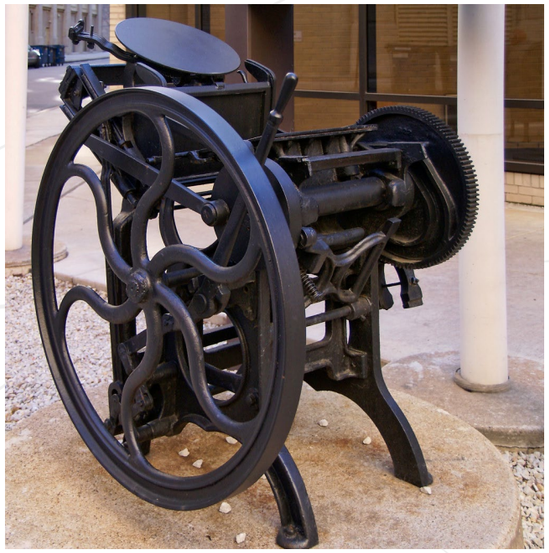
MSEC/NAMRC 51 Blue Sky Competition
Rutgers University, NJ, June 14th 2023

Cognitive Manufacturing Machines

Prof. BINIL STARLY
Professor
Arizona State University

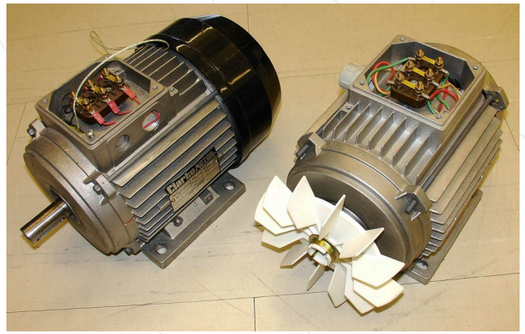
Ira A. Fulton Schools of Engineering
Arizona State University

WAVES OF MANUFACTURING MACHINE DESIGN

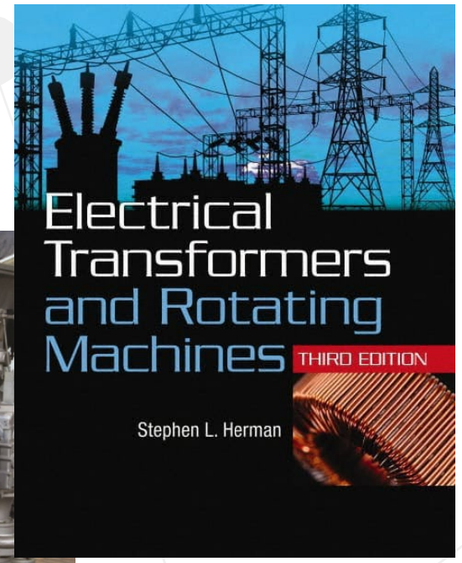


MECHANICAL MACHINES SYSTEMS ERA

1800s – 1900s

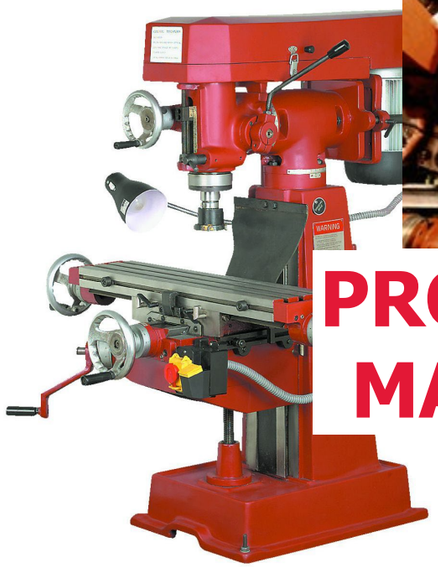


ELECTRICAL MACHINES ERA



1890s – 1960s

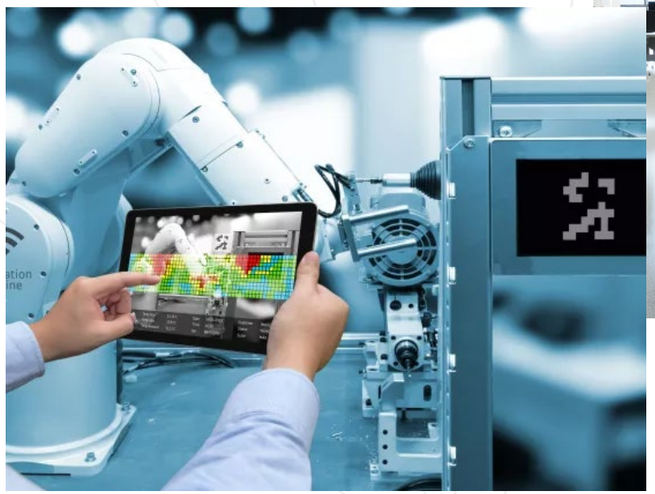
WAVES OF MANUFACTURING MACHINE DESIGN



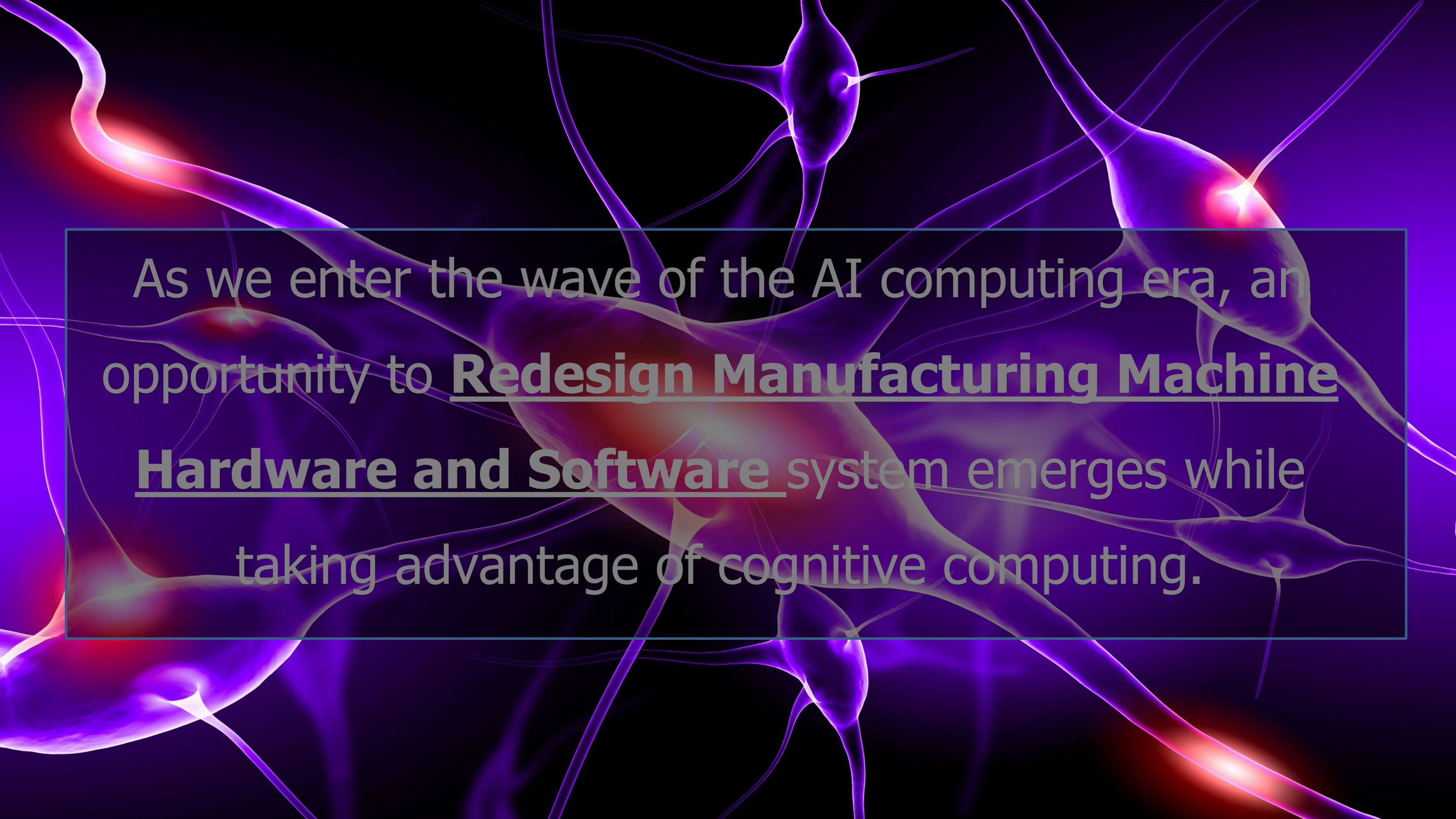
PROGRAMMABLE MACHINES ERA

Beginning 1970s

INTELLIGENT MACHINES ERA



2010s – present


As we enter the wave of the AI computing era, an opportunity to **Redesign Manufacturing Machine Hardware and Software** system emerges while taking advantage of cognitive computing.

BLUE SKY IDEA: THE COGNITIVE MACHINE ERA

Vision based Systems
Sense Everywhere &
Computing Surfaces

Continuous
Short-Term & Long-Term Memory
Knowledge Transfer

Machines can be designed with an AI-Cognitive Computing architecture that provides **Perception**, **Control**, **Learning**, and **Reasoning** with an intrinsic **Value** system to interact with its complex environment.

Context Specific Values
Embodied Value Framework
Beliefs and Desires

Online
Reactive
Opportunistic

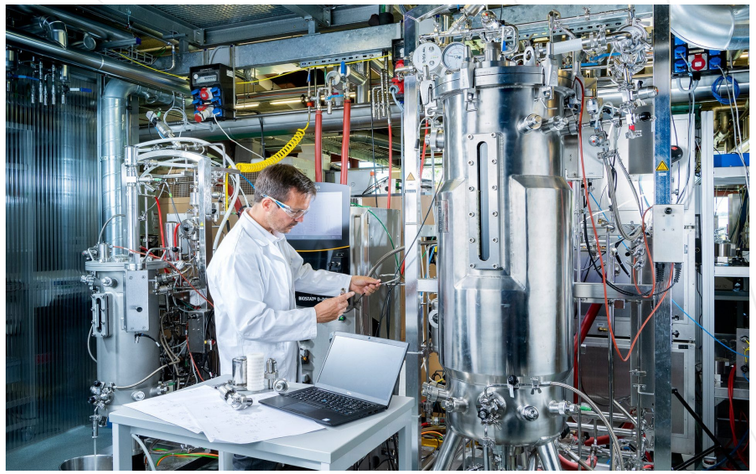
Explainable Reasoning
Problem Solving
Information Seeking

COGNITIVE MACHINE USE CASES

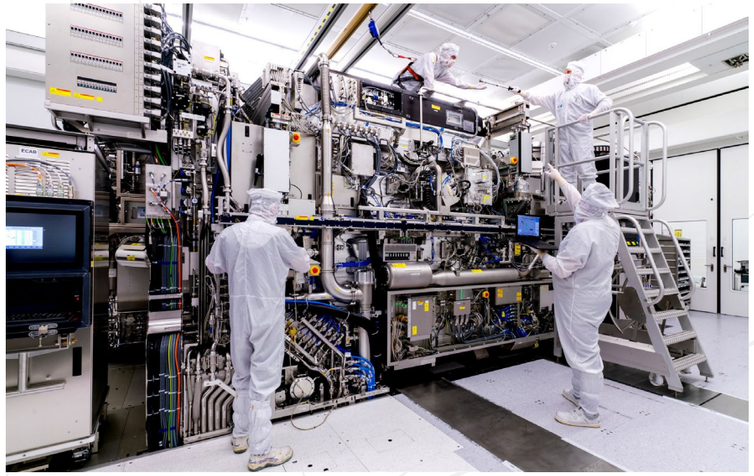
Biofabrication of Synthetic Organs

Lights out Automated Factories

Manufacturing with Machines in Harsh/Extreme Environments



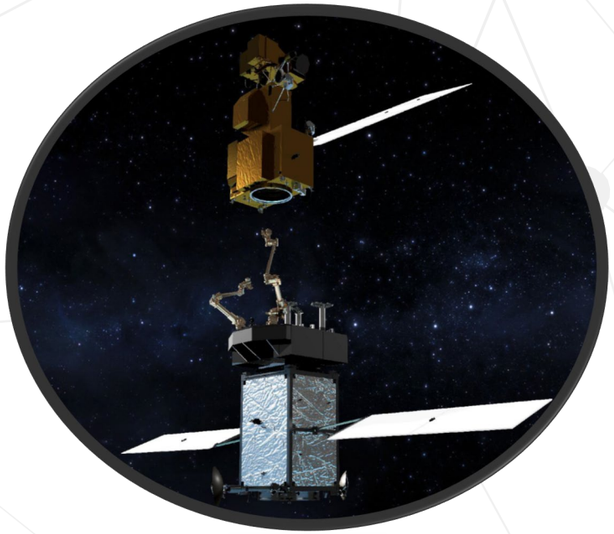
Manufacturing Synthetic Living Cells for Next-Gen Products

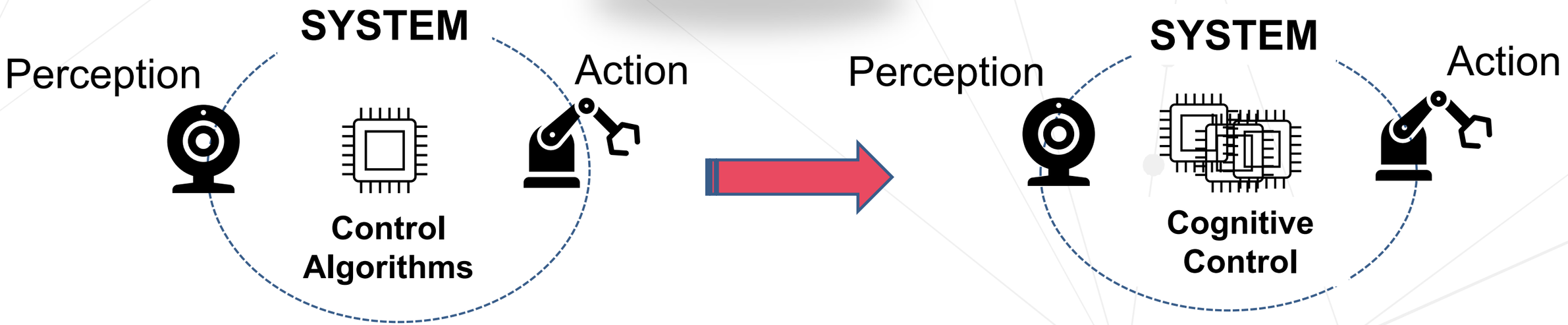


Heterogeneous Advanced Packaging of Computing Chips

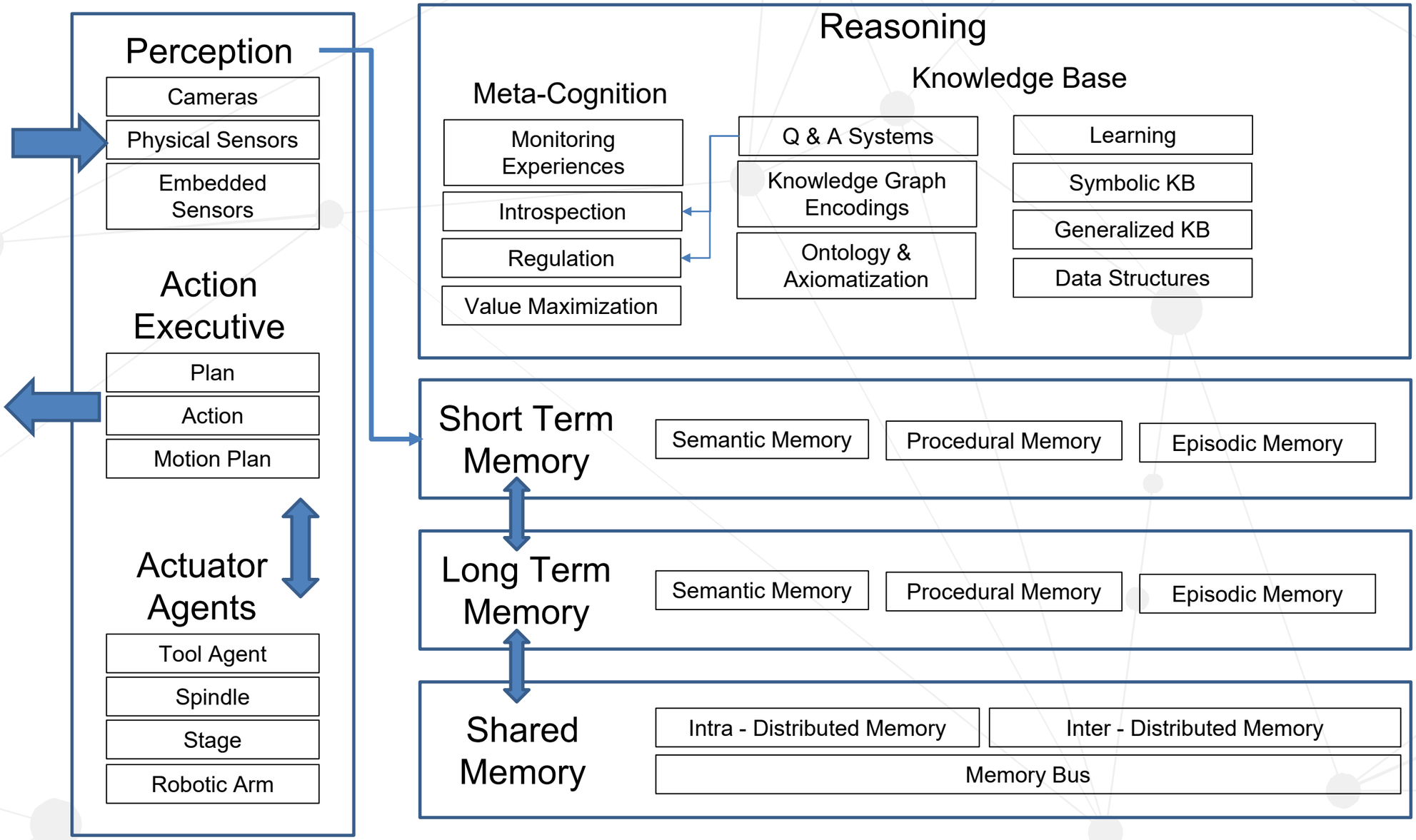
BLUE SKY IDEA: THE COGNITIVE MACHINE ERA

Machines that operate in **HARSH EXTREME, UNPREDICTABLE** Environments





BLUE SKY IDEA: COGNITIVE ARCHITECTURE



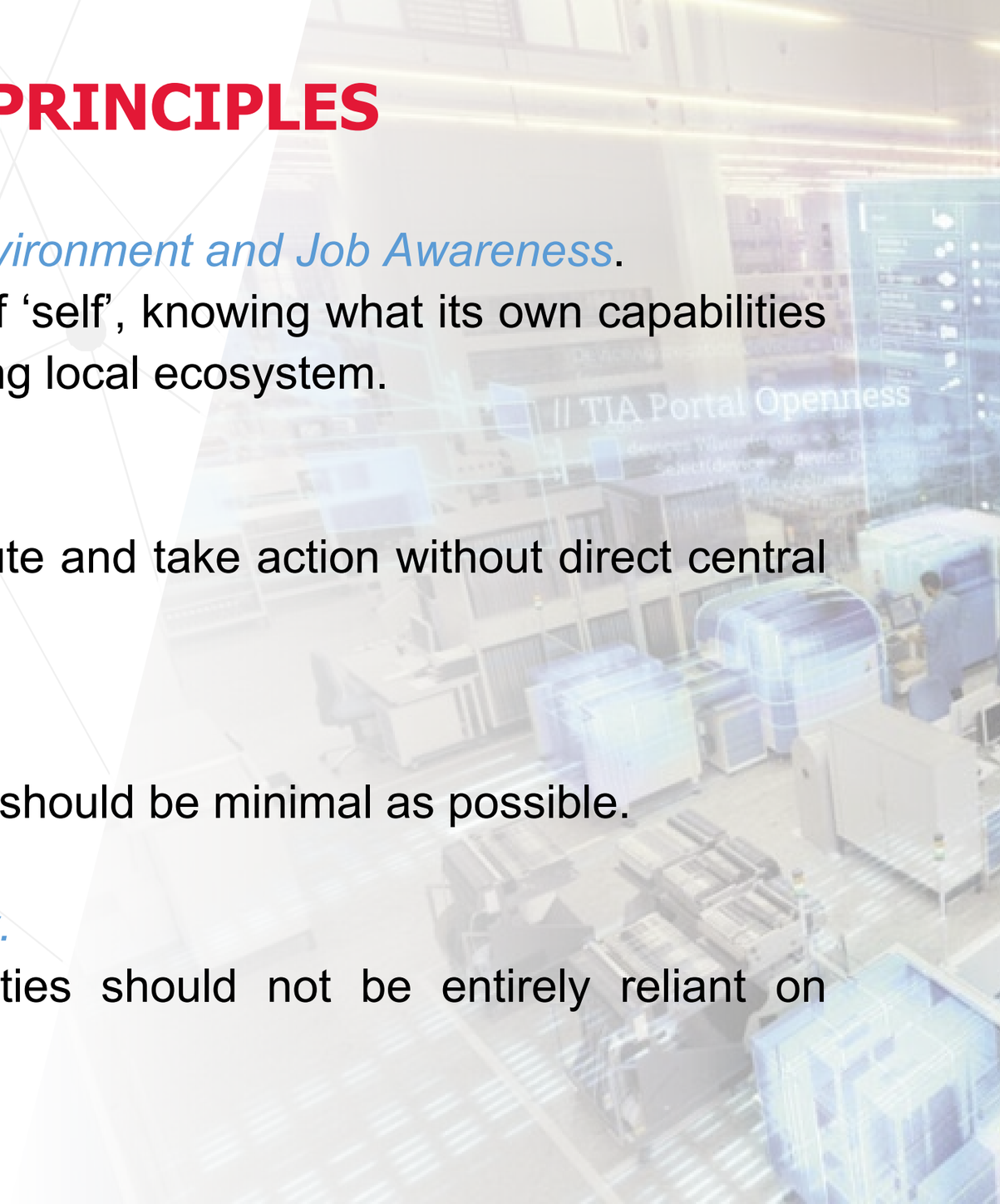
COGNITIVE MACHINE 8 DESIGN PRINCIPLES

A Three Constituent Awareness Principle: Self, Environment and Job Awareness.
The cognitive machine must have an awareness of ‘self’, knowing what its own capabilities are and position it occupies within the manufacturing local ecosystem.

Design Balance of Cognitive Abilities.
Internal sub-system assets must be able to compute and take action without direct central software control.

Energy Cheap Design.
The energy required to maintain its cognitive cycle should be minimal as possible.

Resiliency In-Spite of Sensor/Actuator Degeneracy.
Decision-making abilities and functional capabilities should not be entirely reliant on sensors



COGNITIVE MACHINE 8 DESIGN PRINCIPLES

Episodic Memory: Short-Term & Long-Term Memory.

Retrieve instances from its long-term memory, and able to store, retrieve and compute on recent data acquisition, but retain knowledge gained from long-term knowledge.

Ability to Transfer Knowledge to Other Machines.

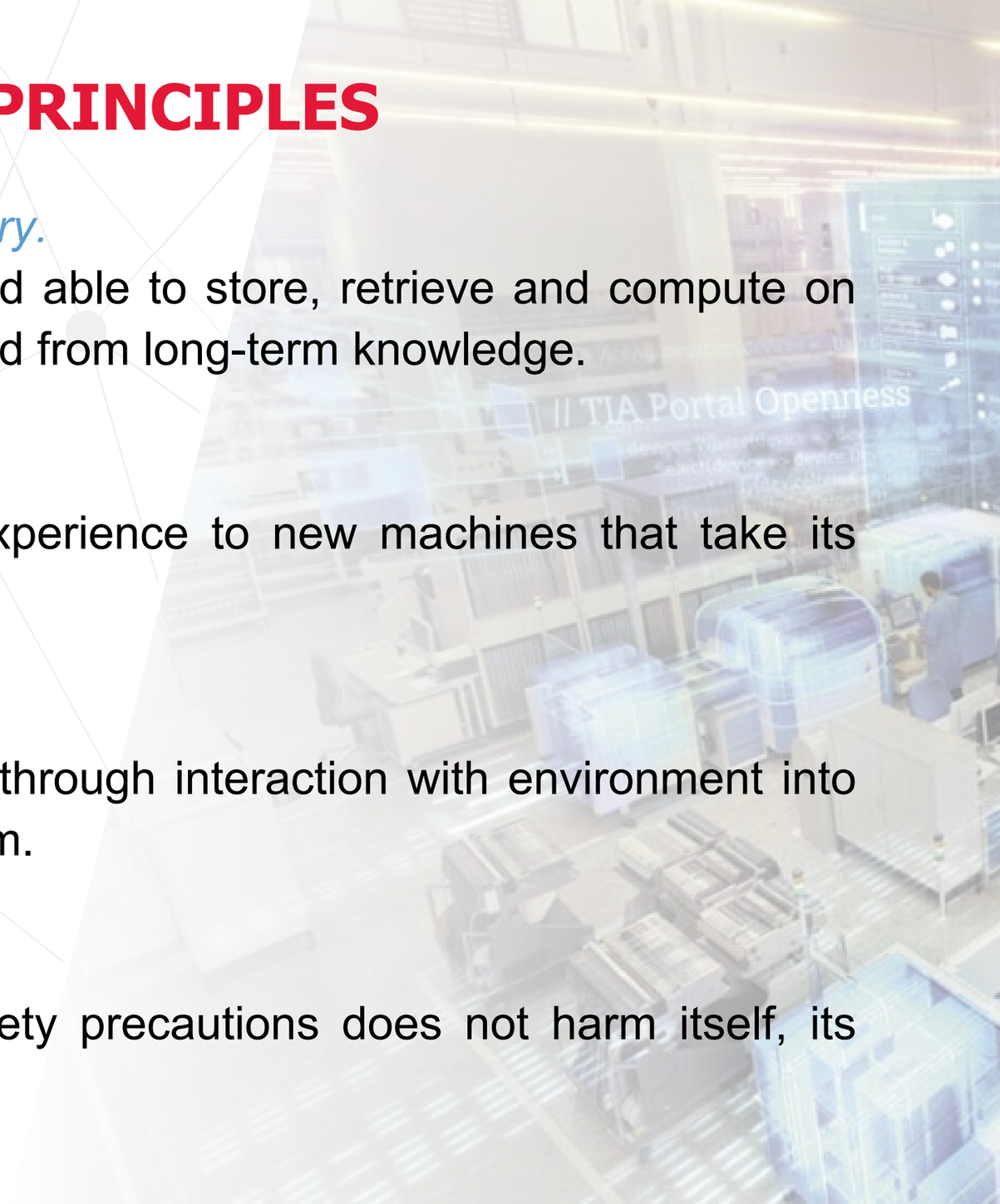
Able to transfer knowledge gained through its experience to new machines that take its place or other similar machines in its environment.

Codification of Experiences into Knowledge.

Must be able to encapsulate experiences gained through interaction with environment into knowledge that is codified in machine readable form.

Innate Value System.

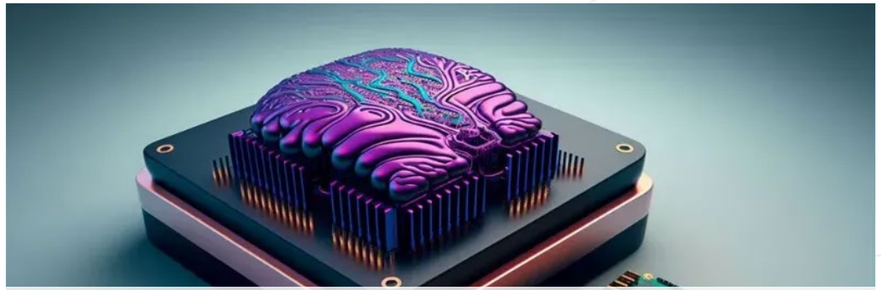
Have prioritized value system to ensure that safety precautions does not harm itself, its products, surrounding machines and humans.



RESEARCH NEEDS

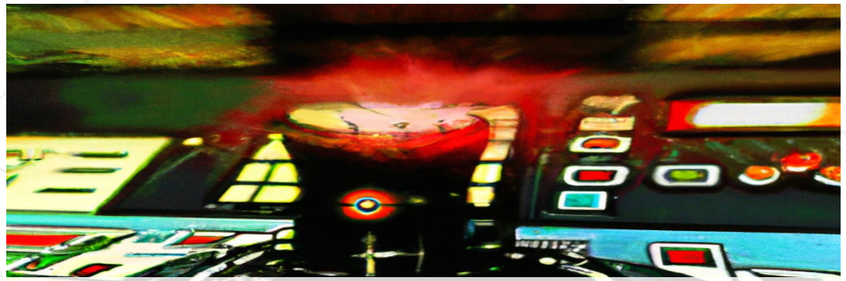
- **Cognitive-AI Hybrid Computing Architecture for manufacturing machines?**
    - **How does the machine's cognitive mind capture 'learning' from experiences?**
- **Can we reduce latency of operations in a hybrid cognitive-AI control?**
    - **How is an attention framework developed in the context of manufacturing?**
- **Given a generic end-goal, how can machines create auto-executable process plans?**
    - **Autonomy for machines requires the development of a value system.**

TECHNOLOGY NEEDS



High-Performance Computing Architectures for cognitive AI at **manufacturing time-scales.**

MFG COMPUTING ARCHITECTURE



Machine Frames and Critical Surfaces are **Digitizable** & Computable

NEW SENSORS & COMPUTING SURFACES

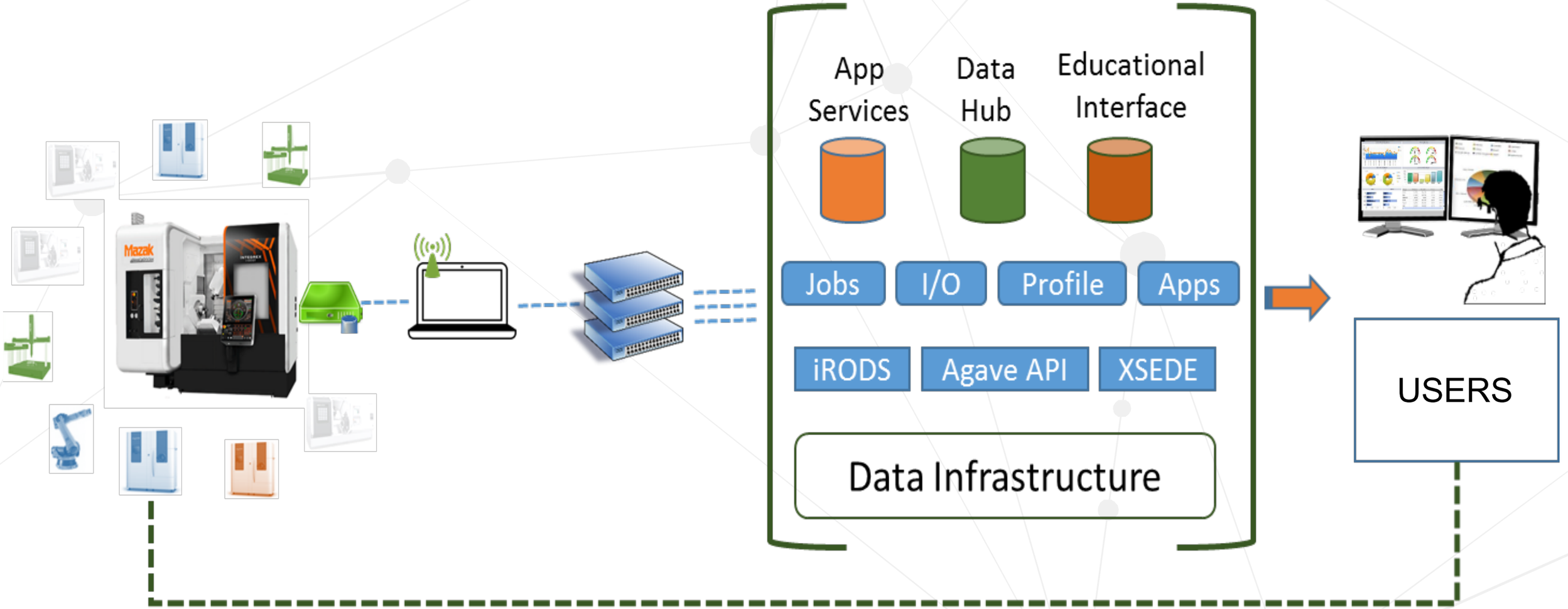
Modeling, Simulation & Control Learning via **Networks of Sim-Assets informing Real-Word Assets**

AI SIM 2 REAL & REAL 2 SIM TECHNIQUES

Reproducible and Interoperable Factory Assets for Democratized Access to MFG Data

DATA ASSET INFRASTRUCTURE

DATA INFRASTRUCTURE FOR COGNITIVE MACHINES



VISION: COGNITIVE MACHINES ERA

- **Rethink Machine Equipment & Process Design:** As opposed to adding a compute layer on top of current hardware layer, let us rethink the design of the machine itself to be data centric.
- **Cognitive AI control:** Reasoning over deep knowledge structures of declarative (know-that), causal (know-why), conditional/contextual (know-when), relational (know-with) to control machine executive actions.
- **New Factory Operating Systems Architecture:** Redo file based operating systems to database centric operating systems to operate connected machines, their interaction up and above the manufacturing system chain.

THANK YOU

Blue Sky Competition Committee

MECHANICAL MACHINES

ELECTRO-MECHANICAL MACHINES

COGNITIVE MFG MACHINES

MECHANICAL MACHINES – COGNITIVE MACHINES

THANK YOU

Ira A. Fulton Schools of Engineering
Arizona State University

Ira A. Fulton Schools of Engineering

School of Manufacturing Systems and Networks

Prof. BINIL STARLY
Professor &
Director