CESMII
THE SMART MANUFACTURING INSTITUTE

ACCELERATING THE DEMOCRATIZATION OF SMART MANUFACTURING

2020 ROADMAP UPDATE

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ABOUT CESMII

CESMII is the United States' national institute on Smart Manufacturing, driving cultural and technological transformation and secure industrial technologies as national imperatives. By enabling frictionless movement of information – raw and contextualized data – between real-time Operations and the people and systems that create value in and across Manufacturing organizations, CESMII is ensuring the power of information and innovation is at the fingertips of everyone who touches manufacturing.

2017
Founded by the Department of Energy (DOE)

$140M
Private/public partnership over 5-year period

IMPROVE ENERGY PRODUCTIVITY
through Sensing, Control, Modeling, Analytics and Platform Technologies

HOW?

Fund the Innovation and R&D necessary to dramatically reduce the cost and complexity of using real-time data from operations to drive revenue and cost improvements and generate cash

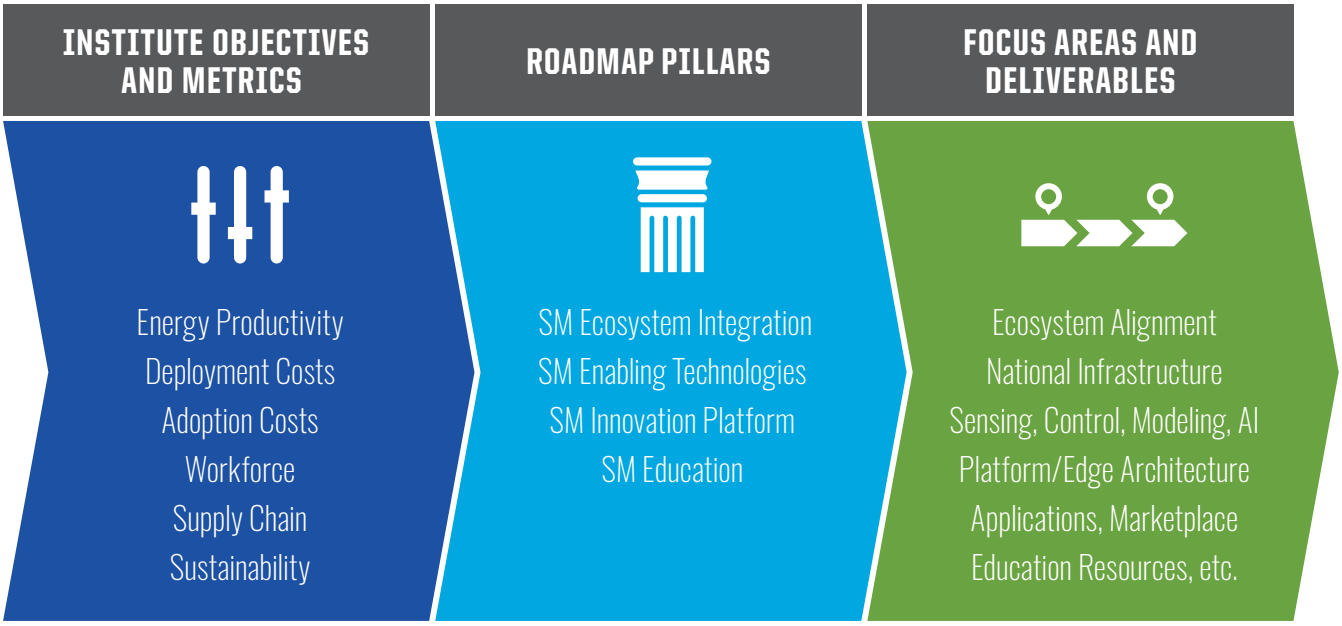
Engaging the smart manufacturing ecosystem through a membership and collaboration model

MANUFACTURER | SYSTEM INTEGRATOR | SW APP VENDOR | ACADEMIA, LABS | MACHINE BUILDER

ABOUT THE CESMII ROADMAP

CESMII's Institute Roadmap is a guiding document to ensure that the work carried out through the institute is directly tied to our published goals, objectives and strategic levers. Our objectives define what we (as an ecosystem driven through public/private partnership) want to accomplish and, in turn, define our roadmap. The roadmap guides how we accomplish our objectives through the published focus areas and deliverables.

This updated Institute Roadmap focuses on the 2020-2022 timeline.



- The original roadmap for CESMII was created in 2017 by bringing together over 100 subject matter experts from the industry, government and academia. The results of this roadmapping effort were captured in a comprehensive Roadmap Findings document

- The Roadmap Findings document was divided into four High Priority Smart Manufacturing (SM) Strategies, representing the four "pillars" of the institute roadmap – SM Ecosystem Integration, Enabling Technologies, SM Platform Infrastructure and SM Education. Each section included strategic objectives, performance targets, gaps, challenges and activity timelines through 2030

- Subsequently, a public facing Roadmap Summary document was created, capturing key elements of the roadmap findings document and identifying specific activities to be pursued during 2017-2018

ABOUT THIS UPDATE

This document represents an update of the 2017 Roadmap Summary document. The purpose of this update is to capture activities that are relevant for the institute to pursue in the 2020-2022 timeframe.

- Retains the intent of the original roadmap
- Incorporates guidance and feedback from CESMII standing committees, Governance Board, CESMII HQ and DOE
- Provides more recent and relevant articulation of the institute's mission, strategic levers and strategic objectives
- Reflects activities considered relevant for the institute in the 2020-2022 timeframe
- Considers what is being addressed through the current portfolio of projects and RFPs
- Provides clarity on items that are retained from the original summary document

INSTITUTE OBJECTIVES AND METRICS

INSTITUTE OBJECTIVES

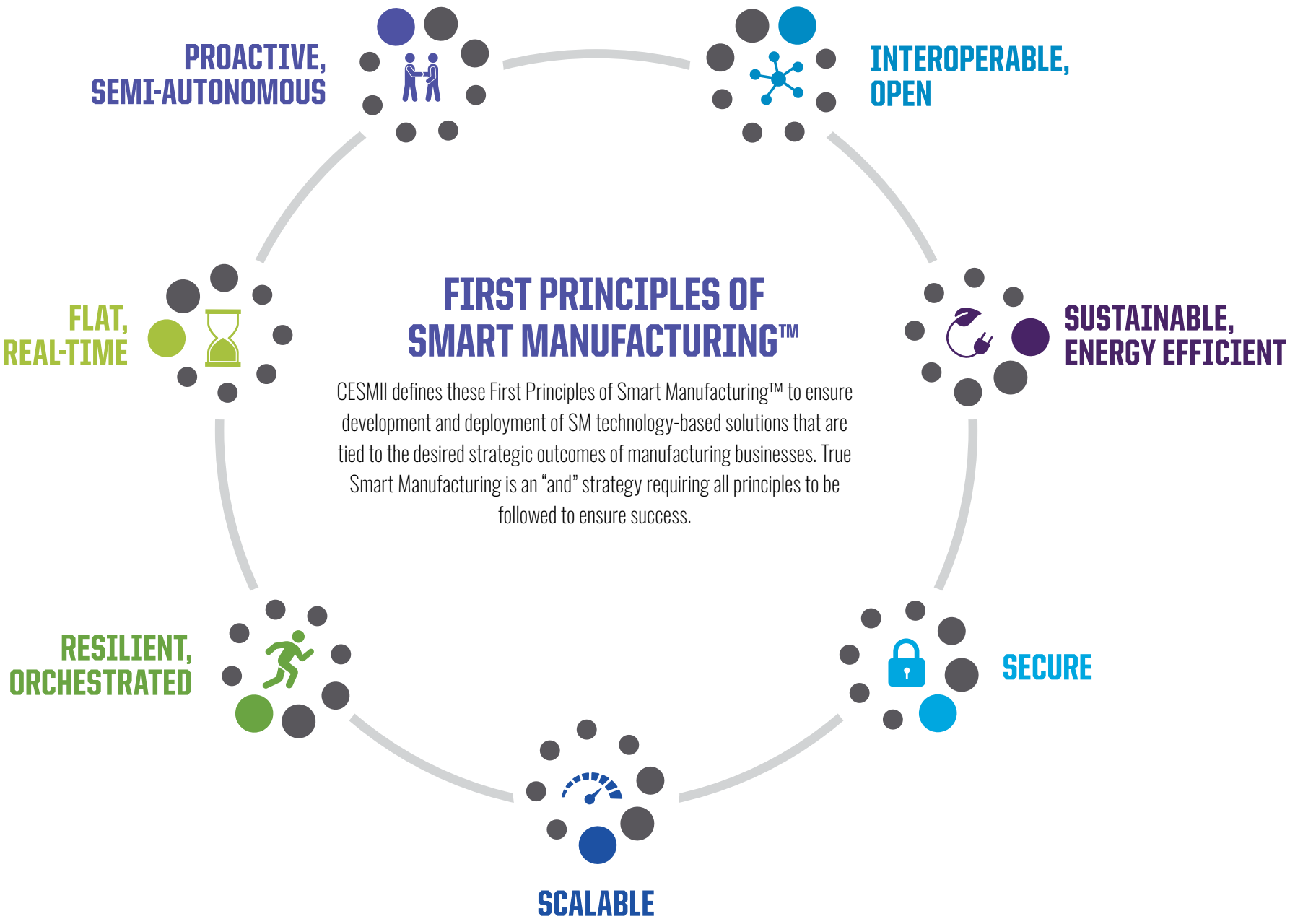
1. Lead a national effort to develop, test, and widely deploy SM technologies and practices in a continuously evolving manner
2. Develop a roadmap for SM technologies, practices, services, and training and update the roadmap periodically as needed
3. Support SM Research and Development and provide capabilities for and collaboration in open, pre-competitive work among multiple parties
4. Establish a technical education and workforce development program that leverages regional networks
5. Stimulate growth of a SM domestic supply chain
6. Demonstrate participation of underrepresented groups in CESMII
7. Be financially self-sustaining

INSTITUTE METRICS

- Energy productivity gains in U.S. manufacturing will be doubled in 10 years
- 15% improvement in energy efficiency in first-of-a-kind industrial testbeds will be achieved within 5 years
- Cost of deploying SM technologies including hardware and software in existing manufacturing processes will be reduced 50% relative to state-of-the-art in 5 years
- Installed and operating cost for adoption of SM technologies including hardware and software will be recovered through energy savings and productivity improvements in 10 years
- SM workforce capacity in U.S. will be increased two-fold by 2020 and five-fold by 2030
- SM supply chain will increase value and participation 40% by 2030
- Be financially self-sustaining after year five of the institute

DEFINING SMART MANUFACTURING

CESMII's mission is to Democratize Smart Manufacturing (SM), making it available to all. We define SM to ground our efforts, noting SM is not a particular technology. It is a business discipline enabled by technology, threaded together to achieve desired results.


PROACTIVE, SEMI-AUTONOMOUS
INTEROPERABLE, OPEN
FLAT, REAL-TIME
SUSTAINABLE, ENERGY EFFICIENT
FIRST PRINCIPLES OF SMART MANUFACTURING™
CESMII defines these First Principles of Smart Manufacturing™ to ensure development and deployment of SM technology-based solutions that are tied to the desired strategic outcomes of manufacturing businesses. True Smart Manufacturing is an "and" strategy requiring all principles to be followed to ensure success.
RESILIENT, ORCHESTRATED
SECURE
SCALABLE

ROADMAP PILLARS

CESMII ROADMAP PILLARS

CESMII's roadmap is structured into four strategic focus areas, or pillars, that are highly integrated. Each pillar serves the institute's work of accelerating the democratization of Smart Manufacturing for transformative performance and energy productivity of all U.S. manufacturers. Functionally, each pillar governs work performed in strategic focus areas of the institute while providing feedback and insights to the complementary pillars of the roadmap.

- SM Ecosystem Integration provides leadership uniting ecosystem collaborators to deliver on the vision of SM democratization
- SM Enabling Technologies focuses on collaborative R&D for closing gaps in key building block technologies, with a goal to create robust configurable technologies that can integrate into the SM system
- SM Innovation Platform, focused on creating an infrastructure that enables movement of information in context, enables reuse of technologies through a marketplace, in a secure, interoperable, scalable and cost effective manner
- And finally, SM Education that focuses on SM principles, building SM skills, providing training and educational resources

ROADMAP PROJECTS SUPPORT ONE OR MORE CESMII PILLARS

SM ECOSYSTEM INTEGRATION

- Unite ecosystem in innovative collaboration
- Develop ambassadors for SM value and principles
- Leverage a national network of innovation centers

SM ENABLING TECHNOLOGIES

- Collaborative R&D
- Develop key technologies
- Robust and configurable
- Integration into SM system

SM EDUCATION

- SM principles and practices
- Build and sustain SM skills
- SM platform and tech training
- Educator resources

SM INNOVATION PLATFORM

- Platform and Marketplace
- Enable reuse of technologies
- Secure, flexible, scalable
- Cost effective deployment

SM ECOSYSTEM INTEGRATION

SM ECOSYSTEM INTEGRATION

The most important goal for CESMII is to achieve democratization of Smart Manufacturing – make SM affordable, sustainable and adoptable for every manufacturer who chooses to take this journey. This strategic pillar delivers the leadership to realize the required integrated ecosystem.

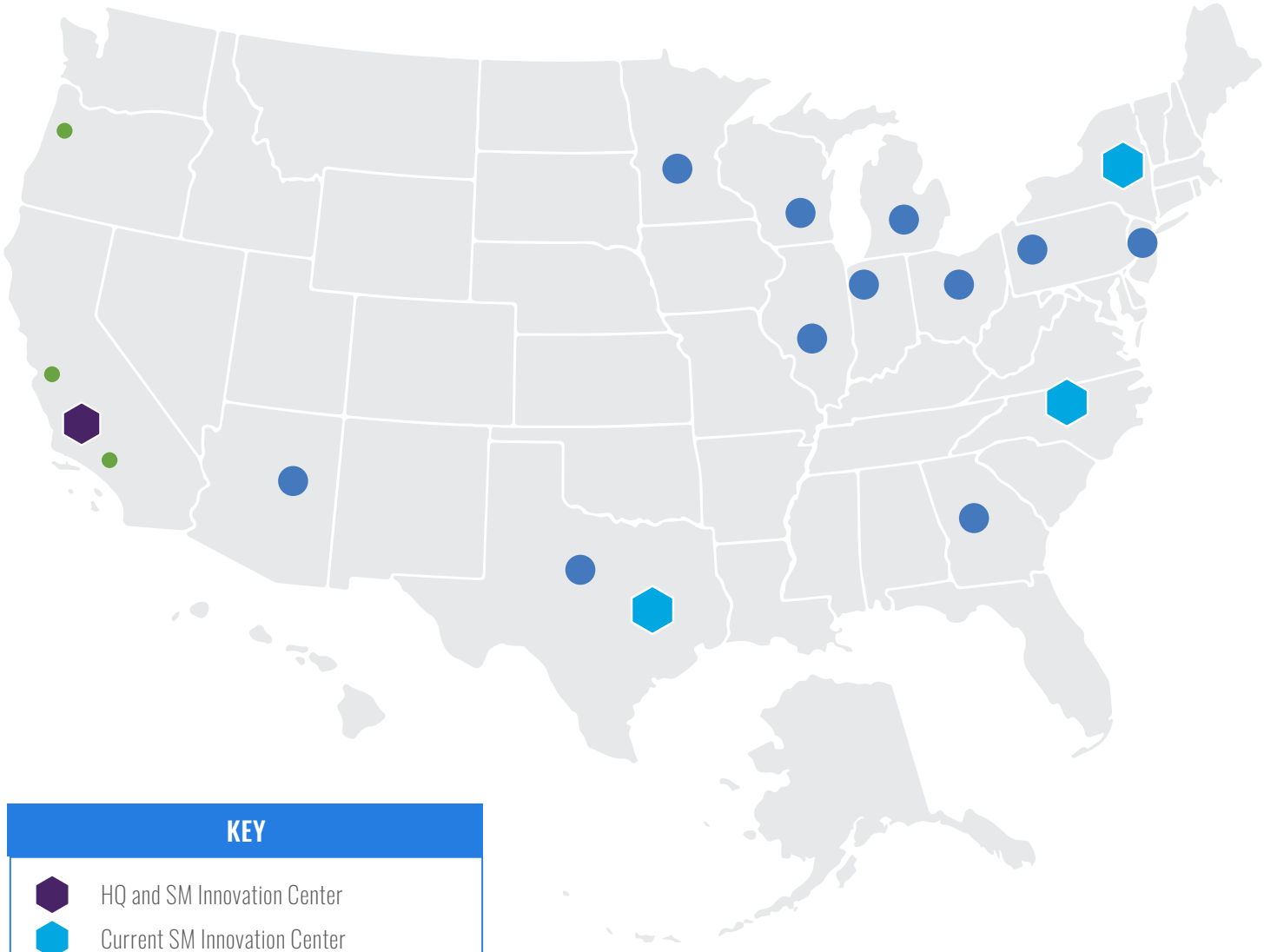
CESMII's strategy to democratize Smart Manufacturing innovation includes a combination of increased access to technology and knowledge for the people engaged in this safe, collaborative, agnostic, open and interoperable ecosystem.

Innovation is achieved when the whole ecosystem works together: Manufacturers and the many organizations that support them in implementing the innovation work together including machine builders, software app vendors, system integrators and academia.

SM ECOSYSTEM INTEGRATION: NATIONAL PRESENCE

CESMII represents a network-of-networks, engaging industry partners and academia nationally from our headquarters in Los Angeles, CA to bring value to our entire ecosystem from coast-to-coast.

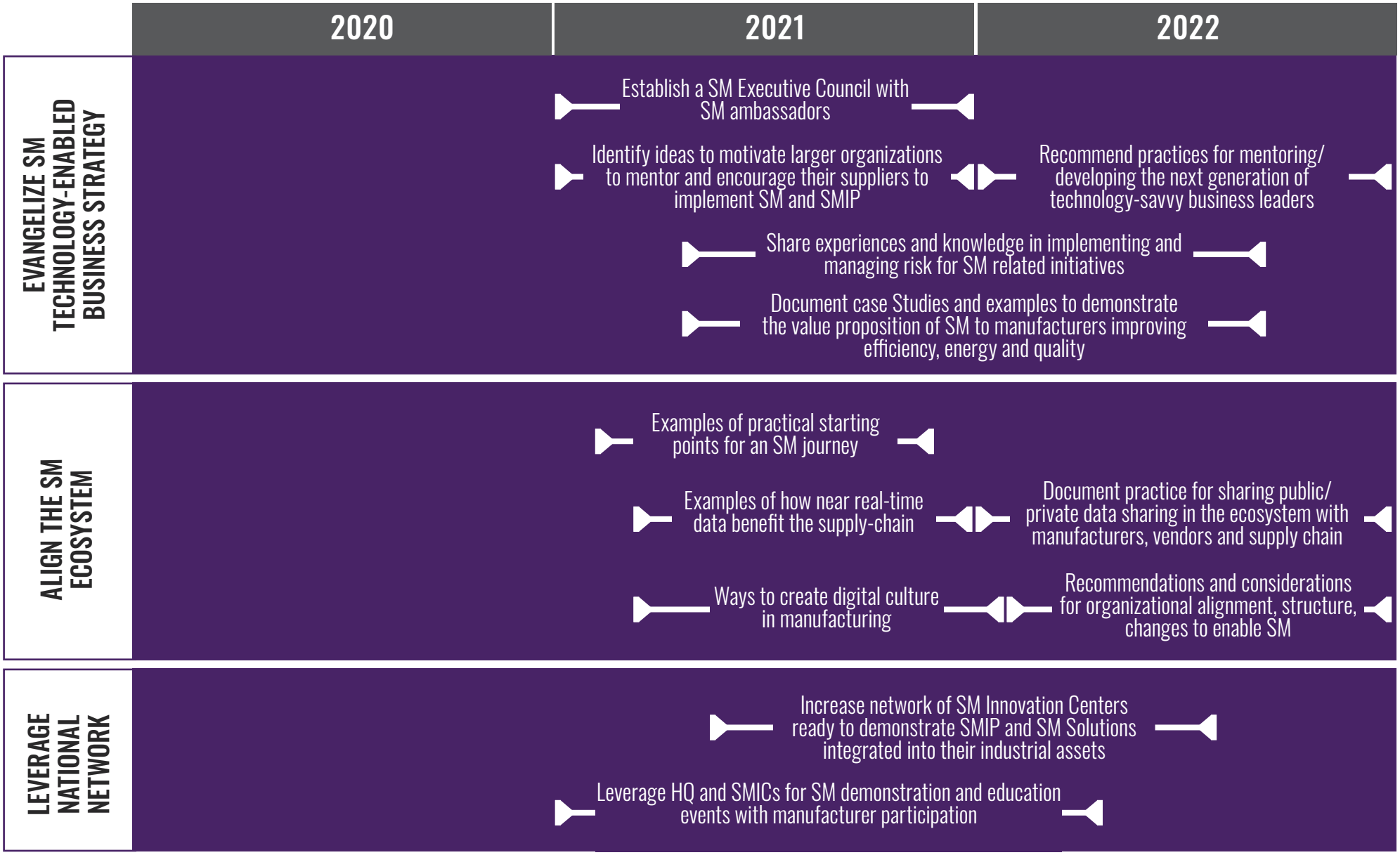
- Aligned around Industry Vertical and Technology Horizontals
- A World-Class Network of Manufacturing Assets Connected to our SM Innovation Platform
- Academia or Industry Partners
- Engage Manufacturing and Supply Chains where they are - local presence, test beds, training...



STRATEGIC OBJECTIVES - SM ECOSYSTEM INTEGRATION

- Develop ambassadors for SM vision, principles, integrated ecosystem, and collaborative value chain
- Engage in strategic initiatives to accelerate SM adoption through reduction of complexity and TCO
- Facilitate the evolution of leadership and executive decision-making awareness on the value proposition for SM, technology-enabled business operating models, and the skills needed in the workforce for SM implementation at manufacturers of all sizes including small, medium, and large manufacturers
- Align the ecosystem of manufacturers, technology vendors, and services providers for innovative collaboration towards delivery of SM vision and outcomes
- Support acceleration of SM adoption through a network of CESMII recognized SM vendors and professionals
- Promote the value and benefits of SM including:
    - ◊ Manufacturing Productivity, Energy Productivity, Supply Chain Resiliency, etc...
    - ◊ SM Principles
- Leverage national network of innovation centers towards demonstration and education of SM solutions
- Facilitate the transformation, to a SM ecosystem, that encompass machine-to-plant-to-enterprise-to-supply-chain connectivity for new speed, resiliency and business models in the supply chain while minimizing risks and uncertainty

SM ECOSYSTEM INTEGRATION: NEAR TERM ROADMAP

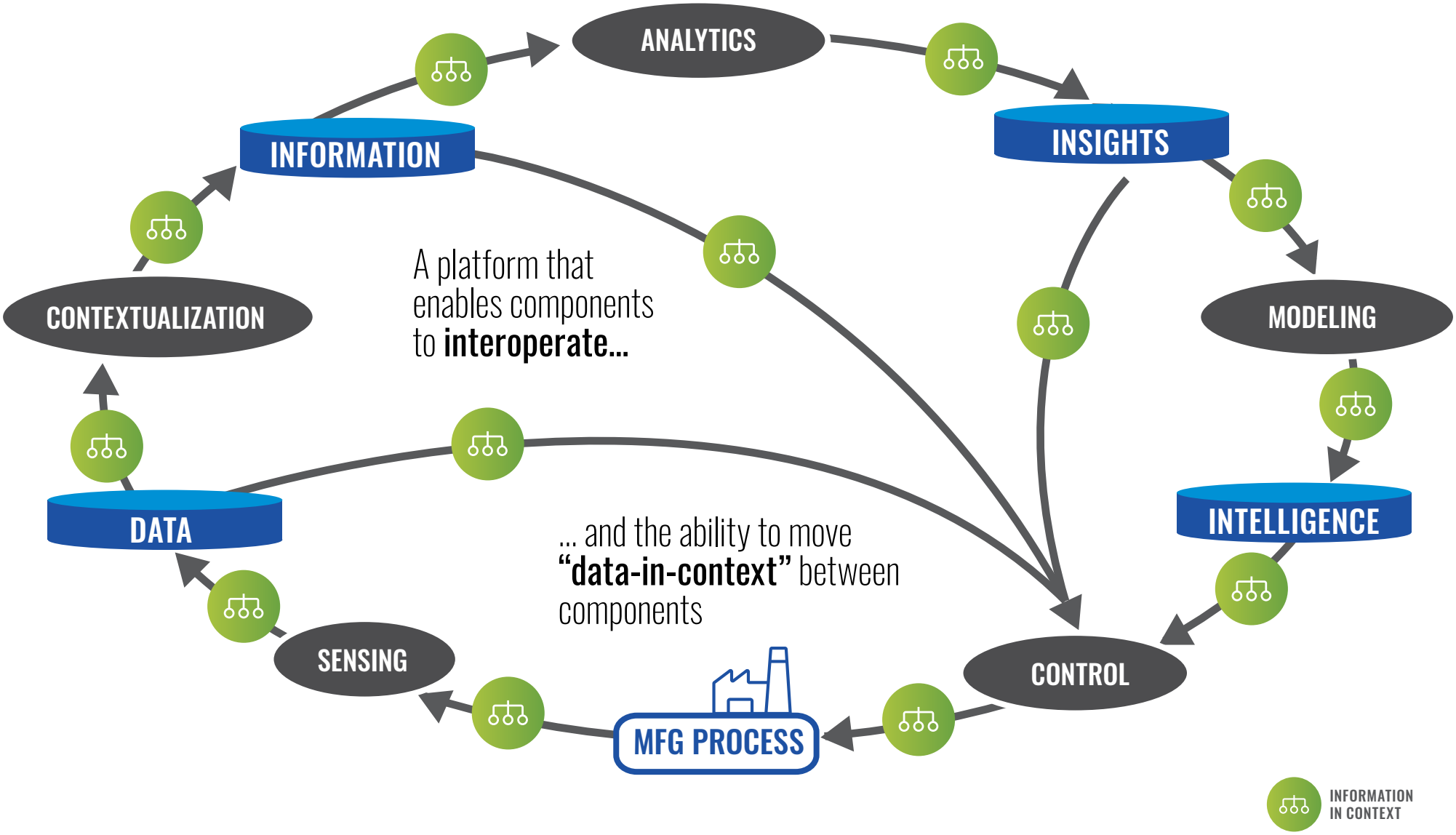


Roadmap projects support one or more CESMII pillars and metrics

SM ENABLING TECHNOLOGIES

SM ENABLING TECHNOLOGIES

There are several technologies that form the building blocks for a Smart Manufacturing solution. These building blocks need to be connected through a platform that enables them to interoperate and more importantly, with the ability to move data in context between them.



STRATEGIC OBJECTIVES - SM ENABLING TECHNOLOGIES

- Facilitate the development, demonstration, and application of the modular, affordable, easy-to-configure, secure, and reusable Cyber-physical-system (CPS) elements and their technical integration requirements to enhance CPS properties for companies of all sizes across manufacturing sectors

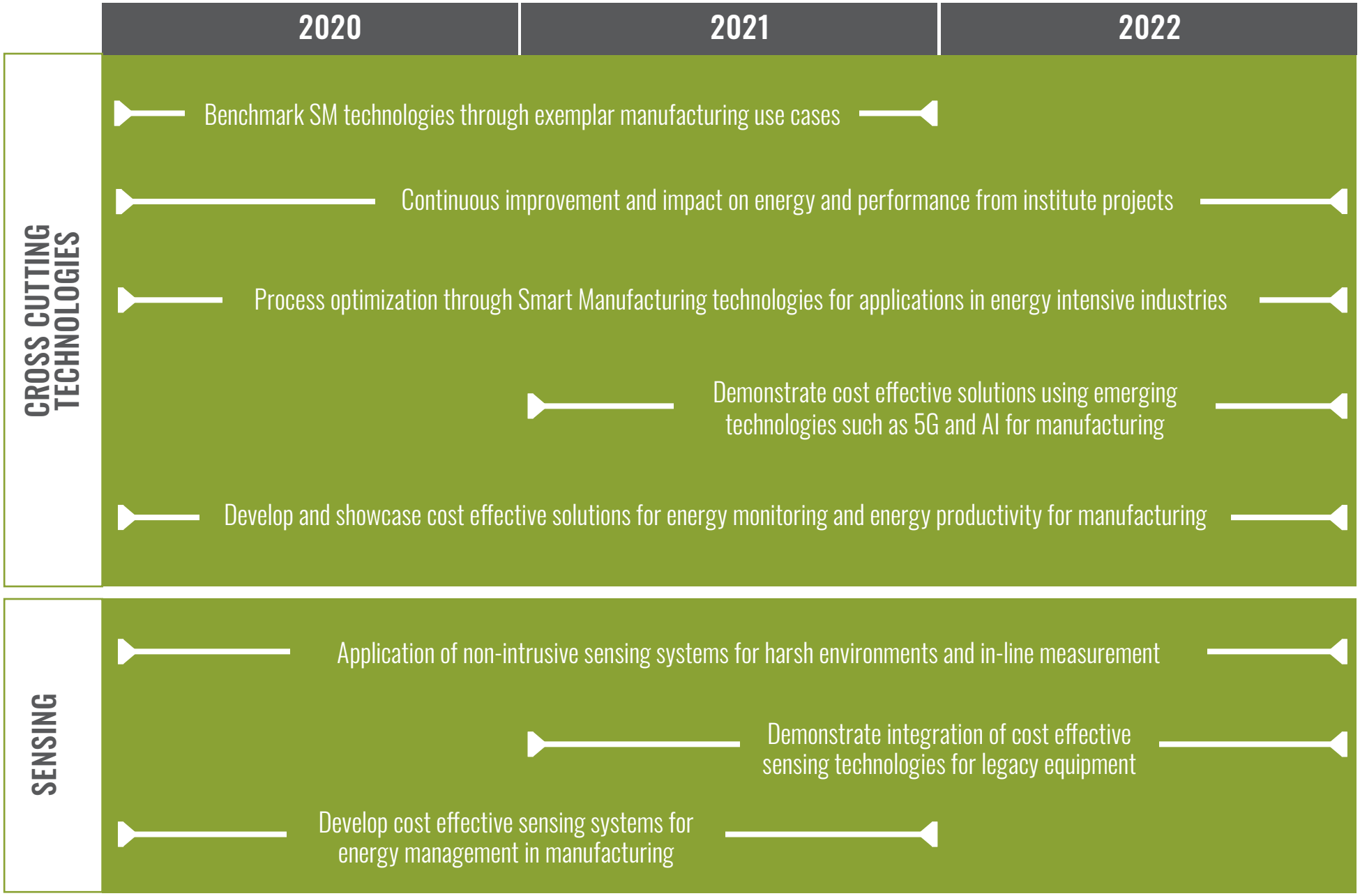
- Develop advanced wired and wireless sensor systems to achieve more affordable, robust, easy-to-configure, and secure data communications

- Increase the successful pace and adoption and application of next-generation data analytics and modeling

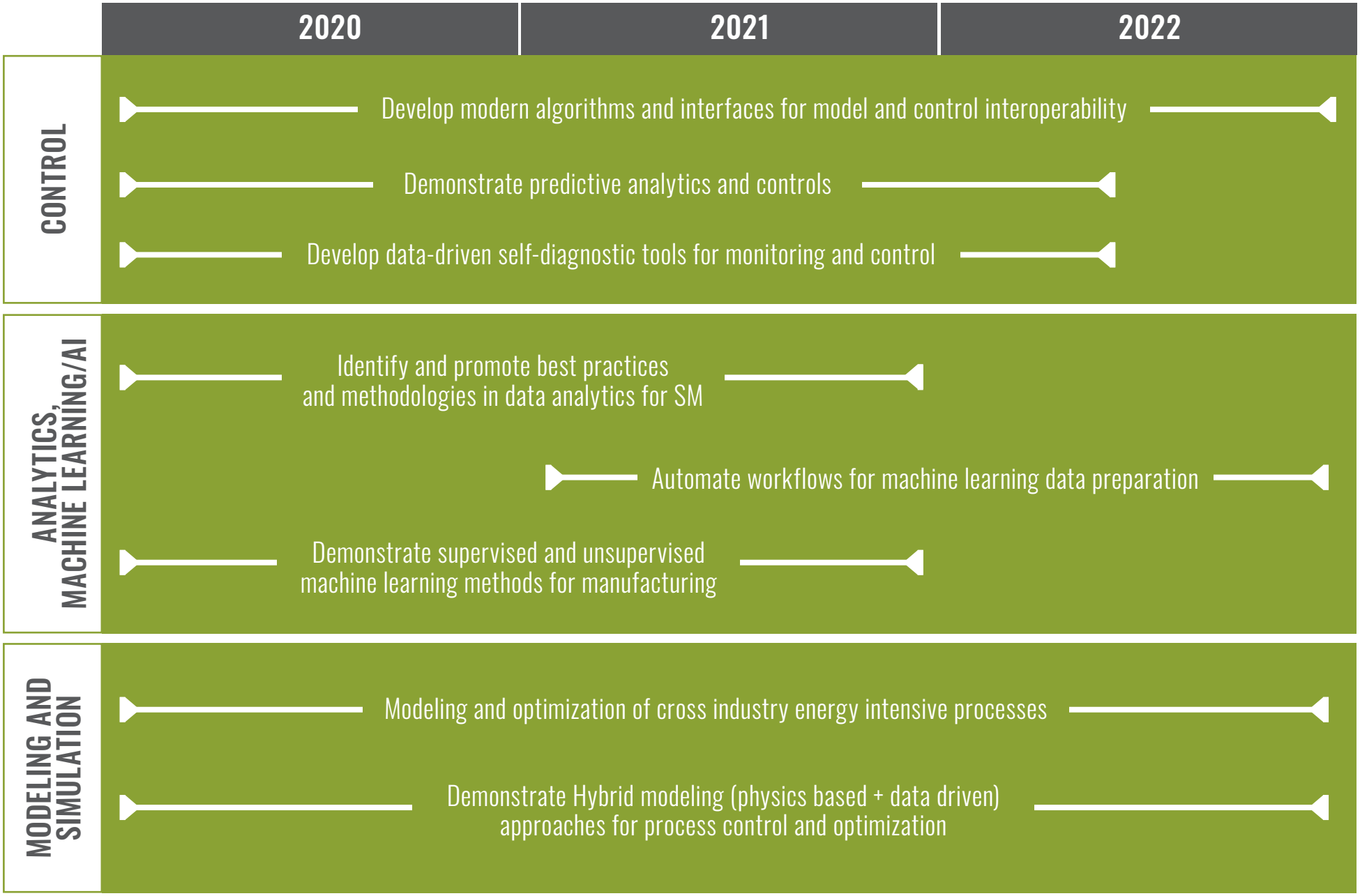
- Make advanced smart manufacturing sensor, controls, platforms and modeling methods, tools, know-how and practices accessible to workers throughout companies and across companies of all sizes

- Identify the patterns of data modeling, tools and shared information that reusability for application and operational reusability

SM ENABLING TECHNOLOGIES: NEAR TERM ROADMAP 1/2



SM ENABLING TECHNOLOGIES: NEAR TERM ROADMAP 2/2

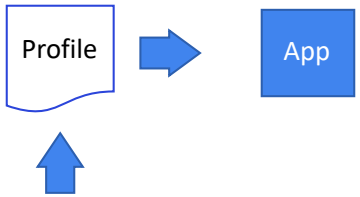


SM INNOVATION PLATFORM

THE SM PROFILE™

A STANDARDS-BASED APPROACH FOR INDUSTRIAL ASSET INFORMATION MODELS, ENABLING INTEROPERABILITY

The SM Profile™ captures key attributes of a device, asset, or process in a structured manner, is collaboratively developed by subject matter experts and provides an abstraction to enable seamless information flow in a Smart Manufacturing solution



Process Level Profile
A collection of Machines (line, supply chain…)

Machine Level Profile
A collection of devices (machine, compressor…)

Device Level Profile
(sensor, drive, robot…)

Captures the key attributes of a device, asset, or process in a structured manner

Provides abstraction and programming interface enabling the flow of data from disparate systems

Developed collaboratively by subject matter experts with deep familiarity with the device, machine or process

Provides mechanisms for software to **automatically learn of changes** and take appropriate actions

Captured in an open OPC standard, and accessed from the **CESMII SM Marketplace**

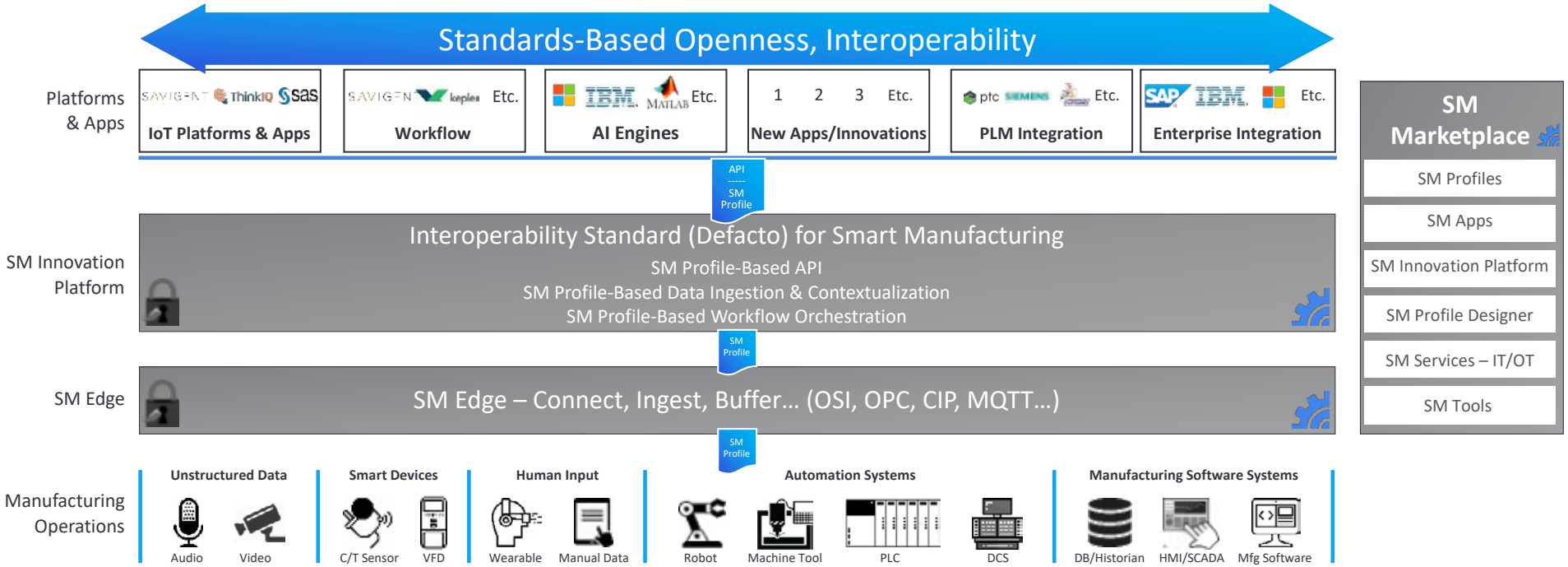
An Example: Extrusion Cylinder

Equipment Specs	Operating Inputs	Measured Outputs	Modeled Measurements	Modeled Forms	Workflow Members
Cylinder Diameter	Cylinder Stroke	Load	Pressure Distribution	Abnormal Detection	Extruding Started
Max Cylinder Stroke	Cylinder Pressure	Cylinder Pressure	Temperature Hot Spots	Diagnostics	Do Machine Changeover
Max Load	Die Temperature	Die Temperature	Constrain Proximity	Prediction	Do Maintenance
Max Cylinder Press	Speed	Speed	Speed	Health	Do Material Change
Max Die Temperature	Etc.	Etc.	Etc.	Etc.	Etc.
Max Speed					

THE SM INNOVATION PLATFORM™

OUR IMPLEMENTATION OF THE CESMII SM SPECIFICATIONS

The SM Innovation Platform™ consists of three major components: 1) SM Edge to collect data in-context and transmit it to the Core Services; 2) Platform Core Services to receive the transmitted data, organize and store it, and make it available to constituent applications and services; and 3) Integrated Applications that consume the data and work together through Workflow orchestrations in a data-centric fashion.

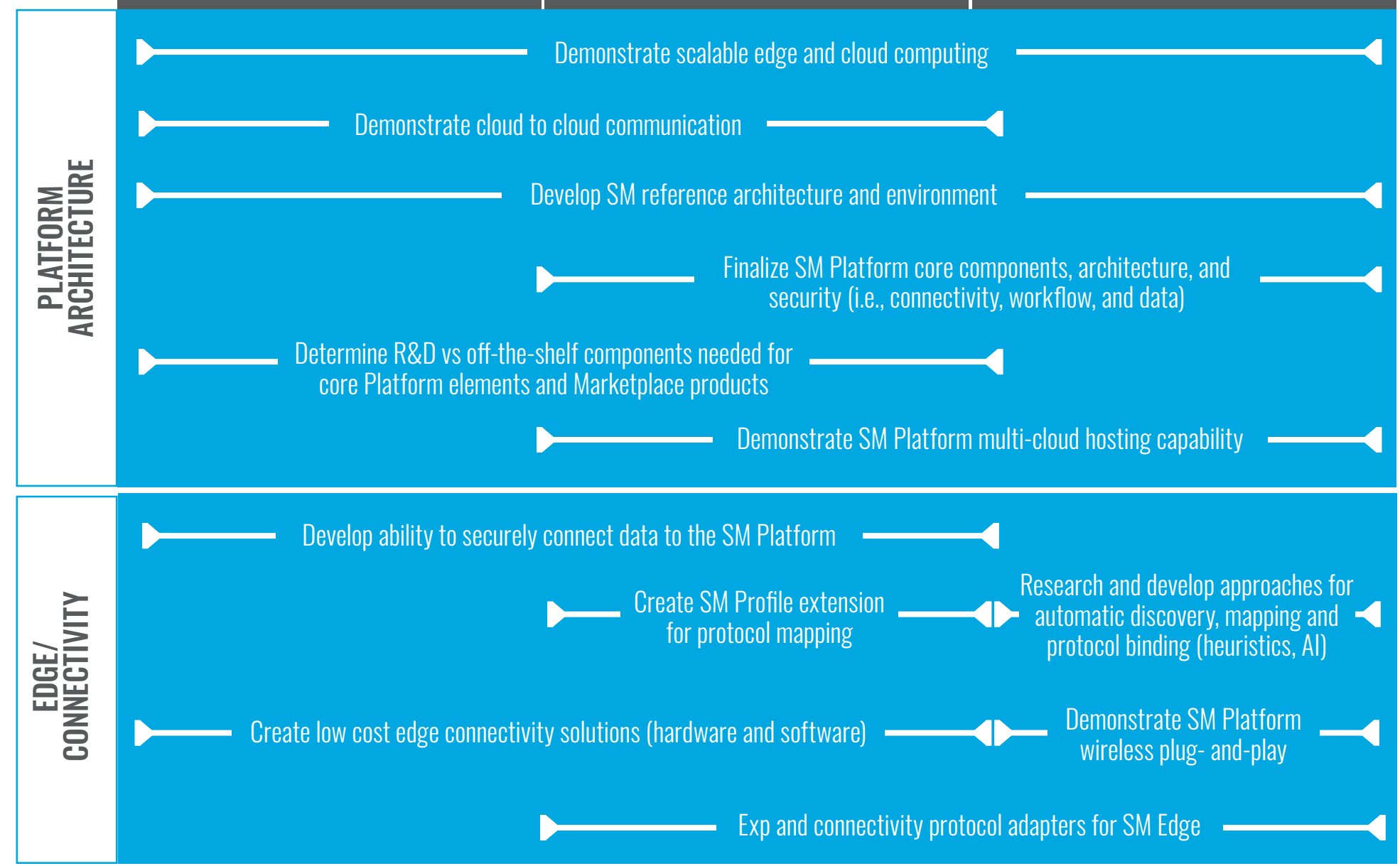


*SPECIFIC SOFTWARE PACKAGES AND VENDOR LOGOS ARE ILLUSTRATIVE EXAMPLES

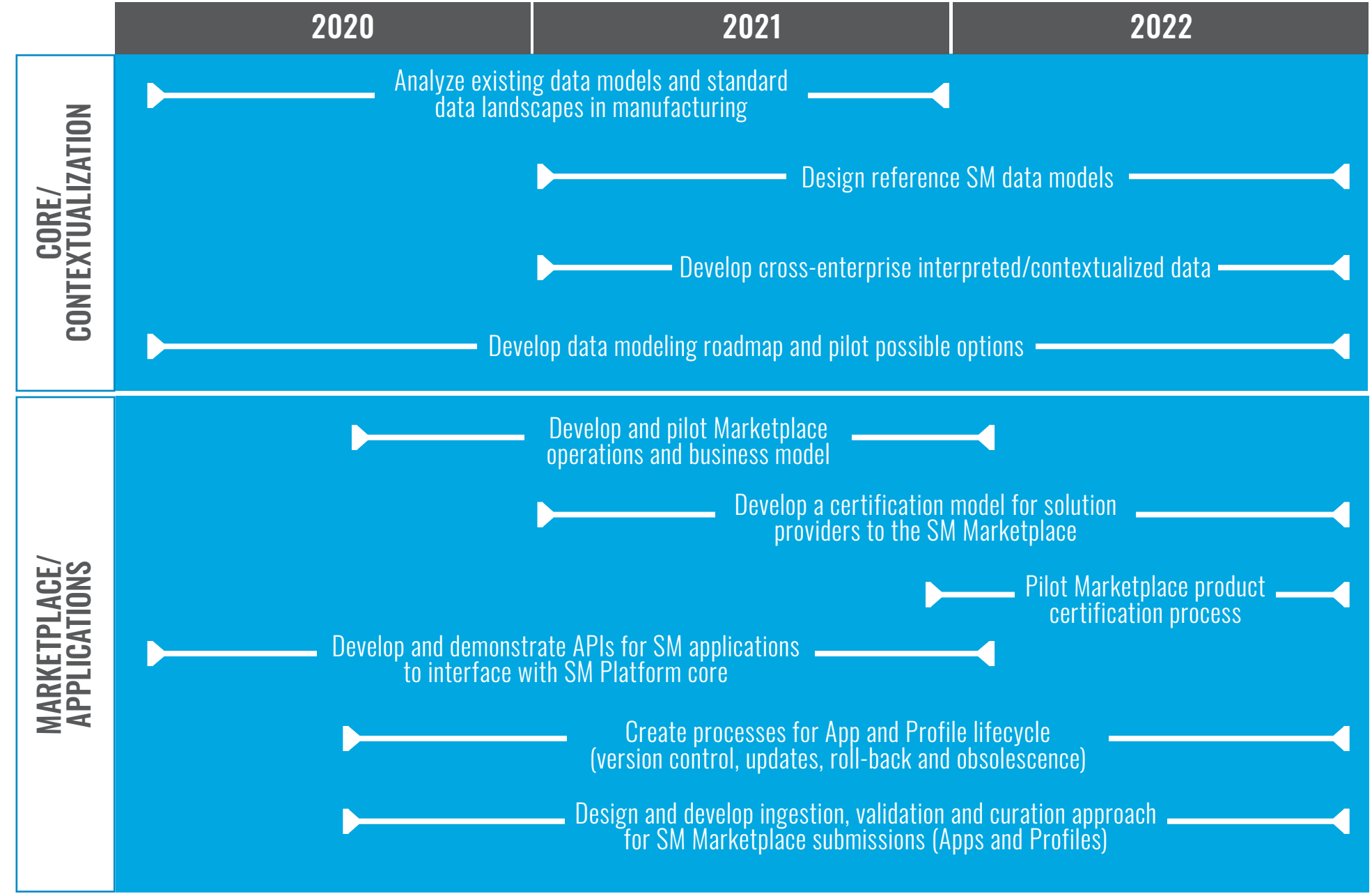
STRATEGIC OBJECTIVES - SM INNOVATION PLATFORM

- Establish reference architecture and specifications for the SM Platform
- Develop the systems engineering tools and methodologies needed for construction and reusability of cyber-physical systems
- Provide assets needed for enterprise data connection and contextualization in edge-to-cloud operational data structures
- Establish solutions of both legacy and future operational technologies and information technologies (OT/IT) and address standards that are open and interoperable
- Engineer secure framework for multi-vendor cyberphysical systems with interoperable hardware and software solutions
- Establish a robust, accessible SM Marketplace of certified and composable applications, configurations, toolkits, data, and services for accelerated development and deployment
- Lead the development of trusted technology, organization, and business cyber security practices that underpin SM

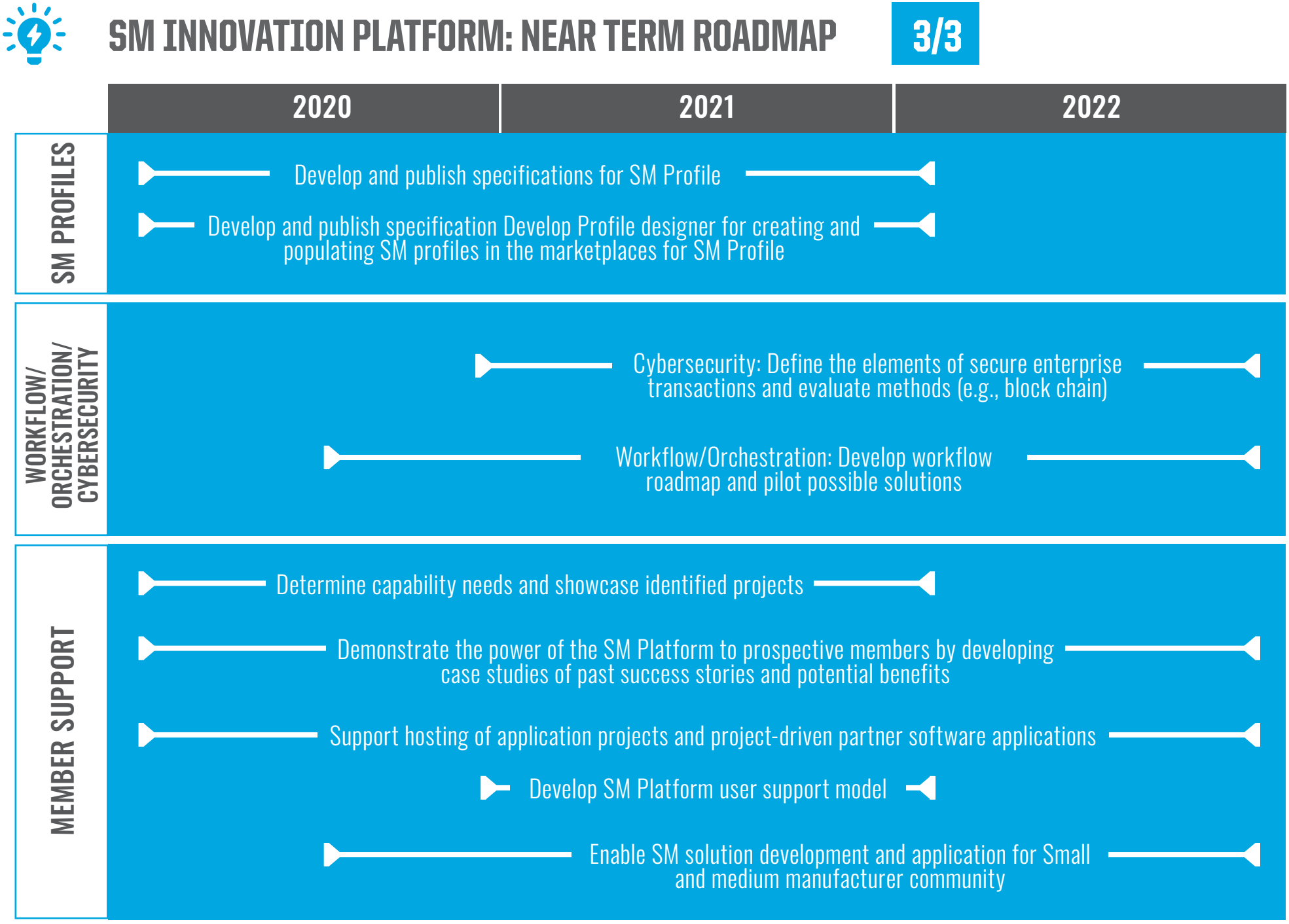
SM INNOVATION PLATFORM: NEAR TERM ROADMAP 1/3



SM INNOVATION PLATFORM: NEAR TERM ROADMAP 2/3



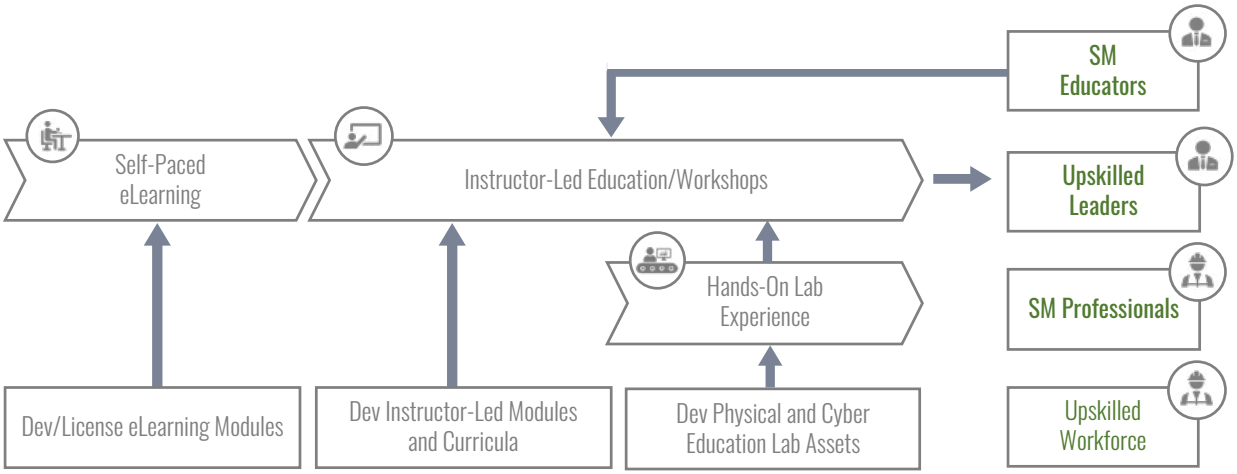
SM INNOVATION PLATFORM: NEAR TERM ROADMAP 3/3



SM EDUCATION

SM EDUCATION

CESMII must educate a wide set of constituents across our ecosystem - manufacturing leaders, engineers and practitioners, consultants, technology vendors and system integrators. Each constituent requires educational content tailored to their needs.



CESMII will produce, and leverage, recognized content to offer extended education and transformational services, educational workshops, eLearning and videos on SM concepts and methods, in addition to delivering Ecosystem and Workforce Education projects and foundational and extended eLearning on CESMII technologies.

I. Framing the Smart Manufacturing Journey and Business Strategy
SM trends, SM solutions landscape, SM benchmarks
SM business readiness assessment, roadmap transformation

II. Smart Manufacturing Cultural and Technological Transformation
SM Overview, Principles, Use Cases, Examples
SM Business Impact, Value and Justification
SM for Sustainability and Energy Efficiency, SM for a Resilient Supply Chain
SM Mfg Process Overview, SM and Manufacturing Functional Disciplines

III. Smart Manufacturing Orchestration, Analytics and Connectivity
OT/IT Fundamentals, Factory Apps and Enterprise Systems,
Augmented Connected Workforce, Analytics/Metrics, Data Lakes,
ML/AI at the Edge, Platform Infrastructure, Data Exchange Stds,
Workflow, Control, Process Modeling, Sensing, Ingestion,
Data Profiles, Data Modeling, Industrial Security Practices

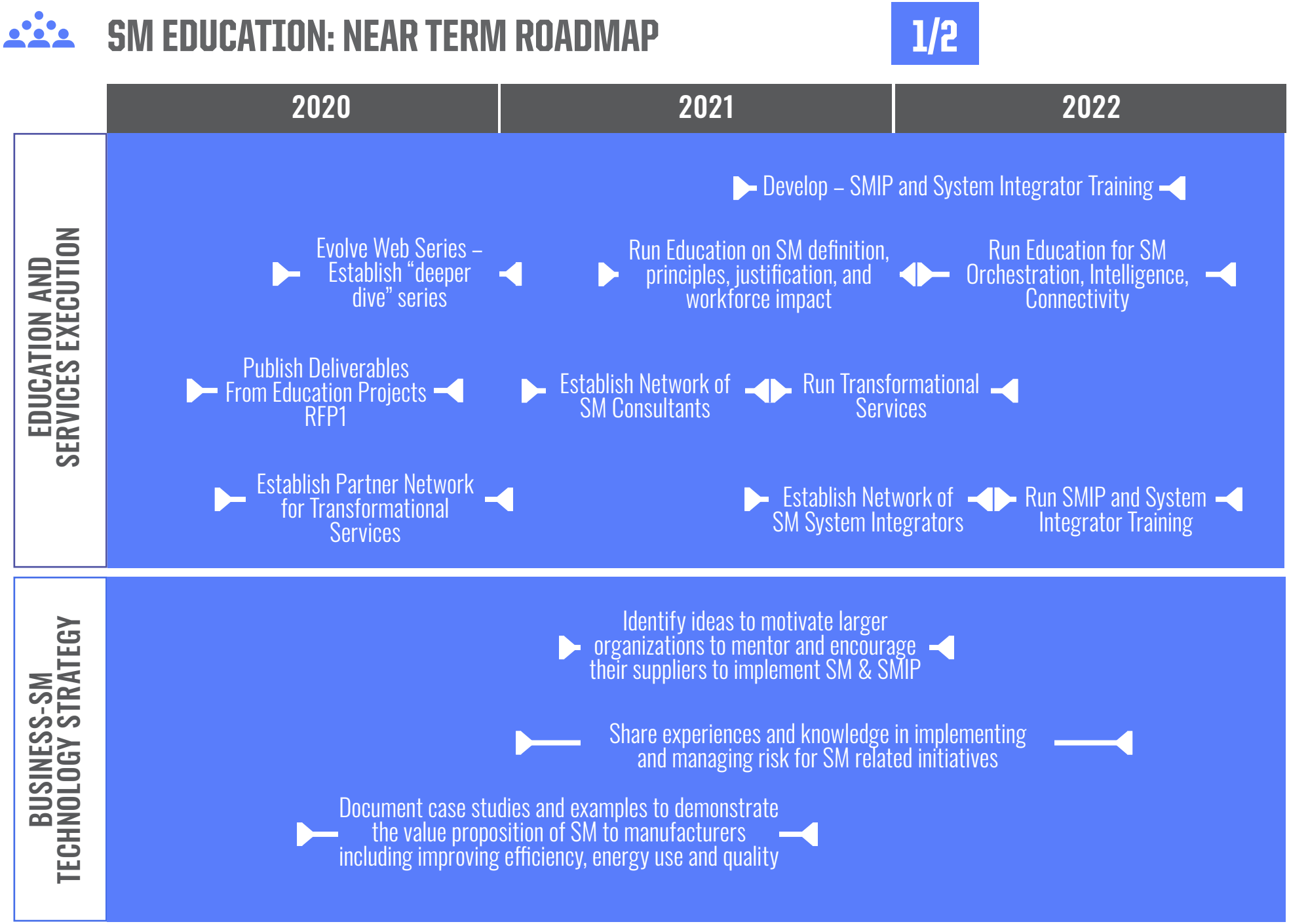
IV. Smart Manufacturing Secured Infrastructure and Technologies
Advanced Manufacturing, Additive/Subtractive, Smart Machines,
Robotics, Cloud and Edge Computing, Cyber-Security Infrastructure

STRATEGIC OBJECTIVES - SM EDUCATION

- Achieve widespread understanding of SM terminology, practices, key SM technologies and methodologies, SM Innovation Platform and SM Profiles practices
- Enhance the capabilities of the future workforce with SM and digital transformation skill sets for business leaders, operators, technologists, and engineering staff
- Provide a knowledgebase and repository of SM educational resources to support a network of SM educators and trainers with SM educational resources that they can leverage in their curricula
- Develop Education Content to support continuous learning programs on SM skills that are paced with changing business, technology, and organization practices

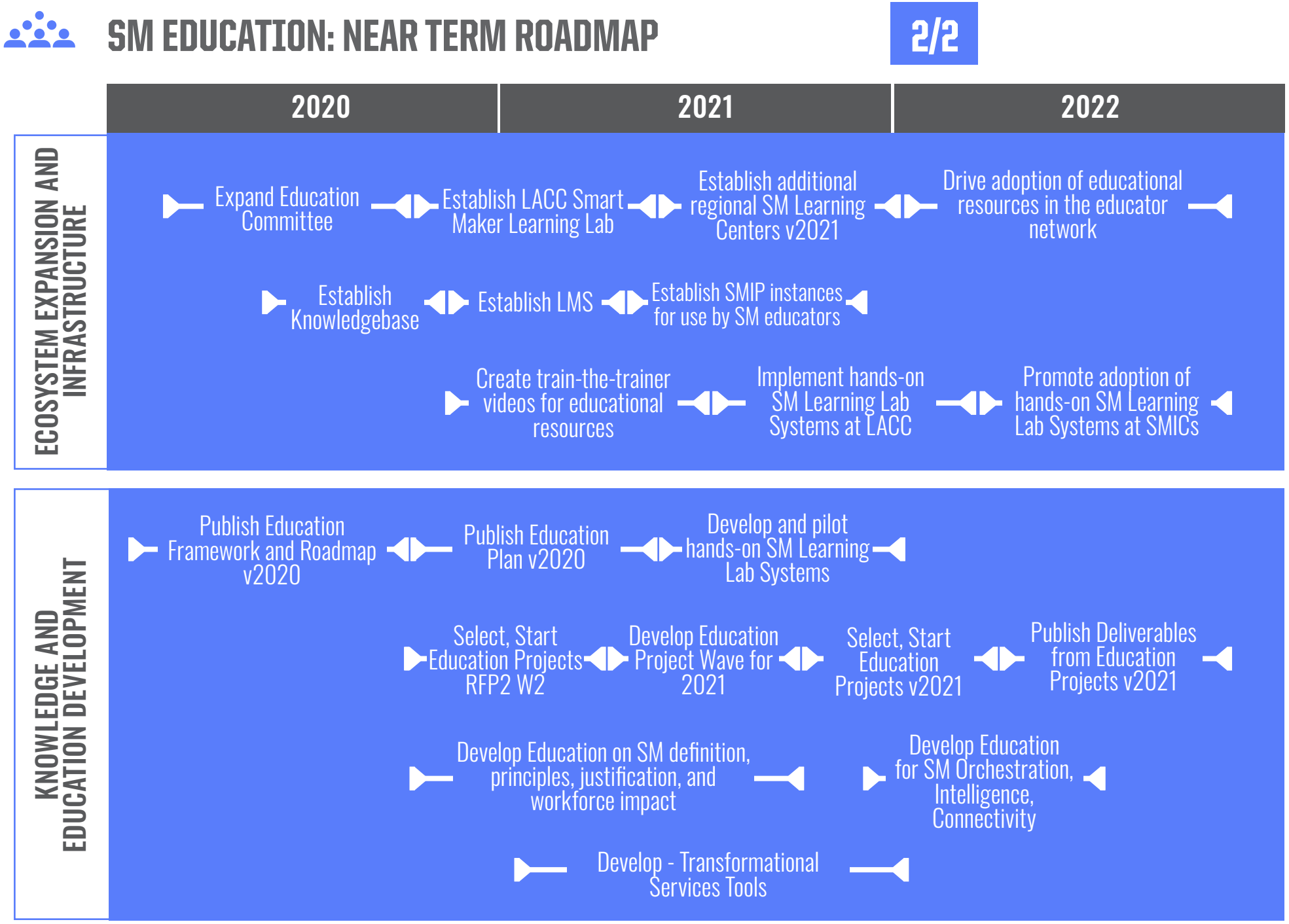
SM EDUCATION: NEAR TERM ROADMAP

1/2



SM EDUCATION: NEAR TERM ROADMAP

2/2



SUMMARY

It has been said that Smart Manufacturing (SM) is a journey, not a destination. We agree. This is a journey we're on together.

As technologies evolve, as our understanding and knowledge evolves, as the adoption of SM evolves, the roadmap for Smart Manufacturing and the institute must also evolve. While much of the original content of CESMII's first roadmap is still very relevant to CESMII's ongoing journey, this document attempts to refine portions of it reflecting the institute's refreshed understanding and priorities, and highlighting activities that are important to pursue in the next two to three years.

This updated roadmap will provide CESMII with significant input on its investment plan in the near to midterm timeframe, impacting the types of RFPs and projects that need to be undertaken to meet the institute's goals and metrics. Our expectation is that as we approach the end of this current timeline, we will be able to continue to further refine this roadmap to guide the institute's activities going forward.