



First International Conference on
3-D Printing and Transportation

NOVEMBER 20–21, 2019

Keck Center, NAS, Washington, D.C.

Convened by
Transportation Research Board

Organized by
TRB Design and Construction Group (AF000)
Aviation Group (AV000)
Operations and Preservation Group (AW000)
Freight Systems Group (AT000)

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TRANSPORTATION RESEARCH BOARD

SAVE THE DATE: NATIONAL CONFERENCE ON TRANSPORTATION ASSET MANAGEMENT
JULY 11-14, 2020
BOSTON, MA



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The 13th National Conference on Transportation Asset Management (TAM) provides an opportunity for all practitioners involved in their agency's asset management initiative to build core competencies and generate new ideas.

- Looking for both practical and innovative presentations.
- Selected abstracts will be featured in either poster or technical podium sessions.
- Presenters will be required to register and attend the conference to be included in the final program.

Presentation tracks and crosscutting issues:

- ◆ Track 1: Implementation
- ◆ Track 2: Data Governance/Tools
- ◆ Track 3: Managing Risk
- ◆ Track 4: Partners and Peers
- ◆ Track 5: Sustaining Asset Management in your Organization
- ◆ Crosscutting Issue 1: Transit
- ◆ Crosscutting Issue 2: Resilience

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MESSAGE FROM THE CONFERENCE CHAIR

First International Conference on 3-D Printing and Transportation



Welcome to the Keck Center of the National Academies of Sciences, Engineering and Medicine for the First International Conference on 3-D Printing and Transportation. Your participation in this conference helps TRB prepare for this Transformative Technology whether you are a sponsor, a member of the planning or scientific committee, a speaker, or a session moderator. We are all inquisitive minds exploring 3-D printing and its impact on transportation.

This conference will provide you an opportunity to share knowledge and information and assess where this technology stands today and where we are going from here. We are fortunate to have representation from a number of public agencies, including different branches of the U.S. Department of Defense (Army, Air Force, Marine Corps), National Aeronautics and Space Administration (NASA), and the U.S. Department of Transportation. Oak Ridge National Laboratory, one of the national laboratories of the U.S. Department of Energy, is an active participant in this conference.

We will open the first day of the conference with a history and background of 3-D printing, followed by 3-D printing processes, materials and equipment, followed by 3-D printing applications, and then close the day by looking at the advances made by different branches of the U.S. Department of Defense. We will start the second day by examining the impact of 3-D printing on freight and then move on to examining its overall social impact (economics, environment, safety, security, legal). In the second-half of the day, we will highlight the synergistic efforts of various government agencies in advancing 3-D printing and finally close the conference with a look on the path forward for this technology.

Best regards,
Dr. Mohammad S. Khan

FIRST INTERNATIONAL CONFERENCE ON 3-D PRINTING AND TRANSPORTATION

Planning Committee

Mohammad S. Khan, High Performance Technologies, Inc.(HPTech)
David Ballard, Gellman Research Associates (GRA), Inc.
Michael P. Case, U.S. Army Engineer Research & Development Center
Rich Davies, Oak Ridge National Laboratory
Patricia Hu, USDOT, Bureau of Transportation Statistics
Tom Kazmierowski, Golder Associates, Inc.
D. Stephen Lane, Virginia Transportation Research Council
Lonnie Love, Oak Ridge National Laboratory
Robert Moses, NASA
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Megan A. Kreiger, U.S. Army Engineer Research and Development Center
Eric L. Kreiger, U.S. Army Engineer Research and Development Center
Julian Leland Bell, Massachusetts Institute of Technology
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Viktor Mechtcherine, TU Dresden, Institute of Construction Materials, Germany
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Brian K. Post, Oak Ridge National Laboratory
Zofia K. Rybkowski, Texas A&M University
Florence Sanchez, Vanderbilt University
Peter Stynoski, U.S. Army Engineer Research and Development Center
Tim Wangler, ETH Zürich Institute for Building Materials, Switzerland
Philip F. Yuan, Tongji University, China
Hongyu Zhou, University of Tennessee, Knoxville

The Transportation Research Board The Transportation Research Board is one of seven major programs of the National Academies of Sciences, Engineering, and Medicine. The mission of the Transportation Research Board is to provide leadership in transportation improvements and innovation through trusted, timely, impartial, and evidence-based information exchange, research, and advice regarding all modes of transportation. The Board's varied activities annually engage about 8,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.

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TRR

JOURNAL OF THE TRANSPORTATION RESEARCH BOARD

TRANSPORTATION RESEARCH RECORD

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SCHEDULE AT A GLANCE

WEDNESDAY, NOVEMBER 20		
TIME	EVENT	ROOM
7:00 am	Registration & Breakfast	Keck 100 Foyer
8:00 am	Opening Remarks TRB Welcome Opening Keynote Address	Keck 100
9:00 am	SESSION 1: History and Background of 3-D Printing 3-D Printing and Transportation: Past, Present, and Future A Review of Reviews: Assessing the Viability of 3-D Printed Construction	Keck 100
10:00 am	Morning Break—15 minutes	Keck 100 Foyer
10:15 am	SESSION 2: 3-D Printing Techniques—Processes, Materials, and Equipment The Properties of 3-D Printing Mortar and Development of 3-D Construction Printing (3-DCP) Delivery System Early-Age Performance of 3-D Printed Carbon Nanofiber and Carbon Microfiber Cement Composites Examining the Effect of Cellulose Nanocrystals (CNC) on 3-D Printed Cement Composites Testing Procedures on Materials to Formulate the Ink for 3-D Printing 3-D Printing of Concrete: A Systems Perspective	Keck 100
12:00 pm	Lunch Presentation: 3D Printed Concrete Infrastructure for Expeditionary Applications	E-Street Conference Room
1:30 pm	SESSION 3: 3-D Printing Applications Large-Scale Additive Manufacturing for Transportation: A Review of State-of-the-Art Applications, Challenges And Opportunities Development of 3-D Printable Lightweight Functional Cementitious Composite 3-D Printing Polymer Concrete for Infrastructure Applications Experimental and Numerical Studies of 3-D Printable Steel Fiber-Reinforced Concrete 3-D Printing of Ultra-High Performance Concrete Formwork for Accelerated Bridge Construction	Keck 100
3:15 pm	Afternoon Break—15 minutes	Keck 100 Foyer
3:30 pm	SESSION 4: 3-D Printing in Defense Applications Advances Made by U.S. Army Advances Made by U.S. Air Force Advances Made by U.S. Marine Corps Department of Defense Perspective	Keck 100
5:00 pm	Evening Networking Reception	Atrium 3rd Floor

SCHEDULE AT A GLANCE

THURSDAY, NOVEMBER 21		
TIME	EVENT	ROOM
7:00 am	Registration & Breakfast	Keck 100 Foyer
8:00 am	Keynote Address	Keck 100
8:30 am	SESSION 5: Impact Of 3-D Printing on Freight Movements Democratization of Manufacturing: Possibilities on the Horizon Additive Manufacturing Transforming Freight Transportation Early Adoption of 3-D Printing: Why and How Panel Discussion: Path Forward	Keck 100 Foyer
10:30 am	Morning Break—15 minutes	Keck 100 Foyer
10:45 am	SESSION 6: Safety, Environment & Social Impacts of 3-D Printing Safety and Security Implications of 3D Printing Using 3-D Printing, Commodity Hardware, Design Thinking, and Modular Architecture to Create Inexpensive Maritime Weather Stations to Extend Vessel Safety and Meteorological Data Gathering 3-D-printed Ultrathin-Wall Ceramic Microlattices for Catalytic Waste Gas Converters	Keck 100
12:00 pm	Lunch Presentation: Transformational Nature of 3-D Printing	E-Street Conference Room
1:30 pm	SESSION 7: 3-D Printing and Space Transportation An Overview of In-Situ Construction Activities at NASA The Proving Ground: Using Low Earth Orbit as a Test Bed for In-Space Manufacturing Technology Development Deep-Space Transportation: Manufacturing for Performance, Persistence, and Resilience The Impact of Additive Manufacturing in the Future Space Economy	Keck 100
3:15 pm	Afternoon Break—30 minutes	Keck 100 Foyer
3:45 pm	SESSION 8: Path Forward for 3-D Printing Research Needs, Roadmap/Strategic Plan Education, Training & Workforce Development Policies, Regulations & Deregulations	Keck 100
5:00 pm	Evening Network Reception	3rd Floor Atrium

CONFERENCE PROGRAM

WEDNESDAY NOVEMBER 20, 2019

7:00 am–8:00 am, *Keck 100 Foyer*

Registration & Breakfast

8:00 am–8:10 am, *Keck 100*

OPENING REMARKS

Mohammad S. Khan, *Conference Chair*, Executive Vice President, High Performance Technologies, Inc. (HPTech)

8:10 am–8:20 am, *Keck 100*

TRB WELCOME

Neil Pedersen, Executive Director, Transportation Research Board

8:30 am–9:00 am, *Keck 100*

OPENING KEYNOTE ADDRESS

David R. Winter, Associate Administrator (Acting), Research, Development, and Technology, Federal Highway Administration, U.S. Department of Transportation

9:00 am–10:00 am, *Keck 100*

SESSION 1: History and Background of 3-D Printing

Moderator: Scott Z. Jones, Mechanical Engineer, Engineering Laboratory, National Institute of Standards & Technology (NIST)

3-D Printing and Transportation: Past, Present, and Future

Mohammad S. Khan, HPTech

A Review of Reviews: Assessing the Viability of 3-D Printed Construction

Jeneé A. Jagoda and Steven J. Schuldt, Air Force Institute of Technology

10:00 am–10:15 am, *Keck 100 Foyer*

Morning Break

10:15 am–12:00 pm, *Keck 100*

SESSION 2: 3-D Printing Techniques—Processes, Materials, And Equipment

Moderator: Megan Kreiger, Lead Mechanical Engineer, U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers

The Properties of 3-D Printing Mortar and Development of 3-D Construction Printing (3-DCP) Delivery System

Kho P. Verian, Scott R. Kowaleski, Matthew D. Carli, Randall P. Bright, and Eerik Maandi, LATICRETE International, Inc.

Early-Age Performance of 3-D Printed Carbon Nanofiber and Carbon Microfiber Cement Composites

M. Kosson, L. Brown, and F. Sanchez, Vanderbilt University

Examining the Effect of Cellulose Nanocrystals (CNC) on 3-D Printed Cement Composites

Yvette Valadez, Cameron Wilson, Mehdi K. Moradllo, and Jason Weiss, Oregon State University

Testing Procedures on Materials to Formulate the Ink for 3-D Printing

Malo Charrier and Claudiane Ouellet-Plamondon, Université du Québec, Canada

3-D Printing of Concrete: A Systems Perspective

Sven G. Bilén, The Pennsylvania State University

12:00 pm–1:30 pm, *E-Street Conference Room*

Lunch & Networking**Lunch Presentation: 3D Printed Concrete Infrastructure for Expeditionary Applications**

Michael Case, Program Manager, U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers

Robert P. Mueller, Senior Technologist, Exploration Research and Technology Programs, National Aeronautics & Space Administration (NASA)

1:30 pm–3:15 pm, *Keck 100*

SESSION 3: 3-D PRINTING APPLICATIONS

Moderator: Kamal H. Khayat, Professor & Director, Center for Infrastructure Engineering Studies, Missouri University of Science and Technology

Large-Scale Additive Manufacturing for Transportation: A Review of State-of-the-Art Applications, Challenges And Opportunities

Mostafa T. Hesarkuchak, Ossama Salem, and Song He, George Mason University

Development of 3-D Printable Lightweight Functional Cementitious Composite

Adam Brooks and Hongyu Zhou, University of Tennessee, Knoxville; Zhenglai Shen, University of Alabama in Huntsville

3-D Printing Polymer Concrete for Infrastructure Applications

Daniel H. Murcia, Moneeb Genedy, and Mahmoud R. Taha, University of New Mexico

Experimental and Numerical Studies of 3-D Printable Steel Fiber-Reinforced Concrete

Jiaqing Wang, Qingli Dai, Ruizhe Si, and Yunxiang Ma, Michigan Technological University, presentation delivered by Hongyu Zhou

3-D Printing of Ultra-High Performance Concrete Formwork for Accelerated Bridge Construction

Atorod Azizinamini, Florida International University

3:15 pm–3:30 pm, *Keck 100 Foyer*

Afternoon Break

3:30 pm–5:00 pm, *Keck 100*

SESSION 4: 3-D PRINTING IN DEFENSE APPLICATIONS

Moderator: Michael Case, Program Manager, U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers

Advances Made by U.S. Army

Eric Kreiger, U.S. Army Corps of Engineers

Advances Made by U.S. Air Force

Karsten Lipiec, U.S. Air Force

Advances Made by U.S. Marine Corps

Captain Matt Audette, U.S. Marine Corps

Department of Defense Perspective

Lieutenant Colonel Aneel Alvares, U.S. Department of Defense

5:00 pm–6:00 pm, *Atrium 3rd Floor*

Evening Networking Reception

THURSDAY NOVEMBER 21, 2019

7:00 am–8:00 am, *Keck 100 Foyer*

Registration & Breakfast

8:00 am–8:30 am, *Keck 100*

KEYNOTE ADDRESS

Industry Significance of 3-D Printing to Transportation Logistics, Traffic Activities, Planning and Asset Management

William Ankner, Principal, Transportation Solutions

8:30 am–10:30 am, *Keck 100*

SESSION 5: Impact of 3-D Printing on Freight Movements

Moderator: Craig A. Blue, Director, Energy Efficiency and Renewable Energy Programs, Oak Ridge National Laboratory

Democratization of Manufacturing: Possibilities on the Horizon

Thomas Kurfess, Chief Manufacturing Officer, Oak Ridge National Laboratory

Additive Manufacturing Transforming Freight Transportation

Lonnie Love, Oak Ridge National laboratory

Early Adoption of 3D Printing: Why and How

Megan Brewster, Vice President of Advanced Manufacturing, Launch Forth

Panel Discussion: Path Forward

Private sector perspectives: Dave Chapin, GE Additive

Jennifer Coyne, Wabtec

Public sector perspective: Caitlin Hughes, USDOT

10:30 am–10:45 am, *Keck 100 Foyer*

Morning Break

10:45 am–12:00 pm, *Keck 100*

SESSION 6: Safety, Environment & Social Impacts of 3-D Printing

Moderator: Major Steven J. Schuldt, Assistant Professor of Engineering Management, Air Force Institute of Technology (AFIT)

Safety and Security Implications of 3D Printing

J. Luke Irwin, RAND Corporation

Using 3-D Printing, Commodity Hardware, Design Thinking, and Modular Architecture to Create Inexpensive Maritime Weather Stations to Extend Vessel Safety and Meteorological Data Gathering

Catherine T. Lawson, George Berg, Roberta Weisbrod, Eric Stern, University at Albany—State University of New York

3-D-printed Ultrathin-Wall Ceramic Microlattices for Catalytic Waste Gas Converters

Seok Kim and Turga Ganapathy, Massachusetts Institute of Technology; Wonpyo Kim and Young Tae Cho, Changwon National University, Republic of Korea; Nicholas X. Fang, Massachusetts Institute of Technology

12:00 pm to 1:30 pm, *E Street Conference Room*

Lunch & Networking**Lunch Presentation: Transformational Nature of 3-D Printing**

Lonnie J. Love, Corporate Fellow, Energy & Transportation Science Division, Oak Ridge National Laboratory

1:30 pm–3:15 pm, *Keck 100*

SESSION 7: 3-D Printing and Space Transportation

Moderator: Robert Moses, Aerospace Technologist & Systems Engineer, National Aeronautics & Space Administration (NASA)

An Overview of In-Situ Construction Activities at NASA

Robert P. Mueller, Senior Technologist, Exploration Research and Technology Programs, National Aeronautics & Space Administration (NASA)

The Proving Ground: Using Low Earth Orbit as a Test Bed for In-Space Manufacturing Technology Development

Tracie Prater, Aerospace Engineer, Materials and Processes Laboratory, National Aeronautics & Space Administration (NASA)

Deep-Space Transportation: Manufacturing for Performance, Persistence, and Resilience

W. Keith Belvin, Center Chief Technologist, Langley Research Center, NASA

The Impact of Additive Manufacturing in the Future Space Economy

Ravi Chaudhary, Director, Advanced Programs and Innovation & Acting Director, Office of Spaceports, Office of Commercial Space, Federal Aviation Administration, U.S. Department of Transportation

3:15 pm–3:45 pm, *Keck 100 Foyer*

Afternoon Break

3:45 pm to 5:00 pm, *Keck 100*

SESSION 8: Path Forward for 3-D Printing

Moderator: Mohammad S. Khan, Conference Chair, Executive Vice President, High Performance Technologies, Inc. (HPTech)

Research Needs, Roadmap/Strategic Plan

S. Jack Hu, Senior Vice President, Academic Affairs & Provost, University of Georgia
 Michael Gorelik, Chief Scientific and Technical Advisor, Federal Aviation Administration (FAA), U.S. Department of Transportation
 Megan Kreiger, Lead Mechanical Engineer, U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers
 Robert Moses, Aerospace Technologist & Systems Engineer, National Aeronautics & Space Administration (NASA)

KECK CENTER FLOOR PLAN





2nd International
Conference on

Nanotechnology of Cement and Concrete (2NCC20)

May 19-21, 2020
Irvine, California

trb.org/conferences/Nanotech20.aspx

Nanomodification and nanoengineering of concrete is capable of dramatically improving its tensile strength, toughness, ductility, and durability properties, which is vital for modern transportation infrastructure. The conference will explore the impact of nanotechnology on behavior and performance of cement based materials and concrete in these topical areas.

- Energy Efficiency, Low Carbon Footprint, Sustainable Materials, By-product Utilization
- Applications of Nanotechnology in Infrastructure
- Nanomaterial Production and Functionalization
- Nanoscale Internal Structure
- High-strength, High-performance, and Ultra-high Performance Concrete
- Films and Coatings, Fiber Reinforcement
- Special Applications: Photo Catalysis, Self-Repair, Biometric
- Modeling and Simulation

Gain exposure to the cutting-edge research conducted in the U.S., Europe, and other countries reported by the top investigators in the field.

Become a part of the community evaluating and implementing this technology.

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