PURDUE UNIVERSITY®

Purdue Polytechnic Institute Advanced Manufacturing Ecosystem

Dr. Nathan W. Hartman
Dauch Family Professor of Advanced Manufacturing

A bit about your presenter…

B.S. and M.S. from Purdue University (design)

Ed.D. from N.C. State (education, cognitive psychology, training & development)

Worked 8 years in manufacturing sector

- Fairfield Manufacturing: machinist
- Caterpillar: designer
- Rand Worldwide: technical training engineer

21 years at Purdue University

- Industry and agency research
- PI or Co-PI with collaborators across campus
- Have done open, proprietary, and controlled research
- Established industry research consortia and secured State line-item funding
- Developed successful proposals for establishing regional economic development networks and federal research institutes
- Serves as subject matter expert for national and international standards committees and federal cabinet-level departments

oerlikon fairfield · CAT · RAND WORLDWIDE · M D The Digital Manufacturing & Cybersecurity Institute · NSF · CYMANII the cybersecurity manufacturing innovation institute · Rolls-Royce · gm · ISO · NIST · P&G · Gulfstream · Collins Aerospace An RTX Business · GE · Sandia National Laboratories · Cummins · LOCKHEED MARTIN · TEXTRON · BOEING · HONDA · Ford · sme EDUCATION FOUNDATION · Lilly Endowment Inc. A private foundation since 1937

University Overview

WHERE IS PURDUE?

- West Lafayette, Indiana
- Two hours southeast of Chicago
- One hour northwest of Indianapolis
- Lafayette just across the river

CAMPUS COMMUNITY

- Over 50,000 total students
- More than 9,300 international students and 1,150 international faculty and staff from 128 countries
- Continually ranked in the top 5 in the country in international enrollment
- More than 1,000 student clubs & organizations
- Around 70 international student groups
- Exchange students welcome to audition for Purdue musical groups and theatre and dance productions
- Mascot: Boilermaker Special

RESIDENTIAL LIFE

- Available on-campus housing offers…
  - Comfortable accommodation
  - Organized social events and residential learning programs
- Meal plan options
- Free local bus service connects campus and the Greater Lafayette area
- Use of Recreational Sports Center is free of charge for all exchange students
- Exchange students can get involved with intramural and club sports

PURDUE UNIVERSITY

TOP 10 MOST INNOVATIVE UNIVERSITY IN AMERICA
U.S. News & World Report, 2023
5 YEARS RUNNING

- College of Agriculture
- College of Education
- College of Engineering
- College of Health and Human Sciences
- College of Liberal Arts
- Daniels School of Business
- College of Pharmacy
- Purdue Polytechnic Institute
- College of Science
- College of Veterinary Medicine


PURDUE POLYTECHNIC
Hands-on education. Real-world success.
PURDUE UNIVERSITY
Polytechnic Institute

30+ MAJORS

BACHELOR OF SCIENCE

PROFESSORS TEACH

80%

UNDERGRAD COURSES

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polytechnic.purdue.edu
techrecruit@purdue.edu
/TechPurdue
Techies Today Podcast


5,912
STUDENTS
Highest-ever enrollment — new records each of the last seven years!
(2017–2023, Polytechnic West Lafayette location)
#3
LARGEST PURDUE COLLEGE BY ENROLLMENT
PURDUE UNIVERSITY
Polytechnic Institute
polytechnic.purdue.edu
techrecruit@purdue.edu
/TechPurdue
Techies Today Podcast

FOR THE LEARNING

Learning through ...

- **Labs** *Learn by doing from firsthand experience*
- **Research** *Dig deeper to expand your knowledge*
- **Projects** *which will include industry clients*
- *Thinking with a* **Global Perspective**
- *Specializing in your* **Area of Study**

FOR THE EXPERIENCES

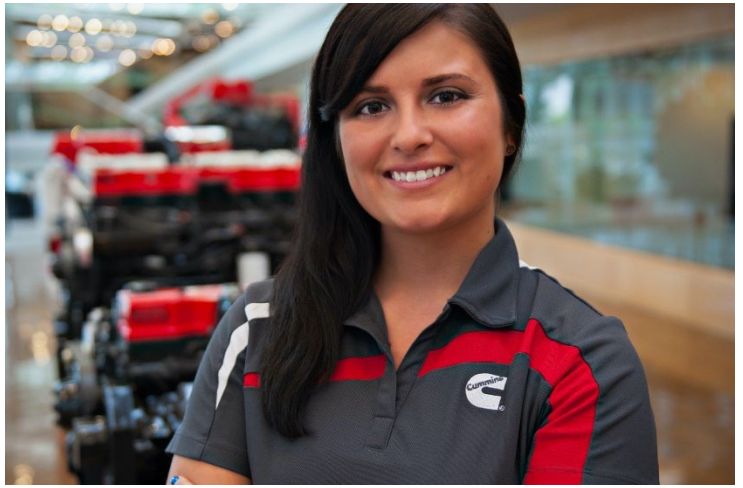
A Polytechnic major is more than just the courses you take:

- **Professors** *Mentors who bring theories to life*
- **Advisors** *Guidance & advice*
- **Student Organizations**

  Apply what you know & have fun
- **Internships** *Job experience & networking*
- **Study Abroad** *Broaden your perspective*

Choice of locations:

- **West Lafayette** *Large university setting*
- **Indianapolis** *Urban setting*
- **Nine more Indiana cities** *Close to home*



DEPARTMENT OF TECHNOLOGY LEADERSHIP & INNOVATION

Majors

Engineering-Technology Teacher Education

Human Resource Development

Organizational Leadership

Concentrations within Organizational Leadership:

- Business Intelligence
- Organizational Design and Transformation
- Project Management

We are the human side of technology.

LEADERS FROM DAY ONE

- Award-winning professors
- Certifications in SHRM & teaching
- Study Abroad opportunities and industry collaborations

2022 GRADS:*

97.0%**

PLACEMENT RATE

$61,145**

AVG. STARTING SALARY

PURDUE UNIVERSITY | Polytechnic Institute

SCHOOL OF AVIATION AND TRANSPORTATION TECHNOLOGY

Majors

Aeronautical Engineering Technology

Aerospace Financial Analysis

Airline Management and Operations

Airport Management and Operations

Aviation Management

Professional Flight

Unmanned Aerial Systems

2022 GRADS:*

97.3%

PLACEMENT RATE

$61,023

AVG. STARTING SALARY

PURDUE UNIVERSITY | Polytechnic Institute

DEPARTMENT OF COMPUTER GRAPHICS TECHNOLOGY

Majors

Animation and Visual Effects

Data Visualization

Game Development and Design

User Experience (UX) Design

Web Programming and Design

2022 GRADS:*

93.6%

PLACEMENT RATE

$68,437

AVG. STARTING SALARY

PURDUE UNIVERSITY | Polytechnic Institute

DEPARTMENT OF COMPUTER AND INFORMATION TECHNOLOGY

Majors

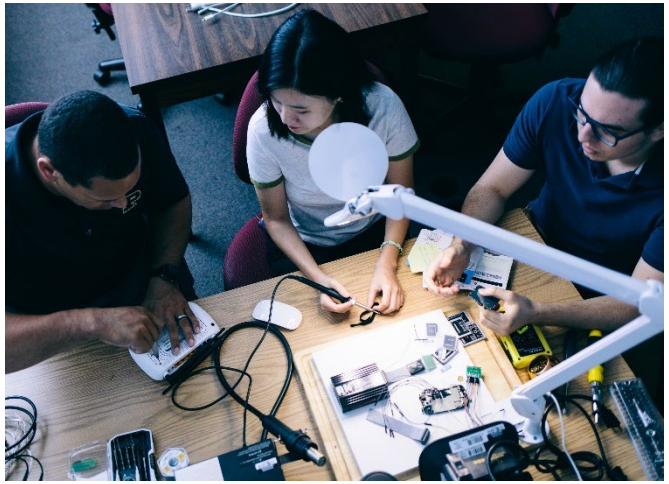
Computer and Information Technology

Computing Infrastructure and Network Engineering Technology

Cybersecurity

Data Analytics, Technologies and Applications

Computer Systems Analysis and Design



Focus Areas

Software Development

Systems Integration

Data Management

Cyber Learning

2022 GRADS:*

95.3%

PLACEMENT RATE

$78,556

AVG. STARTING SALARY

PURDUE UNIVERSITY | Polytechnic Institute

SCHOOL OF CONSTRUCTION MANAGEMENT TECHNOLOGY

Majors

Construction Management Technology

Specializations within this major:

- Commercial Construction Management
- Demolition and Restoration Management in the Built Environment
- Healthcare Construction Management
- Mechanical and Electrical Construction Management
- Residential Construction Management

Building Information Modeling

Design and Construction Integration

2022 GRADS:*

100%

PLACEMENT RATE

$65,317

AVG. STARTING SALARY

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SCHOOL OF ENGINEERING TECHNOLOGY

Majors

Electrical Engineering Technology Program

- Audio Engineering Technology
- Computer Engineering Technology
- Electrical Engineering Technology
- Energy Engineering Technology

Industrial Engineering Technology Program

- Industrial Engineering Technology
- Supply Chain and Sales Engineering Technology

Manufacturing Engineering Technology Program

- Automation and Systems Integration Engineering Technology
- Digital Enterprise Systems
- Mechatronics Engineering Technology
- Robotics Engineering Technology
- Smart Manufacturing Industrial Informatics

Mechanical Engineering Technology Program

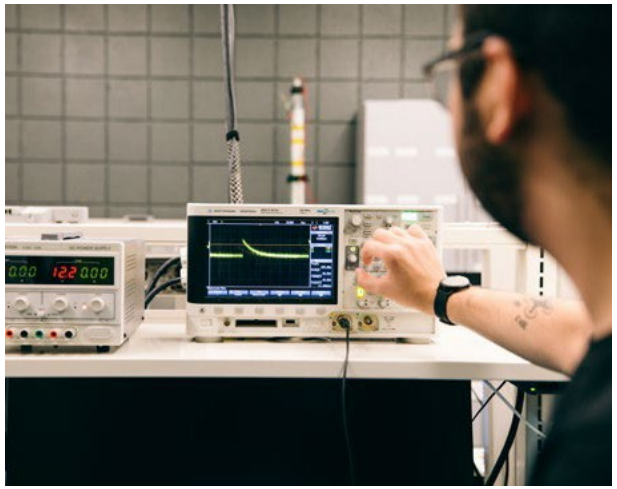
- Mechanical Engineering Technology

Additional engineering technology majors in the college:

Aeronautical Engineering Technology » SATT

Computing Infrastructure and Network Engineering Technology » CIT

Engineering-Technology Teacher Education » TLI



2022 GRADS:*

97.9%

PLACEMENT RATE

$69,830

AVG. STARTING SALARY

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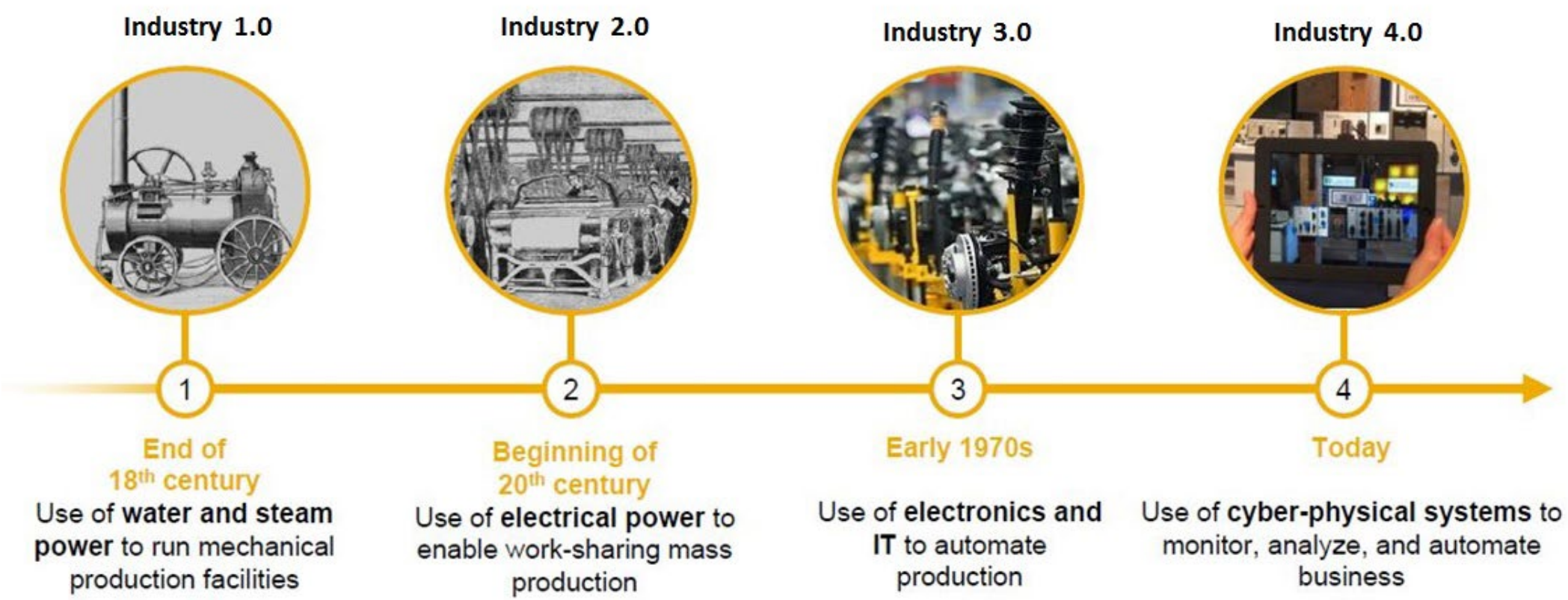
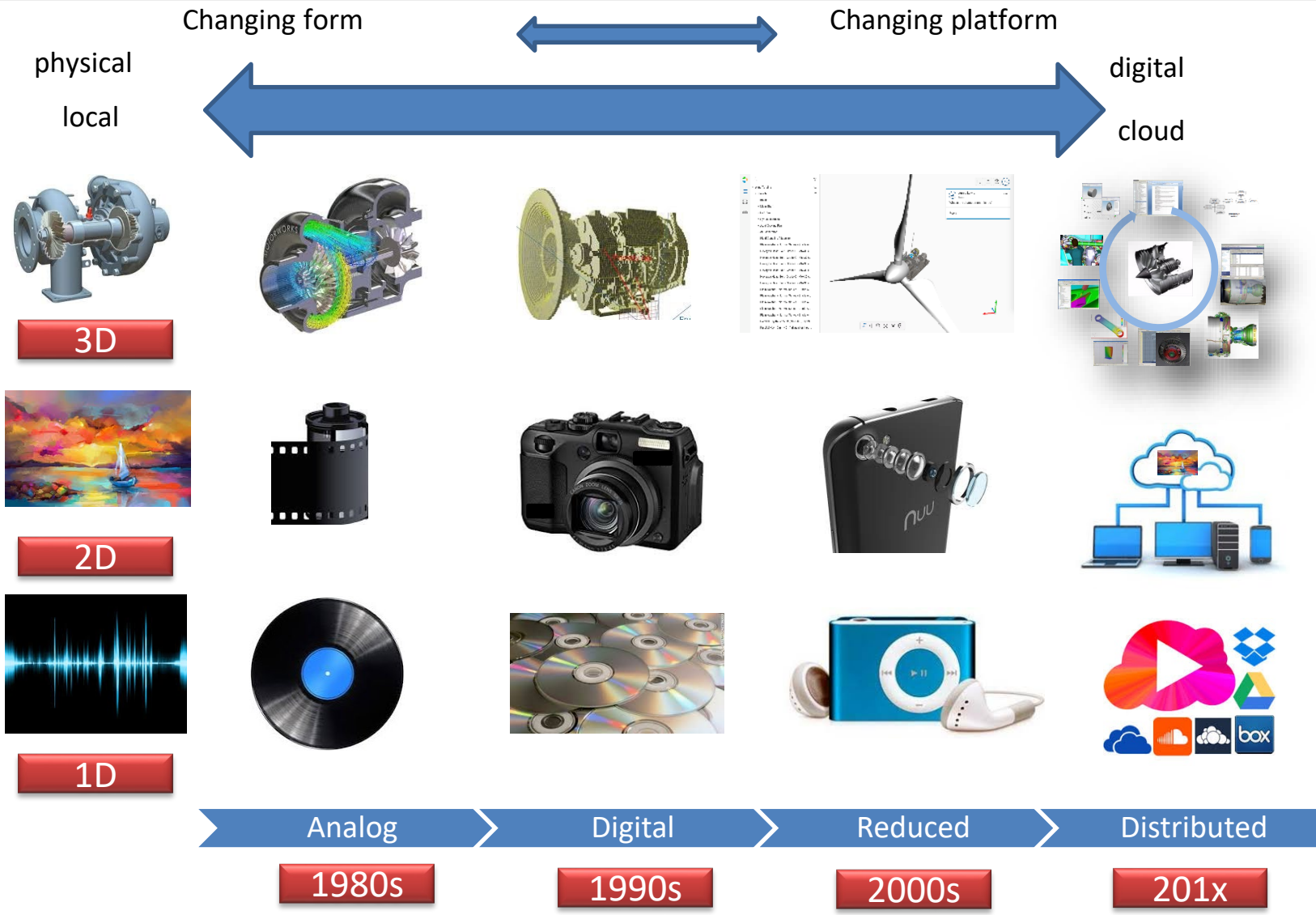
Manufacturing Transformation

The 4th Industrial Revolution

Four Phases of Industrialization



Digital Disruption

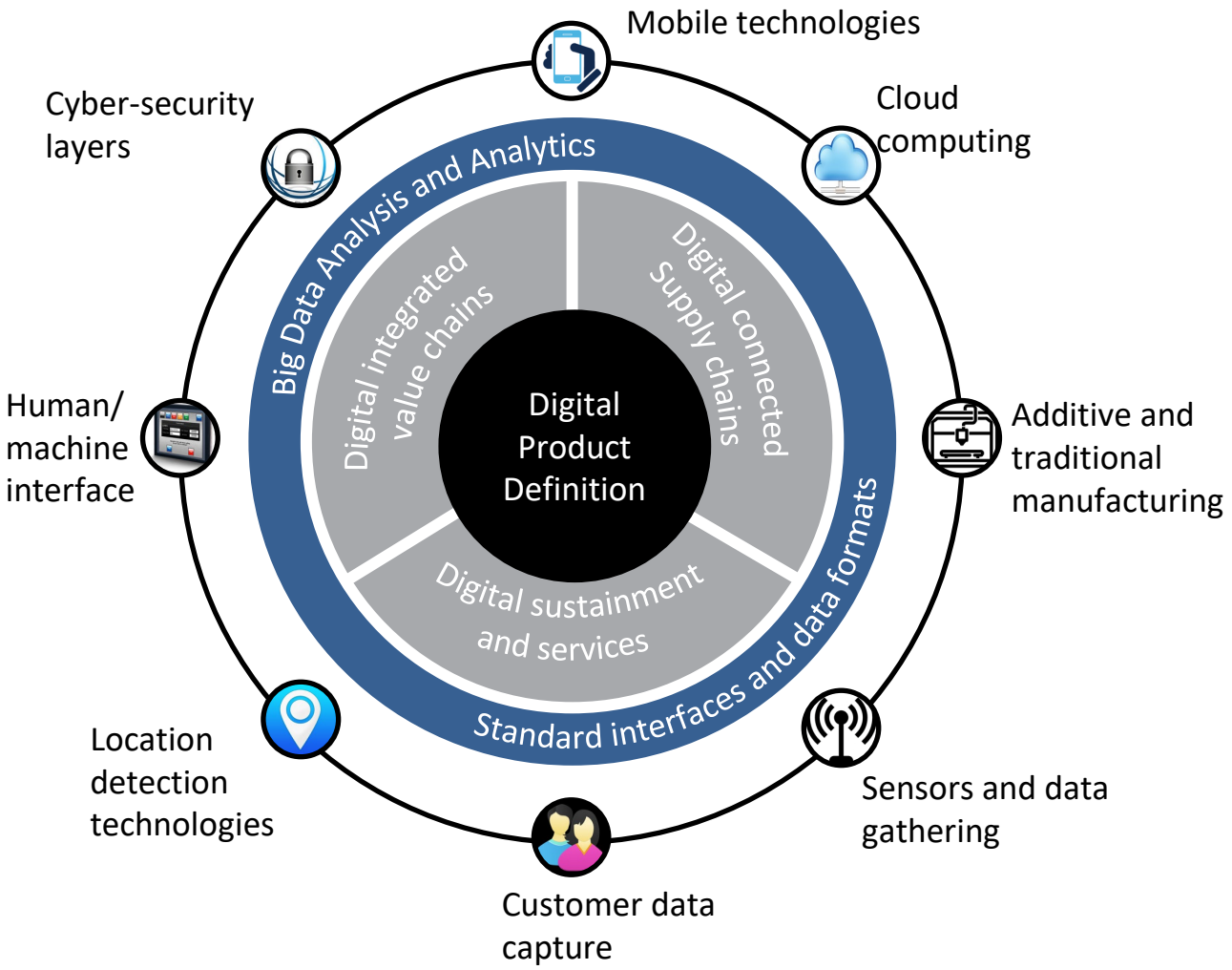


Digitalization allows for new business models to emerge:

- Mass customization
- Economic quantity: 1
- Product as a Service (PaaS)
- Product as a Platform
- Precision application of resources
- Intelligent support services

Adapted from Kurfess, T. (2015). *Advanced Manufacturing, Policy and Technology Opportunities for American Innovation*. 2015 University Turbine Systems Research Workshop.

The Digital Enterprise



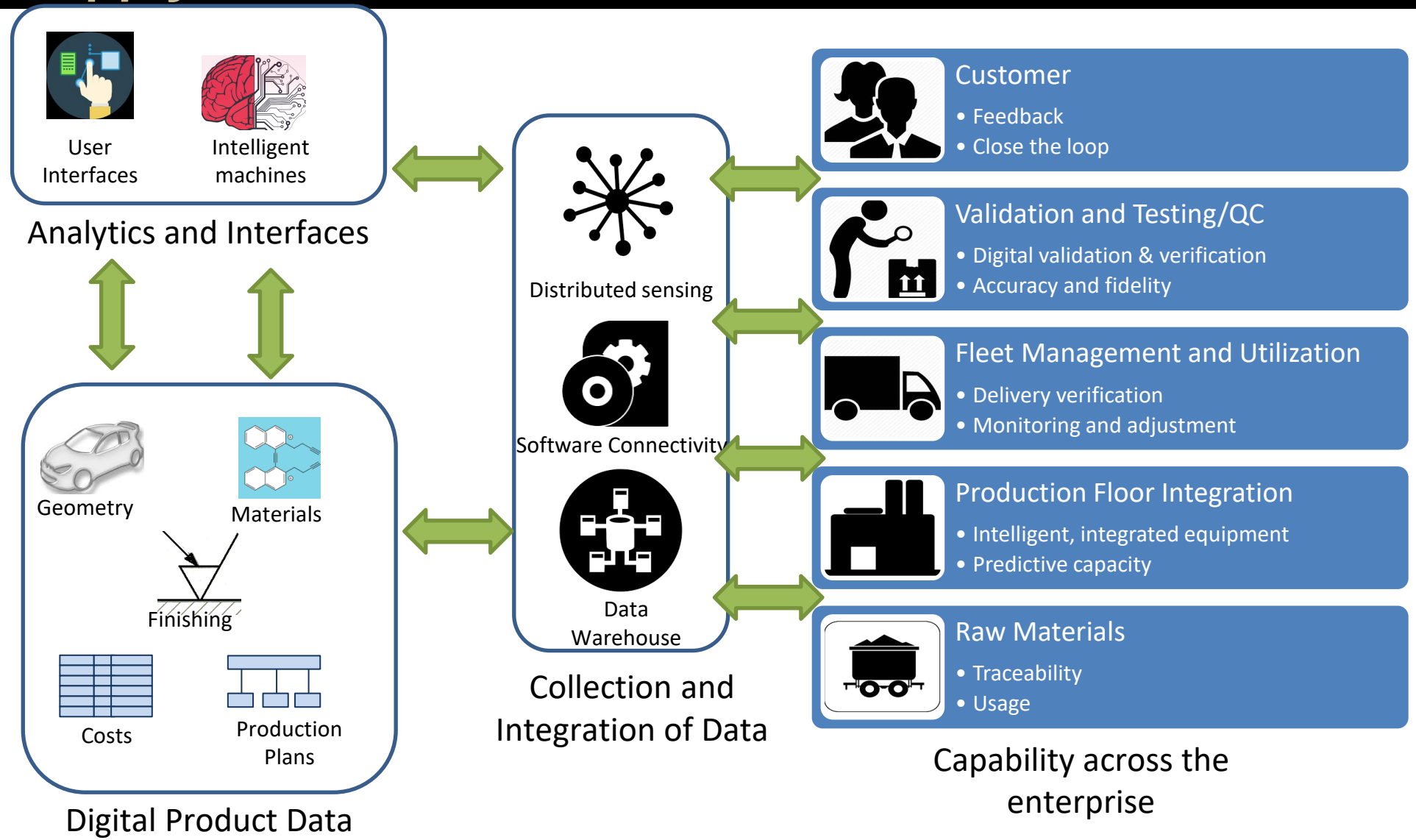
A digital enterprise changes the way people work and how they use information.

Our economy is increasingly digitally driven.

By comparing digital product data to the physical performance of the object, variation can be tracked and used to inform design of next-generation products.

Predictive modeling and validation schemes for products can be developed to diagnose and solve problems that occur.

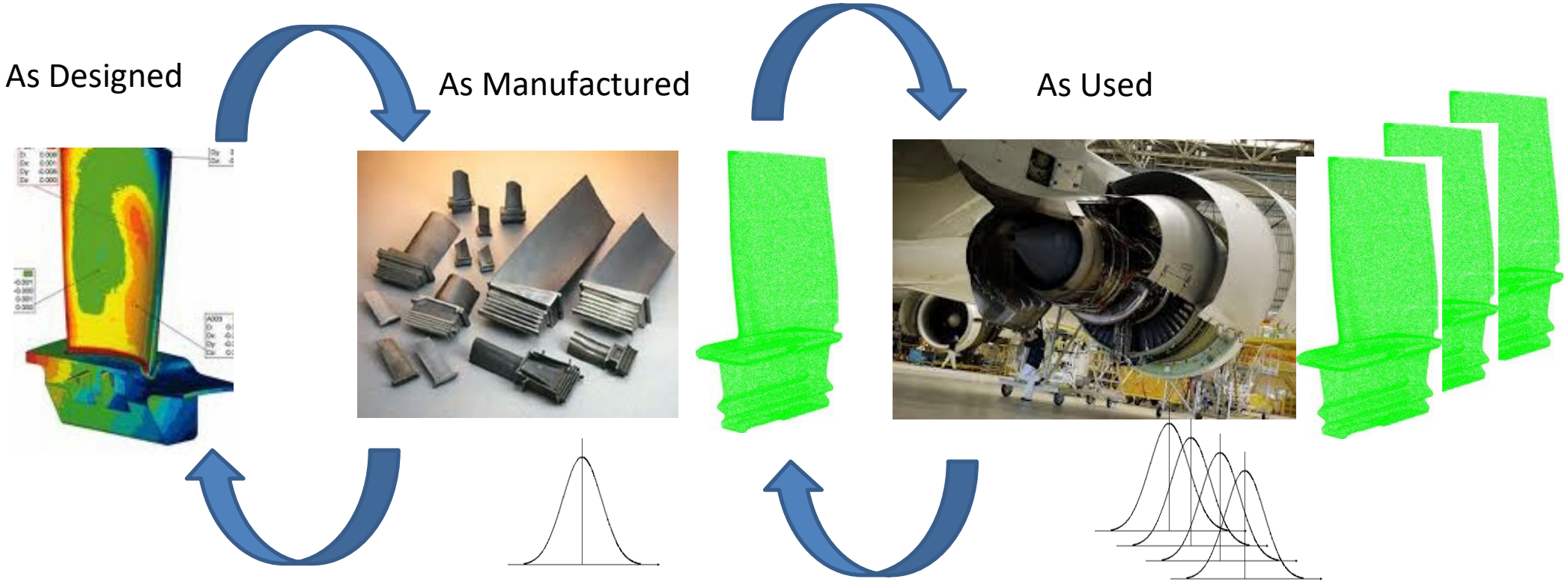
A Supply Chain Full of Authors and Consumers



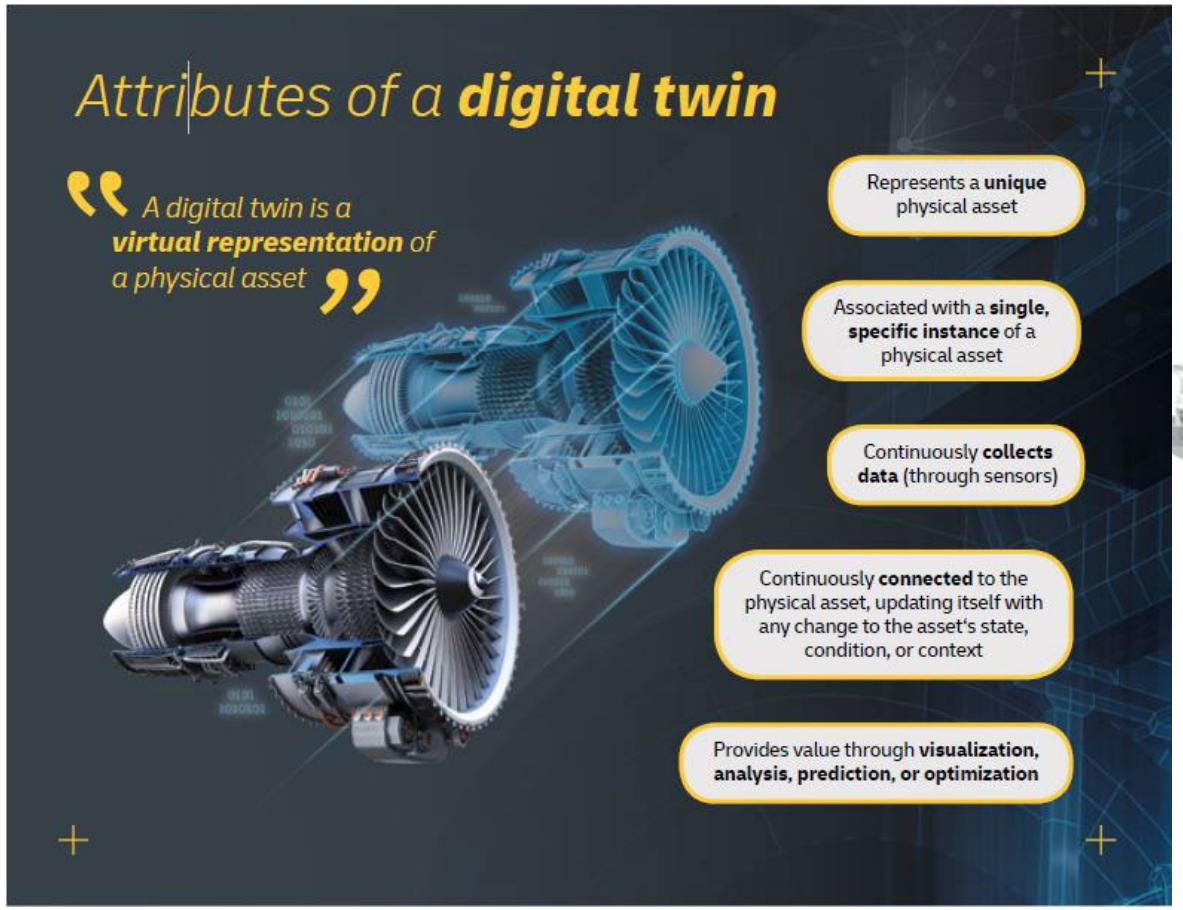
Adapted from Kinnet, J. *Creating a Digital Supply Chain: Monsanto's Journey*, October 2015.

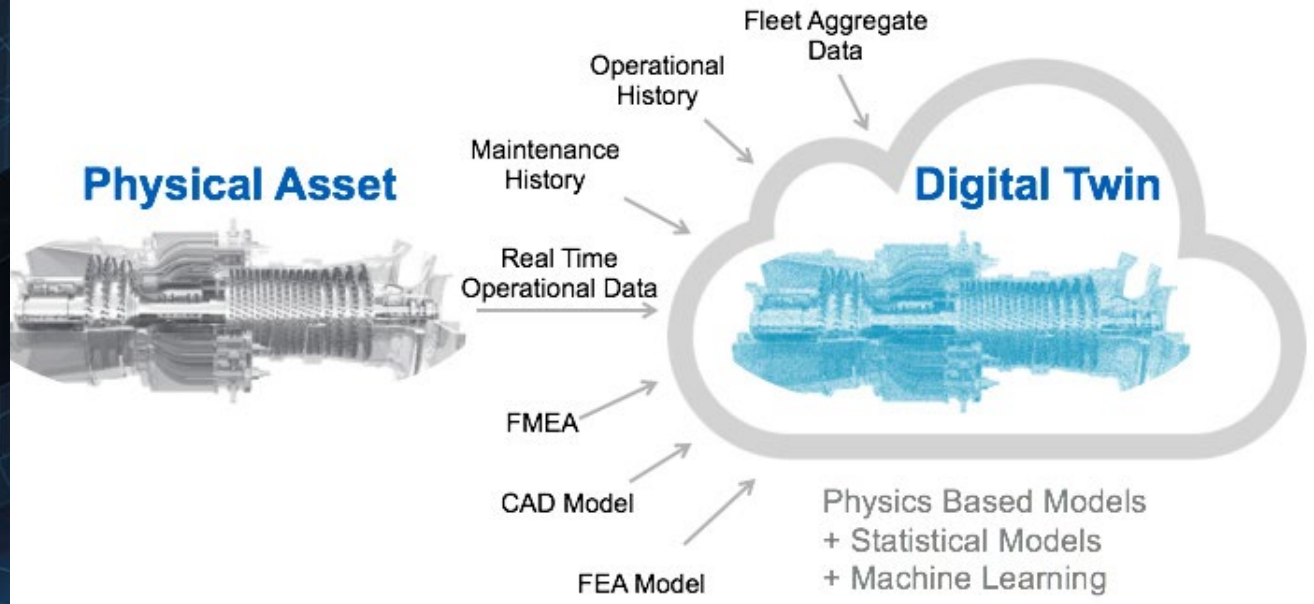
Enabling Digital Twins

By comparing digital product data to the physical performance of the object, variation can be tracked and used to inform design of next-generation products, develop predictive modeling and validation schemes for products, and to diagnose and solve problems that occur.



Using Digital Twins to Drive Business Decisions



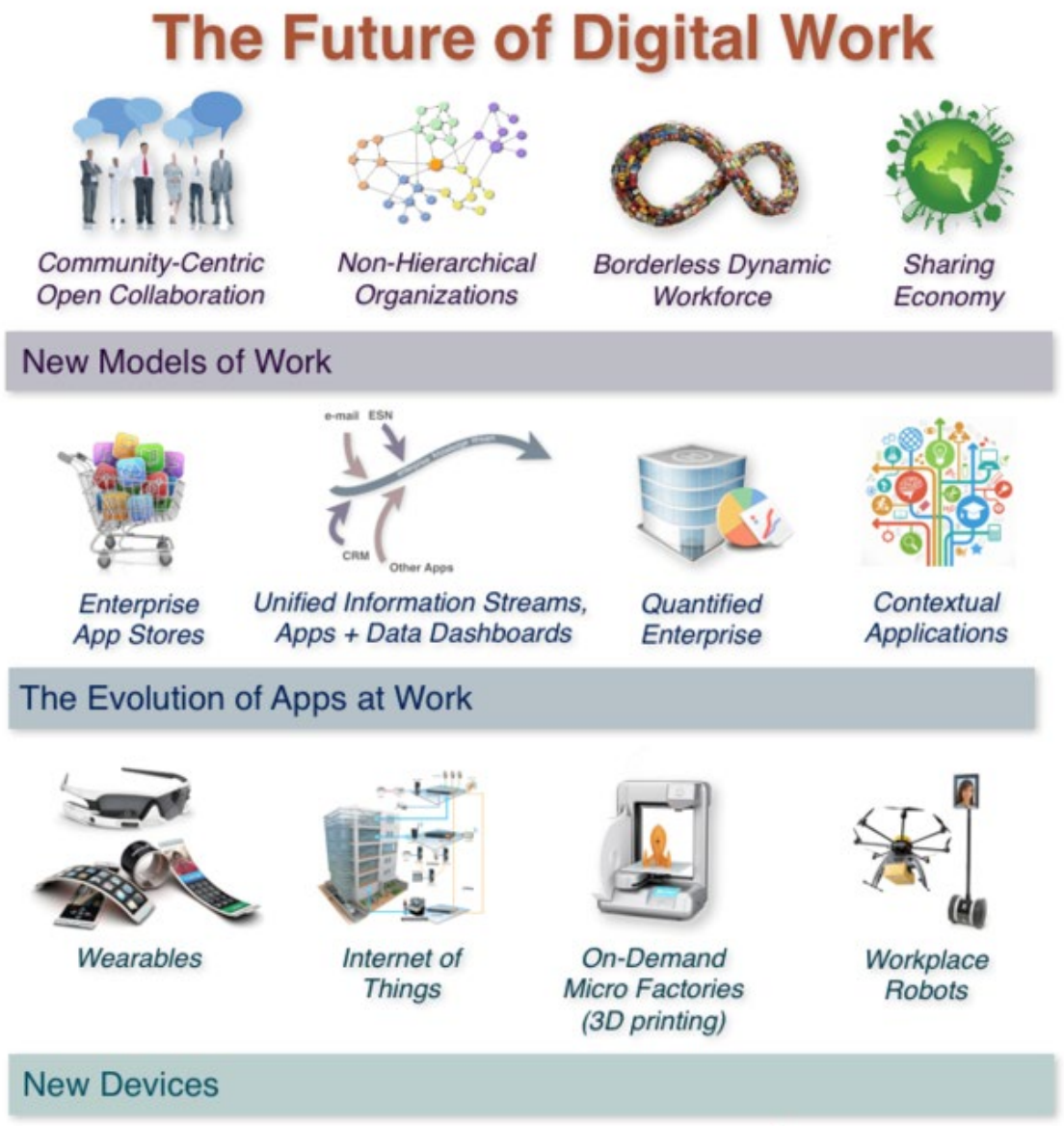


Left Image Source: https://www.dhl.com/content/dam/dhl/global/core/documents/pdf/glo-core-digital-twins-in-logistics.pdf

Right Image Source: https://www.vizexperts.com/blog/digital-twin-and-its-impact-on-industry-4-0

But we have a challenge with no clear solution…

- A lack of a skilled workforce in the places we need them.
- Manufacturing is typically a place-bound, capitally-intensive activity.
- We will not likely birth our way out of this problem.
- Historically, automation only addressed human labor. Today, and in the future, it addressed cognition as well.



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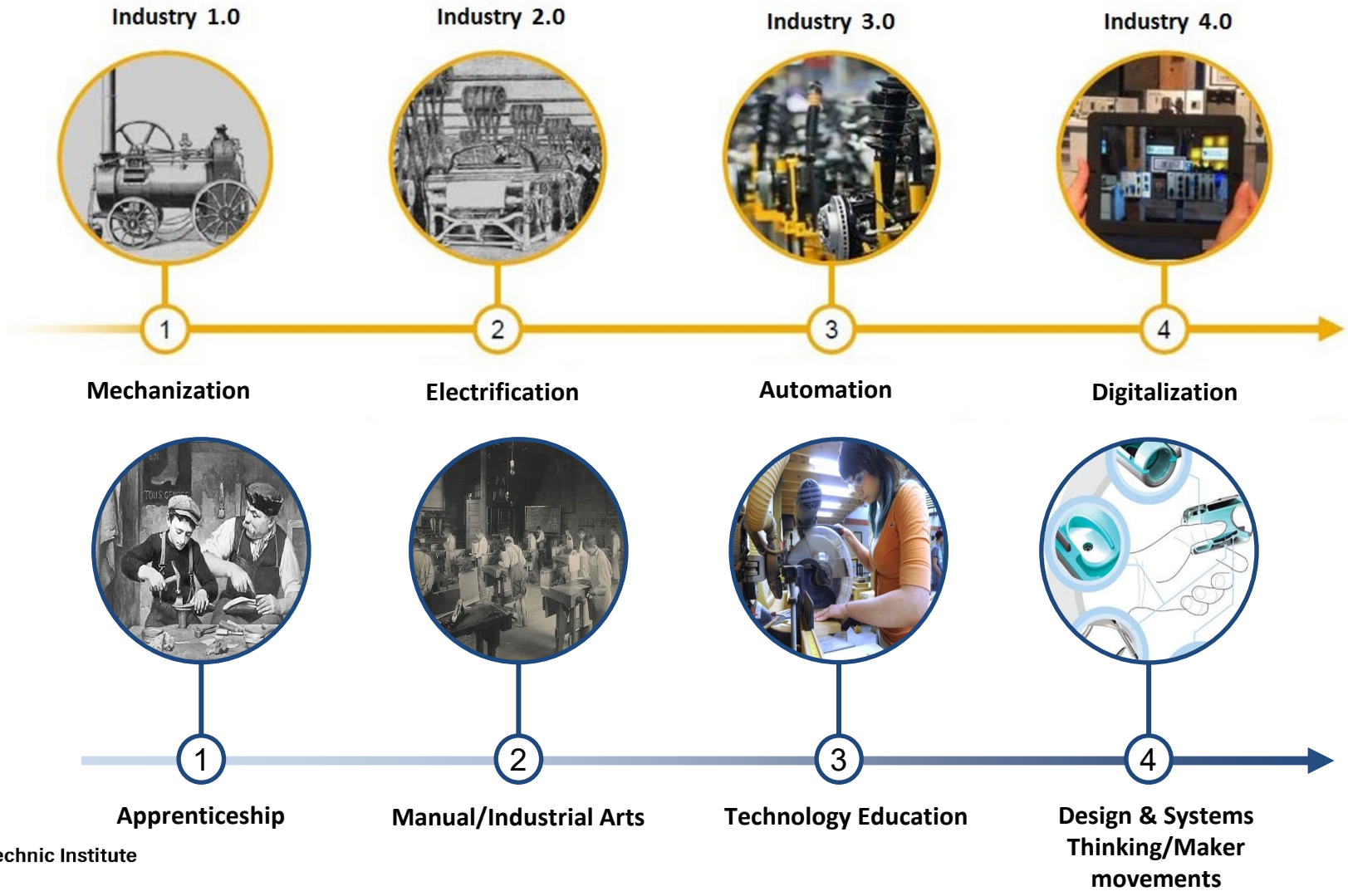
Polytechnic Solution

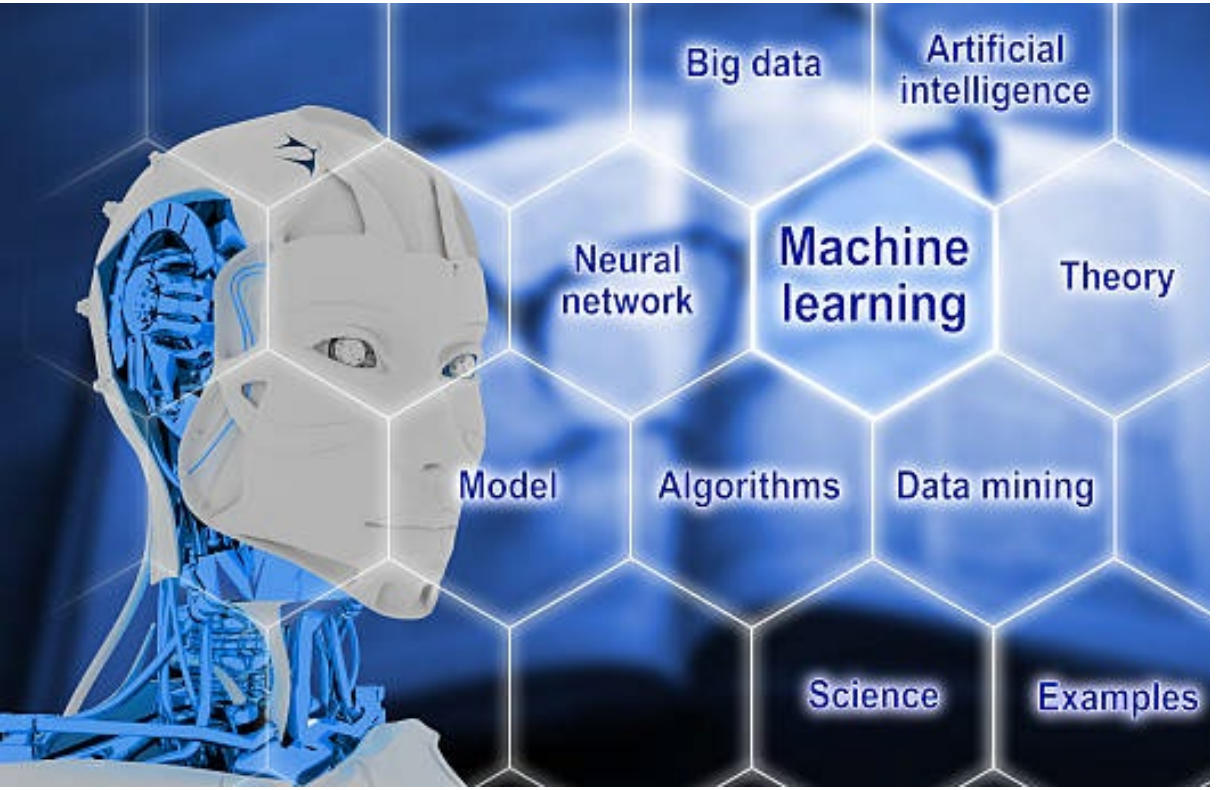
Industrial Revolutions are not new…

…and neither are Educational ones

For every Industrial Revolution, there has been a parallel Education Revolution



Needs for a Next-generation Manufacturing Workforce



We will still need reading, writing, science, and mathematics, but

New skills and literacies will be needed:

- Data literacy
- Technological literacy
- Human literacy
- Systems Thinking
- Entrepreneurship
- Cultural Agility
- Critical Thinking

There will remain a demand for skills to **program, test and oversee machines**.

Social skills; tasks that require emotional intelligence rather than cognitive alone.

Preparing solely for cognitive skills will **not** be enough for the 4th Industrial Revolution

Being an Engaged Polytechnic

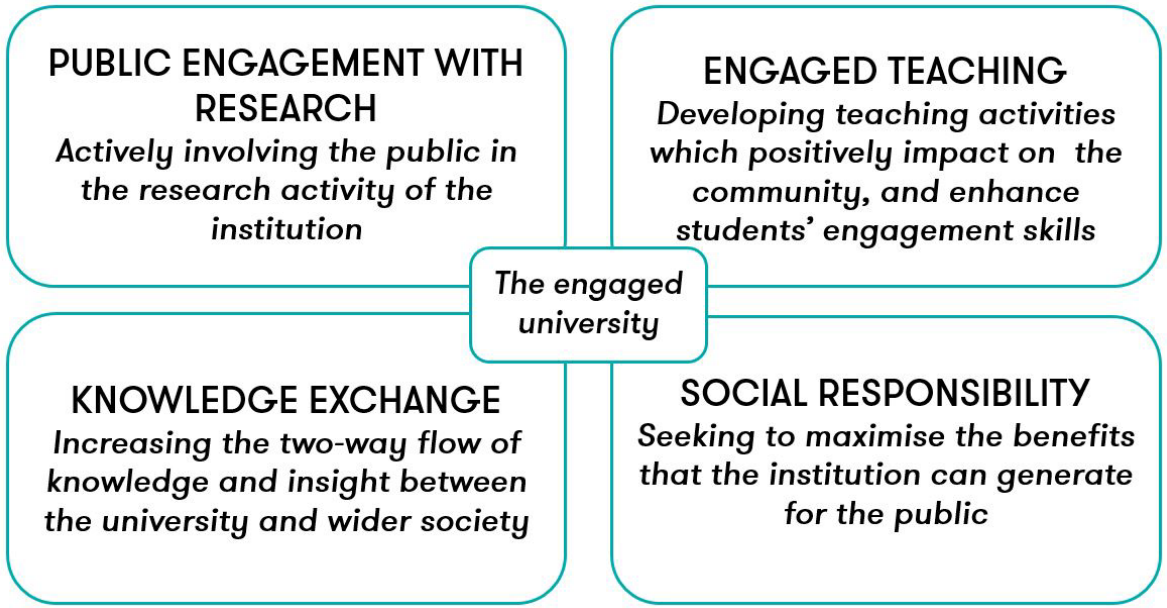
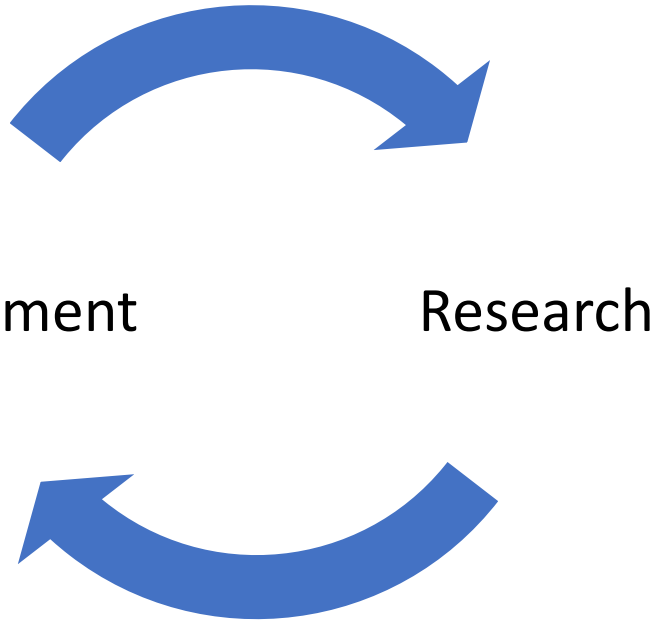


FIGURE 1: Characteristics of engaged universities

What does it mean to be "engaged"?

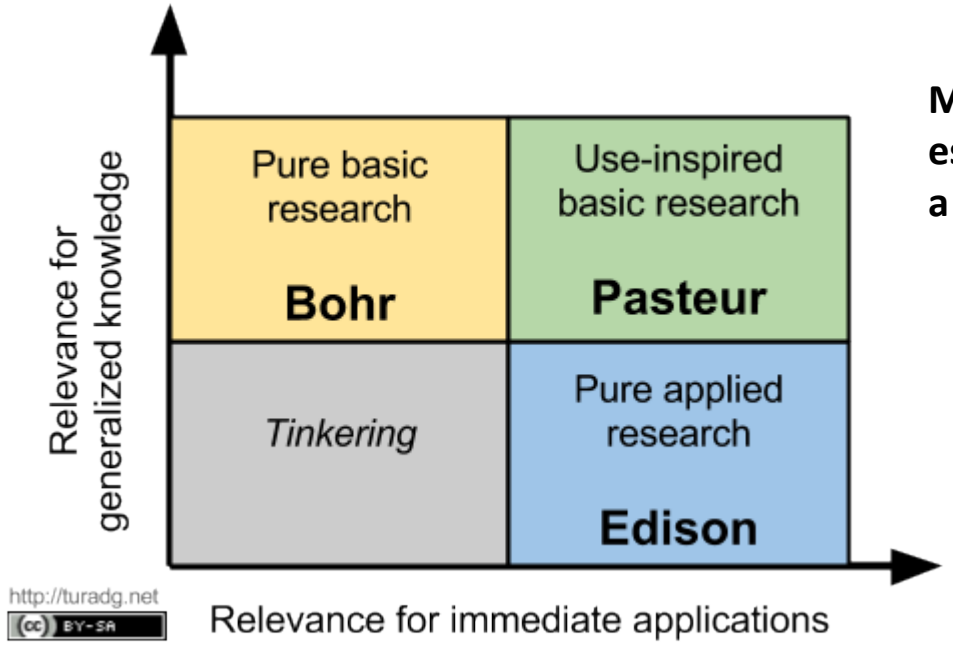
- Moving beyond the typical P&T definition to emphasize the land-grant mission.
- It is a mindset, as well as a set of activities. It is a propensity towards inquiry, service, and a desire to make better for our constituents.
- Creating a sense of agency, urgency, and ownership in our faculty *and* our students relative to their work.
- Engagement often drives our curricula, research, and scholarship. It is our differentiator.

Interaction between Engagement and Research



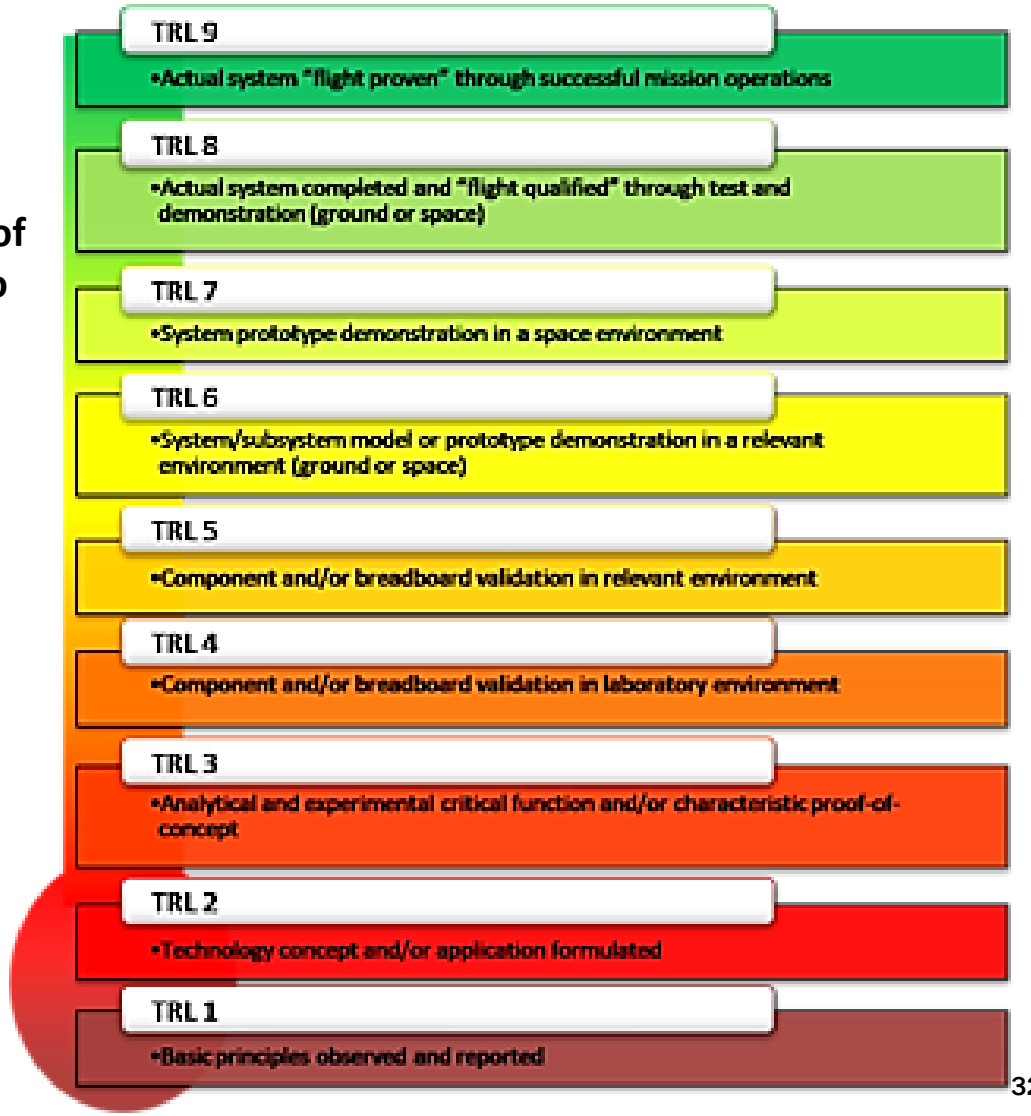
- Reciprocal in nature
- Engagement provides real use cases for Polytechnic research questions
- Often funded at value by industry and government
- Encourages appropriate TRL research by default, depending on the need
- Provides scholarship opportunities beyond traditional venues

Polytechnic Research Model



Moving from a model of esoteric applications to a model of outcomes

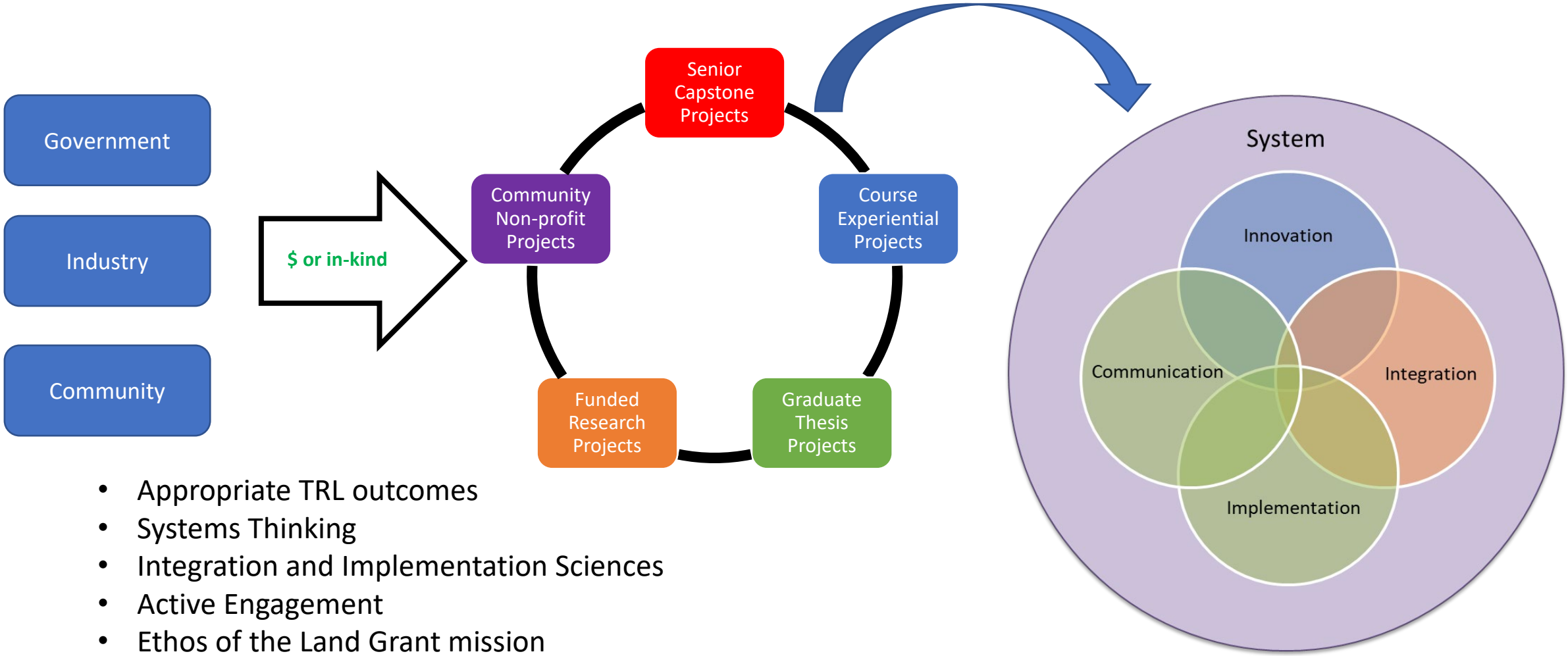
Where does your work fit on the TRL scale?



https://openeducationresearch.org/wp-content/uploads/2014/01/donald-stokes-pasteurs-quadrant-diagram.png

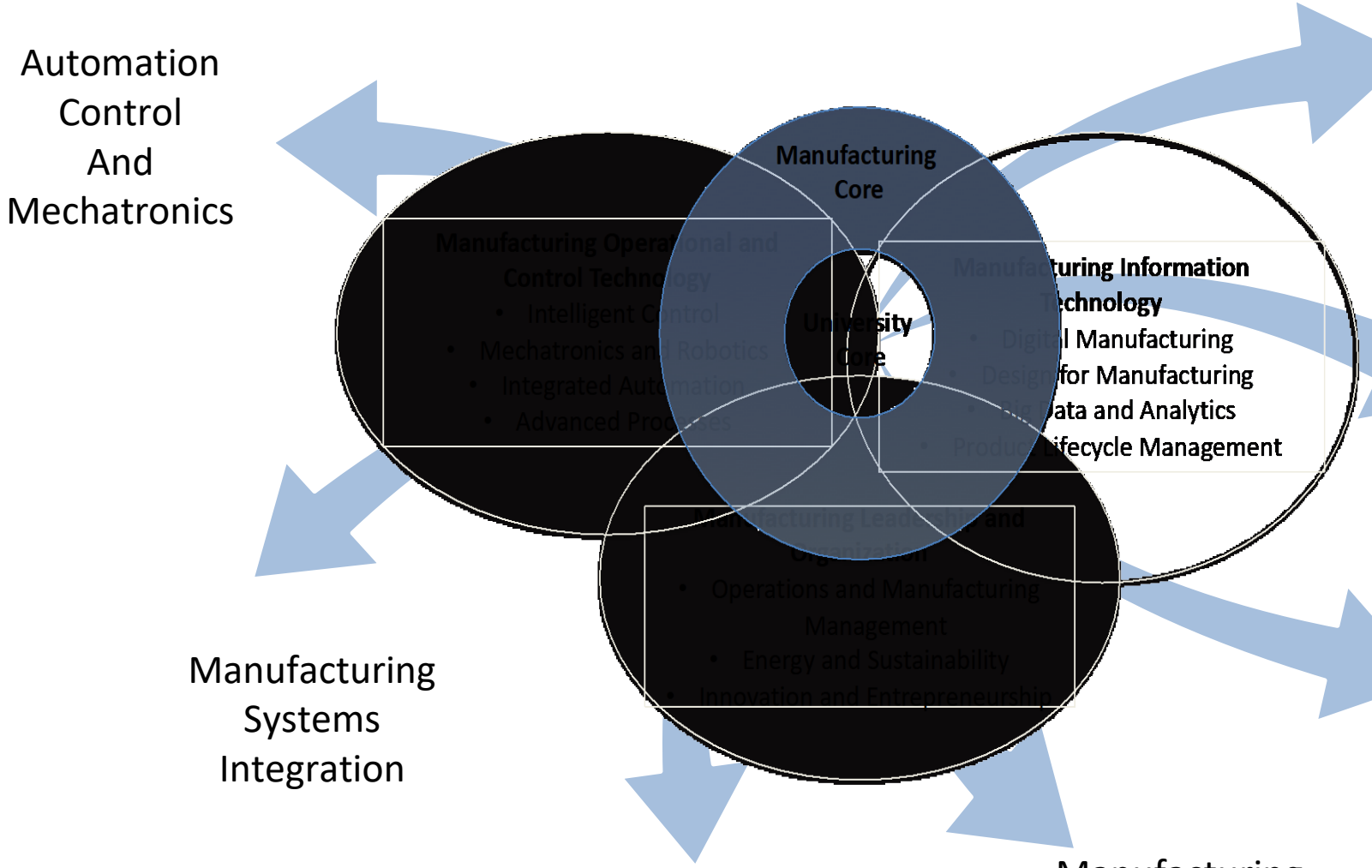
https://www.nasa.gov/directorates/heo/scan/engineering/technology/technology_readiness_level

Connecting Engagement, Research, and Curriculum



- Appropriate TRL outcomes
- Systems Thinking
- Integration and Implementation Sciences
- Active Engagement
- Ethos of the Land Grant mission

Polytechnic Advanced Manufacturing Curriculum Core



Automation Control And Mechatronics

Industrial Network Cybersecurity

Product Lifecycle Management

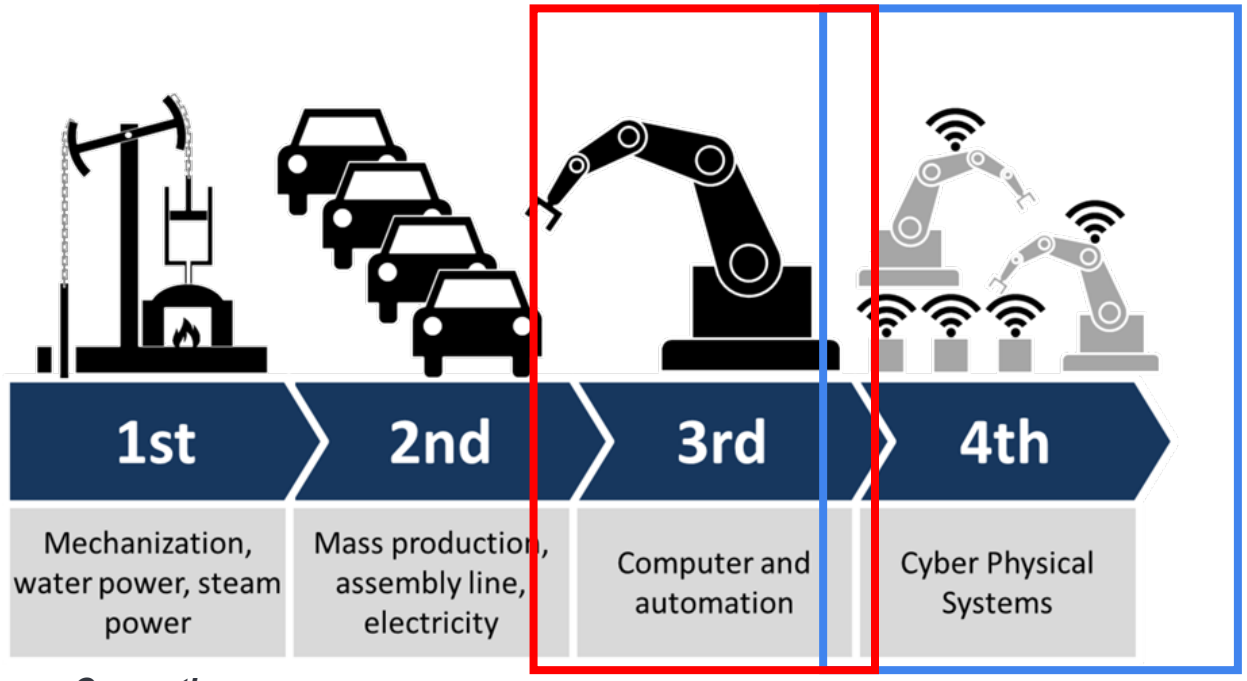
Product Development And Innovation

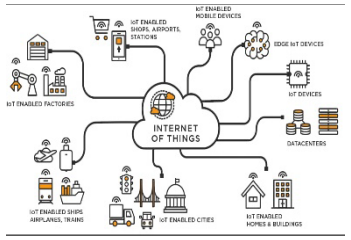
Manufacturing Supply Chain

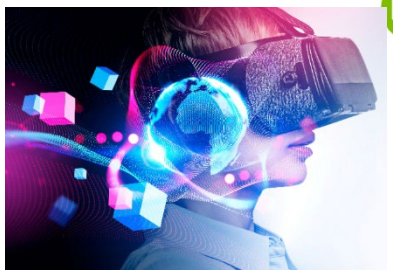
Manufacturing Operations Leadership

Manufacturing Systems Integration

Adapting to the Era of Industrial IoT







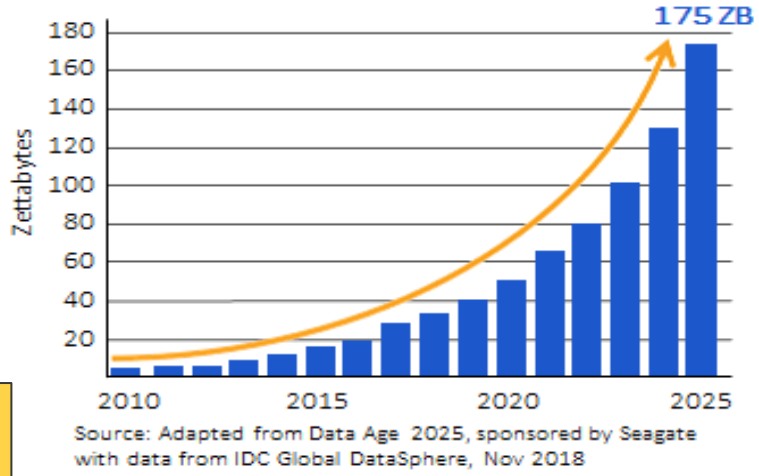
A Connected Manufacturing Enterprise

Currently

- *Automating processes using logic processors and information technology*
- *Robotics & PLCs, CNC, etc*
- *Automated production*

What has Changed

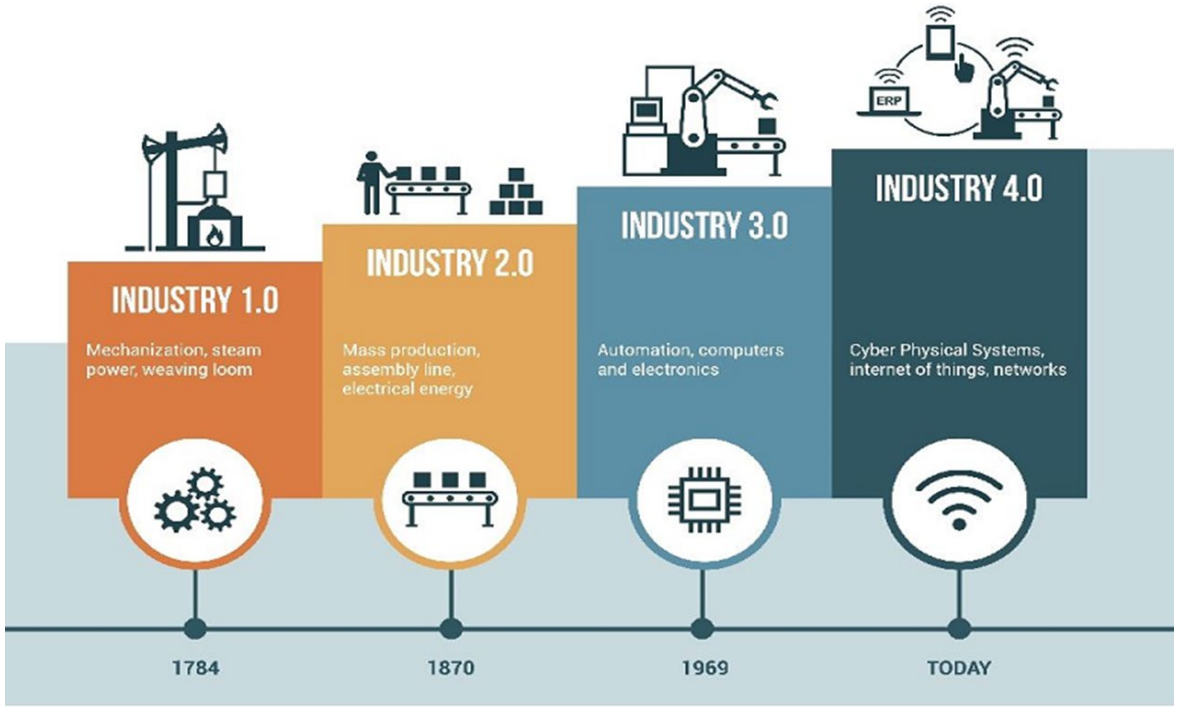
- *Connectivity, Virtualization, & Data Utilization*
- *IoT, AI/ML, Big Data, & Cloud/Edge Computing, & other technologies driving SM*
- *Cyber-Physical Production*
- *Convergence of IT & OT*
- *Human Machine Collaboration & Industrial Metavers*
- *Augmented Intelligence & Behavior*



Annual Size of Global Datasphere

The difficulty and costs in attracting and retaining data scientists has led to a new emerging role — the Citizen Data Scientist. A role often given to existing employees in an organization trained to use data analytics tools and technologies to extract insights from big data. – Gartner 2017

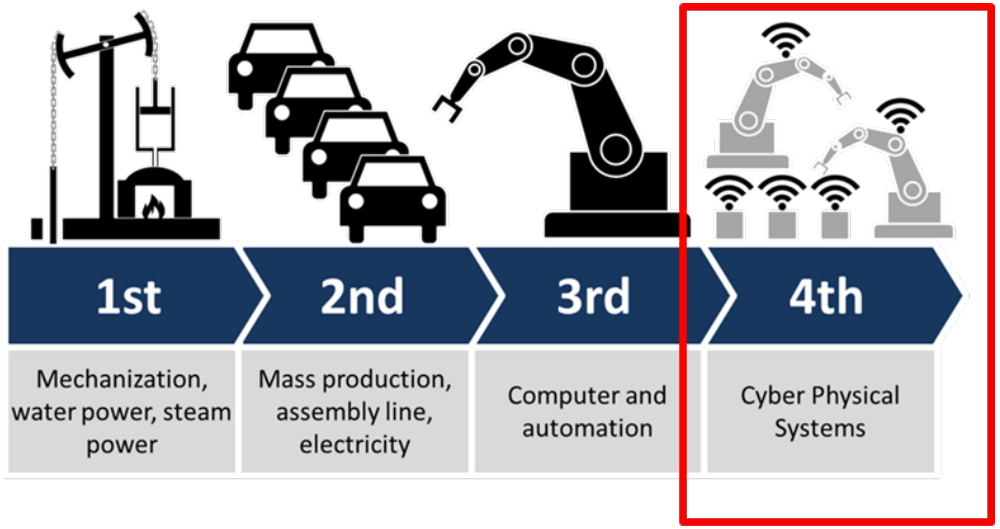
2018 Manufacturing Workforce Challenges



Gartner Survey Shows 57% of Manufacturing Leaders Feel Their Organization Lacks Skilled Workers to Support Smart Manufacturing Digitization Plans

March 2019 – Project Launch Goals

1. Prepare next generation smart manufacturing workforce to address the widening I4.0 skills gap
2. Prepare a workforce who can contribute to, and accelerate the digital transformation of the US manufacturing industries

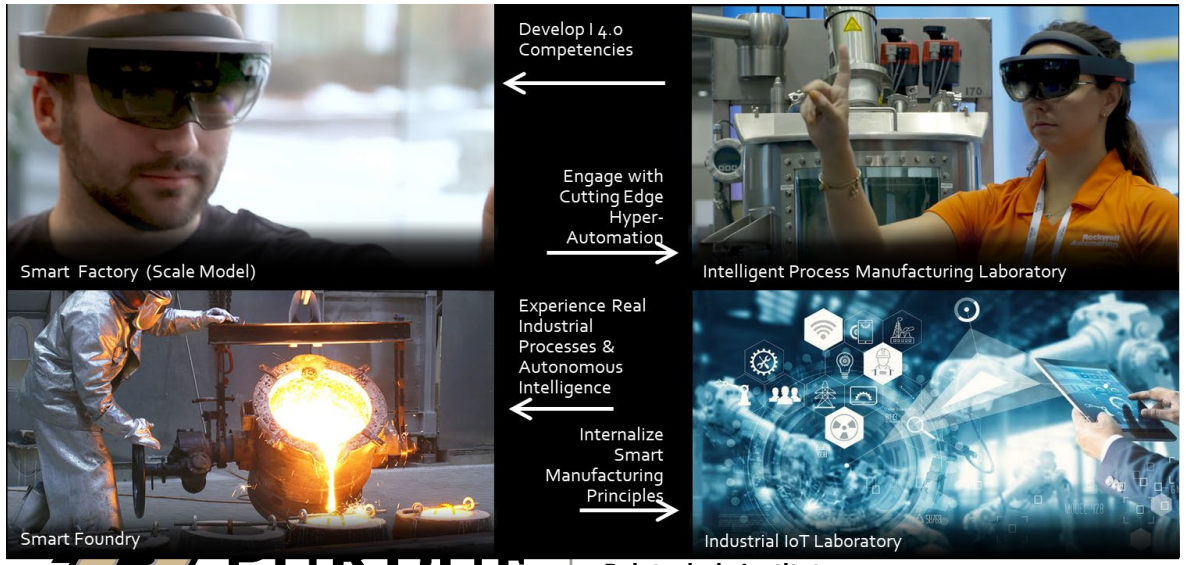


- *Industrial Internet of Things (IIoT)*
- *AI, Big Data, Cloud Computing & Manufacturing Analytics*
- *Cyber-Physical Production Systems*
- *Digital & Data Assisted Systems in Manufacturing*

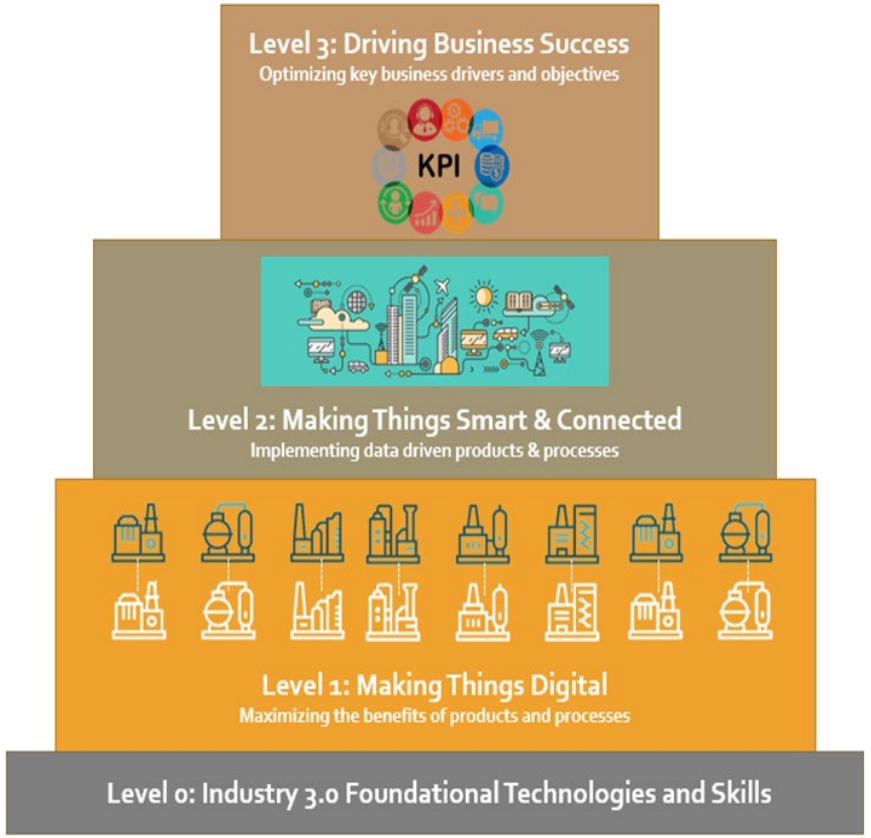
Smart Manufacturing Core Knowledge/Skills

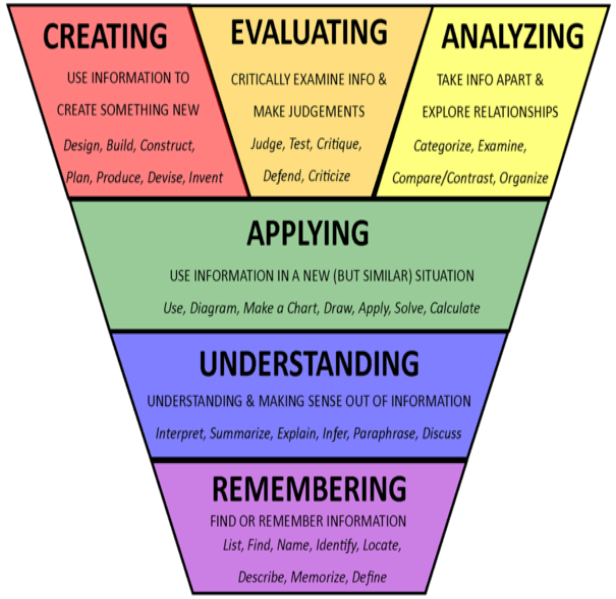
March 2019 – Project Launch Objectives

1. Undergraduate manufacturing program transformation integrating the 9-core capabilities and digitalization strategies of Industry 4.0
2. Develop innovative laboratories where students can imagine, create, innovate, problem solve, and build critical skills relevant to SM skill sets.
   - *Smart Factory*
   - *Intelligent Process Manufacturing Laboratory*
   - *Smart Foundry*
   - *Industrial IoT Laboratory*



Summer 2020: Frameworks to Guide Curriculum Transition





Models/Frameworks used to Inform the Transformation of Program, & Design of Courses, Learning Activities & Facilities

B.S. Degree Programs

BS Smart Manufacturing Industrial Informatics
BS Digital Enterprise Systems

Product Lifecycle Management
MFET 10301 Geometric Modeling Applications
MFET 11301 Product Data Management
MFET 20301 Model-based Definition

Industrial IoT & Cybersecurity
MFET 23000 Industrial IoT Networks and Systems I
MFET 23100 Industrial IoT Networks and Systems II

Manufacturing Cloud/Edge Computing
MFET 25000 Smart Manufacturing Cloud Computing Applications

Manufacturing Modeling, Simulation, & Augmented Reality
MFET 21301 Simulation and Visualization Applications
MFET 35000 Smart Manufacturing Systems Modeling & Simulation
MFET 35100 Mixed Reality Smart Manufacturing Apps & Design

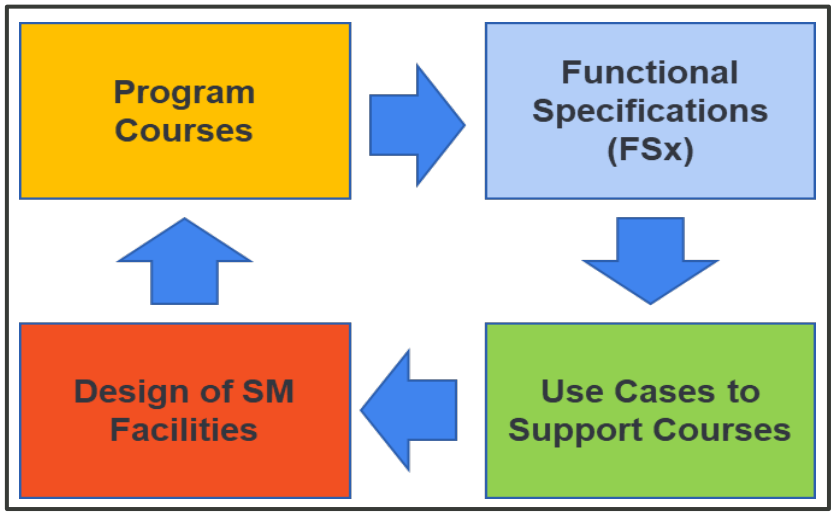
Manufacturing Supply Chain & Smart Connected Systems
MFET 30301 Digital Manufacturing
MFET 35200 Smart Manufacturing Production Information System
MFET 36400 Intelligent Manufacturing Systems II

Manufacturing Intelligence, AI, & Data Analytics
MFET 31301 The Business of Managing Digital Product Data
MFET 36100 Machine Learning Manufacturing Analytics
MFET 36300 Intelligent Manufacturing Systems I

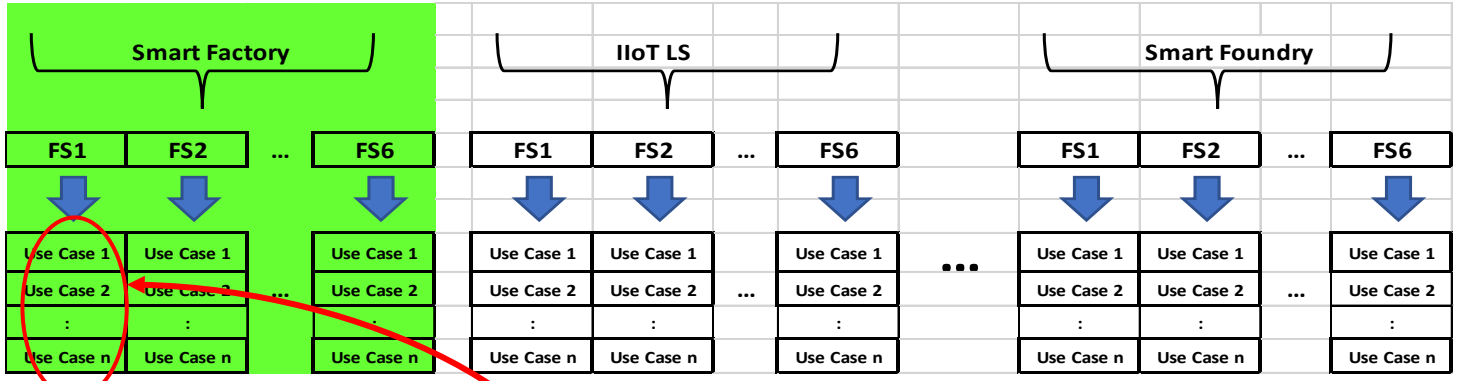
Advanced Robotics Applications
MFET 44000 Smart Manufacturing Autonomous Human Robot Systems

Additive Manufacturing
MFET 41000 Additive Manufacturing

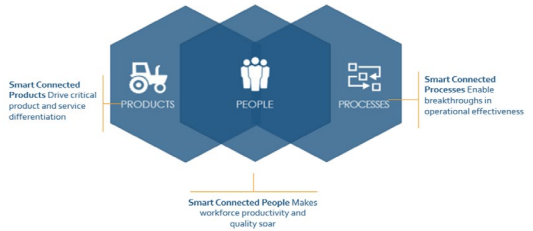
Summer 2021: Smart Manufacturing Labs Design



- Courses informed the Functional Specifications **(FS*x*)**, i.e. the general capabilities to be supported by the SM Facilities
  - ❑ Industrial IoT & Smart Connected Systems (FS1)
  - ❑ Smart Production & Autonomous Systems (FS2)
  - ❑ Smart Supply Chain & Logistics (FS3)
  - ❑ Smart Production Process Management (FS4)
  - ❑ Smart Quality & Inspection (FS5)
  - ❑ Smart Maintenance & Service (FS6)
- Functional Specifications **(FS*x*)** informed the Use Cases
- '**Use Cases**' informed the design of the SM Facilities



	FS1	FS2	FS3	FS4	FS5	FS6
Smart Factory	X	X	X	X	X	X
Smart Foundry	X	X	X	X	X	X
Cont. Process Lab	X	X				X
Industrial IoT Lab	X	X				



	Smart Learning Factory	Industrial IoT Laboratory	Intelligent Process Laboratory	Smart Foundry
MFET 23000	X	X	X	
MFET 23100	X			X
MFET 25000	X	X		X
MFET 34100	X		X	
MFET 35000	X		X	X
MFET 35100	X	X		
MFET 35200	X	X	X	
MFET 36100	X	X		X
MFET 36300	X		X	X
MFET 36400	X	X		X
MFET 41000	X		X	X
MFET 44000	X	X	X	X

Smart Factory	FS1	FS2	...	FS6
MFET 23000	• Utilize IoT devices including sensors, actuators (drives, motion controls, valves, etc.), PLCs, Robots, Vision systems, RFID in the Smart Factory production system to enable the transfer of data through the internet. • Utilize an IoT Gateway to enable device-to-device and device-to-cloud communication integrating a multitude of devices with varying connectivity requirements and protocols. • Demonstrate interoperability across heterogeneous hardware and software solutions across the manufacturing value chain. : • Development Manufacturing Apps to capture and deliver critical production floor and warehouse data to mobile devices.	• Utilization of data and enterprise dashboards for resource management, inventory management, order management, and production management. • Utilization of data and enterprise dashboards for resource management, inventory management, order management, and production management. • Development Manufacturing Apps to capture and deliver critical production floor, supply chain, and warehouse data to mobile devices.	...	• Deploy cloud-based analytics, on-premises, edge deployment for predictive analytics • Utilize AR to remotely assist and effectively instruct and guide operators through maintenance workflows.

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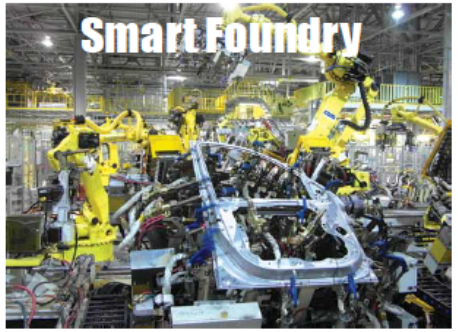
The Gateway Complex - Four Smart, Connected Teaching Labs

Smart Learning Factory (SLF)
- Product/Process Design & Value Creation
- Industrial IoT, Smart Sensors Actuators, PLC, Vision
- Cyber-Physical Production Systems & Operations Mgmt
- Autonomous Human Robot Systems
- Digital Supply Chain Systems
- Human/Machine Collaboration & Augmented Worker
- Cyberinfrastructure & Enterprise Integration
- Production Automation Systems
- Cloud/Edge Computing
- Data Analytics & Manufacturing Intelligence



Smart Foundry
- Industrial IoT, Smart Sensors Actuators, PLC, Vision
- Generative Design &
- Metal 3-D Additive Manufacturing
- Cyberinfrastructure & Enterprise Integration
- Production Automation & Robotics
- Human/Machine Collaboration & Augmented Worker
- Predictive Maintenance and Zero Defect Mfg
- Data Analytics & Autonomous Intelligence

Furnas Industrial IoT Laboratory
- Azure IoT Hub & Toolkits
- Software Defined Networking
- Manufacturing Information Systems
- Data Analytics & AI for Quality Control/Assurance & Predictive Systems
- Artificial Intelligence & Workplace Safety
- Augmented/Virtual (AR/VR) Reality
- Collaborative & Autonomous Robotics
- Cloud/Edge Infrastructure, Networks, & Cybersecurity

Intelligent Process Laboratory
- Industrial IoT, Smart Sensors & Actuators,
- Mobile Plant Asset Management System
- Continuous Process Control Systems
- Digital Twin & Continuous Process Modeling
- Digital Assistance Systems & AR/VR Systems
- Data Visualization & Human Machine Collaboration
- Cyberinfrastructure & Enterprise Integration

Indiana Manufacturing Competitiveness Center (IN-MaC)

Intelligent Manufacturing Testbed



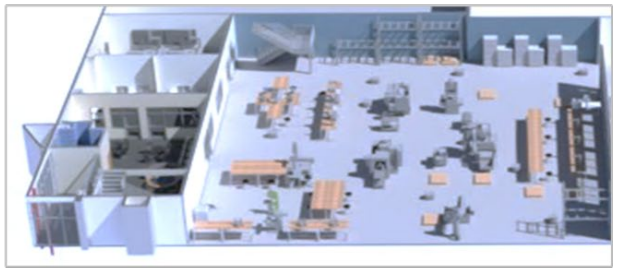
Digital Twin (production)
- Remote / Lights Out

Warehouse + Logistics
- In-Plant and Supply Chain

Metrology
- Production Integrated

Quality Assurance
- Scanning and CMM

Design Verification



Digitally Enhanced Processes
- BOM, BOP, MBWI, AR

Automated Assembly Processes
- Production Monitor

Embedded Sensors
- Roll-to-roll manufacturing

Subtractive and Additive Manufacturing

Prototyping
- Product + Fixture Design

Logistics
- In-Plant AGV's

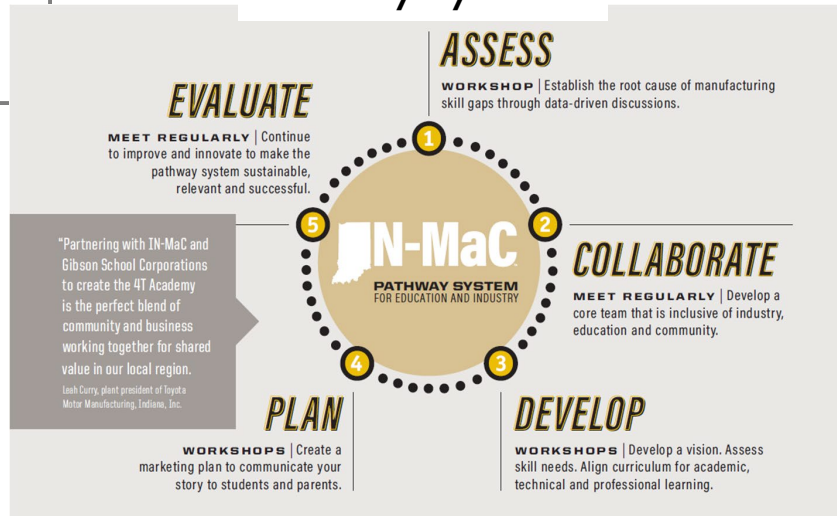
Robots / Cobots
- Assembly Demo

- **Develop and Validate** technologies and methods for Industry
- **Accelerate** the Digital Transformation of manufacturing through the Digital Twin methodology
- **Prepare** students and workforce for careers in advanced manufacturing
- **Connect** Industry, University and Government for manufacturing competitiveness

Design and Innovation Studio

42,000+ STUDENTS 1 TO 1 IMPACT TO DATE	**425+** TEACHER AND INDUSTRY PROFESSIONAL DEVELOPMENT
6 INDUSTRY DESIGN & INNOVATION STUDIOS	**69** STUDIOS IMPLEMENTED 2 TRAINING STUDIOS AT PURDUE & VINCENNES UNIVERITY
213+ STANDARD ALIGNED LESSONS & 61 UNITS	**15+** RESEARCH PUBLICATIONS, PRESENTATIONS, & WORKSHOPS
18 STUDIOS FUNDED & TO BE IMPLEMENTED IN 2024-25	**100+** STUDIOS IN TOTAL BY END OF 2025

Pathway Systems



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