Model Based Systems Bootcamp – Day 2

Simulation in Support of Digital Twins and Industry 4.0

Dave Sturrock, VP Products, Simio LLC

dsturrock@simio.com, Linkedin.com/in/sturrock/

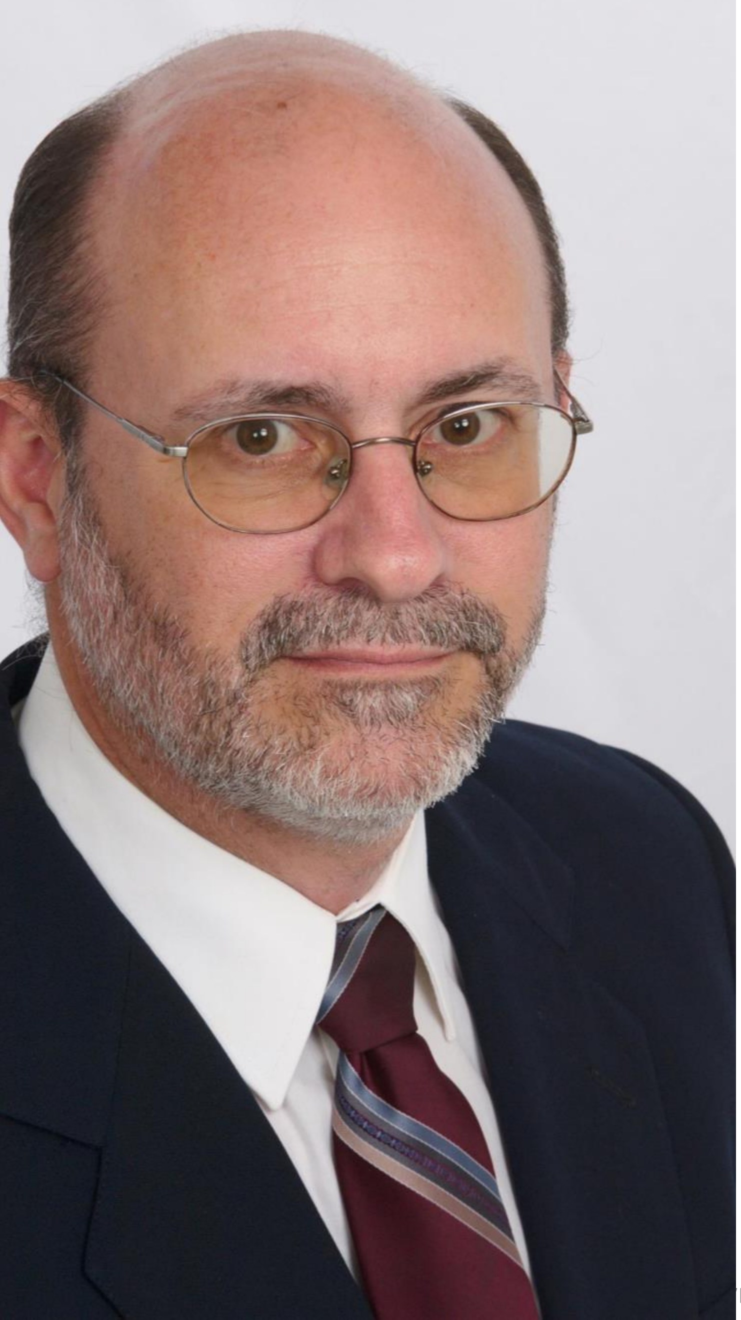
System Design

- Visualize and analyze the system
- Conduct what-if analyses for capacity, overtime, and more
- Explicitly model variability to understand real world outcomes, not steady state approximations

System Operation

- Reduce the pain of scheduling and rescheduling
- Concurrently plan capacity, demand, and material requirements
- Evaluate operational trade-offs (e.g., consequence of changing order priority)

David Sturrock



35 years in Simulation Consulting
- Projects in numerous application areas
- Simulation consultant/trainer
- Lead designer/developer of SIMAN/Arena
- Arena Development and Product Manager

Co-founded Simio LLC in 2008
- Vice-president Products
- Manage Development, Support, & Engineering Staff
- Currently teaches at University of Pittsburgh

Co-author of:
- *Modeling and Simulation of Complex Networks* (2019)
- *Simulation for Industry 4.0: Past, Present, Future* (2019)
- *Simio Simulation: Modeling, Analysis, Applications* (2018)
- *Rapid Modeling Solutions* (2015)
- *Simulation with Arena* (2007)

Workshop Objectives

- Learn why you should care about Digital Twins and Industry 4.0 and how they might benefit you.
- Learn about simulation technology, its strengths and limitations.
- “Get your hands dirty” using the Simio product so you can understand the model-building process.
- Discuss some case studies to see what other organizations have done with simulation.

Workshop Introduction

- **Schedule**
  - Introduction to Digital Twins and Industry 4.0
  - Introduction to Simulation and Simio
  - Experimenting and Analyzing Results
  - More modeling with Simio
  - Process Improvement Principles Workshops
  - Design and Scheduling Case Studies

Hands-on Opportunity

- **Software**
  - If you don't have Simio installed and working, see pre-conference handout or go to: https://www.simio.com/evaluate/

Designing and Operating Manufacturing Facilities is More Complex Than Ever

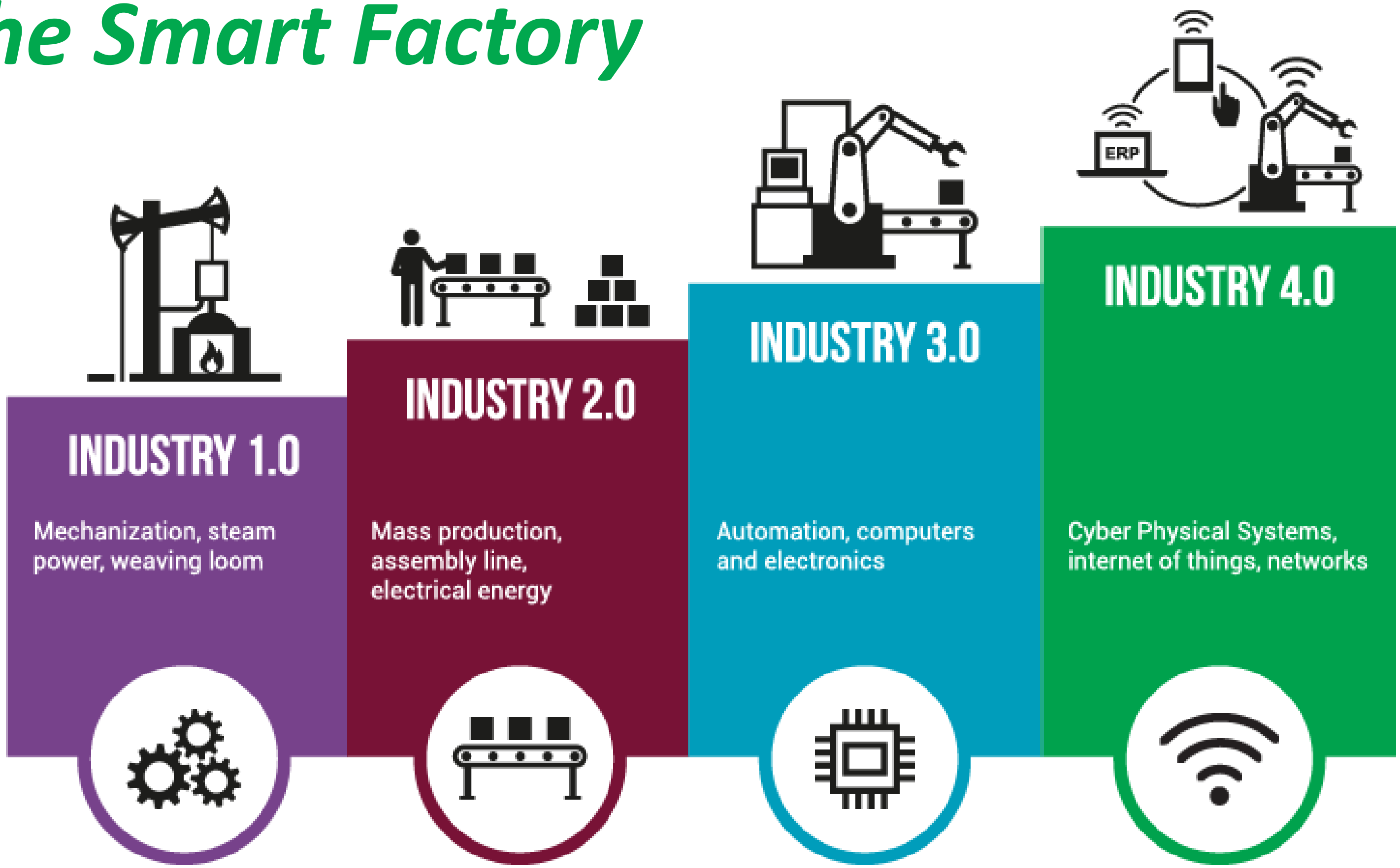
Simio
Forward Thinking

- Manufacturing has become the **response buffer** for supply chains as companies become leaner
- Customers demand increased **product variety and configurability** with **smaller minimum order quantities**, driving a shift to CTO/MTO/ETO
- Facilities are handling **increasingly complex operations** with semi-flexible manufacturing resources
- End customers are demanding **shorter lead times** and increased transparency into their supply chains
- ~25% of manufacturing employees are 55 and over and retiring at a rate of 10,000 per day – manufacturers are struggling with **knowledge drain**

Simulation Example: Global Supply Chain

What is Industry 4.0?

Smart Manufacturing
The Smart Factory



Industry 4.0 – Forbes Definition

Industry 4.0 optimizes the computerization of Industry 3.0

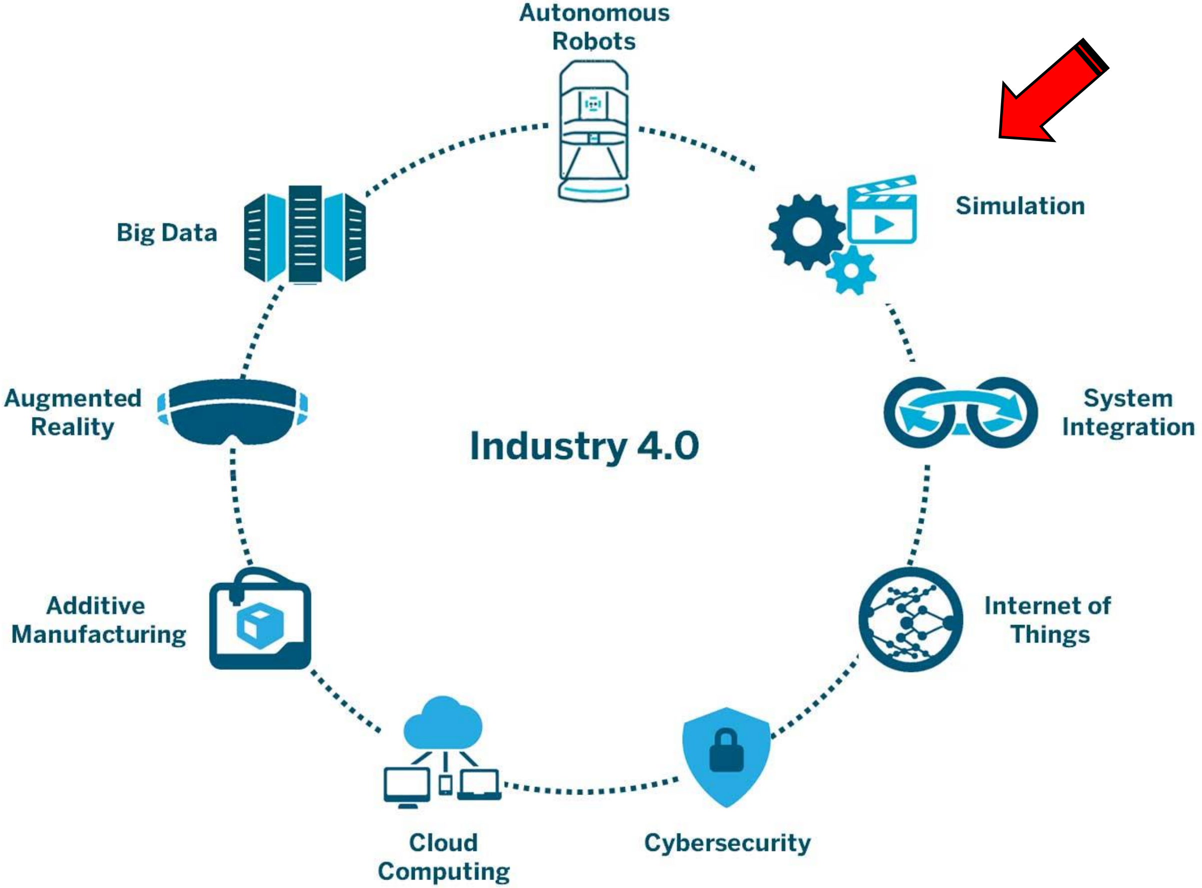
When computers were introduced in Industry 3.0, it was disruptive thanks to the addition of an entirely new technology. Now, and into the future as Industry 4.0 unfolds, computers are connected and communicate with one another to ultimately **make decisions *without human involvement***.

A combination of cyber-physical systems and the Internet of Things make Industry 4.0 possible and the smart factory a reality. As smart machines keep getting smarter with access to more data, our factories will become more efficient and productive and less wasteful.

Industry 4.0 – PWC Research

	In use today	Change over the next five years	In use in five years
Predictive maintenance	28%	+38%	66%
Big data driven process and quality optimisation	30%	+35%	65%
Process visualisation/automation	28%	+34%	62%
Connected factory	29%	+31%	60%
Integrated planning	32%	+29%	61%
Data-enabled resource optimisation	52%	+25%	77%
Digital twin of the factory	19%	+25%	44%
Digital twin of the production asset	18%	+21%	39%
Digital twin of the product	23%	+20%	43%
Autonomous intra-plant logistics	17%	+18%	35%
Flexible production methods	18%	+16%	34%
Transfer of production parameters	16%	+16%	32%
Modular production assets	29%	+7%	36%
Fully autonomous digital factory	5%	+6%	11%

Boston Consulting Group
Nine Transforming Technologies



Industry 4.0 is the vision of the industrial production of the future

Simio: The Factory Digital Twin

Simio
Forward Thinking

One Model – One Standard

Design

- Evaluate the ROI and impact of capex on critical KPIs before investing
- Determine the true capacity of a facility given changing product mix and volume
- Analyze impacts of new product launch, marketing promotions, etc.
- Develop and test labor plans quickly
- Provide a sandbox to evaluate process improvement opportunities and deploy to operation with a click

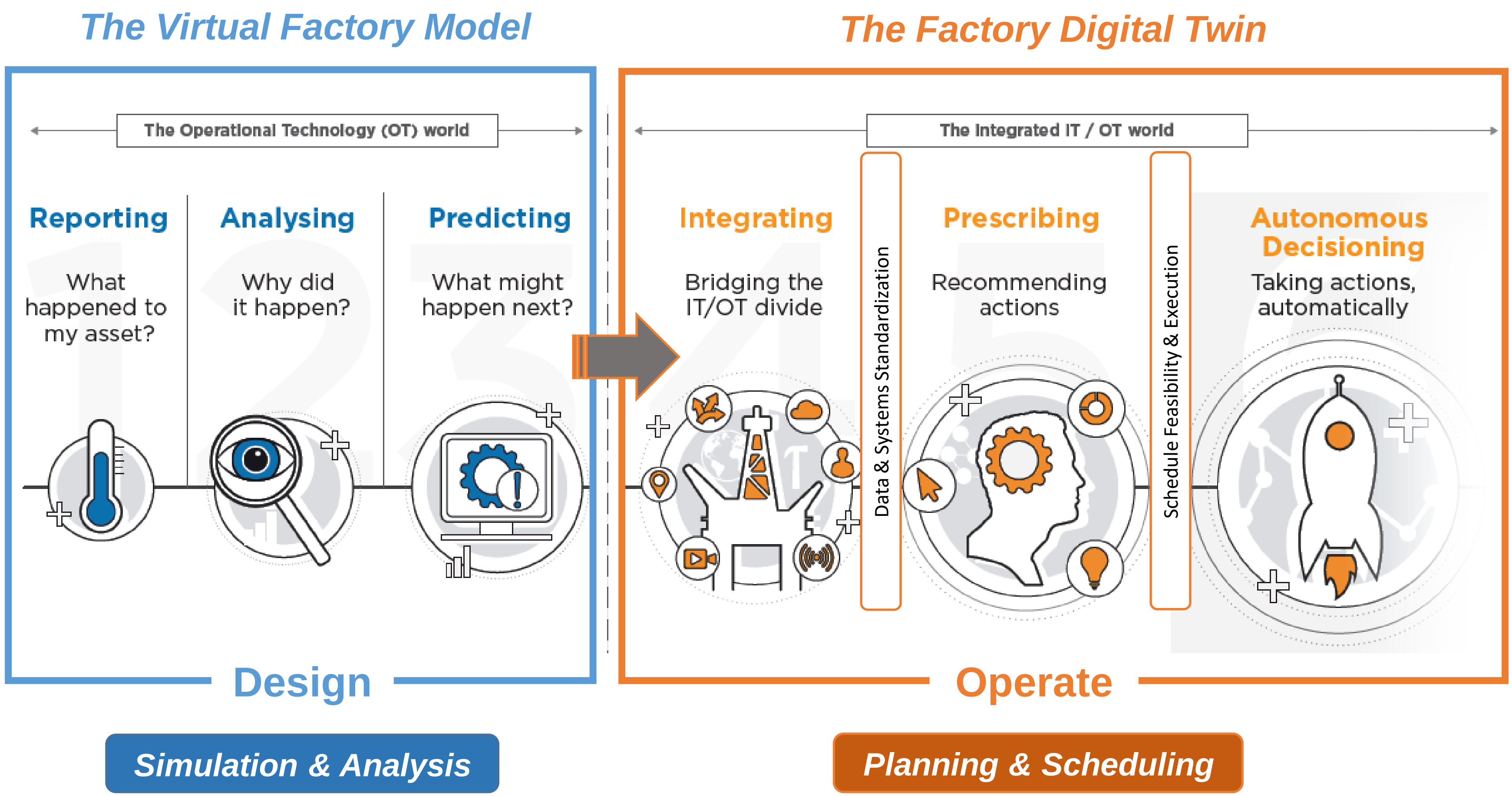
Operate

- Create detailed schedules with item level task lists by resource
- Easily evaluate operational alternatives
- Understand schedule risk based on historic variability
- Get to the “next best” plan when events derail production fast
- Accurately allocate resources and material to improve daily operations

Simulation & Analysis — ***Planning & Scheduling***

Continuous Improvement

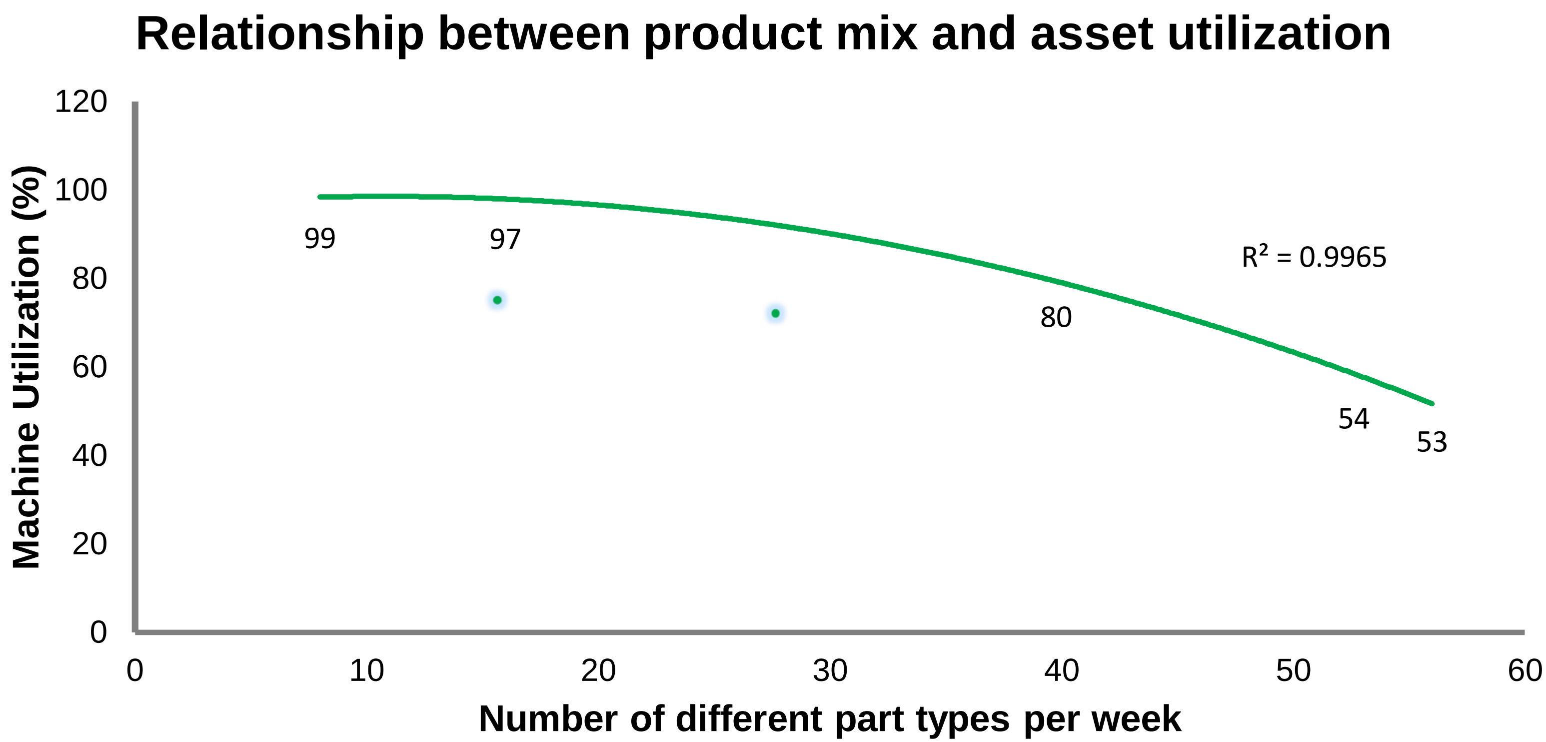
The Digital Continuum



Source: Smart-Energy.com

Example Analysis to Evaluate Business Rules and Operating Policies

Simio
Forward Thinking



The larger the number of part types (product mix) that need to be produced within a given week the less the effective utilization of the equipment due to change overs, setup, calibration, QA, operator availability, etc.

Factory Digital Twin
Model Decision Layers

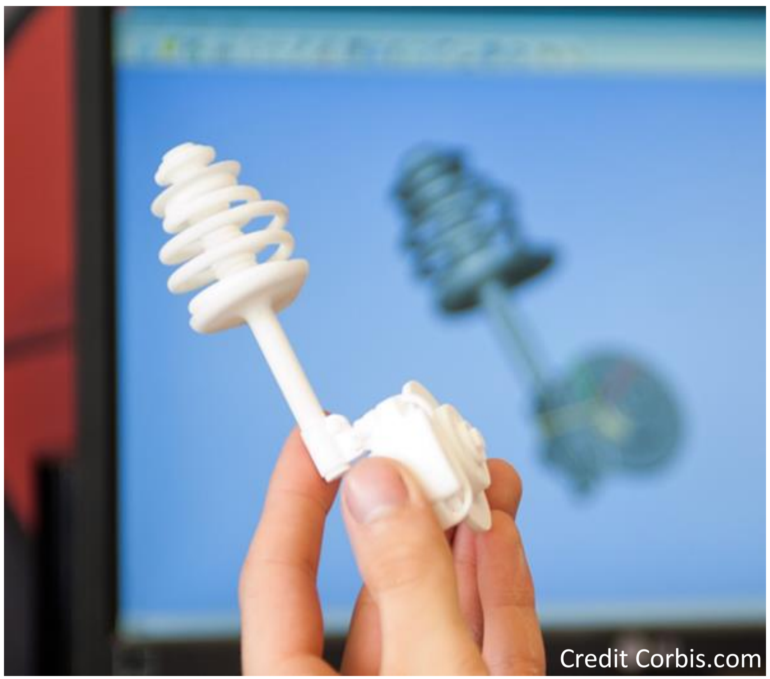
- Defines the physical (i.e. equipment, labor, tooling, transportation), regulatory, safety, etc. constraints that must be obeyed by the system (hard rules) – the system will obey them every time and this is how we create a “feasible schedule”

- The business rules that govern how a system operates – e.g. union requirements, minimum order quantities, stock levels, netting logic, order creation, etc.

- The rules that determine trade-off decisions given multiple conflicting KPIs (soft rules) – these are generally “tribal knowledge” and not tabulated or documented anywhere
- Typically these are the rules we will flex to optimize against the selected KPIs

Digital Twins

Part Digital Twin


Credit Corbis.com

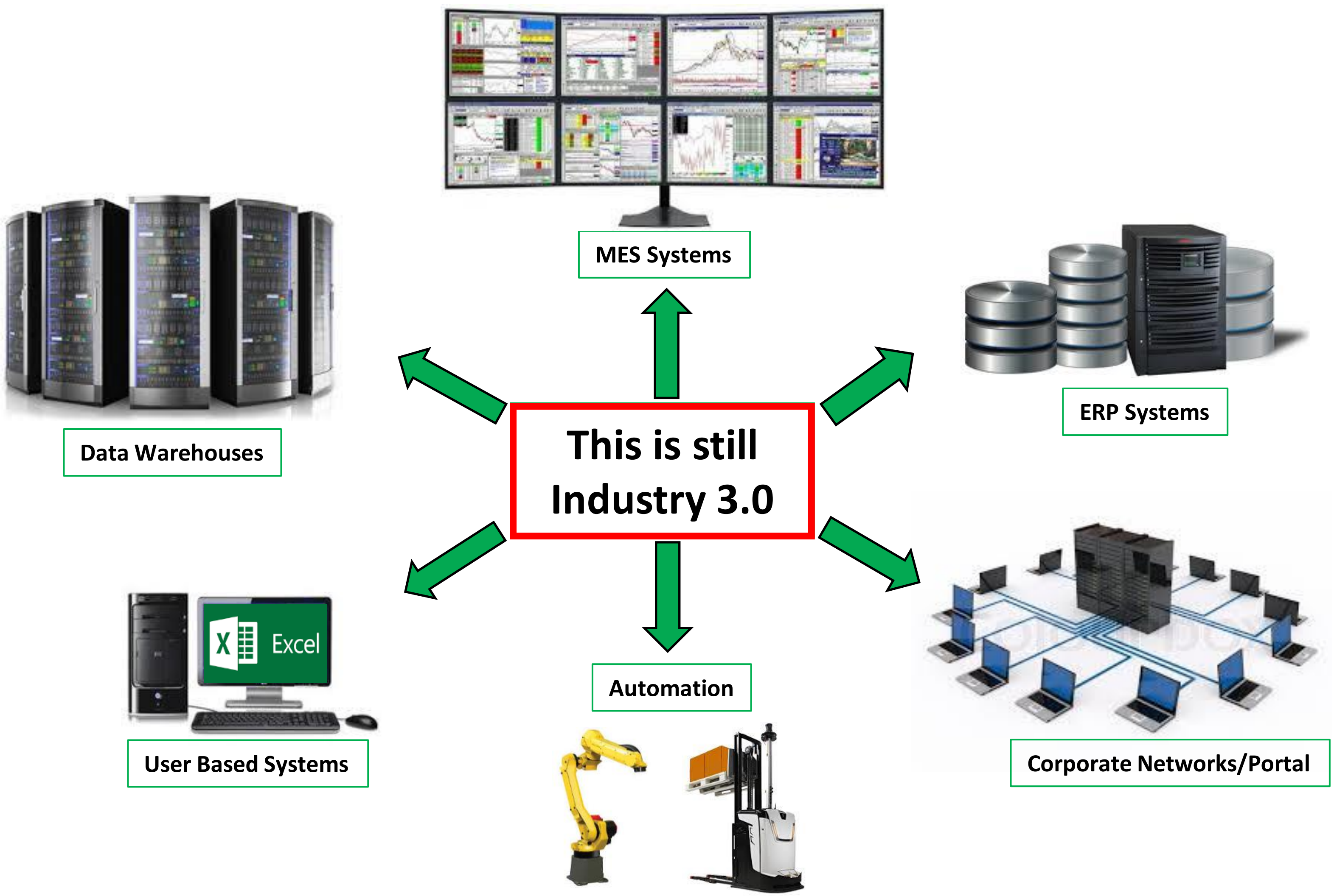
Process Digital Twin

Resource

Factory

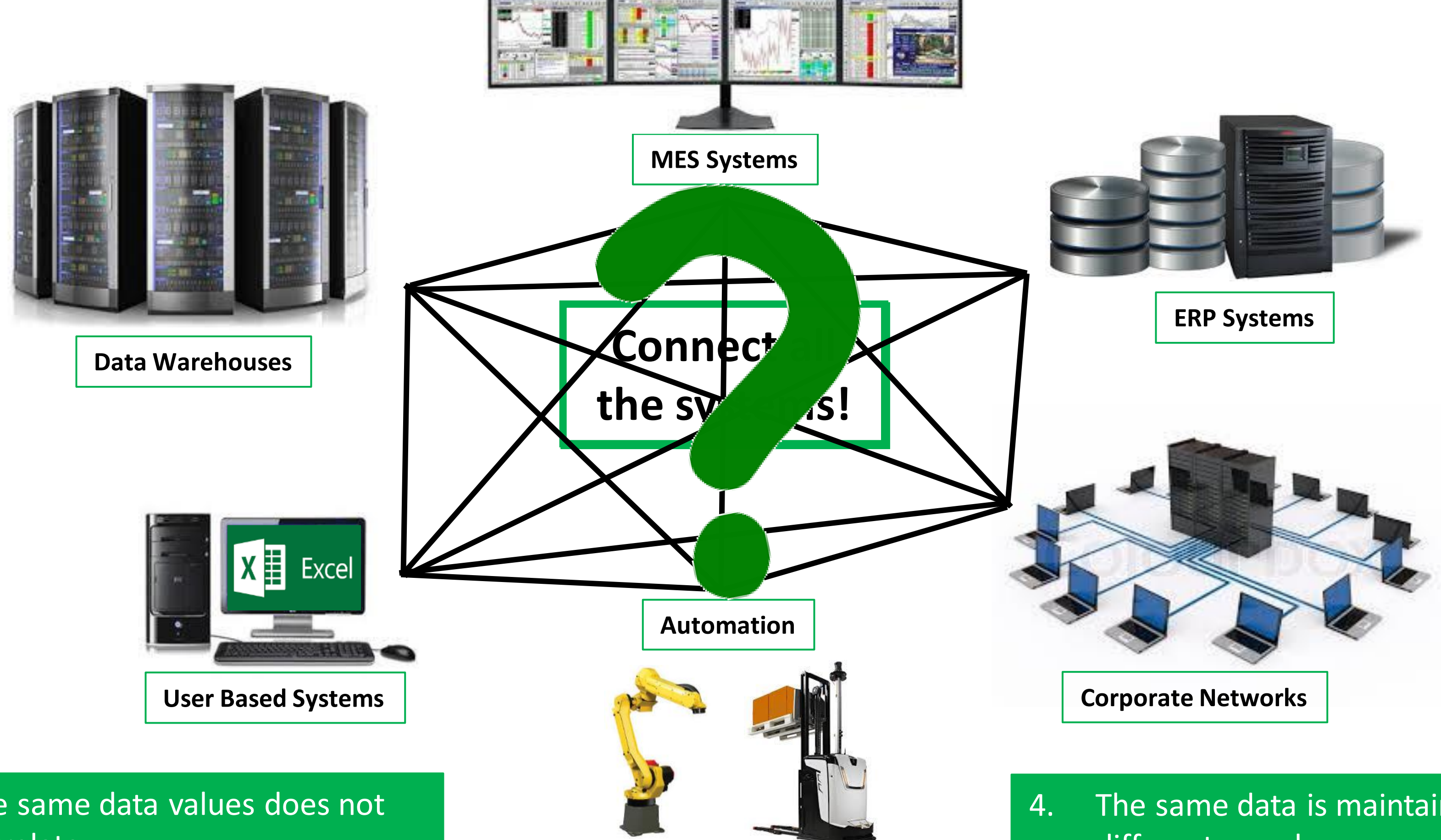
Supply Chain

Current Reality Today



How Do We Enable Industry 4.0?
(The Smart Factory)

1. The data is not at the same level of detail
2. The data is not time synchronized



3. The same data values does not correlate
4. The same data is maintained by different people

Industry 3.0

Current Time

Industry 4.0

What is our current OEE?

What is the current WIP?

What is our resource availability?

MES

Current & Historical Data

ERP

Did we make our targets?

What is our current demand?

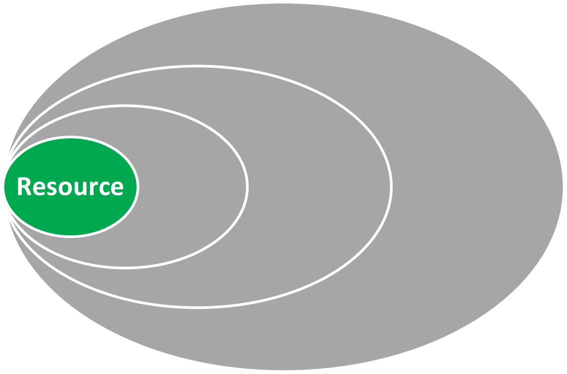
What is our current service level?

Forward looking
What-if analysis
Compare alternatives
Make the decisions
Process review & design
Predict performance
Schedule the operations

Simio
Digital Twin

Resource Level Model

- For an isolated resource to perform any single task, it must meet the following criteria
  - Resource is available
  - Required materials are available
  - Required secondary resources are available (e.g., tools, labor, etc.)
  - Any other required conditions are met
- Scheduling an isolated resource to perform any task requires the ability to check and satisfy all constraints (simply checking for availability is insufficient)

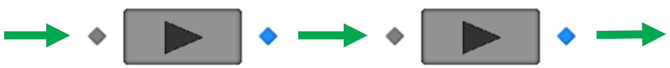


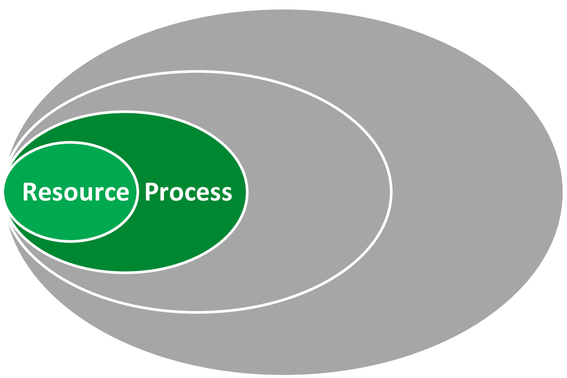
The foundation of a feasible schedule lies in the ability to simultaneously consider all resource criteria, even if they only apply to some tasks

Process Level Model

- For a simple sequential process containing multiple resources to perform any sequence of tasks, it must meet the following additional criteria
  - Resources must be unblocked, as they can now interfere with each other
  - Movement/transportation may apply
- Scheduling a sequential process requires consideration of space (e.g., 3-D) and time (e.g., an event calendar) to fully respect resource interdependence within the process

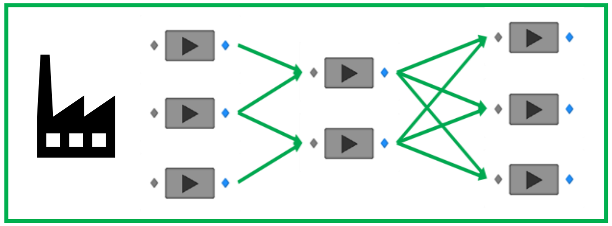
The resource criteria alone would be insufficient to create a feasible schedule for a process

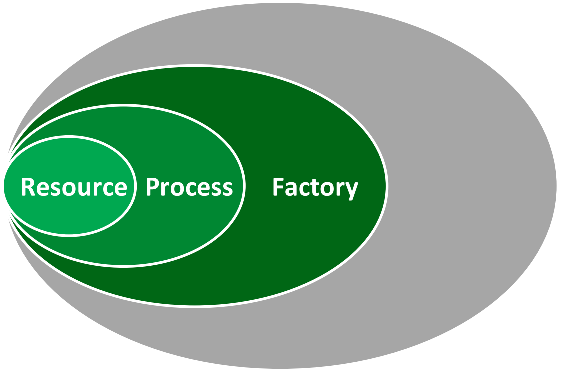




Factory Level Model

- For a factory containing multiple parallel and sequential processes to operate, it must meet the following additional criteria
  - Decisions must be made on how to sequence the demanded products
  - Decisions must be made on which resources to select for the demanded products
  - Resources and processes must pass any logical conditions related business or operating rules (e.g., power grid can't support all 10 ovens simultaneously)
- Scheduling a factory has the following additional requirements
  - Dispatching logic to correctly sequence the demanded products
  - Selection logic to choose the appropriate resource from a group of candidate resources
  - Complex logic to capture system level constraints

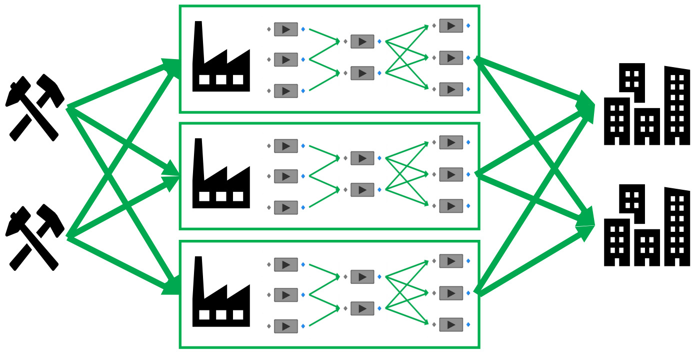


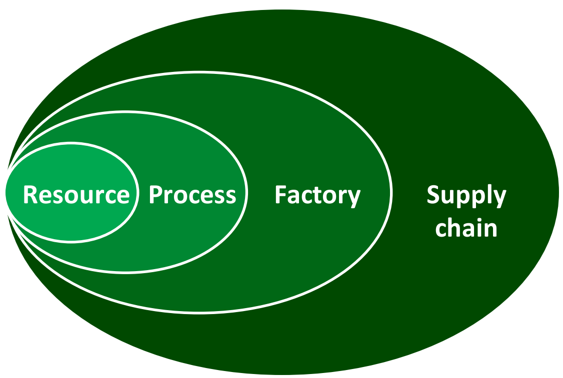


The capacity of the factory is not fixed, rather, it depends on the product mix as well as how the mix is scheduled

Supply Chain Level Model

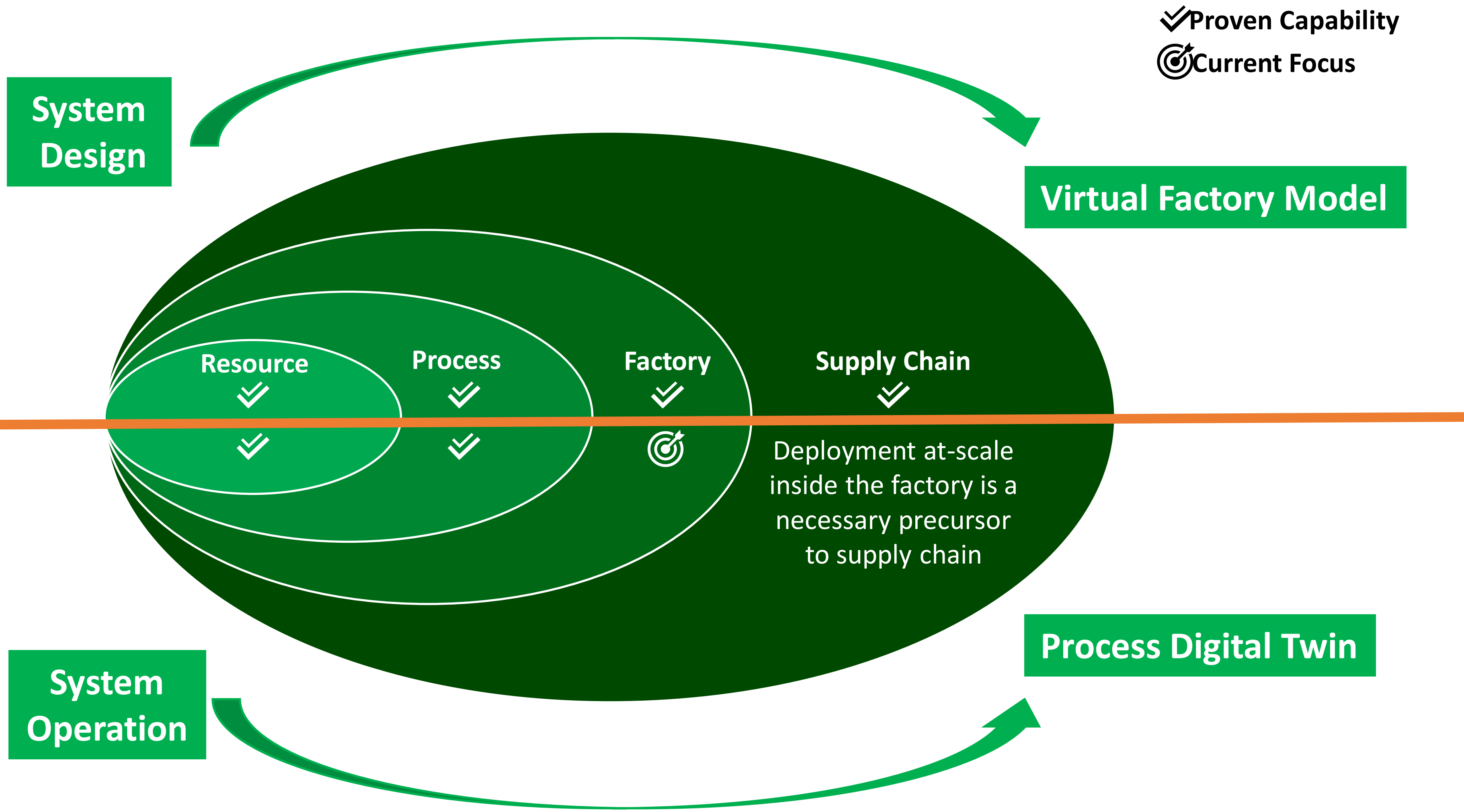
- For a supply chain containing multiple factories to function, it must distribute demand to the factories.
- To distribute demand, the supply chain must understand the capacity of each factory (i.e., the demand can only be satisfied if it can be feasibly produced by the specified factory).
- Because the capacity of the factory depends on the demanded product mix, as well as how it will be scheduled, the factory schedule and the supply chain are interdependent.
- Planning an integrated business process requires a unified standard.





Simio is uniquely designed to provide the standard from the resource level through the supply chain level

The Simio Process Digital Twin Integrates Four Levels of the Process



Simio RPS Deployment

Simio
Forward Thinking

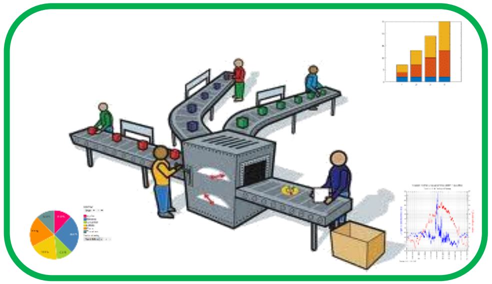
▶Design *(Understanding the Factory)*

- Collect current and historical data plus time study data.
- Statistical analysis, create distributions and probabilistic events.
- Extract process logic and decision rules (experience) from people.
- Virtual Factory Model for design and system analysis.
  - Resources & material constraints
  - Labor, tools & transportation constraints
  - Process logic & decision rules (knowledge)

MES Systems

ERP Systems

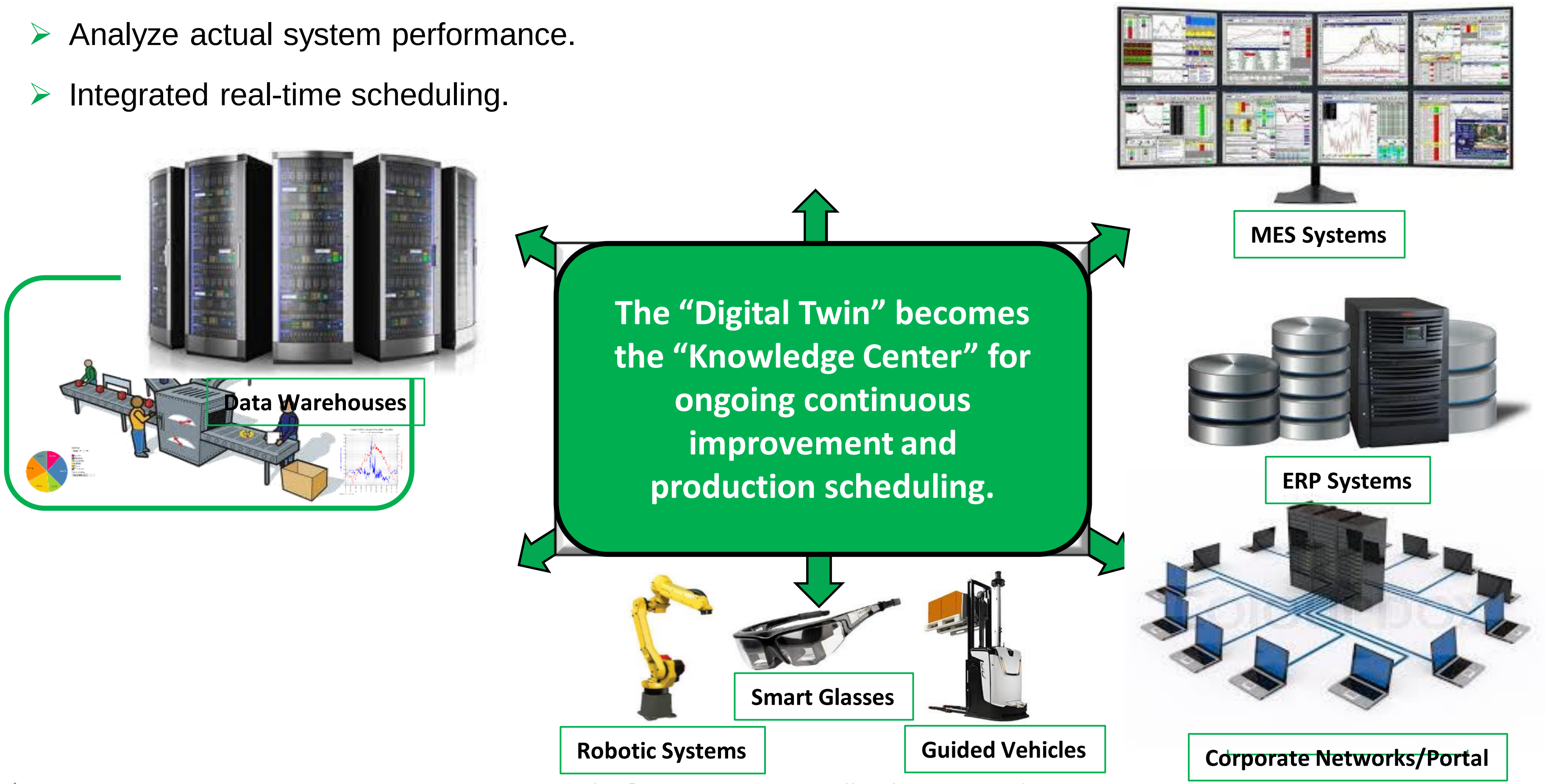
User Based Systems



Simio RPS Deployment

▶Operate (*Enabling the Smart Factory*)

- Creating the “Process Digital Twin”.
- Standardize and correlate the data.
- Analyze actual system performance.
- Integrated real-time scheduling.



Utilizing the Simio RPS Schedule

Simio
Forward Thinking

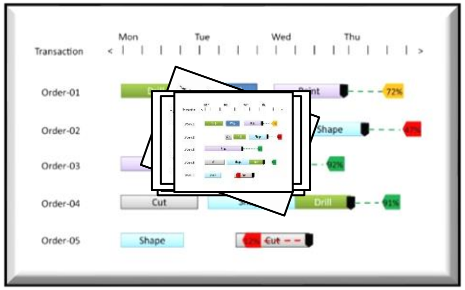
Public Portal

MES Systems

Printer

Data Warehouses

ERP Systems



User Based Systems

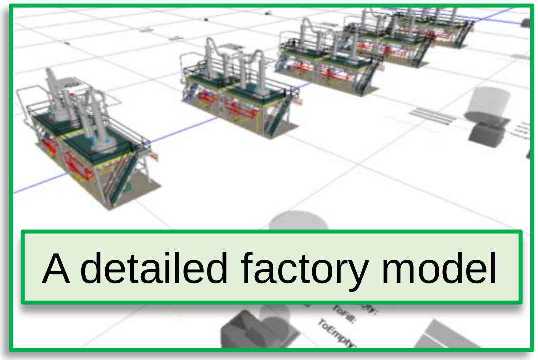
Automation

Corporate Networks/Private Portal

The Solution in Simple Terms

Simio
Forward Thinking

1

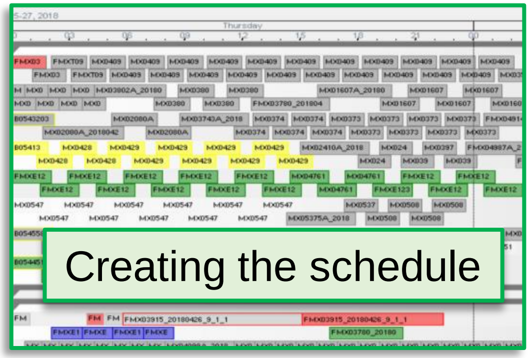


2

Order Id	Customer	Concentration_Pct	Flavoring	Material Name	Release Date	Due Date
Order_01	Sweet Julie	20	Cinnamon	Disk	6/1/2018 12:00:00 AM	7/1/2018 12:00:00 AM
Order_02	Sweet Julie	50	RootBeer	Barrel	6/1/2018 12:00:00 AM	7/1/2018 12:00:00 AM
Order_03	Sweet Julie	60	RootBeer	Barrel	6/1/2018 12:00:00 AM	7/1/2018 12:00:00 AM
Order_04	Sweet Julie	50	ButterScotch	Ball	6/1/2018 12:00:00 AM	7/1/2018 12:00:00 AM
Order_05	Sweet Julie	50	Cinnamon	Ball	6/1/2018 12:00:00 AM	7/1/2018 12:00:00 AM
Order_06	Sweet Julie	10	Cinnamon	Disk	6/1/2018 12:00:00 AM	7/1/2018 12:00:00 AM
Order_0						12:00:00 AM
Order_0						12:00:00 AM
Order_0						12:00:00 AM
Order_1						12:00:00 AM
Order_1						12:00:00 AM
Order_12	Healthy Tr...	10	RootBeer	Barrel	6/1/2018 12:00:00 AM	7/7/2018 12:00:00 AM

Connected to, generated from, and driven by your data

3



Dispatch List Report

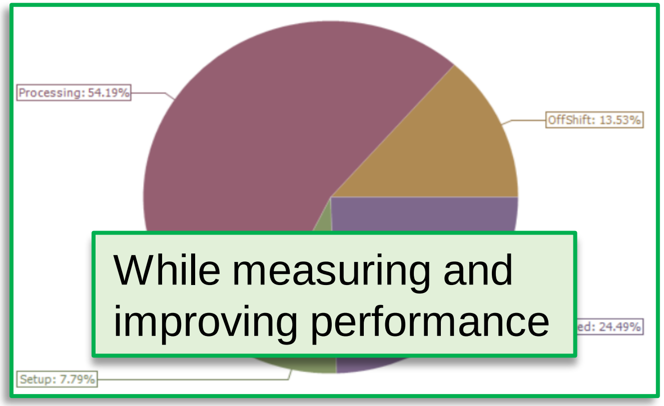
Scheduled Resource

Distiller1

Order Id	Scheduled Quantity	Scheduled Start Time	Scheduled End Time
Order_02	1200	6/1/2018 6:01:49 AM	6/1/2018 10:04:09 AM
Order_27	7800	6/1/2018 5:06:57 PM	6/3/2018 3:19:50 AM
Order_09	9000	6/3/2018 3:19:57 AM	6/4/2018 5:34:45 PM
Order_21	6800	6/4/2018 5:34:52 PM	6/6/2018 12:26:09 AM
Order_05	5200	6/6/2018 12:26:15 AM	6/6/2018 3:25:59 PM
Order_10	12000	6/6/2018 3:26:06 PM	6/7/2018 7:34:10 AM
Order_13			/2018 4:06:57 PM
Order_14			/2018 2:12:15 AM
Order_20			/2018 6:16:36 PM
Order_28	16700	6/8/2018 6:16:43 PM	6/11/2018 10:23:50 AM

Enabling execution

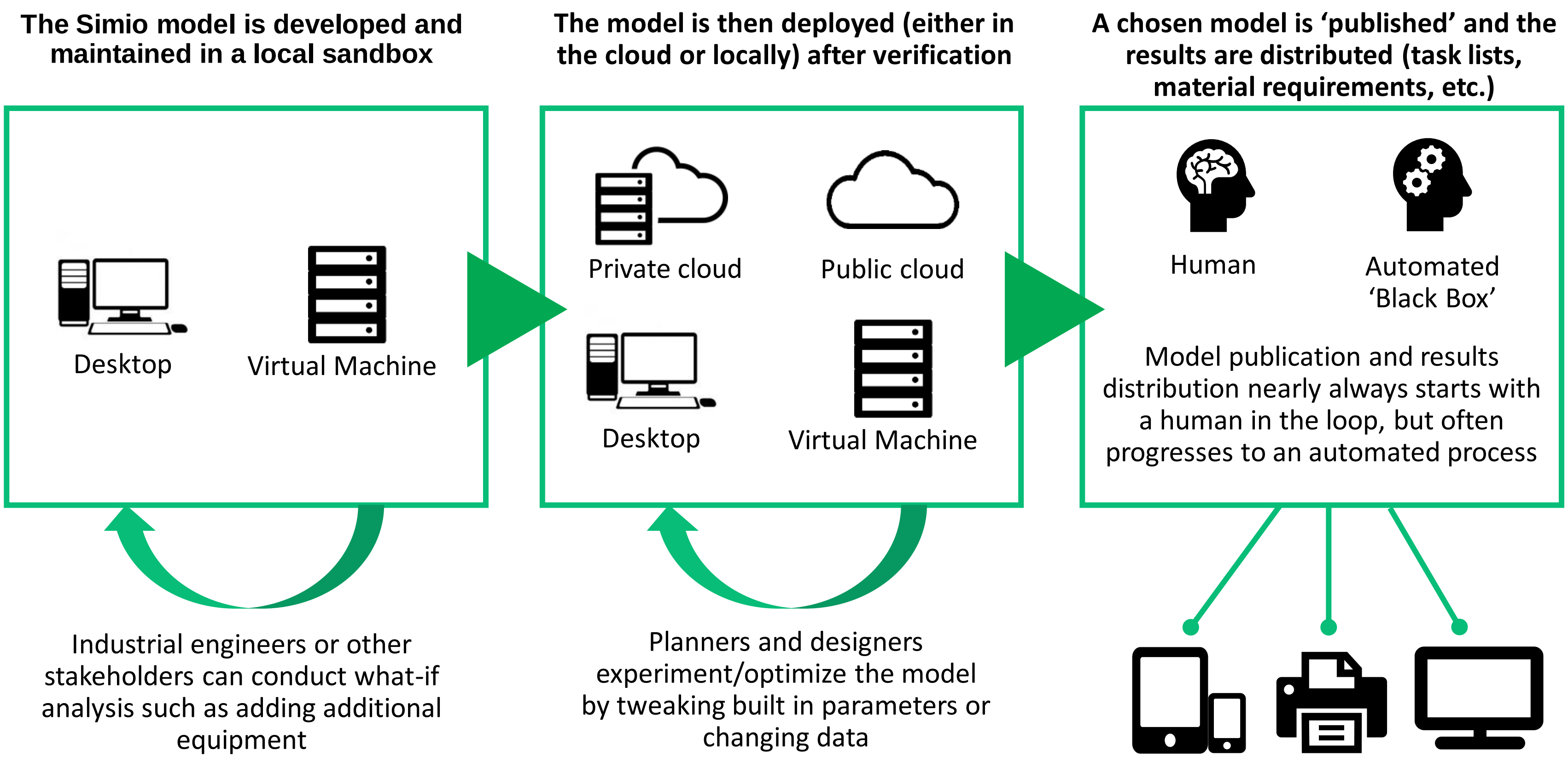
4



5

Simio can be deployed to organizations at any level of digital maturity

Simio Forward Thinking

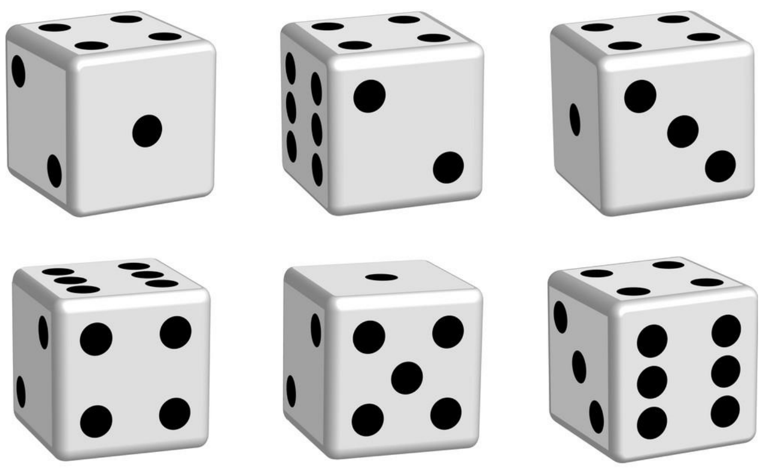


Enabling Technologies

- Accurately captures ***Complexity***
  - Complex Material Handing
    - Cranes, robotic equipment, transporters, workers, etc.
  - Specialized Operations / Resource Allocations
    - Changeovers, sequence dependent setups, operators, etc.
  - Experience-based Decision Logic and operating rules
    - Order priorities, work selection rules, buffering, order sequence, etc.

Enabling Technologies

- Effectively deals with ***Variability***
  - Breakdowns and Unplanned events
  - Worker and Resource schedules
  - Setup, Processing and Teardown times
  - Material and Order arrivals
  - Quality issues

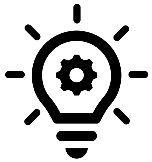


Enabling Technologies

Simio
Forward Thinking

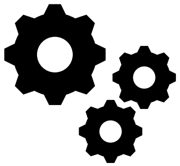
Digital Twin models are generated and driven by data

1 — Data Generated



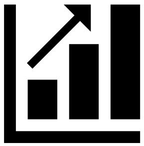
- The processes and objects in the factory are defined by data
- Processing time, capacity, constraints, changeovers, secondary resources
- Enables instant scalability – objects can be reused across facilities

2 — Data Driven



- Connect the model to enterprise data to read in up-to-date orders information, WIP, inventory
- Creates a feasible schedule by simulating the flow of products through the system in time

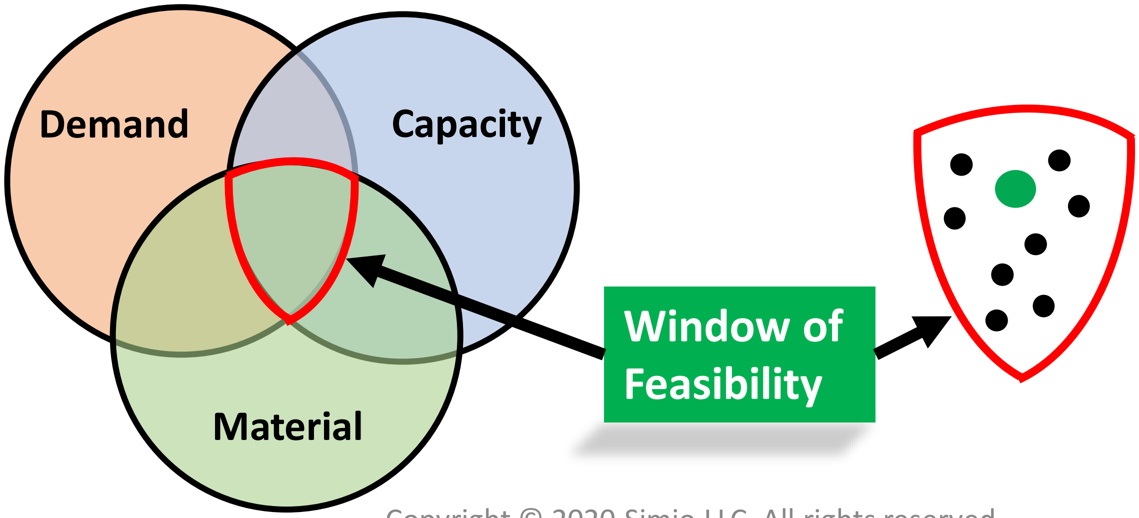
3 — Intelligent Execution



- Tweak model parameters based on planner expertise and current status, then publish and distribute the results
- Automate the process once fully validated and all execution level data is available in real time

Enabling Technologies

- **Schedule *Feasibility* is** ensured because the problem is solves concurrently
  - Simultaneous, in memory, solving for:
    - Demand (sales order, stock orders, production orders, etc.)
    - Capacity (workers, machines, transporters, cranes, etc.)
    - Material (raw material, purchased material, intermediate material, etc.)
  - Simio can then optimize to selected business KPIs within the window of feasibility to ensure shop floor execution is always possible

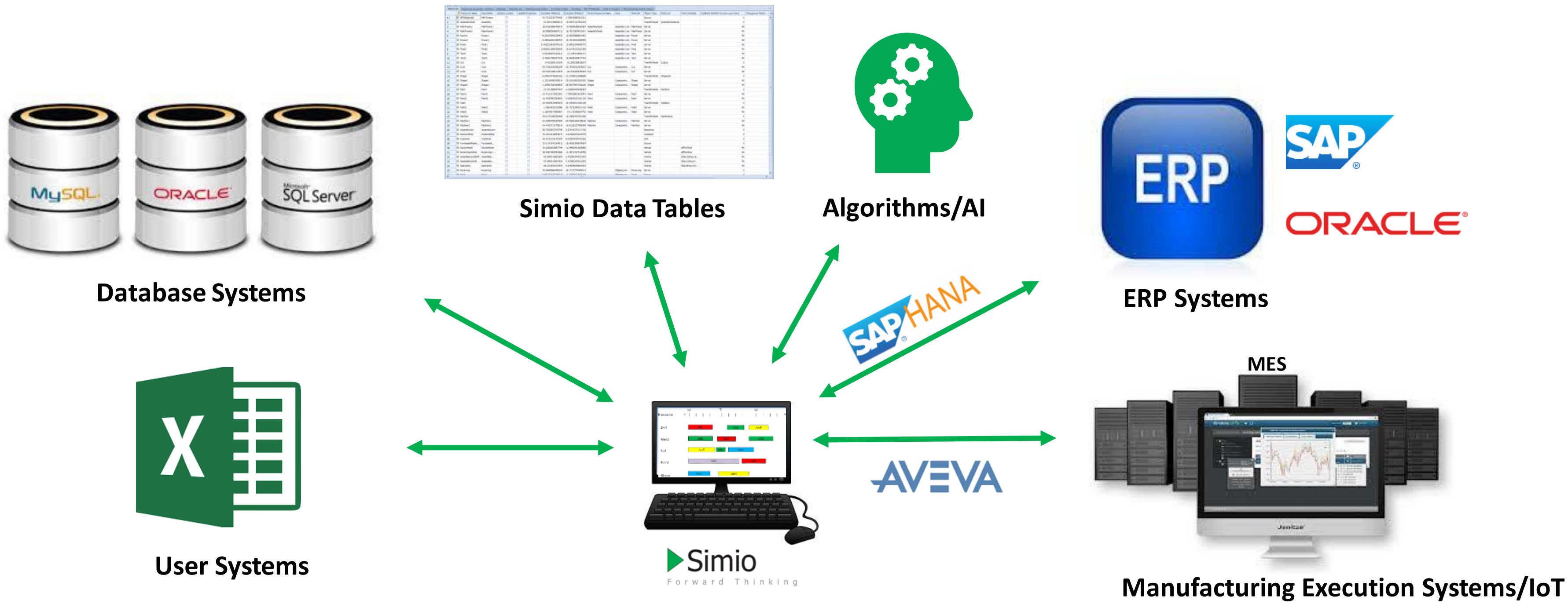


Employ OptQuest (or other external solver) to search applicable parameters within the feasible space for the best plan to meet the desired KPIs

Enabling Technologies

▶ Provides for ***Interoperability*** between systems

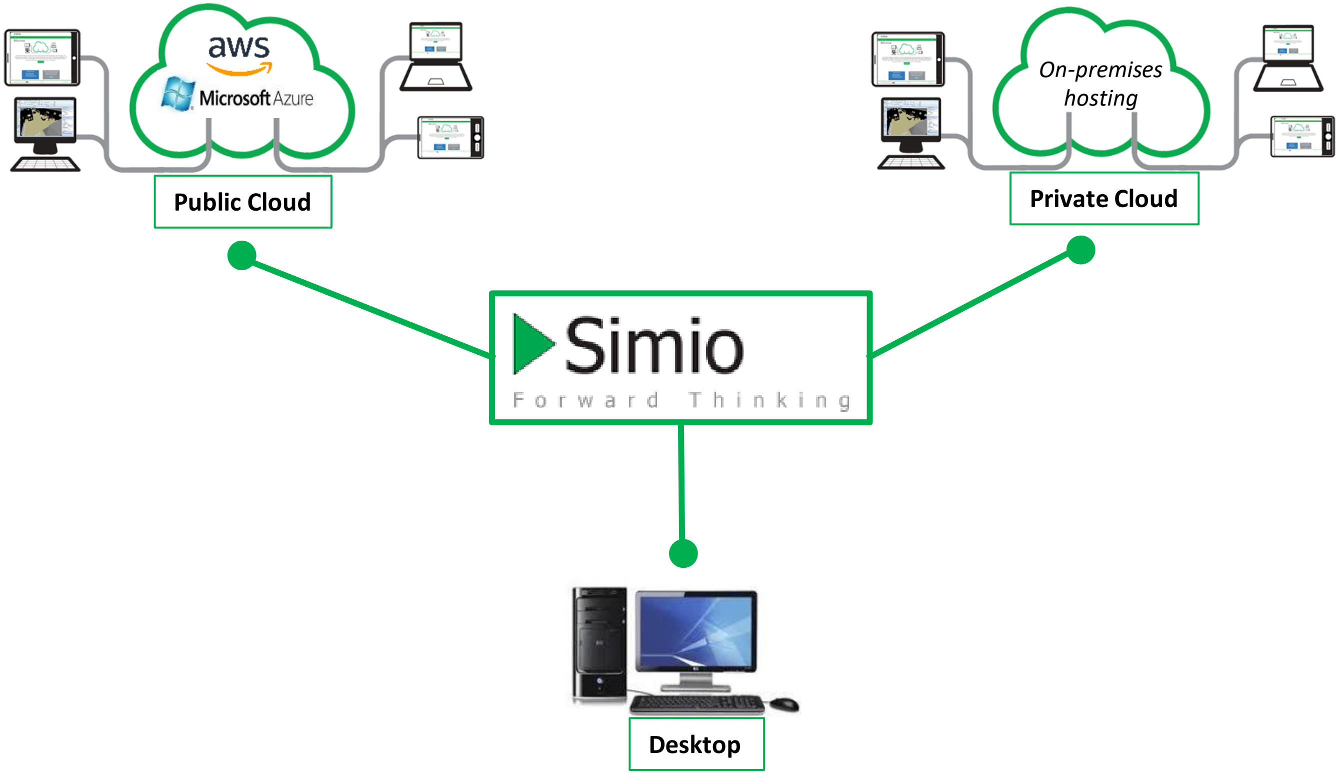
- Manual data entry
- Excel and CSV table binding (Excel)
- Database table binding (SQL/Oracle, etc.)
- External Solvers, Algorithms and AI tools
- XML transformation (ERP/SAP/Oracle, etc.)
- Connecting to Wonderware MES (or others) using the standard API



Enabling Technologies

▶ Flexible Deployment

- Desktop
- Public Cloud Deployment (e.g., Azure)
- Private Cloud Deployment (on-premises)



Value of the process "Digital Twin"

- Visualize the production process (current & future)
- Standardize data and systems
- Harmonize people and processes
- Validate & correlate the operational data
- Predict and optimize future performance against KPIs
- Evaluate alternatives (operational policies)
- Generate & distribute feasible schedules (task level)
- Understand the impact of any ongoing changes:
  - New product introduction
  - Adding production capacity to the line (new equipment)
  - Changing worker skill and shift patterns
  - Material availability and inventory policies (JIT, Kanban, etc.)

Case Study
Fast Moving Consumer Goods

Production Site Executive:

"…corporate sends two-week SAP master plans, I cut the master plan by 20% because my schedulers know my plant does not have enough capacity to meet demand."

"My master schedulers then target hitting 90% of the 80%…"

Note: 90% of 80% means their ***target*** is to perform at **72%** of what SAP expects and has procured supplies for.

Examples Of Realized Value

Design Successes

- Vancouver Airport – Simio saved $100 million by avoiding unnecessary terminal expansion
- Retirement Clearinghouse – Simio shows Americans can add $115 billion to their savings with auto portability
- KCS Rail improved throughput by 13% across a bottleneck resource
- John Deere – Simio forecasted a savings of $240,000 by re-assigning tasks to workers across floor
- Cosan - Simio predicted unnecessary sugar cane transport purchases that saved $550,000
- Virgin Airlines - Simio discovered in time that a new gate plan would decrease on time performance by 50 points and drop them from 1st place market leader to 2nd place

Scheduling Successes

- Royal Dutch Shell – Simio is at the core of a system that saves $300 million per year with logistics efficiency
- Air Force – Simio increased process output 30% that increased revenue $10.35 million
- John Deere - Simio production scheduling tool was used to create a feasible schedule with WonderWare MES
- BAE Systems – Simio helped meet production deadlines and decrease overtime
- Alcoa –Simio is used for their smelter (Potroom and Casthouse) and generates good, feasible schedules
- Denmark Hospitals - Simio handles detailed planning because it calculates an optimal plan for execution, based on a simulated model of the facility, with WonderWare MES

Simio
Forward Thinking

For more information:

www.simio.com

Dave Sturrock
dsturrock@simio.com
Linkedin.com/in/sturrock/