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.

- 13,000 square foot, state-of-the art facility with over 50 AM machines.
- Combined facilities for:
  - AM/3D Printing
  - CNC Machining & Soft Tooling
  - Microscopy
  - Electronics (3D Printed, PCB, and Silicon)
  - Synthetic & Analytical Chemistry
  - CAD & Design
  - Reverse Engineering & Metrology
  - Mechanical Testing
  - Polymer Materials Development
  - Biofabrication and Cell Culture

- Over 60 currently involved faculty, staff, students, and 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.
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
We are actively integrating multiple technologies with AM to produce unique capabilities that result in new and exciting manufacturing processes. The combination of material extrusion, direct wire embedding, micromachining, direct-write of conductive inks, machine vision, and robotic component placement allows the fabrication of unique devices valued in industries like aerospace, biomedical and consumer electronics. This combination of complementary technologies results in the realization of multi-functionality.

3D PRINTED ELECTRONICS
UTEP has been leading the convergence of AM and Direct Printing (DP) technologies over the past decade for the development of 3D Printed Electronics – multi-material, heterogeneous, electronic structures exhibiting non-conventional 3D component placement and conductor routing. We have also now incorporated the use of copper wires/foils embedded through thermal or ultrasonic methods for improved conductivity. These efforts are of particular importance to the aerospace industry, intelligence community, and national defense agencies.
POLYMER-BASED AM
The use of polymers in AM enables the production of parts ranging from automobile components to biomedical implants. A wide variety of material systems are available such as ULTEM (a high performance thermoplastic with excellent strength-to-weight ratio) and 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.

ENGINEERED AND STRUCTURED MATERIALS
We are investigating ways to improve thermoplastic materials that are used to create prototypes and functional parts. This is achieved through the use of additives and material blends that improve material strength, hardness, flexibility, and stretchability as well as optimize permittivity and permeability, increase thermal conductivity, and improve radiation shielding.

CERAMIC-BASED AM
The use of ceramics in AM is gaining popularity for their ability to withstand high temperatures and chemical erosion. Ceramics can be used in printed circuit boards, sensors, heaters and transducers, as well as in biomedical applications such as in the construction of dental and bone implants. Binder jetting technology, one of the Keck Center’s many capabilities, has been studied as a means for building ceramic parts using materials like Barium Titanate IV and Aluminum Oxide.
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.

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 (faster, stronger, and lighter) and less expensive components.
Headquartered at The University of Texas at El Paso, the Keck Center is a lab like no other in the world with 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.
ADDITIVE MANUFACTURING/3D PRINTING

- Custom Multi3D System (Pictured on cover)

Capabilities:
- Material extrusion (*multiple machines*)
- Wire/foil embedding
- Robotic component placement
- Direct write
- Micromachining
- Machine vision
- Powder Bed Fusion

Arcam Electron Beam Melting machines with in situ monitoring, automatic control, and high temperature capabilities

Materials: (*build processing parameters developed for multiple proprietary materials not shown below*)
- Ti6Al4V
- Inconel 625
- Copper
- Ti6Al4V ELI
- Inconel 718
- Niobium
- Cobalt-Chromium
- Inconel 690
- TiAl
- Rene 142
- Maraging Steel
- Stainless Steel 316L

SLM Solutions Selective Laser Melting machine

Materials:
- Ti6Al4V
- AlSi10Mg
- Stainless Steel 316L
- Inconel 625
- AlSi12Mg
- Tool Steel
- Inconel 718
- AlSi7Mg
- Cobalt-Chromium
- AlSi9Cu3

Aconity3D Selective Laser Melting machine with high temperature capabilities

Materials:
- Ti6Al4V
- AlSi10Mg
- Stainless Steel 316L
- Inconel 625
- AlSi12Mg
- Tool Steel
- Inconel 718
- AlSi7Mg
- Cobalt-Chromium
- AlSi9Cu3
- Al2O3

- Material Extrusion
- Stratasys Fused Deposition Modeling machines
  (*large and small build machines*)
  Materials:
- ABS
- ABS-ESD7
- PC-ISO
- ABSi
- Nylon 12
- PPSF/PPSU
- ABS-M30
- PC
- ULTEM 9085
- ABS-M30i
- PC-ABS

An armada of low-cost desktop 3D printers

- Vat Photopolymerization
- 3D Systems Stereolithography machines (*large and small build machines*)
  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
- Inconel 718
- Iron
- Cobalt-Chromium
- ZCorp 3D color printers
- Sand for sand casting applications

- 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
- Cryo ultramicrotome
- 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

CNC MACHINING AND SOFT TOOLING
- Haas Super mini mill
- Mori-Seiki lathe with live tooling
- MCP vacuum casting system
- Techno CNC router
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
- 3D Systems 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 CO2 incubators

3D STRUCTURAL AND PRINTED ELECTRONICS
- Integrated FDM/DP & SL/DP Systems
- Dimatix materials printer
- 2 nScrypt microdispense (direct-write) systems
ACHIEVEMENTS OF THE CENTER

The Keck Center celebrated 16 years of laboratory operations and research focused on additive manufacturing. As of Spring 2017, the Center will expand its operations to a new off-campus facility which will provide additional space for research, business development, and training.

We have had many joint projects within UTEP as well as collaborated with numerous companies, universities, and government agencies on applied research projects ranging from medical devices and custom implants to 3D structural electronic devices such as satellites, UAVs, and wearable sensor systems.

UTEP was selected as the first satellite center of America Makes, the National Additive Manufacturing Innovation Institute. A ribbon cutting ceremony on August 7, 2015 hosted Penny Pritzker, U.S. Secretary of Commerce.

The Keck Center’s new 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 additive manufacturing. It covers a wide scope of topics including new technologies, processes, methods, materials, systems, and applications. New submissions are 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. Researchers focused on creating the Multi3PO System (pictured on the cover) and its low-cost counterpart (under development), for the fabrication of multi-material, multi-functional components.
The Keck Center has a significant and expanding patent portfolio: 9 U.S. patents, 2 foreign patents (Europe and Asia), and 11 pending applications. Some patented technologies include processes for fabricating 3D structural electronics (US Patents 7,419,630 and 7,658,603) in which direct-print micro-dispensing technology has been integrated with SL and FDM.

We developed a micro-Stereolithography (micro-SL) machine based on a Texas Instruments Digital Micro-mirror Device (DMD) that can fabricate unique multiple material structures with an image resolution of ~2 microns. We have also developed automated process interruption in SL, Fused Deposition Modeling (FDM), and Electron Beam Melting (EBM) allowing the in situ integration of other technologies to fabricate custom multi-material, multi-component and multi-function devices.

We are developing new materials for FDM with applications in high temperature, high-speed electronics, medical-grade implants, composite materials, and materials for electromagnetics.

We have studied optimized build parameters for Electron Beam Melting (EBM) of different metals and metal alloys including Ti-6Al-4V, cobalt-chromium, Inconel 625, Inconel 718, copper, niobium, and TiAl. Extensive microstructural studies have been performed to develop these optimized process parameters.

**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 and since then, has expanded to its current 13,000 square feet as a result of funding from the Texas Emerging Technology Fund, the University of Texas System, and Lockheed Martin.
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