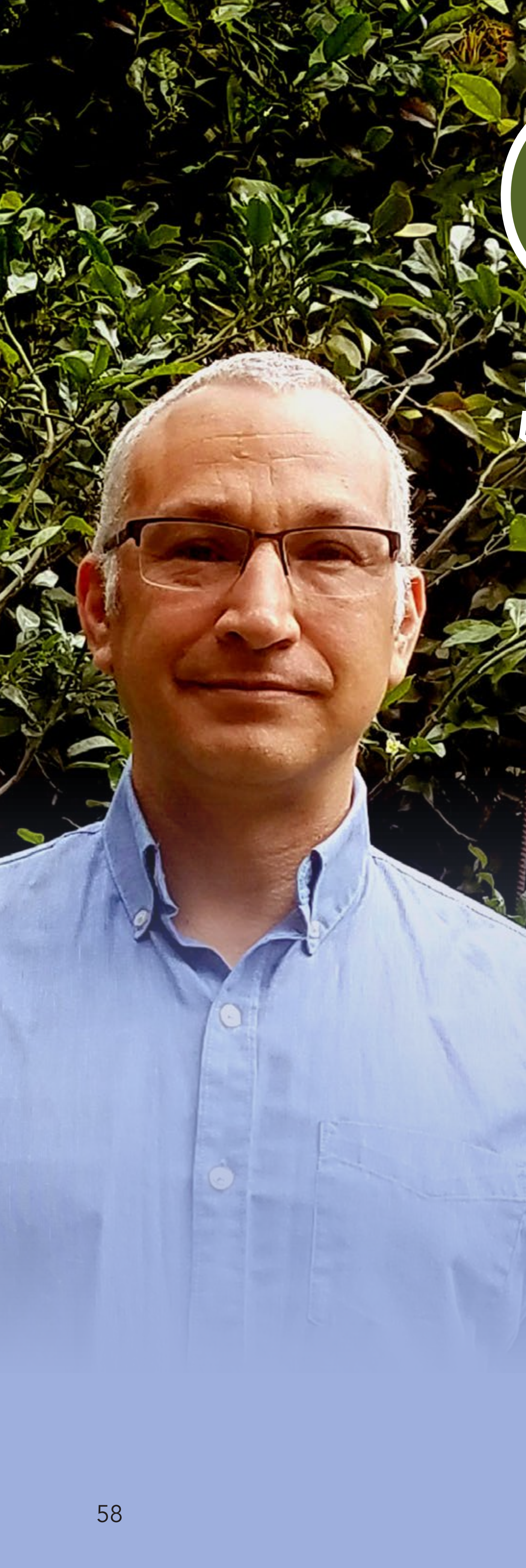


OMAR

Scientific proof

In 2012, Omar Hurricane, a distinguished member of the technical staff at Lawrence Livermore National Laboratory, was asked by the laboratory director to lead a team to delve into studying the physics and engineering obstacles preventing fusion ignition at the National Ignition Facility (NIF). The team's efforts led to a new exploratory "basecamp" strategy and the creation of several pivotal experiments that revealed some of the underlying problems with the ignition point design, while also delivering improved fusion performance and the first evidence of significant alpha particle self-heating.

Hurricane was appointed chief scientist of the Inertial Confinement Fusion Program in 2014, a position he has held ever since. He was named a Fellow of the American Physical Society's Division of Plasma Physics in 2016 and was recently awarded the Edward Teller Medal from the American Nuclear Society for his work on inertial confinement fusion physics.

At the NIF, laser beams create nuclear fusion by generating the same kinds of temperatures and pressures that exist in the cores of stars and giant planets and inside nuclear weapons.

The NIF is the world's most precise and reproducible laser system. It guides, amplifies, reflects, and focuses 192 powerful laser beams on a target about the size of a pencil eraser in a few billionths of a second, delivering more than 2 million joules of ultraviolet energy and 500 trillion watts of peak power.

Hurricane: of principle at the NIF

The NIF generates temperatures of more than 180 million degrees Fahrenheit and pressures of more than 100 billion Earth atmospheres. Those extreme conditions cause hydrogen atoms in the target to fuse and release energy in a controlled thermonuclear reaction.

The NIF, which is the size of three football fields, is used for specific missions, including weapons stockpile stewardship, high-energy-density science, energy security, and building future generations of scientists. In addition, other types of applications are being researched, including advanced lasers and photonics, additive manufacturing, and missile defense.

Hurricane answered questions from ANS Publications Department director John Fabian about the NIF and its work.

How is inertial confinement different from magnetic confinement?

Inertial confinement utilizes a rapid implosion to heat and compress the fusion fuel, much like a piston compressing and heating a gas, and it's literally the inertial mass of the implosion that momentarily holds the fusion plasma together when the plasma reaches its peak temperature and pressure. Magnetic confinement fusion uses magnetic fields to confine the fusion plasma in a quasi-steady state while external heating, like radio-frequency heating, is used to bring the plasma to fusion conditions.

The plasma conditions of the two systems are also very different. Characteristic pressures and timescales of inertial confinement fusion are many hundreds of billions of atmospheres of pressure held over very short timescales of about 0.1 billionths of a second. Magnetic fusion plasma pressures are more like a few atmospheres of pressure held for many tens of seconds.

Most of the current fusion designs being pursued make use of magnetic confinement. Why is LLNL pursuing inertial confinement?

Historically, LLNL has pursued both magnetic fusion and inertial fusion, and we still have a magnetic fusion program today. However, it's certainly true that these days, and over the past several decades, LLNL has emphasized inertial fusion. This is largely because of the national security applications of inertial fusion, and most of our funding stream comes from the National Nuclear Security Agency.

Are there applications of inertial confinement other than fusion power?

Yes. National security applications are a primary use. In addition, any basic research that is focused on plasmas or materials at extreme conditions of pressure, temperature, and high neutron fluxes are uses for inertial fusion.

Continued

LLNL announced that the yield from an August 2021 experiment of more than 1.3 megajoules was eight times more than the yield from experiments conducted in the spring of 2021 and 25 times more than the NIF's 2018 record yield. What was significant about the latest results from the NIF experiments?

The primary significance is reaching the tipping point of thermodynamic instability in the fusion plasma, where the alpha heating power very much dominates over all physics processes that cool the plasma off. This means that ignition in the laboratory is real and obtainable. Moreover, the experiment appears to confirm that much of our theoretical understanding of what is required for ignition is correct.

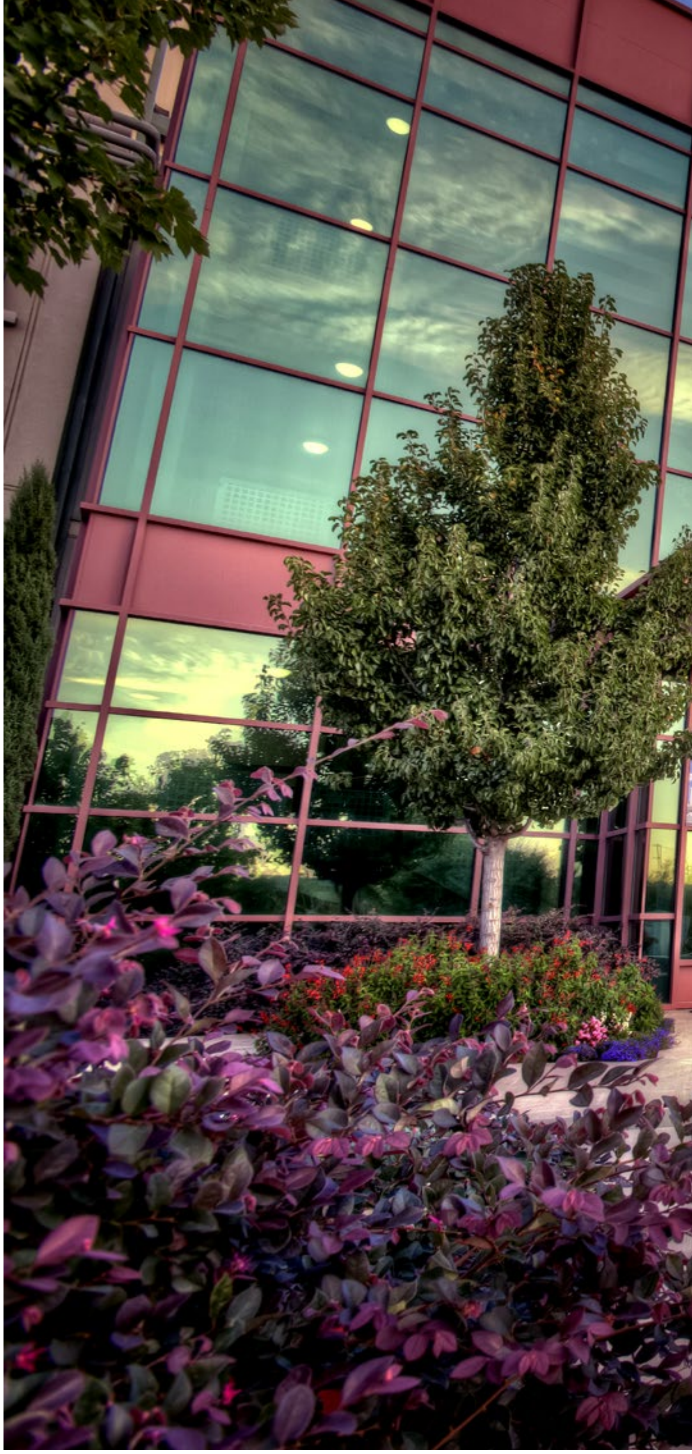
When will the results from the August 2021 experiment be published?

We are preparing the publication presently. Just guesstimating, I would expect the paper to be published sometime in the winter of 2022.

What work is planned for this year and the next five years at the NIF?

We have a great variety of work planned. Repeat experiments, work on increasing the robustness of the August result, work toward increasing the fusion performance of the August result by building on what we've learned and developing a better understanding of the new physics regime we've accessed.

In addition, inertial fusion is only about one-third of the work done with the NIF, and so several national security and basic high-energy-density experiments will also be pursued in parallel.

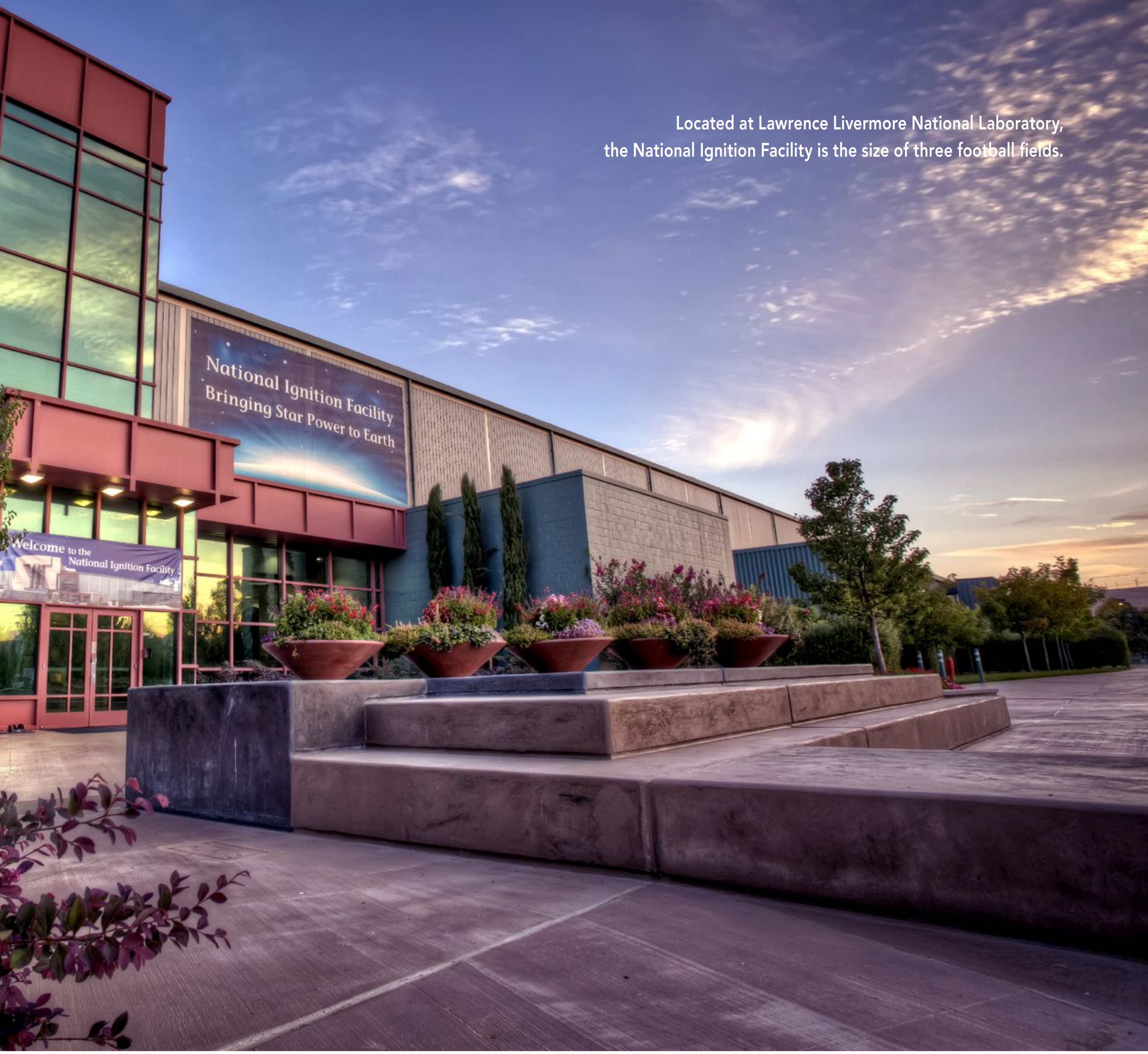


Are data and experience gained at NIF helping any private fusion energy companies?

In an indirect sense, perhaps, but I'm not aware of any formalized direct connections except for our long-standing collaboration with General Atomics in La Jolla, Calif. Of course, we publish a great deal of our work in the open literature, so anyone can read our publications and learn from our results if they choose to do so.

Is LLNL planning to increase its focus on fusion energy? What will be the split between fusion energy research and weapons/stewardship testing?

Presently, our primary funding stream is for stewardship and testing with the capability we've developed. However, many of us working in this area do have some level of interest in fusion energy, which is what attracted us to the field in the first place.



Located at Lawrence Livermore National Laboratory, the National Ignition Facility is the size of three football fields.

Who are some of your coworkers who have advanced work at the NIF?

My close collaborators have included Annie Kritcher, who was the lead designer for the August experiment, and Alex Zylstra, who was the lead experimentalist. Debbie Callahan is our senior hohlraum expert, and she and I devised the strategy and the theory guidance that Annie and Alex used. Of course, a veritable army of people are needed to carry out the work on the NIF spanning the areas of engineering, diagnostics, lasers, cryogenics, and operations.

How close are we to having an operating fusion reactor?

I can answer by saying that while we are very proud of the recent hard-won success, I'd like to emphasize that the result is primarily a scientific proof of principle. That is, the scheme we have working is very far from anything that makes sense for actual fusion energy production.