National Institute of Standards and Technology
U.S. Department of Commerce

The Future of U.S. Manufacturing

Manufacturing facts, trends and Federal activities

Greater Houston Partnership
Advanced Manufacturing Industry Forum

November 6, 2019

Mike Molnar
Advanced Manufacturing National Program Office

Agenda

- Introduction
- 2019 Standards Milestones
- State of Manufacturing
- Fourth Industrial Revolution
- Update on Manufacturing USA
- Future Developments

ManufacturingUSA

NIST Mission

To promote **U.S. innovation and industrial competitiveness** by advancing **measurement science**, **standards**, and **technology** in ways that enhance economic security and improve our quality of life.

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World-Leading Scientific and Engineering Research

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Advanced Manufacturing National Programs

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Technology Transfer and U.S. Innovation

NIST AT A GLANCE

Industry's National Laboratory

3,400+
FEDERAL EMPLOYEES

5
NOBEL PRIZES

2 CAMPUSES
GAITHERSBURG, MD [HQ]
BOULDER, CO

3,900+
ASSOCIATES

11
COLLABORATIVE NIST INSTITUTES

thousands
of BUSINESSES USING NIST FACILITIES

ManufacturingUSA

14
COORDINATING NETWORK OF MFG INSTITUTES

51
MANUFACTURING EXTENSION PARTNERSHIP CENTERS

U.S. BALDRIGE PERFORMANCE EXCELLENCE PROGRAM

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118 years of Standards Development

NIST

1901

Interoperability of fire hose screw threads

Light bulb standards

Standards for Irons and Steels

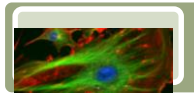
Working with ICC to reduce railway accidents

2019

Advanced communications

Advanced manufacturing

Advanced materials



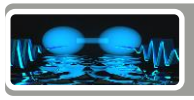
Biosciences

Cyber-physical systems

Cybersecurity

Disaster resilience

Forensic science



Quantum science

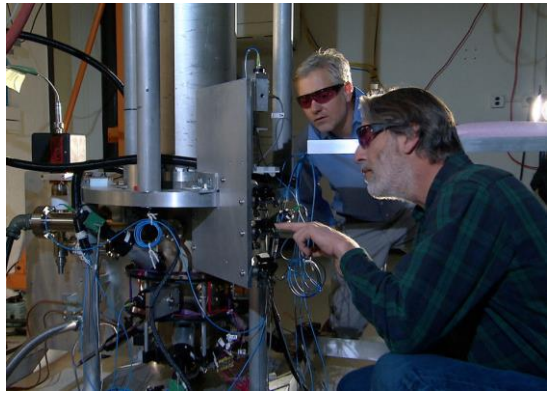
Supporting the Industrial Revolution

Supporting the Digital Revolution

Two types of Standards…

1. **Physical measurement standards** are the realization of the basic units of measurement (e.g., time, distance)
   - *NIST is responsible for developing, maintaining, and disseminating these for the United States*

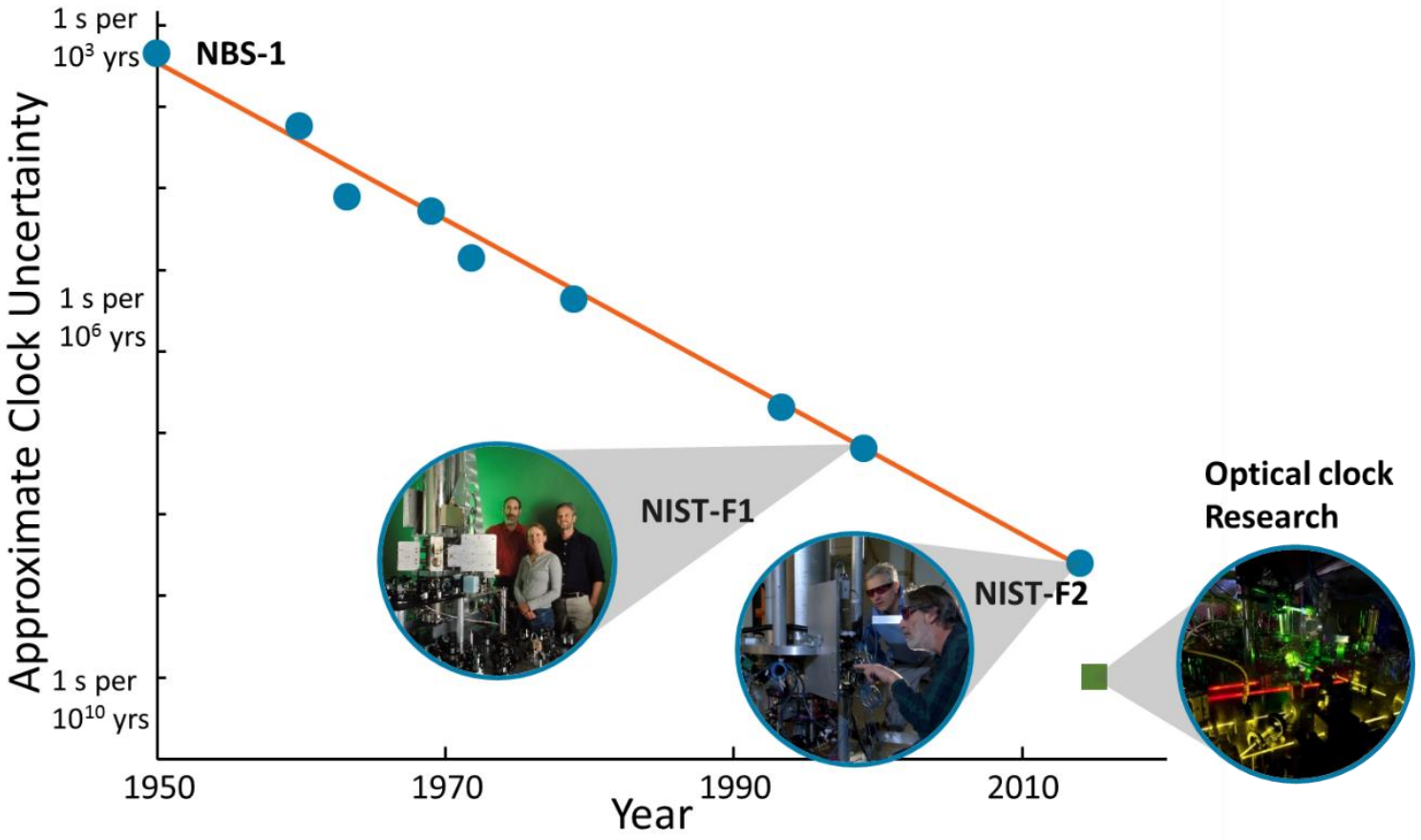
NIST F2 Cesium Atomic Clock



2. **Documentary standards** are written agreements containing technical specifications or other precise criteria that may contain rules, guidelines, or definitions of characteristics.
   - *Developed by collaboration and consensus* in an open environment. NIST facilitates standards development, working with all Standards Development Organizations worldwide

Fire suppression in building codes

How is a standard – like precision time - critical to our world today?



TIME

Record-setting Atomic Clock

NIST/JILA's strontium lattice atomic clock, accurate to 1 second in 15 billion years

Why Precision Matters

Power grid, telecom, and computer networks requires accuracy better than 1 millionth of second per day

GPS System requires accuracy better than 1 billionth of second per day

NIST official time services is used 16 billion times each day to synchronize computer, network and system clocks, and is used to time-stamp hundreds of billions of dollars in U.S. financial transactions every day.

Celebrating a Centennial – NIST WWV Radio

NIST Main Campus - Gaithersburg, MD

Boulder Colorado Campus

- NIST time and frequency center at Fort Collins CO ➔
- Broadcasts synchronizing radio signal for time
- World's longest continuously operating radio station
- October 2019 – 100 years of service!

A millennial worldwide redefinition!
2019 redefinition of the SI Treaty of the Meter

1799
Metric System

1875
Treaty of the Meter

1889
Base units –m, kg, s

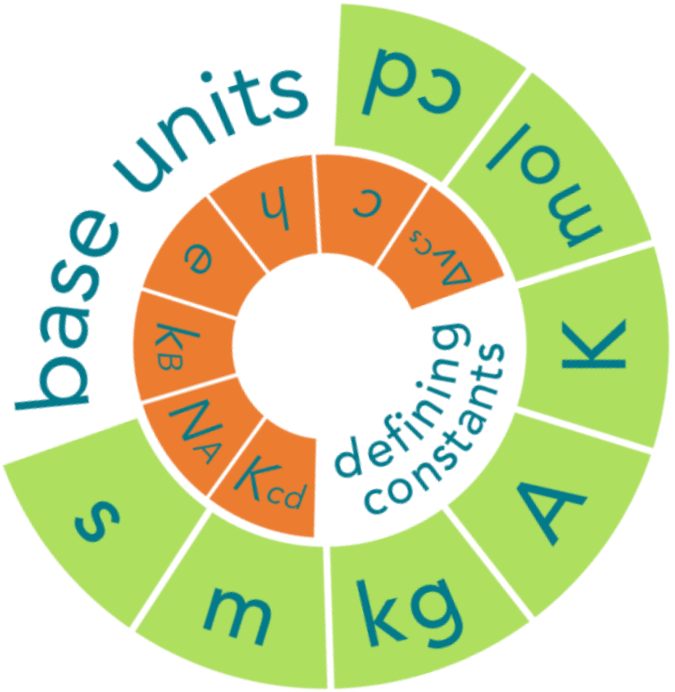
1954
A, K , cd

1967
Second = Cs 133 hyperfine frequency

1971
Mol added as base unit

1983
Meter= c in vacuum

All SI units are defined by physical constants rather than artifacts….
Except for MASS



Meter = 1/10 millionth distance from North Pole to equator, standard was meter bar
Redefined to a universal constant – wavelengths in vacuum

The Global Mass Standard – until 2019!

Le “Grande K” Artifact
the world kilogram standard

The kilogram (kg) is the SI unit of mass; it is equal to the mass of the international prototype of the kg (IPK), a small polished platinum-iridium cylinder cast in 1879

Each country’s National Metrology Institute (NMI) maintains a standard traceable to the “Grand Kilogram”, in a Paris vault.

By definition, the kilogram is whatever the mass of “Le Grande K”.

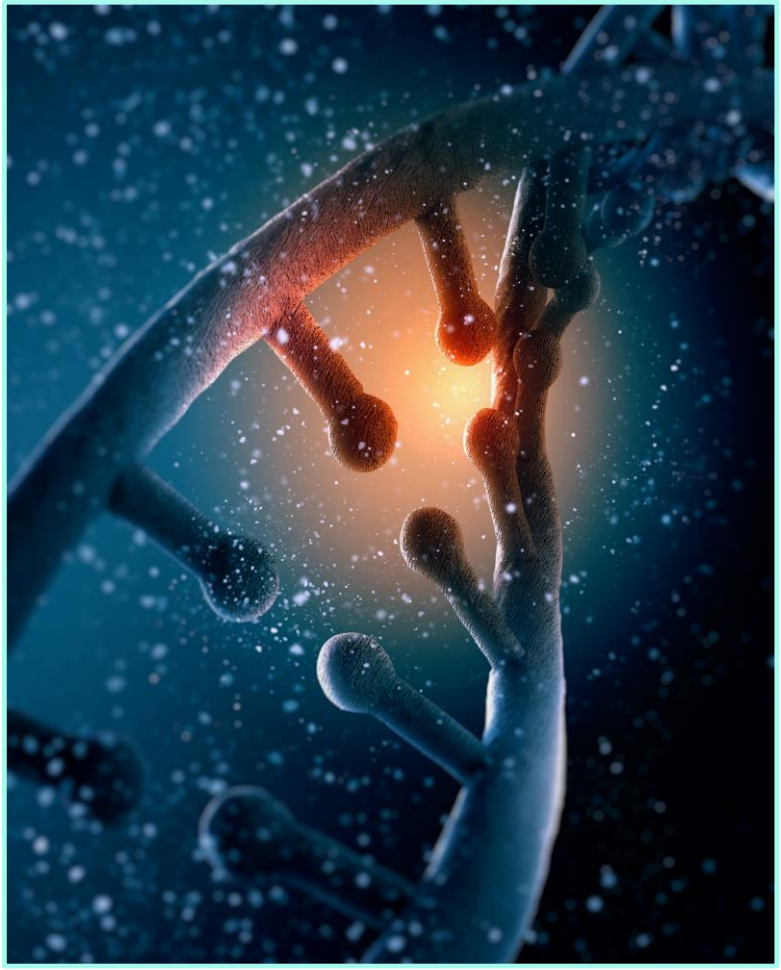
ISSUE: Traceability and comparison measurements
BIGGER ISSUE: The artifact mass is changing! A few atoms gained here and there…. Huge issue for precision manufacturing

Why is scalable, global mass (force) precision needed now?

Modern technology and manufacturing operates at extremes:

- Rocket launch – meganewtons
- Unzip a DNA molecule—piconewtons
- Photon pressure for laser power calibrations — femtonewtons

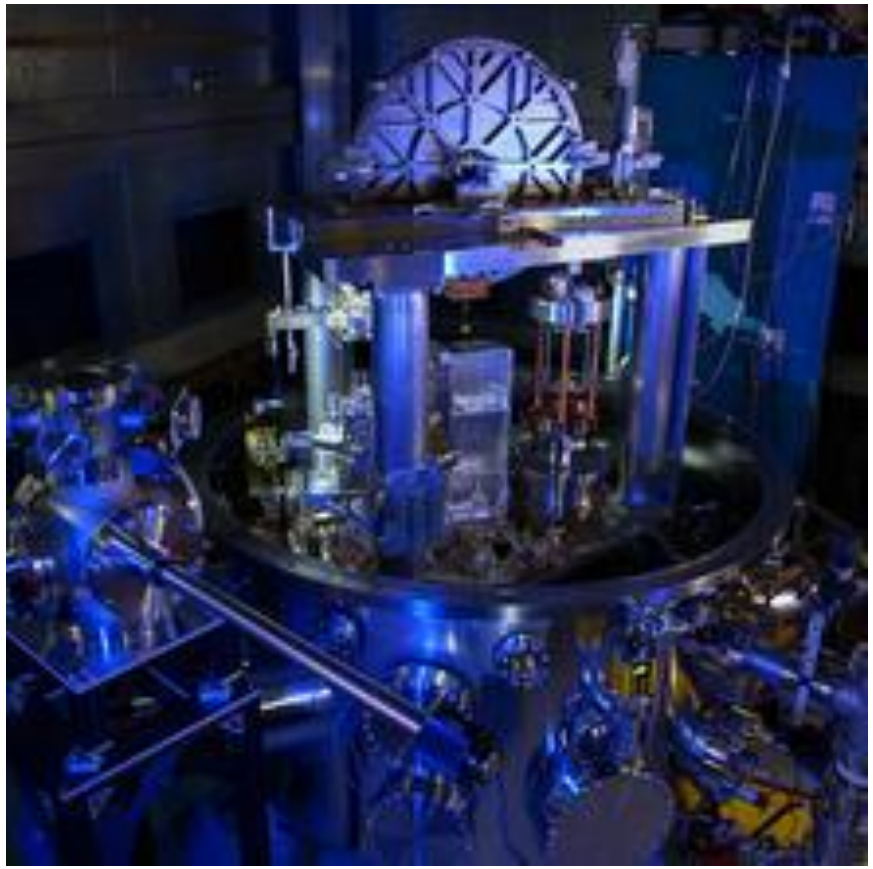
Replacing the kilogram artifact with a precision electronic standard based on a universal constant would revolutionize force measurement, and offer millions of times greater accuracy



Celebrating Standards Redefinition of the SI Units

- The 7 basic SI Units are now based on physical constants
- All other measures are derived from the basic SI units
- Momentous milestone in global standards
- Last remaining artifact-based standard for mass (Kg) was replaced by a means of measuring Planck's constant
- Enabling much greater precision and elimination of the risk of a standards changing over time.

Standards Redefinition of the SI Units



NIST Electronic Kilogram that defined the Planck constant *h*

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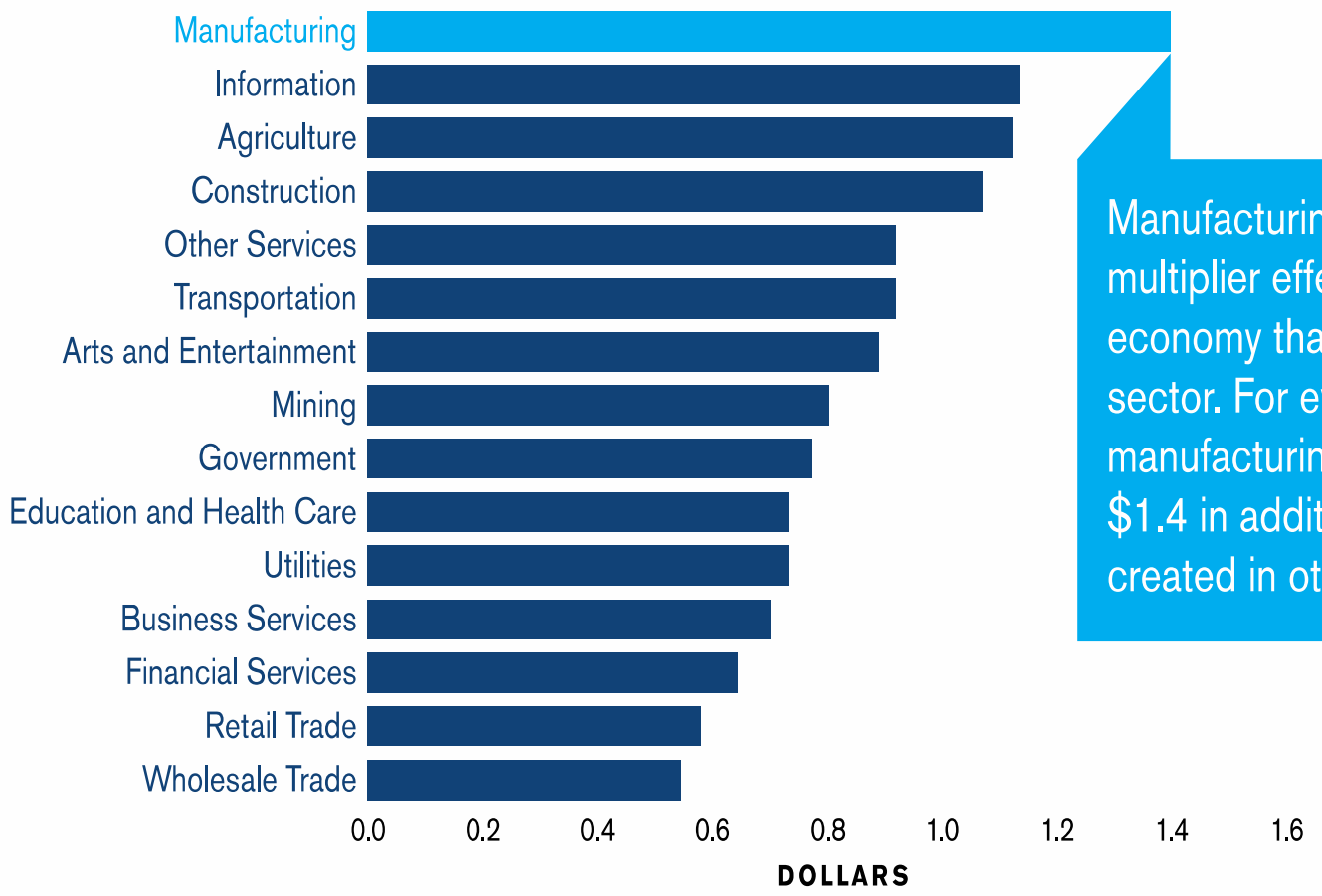
Why should we care about US Manufacturing?

Manufacturing **Economic** Impact

Manufacturing drives jobs throughout economy - including services

10% of Employment, average wages 24% higher

12% of gross domestic product



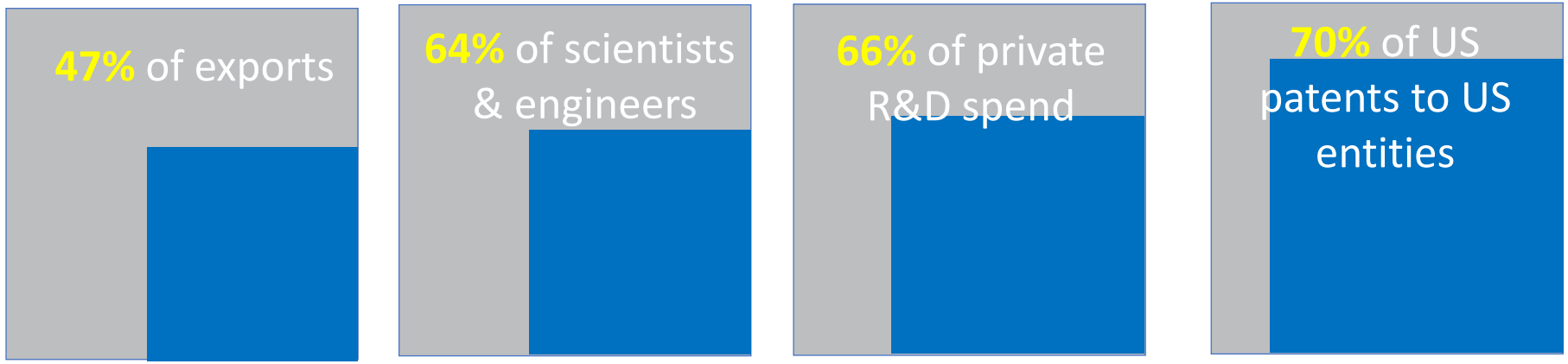
Manufacturing has a higher multiplier effect on the economy than any other sector. For every $1 in manufacturing value added, $1.4 in additional value is created in other sectors.

Source: U.S. Department of Commerce, Bureau of Economic Analysis

Why should we care about US Manufacturing?
Manufacturing **Innovation** Impact

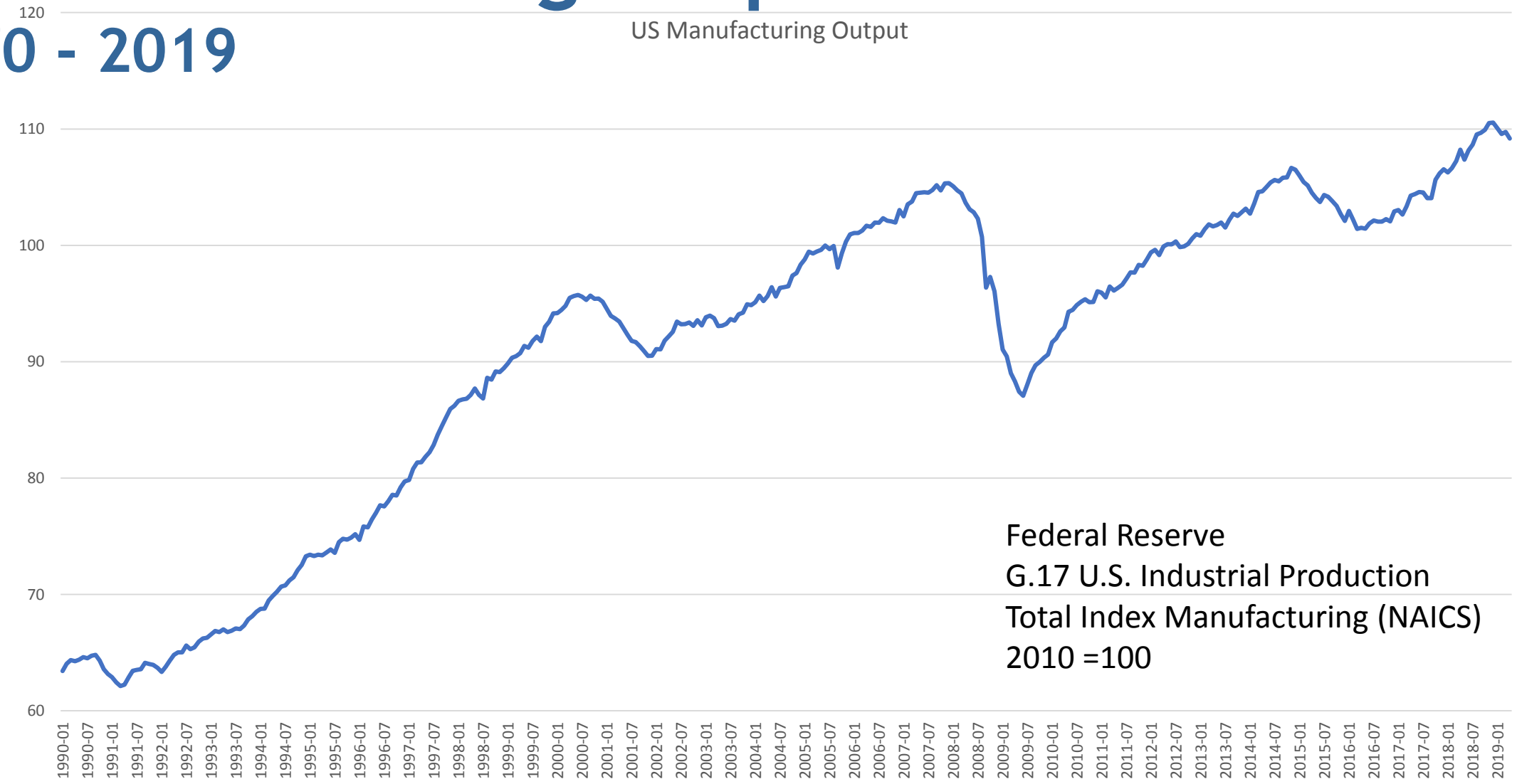
U.S. manufacturers

- Employ over half of all R&D personnel in domestic industry

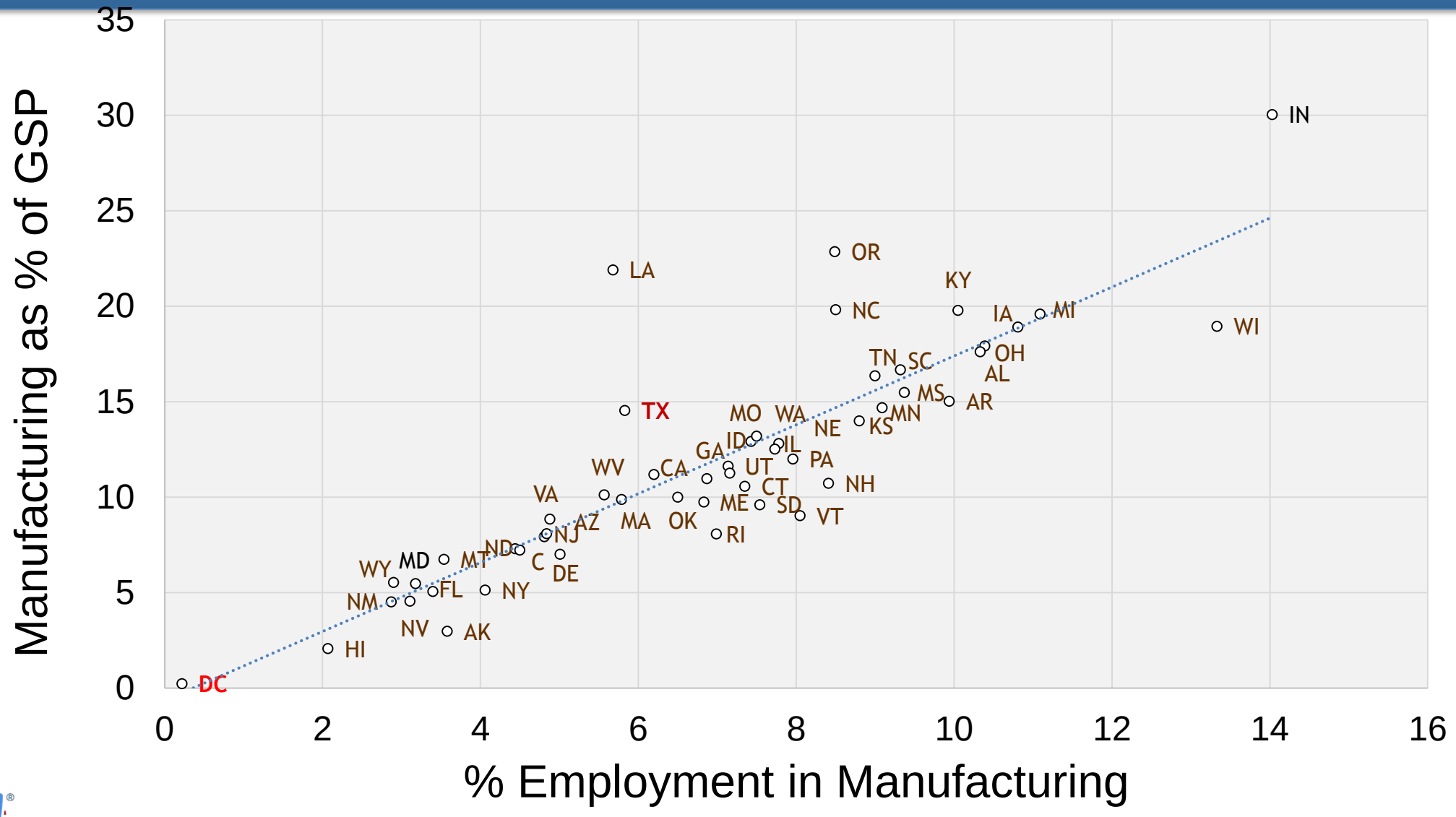


1/3rd of U.S Economic Growth is due to Innovation

US Manufacturing Output
1970 - 2019



% of Gross State Product versus % Employment



Source: Upjohn Institute Report and Bureau of Economic Analysis: Full-Time and Part-Time Wage and Salary Employment By Industry, 2015

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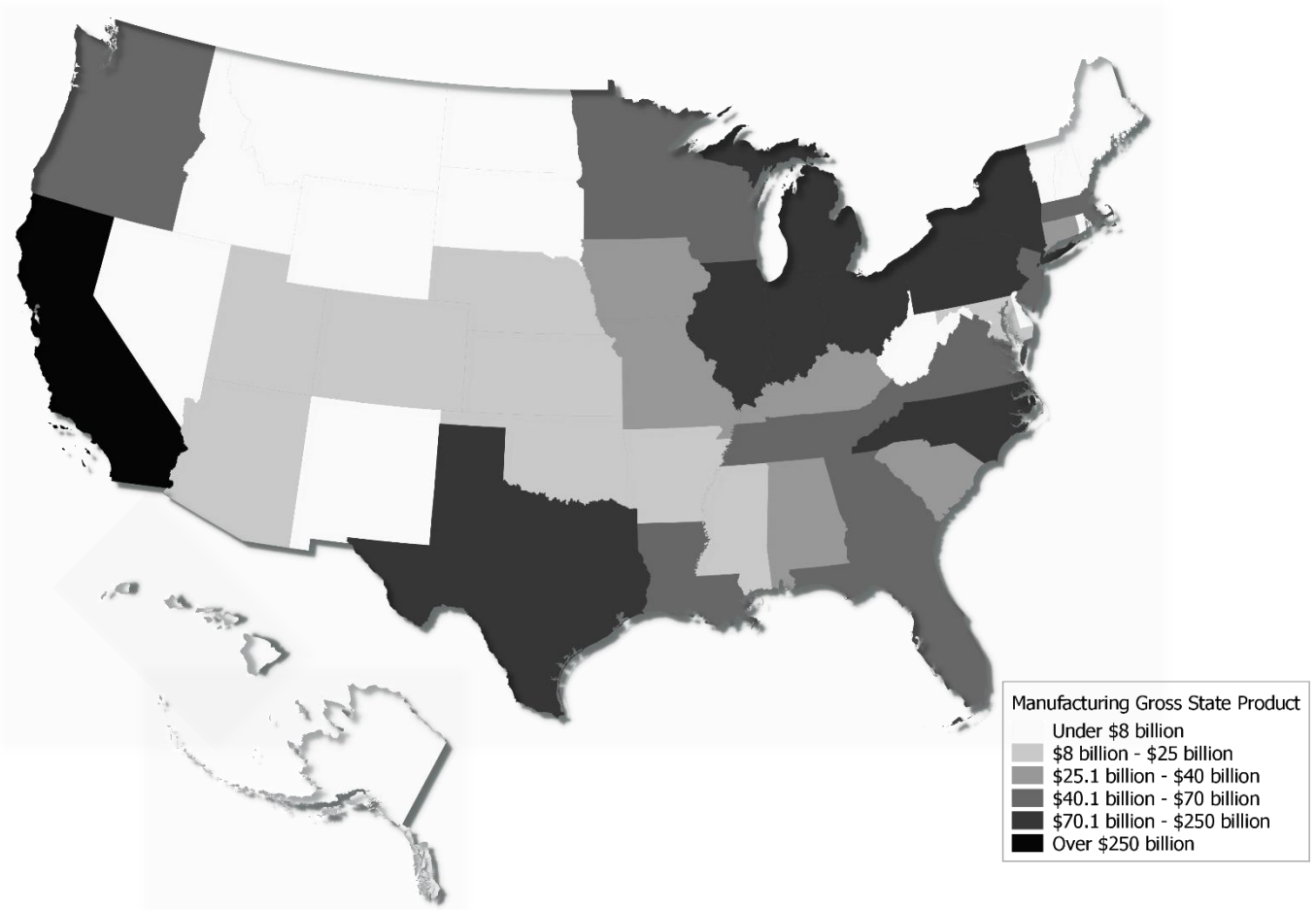
Manufacturing Gross State Product (GSP)



The Great Lakes region, along with North Carolina, California, and Texas, dominate the total value of gross state product (GSP) generated in the United States.

States with Most Manufacturing GSP

1.	California	$277,634,000,000
2.	Texas	$237,082,000,000
3.	Ohio	$109,476,000,000
4.	Indiana	$100,908,000,000
5.	Illinois	$99,514,000,000

Source: Upjohn Institute Report and Bureau of Economic Analysis: Full-Time and Part-Time Wage and Salary Employment By Industry, 2015

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US and Texas Manufacturing Snapshot

United States		Texas
$2.38 trillion	Total Manufacturing Output	$226 billion
291,543	Total Manufacturing Firms	17,457
$1,316 billion	Total Manufactured Goods Exported	$247 billion *(highest in nation!)*
20%	Export Growth 2010-2018	28%
97%	Small Business (<500 employees) Share of Exports	93%
EU, Canada, Mexico, China, Japan	Total 5 Export Markets	1- Mexico, 2 - Canada, 3 - China, 4 - Brazil, 5 – So Korea

Texas: 880,900 manufacturing employees, average compensation $85,051

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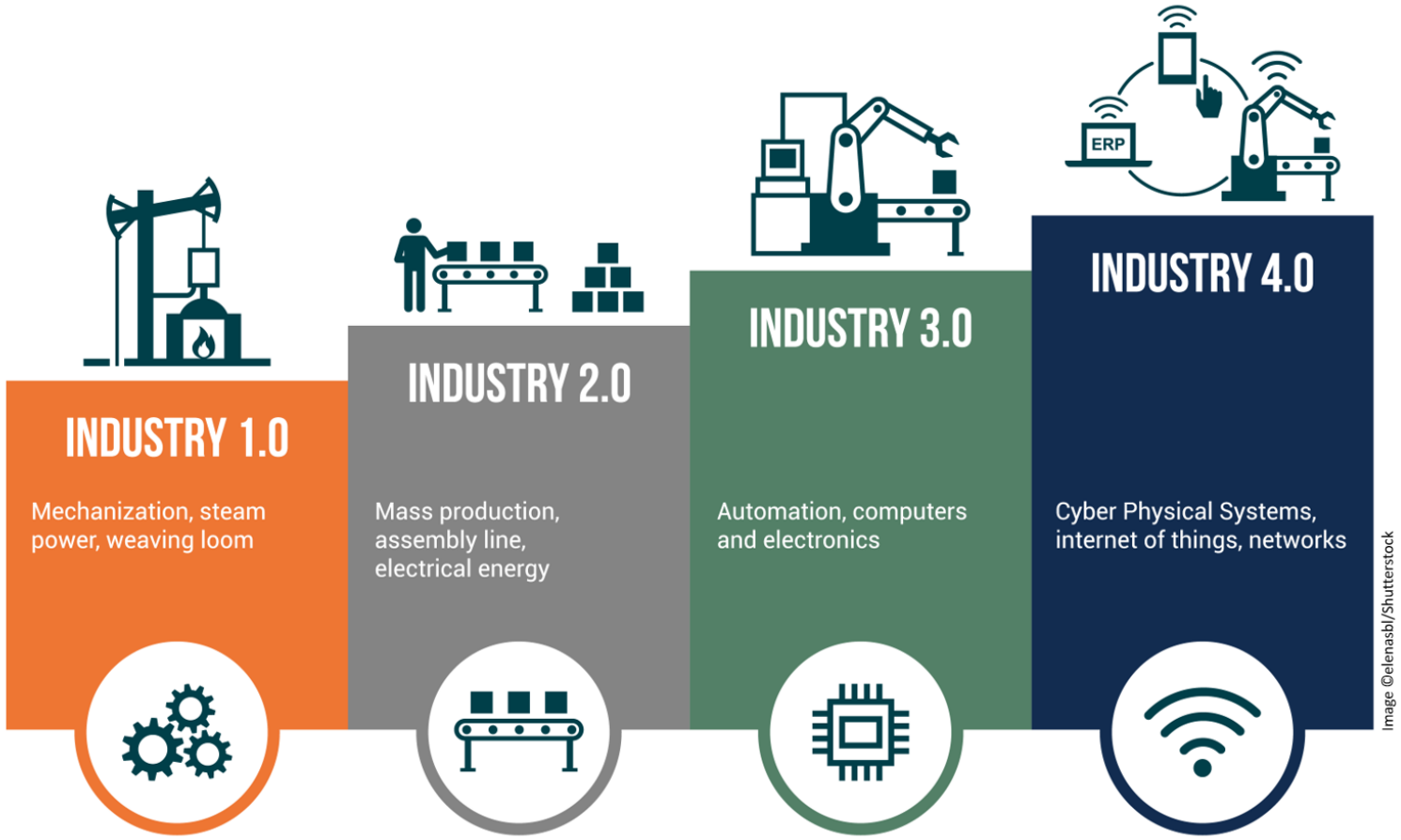
Fourth Industrial Revolution

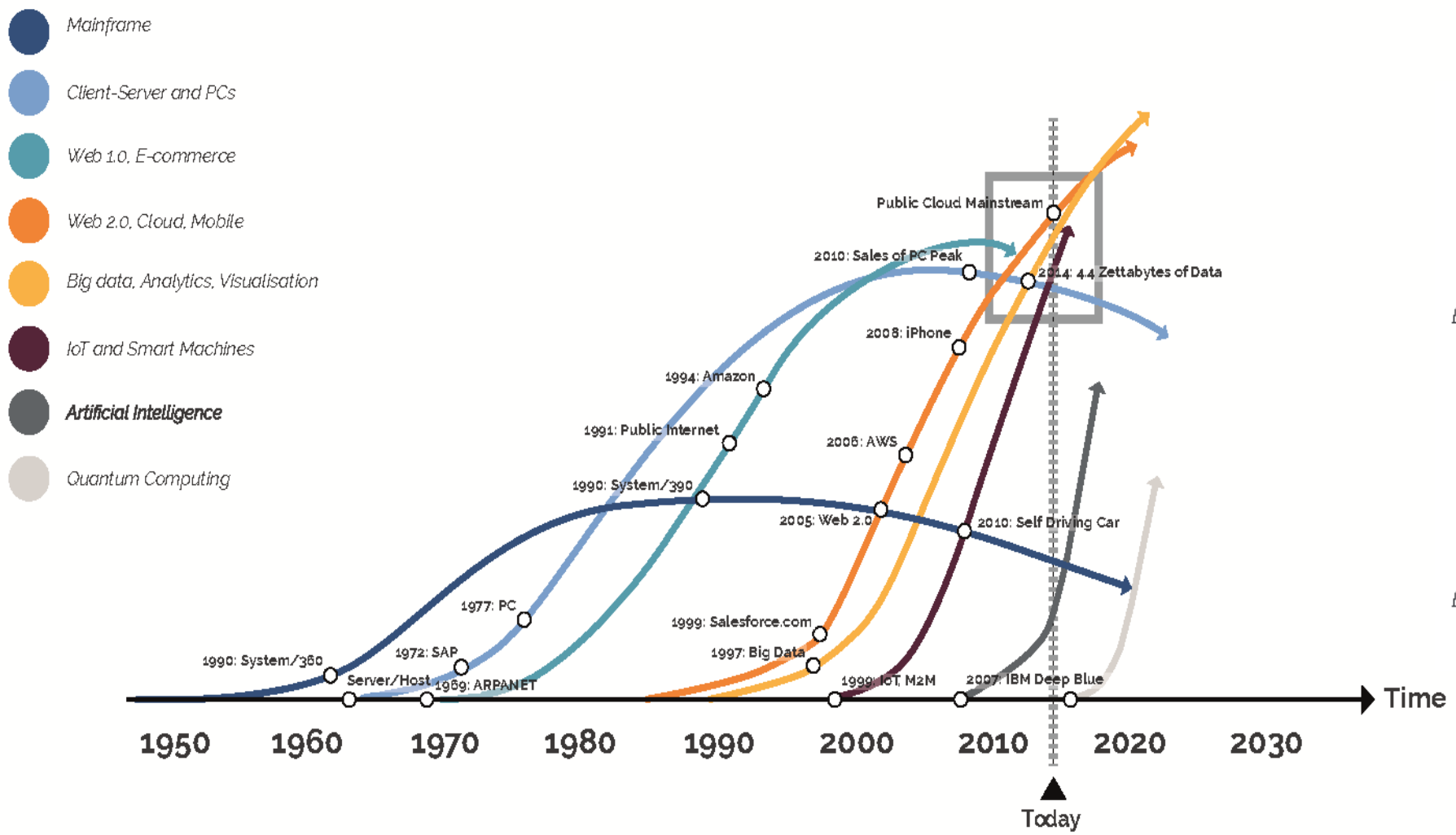


Convergence of advancing technologies together with **precision measurements** and **standards** enabling:

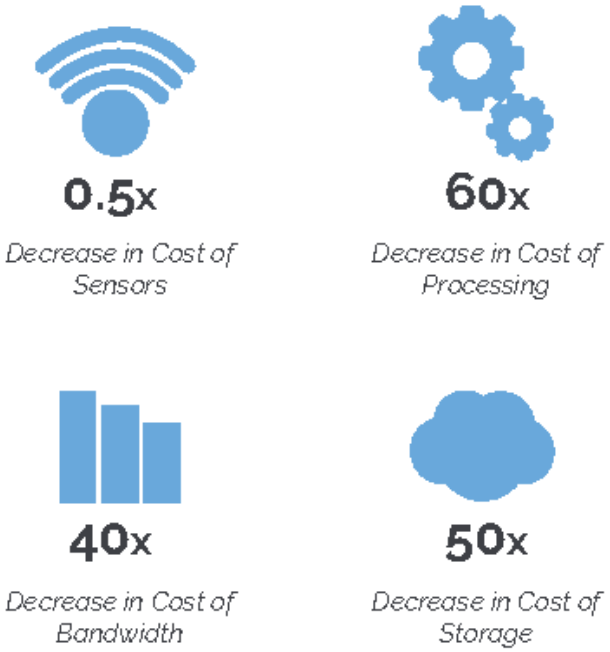
- Fourth Industrial Revolution
- Industrie 4.0
- Internet of Things
- Cyber-Physical Systems

2018 World Manufacturing Forum Report

Figure 3 - The Combinatorial Effect of Technology
(Source: Accenture)



Cost reductions in last decade fueling the Internet of Things



2018 Economic Forum – Future of Jobs

And while it is anticipated that the latest revolution could lead to the displacement of 75 million jobs worldwide in the next 4 years, at the same time it's expected that new opportunities will also lead to 133 million new jobs.[1]

Thus 58 million more jobs will be created by advanced technology than lost. Moreover, the content of jobs, i.e., the tasks involved and the skills required, will likely change for even more workers.

There will not be nearly enough skilled workers to allow full use of advanced manufacturing technology unless there is sufficient retraining of workers, and use of current workers to help bring in the new technology.

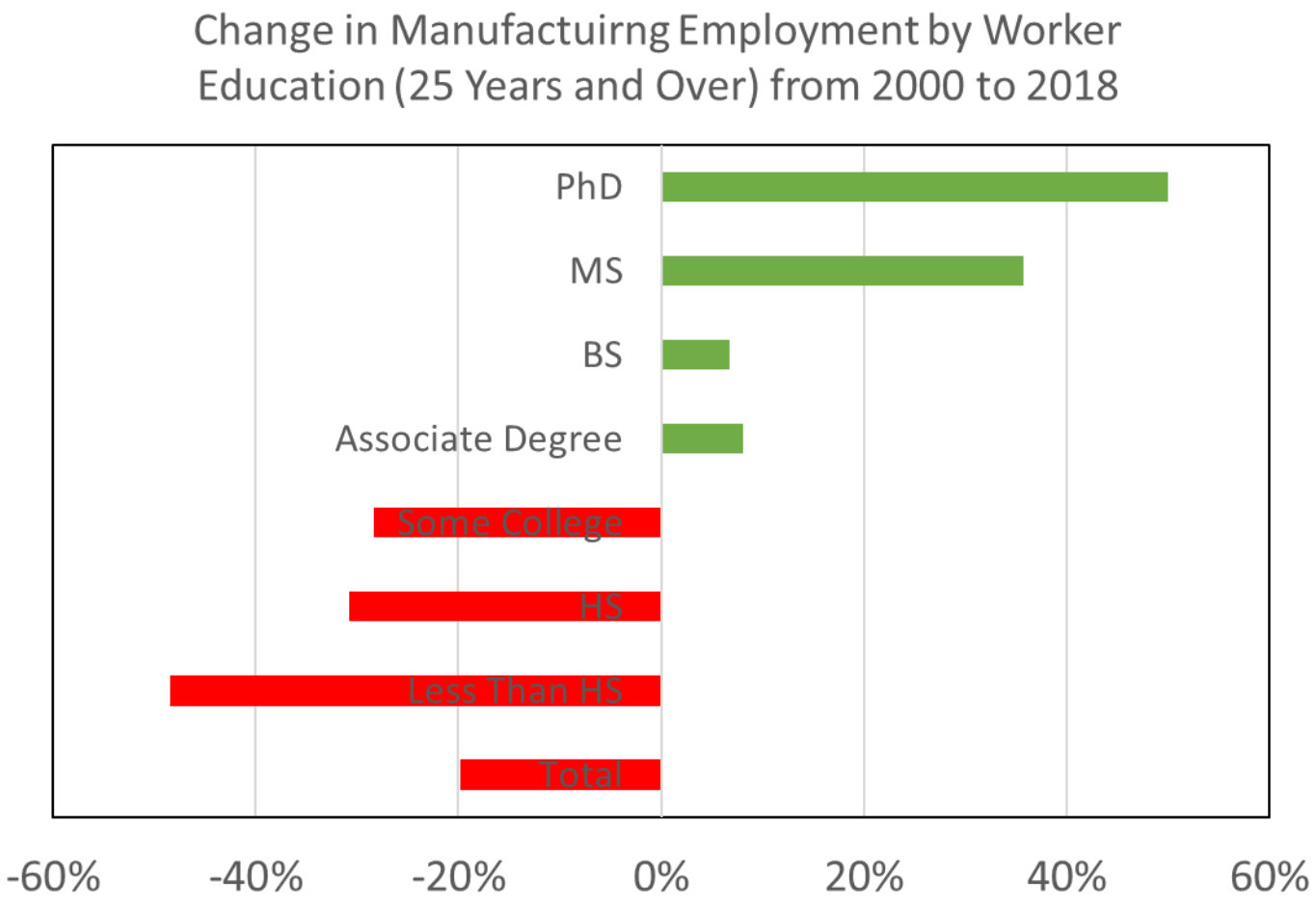
[1] *jobs forecast from "The Future of Jobs Report 2018", World Economic Forum*

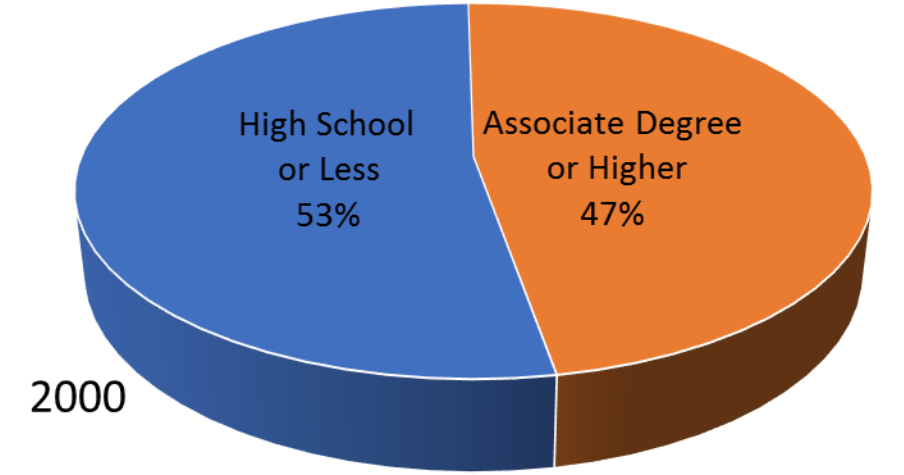
http://www3.weforum.org/docs/WEF_Future_of_Jobs_2018.pdf

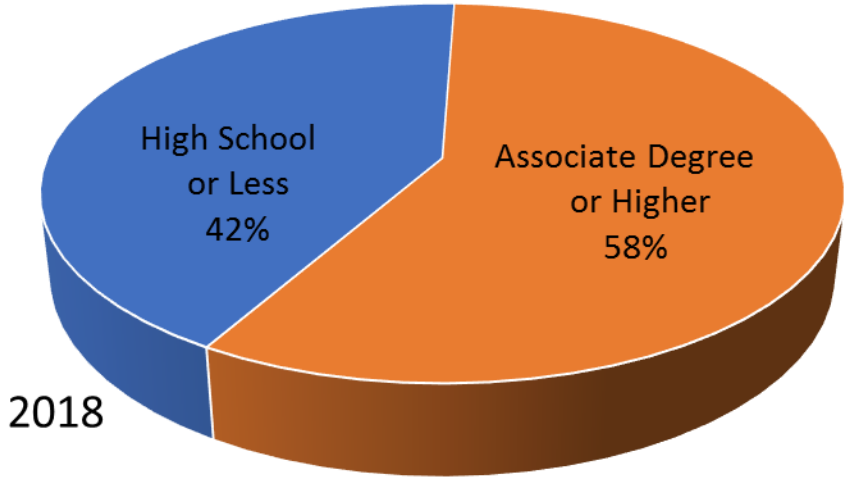
ManufacturingUSA

US Manufacturing – 2000-2018

Manufacturing is a knowledge industry







ManufacturingUSA

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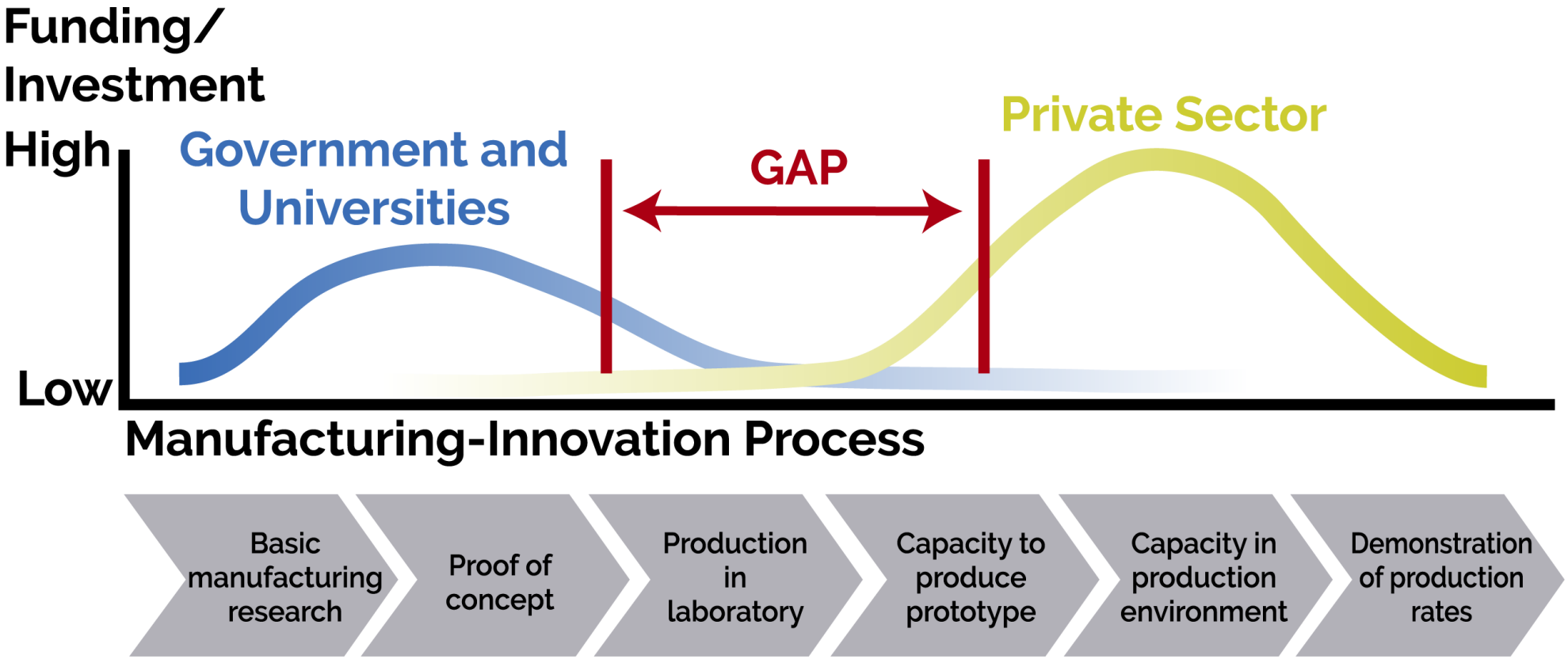
Key Innovation Challenge - “Scale-up Valley of Death”

NIST

- Innovation Pathways, barriers to Tech Transfer
- Private sector investment in applied research
- Private sector investment in U.S. manufacturing
- Education / Workforce Skills in new technologies
- Supply Chain capabilities and capacities

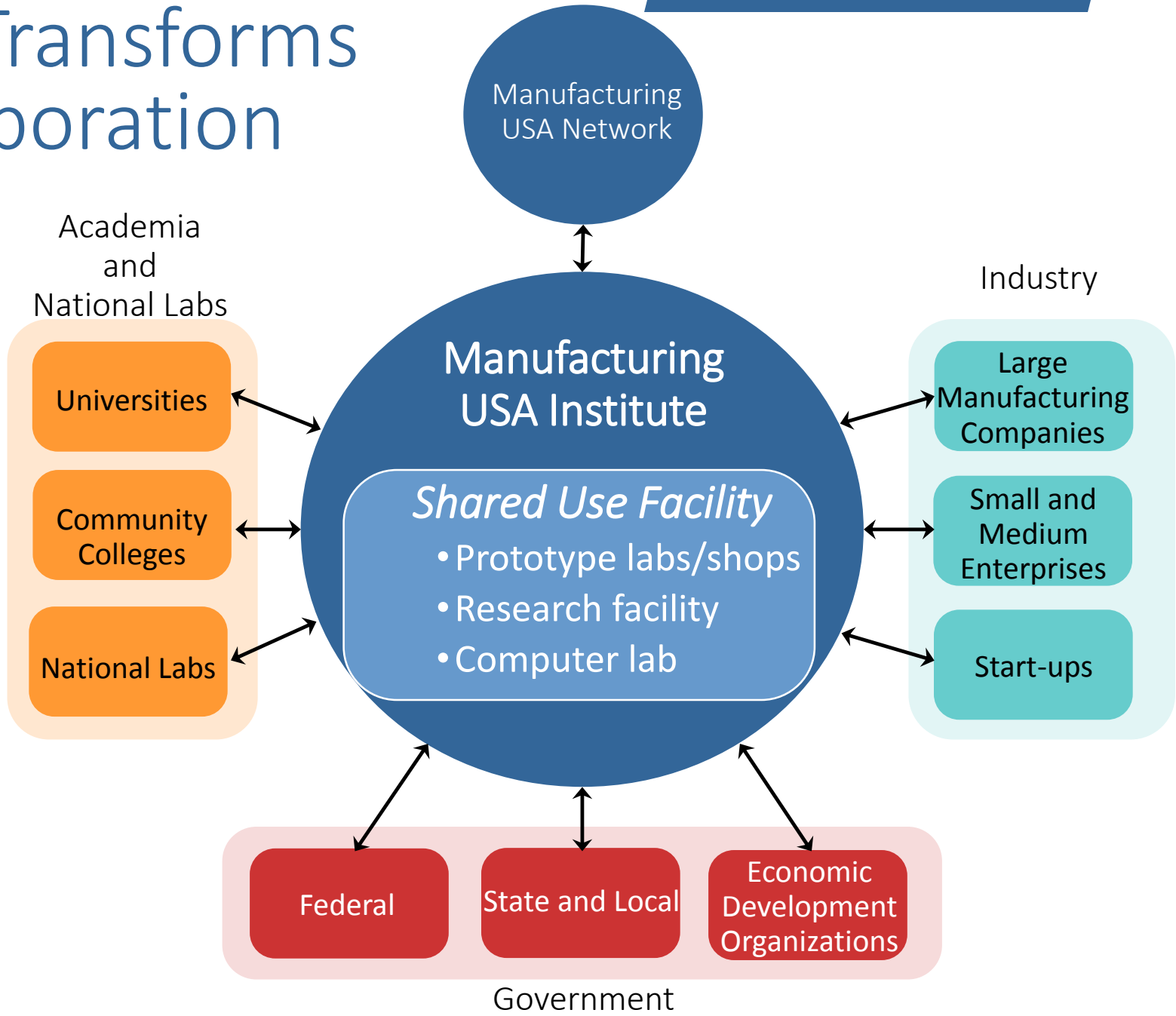


Manufacturing USA

Mission: Connecting people, ideas, and technology to solve industry-relevant advanced manufacturing challenges, thereby enhancing industrial competitiveness and economic growth and strengthening our national security.

Vision: U.S. global leadership in advanced manufacturing

Institute Design Transforms Large Scale Collaboration



Institutes Build Powerful Connections

NEXTFLEX
Flexible Hybrid Electronics
San Jose, CA

CESMII THE SMART MANUFACTURING INSTITUTE
Smart Sensors and Digital Process Control
Los Angeles, CA

MD
Digital Manufacturing
Chicago, IL

REMADE INSTITUTE
Sustainable Manufacturing
Rochester, NY

AIM photonics
Integrated Photonics
Albany, NY
Rochester, NY

biofabusa
Regenerative Manufacturing
Manchester, NH

affoa
Advanced Fibers and Textiles
Cambridge, MA

RAPID Transforming Process Industries
Modular Chemical Process Intensification
New York, NY

NIMBL
Bio-pharmaceutical Manufacturing
Newark, DE

ManufacturingUSA®

lift
Lightweight Metals
Detroit, MI

America Makes
Additive Manufacturing
Youngstown, OH
El Paso, TX

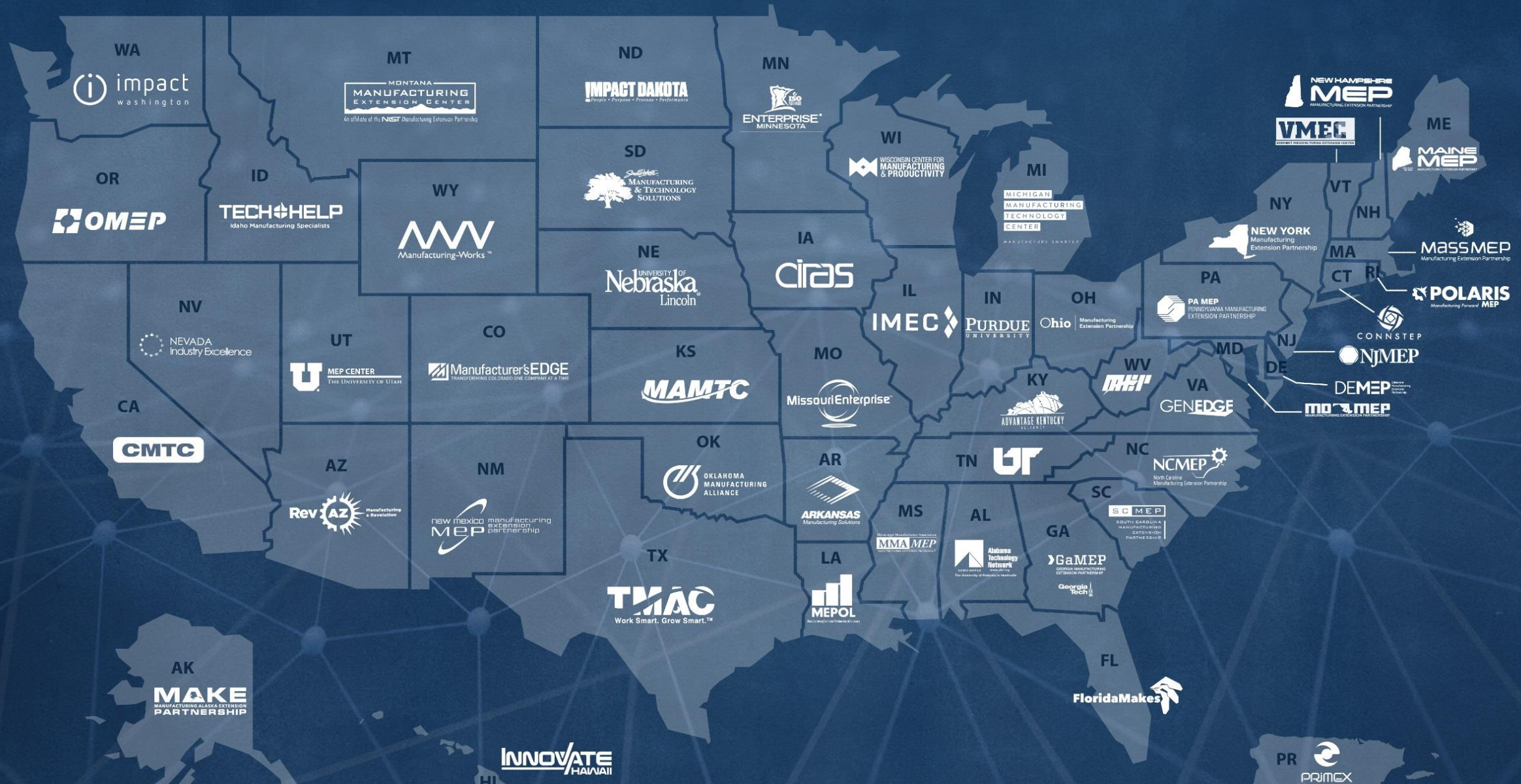
THE COMPOSITES iacmi INSTITUTE
Advanced Composites
Knoxville, TN

ARM
Advanced Robotics
Pittsburgh, PA

PowerAmerica
Wide Bandgap Semiconductors
Raleigh, NC

MEP National Network™

The Go-To Experts for Advancing U.S. Manufacturing



Each Institute

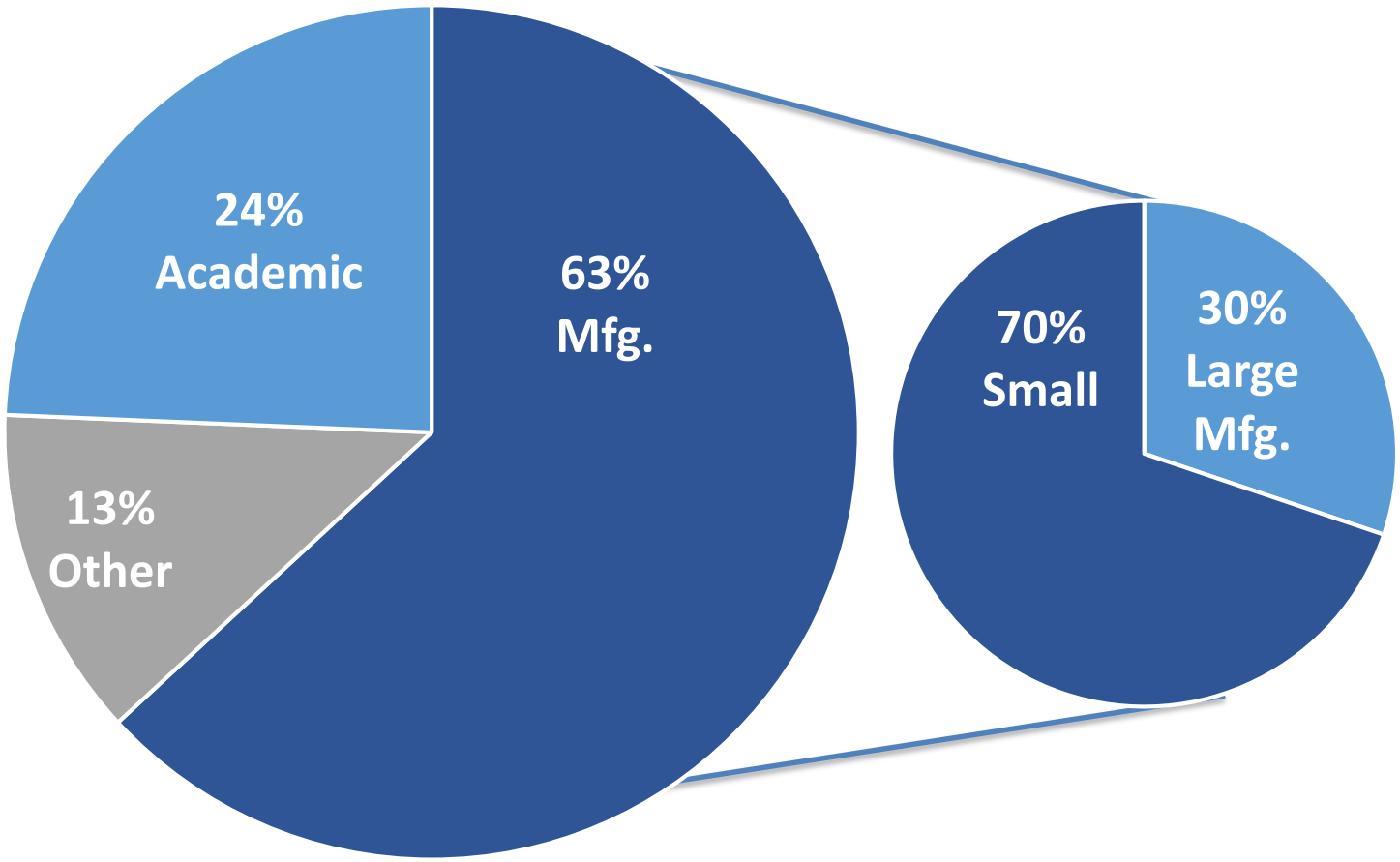
Advances U.S. Manufacturing

1. Industry-led consortium with a clear mission and unique technology focus based on critical industry need
2. Effective collaboration space for pre-competitive applied R&D, solving big challenges
3. Creates value for industry participation and funding
4. Federal start-up funding must catalyze at least 100% co-investment
5. Addresses the skills gap on education and workforce skills for their technology areas

Manufacturing USA 2018 Annual Report

- Released September 18th
- https://www.manufacturingusa.com/reports
- Cover image: The NextFlex flexible Arduino®

1) Impact to U.S. Innovation Ecosystem

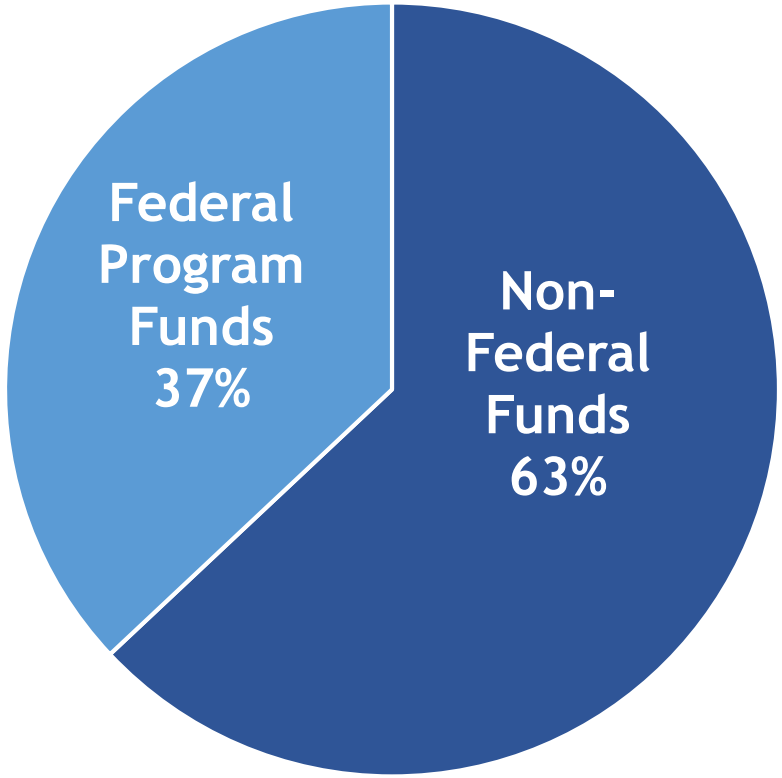


1,937 members (FY 2018)

- **+50% increase** in membership over 2017 and more than double 2016
- **63% from industry**
  - 70% of manufacturers are small and medium-sized
- **474** universities, community colleges, and other academic institutions
- **244** federal, state, and local government, federal laboratories, and not-for-profits

Membership breakdown of the 14 institutes in FY 2018

2) Leveraging Co-investment



1.7 to 1 investment match

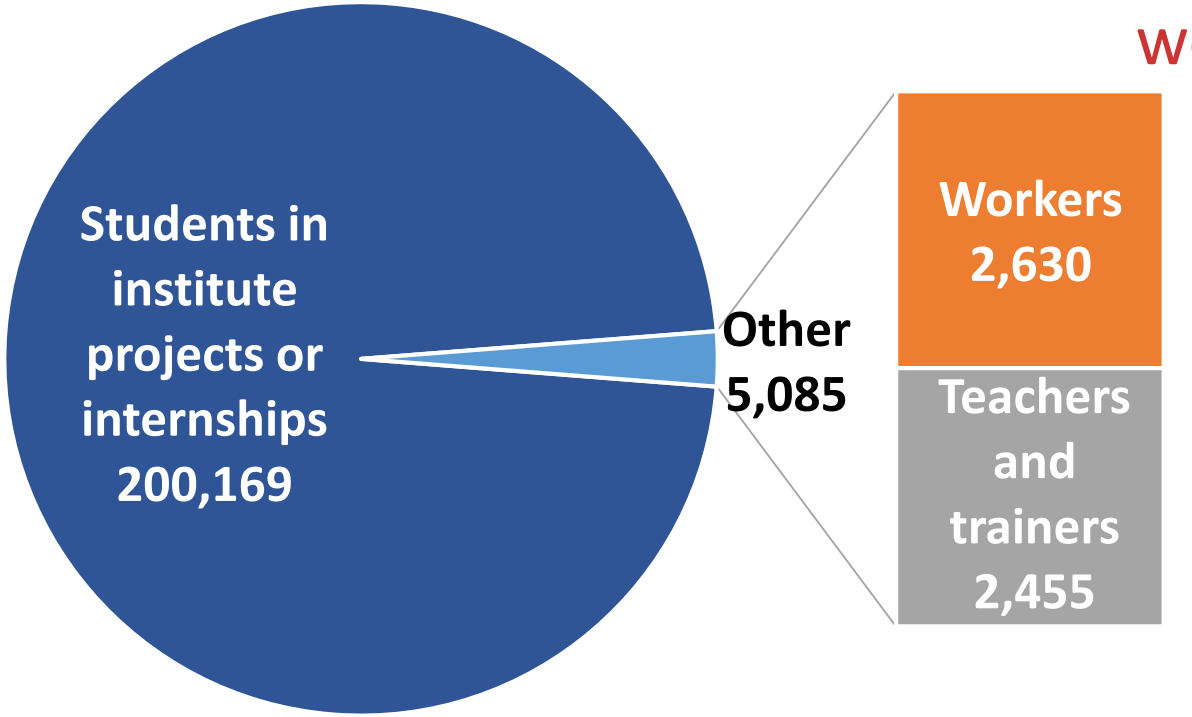
(FY 2018)

$497 million in total institute expenditures

- 63% of institute support came from non-federal matching funds
- 37% came from federal program funds

Expenditures funded all aspects of institute operation (e.g. technology advancement projects, education and workforce training efforts, and capital equipment)

3) Developing an Advanced Manufacturing Workforce



Over **205,000 people** participated in workforce development training programs

→ **Over 7X increase** in two years

- **200,169 students** in institute research and development projects, internships, or training
- **2,630 workers** completed institute-led certificate, apprenticeship, or training programs
- **2455 teachers and trainers** in institute-led training for instructors

4) Transformational Technology Advancement

476 Major Collaborative R&D Projects in FY 2018

74% growth over FY 2017

- High level of participation by industry + progress in meeting technical objectives are early indicators of success
- Transformational technologies are best advanced though **collaborative R&D**

Project Highlight

Laying the Groundwork for Scalable Gene Therapy

- Gene therapy has potential to correct genetic defects and create products to fight cancer and serious health conditions
- Created a new gene therapy process to shorten time needed to manufacture gene therapy medicines and provide a scalable way to deliver products to patients
- Launched a new course to provide necessary skills training to biopharma technicians and manufacturers

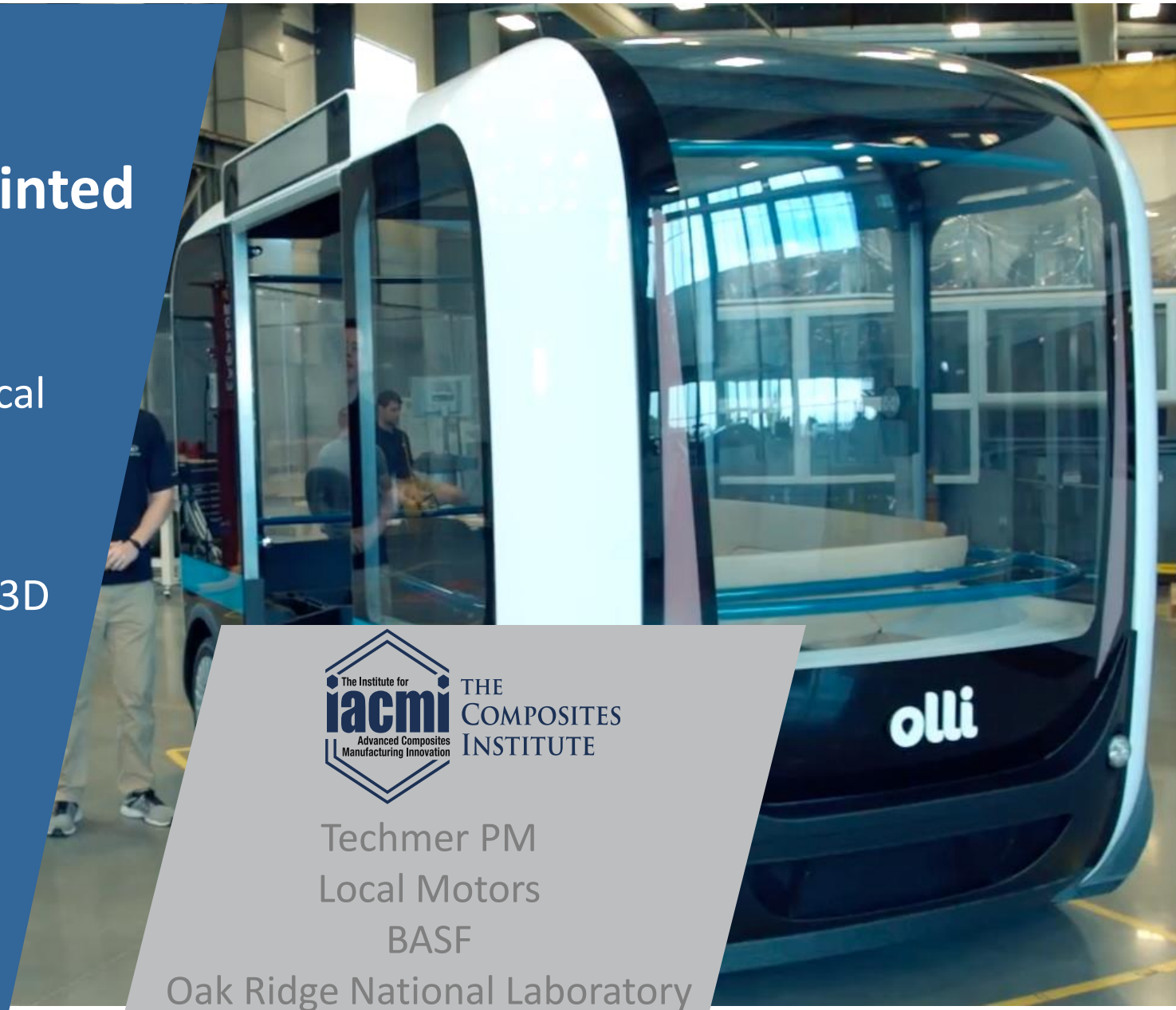
NIMBL

Biomanufacturing Training and Education Center,
North Carolina State
Sudhin Biopharma Co.
University of North Carolina, Chapel Hill

Project Highlight

Partnering to Accelerate 3D Printed Autonomous Vehicles

- Improved materials and processes for Local Motors 3D printed vehicles
- Techmer PM saw increased sales of new 3D products, expecting to double in 2019
- Local Motors installed the world's largest 3D printer and is now producing its self-driving Olli 2.0



The Institute for iacmi Advanced Composites Manufacturing Innovation
THE COMPOSITES INSTITUTE

Techmer PM
Local Motors
BASF
Oak Ridge National Laboratory
University of Tennessee

Project Highlight

Prototyping Rapid Electric Vehicle Chargers

- New charger is 10x smaller and 60% more efficient
- Projected to cost 50% less than current charging stations
- Project aims to create simple, accessible, convenient chargers for consumers similar to getting gas

PowerAmerica

North Carolina State University

Project Highlight

Inspiring Students: FlexFactor®

- Trained +2,000 Silicon Valley students
- Developed 88 product ideas in 2 yrs.
- Students earned college credit
- Replicated in other states

”The challenge in developing the workforce of the future is that most educators have never experienced the careers that we need to prepare our students for in the twenty first century, and FlexFactor overcomes this problem.”

– Vito Chiala, Principal, Overfelt High School, San Jose, CA

NEXTFLEX

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Manufacturing USA Institutes

Electronics

AIM Photonics
Integrated Photonics
Albany, NY
Rochester, NY

NextFlex
Flexible Hybrid Electronics
San Jose, CA

PowerAmerica
Wide Bandgap Semiconductors
Raleigh, NC

Materials

affoa
Advanced Fibers and Textiles
Cambridge MA

IACMI The Composites Institute
Advanced Composites
Knoxville, TN
Detroit, MI

lift
Lightweight Metals
Detroit, MI

Bio-Manufacturing

biofabusa
Regenerative Manufacturing
Manchester, NH

NIIMBL
Bio-pharmaceutical Manufacturing
Newark, DE

Energy Usage / Environmental Impact

RAPID Transforming Process Industries
Modular Chemical Process Intensification
New York, NY

REMADE Institute
Sustainable Manufacturing
Rochester, NY

Clean Energy Smart Manufacturing Innovation Institute
Smart Sensors and Digital Process Control
Los Angeles, CA

Digital Automation

America Makes
Additive Manufacturing
Youngstown, OH
El Paso, TX

ARM Advanced Robotics for Manufacturing
Advanced Robotics
Pittsburgh, PA

MxD
Digital Manufacturing
Chicago, IL

New for 2019/20

DOE sponsored Cybersecurity Institute

New for 2020/21

DOD sponsored Synthetic Biology Institute

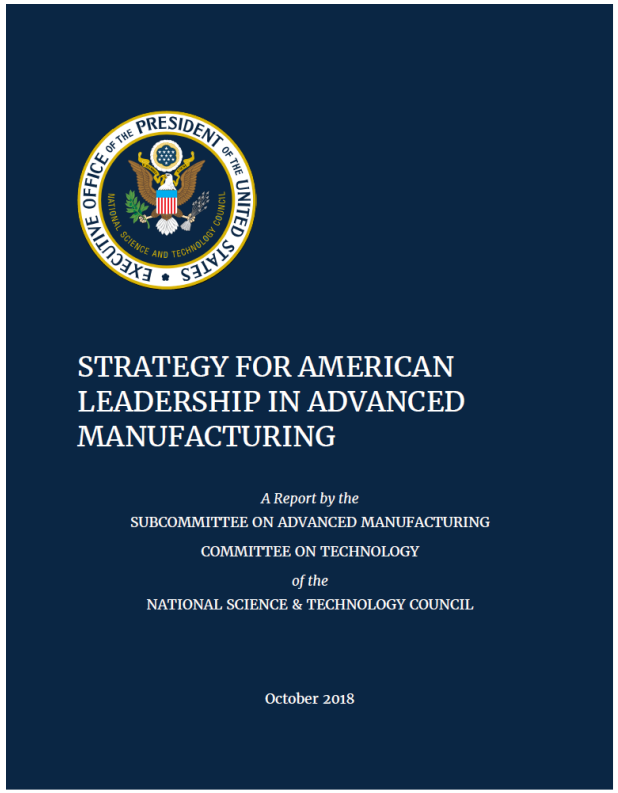
ManufacturingUSA

Strategic Plan for Advanced Manufacturing

Vision: American leadership in advanced manufacturing across industrial sectors to ensure national security and economic prosperity

Goals

1. Develop and transition new manufacturing technologies – **5 Objectives** with **15 priorities**
2. Educate, train, and connect the manufacturing workforce – **4 Objectives** with **9 priorities**
3. Expand the capabilities of the domestic manufacturing supply chain – **4 Objectives** with **11 priorities**


STRATEGY FOR AMERICAN LEADERSHIP IN ADVANCED MANUFACTURING

A Report by the
SUBCOMMITTEE ON ADVANCED MANUFACTURING
COMMITTEE ON TECHNOLOGY
of the
NATIONAL SCIENCE & TECHNOLOGY COUNCIL

October 2018

https://www.whitehouse.gov/wp-content/uploads/2018/10/Advanced-Manufacturing-Strategic-Plan-2018.pdf

2019 Designation – Industries of the Future

American Leadership in Industries of the Future

Artificial Intelligence, Quantum Information Science, and Computing

Quantum Science:

- QEDC, Quantum-based metrology, Quantum engineering, Quantum Communications, JQI, JILA, QuICS, post-quantum cryptography

Artificial Intelligence:

- Trustworthy AI, application in materials communications, IoT, biosciences

Quantum Science

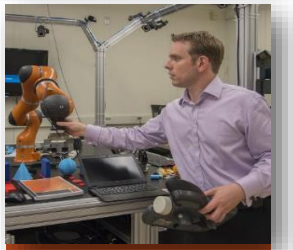
Artificial Intelligence

Advanced Communications Networks and Autonomy

- public safety communications, next generation wireless, spectrum sharing, metrology of communications, trustworthy networks, cyber physical systems/IoT cybersecurity, 5G standards, UAS Challenge

Advanced Manufacturing

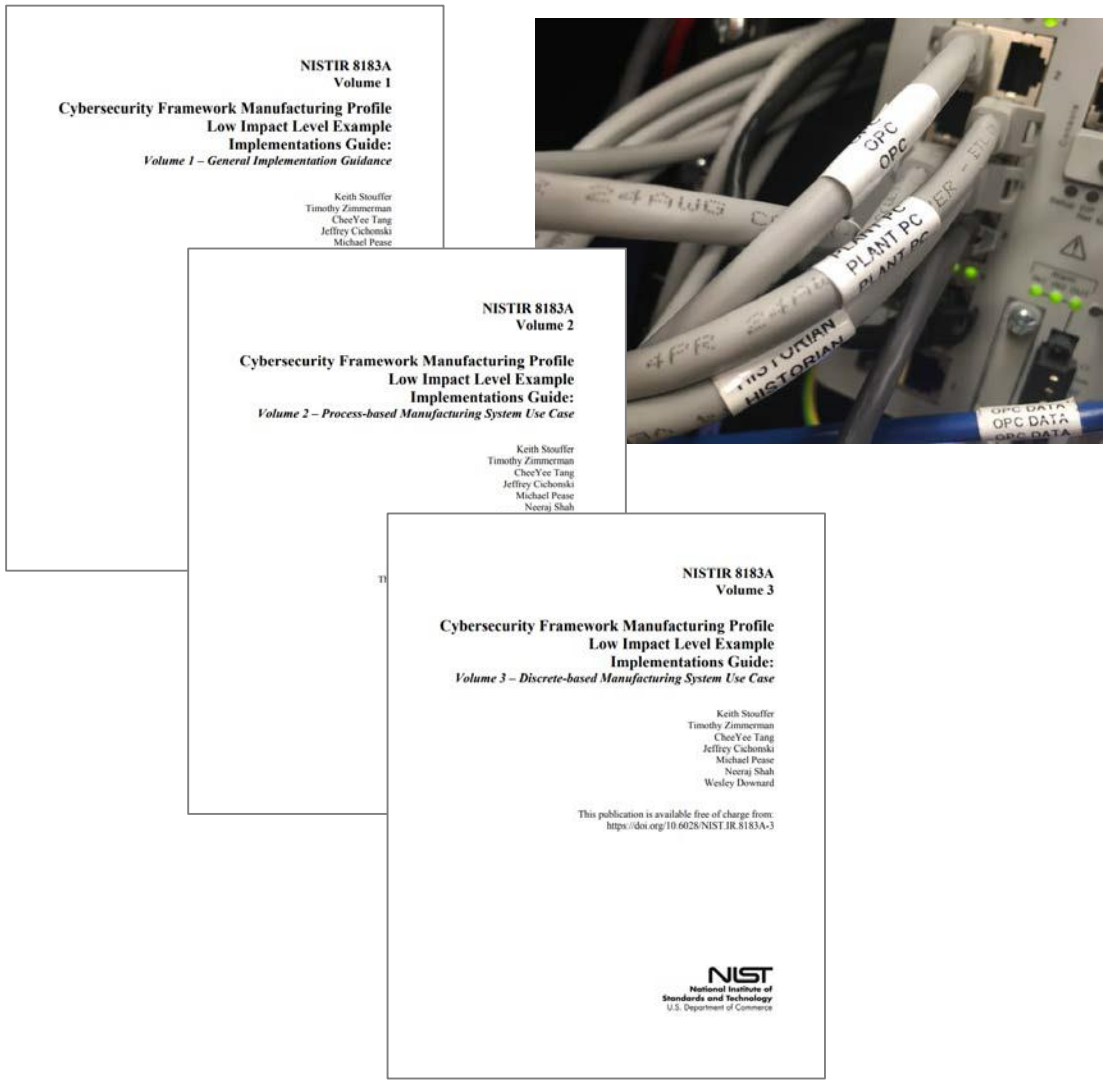
- additive manufacturing, robotics, integration, smart manufacturing , advanced materials, biomanufacturing, precision measurements, nSOFT
- Manufacturing USA
- MEP Network



Advanced Manuf-ing

Advanced Manufacturing:

Implementation Guide for the Cybersecurity Framework



730-page, 3-Volume Guide is the first detailed cybersecurity implementation guide for manufacturers

Answers small and medium-sized manufacturers expressed need in implementing a standards-based cybersecurity program

Enables manufacturers to select and deploy cybersecurity tools that fit their needs AND address operations, reliability, and safety requirements.

Opportunities from Digital Manufacturing

Democratization of tools needed to Design and Make

Shared access to non-profit and commercial makerspaces.

National Institute of Standards and Technology
U.S. Department of Commerce

Future Digital Manufacturers

Inspiration *to* Innovation *to* Making

National Institute of Standards and Technology
U.S. Department of Commerce

Thank you

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