerbated by conflicting research styles and differences of opinion on how the project should proceed. Several sources confirm that Drever feels it is too early to scale up to two large facilities. "What worried him most was whether they could do what they claimed," says one Caltech faculty member. It's not that Drever thinks detecting gravitational waves is impossible, these sources say, but that he thinks the LIGO effort as currently conceived won't achieve the needed sensitivity in time. For now, Drever wants LIGO to commit to an aggressive technology development effort, under his direction, and the construction of a better, perhaps 200-meter, prototype. Caltech's Tom Dombrello, a member of the recently formed LIGO oversight committee headed by former Jet Propulsion Laboratory director Lew Allen, hints at this debate: "If we settle the technical questions that exist between the parties, all [these problems] will go away."

Drever's firing also provoked a battle at Caltech over academic freedom, and according to both supporters and critics of LIGO, it has been a major diversion for the project's management. The battle began in September 1992, when Drever filed a complaint with the academic freedom and tenure committee, an elected faculty panel chaired by theoretical physicist Steve Koonin. Koonin's group investigated the matter and delivered a report in October 1992, siding with Drever on two grievances. First, "the academic freedom committee concluded that [Drever's] separation had been without due process," says Caltech astrophysicist Peter Goldreich, who helped Drever prepare his case. The second finding was that Drever's academic freedom had been infringed when Vogt, in the words of a committee member, "strongly discouraged under the threat of separation" Drever from attending two scientific meetings in which he was scheduled to talk about gravitational wave research. Drever ignored Vogt's second warning and spoke at a meeting in Argentina. On his return, Drever was fired.

Despite the committee's report in October, Caltech did not immediately reinstate Drever to the LIGO team, and several faculty members launched an effort to force that action. "I am really disappointed with the way the administration handled the situation," says Goldreich. The committee report pointedly did not call for Drever's reinstatement, however—a deliberate omission, say committee members who talked to *Science*. The reason: Although the committee agreed that Drever's firing had been handled inappropriately, it could not decide whether LIGO had cause to remove him from the project.

The first clear response to the committee's report was the formation in December of Allen's oversight committee—a move that many felt was long overdue considering that the project was no longer small science but a major engineering job. Around the same time, Caltech tried to resolve the dispute by offering Drever, who remained a tenured faculty member, a reported $1 million over 2 years to set up an independent gravitational wave research effort. Drever rejected the offer because, say his colleagues, he considers LIGO the culmination of his life's work and wants desperately to make it succeed. In recent months, Drever has been negotiating his return to the project. According to Allen, Drever is now a member of the LIGO team, but Drever supporters say that may be true only on paper and that the LIGO team has refused to accept him back.

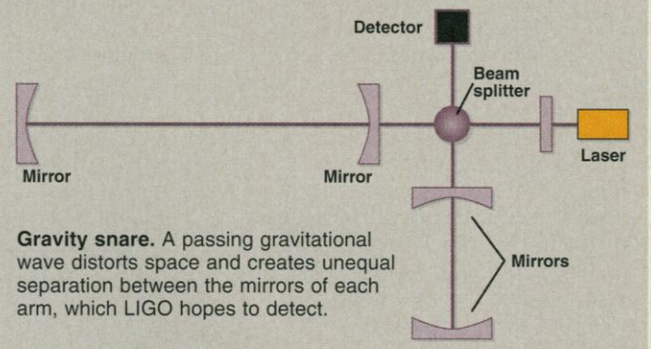
### The O in LIGO

Drever is not alone in his concerns about LIGO's pace and scope. "I still think LIGO is technologically unjustifiable and premature," says AT&T Bell Laboratories astrophysicist J. Anthony Tyson, an experienced gravitational wave researcher who is said to have shocked the LIGO team when he voiced that opinion at a House science committee hearing in 1991. And even before Tyson dropped his bombshell, criticism about the cost of LIGO had been circulating throughout the scientific community (*Science*, 7 September 1990, p. 1106).

The nub of the technical dispute is whether LIGO's massive detectors will be sensitive enough to pick up the signatures of gravitational waves from the only source whose strength and incidence rate researchers can confidently predict: two neutron stars spiraling toward each other. In principle, these gravitational waves should show up as tiny shifts in the interference pattern created by laser beams bouncing down the arms of the LIGO facility (see sidebar), but Tyson, for instance, is convinced that current instruments are not advanced enough to pick out

## How to Catch a Gravitational Wave

Researchers hoping to snare a gravitational wave with their proposed Laser Interferometer Gravitational-Wave Observatory (LIGO) are embarking on one of the most technically challenging tasks scientists and engineers have ever attempted. In essence, they hope to detect the subtle distortions of space-time that Einstein's theory of general relativity predicts will be caused by cataclysmic events such as the spectacularly violent collision of two neutron stars, the merging of black holes, or even supernovae.




**Gravity snare.** A passing gravitational wave distorts space and creates unequal separation between the mirrors of each arm, which LIGO hopes to detect.

If they can overcome the controversies swirling around LIGO, they will build their mammoth instruments at two different, widely separated, sites—the redundancy is needed to weed out local false alarms and to get a sense of the direction of the source. At each site, high-power lasers will fire down two identical 4-kilometer-long vacuum pipes, 4 feet in diameter and perpendicular to each other. At the ends of both pipes, test masses fitted with mirrors will reflect the beams back and forth thousands of times before returning them simultaneously to a detector.

If researchers can control seismic vibrations and a variety of other noise sources that could cause a minute difference in the gaps between the test masses—an incredibly difficult task—those two beams of light would normally travel the same distance and would emerge in phase. But if a passing gravitational wave strayed through the device, known as an interferometer, warping space and creating unequal separations in each arm, the two beams would arrive at the detector out of phase. The interference pattern this would create would provide information about the strength, shape, and polarization of the gravitational wave.

It sounds simple in concept, but not in practice. A strong gravitational wave may disturb the separation of the test masses by as little as $10^{-16}$ centimeters—millions of times shorter than an atom's diameter. The effort to capture such waves, both supporters and critics of LIGO agree, will push current technology to its limits—and beyond.

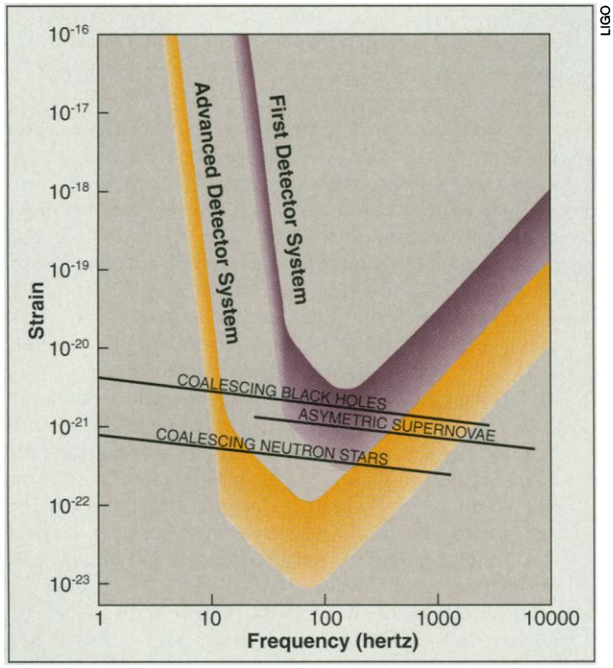
–J.T.

these extremely small signals from seismic, thermal, and photon noise. Although he has called LIGO fascinating and a worthwhile pursuit at some point, Tyson argues for continued small-scale research and technology development before deciding whether to scale up LIGO's 40-meter prototype to two full-scale 4-kilometer facilities.

Even the project's staunchest supporters acknowledge that moving ahead is risky. "According to the best estimates, we probably wouldn't detect these [coalescing neutron stars]" with the initial interferometers, admits Stanley Whitcomb, LIGO deputy director. But there's a chance that the initial facility will do the trick, and it may pick up more powerful speculative sources, say supporters—and if not, the money won't have been wasted. "It's vastly misunderstood that LIGO is a one-shot deal. We're paying up front for a long-term facility," says MIT's Weiss, pointing out that 80% or more of the $250 million will be spent on an expensive vacuum system and other construction costs, not on interferometers, which are cheap in comparison and can be upgraded later. Dramatic gains in sensitivity could be achieved without building a new facility, he notes, by replacing the current interferometers with improved versions.

Nevertheless, Tyson's criticisms of LIGO have struck a chord among others in the astronomical community. "I think it is a very large expenditure for a project that, according to its current specifications, has a small likelihood of detecting astronomical sources," says Princeton theoretical astrophysicist Jeremiah Ostriker. Other astronomers think even an upgraded LIGO might fall short. They question whether the so-called advanced interferometers planned for LIGO's future are a realistic possibility or, as one critic described them, "science fiction." Even some working on LIGO are forced to agree. At the moment, parts of the advanced detectors "are pie in the sky, let's face it," says MIT's Weiss. But Weiss and other LIGO supporters quickly add that they can envision routes—improved lasers, super-reflective mirrors, active suppression of seismic noise—by which their hopes might be met. "For LIGO, there are big risks to get to the advanced detectors, but it's not impossible. Given the scientific payoff, it's worth it," says Stanford physicist Peter Michelson, who has reviewed LIGO for NSF. "It's a difficult judgment call, frankly. You can always say, 'Do more work,'" comments Whitcomb, adding that the LIGO team is continuing an aggressive technology development effort even as it moves ahead with construction.

But with all that uncertainty, say critics of the project, LIGO is a long way from living up to the O—Observatory—in its name. LIGO has never been endorsed by the astronomy community, they point out. It was, for example, conspicuously absent from a priority list of astronomy projects for the 1990s produced by the influential 1991 NRC survey known as the Bahcall report for its senior author, John Bahcall of the Institute for Advanced Study in Princeton.




**Insensitive instruments?** The sensitivity estimates of LIGO's first interferometer, noted by a detector's "strain" measurement, show there is little chance of detecting coalescing neutron stars, although rarer sources provide a better chance. As shading lightens, the detectors approach their theoretical limits.

The simple explanation for that omission has been that LIGO is physics, not astronomy. All of its peer reviews and funding at NSF, for instance, have come out of the agency's physics division. But by selling LIGO to the public and Congress as astronomy, even though the facility may not "see" anything, supporters may have raised expectations and set the stage for the current backlash against the project. "It was not wise to use the O in LIGO," reflects Caltech's Thorne. Whitcomb, however, has no regrets. "We used the word LIGO in a very deliberate sense because it expresses our goals and intentions," he says.

### Political protectors

Despite the growing discontent with LIGO, few expect the project will be drastically slowed down, let alone stopped. "It's a bull in a china shop that we have to deal with. We have no ability to influence it any longer. It's a fait accompli," says University of California, Berkeley, astronomer Marc Davis, who chairs a new NRC panel on astronomy and astrophysics that is meant to provide a followup to the Bahcall report. Such opinions can be traced to the strong perception that LIGO has a favored status among several influential members of Congress, whose states the sites are located in. In particular, Speaker of the House Thomas Foley of Washington and Senate appropriations subcommittee chairman J. Bennett Johnston are seen as the "protectors" of LIGO.

Last year, for instance, the appropriation committees balked at allowing NSF and the LIGO managers to reduce their 1993 construction startup request for the project from $38 million to $20 million, in order to minimize the impact on NSF's small investigators. The committees ordered NSF to spend the full amount on LIGO. A compromise has now been reached, however, Robert Eisenstein, head of NSF's physics division, told *Science* last week. LIGO will indeed be cut down to $20 million this year, plus $5 million for R&D, in the expectation that Congress will appropriate $43 million to $48 million in 1994. Critics of LIGO argue the agreement only delays the pain. "We're going to face the same issues all over again, probably more intensely," warns one astronomer.

Indeed, the bickering over LIGO's budget and timing is likely to intensify. In June, NSF officials will visit Caltech to conduct a technical review of the project and presumably address the concerns put forth by Drever, Tyson, and others. Publicly, the agency remains enthusiastic about LIGO's progress and has refrained from entering the Drever dispute. "Of course, we're concerned about the issue. We treat it as an internal Caltech manner. It is not appropriate for us to be in there micromanaging unless the project is compromised," says Eisenstein. Privately, however, NSF officials admit their patience is wearing thin. Says one, "There's been too much time spent on the Ron Drever situation. NSF may have to stick its nose in soon."

But is there anything NSF could do? Sources close to the project think the disagreements between Vogt and Drever may run too deep for either one to give ground. Comments one Caltech scientist: "I have the impression of two scorpions in a bottle. Only one will end up alive." And that fight-to-the-finish may strike a blow to what is an exciting but already a risky and technically daunting project. The question then will be whether the LIGO project, absent contributions from Drever, can be successful. More than $250 million and the careers of a number of prominent scientists may ride on the answer to that question.

**–John Travis**