Francisco Medina, Ph.D.

Associate Professor, Mechanical Engineering, University of Texas at El Paso
Director Technology and Engagement, W.M. Keck Center of 3D Innovation

DETAILED CURRICULUM VITAE
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EDUCATION

Ph.D. in Material Science and Engineering- December 2013
The University of Texas at El Paso

Dissertation title: "Reducing Metal Alloy Powder Costs for Use in Powder Bed Fusion Additive Manufacturing: Improving the Economics for Production"
Advisor: Ryan Wicker

M.S. in Mechanical Engineering - Dec 2005
The University of Texas at El Paso

Thesis title: "Functional Integrated Layered Manufacturing: Expanding Horizons for Stereolithography"

B.S. in Mechanical Engineering- Dec 2000
The University of Texas at El Paso

PROFESSIONAL EXPERIENCE

ACADEMIC APPOINTMENTS

The University of Texas at El Paso:
Associate Professor Mechanical Engineering, May 2018 – Present
The University of Texas at El Paso:
Lecturer of Mechanical Engineering/Metallurgical & Material Science, September 2009 – August 2013
El Paso Community College:
Part-time Engineering Faculty, September 2008-December 2012

SIGNIFICANT RESEARCH LABORATORY DEVELOPMENT

The University of Texas at El Paso:
Center Manager, W.M. Keck Center for 3D Innovation, August 2000 – August 2013.
Director and Co-Founder, Rapid Design and Manufacturing Laboratory (a University Recharge Center), June 2004 –August 2013

EXPERIENCE

Associate Professor, Mechanical Engineering, University of Texas at El Paso, May 2018- Present
Director Technology and Engagement, W.M. Keck Center of 3D Innovation

Technology Leader, Additive Manufacturing February 2016- June 2018
Director, Additive Manufacturing Consortium, EWI/Buffalo Manufacturing Works

- Establish the vision and goals for the additive manufacturing technology and represent EWI nationally/internationally to help grow the EWI brand.
- Manage over 45 consortium members, as well as, over $1.25M of project contribution and in-kind support yearly.
- Annually organize members new project ideas and help manage the execution of the yearly projects to provide value to the consortium members and grow the consortium.
- In 2016 and early 2017 doubled the number of full members in the U.S., Europe, South America, and Asia. As of October 2017, the AMC consisted of over 45 members, all users of AM technology.
- Manage and organize quarterly meetings that are hosted at EWI and research partner sites, doubled members attendance to 140 attendees on quarterly meetings.
- Lead projects and/or programs of significant importance to the business in additive manufacturing and material development.
- Do business development to seek new opportunities for AM projects in the aerospace, medical, and heavy industry.
- Mentor and review work of other engineers on assigned projects to ensure effective problem resolution.
- Develop and publish research papers for external peer review and comment.
- Introduce new technical ideas or technologies that may lead to industrial applications.

Senior Specialist, Materials Development Sept 2013- February 2016
Arcam AB, Oak Ridge National Laboratories TN

- Managed Arcam's relationship and R&D activities in North America, such as ORNL, Pratt and Whitney, Honeywell, etc.
- Validated and industrialized process themes for Inconel 718 in EBM technology and helped Honeywell manufacture parts for production runs.
- Taught advanced EBM Level 3Training for material development around the world with new AM alloys to universities and aerospace clients.
- Worked with medical device companies such as DiSanto, Lima, and Stryker on material characterization, machine evaluation, new material selection and development.
- Provided advanced EBM application support to customers and potential customers on selection of candidate parts for AM production.
- Provided support and assistance to Arcam's sales force on new machine sales leads.

Director/Center Manager June 2002-August 2013
University of Texas at El Paso, Rapid Design and Manufacturing Lab/W.M. Keck Center for 3D Innovation.

- Managed/supervised over $10M of equipment/instrumentation and over 16 graduate and undergraduate students, 2 post-doctoral, 5 engineers, and 2 administrators.
- Developed (patented and patent pending) additive manufacturing technologies for fabricating bioactive tissue engineered scaffolds, 3D structural electronic devices, and multiple material devices using AM and other integrated technologies.
- Worked with medical device companies and developing unique anatomical models for medical device development.
- Worked with surgeons and providing pre-surgical anatomical models manufactured using additive manufacturing technologies for improved surgical planning, patient diagnosis, and patient consultation (Over 40 cases).
- Helped create and manage a rapid prototyping recharge center for the university and grew it to $750K/year with over 50 industrial customers.
- Brought in ~$2M/year in industrial and federal AM research projects and grants.
- Collaborated with research scientists and engineers and developed new manufacturing techniques.
- Responsible for purchasing equipment and coordinating with facility services on facility needs, grew the center to over 50 AM machines in polymers, ceramics, and metals.
- Responsible for developing and teaching training programs on all equipment and instrumentation.
- Taught special AM courses to private and federal entities that ranged from one to four weeks with hands-on AM machine experience.

Part-time Faculty September 2008-December 2012
El Paso Community College, Engineering

- Teach Engineering Graphics and Engineering Economics.
- Provide assistance on developing the colleges engineering curriculum.

Graduate Professional Coop Jan 2002-June 2002
Sandia National Labs, Advanced Manufacturing Complex.

- Develop new applications for stereolithography by incorporating with other technologies.
- Design and set up experimental test procedures for material compatibility.
- Operate rapid prototyping and 3-D scanning equipment for internal clients.
- Guide and design New Mexico small businesses through small business project development.
- Provide price quotes for rapid prototyping jobs.

Laboratory Manager May 2000-Dec 2002
University of Texas at El Paso, Border Biomedical and Advanced Manufacturing Research Lab.

- Assist graduate students and several undergraduate students on laboratory research.
- MRI/CT image acquisition for volume rendering and model making for in-vitro experimentation.
- Create customized tools and models for surgical planning.
- Manage the operation of the FDM 3000 and SLA250/50 rapid prototyping machines.

Research Assistant Aug 1998-May 2000
University of Texas at El Paso, Engines and Alternative Fuels Research Lab.

- Developed a clutch-activated supercharger for a 2000 Chevrolet Silverado.
- Team member for the 1999-2000 Ethanol Vehicle Challenges (2nd and 4th overall).
- Raised over $40K for the Ethanol Vehicle Challenges.
- Redesigned a chassis dynamometer for midsize vehicles.

Junior Engineer Feb 1993-Aug 1998
Southwest Engineering and Associates

- Implemented the statistical process control for the CNC lathes and mills.
- Developed the painting process for the telemetry shells for the robbing missile.
- In charge of design and manufacturing of special projects.
- Provided managing assistance in the construction of a 5000 ft^2 machine shop.

ACADEMIC EXPERIENCE SUMMARY

COURSES TAUGHT

1. Rapid Manufacturing Systems
2. Introduction to Biomodeling
3. Engineering Economy
4. Engineering Graphics
5. Metals Short Course at RAPID 2013, 2014, 2016, 2017 and to teach 2018
6. Additive Manufacturing Short Course at Aeromat 2014 and to teach 2018
7. Intro to Additive manufacturing for Aerospace Short Course AeroDef 2017 and to teach 2018

SIGNIFICANT COURSE DEVELOPMENT

1. Rapid Manufacturing Systems (undergraduate/graduate).
2. Introduction to Biomodeling (undergraduate/graduate)
3. Engineering Economy (undergraduate)
4. Engineering Graphics (undergraduate)
5. Metals in Additive Manufacturing

RESEARCH LABORATORY DEVELOPMENT

W.M. Keck Center for 3D Innovation

- W.M. Keck Center for 3D Innovation (formerly the Border Biomedical Manufacturing and Engineering Laboratory) as a result of a $1 million grant awarded January 2002 from the W.M. Keck Foundation. Received additional infrastructure grants from Sandia National Laboratories ($1 million), University of Texas System faculty STARS program ($500k), and University of Texas System joint equipment requests with UT medical institutions ($1.4 million, proposals for equipment to participate in collaborative research with UT M D Anderson Cancer Center and UT Health Science Center at Houston). Recently received ~$9 million grant ($3 million state, $3 million UT System, and $3 million industry match) as part of the State of Texas Emerging Technology Fund to formally expand activities in Structural and Printed Electronics within the Keck Center.

- Managed the original (in 2005/2006) renovation and expansion from 1,500 square feet of floor space to over 6,100 square feet as well as the recent (2010/2011) expansion from 6,100

square feet to over 13,000 square feet. Specified and acquired over $6 million in equipment for additive and conventional manufacturing; materials and mechanical testing; experimental fluid mechanics; reverse engineering and metrology; analytical and synthetic chemistry; and cell culture/tissue engineering.

- The W.M. Keck Center for 3D Innovation, an engineering, biomedical and advanced manufacturing laboratory focused on multi-disciplinary biomedical, materials, and manufacturing research, represents a premier university research facility. The Keck Center's research hinges on the development and use of Additive Manufacturing (AM) technologies that allow for fabrication of complex three-dimensional shapes by successively manufacturing thin slices of a desired object and stacking them together one layer at a time. Infrastructure includes over 40 AM machines (11 FDM – including 1 patent pending technology; 11 SL – including 2 patented technologies and 1 bio-SL system; 2 EBM metals – including 1 Arcam A2 and 1 custom high temperature S12; 1 custom DMD-based micro-SL; 1 EnvisionTec DLP; 1 LS; 1 PolyJet; 2 ZCorp; 1 ExOne M-Lab; 11 Desktop 3D Printing Systems (2, VFlash; 1, Fab@Home Model 1; 1, Solido SD300 Pro; 1 Up! Personal Portable 3D Printer; 1 Bits from Bytes 3DTouch 3D Printer; 1 fabbster; 1, MakerBot Replicator; 3, MakerBot Replicator 2), and 3 micro-dispensing systems – including 1 Dimatix and 2 nScrypt micro-dispensing tools). Other manufacturing equipment includes 2 CNC machining centers (1 5-axis Haas Super Mini Mill 2 and 1 Mori-Seiki NL2000 lathe with live tooling) and equipment for dip-spin coating, vacuum casting, pressure casting, and plastic injection molding. Additional facilities include: reverse engineering and metrology (laser scanning, video measurement, CMM, and micro-CT); materials and mechanical testing including static and dynamic axial and torsional testing (Instron 5866, MTS 370 and 370.02 Servohydraulic Systems), optical microscopy and access to SEM and TEM; cardiovascular hemodynamics (experimental fluid mechanics); synthetic and analytical chemistry; and tissue engineering (including scaffold fabrication, polymer synthesis and cell culture capabilities). This Center represents a truly unique facility that provides unparalleled experiences for its students. AM technologies are being used to fabricate unique functional multi-material devices with embedded electronics and patient-specific anatomical shapes for use in pre-surgical planning, surgery, medical device development, cardiovascular flow research, tissue engineering, and more.

- The Keck Center can fabricate 3D objects that are plastic, metal, ceramic, of bio-compatible materials, composite materials, or that contain electronics. Major research efforts are underway in the areas of AM of powder metal alloy systems as well as 3D Structural Electronics in which electronics and thus intelligence can be fabricated within 3D mechanical structures. Using integrated AM technologies, electronics can be fabricated in a 3D structure of arbitrary and complex shape in order to accommodate human anatomy or simply to replace structural components in satellites, planes, cars or furniture with equivalent structures that contain intelligence. The State of Texas recognized the importance of this effort and recently awarded UTEP a multi-million dollar grant to establish and promote these activities.

- Developing (patented and patent pending) additive manufacturing technologies for fabricating bioactive tissue engineered scaffolds, 3D structural electronic devices, and multiple material devices using AM and other integrated technologies.

- Working with medical device companies and developing unique anatomical models for medical device development.

- Working with surgeons and providing pre-surgical anatomical models manufactured using additive manufacturing technologies for improved surgical planning, patient diagnosis, and patient consultation (Over 40 cases).

Rapid Design and Manufacturing Laboratory (a University Recharge Center)

- The Rapid Design and Manufacturing Laboratory, part of the W.M. Keck Center for 3D Innovation, was created to provide contractual engineering and manufacturing services to industry, government agencies, and universities.

- The Rapid Design and Manufacturing Lab provides unique educational opportunities for its students in an industrial-type setting, while allowing the technology developed in the W.M. Keck Center for 3D Innovation (where the fundamental and applied research occurs) to be tested and available to the government, universities, and industry (including the manufacturing, aerospace, defense, biotechnology, medical device, and health care industries), providing a mechanism for commercial ventures between the academic institution and industry, and enabling the institution to utilize its intellectual property, expertise, and infrastructure to bill for services and outreach activities (through industrial collaborations and biomodeling applications such as pre-surgical planning anatomical models) that in whole or in part pay for student salaries, laboratory equipment, maintenance, and materials.

CONSULTING ACTIVITIES

Alliance Spine, LLC, San Antonio, Texas (2008-2009)

Assisted with design and development of several medical products used in spine surgery and provided guidance on use of additive manufacturing for producing surgical instrumentation and implants

BioGeneral, San Diego, California (2006-2007)

Assisted with the implementation and material development of FDM technology for new products.

PROFESSIONAL SOCIETIES

Society of Manufacturing Engineers (current)
2014 Chair of RTAM
Materials Research Society (current)
SAE (current)
ASTM International (current)
F42 Executive board member
TMS (current)
American Society of Mechanical Engineers
MASE/SHIP

PATENTS

ISSUED

1. "Methods and Systems for Integrating Fluid Dispensing Technology with Stereolithography," *U.S. Patent 8,252,223*, F. Medina, R.B. Wicker, J. Palmer, D. Davis, B. Chavez, and P. Gallegos, 2012 (joint UTEP/Sandia National Laboratories patent, continuation of *U.S. Patent 7,658,603*).
2. "Hydrogel Constructs using Stereolithography," *U.S. Patent 8,197,743*, R.B. Wicker, F. Medina, K. Arcaute, L. Ochoa, C.J. Elkins, and B.K. Mann, 2012 (continuation of U.S. Patent *7,780,897*).
3. "Methods for Multi-Material Stereolithography," *U.S. Patent 7,959,847*, R.B. Wicker, F. Medina, and C. Elkins, 2011 (Notice of Allowance Issued February 8, 2011, Divisional Application for withdrawn methods claims from Multi-Material Stereolithography patent, *U.S. Patent 7,556,490*).
4. "Hydrogel Constructs using Stereolithography," *U.S. Patents 7,780,897*, R.B. Wicker, F. Medina, K. Arcaute, L. Ochoa, C.J. Elkins, and B.K. Mann, 2010 (Patent Application 20060237880; disclosed April 2005; filed April 2005 with U.S. Patent and Trademark Office; received first office action dated September 3, 2008; Notice of Allowance dated April 20, 2010).
5. "Methods and Systems for Integrating Fluid Dispensing Technology with Stereolithography," *U.S. Patent 7,658,603*, F. Medina, R.B. Wicker, J. Palmer, D. Davis, B. Chavez, and P. Gallegos, 2010 (joint UTEP/Sandia National Laboratories patent application, Patent Application 20060225834; disclosed July 2004; filed March 31, 2005 with U.S. Patent and Trademark Office; received first office action dated November 5, 2008; Notice of Allowance dated September 22, 2009).
6. "Multi-Material Stereolithography," *U.S. Patent 7,556,490*, R.B. Wicker, F. Medina, and C. Elkins, 2009 (disclosed December 2003, filed July 30, 2004 with U.S. Patent and Trademark Office, Notice of Allowance Issued March 9, 2009).
7. "Methods and Systems for Rapid Prototyping of High Density Circuits," *U.S. Patent 7,419,630*, J. Palmer, D. Davis, B. Chavez, P. Gallegos, R.B. Wicker, and F. Medina, 2008. (joint Sandia National Laboratories/UTEP patent application; Patent Application 20060237879; disclosed July 2004; filed April 2005 with U.S. Patent and Trademark Office).
8. "Reticulated Mesh Arrays and Dissimilar Array Monoliths by Additive Layered Manufacturing using Electron and Laser Beam Melting," U.S. Patent Pending, F. Medina, L.E. Murr, R.B. Wicker, and S.A. Gaytan (Provisional patent application filed May 15, 2009 and full application filed May 14, 2010 with U.S. Patent and Trademark Office).

PATENTS PENDING

9. "Hydrogel Constructs using Stereolithography," Foreign Counterpart Applications Pending in Japan and Europe, R.B. Wicker, F. Medina, K. Arcaute, L. Ochoa, C.J. Elkins, and B.K. Mann, (PCT filed April 2009).
10. "Extrusion-Based Additive Manufacturing System for 3D Structural Electronic and Electromechanical Components/Devices," U.S. Patent Pending, R.B. Wicker, E. MacDonald, F. Medina, D. Espalin, and D. Muse, (disclosed June 30, 2011).
11. "Methods and Systems for Embedding Filaments in 3D Structures, Structural Components, and Structural Electronic, Electromagnetic and Electromechanical Components/Devices," U.S. Patent Pending, R.B. Wicker, E. MacDonald, D. Muse, F. Medina, and D. Espalin, (filed March 14, 2013).
12. "Methods and Systems for Connecting Inter-layer Conductors and Components in 3D Structures, Structural Components, and Structural Electronic, Electromagnetic and Electromechanical Components/Devices," U.S. Patent Pending, R.B. Wicker, E. MacDonald, D. Muse, F. Medina, and D. Espalin, (filed March 14, 2013).

AWARDS AND HONORS

Best Creative Part, 2010 EBM User Group Meeting, Melbourne Beach, Florida, October 5-7, 2010

Solid Freeform Fabrication and Rapid Prototyping Journal Best Presentation Award, 20th Annual Solid Freeform Fabrication Symposium, August 3-5, 2009, for presentation of article entitled "Fused Deposition Modeling of Polymethylmethacrylate for Use in Patient-Specific Reconstructive Surgery" by K. Arcaute, D. Rodriguez, D. Espalin, F. Medina, M. Posner, and R.B. Wicker, (article presented by David Espalin, mechanical engineering undergraduate student).

First Place, Stratasys Users Group Conference Part Competition, Entry entitled "Rapid Manufacturing of an Airplane Window Shade," *2007 Stratasys Users Group Meeting*, Charlotte, North Carolina, September 3-5, 2007

First Place, 3D Systems Users Group Advanced Concepts Technical Competition, Entry entitled "Multi-Material Stereolithography," *2007 3D Systems Users Group Conference*, Daytona Beach, Florida, March 18-22, 2007

Journal article recognized by Emerald Group Publishing as Outstanding Paper and received the Emerald Literati Network Awards for Excellence 2007 (J.A. Palmer, B. Jokiel, C.D. Nordquist, B.A. Kast, C.J. Atwood, E. Grant, F.J. Livingston, F.R. Medina, and R.B. Wicker, "Mesoscale RF Relay Enabled by Integrated Rapid Manufacturing," *Rapid Prototyping Journal*, Volume 12, Issue 3, 2006, pages 148-155)

2004 recipient of the Dick Aubin Distinguished Paper Award for the 2004 Rapid Prototyping and Manufacturing Conference (Rapid Technologies and Additive Manufacturing Division of the Society of Manufacturing Engineers), May 10-13, 2004

First Runner Up, 2004 Stereolithography Excellence Award, 3D Systems North American Stereolithography Users Group and SLS Users Group Joint Conference, Anaheim, California, April 25-29, 2004

SCHOLARLY ACTIVITY

The following code letters are utilized to indicate the nature of the review process:

W. Full paper reviewed by one or more anonymous referees
X. Full paper reviewed by editor or by conference committee, etc.
Y. Abstract of paper reviewed
Z. Not reviewed

JOURNAL ARTICLES AND BOOKS

1. Yang, L., Hsu, K., Baughman, B., Godfrey, D., Medina, F., Menon, M. and Wiener, S., 2017. Additive Manufacturing of Metals: The Technology, Materials, Design and Production. Springer.
2. M. Kirka, F. Medina, R. Dehoff, and A. Okello. Mechanical Behavior of Post-processed Inconel 718 Manufactured Through the Electron Beam Melting Process. Mat Sci Eng A, Vol 680, pp338-346 (2017). *(W)*
3. W. Sames, K. Unocic, G. Helmreich, M. Kirka, F. Medina, R. Dehoff, S. Babu. Feasibility of In Situ Controlled Heat Treatment (ISHT) of Inconel 718 During Electron Beam Melting Additive Manufacturing. Add. Mfg, Vol 13 pp156-165 (2017). *(W)*
4. F. Medina, M. Kirka, U. Ackelid, and R. Dehoff. Developing Superalloy Material Process Parameters for Additive Manufacturing using Electron Beam Melting Technology. Superalloys 2016 pp359-366 (2016). *(W)*

5. P. Nandwana, W. Peter, R. Dehoff, L. Lowe, M. Kirka, F. Medina, S. Babu. Recyclability Study on Inconel 718 and Ti-6Al-4V Powders for Use in Electron Beam Melting. Met Trans B, Vol 47 pp754–762 (2016). *(W)*
6. W.J. Sames, M.M. Kirka, F. Medina, R.R. Dehoff, "In Situ Controlled Heat Treatment of Inconel 718 using Electron Beam Melting" *Rapid Prototyping Journal*, to appear, 2015. (W).
7. P. Nandwana, W.H. Peter, R. Dehoff, F. Medina, "Recyclability study on Inconel 718 and Ti-6Al-4V powders for use in electron beam melting" *Journal of Materials Science and Technology, to Appear, 2015. (W)*
8. M. Kirka, F. Medina, W.J. Sames, R.R. Dehoff, "Mechanical and Microstructure Attributes of Inconel 718 Processed via Electron Beam Melting" *Rapid Prototyping Journal*, to appear, 2015. (W).
9. D. Espalin, J. Ramirez, F. Medina, R. Wicker, "Multi-Material, Multi-Technology FDM: Exploring Build Process Variations," *Rapid Prototyping Journal*, to appear, 2013. (W).
10. E. Martinez, L.E. Murr, J. Hernandez, X. Pan, K. Amato, P. Frigola, C. Terrazas, S. Gaytan, E. Rodriguez, F. Medina, R.B. Wicker, "Microstructures of Niobium Components Fabricated by Electron Beam Melting,", *Metallography, Microstructure, and Analysis*, (10.1007/s13632-013-0073-9). (W).
11. L.E. Murr, E. Martinez, X.M. Pan, S.M. Gaytan, J.A. Castro, C.A. Terrazas, F. Medina, R.B. Wicker, D.H. Abbott, "Microstructures of Rene 142 Nickel-based Superalloy Fabricated by Electron Beam Melting," *Acta Materialia*, Volume 61, 2013, pages 4289-4296. (W).
12. J. Mireles, H.C. Kim, I.H. Lee, D. Espalin, F. Medina, E. MacDonald, and R.B. Wicker, "Development of a Fused Deposition Modeling System for Low Melting Temperature Metal Alloys," *Journal of Electronic Packaging*, Volume 135, Issue 1, (011008), 2013, 6 pages, (doi:10.1115/1.4007160). (W).
13. L.E. Murr, S. Gaytan, E. Martinez, F. Medina, and R.B. Wicker, "Next Generation Orthopaedic Implants by Additive Manufacturing Using Electron Beam Melting," *International Journal of Biomaterials*, Volume 2012, Article ID 245727, 14 pages (doi:10.1155/2012/245727), 2012.
14. X.Y. Cheng, S.J. Li, L.E. Murr, Z.B. Zhang, Y.L. Hao, R. Yang, F. Medina, and R.B. Wicker, "Compression Deformation Behavior of Ti-6Al-4V Alloy with Cellular Structures Fabricated by Electron Beam Melting", *Journal of the Mechanical Behavior of Biomedical Materials*, Volume 16, 2012, pages 153-162.
15. L.E. Murr, S.M. Gaytan, D.A. Ramirez, E. Martinez, J. Hernandez, K.N. Amato, P.W. Shindo, F. Medina and R.B. Wicker, "Metal Fabrication by Additive Manufacturing Using Laser and Electron Beam Melting Technologies," *Journal of Materials Science and Technology,* Volume 28, Issue 1, 2012, pages 1-14. (W).
16. J. Hernandez, L.E. Murr, K.N. Amato, E. Martinez, P.W. Shindo, F. Medina, R.B. Wicker, S.J. Li, and X-Y. Cheng, "Microstructures and Properties for a Superalloy Powder Mixture Processed by Electron Beam Melting," *Journal of Materials Science Research*, Volume 1, Number 3, 2012, pages 124-144. (W).
17. K. Puebla, L.E. Murr, S.M. Gaytan, E. Martinez, F. Medina, and R.B. Wicker, "Effect of Melt Scan Rate on Microstructure and Macrostructure for Electron Beam Melting of Ti-6Al-4V," *Materials Sciences and Applications*, Volume 3, 2012, pages 259-264. (W).
18. L.E. Murr, S.M. Gaytan, E. Martinez, F. Medina, and R.B. Wicker, "Fabricating Functional Ti-Alloy Biomedical Implants by Additive Manufacturing using Electron Beam Melting," *Journal of Biotechnology and Biomaterials*, Volume 2, Issue 3, 1000131, 2012, 11 pages. (W).

19. S.J. Li, L.E. Murr, X.Y. Cheng, Z.B. Zhang, Y.L. Hao, R. Yang, F. Medina, R.B. Wicker, "Compression Fatigue Behavior of Ti-6Al-4V Mesh Arrays Fabricated by Electron Beam Melting," *Acta Materialia*, Volume 60, Issue 3, 2012, pages 793-802. (W).
20. L.E. Murr, E. Martinez, S.M. Gaytan, D.A. Ramirez, B.I. Machado, P.W. Shindo, J.L. Martinez, F. Medina, J. Wooten, D. Ciscel, U. Ackelid, and R.B. Wicker, "Microstructural Architecture, Microstructures, and Mechanical Properties for a Nickel-Base Superalloy Fabricated by Electron Beam Melting," *Metallurgical and Materials Transactions A*, Volume 42, Issue 11, 2011, pages 3491-3508 (doi: 10.1007/s11661-011-0748-22011) (chosen by the Editors of Metallurgical and Materials Transactions to appear on Springer's website, SpringerLink, as a "Free Access" article). (W).
21. L.E. Murr, K.N. Amato, S.J. Li, Y.X. Tian, X.Y. Cheng, S.M. Gaytan, E. Martinez, P.W. Shindo, F. Medina, and R.B. Wicker, "Microstructure and Mechanical Properties of Open-Cellular Biomaterials Prototypes for Total Knee Replacement Implants Fabricated by Electron Beam Melting," *Journal of the Mechanical Behavior of Biomedical Materials,* Volume 4, Issue 7, 2011, pages 1396-1411. (W).
22. M.S. Nuzzo, M. Posner, W.J. Warme, F. Medina, R.B. Wicker, and B.D. Owens, "Compression Force and Pullout Strength Comparison of Bioabsorbable Implants for Osteochondral Lesion Fixation," *The American Journal of Orthopedics*, Volume 40, Number 4, 2011, E61-63. (W).
23. D.A. Ramirez, L.E. Murr, S.J. Li, Y.X. Tian, E. Martinez, J.L. Martinez, B.I. Machado, S.M. Gaytan, F. Medina, and R. B. Wicker, "Open-Cellular Copper Structures Fabricated by Additive Manufacturing using Electron Beam Melting," *Materials Science and Engineering A*, Volume 528, 2011, pages 5379-5386 (doi: 10.1016/j.msea.2011.03.053). (W).
24. S.M. Gaytan, L.E. Murr, D.A. Ramirez, B.I. Machado, E. Martinez, D.H. Hernandez, J.L. Martinez, F. Medina, and R.B. Wicker, "A TEM Study of Cobalt-Base Alloy Prototypes Fabricated by EBM," *Materials Sciences and Applications*, Volume 2, 2011, pages 355-363 (doi: 10.4236/msa.2011.25046). (W).
25. D.A. Ramirez, L.E. Murr, E. Martinez, D.H. Hernandez, J.L. Martinez, B.I. Machado, F. Medina, P. Frigola, and R.B. Wicker, "Novel Precipitate-Microstructural Architecture Developed in the Fabrication of Solid Copper Components by Additive Manufacturing Using Electron Beam Melting," *Acta Materiala*, Volume 59, Issue 10, June 2011, pages 4088-4099. (W).
26. E.O. Kung, A.S. Les, F. Medina, R.B. Wicker, M.V. McConnell, C.A. Taylor, "In Vitro Validation of Finite-Element Model of AAA Hemodynamics Incorporating Realistic Outflow Boundary Conditions," *Journal of Biomechanical Engineering,* Volume 133, Issue 4, 041003 (11 pages), 2011 doi:10.1115/1.4003526. (W).
27. E.O. Kung, A.S. Les, C.A. Figueroa, F. Medina, K. Arcaute, R.B. Wicker, M.V. McConnell, C.A. Taylor, "In Vitro Validation of Finite Element Analysis of Blood Flow in Deformable Models," *Annals of Biomedical Engineering,* Volume 39, Number 7, 2011, pages 1947-1960 (doi: 10.1007/s10439-011-0284-7). (W).
28. A.J. Onstad, C.J. Elkins, F. Medina, R.B. Wicker, J.K. Eaton, "Full-field Measurements of Flow through a Scaled Metal Foam Replica," *Experiments in Fluids*, Volume 50, 2011, pages 1571-1585 (doi: 10.1007/s00348-010-1008-8). (W).
29. J.W. Choi, F. Medina, C. Kim, D. Espalin, D. Rodriguez, B. Stucker, and R.B. Wicker, "Development of a Mobile Fused Deposition Modeling System with Enhanced Manufacturing Flexibility," *Journal of Materials Processing Technology*, Volume 211, 2011, pages 424-432. (2010; doi: 10.1016/j.jmatprotec.2010.10.019). (W).
30. S.M. Gaytan, L.E. Murr, E. Martinez, J.L. Martinez, B.I. Machado, D.A. Ramirez, F. Medina, S. Collins, and R.B. Wicker, "Comparison of Microstructures and Mechanical Properties for Solid

and Mesh Cobalt-Base Alloy Prototypes Fabricated by Electron Beam Melting," *Metallurgical and Materials Transactions A*, Volume 41, Number 12, pages 3216-3227, 2010, doi: 10.1007/s11661-010-0388-y. (W).

31. H.C. Kim, J.W. Choi, R.B. Wicker, "Development of a Multi-material Stereolithography System," *Journal of the Korean Society for Precision Engineering*, Volume 27, Number 3, 2010, pages 135-141 (In Korean). (W).
32. D. Espalin, K. Arcaute, D. Rodriguez, F. Medina, M. Posner, and R.B. Wicker, "Fused Deposition Modeling of Patient-Specific Polymethylmethacrylate Implants," *Rapid Prototyping Journal*, Volume 16, Issue 3, 2010, pages 164-173. (W).
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CONFERENCE AND OTHER PUBLICATIONS

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1. F. Medina, Keynote Address "*Evolution of Additive Manufacturing into Production*", AWS Additive Manufacturing Conference, AWS, October 10-11, 2017, Buffalo, NY (Invited)
2. F. Medina, "*An Overview of the Additive Manufacturing Consortium (AMC) Projects and Collaborations*", The Third Joint FAA – Air Force Workshop on Qualification / Certification of Additively Manufactured (AM) Parts, August 29-31, 2017, Dayton, OH (Invited)
3. F. Medina, Keynote Address "*Industry Overview and Insights*", 3D Metal Printing Experience and Tech Tour, August 16, 2017, Chicago, IL (Invited)
4. F. Medina, "*Design for Additive Manufacturing" Bakers Hughes AM Symposium*", July 24, 2017, Claremore, OK (Invited)
5. F. Medina, Workshop: "*Metal Part Fabrication Using Additive Manufacturing Technologies*", RAPID 2017, SME, May 8, 2017, Pittsburg, PA (Invited)
6. F. Medina, "*Manufacturing Design Considerations for Metal Additive Manufacturing: Medical Implants and Beyond*", Advance Design & Manufacturing Cleveland, March 29, 2017, Cleveland, OH (Invited)
7. F. Medina, Workshop: "*Fundamentals of Additive Manufacturing for Aerospace*" AeroDef 2017, SME, March 6, 2017, Fort Worth, TX (Invited)
8. F. Medina, "*AM Powder Recycling and Reconditioning*", AMPM 2017, APMI International, June 13-15, 2017, Las Vegas, NV
9. F. Medina, "*Optimizing TiAl EBM Parameters for Aerospace Components*" RAPI 2017, SME, May 8, 2017, Pittsburg, PA
10. F. Medina, "*Processing Superalloy Materials in Additive Manufacturing Using Electron Beam Melting Technology*", AeroDef 2017, SME, March 6-9, 2017, Fort Worth, TX
11. F. Medina, "*Large-Scale Additive Manufacturing Production and Inspection for Aerospace Components*", AeroMat 2017, ASM International, April 10-12, 2017, Charleston, NC
12. F. Medina, "*Selecting the Correct Material and Technology for AM Development*", AeroMat 2017, ASM International, April 10-12, 2017, Charleston, NC
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14. F. Medina," *Design for Manufacturability in Metals Additive Manufacturing*", Workshop on Additive Manufacturing for Medical Applications, ASTM, May 3, 2016, San Antonio, TX
15. F. Medina, "*Processing Superalloy Materials in Additive Manufacturing using Electron Beam Melting Technology*" AeroMat 2016, SME, May23-25, 2016, Bellevue, WA
16. F. Medina," *Optimizing EBM Inconel 718 Material for Aerospace Components*" RAPID 2016, SME, May 16-19, 2017, Orlando, FL
17. F. Medina, "*Selecting the right part for production with Metal AM*", AMUG 2016 Conference, April 3-7, 2016, St. Louis, MO

18. M. Kirka, P. Nandwana, R. Dehoff, L. Lowe, F. Medina, W. Sames, and W. Peter. "*Investigating the role of powder feedstock recyclability in Electron Beam Melting of Ti-6Al-4V and Inconel 718*". TMS 2015, 144th Annual Meeting. Orlando, Florida.
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20. M. Kirka, W. Sames, F. Medina, and R. Dehoff. "*Hot Isostatic Pressing as a Means to Enhance the High Cycle Fatigue Resistance of Inconel 718 Produced Through Electron Beam Melting*". TMS 2015, 144th Annual Meeting. Orlando, Florida.
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INFRASTRUCTURE DEVELOPMENT

W.M. KECK CENTER FOR 3D INNOVATION

The W.M. Keck Center for 3D Innovation (Keck Center) was founded in January 2002 as a result of a $1 million grant from the W.M. Keck Foundation of Los Angeles (with the first additive manufacturing machine purchased in August 2000). The Keck Center is an engineering, biomedical and advanced manufacturing laboratory focused on multi-disciplinary biomedical, materials, electronics, and manufacturing research. In 2005/2006, the Keck Center was renovated and expanded from 1,500 square feet of floor space to over 6,100 square feet, and in 2010/2011, the facility was further expanded from 6,100 square feet to over 13,000 square feet. The Keck Center's research hinges on the development and use of Additive Manufacturing (AM) technologies that allow for fabrication of complex three-dimensional shapes by successively manufacturing thin slices of a desired object and stacking them together one layer at a time. The Center's infrastructure has grown from 1 AM machine in 2000 to over 40 AM machines today, including 11 FDM – including 1 patent pending technology; 11 SL – including 2 patented technologies and 1 bio-SL system; 2 EBM metals – including 1 Arcam A2 and 1 custom high temperature S12; 1 custom DMD-based micro-SL; 1 EnvisionTec DLP; 1 LS; 1 PolyJet; 2 ZCorp; 1 ExOne M-Lab; 11 Desktop 3D Printing Systems (2, VFlash; 1, Fab@Home Model 1; 1, Solido SD300 Pro; 1 Up! Personal Portable 3D Printer; 1 Bits from Bytes 3DTouch 3D Printer; 1 fabbster; 1, MakerBot Replicator; 3, MakerBot Replicator 2), and 3 micro-dispensing systems – including 1 Dimatix and 2 nScrypt micro-dispensing tools. Other manufacturing equipment includes 2 CNC machining centers (1 5-axis Haas Super Mini Mill 2 and 1 Mori-Seiki NL2000 lathe with live tooling) and equipment for dip-spin coating, vacuum casting, pressure casting, and plastic injection molding. Additional facilities include: reverse engineering and metrology (laser scanning, video measurement, CMM, and micro-CT); materials and mechanical testing including static and dynamic axial and torsional testing (Instron 5866, MTS 370 and 370.02 Servohydraulic Systems), optical microscopy and access to SEM and TEM; cardiovascular hemodynamics (experimental fluid mechanics); synthetic and analytical chemistry; and tissue engineering (including scaffold fabrication, polymer synthesis and cell culture capabilities). This

Center represents a truly unique facility that provides unparalleled experiences for its students. AM technologies are being used to fabricate unique functional multi-material devices with embedded electronics and patient-specific anatomical shapes for use in pre-surgical planning, surgery, medical device development, cardiovascular flow research, tissue engineering, and more.

The Keck Center can fabricate 3D objects that are plastic, metal, ceramic, of bio-compatible materials, composite materials, or that contain electronics. Major research efforts are underway in the areas of AM of powder metal alloy systems as well as 3D Structural Electronics in which electronics and thus intelligence can be fabricated within 3D mechanical structures. Using integrated AM technologies, electronics can be fabricated in a 3D structure of arbitrary and complex shape in order to accommodate human anatomy or simply to replace structural components in satellites, planes, cars or furniture with equivalent structures that contain intelligence. The State of Texas recognized the importance of this effort and recently awarded UTEP a multi-million dollar grant to establish and promote these activities.

RESEARCH ACTIVITY

SPONSORED PROJECTS

Summary of *Keck Recharge Center* Contractual Services

04/05	$66,072
05/06	$177,004
06/07	$238,627
07/08	$292,636
08/09	$228,995
09/10	$215,499
10/11	$384,257
11/12	$432,073
12/13	$657,000
Total	**$2,692,163**

Chronological List of Sponsored Projects

(most recent proposals listed first; project listing includes project title, PI or Co-PI and names of research collaborators, funding agency, period of grant or contract, and amount awarded)

1. ASTM Center of Excellence (EWI PI, Frank Medina)
   Agency: ASTM
   Period: 2-15-18 through 2-15-23
   Amount Awarded: $1.25M

2. America Makes MAMMALS Feature-based Qualification using DED (EWI PI, Frank Medina)
   Agency: America Makes/AFRL
   Period: 2-15-18 through 2-15-23
   Amount Awarded: $2,000,000
   Amount Awarded to EWI: $550,000

3. DED Multi-material/ Repair (Director, Frank Medina)
   Agency: EWI AMC 2018 Project
   Period: 3-11-18 through 12-31-18
   Amount Awarded: $135,000

4. Evaluation of Post Process Techniques for AM (Director, Frank Medina)
   Agency: EWI AMC 2018 Project
   Period: 3-1-18 through 12-31-18
   Amount Awarded: $130,000

5. Comparison of Commercially Available AM Simulation Tool (Director, Frank Medina)
   Agency: EWI AMC 2018 Project
   Period: 3-1-18 through 12-31-18
   Amount Awarded: $120,000

6. Phase II: In-Process Monitoring & Defect Rectification (Director, Frank Medina)
   Agency: EWI AMC 2018 Project
   Period: 3-1-18 through 12-31-18
   Amount Awarded: $115,000

7. Stainless Steel L-PBF/DED (Director, Frank Medina)
   Agency: EWI AMC 2018 Project
   Period: 3-1-18 through 12-31-18
   Amount Awarded: $135,000

8. Continuing Further testing on Current Projects IN 625" and "IN 718 and Relating Microstructure to AM (Director, Frank Medina)
   Agency: EWI AMC 2018 Project
   Period: 3-1-18 through 12-31-18
   Amount Awarded: $141,000

9. Additive Manufacturing and Characterization

Agency: ARL (PI, Frank Medina)
Period: 7-15-17 through 7-31-18
Amount Awarded: $150,000

10. Process development of metal/oxide mixture (PI, Frank Medina)
    Agency: Exxon
    Period: 12-1-17 through 1-15-18
    Amount Awarded: $120,000

11. Process parameter development for Micro-melt CCM powder in an Arcam A2X system (PI, Frank Medina)
    Agency: Carpenter
    Period: 11-15-17 through 6-30-18
    Amount Awarded: $122,000

12. L-PBF of high strength aluminum alloys phase II (Director, Frank Medina)
    Agency: EWI AMC 2017 Project
    Period: 3-1-17 through 6-30-18
    Amount Awarded: $100,000

13. Nondestructive post-process evaluation of AM parts (Director, Frank Medina)
    Agency: EWI AMC 2017 Project
    Period: 3-1-17 through 6-30-18
    Amount Awarded: $100,000

14. In-process monitoring of defect rectification in L-PBF (Director, Frank Medina)
    Agency: EWI AMC 2017 Project
    Period: 3-1-17 through 12-31-17
    Amount Awarded: $100,000

15. AM Powder Recycling and Reconditioning (Director, Frank Medina)
    Agency: EWI AMC 2017 Project
    Period: 3-1-17 through 4-30-18
    Amount Awarded: $100,000

16. Magnesium EBM process parameter development (PI, Frank Medina)
    Agency: Wright Medical
    Period: 2-15-17 through 8-30-17
    Amount Awarded: $100,000

17. ExOne binder jetting and infiltration development (PI, Frank Medina)
    Agency: Lockheed Martin
    Period: 2-15-16 through 2-15-23
    Amount Awarded: $80,000

18. SS EBM process parameter development (PI, Frank Medina)

Agency: HTL Japan
Period: 8-31-16 through 2-28-17
Amount Awarded: $100,000

19. TiAl (48-2-2) EBM process parameter development (PI, Frank Medina)
Agency: Praxair Surface Technologies
Period: 5-15-16 through 4-31-17
Amount Awarded: $90,000

20. Using IR Imaging for Defect Detection in E-Beam Powder Bed Technology (PI, Ryan Wicker, Co-PI, Frank Medina)
Agency: Lockheed Martin Corp.
Period: 5-9-13 through 11-30-13
Amount Awarded: $80,001

21. Direct Digital Manufacturing for T700-701D Intermediate Maintenance (PI, Ryan Wicker, Co-PI, Frank Medina)
Agency: GE Global Research (through ARDEC)
Period: 10-1-12 through 9-30-15
Amount Awarded: $899,999

22. Enabling Higher Levels of Hardware Integration with the FDM Additive Manufacturing Process (PI, Ryan Wicker, Co-PI, Frank Medina)
Agency: Raytheon
Period: 10-1-12 through 8-31-13
Amount Awarded: $67,761

23. Large-scale Manufacturing of Polymer Matrix Composites using Fused Deposition Modeling a 3-D Printing Technology (PI, Ryan Wicker, Co-PI, Frank Medina)
Agency: Materials Modification, Inc. (from NASA)
Period: 2-13-12 through 2-12-13
Amount Awarded: $45,191

24. Advance Additive Manufacturing Method for SRF Cavities of Various Geometries (PI, Ryan Wicker, Co-PI, Frank Medina)
Agency: RadiaBeam Technologies (from DOE)
Period: 3-1-12 through 11-1-12
Amount Awarded: $45,050 (awarded Phase II, $350k to UTEP)

25. Development of IR Imaging Feedback in E-Beam Powder Bed Technology (PI, Ryan Wicker, Co-PI, Frank Medina)
Agency: Lockheed Martin Corporation
Period: 7-11-12 through 8-31-13
Amount Awarded: $80,000

26. Using IR Imaging for Defect Detection in E-Beam Powder Bed Technology (PI, Ryan Wicker, Co-PI, Frank Medina)
Agency: Lockheed Martin Corp.
Period: 5-9-13 through 11-30-13
Amount Awarded: $80,001

27. Direct Digital Manufacturing for T700-701D Intermediate Maintenanc (PI, Ryan Wicker, Co-PI, Frank Medina)
    Agency: GE Global Research (through ARDEC)
    Period: 10-1-12 through 9-30-15
    Amount Awarded: $899,999

28. Enabling Higher Levels of Hardware Integration with the FDM Additive Manufacturing Process (PI, Ryan Wicker, Co-PI, Frank Medina)
    Agency: Raytheon
    Period: 10-1-12 through 8-31-13
    Amount Awarded: $67,761

29. Large-scale Manufacturing of Polymer Matrix Composites using Fused Deposition Modeling a 3-D Printing Technology (PI, Ryan Wicker, Co-PI, Frank Medina)
    Agency: Materials Modification, Inc. (from NASA)
    Period: 2-13-12 through 2-12-13
    Amount Awarded: $45,191

30. Advance Additive Manufacturing Method for SRF Cavities of Various Geometries (PI, Ryan Wicker, Co-PI, Frank Medina)
    Agency: RadiaBeam Technologies (from DOE)
    Period: 3-1-12 through 11-1-12
    Amount Awarded: $45,050 (awarded Phase II, $350k to UTEP)

31. Development of IR Imaging Feedback in E-Beam Powder Bed Technology (PI, Ryan Wicker, Co-PI, Frank Medina)
    Agency: Lockheed Martin Corporation
    Period: 7-11-12 through 8-31-13
    Amount Awarded: $80,000

32. Implementation of Infrared Imaging Feedback in Electron Beam Melting (PI, Ryan Wicker, Co-PIs, Frank Medina, Eric MacDonald, Larry Murr)
    Agency: Lockheed Martin Corporation
    Period: 4-1-11 through 5-31-12
    Amount Awarded: $139,865

33. EBM Build Parameter Development for Inconel 625, 718 and Ti-Al (PI, Ryan Wicker, Co-PI, Frank Medina)
    Agency: GE Aviation
    Period: 9-1-10 through 8-31-12
    Amount Awarded: $120,000

34. Flow Model Development for Magnetic Resonance Velocimetry (PI, Ryan Wicker, Co-PI, Frank Medina)
    Agency: GE Global Research
    Period: 12-1-11 through 8-31-12
    Amount Awarded: $14,575

35. Manufacturing of Copper Components using EBM (PI, Ryan Wicker, Co-PI, Frank Medina)
    Agency: RadiaBeam, Inc.
    Period: 9-1-10 through 8-31-12
    Amount Awarded: $115,000