



National Science Foundation
WHERE DISCOVERIES BEGIN



Springfield Technical
Community College

Exceptional Education. Proven Results.

2024 Hi-Tec Conference

Transitioning curricula to embrace Industry
4.0 and support Advanced Manufacturing

By

Gary J. Mullett, Department Chair, AET Group
Springfield Technical Community College

August 1, 2024

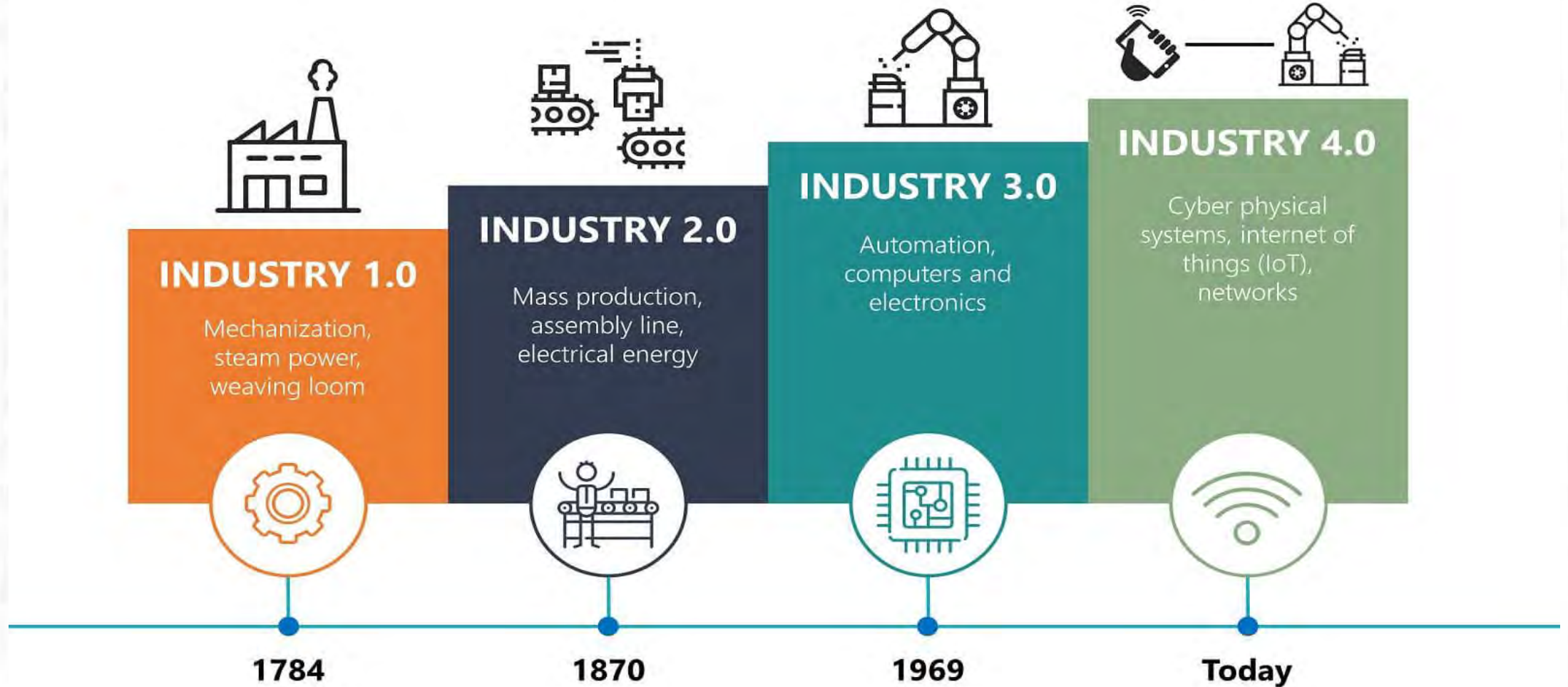
Kansas City, MO

Some background ...

Stages of the Industrial Revolution



Springfield Technical
Community College
Exceptional Education. Proven Results.



Recall opening keynote from yesterday

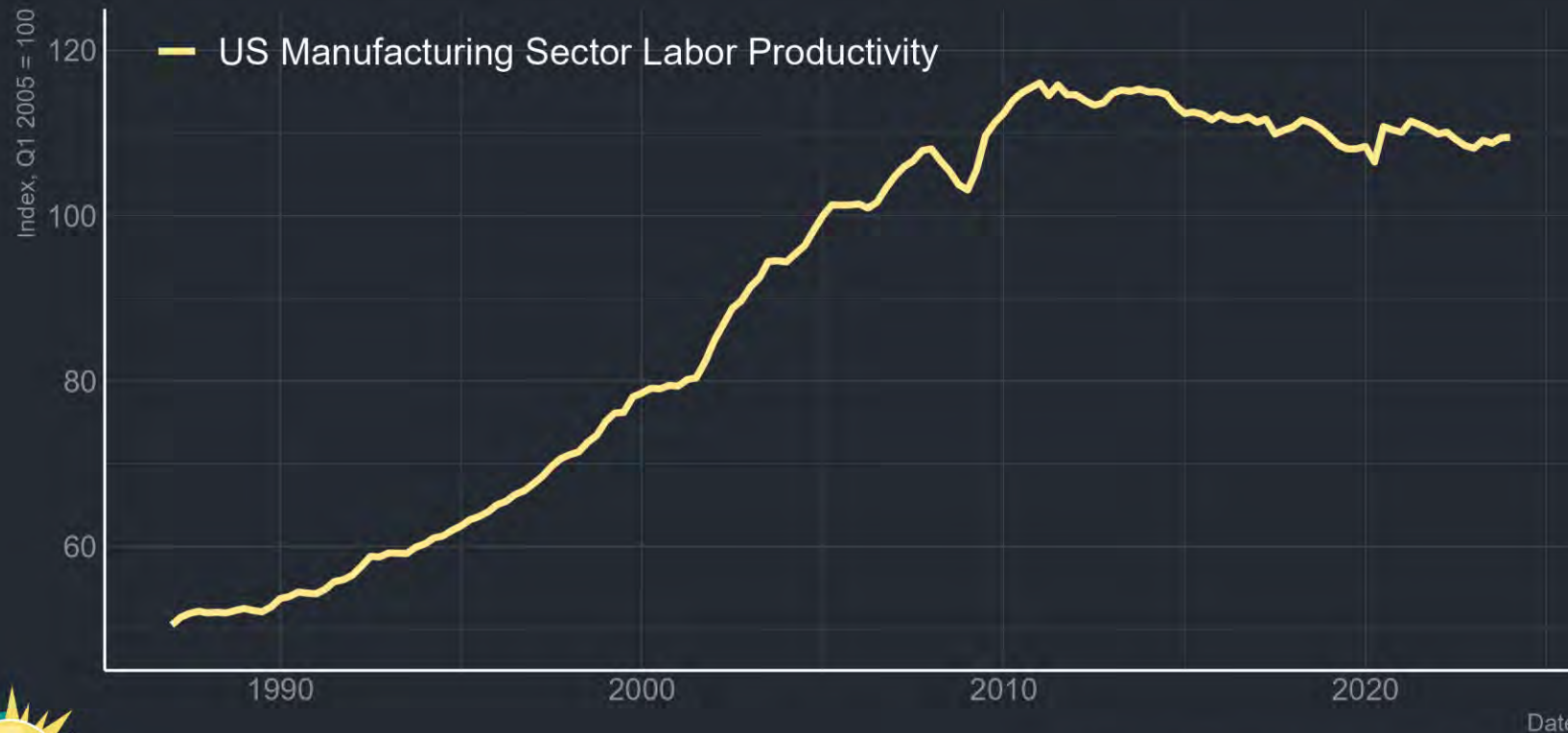


Springfield Technical
Community College

Exceptional Education. Proven Results.

US Manufacturing's Productivity Problem

American Manufacturing Productivity Remains Stuck at Pre-Great Recession Levels



Graph created by @JosephPolitano using BLS Data

Yesterday, we heard that there was about a **twenty year time lag** between the start of the 3rd Industrial Revolution Era (which introduced computer technology) and an attendant increase in productivity. The 4th Industrial Revolution (Industry 4.0) is just in its infancy but with that knowledge we can get started on the road to adapt today's curriculum to serve tomorrow's needs.



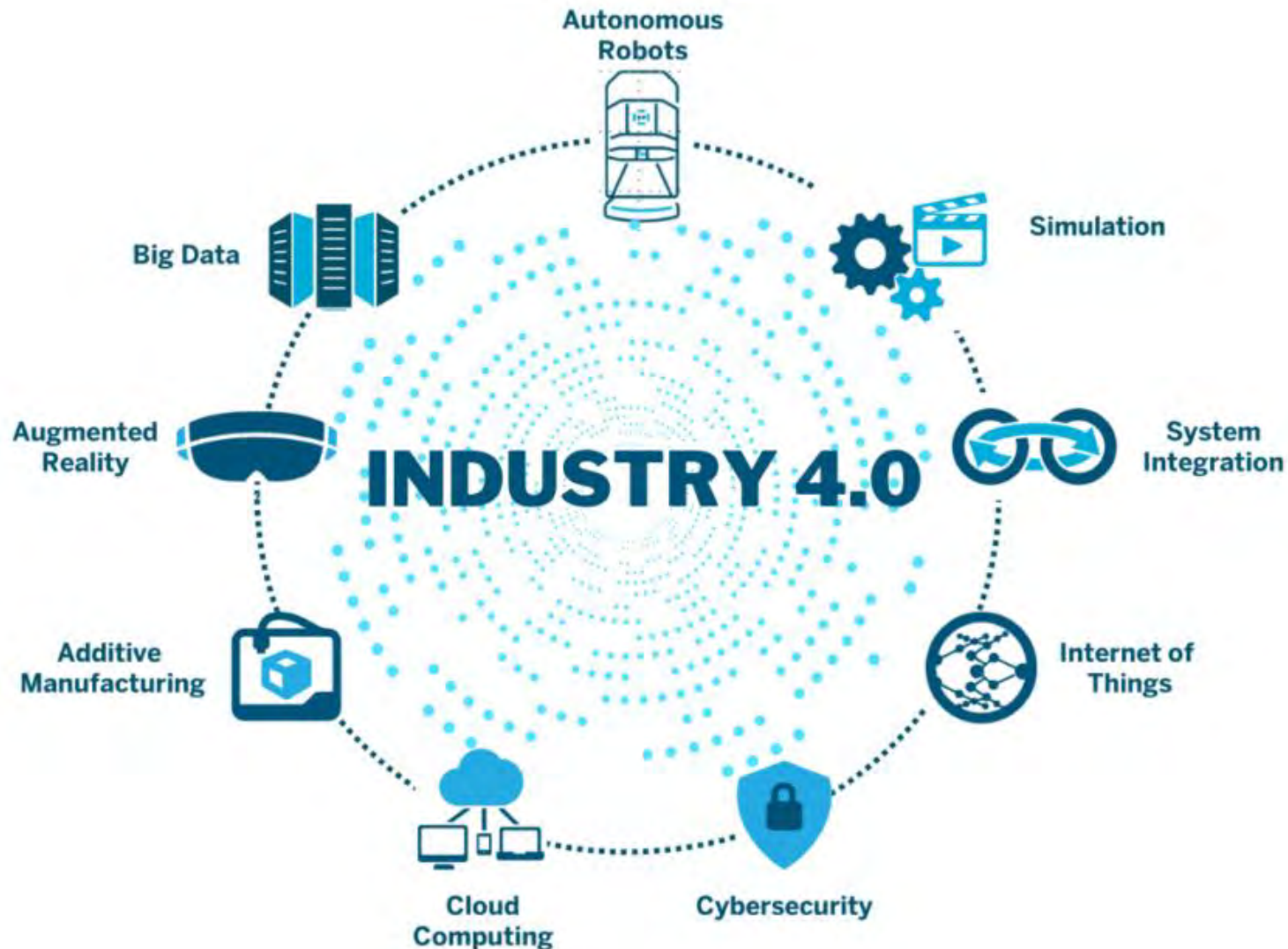
Some more background ...

A partial list of enabling Technologies



Springfield Technical
Community College

Exceptional Education. Proven Results.



Today, Industrial IoT or IIoT, Data Analytics/Big Data, AR/VR/XR, Digital Twins, Cloud/Edge Computing, CoBots, Automation/Robotics, IT/OT integration, OT Cybersecurity, Containerized Software, Industrial Networking, Fieldbuses, 5G/6G Wireless & WiFi 7, Machine Learning/Artificial Intelligence, Model Based Definition (MBD), etc. are driving this transition to everything being connected.

Industry 4.0 – Automation/Robotics/etc.



Springfield Technical
Community College
Exceptional Education. Proven Results.



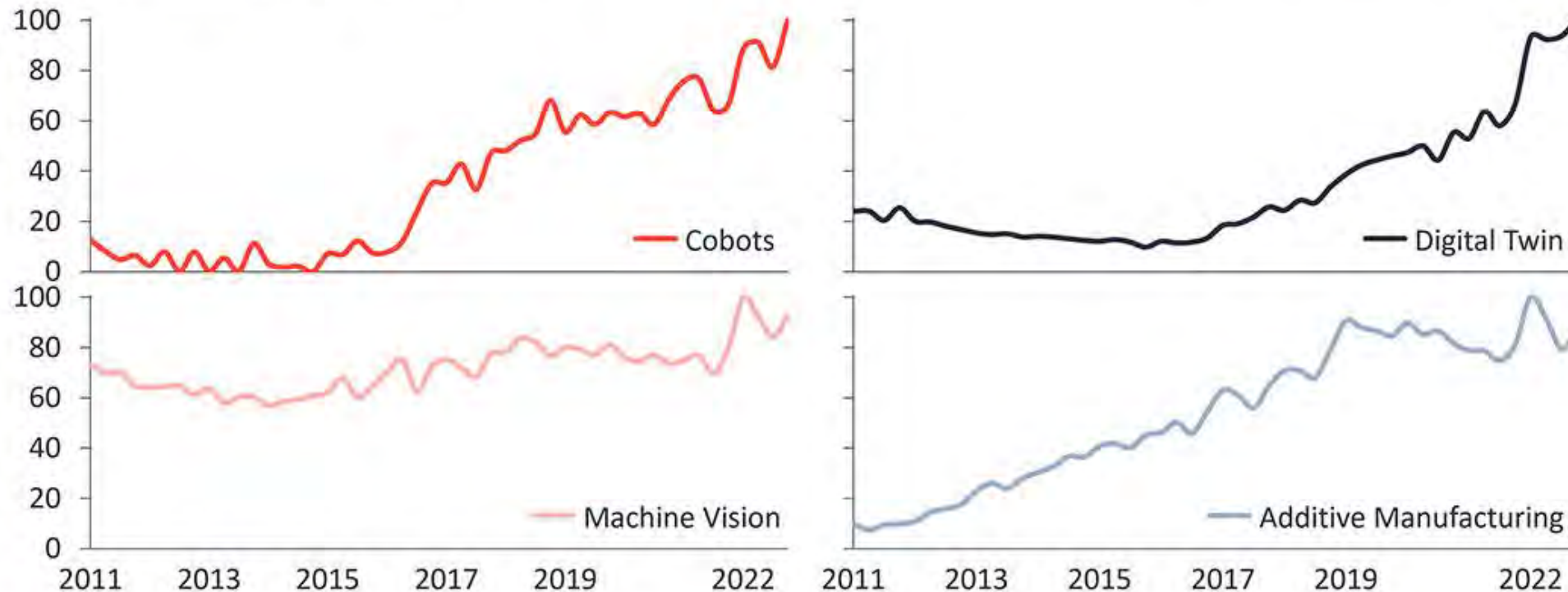
Interest in Industry 4.0



Your Global IoT Market Research Partner

Industry 4.0 technologies search interest – from 2011 to 2022

Relative search interest on Google*



Note: *Numbers represent worldwide search interest relative to the highest point on each graph for the given time. A value of 100 is the peak popularity for the term. A value of 50 means that the term is half as popular.
Source: IoT Analytics Research 2022, Google Trends

Interest in Industry 4.0 apps



Springfield Technical
Community College

Exceptional Education. Proven Results.



November 2023

Your Global IoT Market Research Partner

5 learnings from recent Industry 4.0 implementations



-  **1** Upgrading the ERP often the first step in digital transformation
-  **2** Cloud-native data storage and streaming coming up
-  **3** First successful implementations of private 5G use cases
-  **4** Digitalization becoming a prerequisite to achieving sustainability
-  **5** Continued journey towards predictive maintenance

Source: IoT Analytics Research 2023-Industrial IoT Industry 4.0 Case Study Report 2023. We welcome republishing of images but ask for source citation with a link to the original post and company website.

ERP – Enterprise Resource Planning (software)

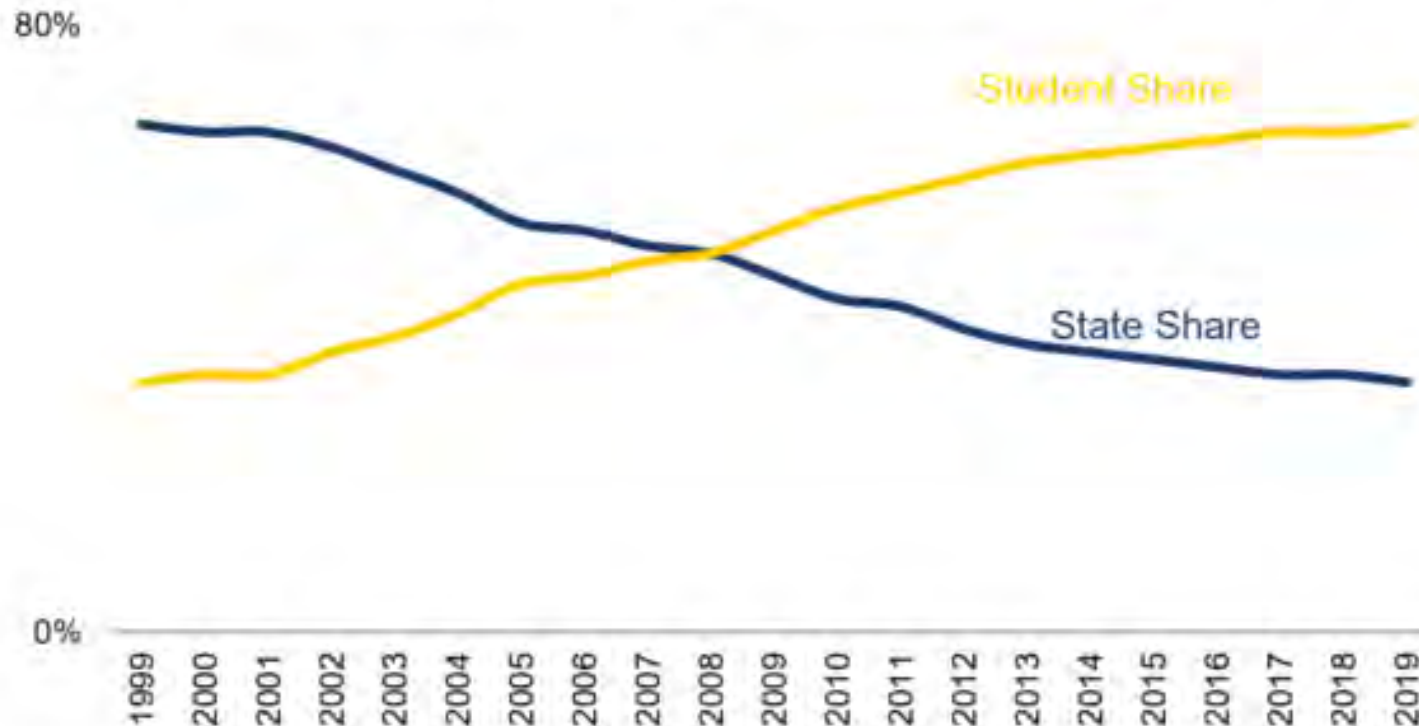
Interest in Funding Higher Ed



Springfield Technical
Community College
Exceptional Education. Proven Results.

Cost of Higher Education Has Shifted From State to Students

State and student shares of total public postsecondary funds in Kentucky



As interest has risen in Industry 4.0, support for higher education has been going the other way.

Although this chart is for the state of Kentucky and is somewhat dated, I would dare say that many of us that teach at two-year colleges have had similar experiences with our funding!

Source: OSBD and Council on Postsecondary Education.

Note: Net General Fund share compared to gross tuition and revenue share.

Covid funding woes, the problem of finding faculty



Springfield Technical
Community College
Exceptional Education. Proven Results.

- At the 2024 ASEE CIEC conference, part of my presentation covered the monetary issues that we all deal with including **the difficulty of hiring new faculty but let's try to look at this challenge in an opportunistic light**
- The NSF and other agencies have provided a lot of funding for advanced manufacturing initiatives – but these projects tend to not be focused on Industry 4.0 in a systemic way – they typically focus on new manufacturing technologies – additive, 3D printing, robotics, automation, etc.
- In my home state, there are 7 community colleges that offer manufacturing/advanced manufacturing degrees and are participating in the MassBridge project funded by DOD

From the MassBridge Project Web Site



Springfield Technical
Community College
Exceptional Education. Proven Results.

- **“The US is facing short and long-term workforce challenges driven by issues such as a “gray wave” of retirements in key technical jobs, the need for higher level of technical skills and training than in the past, misconceptions about the nature of technical jobs, and fragmented training, among others”.**
- **“Projects like MassBridge help address the current technician training gap”** – i.e. building a pipe-line.
- As a member of the MassBridge team, we have yet to give serious consideration to Industry 4.0. Although we hope to eventually get there. Our present focus is on developing a certificate for manufacturing that will serve as a pathway for people who want to get into the industry.

MassBridge Project & Industry 4.0



Springfield Technical
Community College

Exceptional Education. Proven Results.

- To be sure, the topic of the changing nature of the manufacturing industry has come up but we have yet to grapple with how we should address it.
- Our efforts have to date incorporated numerous new teaching methods and technologies to enhance the curriculum developed and to be able to accommodate different delivery modalities.
- In a by-gone era (before the Internet) technology was fairly straight forward. A technology AS degree was about a particular technology and did not have much spill over into other technical fields. Technicians dealt with the technology of their respective fields (so called silo effect).

The effect of the Internet and Moore's Law



Springfield Technical
Community College

Exceptional Education. Proven Results.

- For the last three decades the convergence of technologies that spawned the Internet have not slowed down but have **been continuing to evolve in sync with Moore's Law**
- The technologies of embedded controllers, ubiquitous Internet access, sensors, and ever increasing high-speed wireless have provided us with the tools to implement Internet of Things (IoT) applications which are the enablers of cyber-physical systems (also known as control systems 4.0). Recall our first slide which described Industry 4.0.
- The use of this new control system technology (enabled by the Internet) has started to be adopted across all industry sectors

Industry 4.0 is not limited to manufacturing!



Springfield Technical
Community College
Exceptional Education. Proven Results.

- From my perspective it is very important to recognize that the use of the enabling technologies of Industry 4.0 is not limited to just manufacturing but includes industrial sectors that do not produce goods
- These non-manufacturing industrial sectors like HVACR, transportation, telecom, mining, healthcare, utilities, finance, agriculture, etc. are all starting to employ these technologies to reap the benefits that they offer (usually better efficiency and higher productivity).
- Even Wall Street cares about the latency of high-speed fiberoptic networks when it comes to trading! AI is most likely the next big game changer for the financial world!

What can we glean from this cross-disciplinary nature of Industry 4.0 technology



Springfield Technical
Community College
Exceptional Education. Proven Results.

- Now we discover that Industry 4.0 has made technology fields much more complex.
- Consider the automobile – it has morphed from a gasoline powered mechanical transportation machine to a super-computer on wheels and in the not-too-distant future a transportation robot that humans get into to be brought to their desired destination.
- **Do a search on “Waymo self-driving taxi” and you will find that this is already happening in certain parts of the country (SF & Phoenix – LA and Austin TBD)**
- Industry 4.0 has changed the breath of technology for essentially all the industrial sectors that have embraced it

What are the common Inter-disciplinary Technologies of Industry 4.0?



Springfield Technical
Community College
Exceptional Education. Proven Results.

- Embedded controllers (memory, power electronics, WDT, redundancy, software, programming, OT cybersecurity)
- Communications Interfaces (HMI (Displays, keypads, touch screen, etc.), Internet, Computer Networking (wired and wireless), Cloud/Edge computing, other communication buses (automation, cars, building automation, etc.)
- Fundamentals of Control Systems 4.0 (IoT – Implementing Cyber-Physical Systems, Sensors & Actuators, ML & AI, data analytics, AR/VR/XR, and Digital Twins)
- Also, Automation & Robotics, CoBots, Mechatronics/Electronics (systems level), Wireless (5G & 6G, Wi-Fi 7)

Where are these technologies/skills taught?



Springfield Technical
Community College
Exceptional Education. Proven Results.

- Certainly not in the traditional manufacturing/advanced manufacturing two-year degree programs.
- Are they skills needed by all workers – not necessarily but certainly by the operational technology (OT) support personnel for a certain industry - i.e. electrical/electronics engineering technicians, mechatronics technicians, etc.
- Does it make sense to expand traditional STEM technology curriculums to accommodate this new material – yes and no. A basic overview of what these technologies can do for a particular field is probably worthwhile but not a detailed coverage by any means. Its totally impractical to add all this material!



So, what is the way to provide these evolving skills

- Other than providing an overview/survey of the digital technologies used to implement Industry 4.0 and what their benefits are, two-year manufacturing/advanced manufacturing programs that have a goal of providing **machinist and product designers to local industry don't** really need these additional skills to be employable.
- That said, a one-year certificate or a suite of various workforce development modules for incumbent workers would seem it be the most desirable approach to fill this evolving skills gap at this time. Such offerings would allow for the necessary upskilling of workers in the field.

Let's take a look where these enabling technologies live -



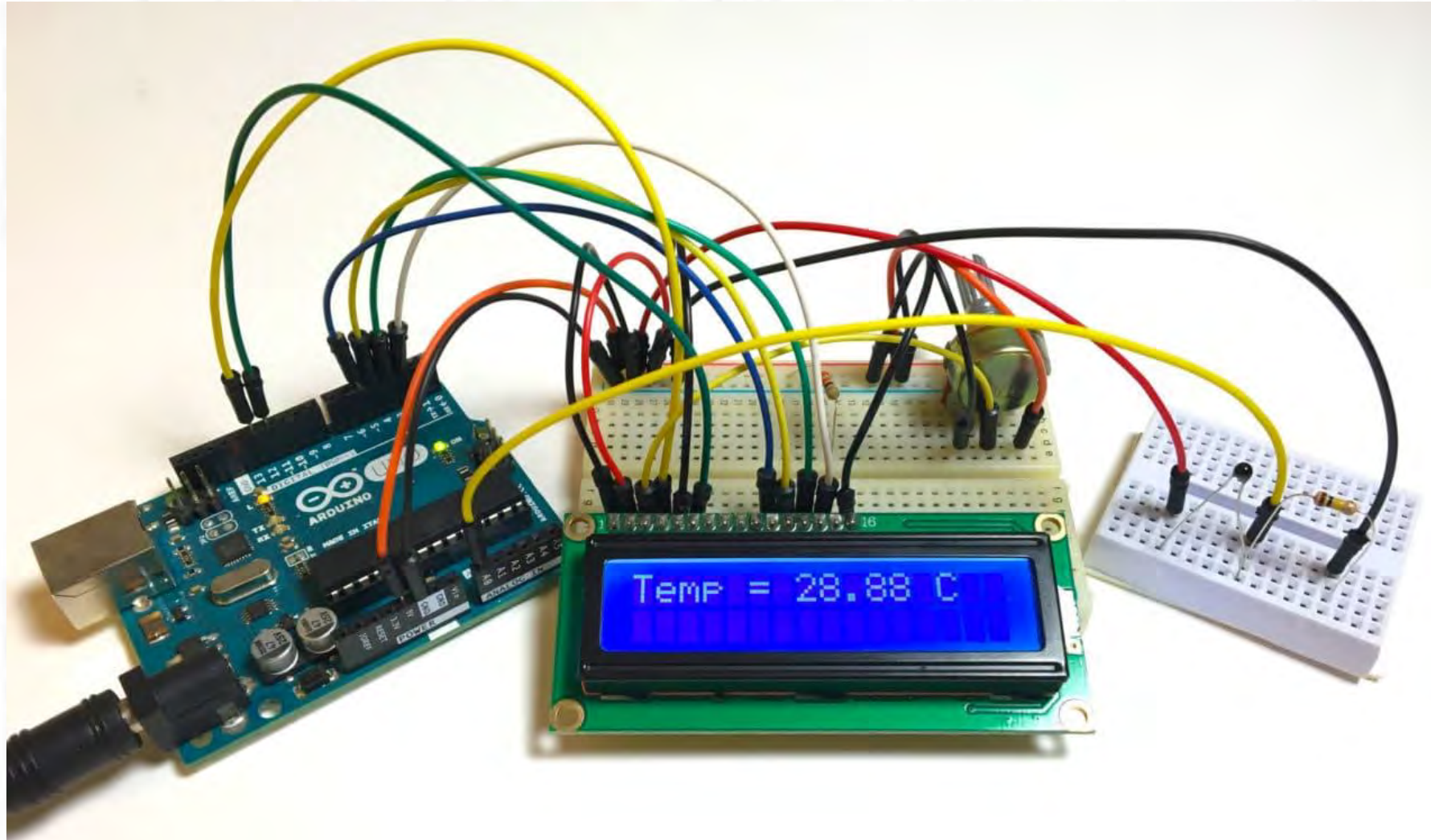
Springfield Technical
Community College
Exceptional Education. Proven Results.

- Embedded controllers (memory, power electronics, WDT, redundancy, software, programming, OT cybersecurity)
- Typically electrical/electronics/mechatronics/Bldg automation technology programs and hardware oriented computer technology programs tend to cover these topics with OT cybersecurity probably being the least common topic.
- Of course, the reason that OT cybersecurity is problematic is because one must be familiar with the operational technology of a particular industry or field. IT deals primarily with cybersecurity as it relates to business applications – this **doesn't bode well for IT/OT integration mentioned on slide #4 as an Industry 4.0 goal!**

Are there barriers to teaching this material? Arduino Temperature Sensor



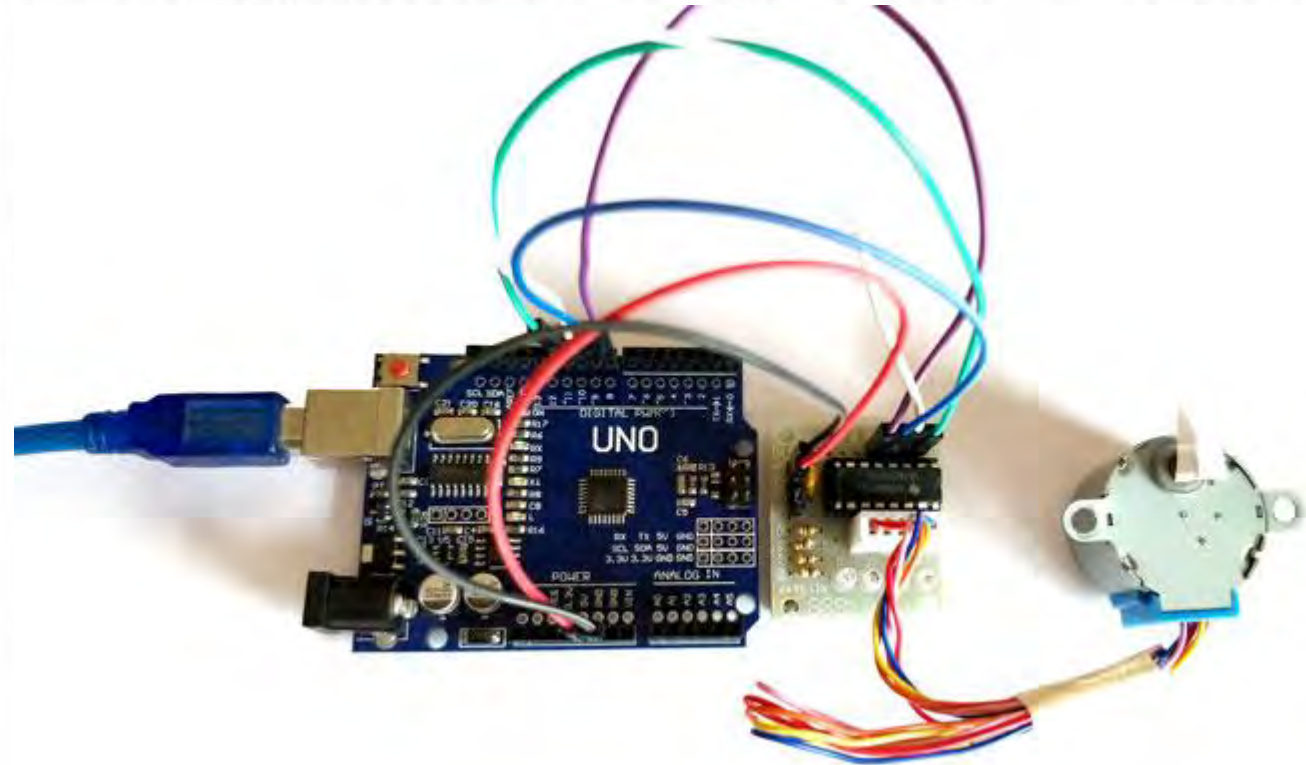
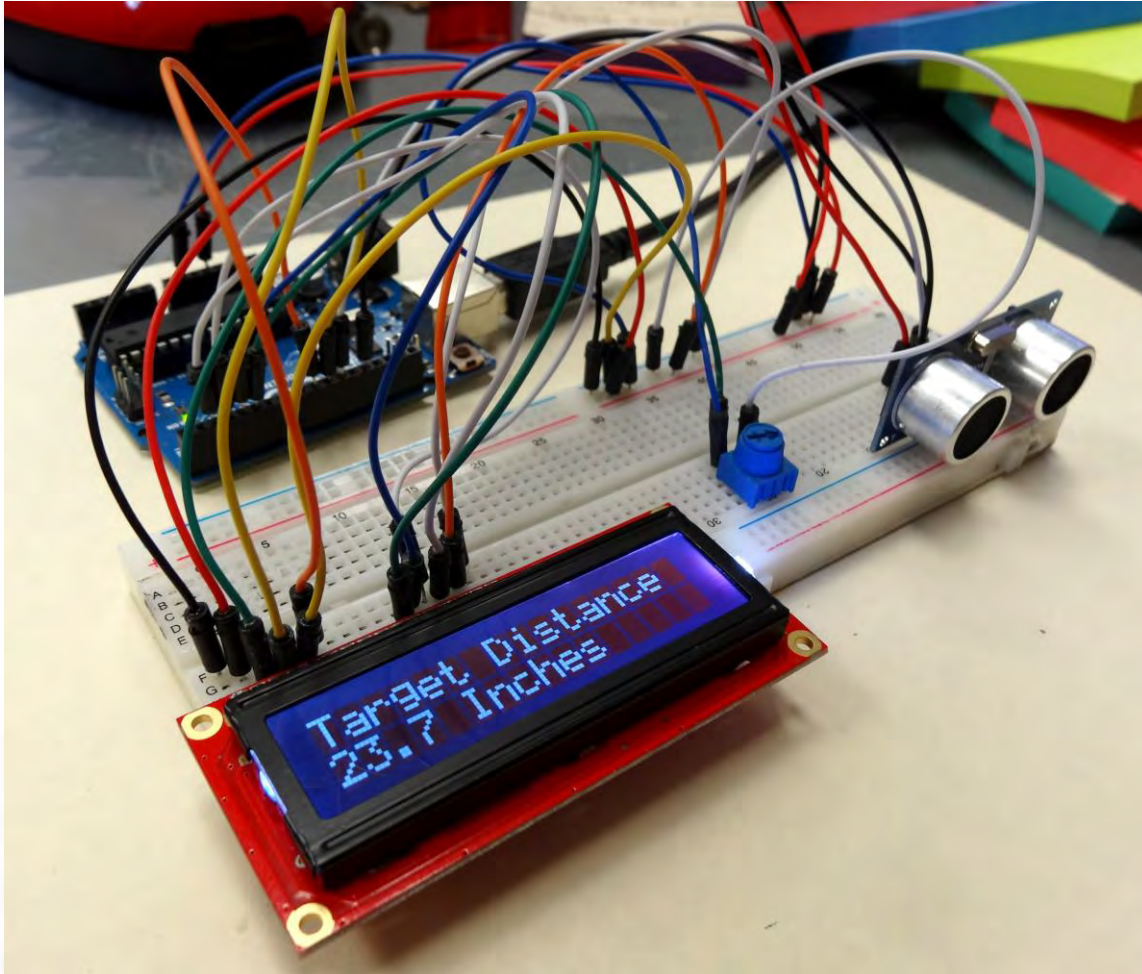
Springfield Technical
Community College
Exceptional Education. Proven Results.





Springfield Technical
Community College
Exceptional Education. Proven Results.

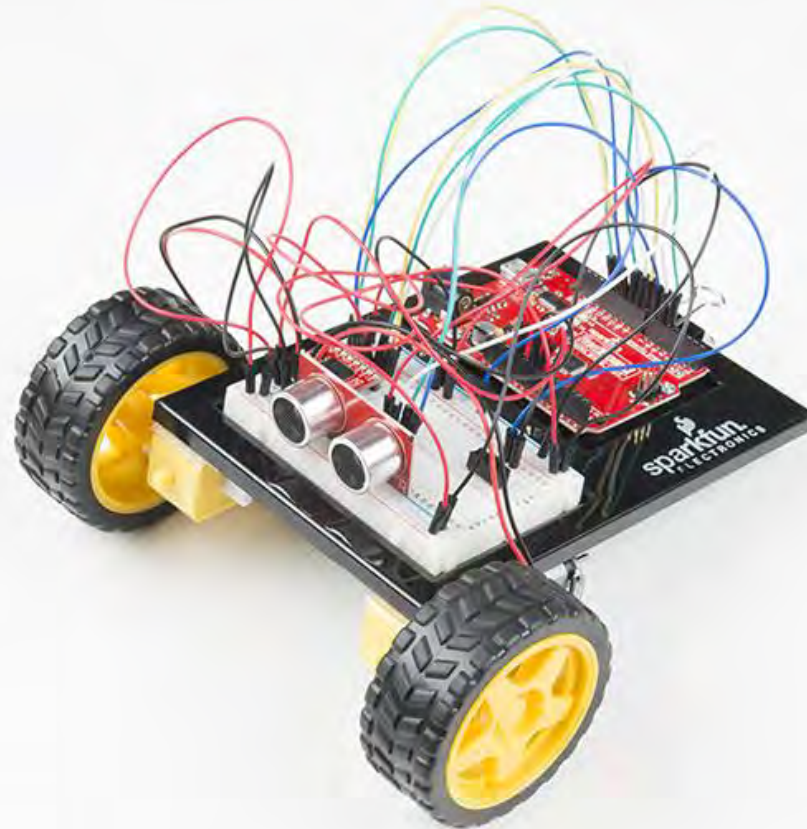
Arduino Ultrasonic Distance Sensor & Stepper Motor Driver



Arduino Robot from the SparkFun Inventors Kit



Springfield Technical
Community College
Exceptional Education. Proven Results.



Arduino R4 with wireless & Raspberry PI 4



Springfield Technical
Community College
Exceptional Education. Proven Results.



NEW

More powerful
processor

Choice of RAM
2GB 4GB

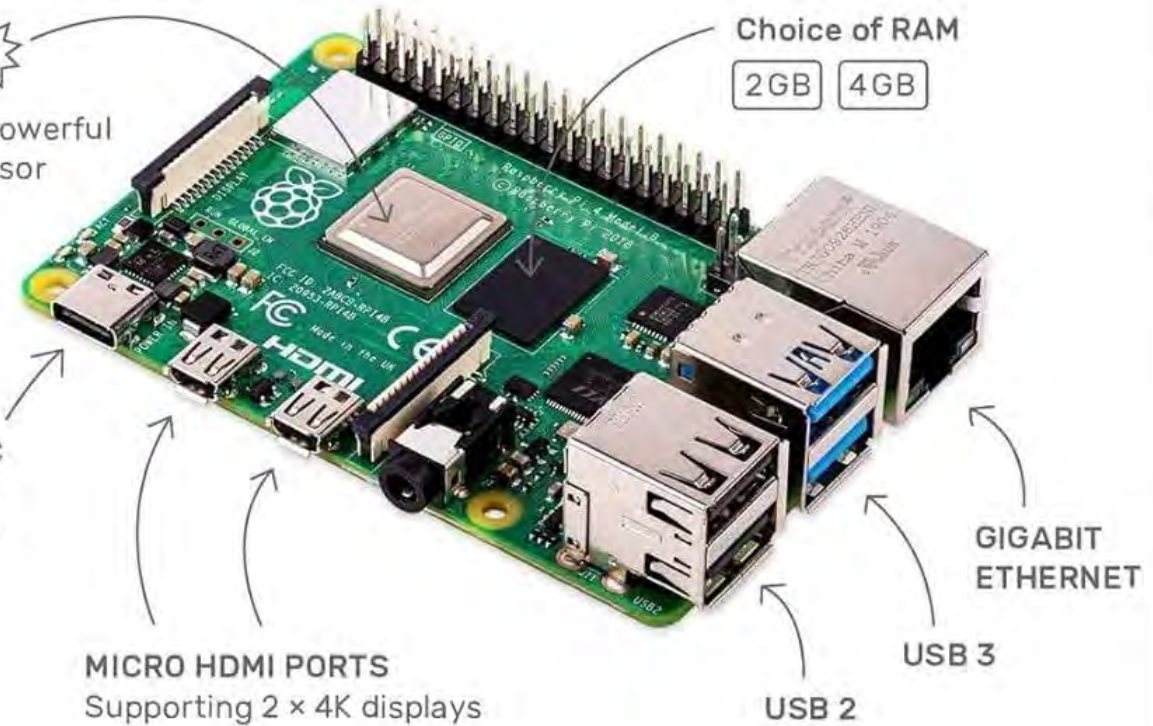
USB-C
Power
supply

MICRO HDMI PORTS
Supporting 2 x 4K displays

USB 2

USB 3

GIGABIT
ETHERNET



Let's take a look where these enabling technologies live



Springfield Technical
Community College
Exceptional Education. Proven Results.

- Communications Interfaces (HMI (Displays, keypads, touch screen, etc.), Internet, Computer Networking (wired and wireless), Cloud/Edge Computing, other communication buses (automation, cars, building automation, etc.)
- A hardware oriented computer technology program will cover most of the hardware devices (A+), the Internet, and computer networking (Cisco Academy) topics, as well as Cloud/Edge Computing.
- The specialized automation, automobile, and building automation buses are typically covered only in programs devoted to those topics.

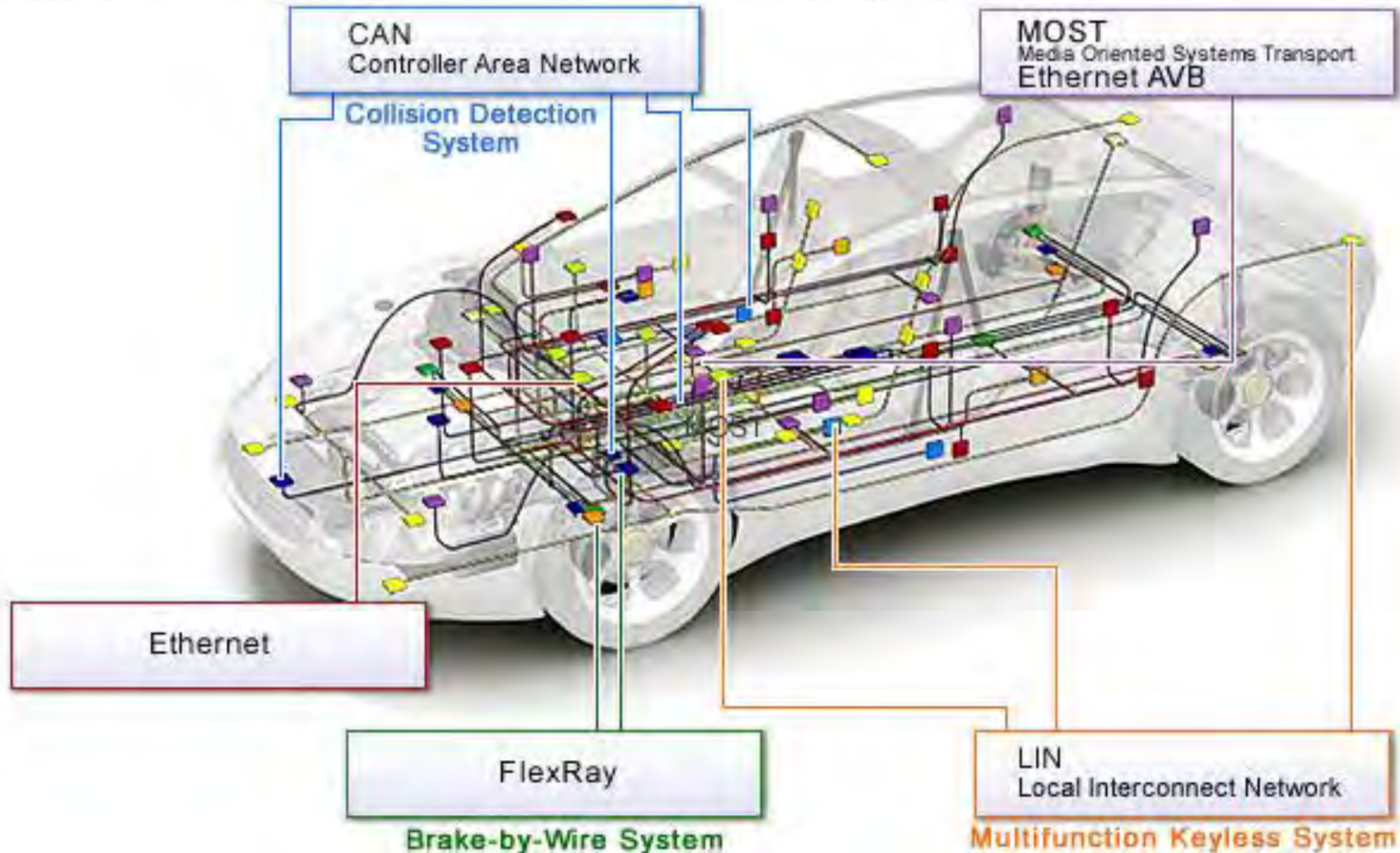
Let's take a look where these enabling technologies live (Cont.)



Springfield Technical
Community College
Exceptional Education. Proven Results.

- **Cisco's** IIoT division is working on several new courses for Industrial networking and networking for OT but they have not been piloted yet
- Presently, Cisco has some overview material on-line for IoT fundamentals but it is very limited in its scope
- **Various "field buses" such as Foundation Fieldbus, BacNet, DeviceNet, ControlNet, Modbus, and PROFIBUS** tend to be manufacturer specific and not widely taught to two-year technology students
- Vehicles have their own buses such as CAN, CAN FD, LIN, FlexRay, SENT, MOST, and (two-wire) automotive ethernet

Automotive Networks



Let's take a look where these enabling technologies live (Cont.)



Springfield Technical
Community College
Exceptional Education. Proven Results.

- Fundamentals of Control Systems 4.0 (IoT – Implementing Cyber-Physical Systems, Sensors & Actuators, ML & AI, data analytics, AR/VR/XR, and Digital Twins)
- My college offers an IoT Certificate under the Computer Systems Engineering Technology program and the Electrical Engineering Technology program has a Control Systems course which covers the hardware topics and Sensors & Actuators are covered in both programs. Other colleges offer these topics to varying degrees in their Mechatronics/Automation/Robotics programs

Let's take a look where these enabling technologies live (Cont.)



Springfield Technical
Community College
Exceptional Education. Proven Results.

- ML & AI are new emerging areas which, as yet, tend not to be standalone programs or certificates at the two-year college level – at this time it is unclear where these topics might finally reside
- Several universities offer higher level certificates (MIT, U Austin, etc.) – Intel has an AI certificate which some community college have looked into – the NSF will shortly announce a new AI ATE consortium which will surely provide some curricula and guidance in this area
- Most in industry see AI being implemented in their operations in the future (from Microsoft June, 2024 paper)

ML/AI Use Cases



Springfield Technical
Community College
Exceptional Education. Proven Results.

- Quality control, process optimization and supply chain optimization are the most important AI use cases for manufacturers.
- In addition, use cases for generative AI (i.e. ChatGPT) appear on the rise for applications such as data querying and coding assistance.
- The utilization of data querying and coding support can enhance use cases such as quality control and process optimization by aiding and accelerating root cause analysis and application development

Data Analytics Use Cases



Springfield Technical
Community College

Exceptional Education. Proven Results.

- Data Analytics programs have tended to reside in the Business Departments of colleges but this is changing – there was a session at this conference titled – Designing the future of work: Data Analytics Pathway
- Data Analytics programs are being developed at two-year colleges that do not reside in the business departments
- One of my favorite uses of data analytics is to use sensor data for the ongoing prediction of maintenance which can reduce machine downtime – the bane of the manufacturing floor

Let's take a look where these enabling technologies live (Cont.)



Springfield Technical
Community College
Exceptional Education. Proven Results.

- AR/VR/XR and Digital Twins are lumped together for obvious reasons but there are presently numerous barriers to adoption of these emerging technologies (mainly development cost and time) at the two-year college level
- These types of educational simulation tools can be used across many different fields and their development is ongoing
- Industry can use these technologies to simulate operations and optimize manufacturing processes

Let's take a look where these enabling technologies live



Springfield Technical
Community College
Exceptional Education. Proven Results.

- Also, Automation & Robotics, CoBots, Mechatronics/Electronics (systems level), Wireless (5G & 6G, Wi-Fi 7)
- Automation/Electrical/Electronics/Mechatronics/Robotics programs tend to cover topics in Automation, Robotics, and CoBots and tend to provide the support personnel for advanced manufacturing equipment
- Emerging wireless technologies for the industrial sector and manufacturing floor are not commonly taught and tend to be setup, installed, and maintained by outside third party vendors. Courses at the two-year college level in wireless technologies are rare but not non-existent



Industry 4.0 is Inter-disciplinary

- As one may see from this presentation, the underlying enabling technologies of Industry 4.0 are inter-disciplinary in nature and this poses a problem (sometimes know as “truf”) **at the two**-year college level
- Most community colleges offer programs that are not inter-disciplinary in nature. However, what is changing is program options. For instance, Central Community College, offers several flavors of its mechatronics program certificate – automation, control systems, fluid power, industrial technology, instrumentation, and process control – all with a common core of courses under the mechatronics banner

Industry 4.0 is Inter-disciplinary (Cont.)



Springfield Technical
Community College
Exceptional Education. Proven Results.

- Recall the slide that mentioned IT/OT integration? This is a difficult problem/predicament that has been around for a long time – most of us in this technology area have anecdotal stories that we can share about the **IT department's desire to control all networking in an enterprise**
- However, at this point, most recognize the benefits of working toward this goal of IT/OT integration
- Of course, this highlights the role and need for cybersecurity for both IT and OT networks – most IT departments are not ready for this yet!



What are 4-year institutions doing?

- Several speakers at the 2024 ASEE CIEC Conference talked about how their Mechanical Engineering Departments were dealing with Industry 4.0 at the BS degree level
- The addition of hands-on courses using low-cost Arduino boards as the embedded controller platform coupled with various sensors were described
- Interestingly, there were reports of great student satisfaction with these new courses – seems that they enjoyed doing something practical!



So what should we be doing?

- I would advocate for the design of an Industry 4.0 certificate that could supplement various two-year degree programs with the skills necessary to support the digital technologies adopted by a company. This certificate could be useful for both incumbent workers and students that have gone through other technical programs
- At this time, most of us would have to draw from what we already have available to us in other existing programs
- Presently, at my college we have an Electrical Engineering Technology Program that emphasizes Automation and Robotics

What would a certificate look like, what would it be called?



Springfield Technical
Community College
Exceptional Education. Proven Results.

- The content of the certificate would be the easy part. There is enough material listed in the early slides of this presentation to generate 24 – 30 credits and maybe provide some latitude with electives that address specific industries.
- The more difficult part is the name of the certificate. Any name needs to capture the essence of what type of job skills it leads to. Some things that come to mind are: digital industry technician, systems technician, systems integration technician, IIoT technician, etc.
- This is a work in progress, but this is the time that is right to introduce curricula that addresses these new skills gaps.

A possible certificate under the Electrical Engineering Technology Program



Springfield Technical
Community College
Exceptional Education. Proven Results.

- Industry 4.0 Certificate
 - ELE110 Mechatronics 1
 - ELE111 Introduction to Industrial IoT
 - EET115 Introduction to PLCs
 - CSO105 Introduction to Networking
 - EET130 Fundamentals of Motor Controls

 - ELE115 Mechatronics 2
 - ELE128 Security & Networking for IIoT
 - EET235 PLCs 2
 - EET140 Fundamentals of Robotics
 - EET250 Control System Theory

More Industry 4.0!



Springfield Technical
Community College
Exceptional Education. Proven Results.

