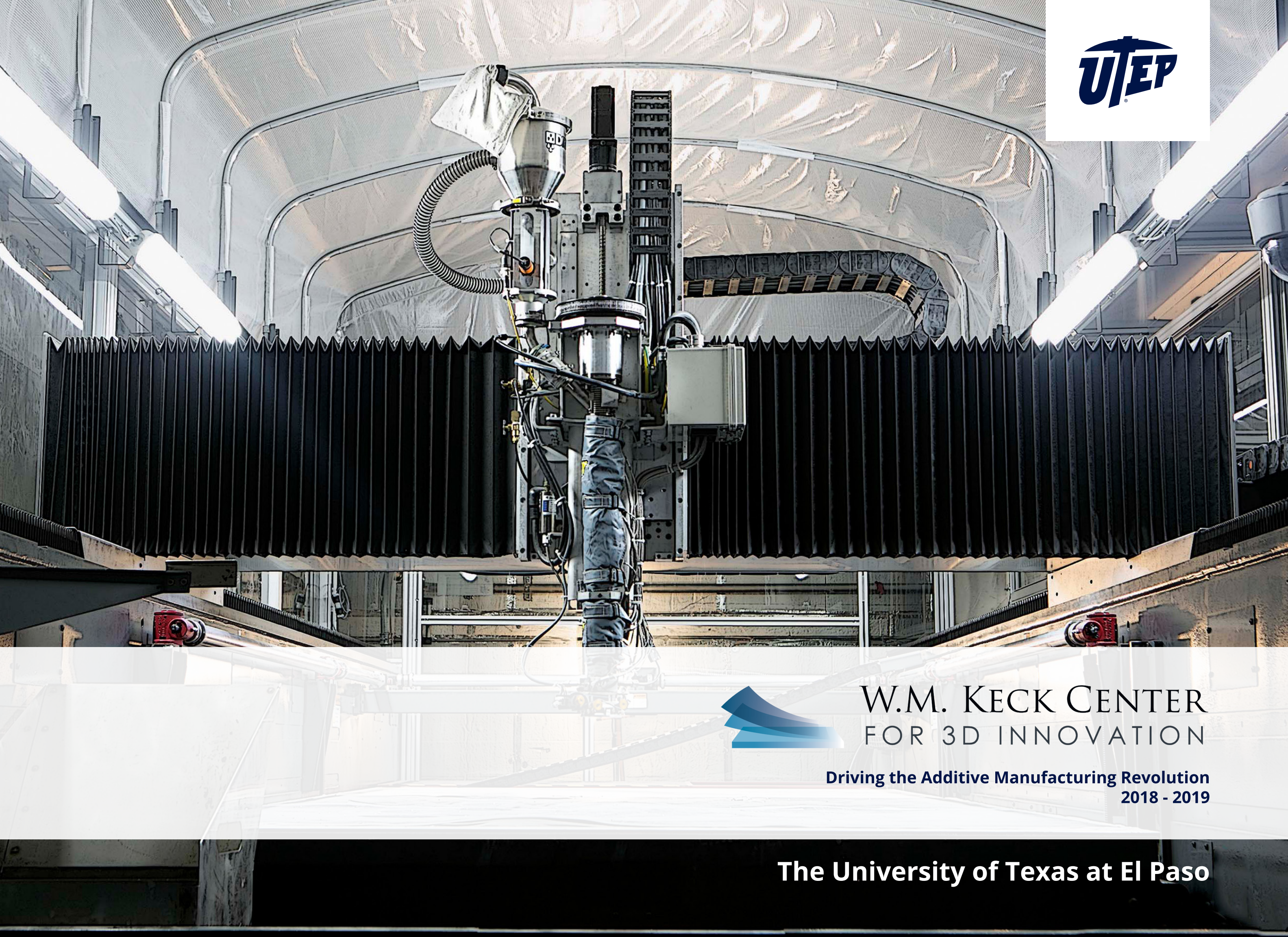


W.M. Keck Center for 3D Innovation

Driving the Additive Manufacturing Revolution
2018 - 2019

The University of Texas at El Paso

THE W.M. KECK CENTER FOR 3D INNOVATION

is located at The University of Texas at El Paso (UTEP). The Keck Center is a unique multidisciplinary research facility focused on the use and development of Additive Manufacturing (AM) technologies with primary focus areas in AM Technology Development, Engineered and Structured Materials, and Advanced AM Applications.

OUR VISION

is for AM technology to revive the economy through a transformation in the way products are designed and manufactured, taking advantage of distributed manufacturing and 3D multi-functional designs enabled by AM.

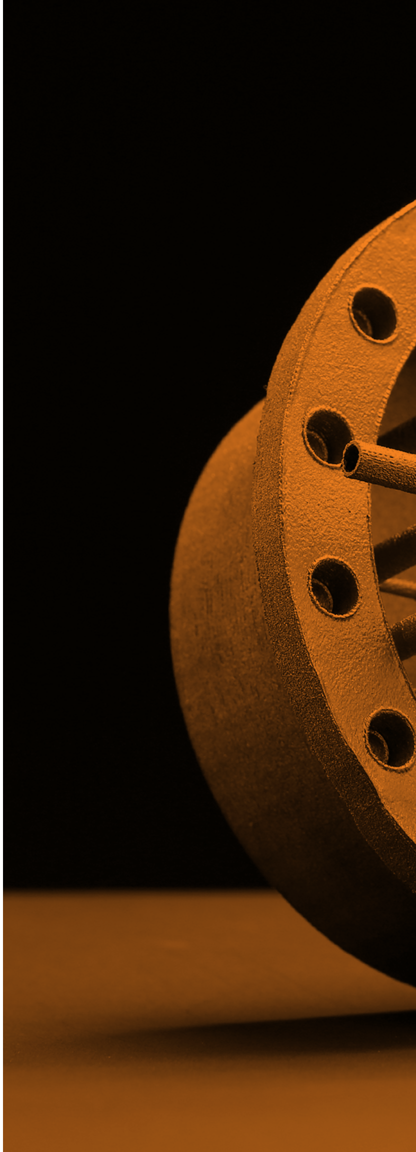
OUR MISSION

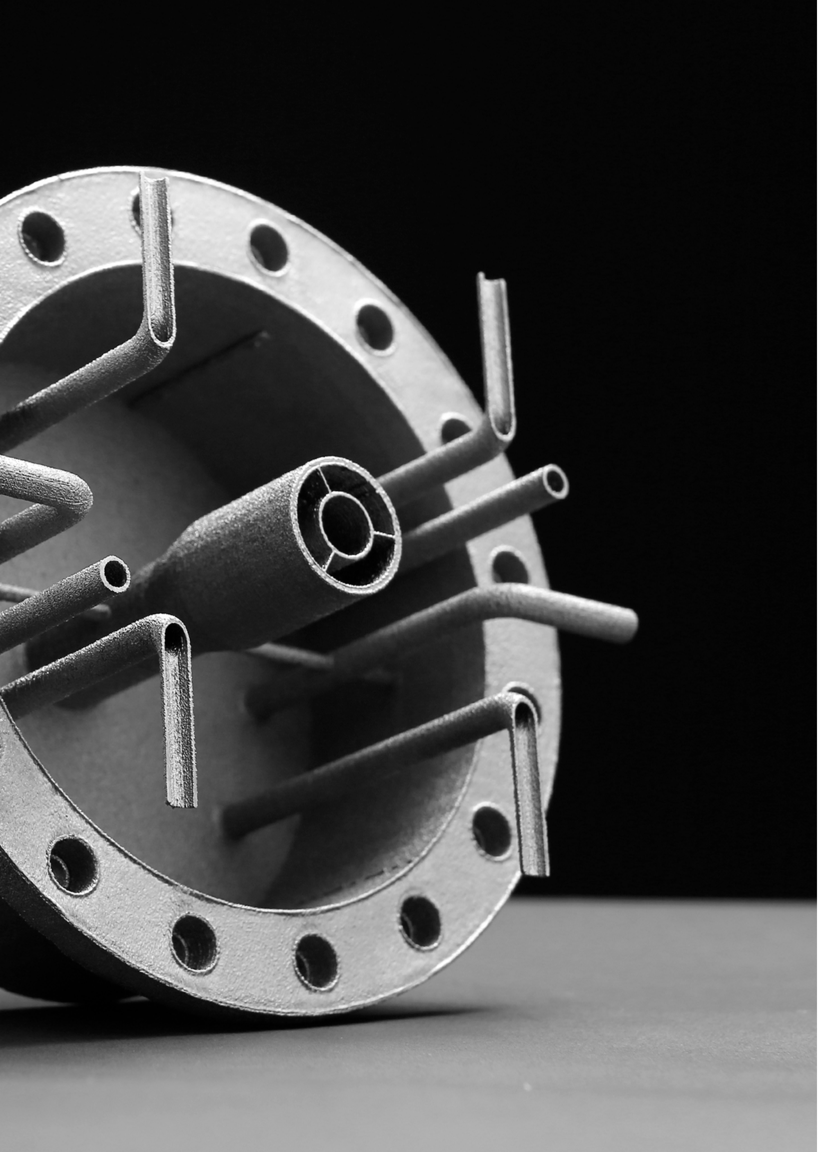
is to lead the AM transformation through multi-disciplinary activities that include education, research, outreach, technology development and commercialization, and industrial partnerships.

- Our 13,000 square foot, state-of-the-art on-campus facility houses more than 65 AM machines.
- Our second (off-campus) facility has an additional 17,000 square feet available for research, training, and economic development.
- The Keck Center has combined facilities for:

- AM/3D Printing
- Hybrid AM
- CNC Machining & Soft Tooling
- Microscopy and Characterization
- Synthetic & Analytical Chemistry
- CAD & Design
- Reverse Engineering & Metrology
- Mechanical Testing
- Polymer Materials Development
- Biofabrication and Cell Culture

- We have more than 60 currently involved faculty, staff, students, and post-doctoral researchers.
- Everything we do involves additive manufacturing.





OUR GOALS

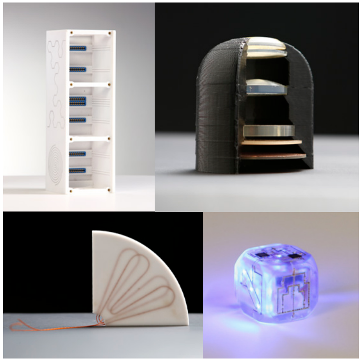
1. Develop strong multi-disciplinary national and international collaborations with other universities, government agencies, and industrial partners as well as strengthen and expand collaborations within UTEP.
2. Develop broad expertise and expand horizons by engaging new faculty in Center activities.
3. Educate and train undergraduate and graduate students in AM.
4. Mentor and engage K-12 students, teachers, and the public in AM.
5. Disseminate research results in technical journals and conference proceedings.
6. Develop patents and other intellectual property with licensing opportunities.
7. Increase exposure of UTEP and the Keck Center through invited national and international presentations.
8. Serve the needs of inventors, entrepreneurs, and industry through education and access to expertise and world-class AM facilities.
9. Become recognized as the premier university research center in the world focused on AM.
10. Expand expertise in 3D design, fabrication, and testing; AM materials (ceramics, metals, polymers, and composites); novel processing of materials (AM processes); AM process control; hybrid AM systems; 3D printed electronics; and applications of AM.

RESEARCH HIGHLIGHTS

Additive Manufacturing technology allows us to take a computer-aided design (CAD) of an object and quickly create a 3D model, mold, or functional part by precisely building layers of material. It is an exciting technology that explores new worlds of research, limited only by the imagination.

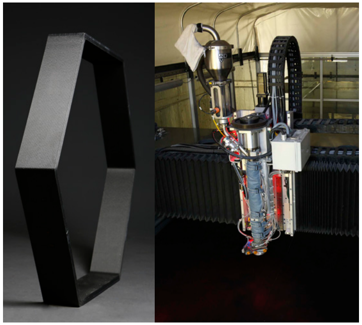
HYBRID AM

The active integration of multiple technologies with AM, produces unique capabilities that result in new and exciting manufacturing processes. The Keck Center's Multi^{3D} technology combines complementary processes resulting in the realization of multi-functionality. The Foundry Multi^{3D} System, All-In-One Multi^{3D} System, Multi-functional BAAM System, and the Compact Multi-Tool Fabricator, combine thermoplastic material extrusion, wire and foil embedding, machining, direct-write, and robotic component placement for the fabrication of unique devices valued in industries such as aerospace, biomedical, and consumer electronics.



LARGE AREA AM

The Cincinnati Big Area Additive Manufacturing (BAAM) System, with a print area of 140 x 65 x 72 inches, allows for large-scale rapid prototyping and direct fabrication of construction and vehicle components, to name a few. The BAAM extrudes at a rate of 20 lb/min with materials ranging from carbon-filled ABS to polyethylene terephthalate glycol (PETG). UTEP's custom BAAM system will soon include a wire embedding tool that will allow for large-scale 3D printed parts with embedded filaments or wires for reinforcement of electrical interconnect.

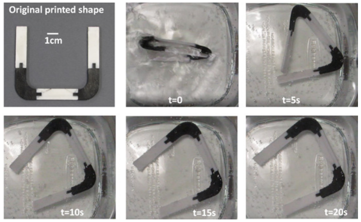


POLYMER-BASED AM

The use of polymers in AM enables the production of parts with applications ranging from automobile components to biomedical implants. There exists a myriad of material options, ranging from ULTEM (a high performance thermoplastic with excellent strength-to-weight ratio) to polyethylene glycol (a biocompatible and potentially biodegradable polymer). Common polymer AM processes include material extrusion and vat photopolymerization, both technologies contained in the Keck Center's broad collection of machines.

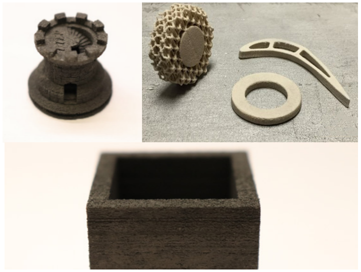
AM-ENABLED MATERIALS SCIENCE

By developing novel polymer matrix composites and polymer blends, we can create printable materials with tunable physical properties such as mechanical strength, hardness, flexibility, and elasticity as well as optimized electromagnetic properties such as permittivity and permeability. Materials development also allows for fabrication of components with enhanced thermal conduction or radiation shielding, as well as the creation of new biopolymer-based composites or polymers with shape memory characteristics. Similarly, for metal-based AM, nucleation agents have been selectively introduced into metal powder feedstock materials processed via powder bed fusion AM technologies to tailor microstructure. The control of the phases that develop, has also been achieved through in situ nitriding by substituting the shield gas used during laser powder bed fusion AM.



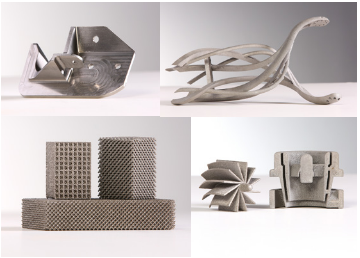
CERAMIC-BASED AM

The use of ceramics in AM is gaining popularity for their inherent mechanical, electrical, and thermal properties. Ceramics can be used in printed circuit boards, sensors, heaters, transducers, high temperature functional materials, nuclear materials, and biomedical applications such as in the construction of dental and bone implants. At the Keck Center, ceramics printing technologies such as binder jetting, vat photopolymerization, and paste extrusion have been studied as means for printing ceramic parts using materials such as AlN, $BaTiO_3$, PZT, Al_2O_3, SiC, $LiNbO_3$, and SiO_2.



METAL-BASED AM

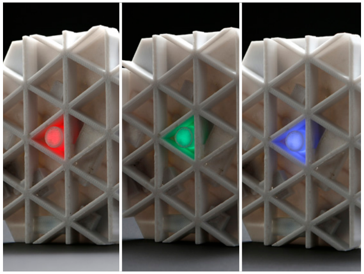
AM of metals refers to a class of AM processes where end-use parts are directly fabricated, usually layer-by layer, from digital data. Technologies that fabricate from powder metal systems hold promise to revolutionize the way we currently fabricate complex metallic components by enabling the design and production of more efficient (stronger and lighter), less expensive components. Our research in this area has focused on development of process parameters for an array of powder materials (listed on page 8) and in situ process monitoring to understand the process in a more effective manner.



APPLICATIONS OF AM

3D Printed Electronics

Over the past decade, UTEP has tuned its hybrid manufacturing capabilities for the development of 3D Printed Electronics – multi-material, heterogeneous, electronic structures exhibiting non-conventional 3D component placement and conductor routing. The incorporation of copper wire/foil embedding through thermal or ultrasonic methods allows for enhanced conductivity between electronic components. These efforts are of particular importance to the aerospace industry, intelligence community, and national defense agencies.



Biomedical Printing Applications

We are capable of creating 3D anatomical models to aid surgeons and medical researchers. Individualized computer and physical models can be created from medical imaging data to simulate the anatomy of, for example, an abdominal aneurysm, a human jawbone, or even a human brain. We also study flow characteristics in individualized cardiovascular system models and are breaking new ground by creating bioactive tissue engineering “scaffolds” that give regenerated tissue a place to live and grow. These complex-shaped hydrogel constructs have been applied in guided angiogenesis and nerve regeneration.

FACILITIES

Headquartered at The University of Texas at El Paso, the Keck Center is a lab like no other in the world. The Keck Center features a unique blend of equipment and facilities to perform fundamental and applied research allowing for trailblazing discoveries to be made in limitless arenas of science, including electronics fabrication, materials science, biology, chemistry, and many more.

MULTI^{3D} TECHNOLOGY

Multi-functional BAAM

Capabilities:

- Pellet-fed material extrusion
- Wire embedding *(coming soon)*

Foundry Multi^{3D} System

Capabilities:

- Filament-fed material extrusion
- Robotic component placement
- Machining
- Wire/foil embedding
- Direct write

All-In-One Multi^{3D} System

Capabilities:

- Filament-fed material extrusion
- Pellet-fed material extrusion
- Robotic component placement
- Machining
- Wire/foil embedding

Compact Multi-Tool Fabricator

Capabilities:

- Filament-fed material extrusion
- Pellet-fed material extrusion *(coming soon)*
- Wire embedding
- Machining

ADDITIVE MANUFACTURING/3D PRINTING

Powder Bed Fusion

Arcam EBM machines with in situ monitoring, automatic control, and high temperature capabilities

Materials:

- Ti6Al4V	- Inconel 625	- Copper
- Ti6Al4V ELI	- Inconel 718	- Niobium
- Cobalt-Chromium	- Inconel 690	- TiAl
- Rene 142	- Maraging Steel	- Stainless Steel 316L
- Rene 80	- Pure Iron	- Al 4047

SLM Solutions machine

Materials:

- Inconel 718	- Stainless Steel 316L
- AlSi10Mg	- Niobium

Aconity3D laser-based powder bed fusion system with high temperature capabilities, co-axial high-speed camera, and single-wavelength pyrometers

Materials:

- AlSi10Mg	- Al6061

Material Extrusion

Stratasys FDM machines (large and small build volumes)

Materials:

- ABS	- ABS-ESD7	- PC-ISO
- ABSi	- Nylon 12	- PPSF/PPSU
- ABS-M30	- PC	- ULTEM 9085
- ABS-M30i	- PC-ABS	- ULTEM 1010

An armada of desktop 3D printers, including Stratasys uPrint and Lulzbot Taz systems

Materials:

-ABS	- Flexible filaments
-PLA	- Experimental materials

Vat Photopolymerization

3D Systems SLA machines (large and small build volumes)

Materials:

- WaterShed XC 11122	- Somos NeXt	- Somos 9120
- Somos NanoTool	- Somos NanoForm 15120	
- ProtoTherm 12120	- ProtoCast AF 19120	
- Accura SL5530	- Formlabs Resins	

- Poly(ethylene glycol) for biomedical applications

Custom Micro-Stereolithography system

EnvisionTec DLP system

Binder Jetting

ExOne developmental and manufacturing-grade systems

Materials:

- Al2O3	- Stainless Steel	- Tungsten
- Inconel 625	- Iron	- Inconel 718
- Cobalt-Chromium	- Sand for sand casting applications	

ZCorp 3D color printers

Material Jetting

Objet Polyjet system

Sheet Lamination

Solido desktop system

POLYMER EXTRUSION LAB

- Dr. Collin twin screw extruder/compounder with monofilament spooling system and pelletizer
- Filabot single screw extruders
- Custom desktop extruders
- Tinius Olsen polymer impact tester
- Tinius Olsen melt indexer
- Mitutoyo durometer
- Brabender GranuGrinder
- DriAir CAFM micro dryer
- Desktop material extrusion 3D printers
- Custom strand pelletizer
- RMC Boeckeler ultramicrotome equipped with CR-X cryo system
- Hitachi variable pressure SEM equipped with STEM, BSE, standard and low vacuum SE detectors and EDS system
- Thermo Scientific Nicolet FT-IR spectrometer
- Materials developed:

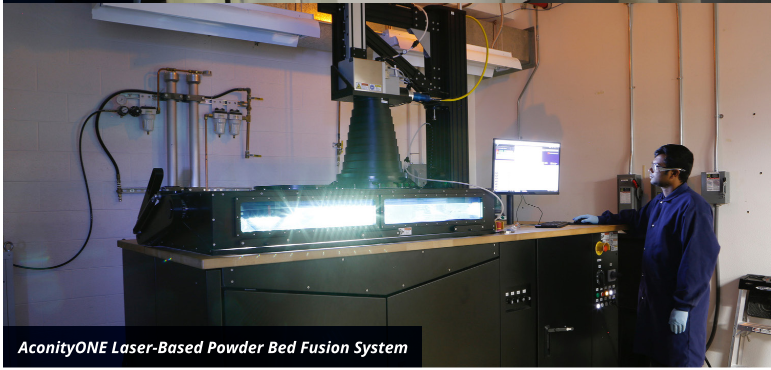
- Novel polymer matrix composites
- Novel polymer alloys
- ABS, PC, PLA, PEEK, and thermoplastic elastomers
- Shape memory polymers

CNC MACHINING AND SOFT TOOLING

- Haas Super mini mill
- Mori-Seiki lathe with live tooling
- MCP vacuum casting system
- Techno CNC router

SLM 125 HL

ExOne M-Flex


AconityONE Laser-Based Powder Bed Fusion System

MATERIALS CHARACTERIZATION

This equipment is available through the Department of Metallurgical, Materials, & Biomedical Engineering

- Bruker XRD
- Hitachi field emission and tabletop scanning electron microscopes (SEM)
- Hitachi transmission electron microscope (TEM)
- SEM and TEM specimen preparation equipment and facilities

REVERSE ENGINEERING AND METROLOGY

- SCANCO micro-CT scanner
- LDI laser scanning system
- OGP optical metrology system
- NextEngine 3D laser scanner

MECHANICAL TESTING

- Instron electromechanical testing machine with temperature-controlled chamber
- 2 MTS servohydraulic test systems *(monotonic and cyclical capabilities in axial and torsional loading conditions)*

SYNTHETIC AND ANALYTICAL CHEMISTRY

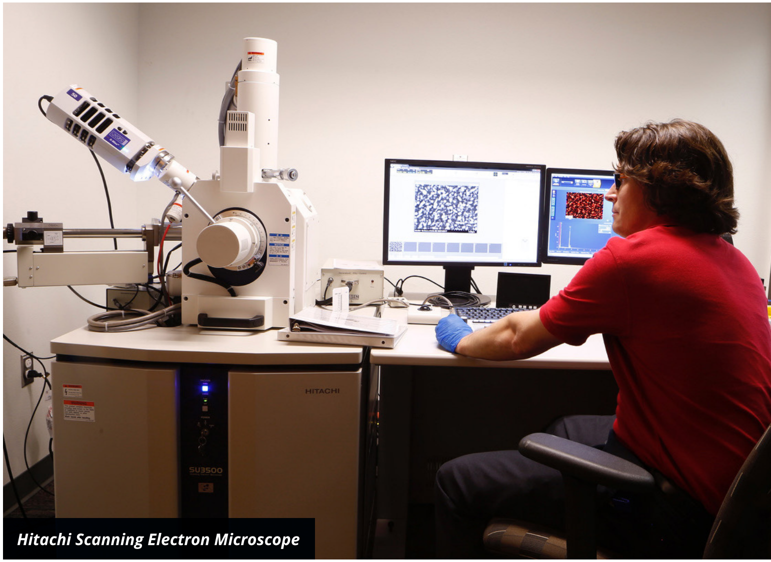
- Chemical laboratory furnished with synthesis, measurement, and preparation equipment
- Sentro Tech 1600°C box furnace
- JPW Industrial 260°C oven
- Neytech 1100°C furnace
- Vac-u-max vacuum and powder sifter

CELL CULTURE [TISSUE ENGINEERING]

- Labconco biosafety cabinet
- Leica inverted and Stereomicroscopes
- Sartorius water purification and reverse osmosis systems
- Waterjacket CO_2 incubators

3D STRUCTURAL AND PRINTED ELECTRONICS

- Integrated FDM/DP & SL/DP Systems
- Dimatix materials printer
- 2 nScrypt microdispense *(direct-write)* systems
- Dukane ultrasonic embedding horns



Hitachi Scanning Electron Microscope

ACHIEVEMENTS OF THE CENTER

The Keck Center celebrated 18 years of laboratory operations and research focused on additive manufacturing.

As of Spring 2017, the Keck Center expanded its operations to a 17,000-square-foot, off-campus facility, which provides additional space for research, business development, and training.

UTEP will serve as the North American base of operations for Aconity3D, one of the world's emerging technology leaders in the production of laser-based 3D printing equipment, under a new agreement announced by the two organizations in the summer of 2018. Through this agreement with UTEP, Aconity3D will further enhance its production and service operations, attract high-end jobs for engineering students in the community, and advance the broader technology through meaningful research investigations involving UTEP, Aconity3D, government agencies, and industry.

UTEP is a satellite center of America Makes, the National Additive Manufacturing Innovation Institute. A ribbon cutting ceremony on Aug. 7, 2015, hosted the Honorable Penny Pritzker, former U.S. Secretary of Commerce.

In Fall 2017, UTEP debuted its Graduate Certificate in 3D Engineering and Additive Manufacturing through the Department of Mechanical Engineering. This program leverages Keck Center expertise in AM as well as its highly-equipped manufacturing and testing facilities to train the next generation of engineers. UTEP has partnered with America Makes and Autodesk to further enhance the curriculum and give it an industry edge.

The Keck Center has a significant and expanding patent portfolio: 12 U.S. patents, 3 foreign patents (Europe and Asia), and multiple pending applications. Four patents have been licensed by companies, including “Method and Apparatus for Wire Handling and Embedding on and Within 3D Printed Parts” (15/244/061), “Electronic Die with Microprocessor and Accelerometer for Visual Enhanced Gaming” (9,908,307), and “Methods and Systems for Integrating Fluid Dispensing Technology with Stereolithography” (7,658,603 and 8,252,223).

The Keck Center’s peer-reviewed journal, Additive Manufacturing, is published in cooperation with Elsevier and affiliated with America Makes to provide academia and industry with high quality research articles and reviews in AM. It covers a wide scope of topics, including new technologies, processes, methods, materials, systems, and applications. New submissions are always welcome.

UTEP has a long history of leading the global development of hybrid additive manufacturing. Examples of this include three multi-million dollar research efforts as the result of grants awarded by America Makes. These projects have resulted in the creation of the Foundry Multi^{3D} System, the All-In-One Multi^{3D} System, and the Multi-functional BAAM system, all with the purpose of building multi-material, multi-functional components.

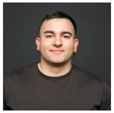
HOW WAS THE CENTER ESTABLISHED?

The Keck Center was established in 2000 as part of a $1 million grant from the W.M. Keck Foundation. It expanded to its current 13,000 square feet in 2011 as a result of funding from the Texas Emerging Technology Fund, the University of Texas System, and Lockheed Martin.

STUDENT RESEARCHERS


Carlos
Acosta


Sol
Barraza


Valentin
Becerra


Alejandra
Belmont


Adrian
Belmontes


Diego
Bermudez


Kazi
Billah


Israel
Carrete


Pablo
Castrejon


Colton
Caviglia


Luis
Chavez


Heidi
Fehr


Brandon
Fischer


Diana
Gandara

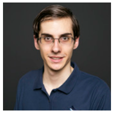

Oscar
Garcia


Stephanie
Guerra

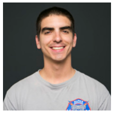

Leonardo
Gutierrez


Edgar
Heredia


Lluvia
Herrera


Alexander
Hillstrom


Naim
Jahangir


Xavier
Jimenez


Dominic
Kelly

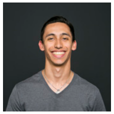

Jake
Lasley

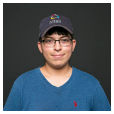

Ferrant
Mayoral


Christopher
Minjares


Jose
Motta


Hao
Moy


Andre
Navarro


Michael
Nigro


Joseph
Prochovnik


Carlos
Rodriguez


Andrea
Saenz

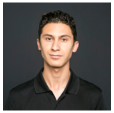

David
Saenz


Kevin
Schnittker


Zia
Uddin


Issac
Varela


Jaime
Varela


Sebastian
Vargas


Angel
Vega

Student researchers not pictured: Andres Llausas, Christian Rodarte, Charlie Sullivan, Carlos Tafoya, Enrique Vasquez, Evelyn Vasquez, Andrea Villela

POST-DOCTORAL RESEARCHERS

Edel Arrieta, Ph.D.

Carlos Diaz, Ph.D.

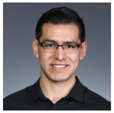
STAFF

Mireya Flores, M.S.
Center Manager

M. Alexandra Plasencio, B.B.A.
Business Manager

Philip Morton, B.S.
Applications Manager

Luis Ochoa, B.S.
Manager
3D Printing and
Manufacturing Services



Jose Coronel, M.S.
Research Manager

Mahesh Tonde, M.S.
Manager
3D Printing and
Manufacturing Services

Alfonso Fernandez, B.S.
Powder Bed Manager

FACULTY

Ryan Wicker, Ph.D., P.E.
Director & Founder
Professor
Department of
Mechanical Engineering

Francisco Medina, Ph.D.
Director of Technology and
Engagement
Associate Professor
Department of
Mechanical Engineering

David Espalin, Ph.D.
Director of Research
Assistant Professor
Department of
Mechanical Engineering

Chiyen Kim, Ph.D.
Research Assistant Professor
Department of Mechanical
Engineering

David A. Roberson, Ph.D.
Associate Professor
Department of
Metallurgical, Materials, &
Biomedical Engineering

Cesar Terrazas, Ph.D.
Research Assistant Professor
Department of Mechanical
Engineering

Yirong Lin, Ph.D.
Associate Professor
Department of Mechanical
Engineering

THE UNIVERSITY OF TEXAS AT EL PASO
COLLEGE OF ENGINEERING

CONTACT US

The University of Texas at El Paso
Engineering Building, Room 108
500 W. University Ave.
El Paso, Texas 79968
Phone: (915) 747-7443
Fax: (915) 747-5019
Email: wmkeckcenter@utep.edu
Website: http://www.keck.utep.edu

W.M. KECK CENTER FOR 3D INNOVATION

Driving the Additive Manufacturing Revolution
2018 - 2019

America Makes
National Additive Manufacturing Innovation Institute