The Improvement Challenge of Industry 4.0

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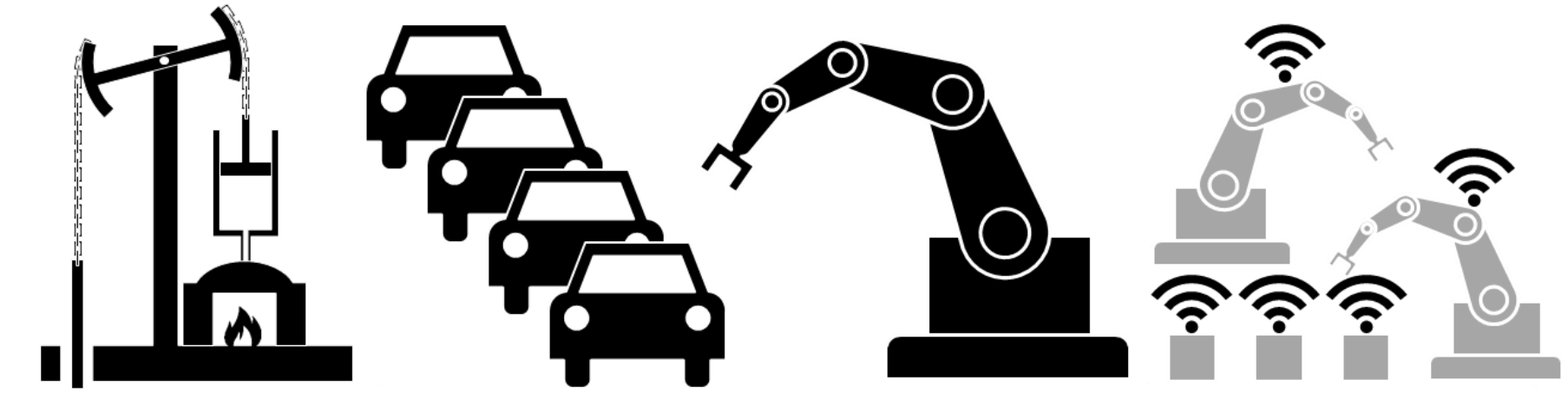
Outline

- What is Industry 4.0? (What were Industry 1.0, 2.0, and 3.0?)
- The improvement-industrial revolutions link, and the evolution of improvement systems
- What improvement strategy is best for Industry 4.0?
- Summary

- Industry 4.0 is the fourth major industrial revolution:
  - 1.0 enabled by water and steam power in early 19th century
  - 2.0 by process standardization (assembly line) and electricity at the beginning of the 20th century
  - 3.0 by computerization and automation (robotics) in latter part of the 20th century
- Big Data, the Internet of Things (IoT), and cyber-physical systems are creating the fourth industrial revolution now

Each Revolution Was Built Upon That Preceding It

The Improvement Challenge of Industry 4.0



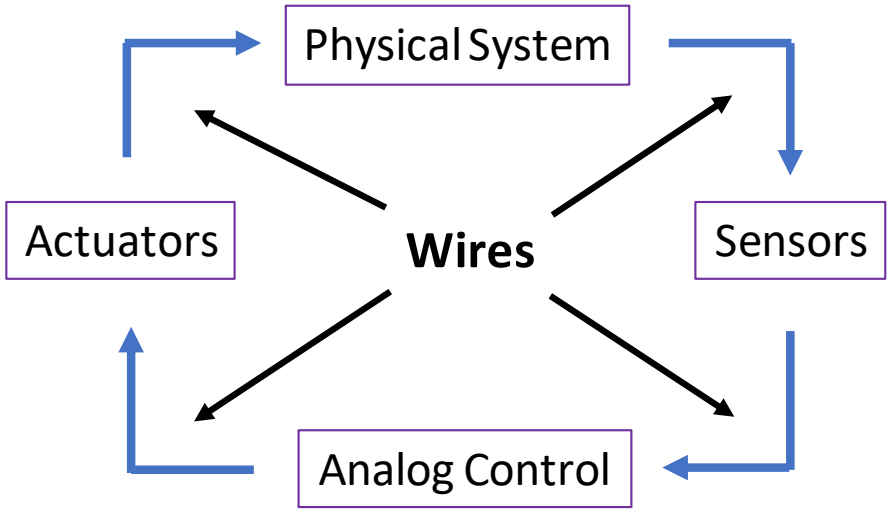
1st	2nd	3rd	4th
Mechanization, water power, steam power	Mass production, assembly line, electricity	Computer and automation	Cyber Physical Systems

Source: Christoph Roser

- IoT directly connects objects, often bypassing humans (e.g., aircraft engines send continuous data feeds around the globe during flight)
- "Cyber-physical systems" integrate humans, hardware, and software in real time (e.g., Uber)
- Zeta-bytes (10^{21} bytes) of data now exist; how to make use of such massive data? *Software helps*!
- Robots not only replace physical labor, but analytics also make *complex decisions*, often without involving humans

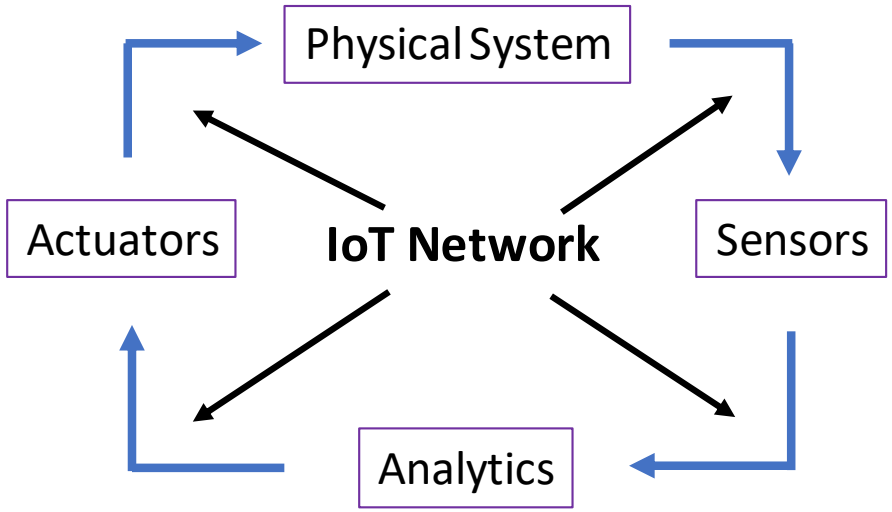
Data are Core to Industry 4.0

Industry 3.0
Computer-Controlled Industrial System



Typically Small System
Drives, Reactors, Conveyors

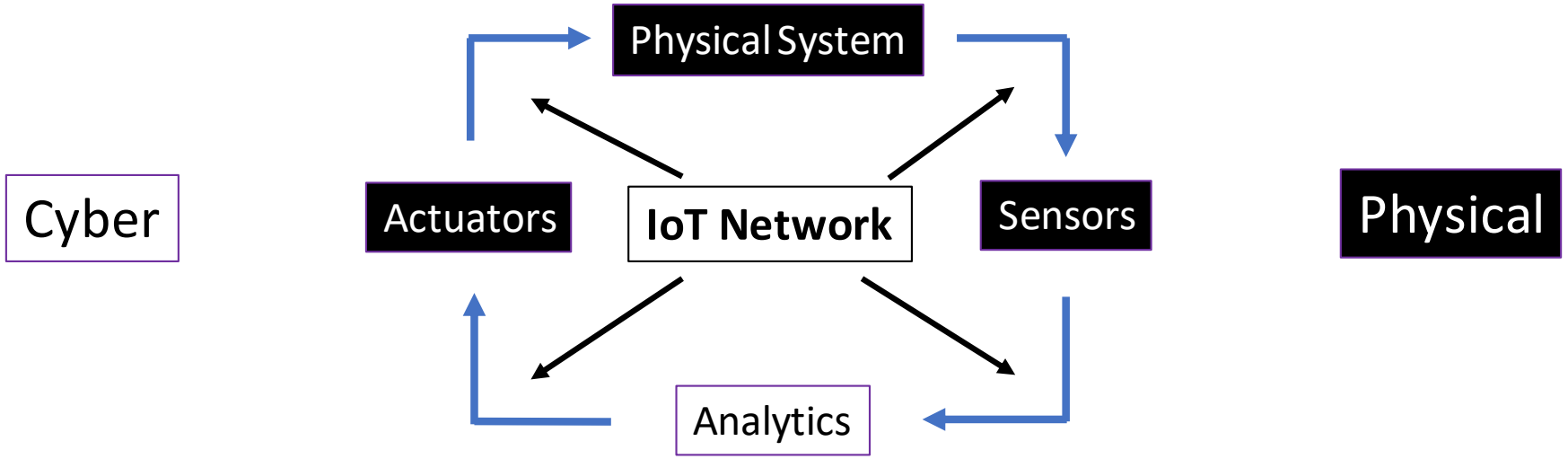
Industry 4.0
Cyber-Physical System



Large System
Entire Facility, Supply Chain

Industry 4.0

Cyber-Physical System



How Should We Approach Improvement of Such a System?

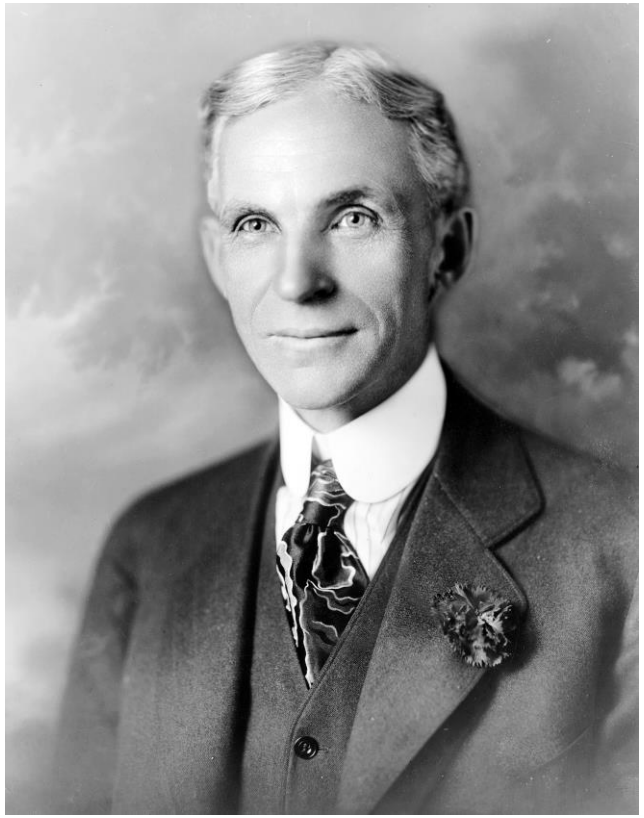
- The evolution of continuous improvement systems closely parallels industrial revolutions
- Each revolution brought new capabilities and opportunities
- New sources of *data* have been a key enabler
- Leaders around the globe developed creative improvement approaches to capture these new opportunities
- *However, the improvement story for Industry 4.0 has not yet been written*

Improvement Systems and Industrial Revolutions are Tightly Linked

- Frederick Taylor's introduction of "scientific management" dramatically enhanced the impact of Industry 1.0
  - Studied best way to perform manual tasks; trained workers in best methods (successful because work was not yet standardized)
  - Gave rise to broad use of industrial procedures
  - Launched a new discipline: *industrial engineering*
- Focus of improvement was on engineers' expertise; little to no input from workers

Perhaps the Greatest Individual Contribution to Growth of US Industry

- Henry Ford's assembly line use changed industry forever (Industry 2.0)
- Process standardization and separation of labor led to dramatic efficiency gains
- Widespread use of electricity reduced physical labor (Operators began to *interact with machines)*
- Repetitive processes well suited to application of statistical quality and process control (SQC, SPC)
- SQC, SPC, and eventually Total Quality Management (TQM) enabled achievement of new levels of quality
- Involved operators in improvement



Automobiles: the "Machine that Changed the World"

- Move to automation and computer control of processes (Industry 3.0) dramatically increased improvement options
- *Automated collection of data* further enabled SQC, SPC, TQM and even more intensive statistical methods
- *Systems approaches (*Six Sigma, etc.) broadly adopted to utilize data
  - Produce dramatic improvement in quality, cost, and profitability
  - "Level the playing field" for global manufacturers
- Organization for improvement becomes *more complex*:
  - Traditional groups avoid errors with standards, ISO, etc.
  - New groups drive growth and profitability improvement

More Data Brings New Methods but Also New Challenges

Industrial Revolution	Basis	New Improvement Approaches
1.0	Steam & Water Power	Scientific Management
2.0	Assembly Line, Electrification	SQC, SPC, TQM
3.0	Computerization, Automation	Lean Six Sigma, ISO
4.0	IoT, Big Data, Cyber-Physical	??????

What is the Improvement Strategy for Industry 4.0?

- The best improvement strategy for Industry 4.0 is uncertain
- Massive data enables "Big Data Analytics" (machine learning); cyber-physical systems enable artificial intelligence (AI)
- However, key challenges remain:
  - What software systems can handle the data?
  - How to make improvement a corporate value?
  - How to increase employee participation?
  - How to incorporate the new (Big Data Analytics, AI) without losing the benefits of existing approaches (Six Sigma, etc.)?
  - How to *integrate the improvement work*, and avoid "islands of improvement", with each group competing against the others?

The Improvement Challenge of Industry 4.0

Some clues to consider:

- Each improvement phase was built upon previous phases
  - TQM utilized scientific management procedures
  - Six Sigma incorporated SPC
  - Lean involves a modern adaption of Taylor's methods, but with operator involvement
- Fundamentals of quality management, such as ISO standards, are still important in a Big Data world
- The *challenge is not only technical*
  - How should improvement work be organized?
  - What training is necessary?

Lots of Unanswered Questions Remain

Critical point: the problems to be solved in Industry 4.0 are too complex and diverse for any one method to suffice

- A "*portfolio*" of improvement methods is required
- Large, complex, unstructured problems present a unique challenge, for which *Statistical engineering* has been proposed - see website of International Statistical Engineering Association (https://isea-change.org/)

What is the Right Portfolio of Methods?

- I propose that only a *holistic approach* will suffice—an improvement *system* versus favorite tool
- Improvement must be seen as a *core business function (a*long with finance, marketing, research, etc.)
- Improvement plans must flow from the business context and strategy (part of business planning cycle)
- All improvement work must be integrated within one new improvement organization

A New Paradigm for Improvement is Needed

My and Ron Snee's view: improvement work typically occurs within at least *three distinct functions* currently, e.g.:

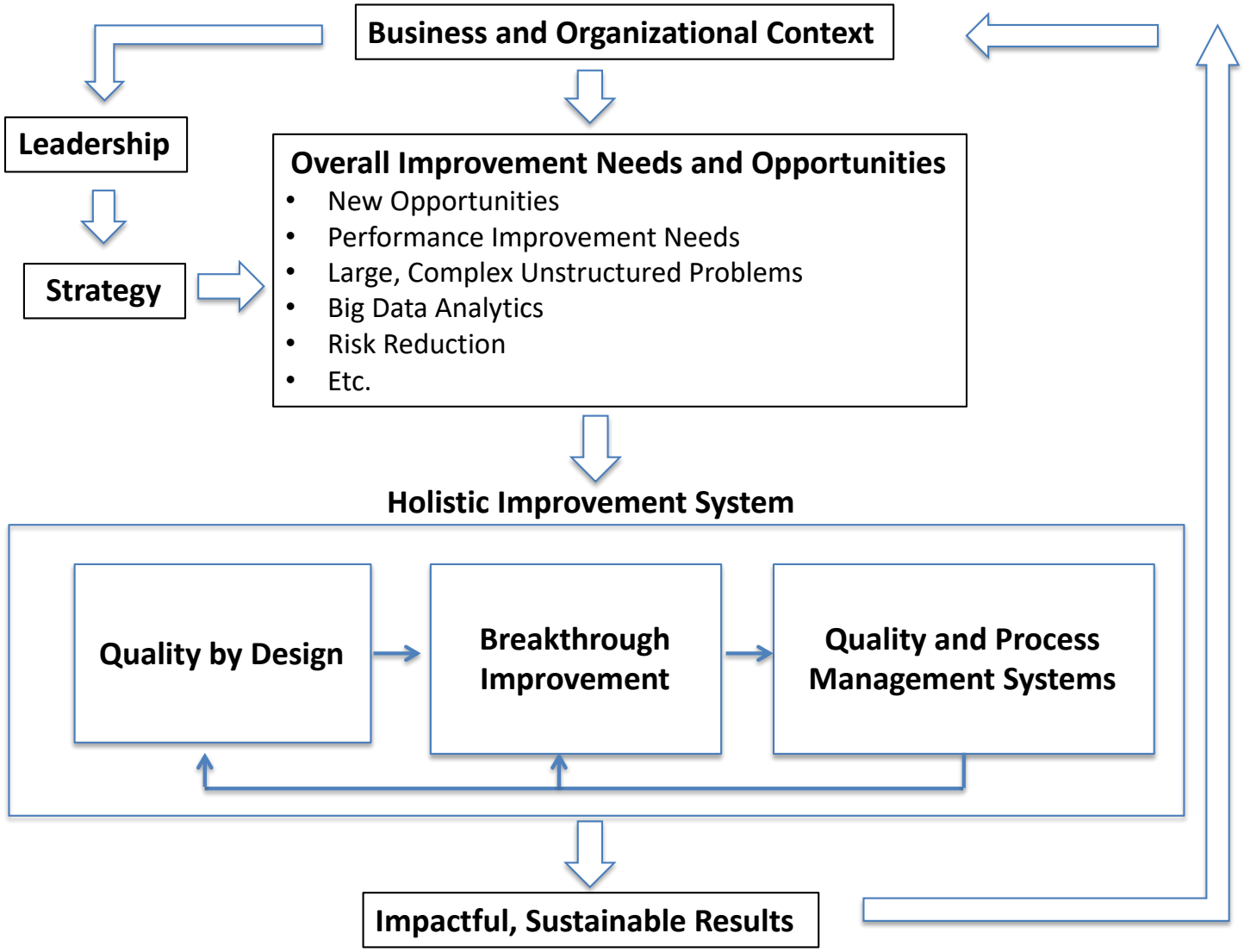
1. Research and development:
   Quality by design: new product and process development
2. Industrial Engineering (Lean Six Sigma, etc.):
   Breakthrough improvement projects and methods
3. Quality:
   Quality and process management systems (testing and measurement, ISO, inspection, standards, etc.)

These Groups Rarely Work Effectively Together

- A radical idea: make improvement a core business function, led by Chief Improvement Officer (CIMO)
- Ensure *cooperation and integration* of improvement efforts
- Match improvement method to problem for each project (don't force-fit predetermined methods to problems)
- Improvement organization manages "portfolio" of improvement methods and projects
- Capability development (training) system ensures critical mass of diverse improvement skills

A Truly Holistic Approach to Improvement

Holistic View of Improvement



Source: Leading Holistic Improvement, Snee and Hoerl, 2018

Holistic Improvement System Needs and Sample Approaches

Quality by Design

Needs

- Business innovation
- Process design/redesign
- Product design/redesign
- Organizational design/redesign

Approaches

- Innovation/Creativity
- DFSS
- TRIZ

Breakthrough Improvement

Needs

- Meet annual and strategic plans
- Better product/process performance
- Better organizational performance
- Mission critical problems

Approaches

- Six Sigma
- Lean Enterprise
- Statistical Engineering
- Big Data Analytics
- Workout

Quality and Process Management Systems

Needs

- Quality & process management system
- Risk management system
- IT system
- Measurement system
- Training system

Approaches

- ISO/Baldrige
- Total Productive Maintenance
- Internet of Things
- Kepner-Tregoe

Source: Leading Holistic Improvement, Snee and Hoerl, 2018

Foundations of a holistic improvement system:

- Committed leadership (beyond "supportive")
- Organizational infrastructure
  - One improvement organization, integrating all three types of improvement
  - An integrated project selection and management system, selecting projects and improvement methods for each
  - Processes for budgeting, planning, communications, etc.
- Top talent – leadership and expertise in improvement
- A capability development system to ensure "critical mass" of skills across the organization

Keys to Success: Leadership, Talent, and Infrastructure

- Start where you are currently

  "A journey of a thousand miles begins with a single step." -Laozi
- Gradually migrate improvement efforts toward a holistic system
  - Incorporate multiple improvement methods
  - Match method to problem, versus other way around
  - Work on improvement across organizational boundaries and broaden scope of quality/improvement organization
  - Move from "waves of training" to strategic development system, matching development to skills needed, and sustain over time
  - Migrate toward a single improvement project portfolio

"Evolution" is Likely to Work Better than "Revolution"

- We are entering a new industrial era: Industry 4.0
- While much has changed, much remains the same
  - Data has been important, and is even more important now
  - New improvement systems have followed industrial revolutions
- Industry 4.0's improvement challenge of has not yet been answered
- I propose a *holistic approach*:
  - Improvement as a core business function
  - Chief Improvement Officer (CIMO)
  - Integration of all improvement work
  - Diverse portfolio of improvement methods

I Look Forward to Hearing About Your Successes!