

R&D Needs for Digital Twins*

From a research lab
+ Researcher's
+ Manager's
+ Practitioner's
perspective

Kalyan Perumalla

Oak Ridge National Laboratory

Digital Twins in Production Engineering and High-Performance Computing Education
Inception Workshop, Tenn. Tech U & U. Tenn. Chattanooga, December 3-4, 2020

ORNL is managed by UT-Battelle, LLC for the US Department of Energy

Some Motivating Questions

Education...Training...Exposure...Support

- What kinds of DT training of recruits would ideally benefit research labs?
- How can graduates be prepared to hit the road running in DT research at the labs?
- What facilities across universities can help prepare budding DT researchers?
- What academic environments can help new staff progress in their careers at research labs?

DT=Digital Twin+Thread

R&D Needs for Digital Twins (and Threads)

Paradigms

- Digital Twins
- Digital Threads

Potential gains

- Predictive
- Intelligent
- Proactive
- Nimble
- Safe
- And many more

Aerospace	Navy	Nuclear
<ul style="list-style-type: none">•Planes•Helicopters•UAVs	<ul style="list-style-type: none">•Ships•Submarines	<ul style="list-style-type: none">•Reactors•Regulation
Automobiles	Health	Energy
<ul style="list-style-type: none">•Autonomous•Fleets•Logistics	<ul style="list-style-type: none">•Personal•Medical	<ul style="list-style-type: none">•Buildings•Batteries
	Cyber	Systems
	<ul style="list-style-type: none">•Security•Elastic provisions	<ul style="list-style-type: none">•Office•Education

A Meta View

Digital Twin (+Thread)

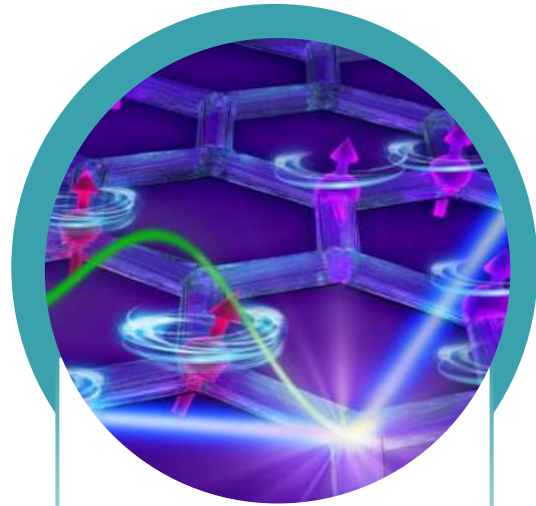
is a relatively malleable concept, **yet** sufficiently clear to inspire rethinking to achieve several new, reimagined goals

These paradigms have now ignited **new R&D** in a wide range of businesses, products, processes, and systems

There is immense scope to now move from anecdotal to **methodical**

R&D Needs for Digital Twins: **Broad Categories**

WHAT



Science

Fundamental Theories;
Unification; Formal Definitions;
Problem Formulations;
Limits

WHO



Skills

Computation;
Data Science;
Application & Functional Knowhow;
Team-based Agile R&D

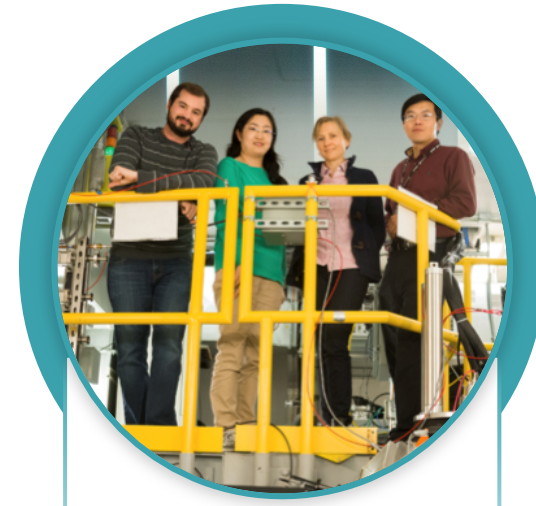
HOW



Facilities

Lab-level Testbeds; HPC;
Large Testbeds;
Software-Frameworks; 3D Immersive Environments

WHERE

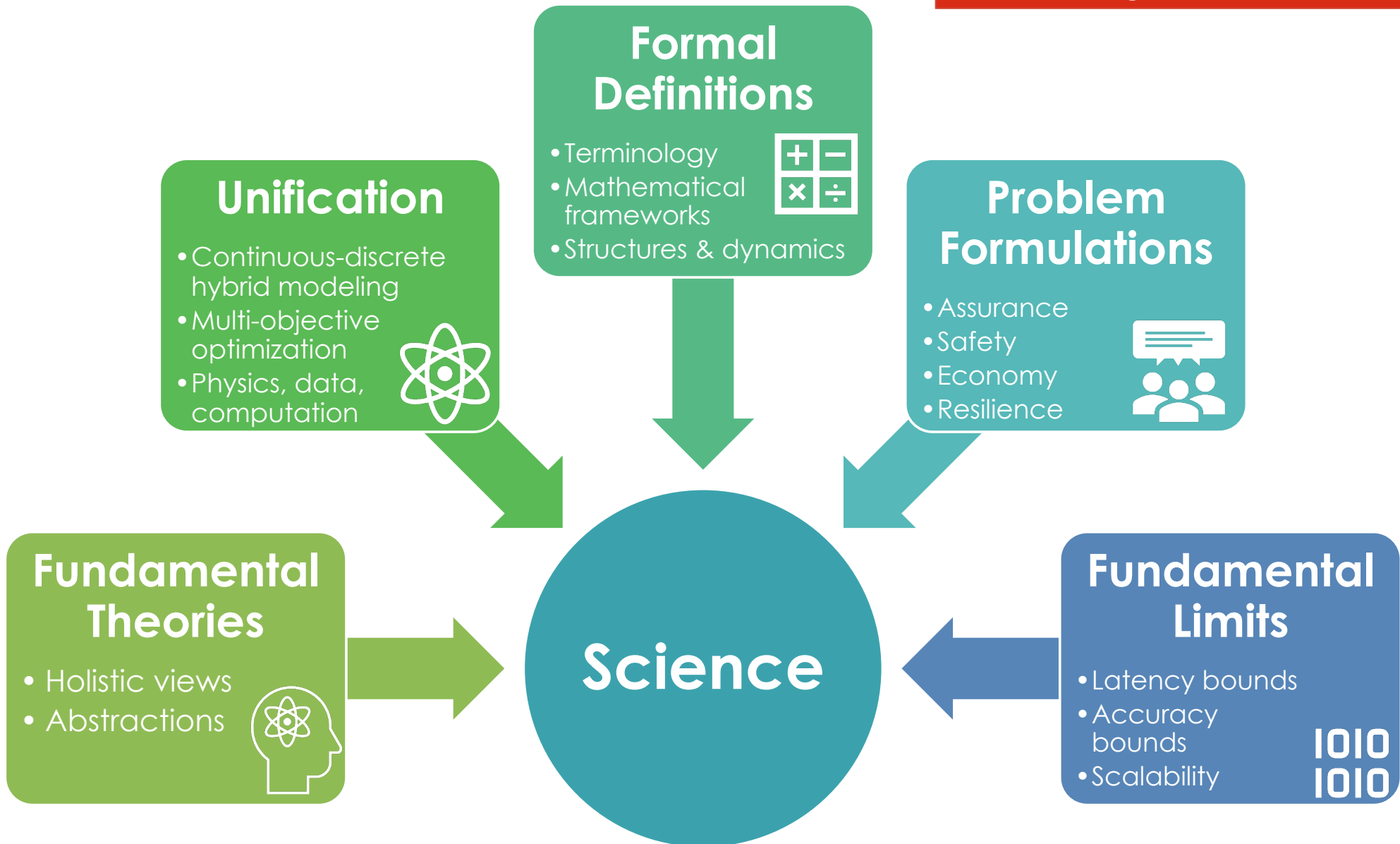


Ecosystem

Certifications; Standards;
Professional Bodies; Consortia;
Innovation Awards and Recognition

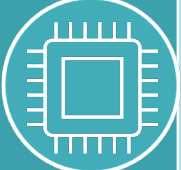
R&D Needs for Digital Twins: **Science**

Pure, methodical, conceptual
Standing the test of time




R&D Needs for Digital Twins: **Skills** of Research Staff

Training and traits for success



Skills in Computational Techniques

- Discrete/continuous simulation
- Numerical methods
- IT/OT H/W & S/W
- Hardware-in-the-loop
- Parallel Computing




Data Science and Data Handling

- AI/ML methods
- Statistics, Uncertainty
- Heterogeneous and Multi-modal Data Management



Exposure to Applications

- Domains
- Functions
- Products
- Services



Modern Agile Development

- Scaled Agile Frameworks
- DevOps, Continuous Integration/Development
- Cloud-based Operations
- Immersive Environments



Modern Software Technologies

- Languages (Python, R, ...)
- Packages and Libraries
- Virtual Environments and Containers
- Distributed Networked Systems

R&D Needs for Digital Twins: **Facilities** for Research

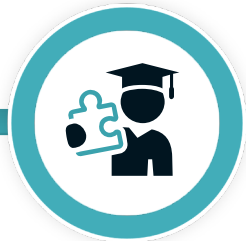
Key enablers for the new crop of researchers

Lab-level Testbeds

“Tinker” labs of cyber-physical systems and components

Beginner-oriented apparatus

Hands-on teaching, training, testing

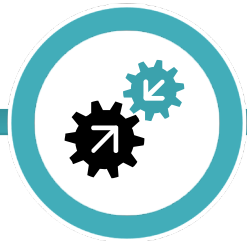


Large-scale Testbeds

Multi-use, multi-purpose, multi-system installations

Larger scale experimentation

Longer time-scales
Richer complexity – systems, products



Computing and Data Support

Software-hardware Frameworks

Application-agnostic engines
IT/OT-inclusive systems

High-Performance Computing (HPC)



Collaborative and Immersive Environments

Remote access to hardware testbeds

High-fidelity visualization

3-D, Holographic environments



R&D Needs for Digital Twins: **Ecosystem**

Rich environment for professional research staff

Research labs need new Digital Twin ecosystem for staff

- Selections
- Evaluations
- Promotions
- Rewards
- Incentives
- Highlights

Researchers need new Digital Twin ecosystem to thrive

- Peer communities
- Continued learning
- Idols, Ideals
- Standards, Certifications
- Best practices



Q&A

Kalyan Perumalla, Ph.D.

Distinguished R&D Staff, **Oak Ridge National Lab**

Joint Full Professor, Dept. of ISE, **U. of Tennessee**

Adjunct Professor, School of CSE, **Georgia Tech**

Chair, **ACM SIGSIM**

perumallaks@ornl.gov | 865-241-1315

www.ornl.gov/staff-profile/kalyan-s-perumalla

