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The California Tech

New Process Allows 3-D Printing of Nanoscale Metal Structures

ROBERT PERKINS
Caltech Strategic Communications

This article is adapted from a story that was originally published online at caltech.edu.

Synthesizing organic scaffolds that contain metal ions enables 3-D printing of metallic structures that are orders of magnitude smaller than previously possible.

For the first time, it is possible to create complex nanoscale metal structures using

to engineering ultralightweight aircraft components. It also opens the door to the creation of a new class of materials with unusual properties that are based on their internal structure. The technique is described in a study that will be published in *Nature Communications* on February 9.

In 3-D printing—also known as additive manufacturing—an object is built layer by layer, allowing for the creation of structures that would be impossible to manufacture by conventional subtractive methods such as etching or milling. Caltech materials scientist Julia Greer is a

created exceptionally lightweight ceramics that spring back to their original shape, spongelike, after being compressed.

Greer's group 3-D prints structures out of a variety of materials, from ceramics to organic compounds. Metals, however, have been difficult to print, especially when trying to create structures with dimensions smaller than around 50 microns, or about half the width of a human hair.

The way 3-D printing works at the nanoscale is that a high-precision laser zaps the liquid in

structures at the nanoscale," says Greer, professor of materials science, mechanics, and medical engineering in Caltech's Division of Engineering and Applied Science. "There's a chemical reaction that gets triggered when light interacts with a polymer that enables it to harden and then form into a particular shape. In a metal, this process is fundamentally impossible."

Greer's graduate student Andrey Vyatskikh came up with a solution. He used organic ligands—molecules that bond to metal—to create a resin containing mostly polymer, but which carries along with it metal that can be printed, like a scaffold.

In the experiment described in the *Nature Communications* paper, Vyatskikh bonded together nickel and organic molecules to create a liquid that looks a lot like cough syrup. They designed a structure using computer software, and then built it by zapping the liquid with a two-photon laser. The laser creates stronger chemical bonds between the organic molecules, hardening them into building blocks for the structure. Since those molecules are also bonded to the nickel atoms, the nickel becomes incorporated into the structure. In this way, the team was able to print a 3-D structure that was initially a blend of metal ions and nonmetal, organic molecules.

Vyatskikh then put the structure into an oven that slowly heated it up to 1,000 degrees Celsius (around 1,800 degrees Fahrenheit) in a vacuum chamber. That temperature is well below the melting point of nickel (1,455 degrees Celsius, or about 2,650 degrees Fahrenheit) but is hot enough to vaporize the organic materials in the structure, leaving only the metal. The heating process, known as pyrolysis, also fused the metal particles together.

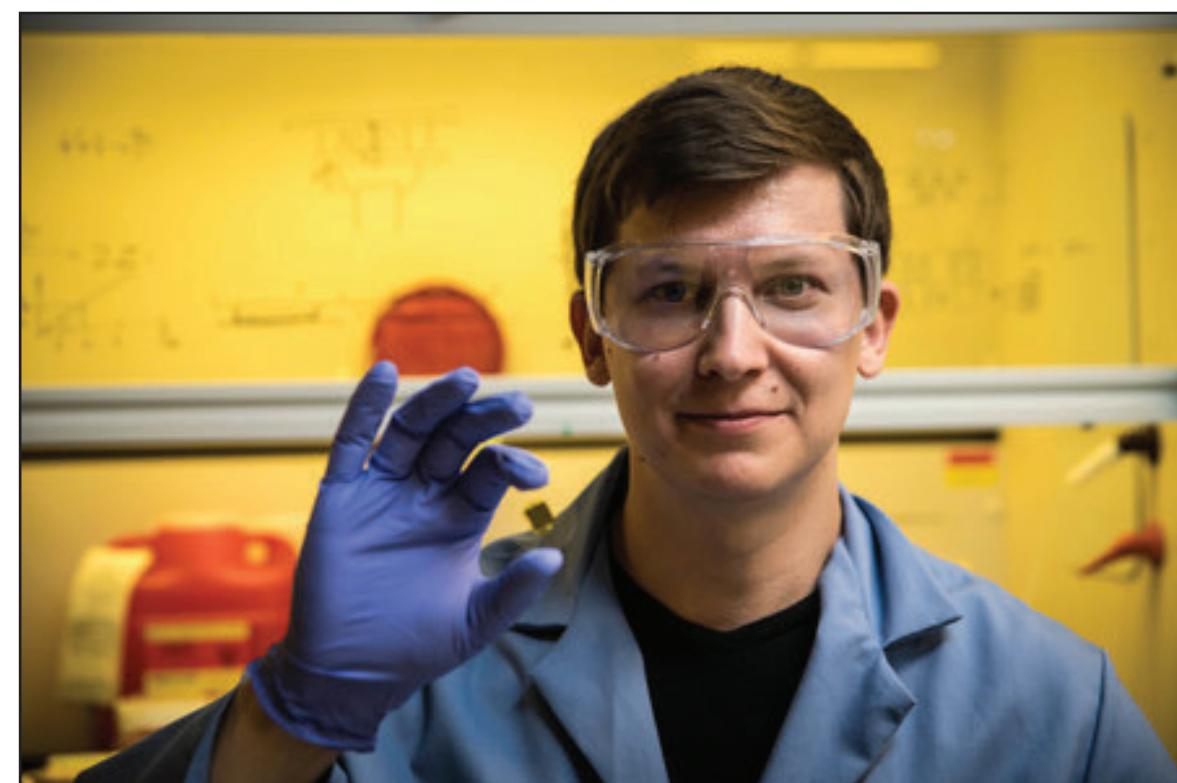
In addition, because the

process vaporized a significant amount of the structure's material, its dimensions shrank by 80 percent, but it maintained its shape and proportions.

"That final shrinkage is a big part of why we're able to get structures to be so small," says Vyatskikh, lead author on the *Nature Communications* paper. "In the structure we built for the paper, the diameter of the metal beams in the printed part is roughly 1/100th the size of the tip of a sewing needle."

Greer and Vyatskikh are still refining their technique; right now, the structure reported on in their paper includes some voids left behind by the vaporized organic materials as well as some minor impurities. Also, if the technique is to be of use to industry, it will need to be scaled up to produce much more material, says Greer. Although they started with nickel, they are interested in expanding to other metals that are commonly used in industry but are challenging or impossible to fabricate in small 3-D shapes, such as tungsten and titanium. Greer and Vyatskikh are also looking to use this process to 3-D print other materials, both common and exotic, such as ceramics, semiconductors, and piezoelectric materials (materials with electrical effects that result from mechanical stresses).

The study is titled "Additive Manufacturing of 3D Nano-Architected Metals." Co-authors include Caltech Resnick Sustainability Institute Postdoctoral Scholar in Applied Physics and Materials Science Akira Kudo and mechanical engineering graduate student Carlos Portela as well as collaborators Stéphane Delalande of the Centre Technique de Vélizy in France and Xuan Zhang of Tsinghua University in China. Funding for this research came from the Department of Defense.



Caltech graduate student Andrey Vyatskikh shows a square of silicon substrate upon which a 3-D metal structure has been printed. The structure itself is smaller than a speck of dust.

Photo Courtesy of Caltech

pioneer in the creation of ultrathin 3-D architectures built via additive manufacturing. For instance, she and her team have built 3-D lattices whose beams are just nanometers across—far too small to be seen with the naked eye. These materials exhibit unusual, often surprising properties; Greer's team has

specific locations of the material with just two photons, or particles of light. This provides enough energy to harden liquid polymers into solids, but not enough to fuse metal.

"Metals don't respond to light in the same way as the polymer resins that we use to manufacture

3-D printing, thanks to a new technique developed at Caltech.

The process, once scaled up, could be used in a wide variety of applications, from building tiny medical implants to creating 3-D logic circuits on computer chips

experimental setup that starved the catalyst of water. "When you take away some of the water, the reaction slows down, and you are able to take a picture of what's happening during the reaction," he says.

Those pictures revealed the active site of the catalyst—the specific location where water is broken down into oxygen—and showed that iron was performing the water-splitting reaction, not nickel.

"Our experimentally supported mechanism is very different than what was proposed," says Hunter, first author of a paper published February 6 in *Joule*, a journal of sustainable-energy research, describing the discovery. "Now we can start making changes

to this material to improve it."

Gray, whose work has focused on solar fuels for decades, says the discovery could be a "game changer" for the field. "This will alert people worldwide that iron is particularly good for this kind of catalysis," he says. "I wouldn't be at all shocked if people start using these catalysts in commercial applications in four or five years."

The paper describing the research is titled, "Trapping an Iron(VI) Water Splitting Intermediate in Nonaqueous Media." Other co-authors are Gray; grad student and Resnick fellow Niklas B. Thompson, laser technologist Astrid M. Muller, and faculty associate Jay R. Winkler of Caltech's Beckman

Institute; Professor of mineralogy George R. Rossman of Caltech's Division of Geological and Planetary Sciences; and Michael G. Hill of Occidental College.

Support for the research was provided by the National Science Foundation and the Arnold and Mabel Beckman Foundation.

Production of Solar Fuels Inches Closer with Discovery by Caltech Scientists

EMILY VELASCO
Caltech Strategic Communications

This article is adapted from a story that was originally published online at caltech.edu.

Research Uncovers Mechanism Behind Water-Splitting Catalyst

Caltech researchers have made a discovery that they say could lead to the economically viable production of solar fuels in the next few years.

For years, solar-fuel research has focused on developing catalysts that can split water into hydrogen and oxygen using only sunlight. The resulting hydrogen fuel could be used to power motor

vehicles, electrical plants, and fuel cells. Since the only thing produced by burning hydrogen is water, no carbon pollution is added to the atmosphere.

In 2014, researchers in the lab of Harry Gray, Caltech's Arnold O. Beckman Professor of Chemistry, developed a water-splitting catalyst made of layers of nickel and iron. However, no one was entirely sure how it worked. Many researchers hypothesized that the nickel layers, and not the iron atoms, were responsible for the water-splitting ability of the catalyst (and others like it).

To find out for sure, Bryan Hunter (PhD '17), a former fellow at the Resnick Institute, and his colleagues in Gray's lab created an

experimental setup that starved the catalyst of water. "When you take away some of the water, the reaction slows down, and you are able to take a picture of what's happening during the reaction," he says.

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FEBRUARY 13, 2018

THE CALIFORNIA TECH

Caltech Y Column

CALTECH Y

The Caltech Y Column serves to inform students of upcoming events and volunteer opportunities. The list is compiled by Katherine Guo from information given by the Caltech Y and its student leaders.

Founded by students in 1916, the Y was organized to provide extracurricular activities planned and implemented by students as an opportunity to learn leadership skills and discover themselves. The mission of today's Y remains the same—to provide opportunities that will prepare students to become engaged, responsible citizens of the world. The Y seeks to broaden students' worldviews, raise social, ethical, and cultural awareness through teamwork, community engagement, activism, and leadership. More information about the Caltech Y and its programs can be found at <https://caltechy.org>. The office is located at 505 S. Wilson Avenue.

Upcoming Events

Costa Rica Alternative Spring Break Trip

Saturday, March 17th through Sunday, March 25th (9 days) | Cost: \$950

Applications Due: by Noon on November, 22nd

The Caltech Y is excited to seek applicants for our 2017 Alternative Spring Break trip to Costa Rica. Join other Caltech students for a conservation focused spring break trip this year. On the Costa Rica trip we will be working with a host organization OSA Conservation www.osaconservation.org – which is dedicated to protecting the globally significant biodiversity of Costa Rica's Osa Peninsula. Don't miss out on this fantastic opportunity to explore another part of our planet and make a tangible difference in the world.

Trips fees include transportation, lodging, and most food. The Costa Rica Alternative Spring Break trip is coordinated by the Caltech Y and has been made possible thanks to generous funding from the Frank and Elsie Stefanko Fund, the George Housner Fund, Caltech Student Affairs, and the Caltech Y. Spaces are limited.

Visit http://caltechy.org/programs_services/areas/asb/ for applications and more information.

The Caltech Y Social Activism Speaker Series presents:

Solving Climate Change: From Policy to Personal

Thursday | November 30th | 4:00 to 6:00 PM | Location: TBD

The Caltech Y Social Activism Speaker Series is hosting a panel with members of the Citizens' Climate Lobby, a non-partisan volunteer organization dedicated to national policy to address climate change.

Climate change is one of the most pressing issues facing humanity. While the impacts of emissions up to now will be felt potentially for decades, significant policy changes are required in the immediate future to address greenhouse gas emissions and reverse the warming

trend in the long term. Passing legislation to deal with this pressing issue however, remains a problem. CCL campaigns for the passage of a Carbon Fee and Dividend bill designed to tax carbon emissions and return carbon dioxide to its pre-1990s levels. This discussion will feature a panel of CCL members from a variety of backgrounds each of whom will bring their perspective to this issue. Each panel member will talk about their views and then take questions from the audience.

Presentations are intended to introduce one perspective in order to stimulate thought and to provide a forum for respectful dialogue and examination. The views expressed by speakers are solely those of the speakers. Presentations do not necessarily reflect the opinion of the California Institute of Technology or the Caltech Y and should not be taken as an endorsement of the ideas, speakers or groups.

Decompression 2.0

Friday | December 1st | 3:00 to 5:00 PM | Center for Student Services

We made the move... Decompression is now an end of the week stress reliever with activities, snacks and entertainment. Don't go into finals week stressed out. Join us at the end of class week for a little break before studying. A variety of drinks and snacks, entertainment and activities will be provided.

Caltech Y Explore LA Series The Broad Museum

Sunday | December 3rd | 2:30 PM | Cost: \$5 | Transportation Included

Sign-up starting Thursday, 11/16 at the Caltech Y

Join us on a visit to The Broad with the Caltech Y! The Broad is a contemporary art museum founded by philanthropists Eli and Edythe Broad. Designed by Diller Scofidio + Renfro in collaboration with Gensler, the museum is home to 2,000 works of art from the Broad collection, which is among the most prominent holdings of postwar and contemporary art worldwide, and presents an active program of rotating temporary exhibitions and innovative audience engagement. The 120,000-square-foot building features two floors of gallery space and is the headquarters of The Broad Art Foundation's worldwide lending library, which has actively loaned collection works to museums around the world since 1984. With in-depth representations of influential contemporary artists like Jean-Michel Basquiat, Barbara Kruger, Cy Twombly, Ed Ruscha, Kara Walker, Christopher Wool, Jeff Koons, Joseph Beuys, Jasper Johns, Cindy Sherman, Robert Rauschenberg, and more, plus an ever-growing representation of younger artists, The Broad enriches, provokes, inspires, and fosters appreciation of art of our time. This offer is for students only; however, students purchasing tickets are permitted to purchase tickets for up to one guest each – and that guest can be a non-student. Explore LA is coordinated by the Caltech Y. The Caltech Y is located in the Tyson House 505 South Wilson (Bldg. 128).

The Caltech Y Social Activism Speaker Series is hosting a panel with members of the Citizens' Climate Lobby, a non-partisan volunteer organization dedicated to national policy to address climate change.

Climate change is one of the most pressing issues facing humanity. While the impacts of emissions up to now will be felt potentially for decades, significant policy changes are required in the immediate future to address greenhouse gas emissions and reverse the warming

Caltechlive!

EARNEST C. WATSON LECTURE SERIES

WEDNESDAY, FEBRUARY 14, 2018 · 8 PM

USING THE BRAIN OF A MODERN FLY TO RECONSTRUCT THE BEHAVIORS OF AN ANCIENT WORLD



Michael H. Dickinson, Esther M. and Abe M. Zarem Professor of Bioengineering and Aeronautics, Caltech Division of Biology and Biological Engineering

Using an assortment of modern techniques from different fields such as neuroscience, biomechanics, and engineering, Dr. Dickinson is attempting to reconstruct the behavior and ecology of the ancestral insects through his investigations of the common fruit fly. His research provides a fascinating window into the past, providing new insight into the evolution of our planet's most diverse group of organisms.

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Mentors for L.I.F.E

Volunteer times: 2:45 - 5:00 PM at various locations in Pasadena

Stressed out by school? Step outside the Caltech bubble and mentor tweens who've yet to even consider college. Things you could do: Build a baking soda and vinegar volcano, read a book aloud, play sports or board games, teach the alphabet of another language, do a craft. Having a mentor makes an at-risk student 55% more likely to attend college, 78% more likely to volunteer regularly, and 130% more likely to hold a leadership position. Interested? If you have 180 seconds, you can watch this video and be inspired. If you have an hour a week, you can mentor someone and be their inspiration. If you feel unqualified, don't worry. Ultimately, mentoring is about being a consistent, dependable friend—not a surrogate parent or psychiatrist.

For more information and to RSVP, contact azhai@caltech.edu. Eligible for Federal Work Study.

Hathaway Sycamores

Every Monday | 5:45 - 8:00 PM | Highland Park

Volunteer at Hathaway Sycamores, a group that supports local underprivileged but motivated high school students. There are a variety of ages and subjects being tutored. The service trip includes about 40 minutes of travel time and 1.5 hours of tutoring. Transportation is included.

For more info and to RSVP email Elisabeth at egallmei@caltech.edu. Eligible for Federal Work Study.

To get started, contact noelle@caltech.edu.

New NASA Space Sensors to Address Key Earth Questions

ALAN BUIS
JPL Strategic Communications

This article is adapted from a story that was originally published online at caltech.edu.

that NASA undertake this type of regularly solicited, science-based, quick-turnaround project. The council's recently released decadal survey recommended the continuance of the program.

"PREFIRE and EMIT make innovative use of technologies

Logan, Utah, are mission partners. JPL is responsible for project management and is building and delivering the instrument. Brian Drouin of JPL is the deputy principal investigator, while JPL's Brian Kahn and Nicole-Jeanne Schlegel are co-investigators.

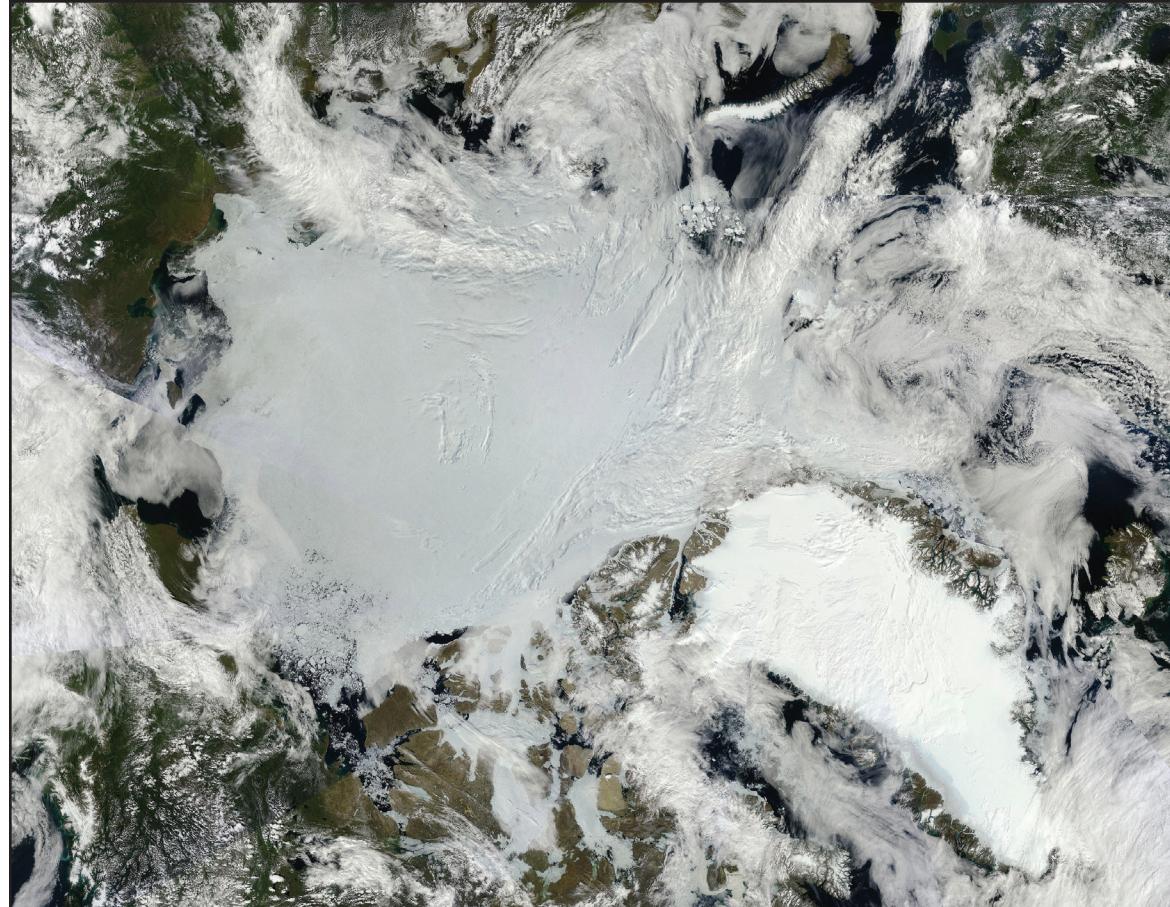
global impacts of dust on weather, atmospheric circulation and other aspects of Earth's environment are not well established.

EMIT's hyperspectral instrument will measure the different wavelengths of light emitted by minerals on the surface of deserts and other dust sources to determine their composition. The EMIT sensor is based in part on NASA's Moon Mineralogy Mapper instrument aboard the Indian Space Research Organization's Chandrayaan-1 spacecraft.

The EMIT team brings together broad expertise that covers mineral measurements, soil science, remote sensing of surface properties and Earth system modeling. The project's modeling component will use the data collected to advance our understanding of the role of atmospheric dust in Earth's climate and better predict how it can be expected to change in the future.

Earth Venture missions provide an innovative approach to address Earth science research with regular windows of opportunity to accommodate new scientific priorities. The missions are managed by NASA's Earth System Science Pathfinder program, located at NASA's Langley Research Center in Hampton, Virginia, for the agency's Science Mission Directorate.

The first Earth Venture instruments headed to space are preparing for launch within the next year. The Global Ecosystem Dynamics Investigation (GEDI) and the ECOSystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) will measure the distributions, canopy heights and changes in global vegetation from the space station, providing insights into how forests and ecosystems are affected by changes in



A pair of CubeSats will probe a little-studied portion of the radiant energy emitted by the Arctic environment for clues to why the region is warming faster than the rest of Earth. This composite satellite image shows the expanse of Arctic sea ice (center) and the Greenland Ice Sheet (lower right).

Photo Courtesy of NASA

Why is the Arctic warming faster than the rest of the planet? Does mineral dust warm or cool the atmosphere? NASA has selected two new, creative research proposals to develop small, space-based instruments that will tackle these fundamental questions about our home planet and its environment. NASA's Jet Propulsion Laboratory in Pasadena, California, is a key participant on both instruments.

The Polar Radiant Energy in the Far Infrared Experiment (PREFIRE) will fly a pair of small CubeSat satellites to probe a little-studied portion of the radiant energy emitted by Earth for clues about Arctic warming, sea ice loss and ice-sheet melting. Tristan L'Eucuyer of the University of Wisconsin, Madison, is the principal investigator.

The Earth Surface Mineral Dust Source Investigation (EMIT) will use a sensor mounted to the exterior of the International Space Station to determine the mineral composition of natural sources that produce dust aerosols around the world. By measuring in detail which minerals make up the dust, EMIT will help to answer the essential question of whether this type of aerosol warms or cools the atmosphere. Robert Green of JPL is the principal investigator.

These two instruments were competitively selected from 14 proposals considered under NASA's fourth Earth Venture Instrument opportunity. Earth Venture investigations are small, targeted science investigations that complement NASA's larger missions. The National Research Council recommended in 2007

first developed by NASA for planetary missions to address important, longstanding questions about Earth," said Michael Freilich, director of the Earth Science Division at NASA Headquarters in Washington.

The Arctic helps to regulate Earth's overall temperature by radiating back into space much of the excess energy from the Sun that is absorbed at lower latitudes. Current satellite instruments do not detect all of the wavelengths of this energy radiating from our planet. PREFIRE will fill in the current data gap at far-infrared wavelengths, collecting information that will help scientists diagnose the impact of this outgoing radiation on the Arctic region's energy balance.

PREFIRE will fly miniaturized thermal infrared spectrometers on two CubeSat satellites, each about the size of a loaf of bread. The sensors are based on technology previously flown on the Mars Climate Sounder, an instrument on NASA's Mars Reconnaissance Orbiter. The CubeSats will orbit Earth's poles to measure far-infrared emissions and how they change throughout the day and over seasons. The observations will allow scientists to assess how changes in thermal infrared emissions at the top of Earth's atmosphere are related to changes in cloud cover and surface conditions below, such as the amount of sea ice and meltwater on the surface of the ice.

The PREFIRE team brings together expertise in remote sensing, Earth system modeling and Arctic ice. JPL and the Space Dynamics Laboratory of North

water availability and other environmental and human factors.

For more information about the Earth Venture program, visit:

<https://essp.nasa.gov>

NASA uses the vantage point of space to increase our understanding of our home planet, improve lives and safeguard our future. NASA develops new ways to observe and study Earth's interconnected natural systems with long-term data records. The agency freely shares this unique knowledge and works with institutions around the world to gain new insights into how our planet is changing.

For more information about NASA's Earth science activities, visit:

<https://www.nasa.gov/earth>

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SPORTS

THE CALIFORNIA TECH

FEBRUARY 13, 2018

5

Eiden dominates paint at Oxy

GOCALTECH.COM

Actual Sports Content Editor

EAGLE ROCK, Calif. (Feb. 7, 2018) – Junior center Elizabeth Eiden proved difficult to stop and perhaps just as difficult to score on when the Caltech women's basketball team traveled to Occidental College on Wednesday evening.

Eiden played the entire game and went a selective 9-for-13 from the field en route to 20 points and eight rebounds. She also tied a school record with seven blocks to further cement her status as one of the SCIAC's premier shot blockers. The center maintained a consistent presence throughout the game, logging six points in each of the first three quarters as well as two blocks in each of those quarters. Eiden received support from sophomore guards



"OOOFF." - Elizabeth, probably.

-gocaltech.com

Samantha D'Costa and Grace Peng. Both players joined Eiden in double-figures with D'Costa scoring 17 points while Peng gathered

12 points. Juniors Nika Haleftiras and Madeline Schemel rounded out the starting lineup and distributed nine of the Beavers' 11 assists.

Caltech once again showed it could hang with the likes of a team like Oxy and led after each of the first three quarters, outscoring the home team in every stretch. Over that span, the Tigers had few answers for Eiden's size and presence, as the junior scored 18 of her 20 points between the first three quarters to pace the visitors. The third quarter turned out to be the Beavers' strongest defensively

and while they took just 11 shots, they executed on five of them and found success in getting to the free throw line. By third quarters' end, Caltech led Oxy, 47-37, before the Tigers began to make moves in the fourth quarter.

Andrews sets pace, Beavers hang with second-place Oxy

GOCALTECH.COM

Actual Sports Content Editor

PASADENA (Feb. 7, 2018) – Sophomore guard Alec Andrews guided the Caltech men's basketball team offensively in a defensive struggle against second-place Occidental College in the two teams' third meeting of the season on Wednesday evening.

Andrews led the way with 19 points on 8-of-15 shooting and made 3-for-4 at the free throw line to account for all of his team's points on free throws. 13 of Andrews' points came in the second half of a game in which the Beavers remained competitive with a larger Oxy team. Both teams took care of the ball and neither team got overly aggressive as far as foul trouble was concerned. The two teams combined

for just 16 fouls and Caltech had to give three fouls in the final minute of the game

to send Oxy to the line. Freshman guard Gokul Srinivasaragavan joined Andrews in double-figures and went 3-for-6 from beyond the arc. Sophomore forward Calvin Huh came off the bench to defend the glass for the Beavers, pulling down nine rebounds to go with six easy points.

The Beavers trailed the Tigers by just seven points at halftime and opened the second half on a 14-9 run to bring the deficit to just two points in the middle of the period. Andrews shined offensively during this stretch, scoring six consecutive points for the Beavers and scoring eight of his 19 points within the half's first eight minutes.



Hair on fleek dude.

-gocaltech.com

Baseball set to continue evolution in 2018

GOCALTECH.COM

Actual Sports Content Editor

PASADENA (Feb. 7, 2018) – The evolution of the Caltech baseball team reached new heights in 2017, the likes of which had not been reached in nearly 30 years.

Late-game heroics from rising sophomore Alex Corado and a sound pitching performance from now-junior Jonah Krop on March 31, 2017 earned the Beavers their first SCIAC victory since 1988 in a 4-3 walk-off win over Pomona-Pitzer Colleges. The victory snapped a 29-year winless streak. The Beavers went on to win one more SCIAC game at Whittier College, a 13-12 victory

Fast-forward one year and Head Coach Matthew Mark and his team are looking forward to building upon last year's momentum, fostering the evolution of Caltech's baseball program.

"Good teams evolve and it's up to us this year to adapt, and continue to set the bar high," Mark said.

Mark and his assistants Wayne Edwards and Mark Davis will be tasked with finding new players to fill the roles of the departed seniors.

"I think it goes without saying this group is unburdened," Mark said. "There's no more out there as far as bad streaks for us. You just get to move forward and it's nice to not let history define our approach and to move forward."

At the dish, the Beavers will be returning the meat of their order, many of whom have shown a propensity to hit for a high average. Senior Chris McCarren is coming off a career year where he led his team with a .374 batting average, good for fifth among SCIAC players. Perhaps just as notably, McCarren finished the season as the only SCIAC player with at least 10 stolen bases to have a perfect steal percentage. He also finished eighth in on-base percentage and 12th in assists, establishing himself among the conference's top two-way shortstops. Junior catcher Mark Burleson like McCarren stepped into a leadership role last year but relied more on his power than

finesse, finishing the season with 10 doubles to tie four other players for the Caltech record as well as a team-best four home runs while still maintaining a .317/.365/.476 triple-slash line. Another junior, Connor Moffatt is expected to split time between second and third base as has been the case in recent years. He also brings with him two of the Beavers' six returning home runs from the prior season.

Senior Garrett Levine provided Caltech's sixth home run from a season ago and will return to his role as an enforcer on the mound and in the batter's box. Fellow senior David Watson, meanwhile continued to benefit from his improved defense as a junior and should once again be a fixture in the middle-back end of his team's batting order as a near-every day first baseman and one of the team's three senior cornerstones.

"We have three seniors that have been everyday players for us outside of injury for the better part of four years," Mark said. "These are the guys I had the opportunity to go see and work with through the entire recruiting process. Now we have two Watsons on the team and we have people who come from all over to play for us. But between McCarren, Levine and David Watson they are the first three that kind of set things in place. Last year's class was special and these three are continuing examples of our movement forward and upward."

Back on the mound, the Beavers seem to have two of their three rotation members figured out. Returners Jonah Krop and Cortland Perry established themselves as stabilizing members of last year's rotation, with pure pitcher Krop being one of two pitchers to exceed 80 innings and dropped his

ERA down by more than double his freshman total while leading the team in starts (14),

strikeouts (48), WHIP (1.62) and wins (4).

Perry, meanwhile had his usage varied between being a middle infielder and a utilityman. He can do some good things for us on the mound and in the batter's box so I'm excited to see the year he has."

Caltech is also welcoming in freshman

corner infielder Mitchell Watson, catcher Ari Rosner and another freshman, Dominic Catanzaro. Watson, the brother of the Beavers' senior first baseman, brings with him a legitimate offensive prowess in addition to power from the right side of the plate. His presence will be especially crucial on days where otherwise everyday infielders like Levine and Perry are required to pitch. Rosner could prove valuable on days where Burleson needs a breather or is asked to DH.

"We won't have as many freshmen in the lineup compared to previous years and that's the way most programs are," Mark said. "The best of the best will play with freshman will push the upperclassmen and it's up to older players to answer that call."

The returning group also includes sophomores David Adams, Minjae Kim and Alex Wuschner, all of whom will be competing for time in the outfield. Each of these players came to Caltech with impressive resumes and benefited from playing time. It would be no surprise if one or several players from this group takes a leap forward in 2018, especially with the Beavers looking to improve on their win total.

"I'm really proud of the effort they put in the offseason," Mark said. "Our focus is all in and all out for whatever it takes. It's not a quantity thing, it's 100-percent effort on any play that's asked of you."



Ay, mami - it's baseball season!

-gocaltech.com

and being a difference maker atop the order as a middle infielder. His versatility allowed him to finish in the top five of 18 statistical categories, though his experience pitching against SCIAC competition could incur more mound usage.

Another pure pitcher, sophomore Grant Messner, boasts perhaps some of the best arm talent on the team and has the stuff to be among the SCIAC's top arms, depending the way Mark chooses to deploy him. As for the third starter slot, the versatile Levine could be tabbed to handle the role at some point but primarily operated in a multi-inning relief capacity in 2017, leading the team with two saves. Another option might be freshman Dillon Holder. Holder, like Levine and Perry profiles as a two-way player, the type of player Mark likes to have for flexibility purposes. Returner Alex Corado, who saw

ANNOUNCEMENTS

THE CALIFORNIA TECH

ANNOUNCEMENT:

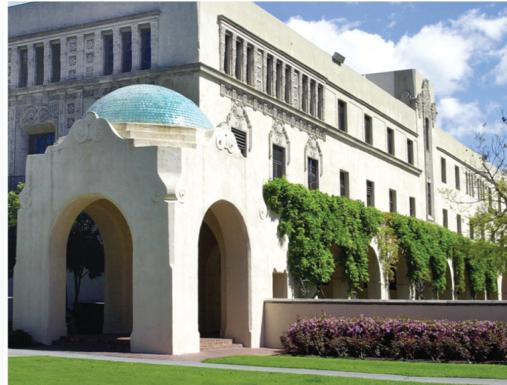
VICE PROVOST, CHIEF DIVERSITY OFFICER, AND PROFESSOR OF ENGLISH CINDY WEINSTEIN HOLDS REGULAR OFFICE HOURS AS AN OPPORTUNITY FOR UNDERGRADUATE STUDENTS, GRADUATE STUDENTS, AND POSTDOCS TO MEET FOR DISCUSSIONS PERTAINING TO THE COUNCIL ON UNDERGRADUATE EDUCATION; CALTECH ACCREDITATION; THE STAFF AND FACULTY CONSULTATION CENTER; STUDENT-FACULTY PROGRAMS; THE CENTER FOR TEACHING, LEARNING, AND OUTREACH; THE CALTECH DIVERSITY CENTER; AND THE CALTECH LIBRARIES.

THERE ARE FOUR 15-MINUTE APPOINTMENTS AVAILABLE PER OFFICE HOUR. SIGN UP AT THE OFFICE OF THE VICE PROVOST IN PARSONS-GATES ROOM 104, BY PHONE AT 626-395-6339, OR BY EMAIL TO DLEWIS@CALTECH.EDU. WE LOOK FORWARD TO HEARING FROM YOU!

STUDENT OFFICE HOURS FOR WINTER TERM 2018:

2/15/18 THURSDAY 9:00-10:00 A.M.
 2/21/18 WEDNESDAY 11:00 A.M.-12:00 P.M.
 2/27/18 TUESDAY 10:00-11:00 A.M.
 3/8/18 THURSDAY 11:00 A.M.-12:00 P.M.
 3/12/18 MONDAY 10:00-11:00 A.M.
 3/19/18 MONDAY 10:00 A.M.-11:00 A.M.

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CROSSWORD

ASCIT Minutes

Meetings are every week in SAC 13

No Minutes Submitted for Week of February 13th

ASCIT Board of Directors Meeting

Minutes for February 2, 2017. Taken by Dana He.

Officers Present: Sakthi Vetrivel, Rachael Morton, Sara Adams, Sarah Crucilla, Alice Zhai, Dana He

Guests: Amulya Mohan, Michael Rupprecht

Call to Order: 5:05 pm

President's Report (Sakthi):

- Contacted Krispy Kreme for Midnight Donuts on February 12th.
- Had faculty board meeting. Talked about Caltech Fund and Freshman Admission Committees.

Officer's Reports:

V.P. of Academic Affairs (Kavya):

- Mathematica workshop went well.
- Course compliments will be soon.
- Student-faculty lunches for this term will come out soon.
- Been looking at expanding research programs with our year-round research list and student-led presenter research seminars.

V.P. of Non-Academic Affairs (Rachael):

- IHC, COUCH, Sakthi, and Kavya came together last night to discuss Bechtel decision. IHC is meeting tonight to divide this issue into topics, with rotation being a major topic. Will hopefully send out an email tonight with IHC's stance on rotation changes and how they plan to tackle changes. Sent out survey earlier to get a feel on what student's opinions are and what students care about. Will create an equivalent Google survey for those without access to Donut.

Director of Operations (Sara):

- Will pick up ASCIT equipment from Fleming today.
- Started narrowing down what we want for ASCIT screening room and start writing proposal. Could pay out of slush fund instead of MHF to complete it sooner. Could also ask for retroactive MHF fund.

Treasurer (Sarah):

- Sent out messages to three people who requested money and were approved last week.
- MHF is meeting next week. Decisions will come out after.

Social Director (Alice):

- Booked venue for ASCIT formal. Will be on Friday, April 6th. Will be late buses for athletes, etc.

- Planning Color Me Mine event for 40 people. Trying to devise more fair system for event sign-ups.
- ASCIT movie night will be February 23rd for Black Panther.
- Be a Kid Again Day will be February 25th from 7 – 10 pm.

Secretary (Dana):

- Nothing to report.

If anyone has any questions or concerns about a section of the minutes please email the appropriate officer. We are happy to answer any questions.

Meeting Adjourned: 5:33 pm

ARC Minutes 2.4.2018

Present: Kavya Sreedhar, Allison Tang, Alex Reeves, Erika Salzman, Arushi Gupta, Vibha Vijayakumar, Adrian Huang, Michael Yao, Matthew Zeitlin, Andrew Zhou

Minutes submitted by: Allison Tang and Shreya Ramachandran

1. Programming

- Student Faculty Lunches (SFLs): two SFLs this term; organize & contact profs
- Course Compliments: send out the google form today/tomorrow to gather positive feedback about profs/TAs who enter draw for Prof/TA of the month; nominators take them out for lunch
- UG+Grad Student Research Seminars: collab with GSC to set up student seminar series
- Course Concerns: no new course concerns
- Option Fair: Friday, February 16th, 11:30am to 1:30pm, email going out today

2. Projects

- TQFR Improvement: working on student guide to TQFRs
- Core Connections: CS141 project to research how students see connections from core to upper-level classes

3. Miscellaneous

- ARC turnover: new members joining
- CS2 Millikan Study Session: will happen if enough tutors can be found

The ARC website at arc.caltech.edu has more information about what the ARC does if you are interested. We meet every Sunday at 11am in SAC13 and our meetings are open to everyone! If you have any questions, please feel free to email ksreedha@caltech.edu.



ARC Tip of the Week

View unit loads and enrollment figures for each option/minor here:

https://www.registrar.caltech.edu/documents/73-undergraduate_option_requirements_2017-18.pdf

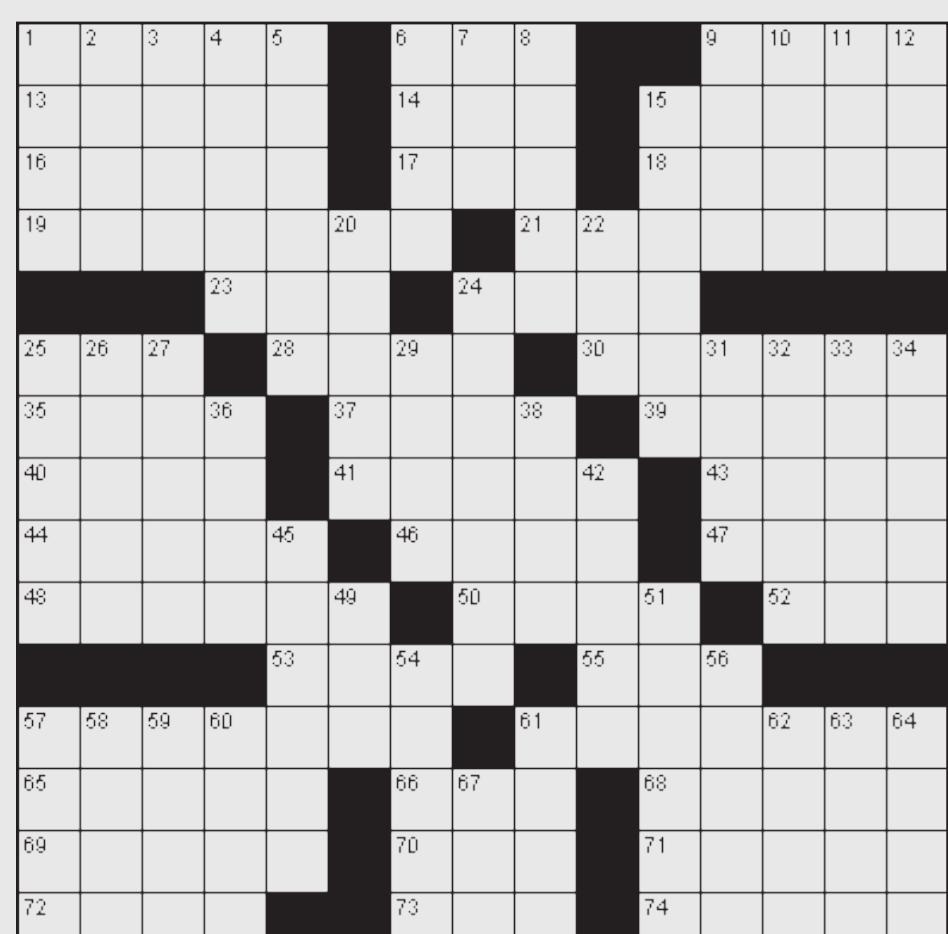
Crossword

Across

- Personnel
- Used in varnishes and sealing wax
- Palisade
- Paved area
- Self
- Be in contradiction with
- Golf clubs
- Plaything
- Part of a church
- Scourge
- Tropical birds
- Transgression
- Place restrictions on
- Buddy
- Impose and collect
- Basement
- Zeal
- Ecstatic
- Become active
- Memorization by repetition
- Becomes fatigued
- Facial expression
- Shout of approval
- Kind of tide
- Family line of descent
- More difficult
- Cutis
- Condensation
- Cribs
- Summit
- Be earlier in time
- Maybe
- Ashen
- Fish eggs
- Form of entertainment
- Selected as the best
- Male title
- Expiate
- Friendly nation
- Moose
- Depress
- Gyrate
- Counterbalance used to obtain net weight
- Molecule
- Amercements
- Ancient remains from a past age
- Allows
- In the past
- Aquatic South American rodent
- Low dam
- In addition
- Kind of rhythmicity
- Fermentation sediment
- Hairdresser
- Unable to move or resist motion
- Part of a circle
- Evergreen conifer
- Spiny-finned freshwater fish
- Hawaiian greeting

27. Subsequently

- Conceited
- Segments of tree trunk
- Glaringly vivid and graphic
- Stage whisper
- Refresh
- Requirement
- Hard strong durable wood
- Malice
- Draw back
- Pole made of metal or wood
- Being approximately average
- Brief and to the point
- Snapshot
- Supplication
- Small stream
- Malevolent
- Urban area
- Fringe benefit
- Affirm
- Languish
- Oracle
- Lubricant



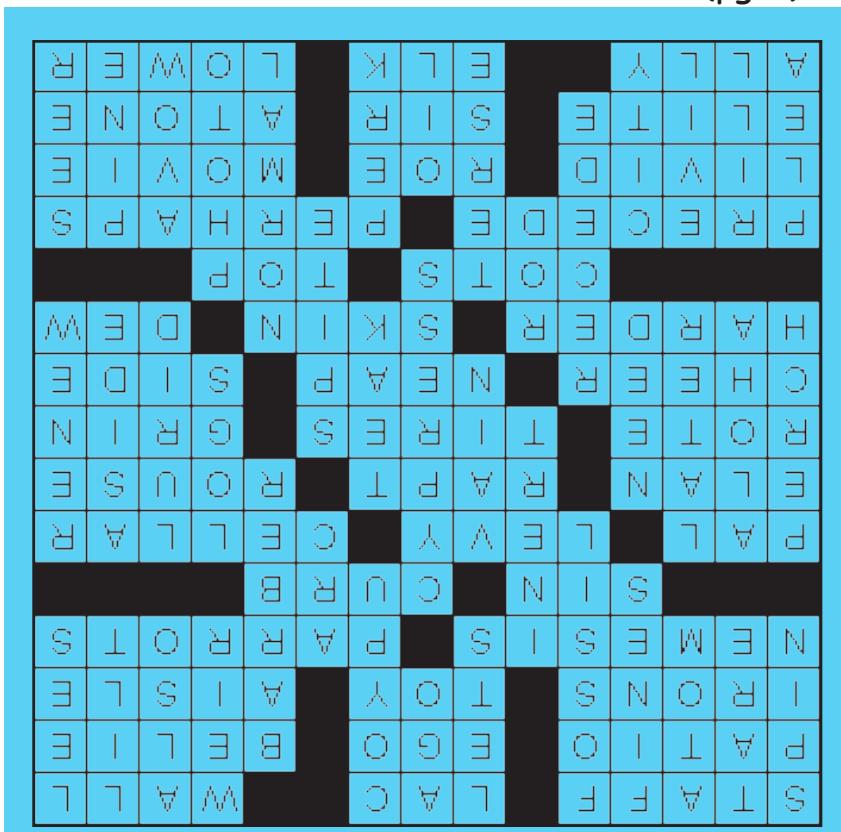
HUMOR

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FEBRUARY 13, 2018

THE CALIFORNIA TECH

Answers to current crossword (pg 7)



-<http://puzzlechoice.com>

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