meeting of fusion scientists in Snowmass, Colorado, a consensus emerged that a strategy to boost burning plasma science should be developed; that task was done at an August meeting in Austin, Texas.

The burning plasma panel report to FESAC contains a series of "strategy recommendations":

▶ "Since ITER is at an advanced stage, has the most comprehensive science and technology program, and is supported internationally, we should now seek to join the ITER negotiations with the aim of becoming a partner. . . ." Becoming a full partner, the report says, will likely require funding of approximately $100 million per year.

▶ "Since FIRE is at an advanced preconceptual design stage, and offers a broad scientific program, we should proceed to a physics validation review . . . and be prepared to initiate a conceptual design."

▶ "If ITER negotiations succeed and the project moves forward . . . then the US should participate. The FIRE activity should then be terminated."

▶ "If ITER does not move forward, the FIRE should be advanced as a US-based burning plasma experiment."

Although ITER and FIRE were the primary focus of the report, a smaller project proposed in Italy, called IGNITOR, was also considered by panel members. They concluded that if IGNITOR is built, the US should collaborate primarily through research participation.

The current DOE efforts are focusing on burning plasma because of the time pressure involved in rejoining ITER, but agency officials said the multibillion dollar National Ignition Facility will take care of inertial confinement fusion; NIF is at Lawrence Livermore National Laboratory in California. Intended primarily as a way to maintain the US nuclear weapons stockpile, NIF will be "many times larger than any previous inertial confinement device," a recent DOE report noted. DOE supports several other inertial confinement fusion labs.

Orbach said the FESAC and NRC burning plasma reports will be central to a decision by President Bush on whether to rejoin ITER negotiations. Supporters of the program are aware that the budget is tight and it will be difficult to get $100 million per year to support US involvement in ITER. The project's estimated cost in 1998, nearly $10 billion, was a key reason the US withdrew. ITER has been scaled back to an estimated $5 billion, the amount on which the $100 million US contribution is based.

In addition to the federal budget being very tight, policymakers are highly skeptical about the promise of fusion. Having heard promises for the past 20 or 30 years that fusion was just 20 or 30 years away, FESAC and Orbach must persuade the administration and Congress that the science really has progressed.

"The skepticism is very real," said Anne Davies, director of the DOE's Office of Fusion Energy Sciences. The science has made enormous strides in the past 10 years, she said, "and I think we're absolutely ready to build a burning plasma experiment." But she noted that the cynics are still saying "we've heard that before."

Orbach is also concerned about the skeptics. "But we've never had a united [fusion] community before," he said. "Congress will listen . . . if we are united and give them a detailed timeline."

Jim Dawson

MARVEL COMICS

Teaching Physics with Superheroes

How did Superman get to be so strong? What killed Spider-Man's girlfriend Gwen Stacy? How fast can the Flash run? Jim Kakalios, a condensed matter experimentalist and comics buff, analyzes questions like these from action comics to teach physics in a freshman seminar at the University of Minnesota–Twin Cities.

"Take Superman," says Kakalios. "What does it take to leap a tall building in a single bound?" To find out, Kakalios's students use Newton's laws of motion. "We calculate how much force is required," says Kakalios. That leads to the question, How did his legs get so strong? "Back in the 1930s," Kakalios says, "it was presumed that Superman was so strong because he was acclimated to Krypton's gravity." In the class, the gravitational force of Krypton—Superman's home planet—is calculated to be about 15 times that of Earth's. "We talk about Newton's law of gravity, and then we talk about how you would build such a planet, and not make it a gas giant. I bring in things from different parts of the physics curriculum, and show how interconnected everything is," says Kakalios. "It turns out that the only way we could figure out how to make such a planet, it would be very unstable—it would explode." It's an amusing twist, he adds, "that this is completely consistent with the comics."

Another example is the controversy over the death of Gwen Stacy, who was knocked off a bridge tower. Spider-Man may have been surprised to find her dead when he caught her in his web, but Kakalios's students weren't: By estimating the height of the bridge, Gwen's mass, and the time Spider-Man had to catch her, and then using conservation of momentum, says Kakalios, "it turns out the force has to be at least 10 Gs. If she experienced such a sudden jerk, it's not unreasonable that she would have broken her neck."

The Bernoulli principle, time travel, and the biological and physical feasibility and implications of shrinking to the size of an atom or growing into a giant are among the topics Kakalios's class tackles through comics. The comics don't get the science right all the time, says Kakalios,


TOM FOLEY

KAKALIOS

"but I am struck by how often they do." Over the years, he says, comics have kept up with the times: In the 1940s, a lot of superheroes gained their powers through some mystical artifact from the Far East; in the 1960s, they got them through radioactivity; and, since the 1990s, they get them through genetic engineering. A few years ago, adds Kakalios, results on entangled quantum states found their way into a comic book just months after they were published in *Physical Review Letters*.

"Interestingly," says Kakalios, "when I talk about comic-book examples, no one asks how they'll use it in real life. They never expected comics to be accurate. Once you show them it's relevant, and develop the physics, I put in real-world applications." For example, he continues, "once we've talked about the Spider-Man story line, and shown that it's conservation of momentum [that delivers the impact that kills Gwen], I bring in airbags. They increase the time to slow your head down. The force to your head can still knock you out, but it doesn't kill you."

It's a sneaky class, says Kakalios. "Basically, the course is really 'physics in the everyday world.' [Students] are so busy eating their superhero ice cream sundaes, they don't notice that I am feeding them their spinach."

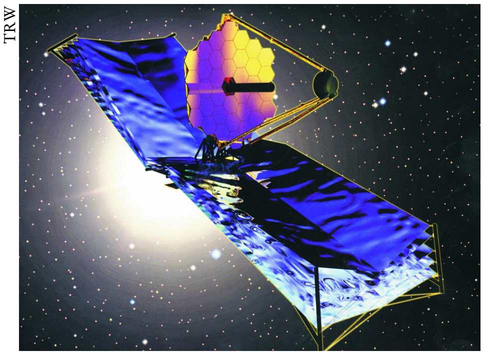
TONI FEDER

Hubble Successor Takes Shape

NASA, in signing a contract last month with TRW Inc to build the next-generation space telescope, has taken a big step toward peering at objects that are around 400 times fainter than are visible with current ground- or space-based telescopes. The move means that, after months of "blackout" associated with the NASA selection process, research groups can start working with the engineers on integrating the science instruments into the spacecraft, says Peter Jakobsen of the European Space Agency, a partner in the new observatory. The telescope has been named the James Webb Space Telescope, after NASA's second administrator, who served in the 1960s.

The JWST design calls for at least six times the light-collecting area of the 2.4-meter Hubble Space Telescope (HST) but the same 0.1-arcsecond resolution. "The original requirements were chosen to complement the capabilities of other telescopes, both existing and planned," says John Mather, JWST project scientist at NASA's Goddard Space Flight Center in Greenbelt, Maryland. In September, a JWST science working group was formed to construct a research program for the telescope. "New discoveries over the last few years do call for some updates to the proposed observing plan," says Mather. The JWST will mainly study the early universe, giant extrasolar planets, supernovae, and supermassive black holes.

The competition for the $824.8 million contract came down to TRW and Lockheed Martin Corp, and industry observers were not surprised by the outcome. The contract, which NASA and TRW signed on 11 October, is for the design and construction of the observatory's 6-meter primary mirror and spacecraft chassis. The JWST design has a primary mirror consisting of 36 semirigid hexagonal segments, similar to those used by the ground-based Keck telescopes, that will unfurl from the spacecraft once it reaches orbit. "I'm anxious to begin moving ahead on JWST," says Marcia Rieke, a working group member from Steward Observatory in Tucson, Arizona. "I'm glad that a contractor has been finally selected." TRW is responsible for integrating the module containing the three science instruments from the US and international partners—a near-infrared camera, a multiobject spectrometer, a mid-infrared camera and spectrometer—and the guider into the spacecraft, and for performing preflight testing and an in-orbit checkout of the observatory. The JWST, which, unlike the HST, is not designed to be serviced by astronauts, is scheduled to be launched in 2010. It will be positioned 1.5 million kilometers beyond Earth's orbit at the second Lagrange Point (L2), where the gravity of the Sun and Earth cancel each other out. The L2 location will allow the JWST to be easily cooled to 30–50 K, as a single Sun shield can block light and heat from both the Sun and Earth. This will simplify the design of the spacecraft, which is expected to last 5–10 years.


TRW

AN ARTIST'S RENDERING of the James Webb Space Telescope.

The JWST is the first NASA observatory not named after a scientist or astronomer. "It is fitting that Hubble's successor be named in honor of James Webb," says current NASA Administrator Sean O'Keefe, who chose the name. "Indeed, [Webb] laid the foundations at NASA for one of the most successful periods of astronomical discovery." Astronomers seem more resigned to the name change. "As a scientist, I would have preferred the telescope to be named after a very prominent scientist, but clearly Webb had major accomplishments," says Mario Livio, head of the science division at the Space Telescope Science Institute in Baltimore, Maryland. "It is a change from tradition," says working group member Simon Lilly of ETH Zürich in Switzerland. "But I have no particular problem with it myself. Europeans and Canadians may find it less easy to identify with a NASA administrator than with a prominent scientist, but in the end, it is a case of 'he who pays the piper calls the tune.' "

PAUL GUINNESSY

News Notes

Stockpile stewardship grants. The National Nuclear Security Administration (NNSA), a semiautonomous agency within the Department of Energy, is awarding $27.5 million in grants to universities and colleges to conduct research related to stockpile stewardship or to maintenance of the US nuclear weapons inventory. Everet Beckner, the agency's deputy administrator for defense programs, said the grants are part of the NNSA's stewardship science academic alliances program and contribute to "the science which underpins the NNSA stewardship of the nuclear weapons stockpile. These grants are also a key means of training the scientists needed to maintain the outstanding capabilities of our national laboratories."

The grants will fund such projects