Process Operations: A Roadmap from the Present to a Hyper-connected Future

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Outline

- ✓ PSE: From Past to Present
- ✓ Process Operations Evolution
- ✓ Nowadays Business Context
- ✓ Dangers and Opportunities in a Hyper-connected Future
- ✓ A Roadmap to a Hyper-connected Future

PSE: From Past to Present

- ✓ From steady-state and spatially lumped to **dynamic and spatially distributed modeling, simulation and optimization**.
- ✓ From isolated designs to **systematic methods for process and network synthesis**.
- ✓ From large plants to **process intensification.**
- ✓ From chemical and petrochemical products and processes to pharmaceutical and biotechnological ones, to systems biology as well as particulate and nano-structured products.
- ✓ From deterministic LP, NLP, MILP simple formulations to **MINLP and disjunctive models and global optimization of deterministic and stochastic systems**
- ✓ **…….**

PSE: From Past to Present

- ✓ From simple monitoring and control to **model-based control and real time optimization.**
- ✓ From controlling and managing a process plant in isolation towards the **agile management of a process plant that is part of global supply chains** comprising several actors – suppliers, logistic providers, customers – situated in different geographical locations.
- ✓ From production planning and scheduling to **enterprise-wide management to supply chain management.**
- ✓ From isolated systems to **horizontal and vertical integration.**
- ✓ From economic objectives to **trade-offs among economics, sustainability, energy and environmental issues**.
- ✓ …..

PSE: From Past to Present

PSE

- Selected unit operations
- Processes

PSE^2

- Enterprise

PSE^3

- Multi-enterprises

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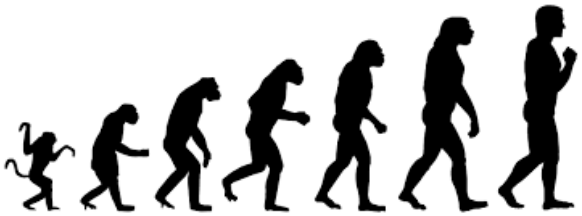
Process Operations Evolution

1987: First FOCAPO Conference



1980 - 2000

Regular Topics
- Planning
- Scheduling
- Control/Dynamics
- Identification/ Diagnosis

Emerging/"Hot" Topics
- Plan wide optimization
- Environmental Issues

2000-2020

Regular Topics
- Planning
- Scheduling
- Control
- ……

Emerging/"Hot" Topics
- Supply chain
- Integration
- Stochastic optimization
- Sustainable resource management

2020 - 2040

?

Nowadays Business Context

Globalized and Competitive Economy

- Turbulent and volatile markets, enlarged demand uncertainty
- Sharp fluctuations in fuel pricing
- Improved product time-to-market
- Shorter product life cycles
- Increasing levels of product varieties
- Outsourcing
- Tough customer service requirements: Accurate deliveries, short lead-times, high levels of efficiency, flexibility, etc.
- ……

Nowadays Business Context

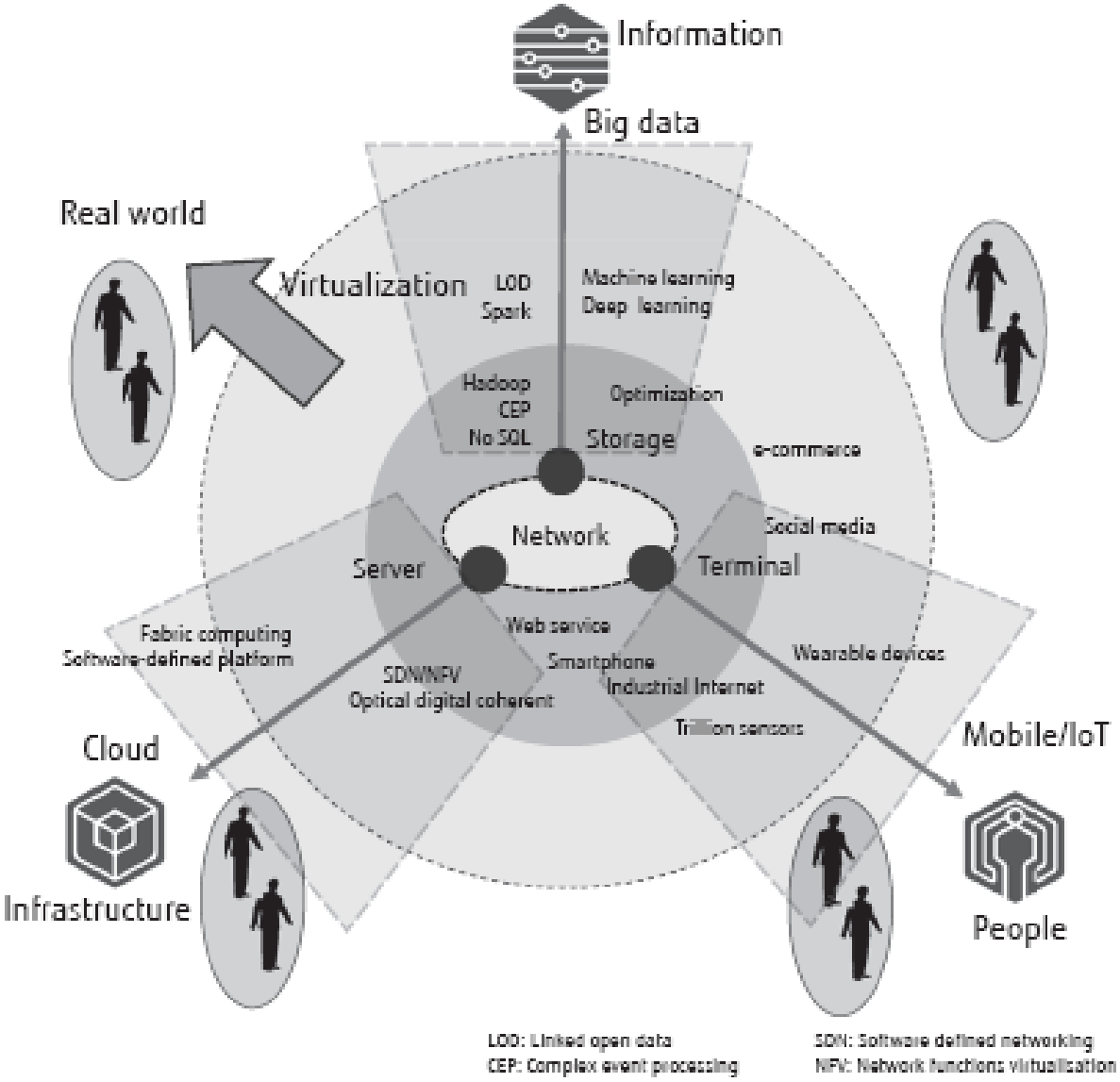
Information & Communication Technology (ICT) Trends

- Proliferation of mobile devices
- Pervasive connectivity
- Affordable smart sensors
- Accelerated computer power

- Internet of Things (IoT), Industrial Internet of Things (IIoT)
- Big data
- Cloud computing

Fourth Industrial Revolution: Industry 4.0, Smart Manufacturing

ICT Megatrends



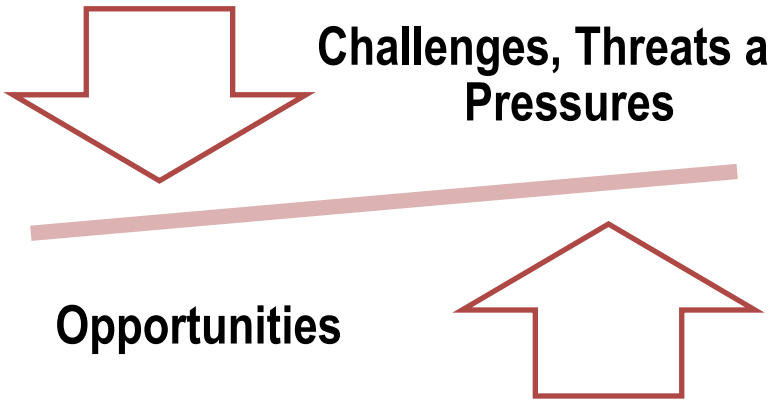
Iida, 2016
Fujitsu, Sci. Tech. J

Dangers and Opportunities in a Hyper-connected

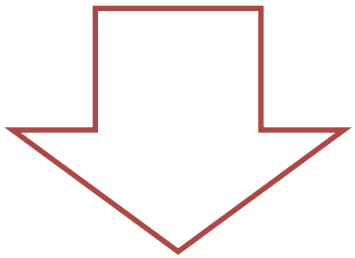
Fourth industrial revolution

- ✓ Based on the comprehensive use of cyber-physical systems.
- ✓ Extends the digital impact of the third industrial revolution, making available a huge pool of technologies and information

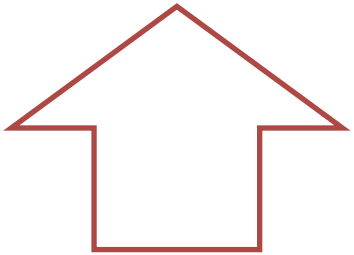
- ✓ Broader scope of Process Operations. Continuous expansion of the system boundaries



Dangers and Opportunities in a Hyper-connected



Challenges, Threats and Pressures



Opportunities

Supply Chain Management

Scheduling

Dangers and Opportunities in a Hyper-connected

Supply Chain Management

1980 – 2000: SCM known as Logistics
ERP Systems

2000 – 2020: Increased number of partners
Company centric view
Linear alignment of echelons
SCM systems

2020 – 2040: Non-linear multi-enterprise SC
Customer centricity
Consolidated visibility

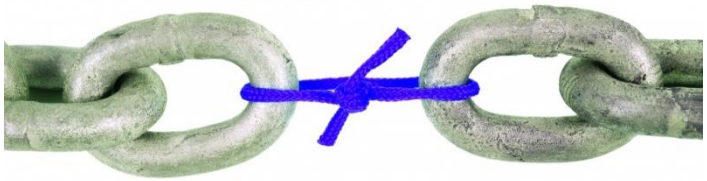
Dangers and Opportunities in a Hyper-connected Future

Current SC Weaknesses/Threats

- ✓ Decoupling of SC strategic solutions, from tactical and operational ones
- ✓ Limited integration of SCM systems with other applications →

  Interoperability is barely reached

  Absence/limited collaboration between business partners
- ✓ Lack of holistic end-to-end visibility
- ✓ Unsuitable data handling: Lack of data and/or a jungle of data with minimum informative value
- ✓ Increased level of uncertainty



Dangers and Opportunities in a Hyper-connected Future

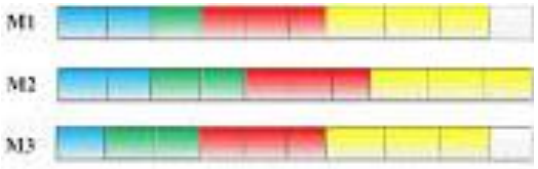
2020 – 2040 Supply Chains

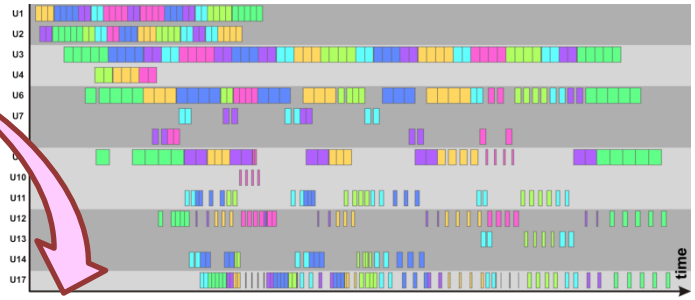
- ✓ Ubiquitous data
- ✓ Enhanced visibility
- ✓ Increased asset virtualization
- ✓ Knowledge-enabled workforce
- ✓ Much more dynamic links among partners → supply chains and their associated business processes will be constantly morphing
- ✓ Shorter time-frames of strategic and tactical decisions → Flattened SC hierarchy with levels that have blurred boundaries.

Requirement: Capacity to develop SCM systems characterized by self-adaptive dynamic models able to cope with modifications in the context and to empower human involvement

Dangers and Opportunities in a Hyper-connected

Scheduling

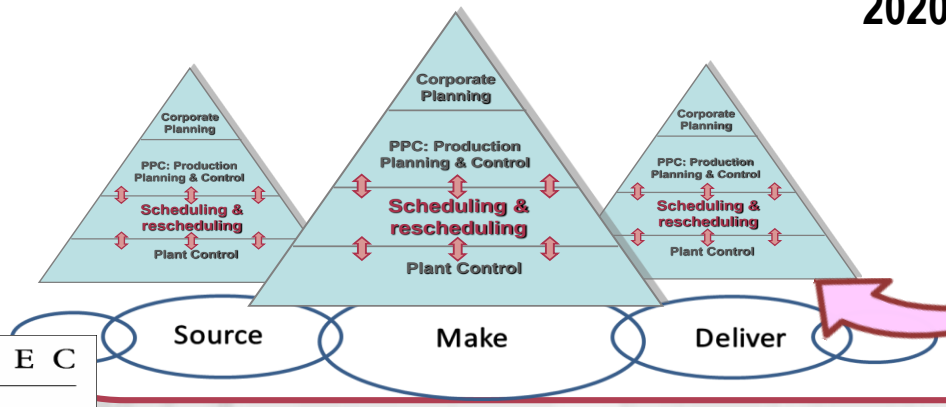




1980 – 2000: First approaches for low dimensionality problems
Mainly Heuristic/ Dispatching methods
Simple MILP-based formulations. First STN and RTN based methods

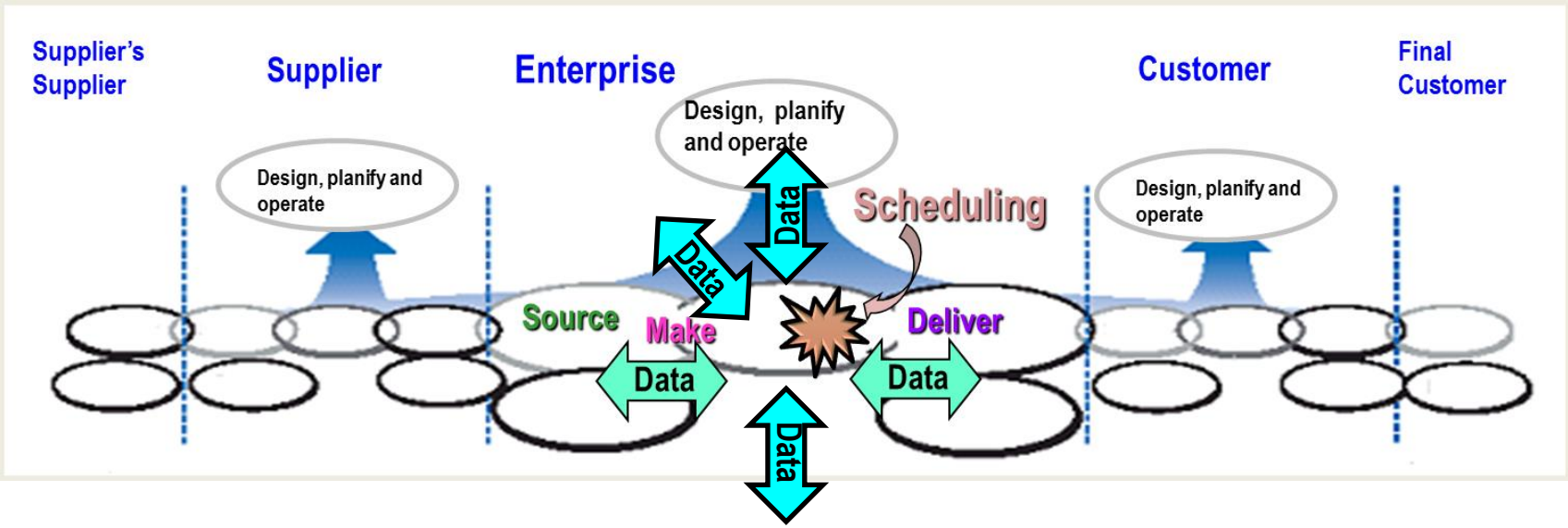
2000– 2020: More systematic approaches
Elaborated time representations
Resource Limitations
Uncertainty handling
Attempts to integrate Scheduling with Control and Planning

2020-2040: Comprehensive scheduling approaches
Full integration with the enterprise and SC applications
Thorough uncertainty handling



Dangers and Opportunities in a Hyper-connected

Current Scheduling Weaknesses/Threats

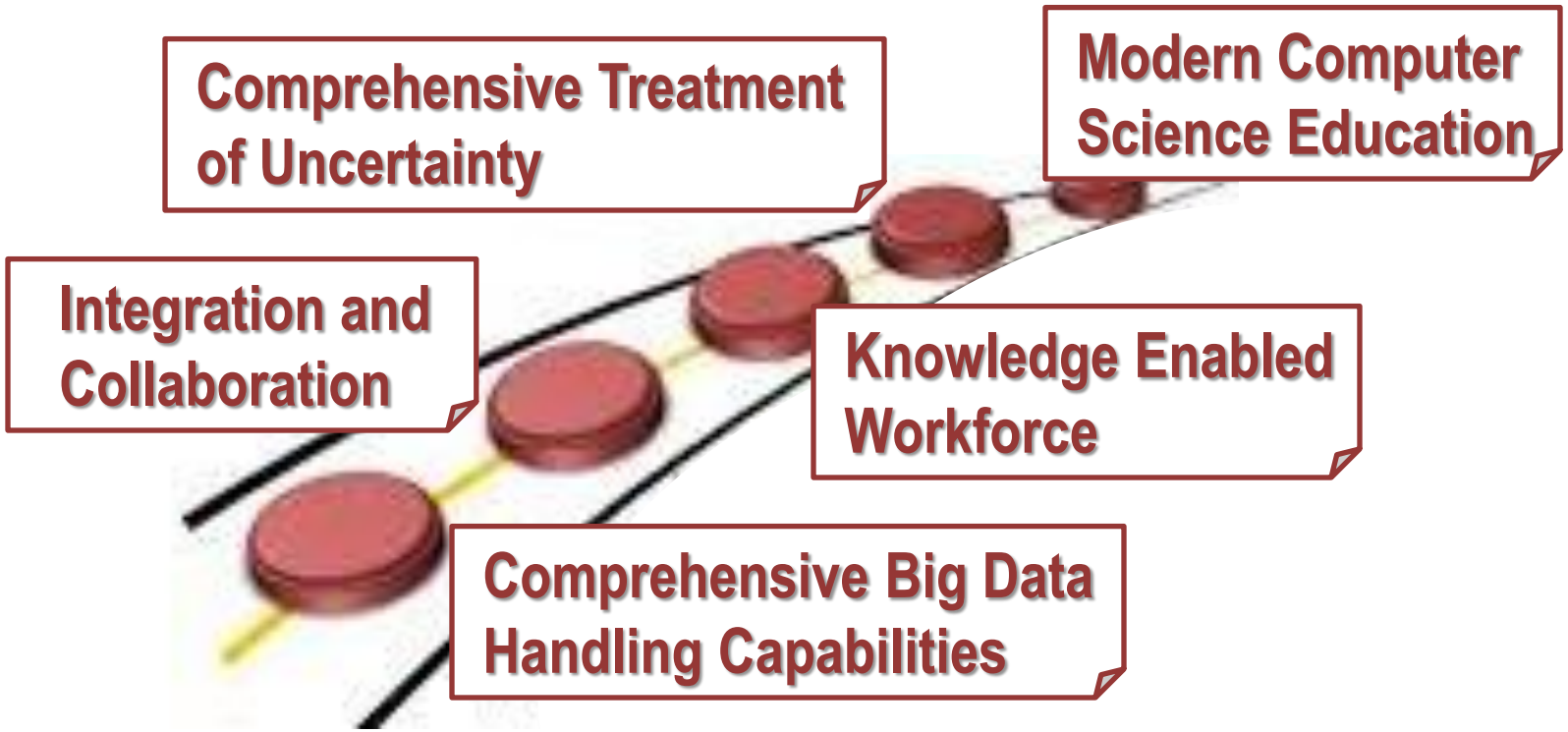


Dangers and Opportunities in a Hyper-connected Future

Current Scheduling Weaknesses/Threats

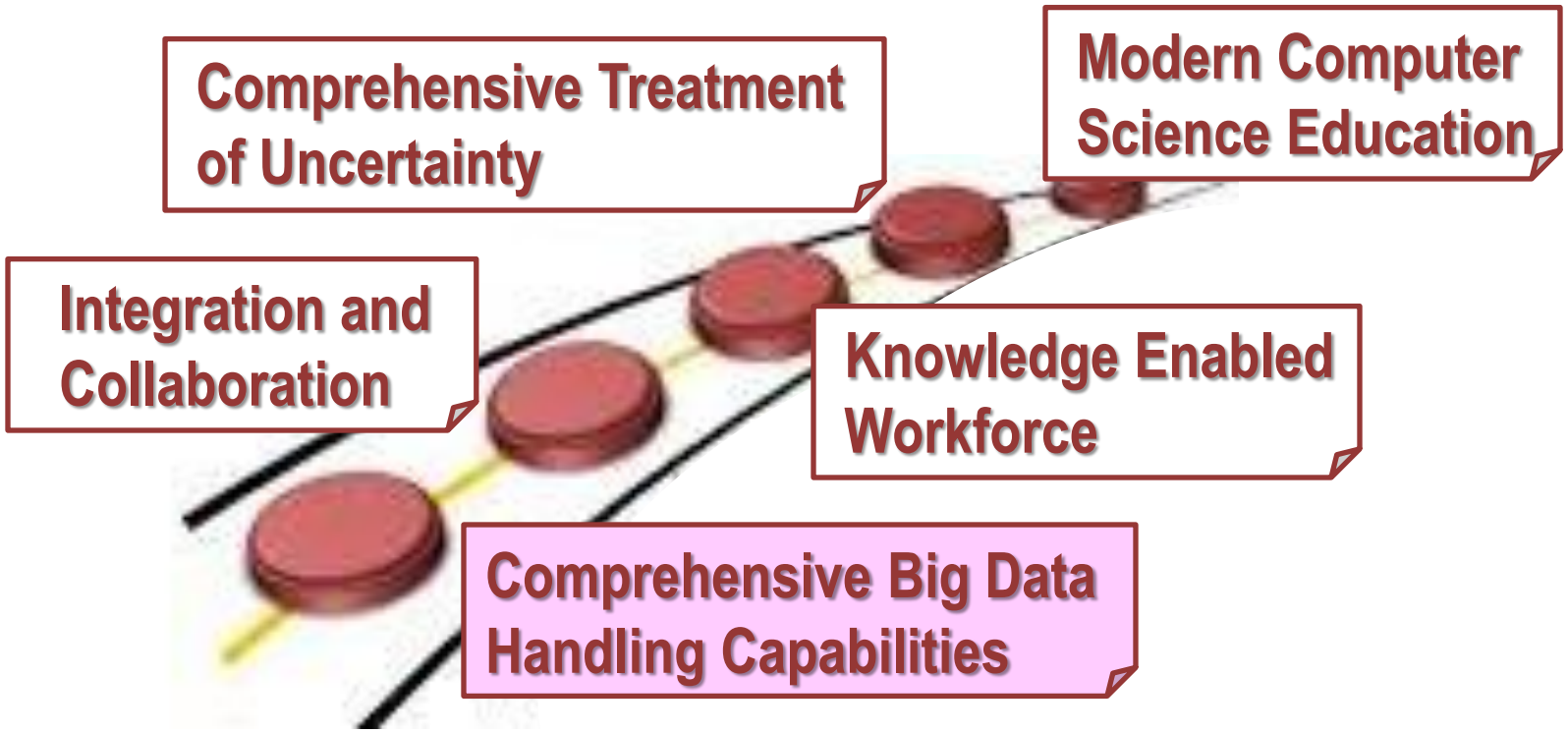
- ✓ Academic developments have not penetrated industrial practice to the extent possible.
- ✓ Lack of high level languages for model development → Taylor-made model development.
- ✓ Solution approaches that neglect human interaction.
- ✓ Lack of integration of the scheduling function within the enterprise and the supply chain dimensions.
- ✓ Decoupling of predictive/robust and reactive scheduling.
- ✓ Weak treatment of uncertainties and disruptive events, which are becoming increasingly important.

A Roadmap to a Hyper-connected Future



- ✓ How to master the digital innovation challenge?
- ✓ How to take advantage of a hyper-connected environment?

A Roadmap to a Hyper-connected Future



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Comprehensive Big Data Handling Capabilities

- ✓ Simply collecting data and making it available to a wide audience does not guarantee anything. On the contrary, it might lead to chaos → How to structure data?
- ✓ How to articulate huge amounts of data (with different syntaxes and semantics) of several partners that need to collaborate?

- ✓ Develop **big data management frameworks that are integrated with the process operations applications.**
- ✓ Incorporate competences on **big data analytics**:
  - Descriptive: What happened
  - Diagnostic Why it happened
  - Predictive: What will happen
  - Prescriptive What actions to take/promote

Comprehensive Big Data Handling Capabilities

Big Data Applications

understand the data
garner information and knowledge from it,
intelligently combine it with other data sets

To efficiently do this

- ✓ We need to be able to represent the assumptions and conceptualizations that underpin knowledge in the application domains
- ✓ Data creators and publishers need to make explicit what their data represents together with the context of the data and its creation.

Domain Ontologies & Ontologies for Big Systems

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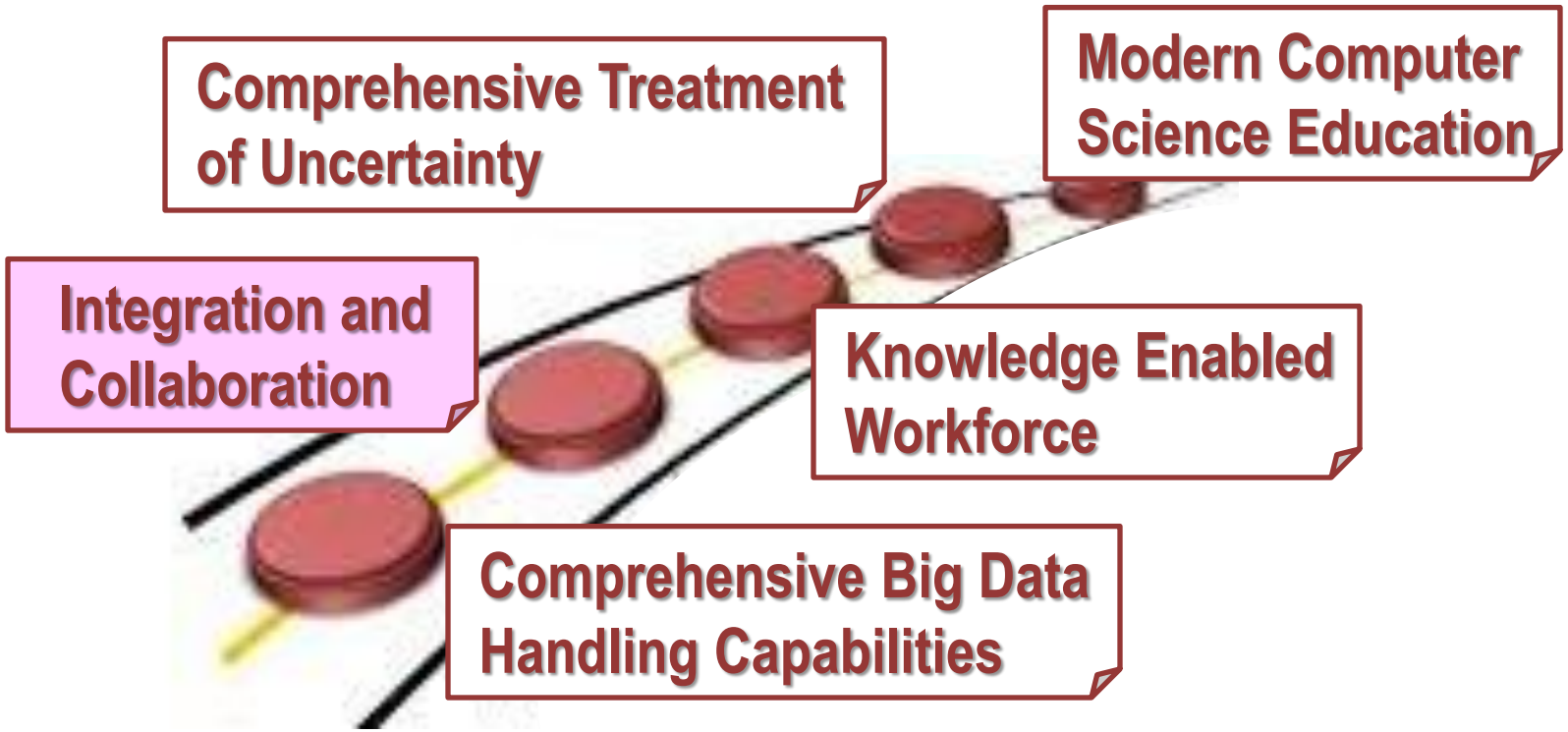
Comprehensive Big Data Handling Capabilities

Domain Ontologies & Ontologies for Big Systems

Ontologies and ontological analysis are vital parts of any solution addressing the problems of architecting and engineering big/ complex systems and big data. Ontologies can be used to:

- ✓ Make explicit and accessible the critical assumptions about the nature and structure of engineered systems and their components.
- ✓ Help people better understand and disentangle the complexity of big engineered systems and their social, economic, and natural environment
- ✓ Enable integration among systems and data through semantic interoperability.

A Roadmap to a Hyper-connected Future



- ✓ How to master the digital innovation challenge?
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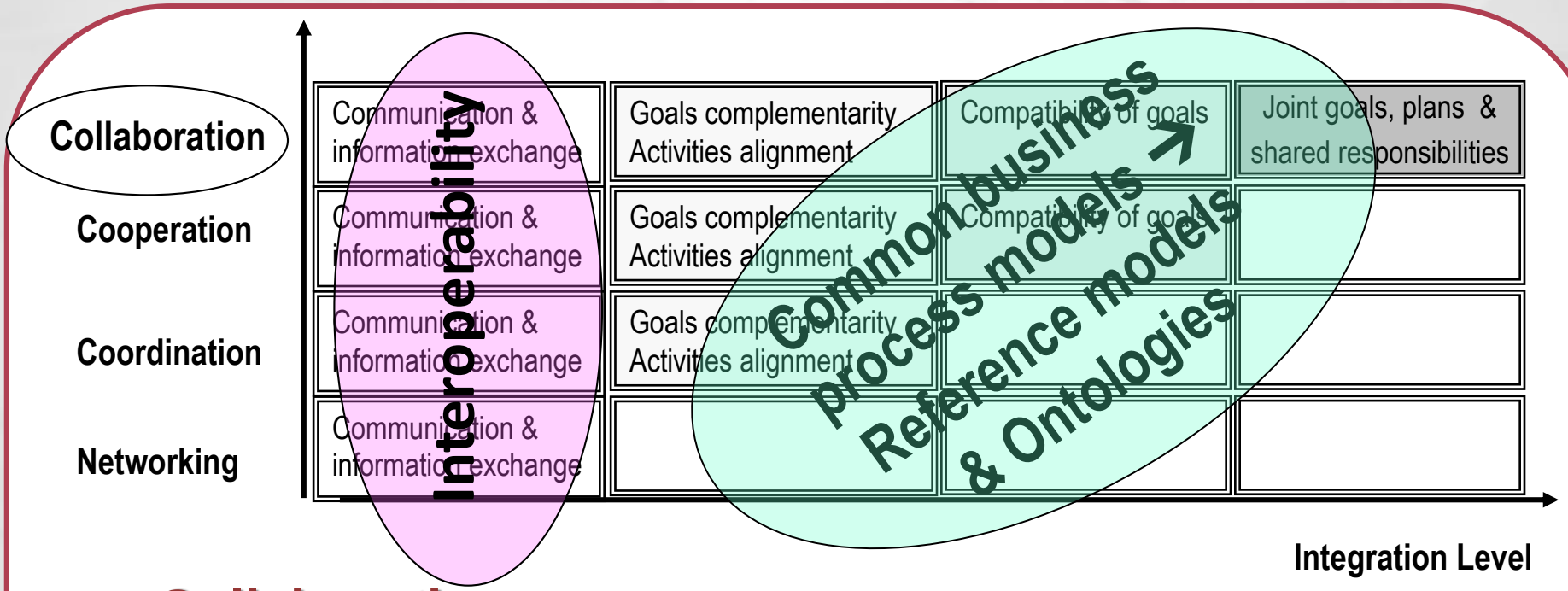
Integration and collaboration

- ✓ Integration is not just data exchange. It should be based on **semantic interoperability**.
- ✓ **Integration is a team task** (e.g., Development of a SC Performance Evaluation System)
- ✓ **True integration** is based on synchronization and collaboration. Nowadays it **should be seen as a model-based problem**.
- ✓ True integration **allows developing a genuine multiscale behavior** that not only addresses the computation of some needed information on a finer scale to pass it to a coarser scale or vice versa, but also allows **integrating multi-scale models**

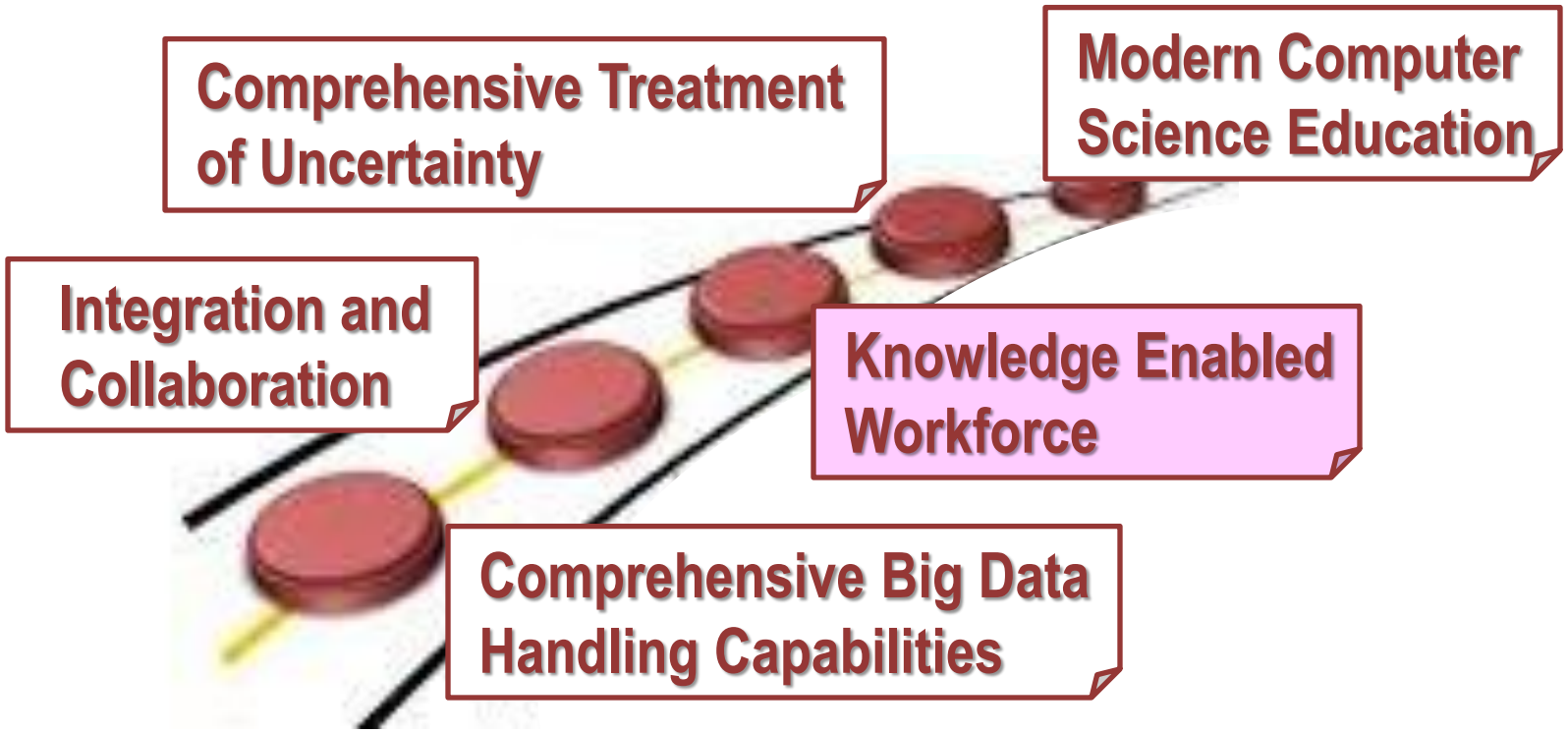
Integration and collaboration



- **Collaboration**

  A demanding process in which participating entities share information, resources and responsibilities to jointly plan, implement, and evaluate a program of activities to achieve a common goal and jointly generate value (Camarinha-Matos et al., 2009)

A Roadmap to a Hyper-connected Future



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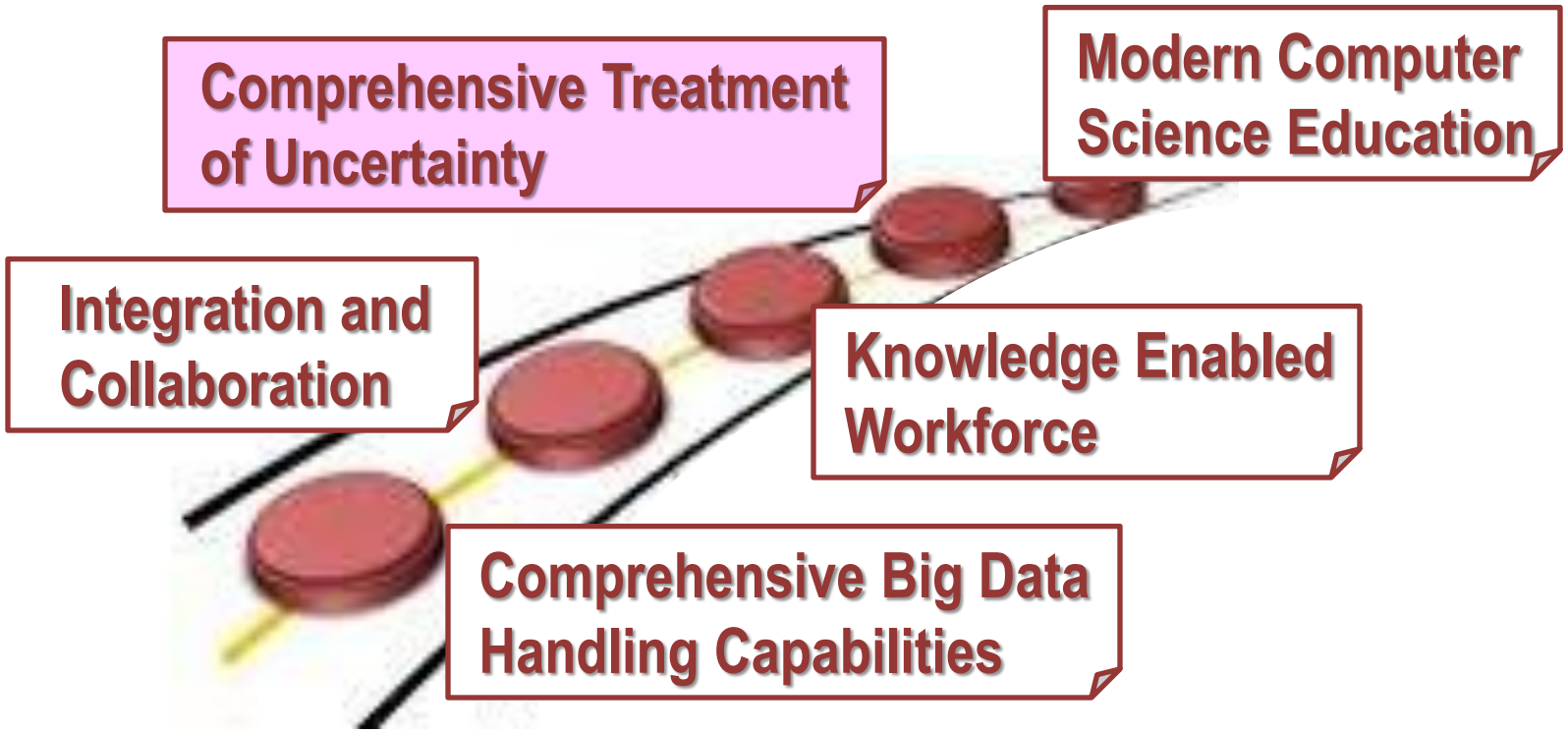
Knowledge Enabled Workforce

- ✓ Move users to the **self training paradigm** that millennials are used to.
- ✓ Develop decision support systems in which humans interact with the application in the same way they interact with other humans. Systematically **integrate humans into the problem definition and solution processes**, but without requiring them expertise.
- ✓ **Develop applications as Mixed-initiative Optimization Systems (MIO)**. Both Scheduling and Supply Chain Management systems are complex socio-technical systems, that need to be designed as MIO systems.
- ✓ MIO systems are based upon collaboration between the **system and the user,** taking into account that both possess **complementary capabilities.**

A Roadmap to a Hyper-connected Future



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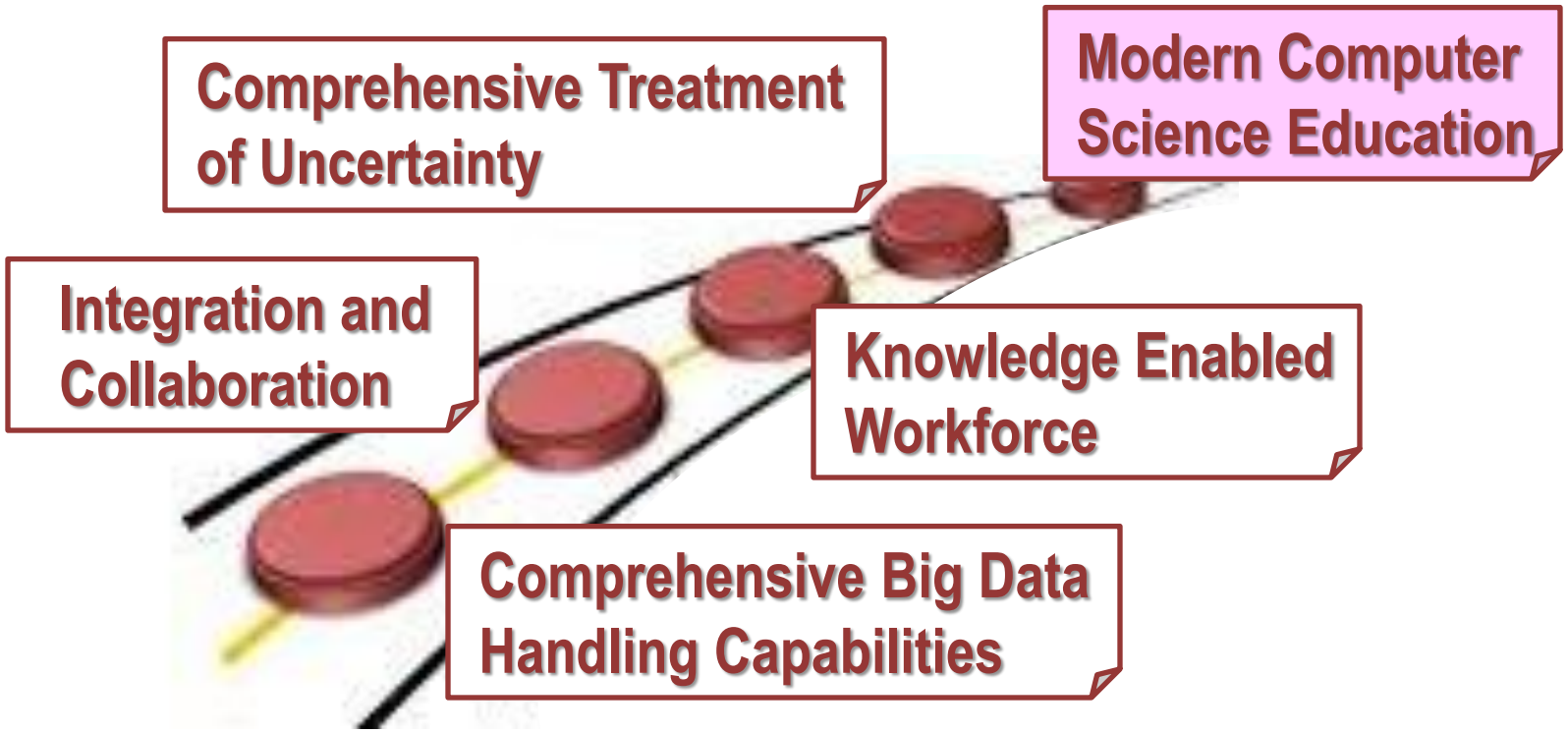

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Modern Computer Science Education

- ✓ Computer science support of process operations goes beyond the development of efficient models and powerful algorithms. Algorithms are necessary and they will always be necessary, but are not sufficient..
- ✓ The solution of complex models will remain one of the major areas of activity in PSE. The size of models will steadily grow up, as well as the number of interactions with other components.
- ✓ Educate ourselves on modern computer science
  - ✓ Master basic software engineering principles
  - ✓ Address both functional and non-functional requirements elicitation
  - ✓ Learn and develop new computer science methodologies and technologies – ontologies, big data handling, cloud computing, machine learning, etc., with the experts in the field, which are computer scientists.

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Many thanks for your kind attention

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