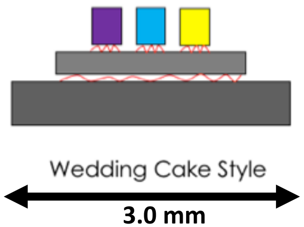
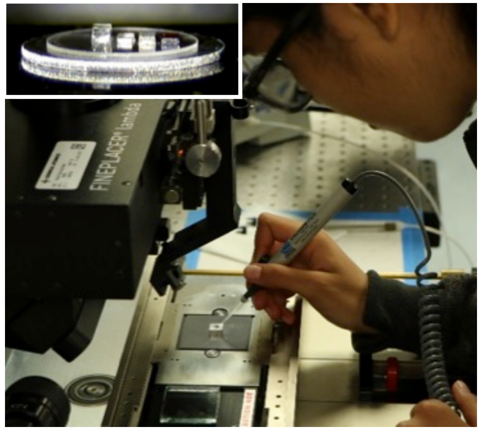
General Atomics/DIII-D
SULI Participation Highlights
Summer 2018

Work supported by U.S. DOE under DE-FC02-04ER54698.

Achieving Thin Bond Lines in High-Energy-Density Science Experimental Targets
SULI participant at General Atomics





Pegah Bagheri, a sophomore Mechanical Engineering student at UC–Riverside studied thinner, consistent glue bond thickness in support of EOS material science. A highlight of the summer was discussing her project with DOE Secretary Perry. Pegah plans to continue her studies at UC–San Diego.

- Bond line thickness is a critical attribute in physics packages to reduce error in equation of state (EOS) material science experiments conducted at the DOE's NIF, Z and OMEGA facilities. Pegah Bagheri investigated mechanical assembly techniques, to achieve sub 3 µm glue bonds between planar components. She conducted 40+ experiments to test her hypotheses, and achieved multiple examples of sub 1.5 µm glue bond lines.
- Pegah learned multiple precision assembly and characterization systems, and her research explored glue viscosity, dispensing volume, assembly force and custom tooling parameters. She quantified component attributes and correlated those attributes to bond thickness, uniformity and consistency.
- Four key recommendations resulted from Pegah's research and have been incorporated into GA's best practice techniques:
  - Wedding cake assembly is preferred (design)
  - Dispense smaller volume of glue (process)
  - Use lower viscosity glue (process)
  - Increase assembly bonding force (process)

Impact of Pedestal Parameters on a Controlled H-L Back Transition in DIII-D Plasmas
SULI participant at DIII-D/General Atomics

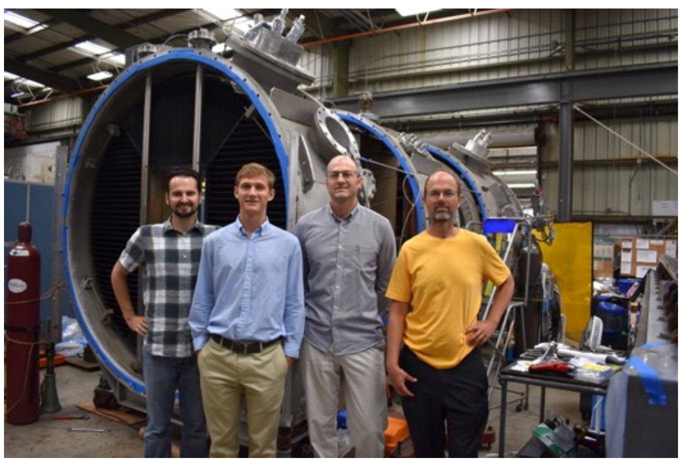
Top: Cody Moynihan attends the 2018 BOUT++ workshop at LLNL. *Bottom*: Cody with other SULI students celebrating their accomplishments at La Jolla shores.

- High confinement mode plasmas are the target regime for future reactors, and occur after a bifurcation from a low confinement state
- Understanding the transitions from high to low confinement modes of operation are important for ITER and future reactors to avoid releasing excessive stored energy onto plasma facing components
- Experiments have shown that plasma resistivity and rotation can affect the ferocity of energy release during the H-L back transition
- Cody Moynihan, a rising senior at the University of Illinois, scanned resistivity and rotation parameters using the BOUT++ code running simulations on NERSC, and successfully characterized the primary edge instability at the H-L back transition
- Cody collaborated with the team at LLNL throughout the summer and presented his research to an international community at the end of the appointment, and will be presenting a poster on the research at the APS-DPP meeting in Portland, OR in November 2018.

Cody says: "**I thoroughly enjoyed the opportunity to work with scientists having a wide array of scientific knowledge that were all very willing to help grow the next generation of researchers. Coming from an experimental background, it was great to see the way that experimental and computational scientists work together towards a common goal.**"

Finding Hot Spots to Improve Fusion Performance

SULI participant at DIII-D/General Atomics

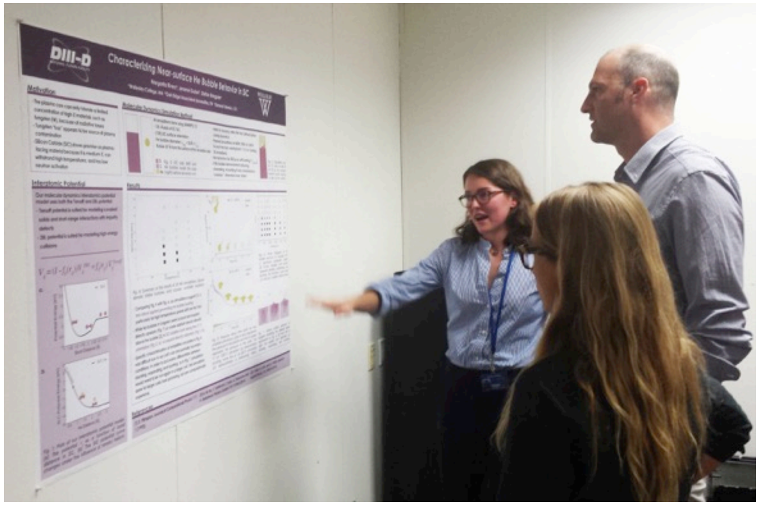


Top: Tyler Carbin stands atop DIII-D prior to (below) posing with his mentor team of (L-R) David Pace, Mark Kostuk, and Igor Sfiligoi.

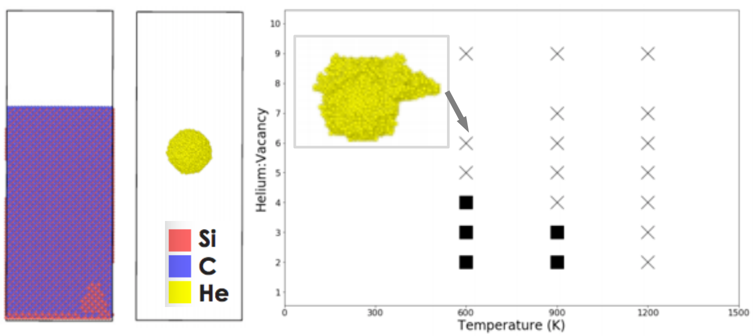
- The DIII-D tokamak uses 20 MW of particle beam power, from eight distinct beams, to both heat and drive current in its fusion plasmas. Sometimes, a portion of this power hits the outer wall and produces carbon impurities that reduce fusion performance.
- Tyler Carbin's (U. Maryland) 2018 SULI experience focused on using an advanced GPU/CPU hybrid code that calculates the full trajectories of millions of particles injected by the beams. Tyler studied past experiments featuring unique cases of significant wall heating from this beam power. He demonstrated that a single beam is responsible. Furthermore, he identified possible paths to avoiding this scenario by making small changes to plasma shape.
- Tyler's work will be presented as a poster at the 2018 American Physical Society's Division of Plasma Physics conference in Portland, Oregon.
- **"I was excited to work on a project that used advanced computing, but was directly related to something physically realistic,"** notes Tyler, **"It's amazing how we can simulate these particles and then improve how we run the tokamak."**

Establishing He Bubble Stability and Dynamics in Silicon Carbide

SULI participant at DIII-D/General Atomics



Maggie Rivers describing her research to members of the DIII-D team.



Atomic model of silicon carbide with a nanometer sized He bubble (left). The plot to the right shows stable (squares) and unstable(crosses) bubbles as a function off temperature based on the ratio of helium to vacancies. The inset is an example highlighting the features of a bursting bubble.

- Silicon Carbide shows promise as a low-Z fusion material due to its excellent thermomechanical properties and low activation. One of the most troubling concerns is the potential accumulation and bursting of helium and H/D/T bubbles that results from ion deposition and material transmutation. This can lead to premature failure of material components.
- Atomistic modeling can be used to understand the stability of near surface nanometer bubbles and characterize the dynamics of bursting.
- Maggie Rivers, an exceptional senior studying physics and mathematics at Wellesley College, explored the stability of He bubbles in silicon carbide using molecular dynamics (MD) simulations. She first learned how to setup and describe an atomistic system and run simulations using the LAMMPS MD package. In addition, she validated a newly developed interatomic potential necessary for accurately describing interactions between SiC and He. The results of her work show that nanosized He bubbles within SiC are stable only within a significantly narrow temperature and He-to-vacancy-ratio region. In contrast, tungsten can tolerate He bubbles at temperatures up to 2500 K, although still at low He/vacancy ratios.

Imaging the Magnetic Field Pitch Angle on DIII-D

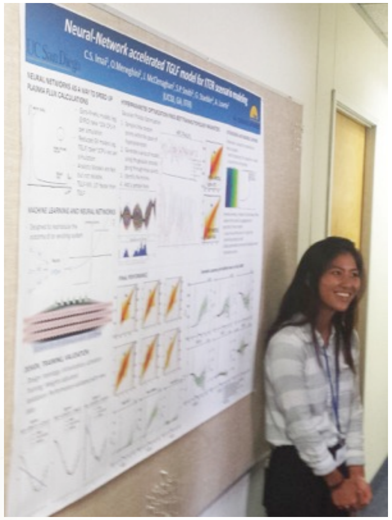
SULI participant at DIII-D/General Atomics

- Stephen Kasdorf, a rising senior studying applied physics and electrical engineering at Colorado State university, showed how elliptically polarized light created a systematic error in the measurement of the magnetic field pitch angle on DIII-D.
- Stephen worked with Brian Victor (LLNL) on an imaging motional Stark effect diagnostic based on a design by John Howard from Australia National University. This diagnostic images neutral beam emission to measure the magnetic field pitch angle in the plasma.
- Based upon Stephen's work new optical components will be tested to minimize the deleterious effects of elliptically polarized light on the measurement.
- Stephen's poster won best poster at the DIII-D SULI poster session held at the end of the summer.

Says Stephen, 'My experience at General Atomics helped to solidify the fact that I want to work in fusion energy for my career. I got to develop skills in data analysis and presenting scientific data that will help me no matter where I end up.'

Applying Machine Learning to Predict Tokamak Behavior

SULI participant at DIII-D/General Atomics



Above, Sarah Imai presents her poster at the end of her summer at GA (above). She also traveled to Portland, OR in November and presented her work at the APS DPP meeting.

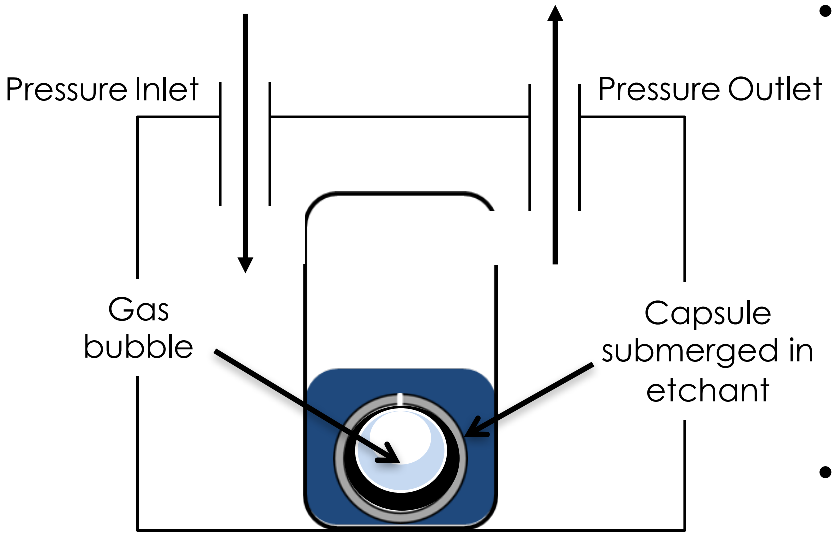
At left, Sarah learned about plasma physics as the computer code she worked on 'learned' to optimize its results.

Chieko Sarah Imai (University of California San Diego), a rising junior studying cognitive science with an emphasis on machine learning, got an opportunity to apply her studies to a new topic and get her first introduction to the field of plasma physics through a project to optimize a computer program that characterizes fusion plasmas called TGLF-NN.

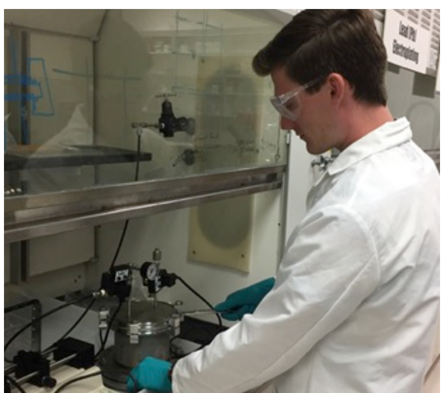
TGLF is a code developed at GA that calculates the energy flux within the magnetized plasma, and the TGLF-NN is the neural network that learns to emulate the outputs of TGLF.
Under the direction of GA scientist Orso Meneghini, Sarah explored hyper-parameter optimization of the neural network training, as well as exploring the dataset using auto-encoders. Finally, ensemble learning was used to produce the best performing model of TGLF-NN.

Fluid Transfer Through Micron Scale Holes

SULI participant at General Atomics



Schematic of pressure cycling system - Pumping action generated by cycling chamber pressure resulting in expansion and collapse of gas bubble



Spencer Glenn a graduate of the College of Idaho (B.S. in Mathematics & Physics) studied fluid transfer in micron scale holes

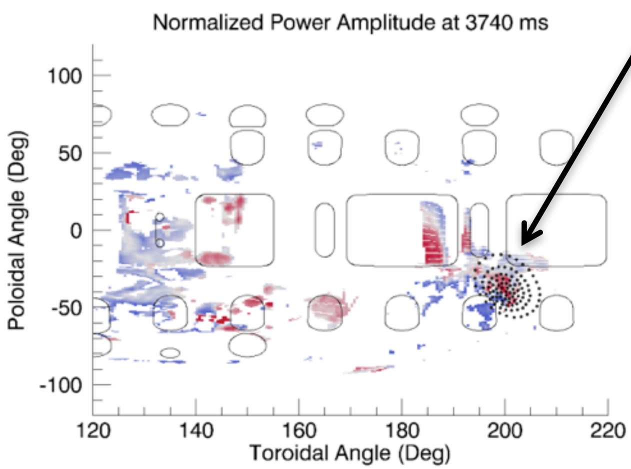
- In the fabrication of targets for inertial fusion experiments, removal of silicon mandrels from the interior of diamond capsules is rate limited by the introduction of etchant to the silicon and subsequent removal of the chemical waste products from the local region. As hole diameters get smaller the timescale becomes prohibitively long.
- Spencer Glenn, recently graduated from the College of Idaho, studied fluid transfer through 2, 5, and 10 micron diameter holes to identify the timescales required to exchange the liquid contents.
- Spencer learned about UltraViolet-Visible spectrophotometry and executed a series of experiments to track the rate of dye solution transfer through holes by monitoring the UV-Vis response curve. He fitted diffusion models to his data and extrapolated it to time of completion.

Tracking a Microwave Beam Into (and Out of) a Tokamak Plasma

SULI participant at DIII-D/General Atomics

Left, Jon Pizzo examines one of DIII-D's gyrotrons, which generate the microwave power used in the experiments Jon analyzed.

Below, a comparison of the predicted energy deposition location on the wall of the tokamak (black dots) and the measured wall heating, with red signifying the maximum heating. Agreement is very good, indicating that the model is valid.



- DIII-D uses the absorption of a beam of microwaves to heat the plasma to fusion-relevant temperatures, which is called Electron Cyclotron Heating. At very high plasma densities, the beam of microwaves can be refracted out of the plasma altogether and the beam can hit the wall of the vacuum vessel.
- Jon Pizzo, a rising junior at Rensselaer Polytechnic, compared experimental data from a DIII-D discharge in which the beam was allowed to refract in this way under carefully controlled conditions with computer models, with the goal being to validate those models under this extreme condition.
- Jon's results proved that even in this case, the modeling tools describe the microwave beam's behavior quite accurately.
- In the process, Jon learned a great deal about topics not covered in his undergraduate physics curriculum, and how research is done by a team of individuals, each expert in his or her own field of specialization.

Automating Interferometric Measurements of ICF Capsules

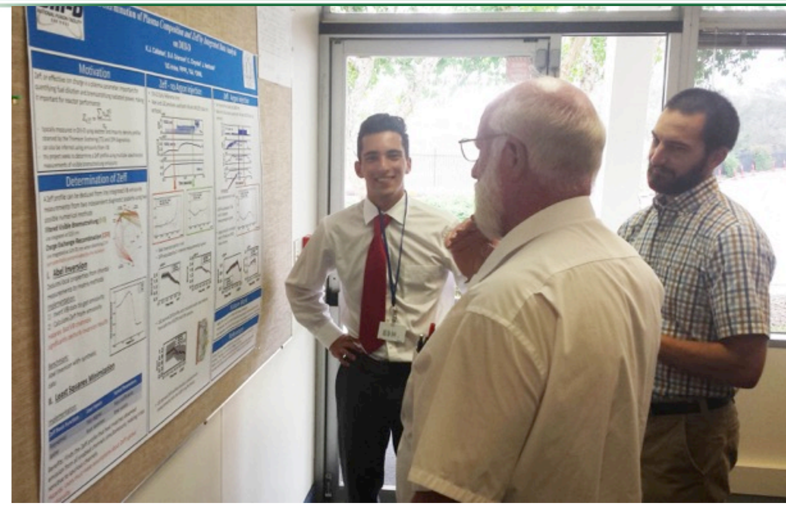
SULI participant at General Atomics

Andres Padilla develops the software and operates the interferometer station (top) and analyzes the images of fringes (bottom) at General Atomics

- Outstanding senior Andres Padilla, studying Aerospace Engineering at the University of California in Los Angeles (UCLA), spent ten weeks at General Atomics implementing new hardware and developing new software supporting the automation of interferometric dimensional measurements of ICF capsules.
- Andres' LabVIEW code interfaced with stages, sensors, and a camera to allow images of the interference fringes to be captured and indexed to the absolute position of the stage and location on the capsule.
- In addition to providing a record of this previously manual and subjective measurement, these image stacks can now be generated automatically and will allow future algorithm development for determining interface locations.
- This work provided significant labor savings and a stepping stone to full automation in the future.

Solving the Measurement Integration Challenge

SULI participant at DIII-D/General Atomics



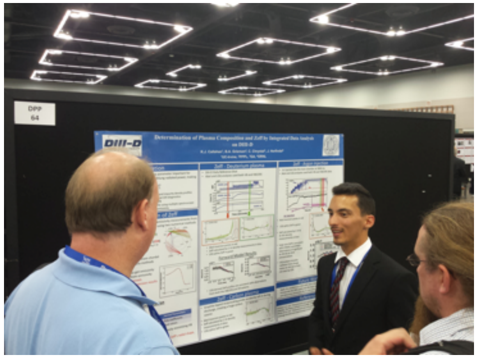
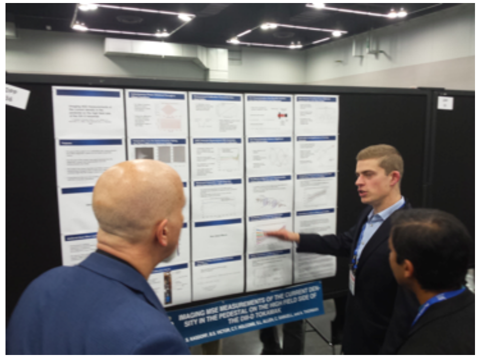
Kyle Callahan (left) discusses his work with GA staff scientists Colin Chrystal (right) and Keith Burrell, the recipient of the APS-DPP's 2018 Maxwell Prize

Kyle says: "**My experiences with the SULI program at DIII-D were my first glimpses of the life of a scientist at a national facility, and of what is needed for individuals to be successful contributors to their scientific communities. This opportunity has shown me how essential networking and collaboration are to performing good science.**"

- Tokamak fusion reactors are required to radiate a significant fraction of the power before the heat flux hits the material surface. Typically, impurities that radiate power are injected, but when the impurities make their way into the core plasma, they can dilute the fusion fuel. Determining the effectiveness of a strategy for impurity injection and removal requires measuring the core impurity content.
- University of California Irvine SULI student Kyle Callahan took on the challenge of using multiple impurity measurements from charge exchange recombination spectroscopy, visible bremsstrahlung, soft X-ray and a survey ultraviolet spectrometer to determine the amount of many types of plasma impurities in DIII-D plasmas.
- Kyle's poster summarizing his summer work excited a good deal of interest - he won an undergraduate research poster prize at the American Physical Society Division of Plasma Physics 2018 meeting in Portland.
- Towards the future, Kyle has taken a keen interest in science policy and reached out to previous SULI students who have worked in Washington DC.

An Excellent Showing at APS Division of Plasma Physics in Portland!

SULI participants at DIII-D/General Atomics

Kyle Callahan (left) and Stephen Kasdorf (right) presenting their work in Portland to fellow scientists.

Callahan and Kasdorf pose with Bob Pinsker, the GA/DIII-D Laboratory Education Director, holding their prize certificates at the Student Appreciation Reception in Portland.

Each year, the most highly motivated of the SULI students that spent their summer at GA/DIII-D sometimes find that they are able to travel to the American Physical Society Division of Plasma Physics meeting in the following autumn to present their work in the Undergraduate Research poster session. In 2018, thanks to an additional grant from DOE Office of Fusion Energy Sciences, all 7 of the students who had done their summer projects at DIII-D attended the APS-DPP in Portland, Oregon.

The DPP presents 6 awards to the students whose presentations are judged of the highest quality in the session. In 2018, no less than two of the DIII-D Seven received these prestigious awards, out of a total of about 66 posters in the session, a wonderful result!