an attempt to compensate for poor or nonexistent advanced labs.

As the US population ages, an increasing share of federal revenue will go for Social Security and health care benefits. Less money will be available for discretionary federal spending, such as for student lab equipment, so petitioning NSF for funds is not promising. Physics teachers should be petitioning their own universities to make some tuition money available for that purpose.

The typical department budget for lab equipment and supplies is approximately $1000, according to the report. If the college charges $30 000 annual tuition, why not use $1000 of that to upgrade lab equipment? If 20 students took the lab each year, that lab would receive $20 000, which should be enough to pay for one new or refurbished experiment set-up. If we assume student pairs rotated through 10 experiments and that each required only one apparatus set, after 10 years all experiments would be upgraded or refurbished!

The article reports complaints about century-old lab experiments. Yet there is nothing wrong with letting students perform a few classic experiments such as the Millikan oil drop, the Michelson interferometer, or the Franck–Hertz tube. Recent PHYSICS TODAY pieces (July 2016, pages 8 and 38; March 2017, page 11) have suggested that students should learn the history of physics. Doing classic experiments allows students to experience using simpler equipment and getting meaningful results without using computerized black boxes. I never appreciated how hard it is to measure the universal constant of gravitation G until I used a Cavendish balance.

Feder reports that new professors are reluctant to get involved with maintaining student lab equipment because such activity does not contribute to obtaining tenure. Perhaps we need a reform of the tenure process so that ratings include those activities that directly help undergraduate students. For their tuition dollars, students should be getting good laboratory training.

In a separate editorial (PHYSICS TODAY, June 2016, page 8), Charles Day commented that the student labs he took did not inspire him to become an experimental physicist. I think his complaint is invalid. Student labs are not recruiting events for the field but training sessions that should

- Teach some laboratory techniques and practices.
- Give experience in analyzing real-world data whose error distribution does not follow a Gaussian distribution.
- Observe physics phenomena firsthand.
- Verify firsthand that some textbook theory is borne out by experiment.
- Allow one to learn some physics topics not covered in other courses.

As demonstrated by the effort required to become proficient at playing a musical instrument, learning a craft is hard work, and not all of it is inspiring.

Victor J. Slabinski
(victor.slabinski@fairlington.net)
Arlington, Virginia

[Editors' note: Some of the issues Victor Slabinski mentions are also discussed in the feature article "Introductory physics labs: We can do better" by Natasha Holmes and Carl Wieman on page 38 of this issue.]

Funding concerns for big telescopes

The news story "Fates of two big radio dishes hang in the balance" (PHYSICS TODAY, February 2017, page 26) toes the official line of the NSF astronomical sciences division (AST) with regard to the Arecibo Observatory and the Robert C. Byrd Green Bank Telescope. It implies that the AST conducted a complete and reasonable evaluation of its commitment to these observatories. I do not agree.

On 27 April the AST published a letter, "MPS-AST Facility Divestment Activity," that provided "a top-level summary of the current status of NSF actions regarding facility divestment recommendations made in 2012." The story mentions the recommendations, commonly called the 2012 portfolio review. One recommendation is that "AST should reevaluate its participation in Arecibo . . . later in the decade in light of the science opportunities and budget forecasts at that time." A follow-up assessment in 2016 considered the budget but not the science, and included serious errors and omissions. Arecibo and Green Bank science is unique and cutting edge, with significant discoveries and developments since the 2012 review.

As one example, the North American Nanohertz Observatory for Gravitational Waves (NANOGrav), which uses both Arecibo and Green Bank, is precisely in line with the national priority of multimessenger astrophysics—the combined use of photons, cosmic rays, neutrinos, and gravitational waves—outlined by NSF director France Córdova in her May 2016 speech to the National Science Board. NANOGrav is our nation's second gravitational-wave observatory, sensitive to a different frequency range and far cheaper — the combined total annual operating costs for Arecibo and Green Bank are less than for LIGO, about $24 million versus $30 million, and without the $1.5 billion price tag for LIGO development, construction, and support, as Cordóva reported to Congress on 7 June.

The Arecibo and Green Bank contribution to gravitational-wave astrophysics was touched on in "Pulsar timing arrays are poised to reveal gravitational waves" (PHYSICS TODAY, July 2017, page 26), which quotes Xavier Siemens of NANOGrav as saying, "We want to buy all the available time at Arecibo and Green Bank. . . . It would save both telescopes." Córdova discussed building additional detectors "to observe other parts of the frequency spectrum," but did not mention that such a detector already exists in the US and is in jeopardy of losing necessary NSF-sponsored facilities.

I wondered whether NSF is interested in providing that funding. My emails to the NSF physics division on that subject received a reply from the program director for gravitational physics suggesting that I contact the AST.

NANOGrav has not yet made a detection, but since sensitivity improves with the time spanned by the measurements, that day is rapidly approaching. When the LIGO detection was announced, several other nations quickly funded gravitational-wave detectors. Why is NSF fighting to close one of the two US gravitational-wave observatories?

NSF loudly promotes beneficial broader impacts to society as underlying its funding decisions. Observatories on foreign soil cannot compete with one in the US for broader impacts on American citizens. Both Arecibo and Green Bank are in areas where their broader impacts on local communities are especially important, and both provide significant broader international impacts.

The February PHYSICS TODAY article states that the environmental impact statements (EIS's) that NSF must submit "look at social and economic factors in addition to financial and environmental ones." However, an EIS does not replace consideration by NSF of intellectual merit within and across fields of science and broader impacts locally, nationally, and internationally.

AST appears to be basing its course of action not on merits of the science or benefits to society but on other considerations, such as the personal preferences of managers and the desire to deflect attention from past mistakes. Thus the process changes from evaluation of scientific and societal merits to a political fight.

The science and broader impacts are clear. AST has ignored them and has damaged its own interests and those of other fields of science served by the observatories.

On 20 September Hurricane Maria hit Puerto Rico, and Arecibo incurred damage. But Maria is not the first hurricane the observatory has endured, and the storm's results show that with competent management Arecibo, now 54 years old, can continue producing world-class science.

On 15 November NSF issued a decision on the way forward for the Arecibo Observatory. AST will not close Arecibo but will ramp down its current support from $8 million to $2 million per year over the next five years. NASA supports the Arecibo planetary radar program and has contributed $4 million of the total $12 million for the past several years. However, NSF and Arecibo managers rejected an offer from Breakthrough Listen, an international project searching for extraterrestrial life, to contribute to Arecibo and also missed an opportunity for NANOGrav to contribute.

In addition, NASA has not considered increasing its participation and will pay only incremental operating costs, excluding maintenance, security, and other base costs. These decisions add risk for the future of Arecibo.

Such past fumbling is not promising. However, a new managing organization for Arecibo may be in place as soon as April 2018, and we can hope that the new management will make better decisions than current management.

With some creativity and desire, NSF managers can contribute to a solution that meets the need of AST and preserves the unique scientific capabilities and services that Arecibo and Green Bank provide. Otherwise, the decision to ramp down current NSF support will likely ramp up the political fight.

Brett Isham
(bisham@bayamon.inter.edu)
Interamerican University of Puerto Rico
Bayamón

Tales of the Soviet hydrogen bomb

I was one of a very few non-Russian and non-US participants at the fascinating History of the Soviet Atomic Project conference held in May 1996 at the Joint Institute for Nuclear Research in Dubna, north of Moscow. The article "The secret of the Soviet hydrogen bomb" by Alex Wellerstein and Edward Geist (PHYSICS TODAY, April 2017, page 40) brings up many memories from that meeting.

After arriving home from the conference, I wrote an article about it for my institute's magazine. I think a few details and reflections from that article are worth adding to the international record. They mainly derive from my discussions with Arnold Kramish, a Manhattan Project veteran whom I got to know well during the Dubna meeting and through letters exchanged in the years before his death.

After the war Kramish had worked for the US Atomic Energy Commission as a liaison to the Central Intelligence Agency; he provided intelligence estimates on Soviet nuclear capabilities. Shortly before the Teller–Ulam idea was born in early 1951, he had passed on to Stanislaw Ulam intelligence material about Soviet experiments in which extremely strong magnetic fields had been used to compress fusion materials. That information had come from repatriated Austrian physicist Josef Schintlmeister, who, as a victim of the Soviet Alsos operation, was forced to work on the Soviet atomic bomb project and then got insight into work by Peter Kapitza and Andrei Sakharov. Kramish strongly believed that the information Schintlmeister had gathered was the seed of Ulam's idea of arranging extreme compression of thermonuclear fuel by a physically distinct primary fission charge. Add to that Edward Teller's idea to employ radiation implosion and the now classical hydrogen bomb was conceived.

However, as mentioned in the Wellerstein and Geist article, the concept of radiation implosion stems from a patent filed by Klaus Fuchs and John von Neumann at Los Alamos in May 1946. Fuchs then, like all other British participants in the Manhattan Project, had to go back to the UK in June 1946.

Did Fuchs provide the radiation implosion idea to the Soviets? Yes he did, according to former Soviet intelligence chief Vladimir Barkovsky, who spoke at the Dubna meeting. He had collected the documents from Fuchs in London on 13 March 1948; during his talk Barkovsky even showed sketches of the patent. In conversation during the conference banquet, he also said that he thought Fuchs, back in Washington, DC, in 1947 or 1948 for a meeting about UK and US cooperation on nuclear weapons, had gotten new material from an unknown messenger.

It is ironic that the development of the H-bomb actually proceeded in a kind of behind-the-scenes *de facto* cooperation between the two nuclear powers at the time, the US and the Soviet Union. While both nations were struggling to develop thermonuclear weapons, they didn't realize that the three most important components—compression, staging, and radiation implosion—were already available to be put together. The breakthrough was delayed in the US by Teller's long inability to give up his belief in his baby, the Classical Super; and in the Soviet Union, by Sakharov's preoccupation with his baby at the time, the *Sloika*.

A final note on the inflamed relationship between Stan Ulam and Teller: Kramish told me that right after the new H-bomb idea had been conceived, Teller called for a meeting to discuss it. He asked Kramish to take part, and then, after a short pause, Teller added, "Don't tell Stan!"

Lars-Erik De Geer
(ledg1945@gmail.com)
Stockholm, Sweden