Big Data in Manufacturing: The Era of Smart Manufacturing Networks

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AGENDA

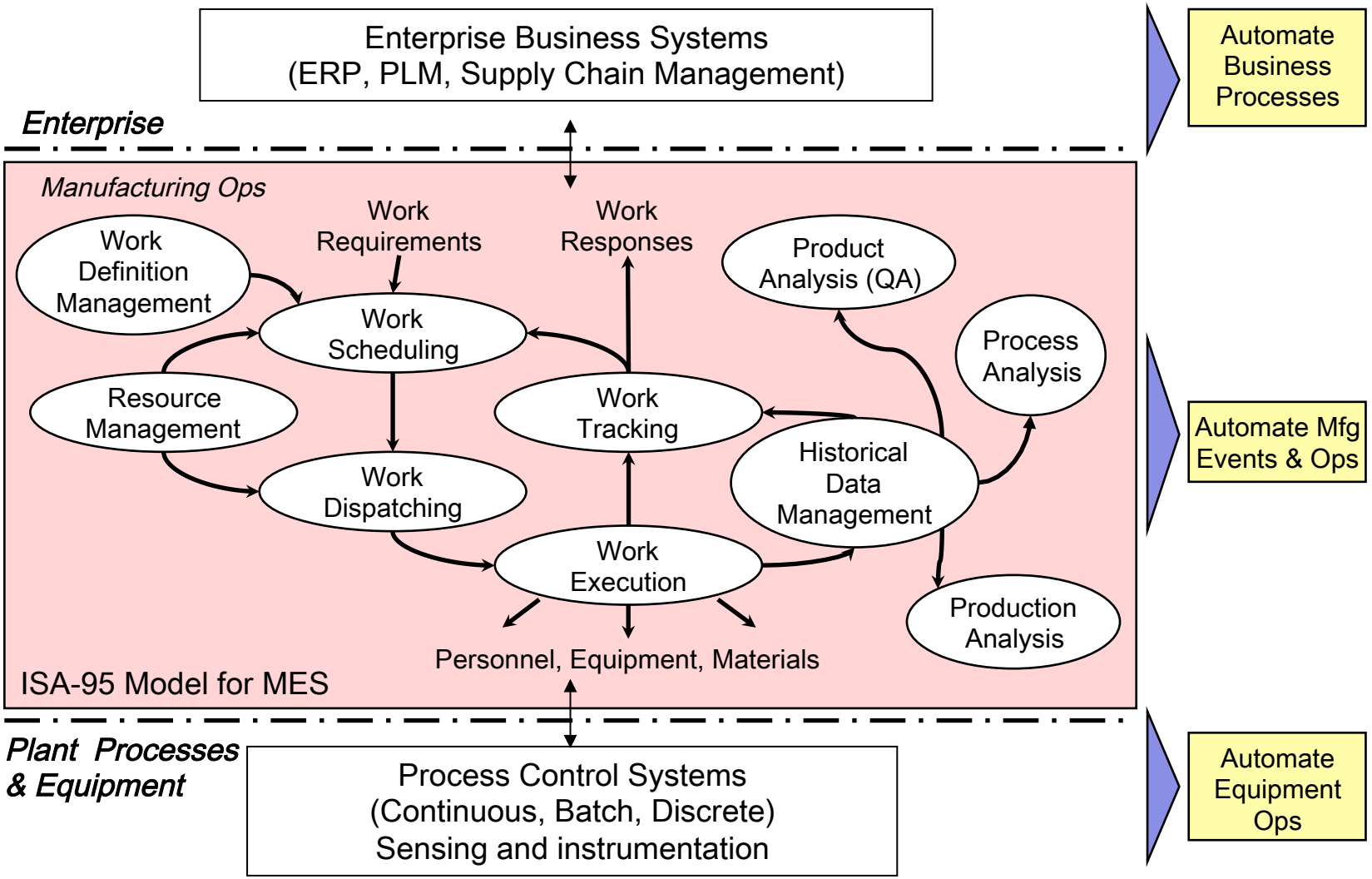
- Overview of the Situation
- Smart Manufacturing Networks
- Example: The Manufacturing Blueprint Model
- Closing Remarks

Overview of the Situation

Manufacturing Barriers to Achievement

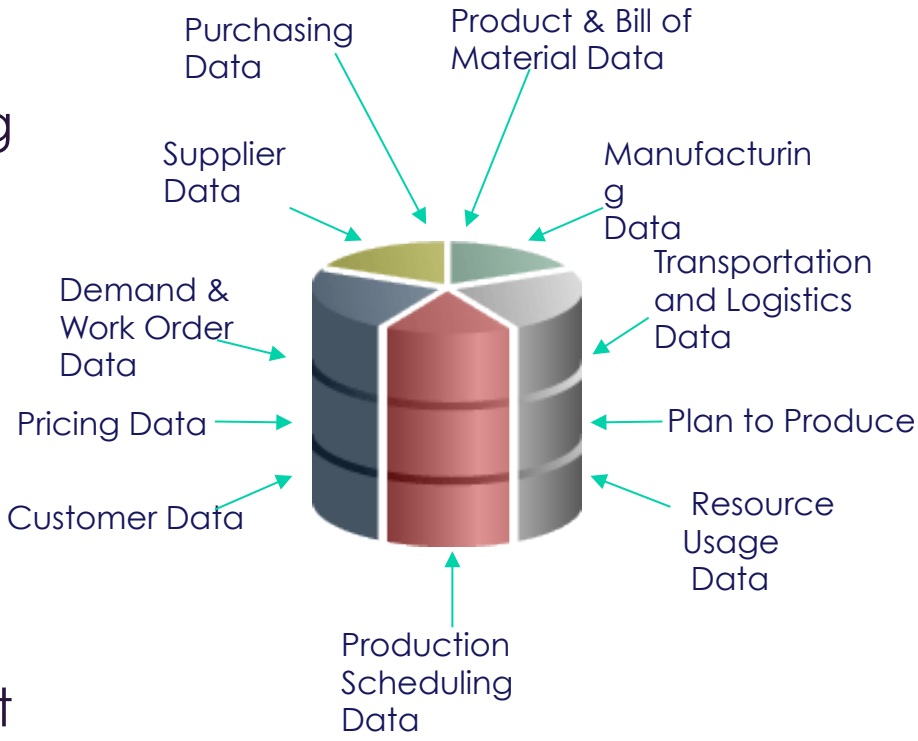
KEY CHALLENGES	EXPLANATION
Manufacturers need to track, and trace products from "cradle to grave", i.e., from raw materials and work in progress to finished products.	• Manufacturing data, operations & processes should be integrated to link toward a shared manufacturing goal. • Dislocated assembly lines must be directly related to mfg management …uction planning & control.
Disconnect between Business & Shop Applications	…Management are Complementary …nterface offering analytics for executive decision
Disconnect between PLM & Manufac	…raditionally centered around Product Development
Limited point-to-point connections bet… Business IT & Factory Automation	…o timely reaction to problems & changes
Lack of visibility into plan to produce p… help eliminate bottlenecks	…production attainment to plans, plant performance …ons in current performance & root cause analysis …n the production process …urce and material usage and variances
Unable to identify work order performance related to on-time completions and quality	…l work orders that are stuck and need to be expedited • Little visibility into work order cycle times and work order aging of open orders • Track execution of "perfect work orders" that are on-time and high quality

Factory Model: Connect Enterprise to Shop-Floor

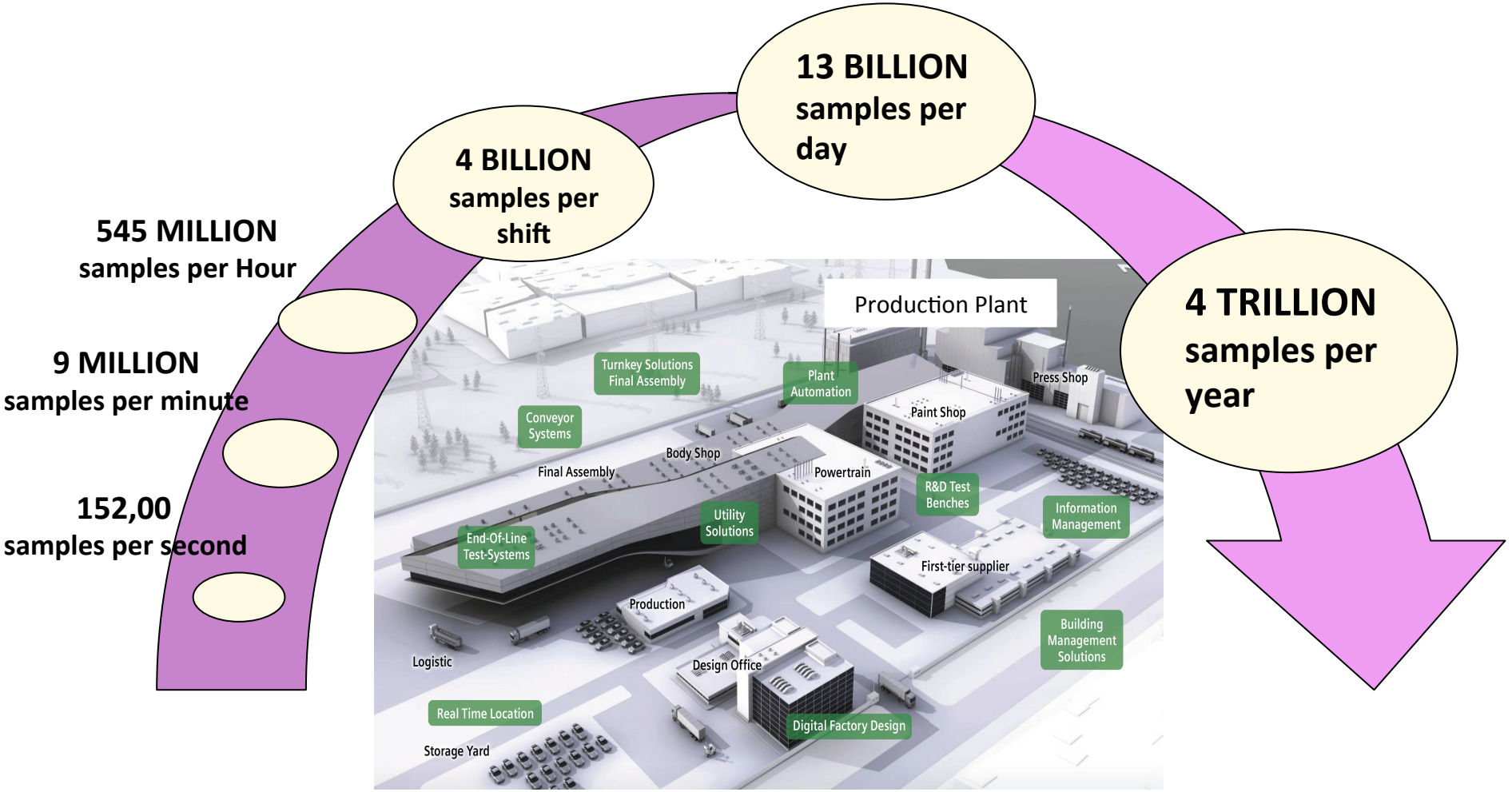


Manufacturing & Big Data

- A mfg plant uses digital sensors, intelligent motors, computerized machines, robotics, & other technology to manage each specific stage or operation of a mfg process.
  - These complex manufacturing systems are increasingly generating masses of data accessed by a growing # of devices.
- Data analysis is the foundation for information sharing & decision making solutions that enable operators & business analysts instant access to plant data no matter where they are located.



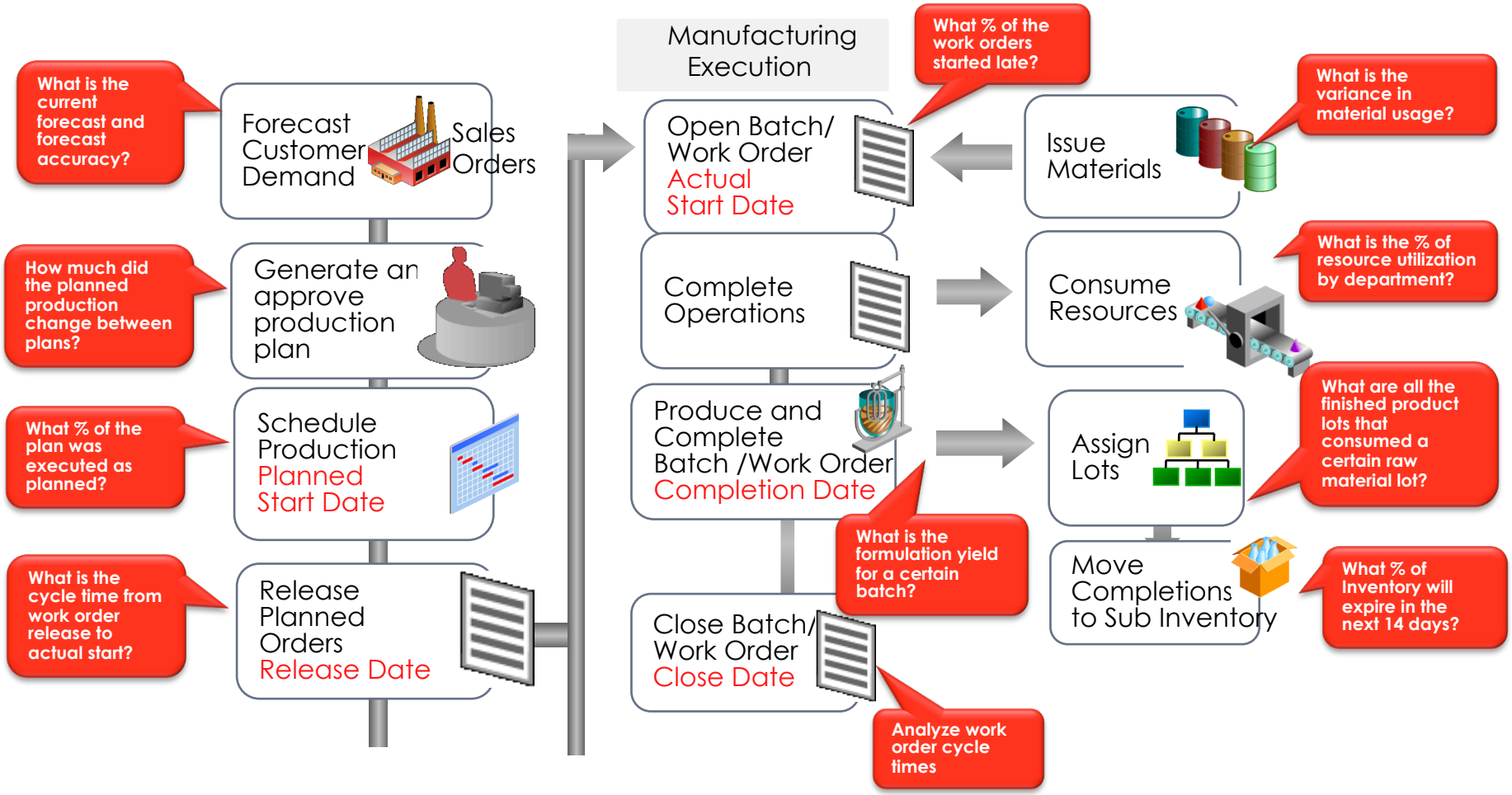
Production Plant Data



The above figures reflect the data generated from just one of many machines that produce a particular consumer packaged product, underscoring the sheer volume of data created by industrial companies.

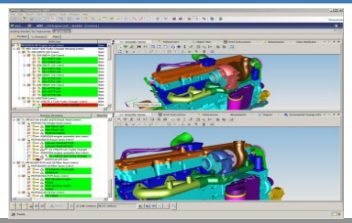
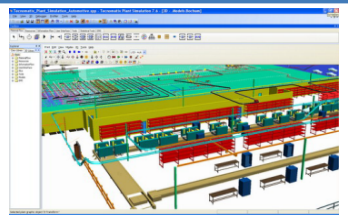
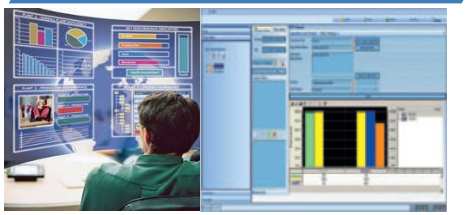
Source: GE Intelligent Platforms.

The Need for Analytics



Smart Manufacturing Networks

Manufacturing IT Solutions

Product Design	Production Planning	Plant Automation	Production Execution
			
▪ Body design ▪ Assembly configuration ▪ Packaging ▪ Powertrain design ▪ Supplier collaboration ▪ BOM management	▪ Production Cell Design ▪ Assembly sequence ▪ NC Programming ▪ Offline Robot programming ▪ Process Simulation ▪ Building layout	▪ SW engineering ▪ HW engineering ▪ Construction ▪ Installation ▪ Commissioning	▪ Detailed Order Scheduling ▪ Resource management ▪ Track & trace ▪ Production monitoring ▪ Performance analysis ▪ Warehouse mgmt. ▪ Quality management

Faster Time-to-Production:
Faster vehicle/ variant design process & early data availability for production planning

Faster design /engineering of plant automation:
Integration of automation in digital environment – "virtual commissioning"

Efficient Production Execution:
Integrated production data management from ERP to Shop Floor

Efficient Management of changes in product design and production:
Closed-feedback-loop for product design and production execution
Data consistency throughout the entire product life cycle

Source:

Manufacturing Networks

- A *Mfg Network* is a permanent or temporal coalition comprising production systems of geographically dispersed OEMs or 1st/2nd tier suppliers that collaborate in a shared value-chain to conduct joint manufacturing.
- Enhancing mfg network visibility, information sharing & mfg process integration are major contributors to effective managing manufacturing networks.
  - Each partner in the network produces *one or more product part(s)* assembled into final service-enhanced products under the control of joint production schedule, while keeping its own autonomy.
  - *Production schedules* are monitored & optimized collectively to accomplish a shared manufacturing goal.

Smartness in Manufacturing

Manufacturing Smartness is:

- Gaining line of sight, optimizing use of dispersed resources & expertise, & planning a coordinated response to individual (partner) & collective (network) manufacturing needs.

Increasing intelligence of machinery and production lines decreases the need for human intervention in manufacturing processes.

Seven Steps to Smart Manufacturing Networks

Smart Manufacturing Networks: The RoadMap

1. Structuring & Leveraging Partnering Manufacturing Arrangements
2. Enablement of Manufacturing "Intelligence"
3. Embedding Manufacturing Analytics
4. Network Modelling, Simulation and Forecasting Methods and Tools
5. Building a Demand-driven Manufacturing Network
6. Network-wide Resource Integration & Optimization
7. Managing the Manufacturing Network Lifecycle

(1) Structuring & Leveraging Partnering Manufacturing Arrangements

Network-wide integration of partners, expertise & resources into collaborative manufacturing arrangements

① Vertical Integration

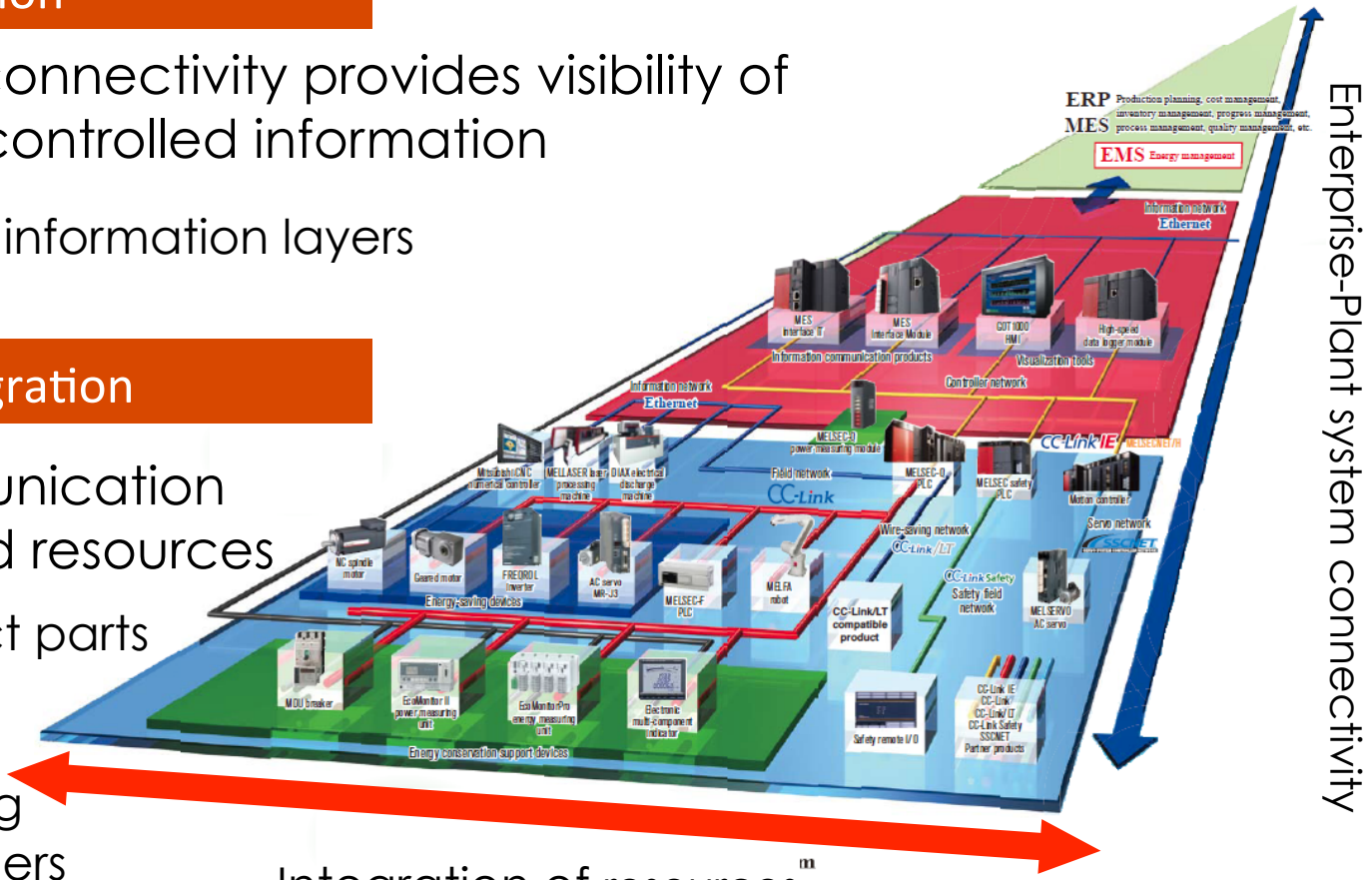
Enterprise-plant connectivity provides visibility of production and controlled information

⇨ Links different information layers

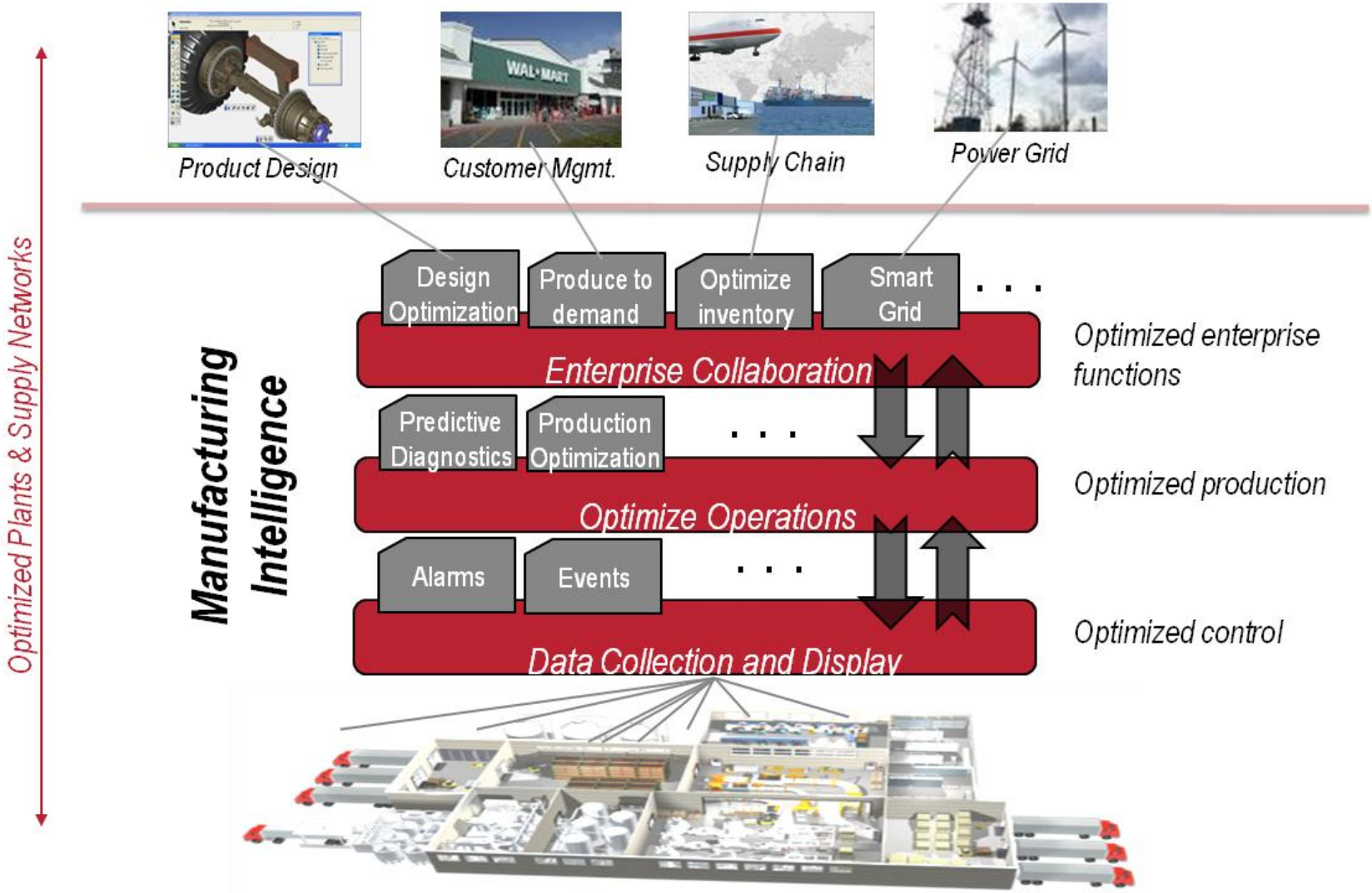
② Horizontal Integration

Seamless communication among dispersed resources

⇨ Linking product parts & processes throughout manufacturing network partners



(2) Smart Manufacturing is enabled by *Manufacturing Intelligence*



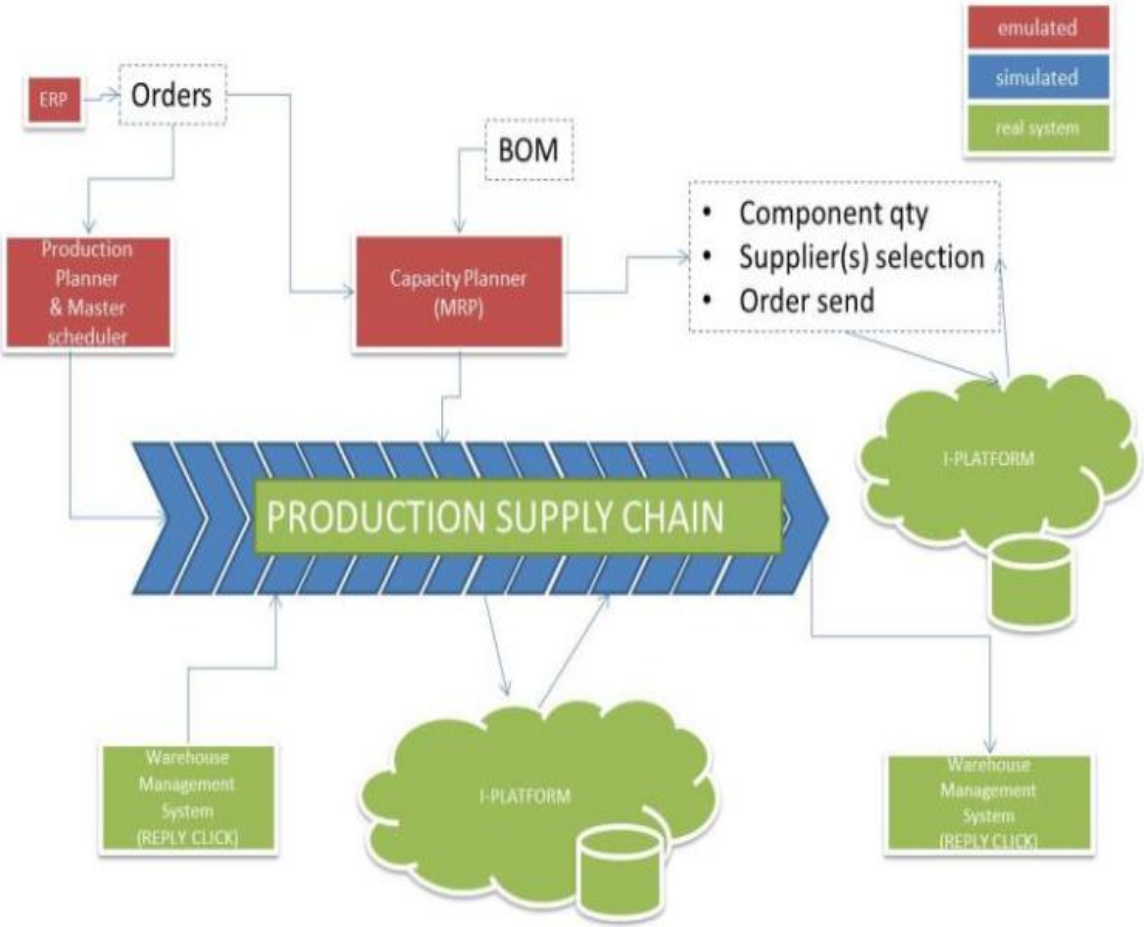
(3) Embedding Manufacturing Analytics & Predictive Diagnostics

Focus on Manufacturing Analysis

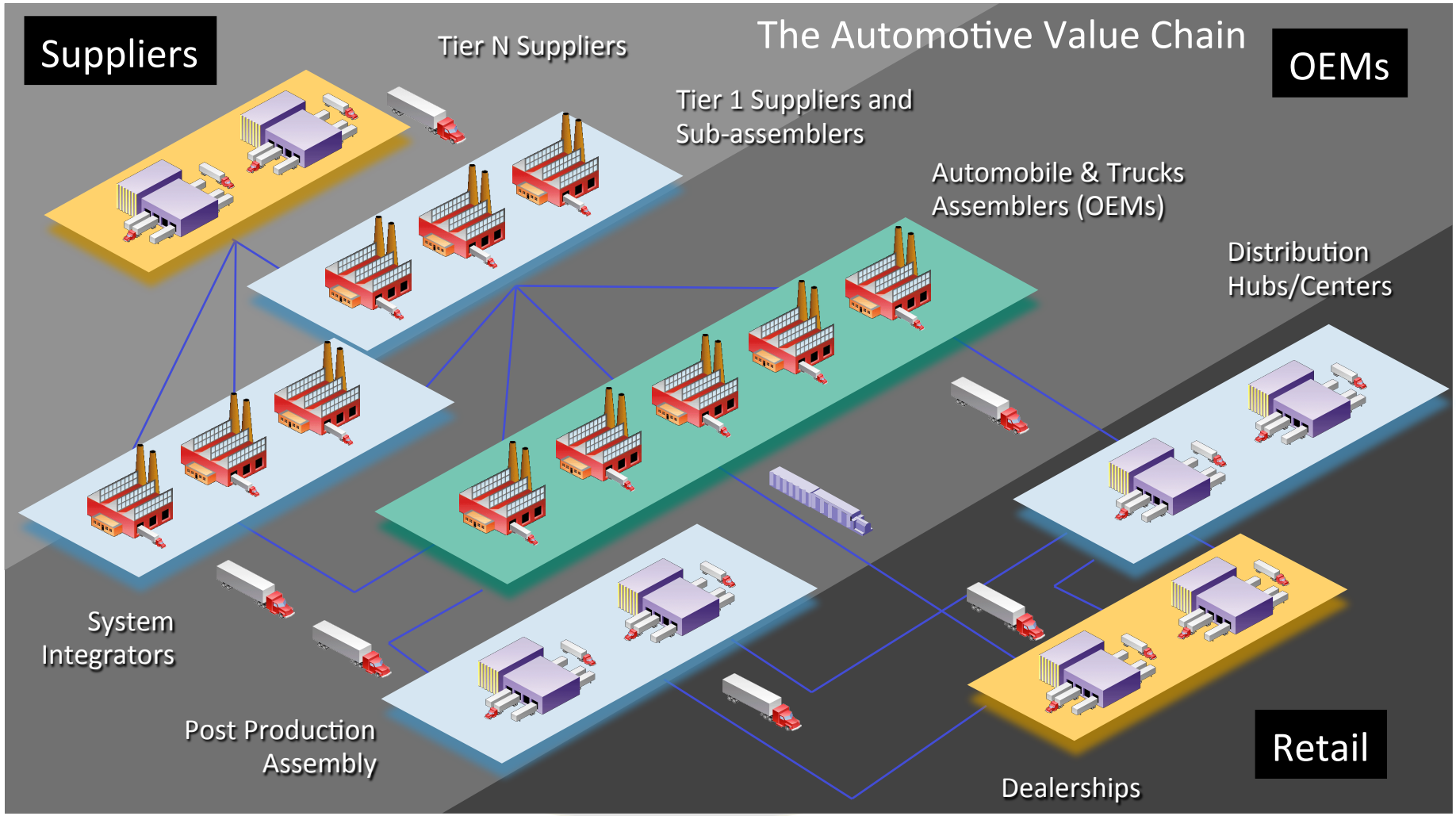
- Inside the factory, having the ability to utilize the mass of data on orders and machine status allows production managers to optimize ops, factory scheduling, maintenance, & workforce deployment.
- Data cross-correlation & KPI monitoring can help reduce defects & control costs of products.
  - Analytics can predict failure and downtime of assets in advance by comparing its historical data against current performance - looking at trends and patterns for signs of deterioration - to detect, diagnose and predict issues before they occur. This helps manufacturers retrace problems for better resolution..

(4) Network Modelling, Simulation & Forecasting Methods & Tools

- Modelling & simulation for the management of integrated product-process-production systems:
  - Achieving sustainable mfg requires methods and tools for modelling, simulating and forecasting the behaviour of production processes, resources, systems, factories & mfg networks during their life-cycle phases
- Virtual models spanning all levels of the mfg network & its life-cycle:
  - A holistic & coherent virtual model of the network & its production processes & machinery will result from the integration of modelling, simulation & forecasting methods & tools during all the phases of the network life-cycle

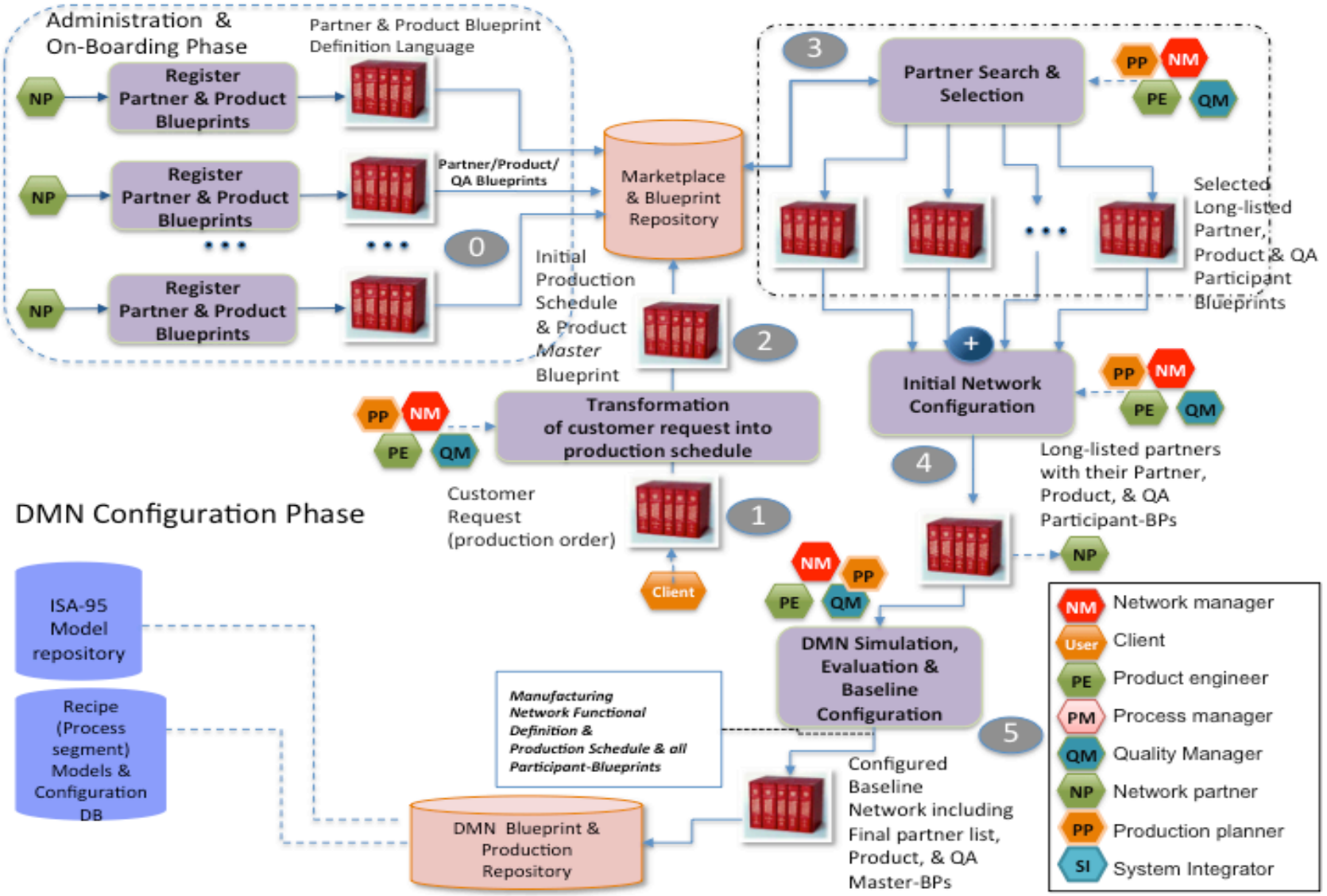


(5) Network-wide Resource Integration & Optimization



integrate data & processes

(6) Building a Demand-driven Manufacturing Network



(7) Managing the Manufacturing Network Lifecycle

Consumer

PHASE-1: Network Analysis & Configuration

PHASE-2: Network Design

PHASE-3: Network Execution Mgt & Monitoring

Consumer Request

STEPS:
- Identification, prioritization & aggregation of requirements
- Selection of partners

INPUT: Customer request

OUTPUT: Baseline Configuration, SCOR Level 2 Processes, Preliminary Production Schedule

STEPS:
- Transformation of the production schedule
- Decomposition of high-level processes
- Decomposition of process choreographies
- Mapping of orchestration processes to segments.

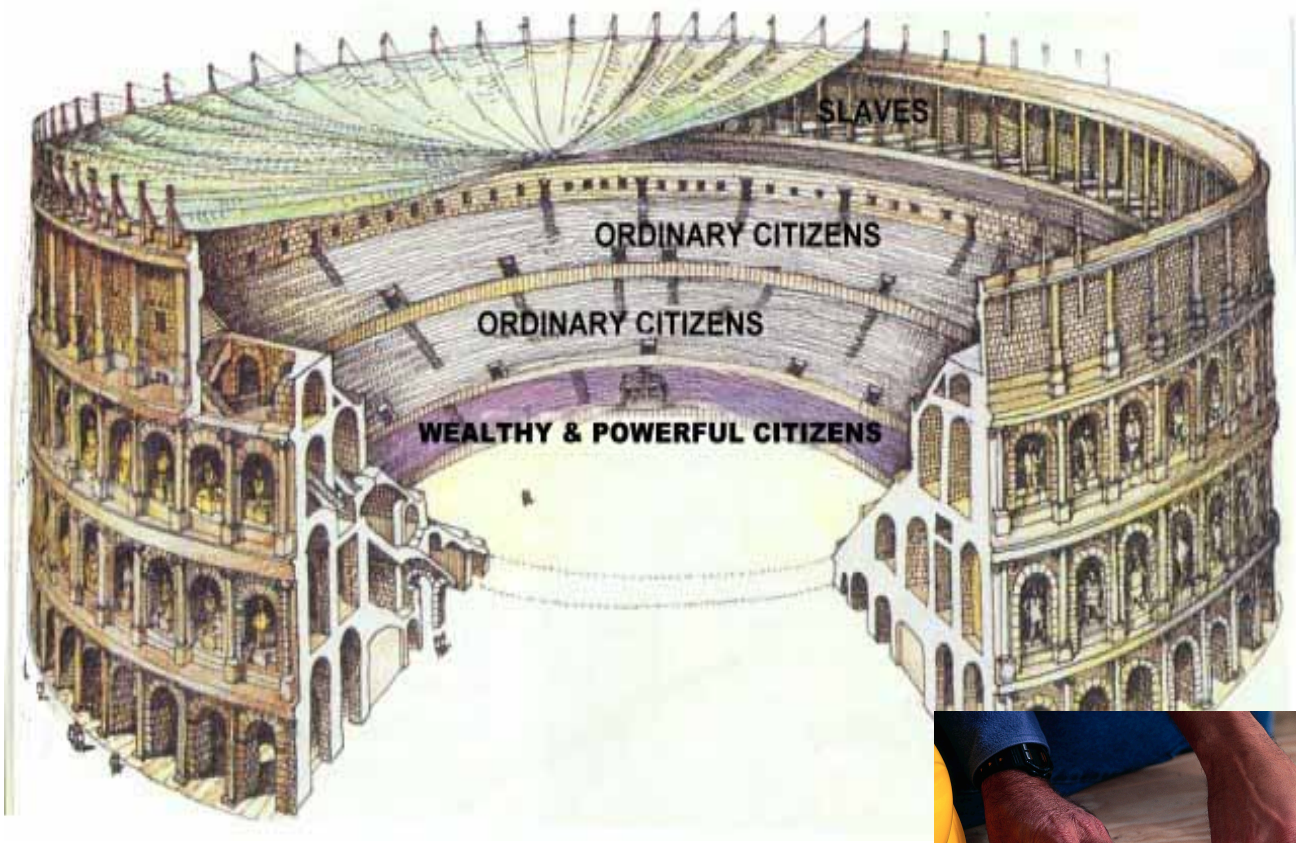
OUTPUT: Level 3-5 end-to-end processes, production schedule

STEPS:
- Process and production tracking
- Performance analysis
- Resource availability mgt
- Repair, adaptation & tuning

OUTPUT: executing MN & adaptation schedule.

Network refinement & improvement

Example: The Manufacturing Blueprint Model



The Manufacturing Blueprint Model: The Holy Grail

" Collection & use of engineering data in manufacturing facilities today is relatively inefficient due to the lack of standardized, easily usable data systems. Significant improvements are needed.
This includes better data protocols and interfaces and collecting, storing, reconciling, and using data across the manufacturing enterprise."

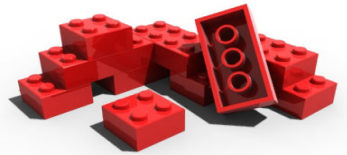
Smart Manufacturing Leadership Coalition "Implementing 21st Century Smart Manufacturing" 2011

Mfg Blueprints: From Dispersed to Structured Mfg Knolwedge

The Mfg Blueprint model:

Manages & cross-correlates segregated mfg knowledge about increasingly complex products comprised of machines, equipment, workplaces, personnel and software components with unique configurations that pertain to different product models & different market segments. It includes:

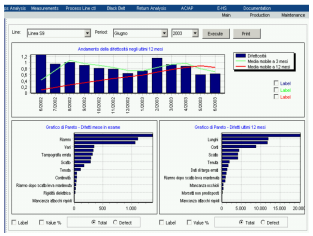
- A complete build record of individual products, traceable components, equipment, materials, assemblies and systems.
- "Should build" reference product structures & processes that can be used to verify the assembled product.
- A richer & more accurate product planning & definition throughout the mfg lifecycle.
- It defines a product as work-plans, parts lists, end-to-end processes, recipes, process instructions & product data sets that arise during product development.



4x4 MfG Model = Resources, Processes & Products

People/Partners

← Personnel & partner resources managed for production



Capability/Capacity

← What is available for use for production

Equipment

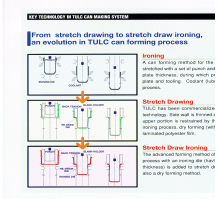
← Equipment resources managed for production

Product Definitions

← What is needed to make a product

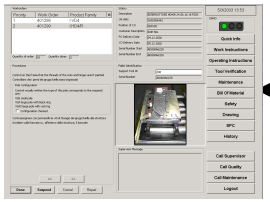
Production Matereials

← Material resources managed for production



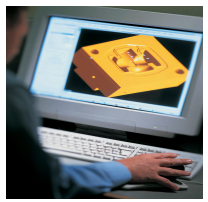
Production Schedule

← What to make & resources to use



Process Segments

← View of production flow processes



Production Performance

← What was made & which resources actually used

Four Resource Object Models

Capability, Product, Schedule, and Performance Info.

Partner & Product Blueprints

Partner Blueprint

- Capture unique skills and capabilities in the DMN and makes them available to potential partners to help address opportunities in new network configurations. It includes:
  - Company Background: contact information, size, annual reports, reference customer, financial growth and annual turn-over
  - Products / Services: types of product and services, market, industry sector, geographical region, type of material (BOM)/information needed (e.g., CAD data).
  - People: their skills, track record
  - Processes: key processes, key process skills,
  - New Potential: potential new products, case histories of other network collaborations,
  - Qualifications: name of standards awarded, patents, references to customers.

Product Blueprint

- Uses MBOM info. It includes the components, the equipment, elements of work procedures & associated resources needed to accomplish production requests:
  - Resource Definition Information –material, & equipment resource definitions used for production.
  - Product Definition Information –resources & segments required to make a product.
  - Environmental Information - CO2 footprints, greenhouse gas emissions, etc.
  - Production Schedule Information – minimizes production time & costs, by proving a production facility with info. regarding what to make, when, with which staff, and on which equipment.
  - Production Capability Information – current capabilities of production for equipment,& material. It also defines capabilities that are available for production.

End-to-end Process Blueprint

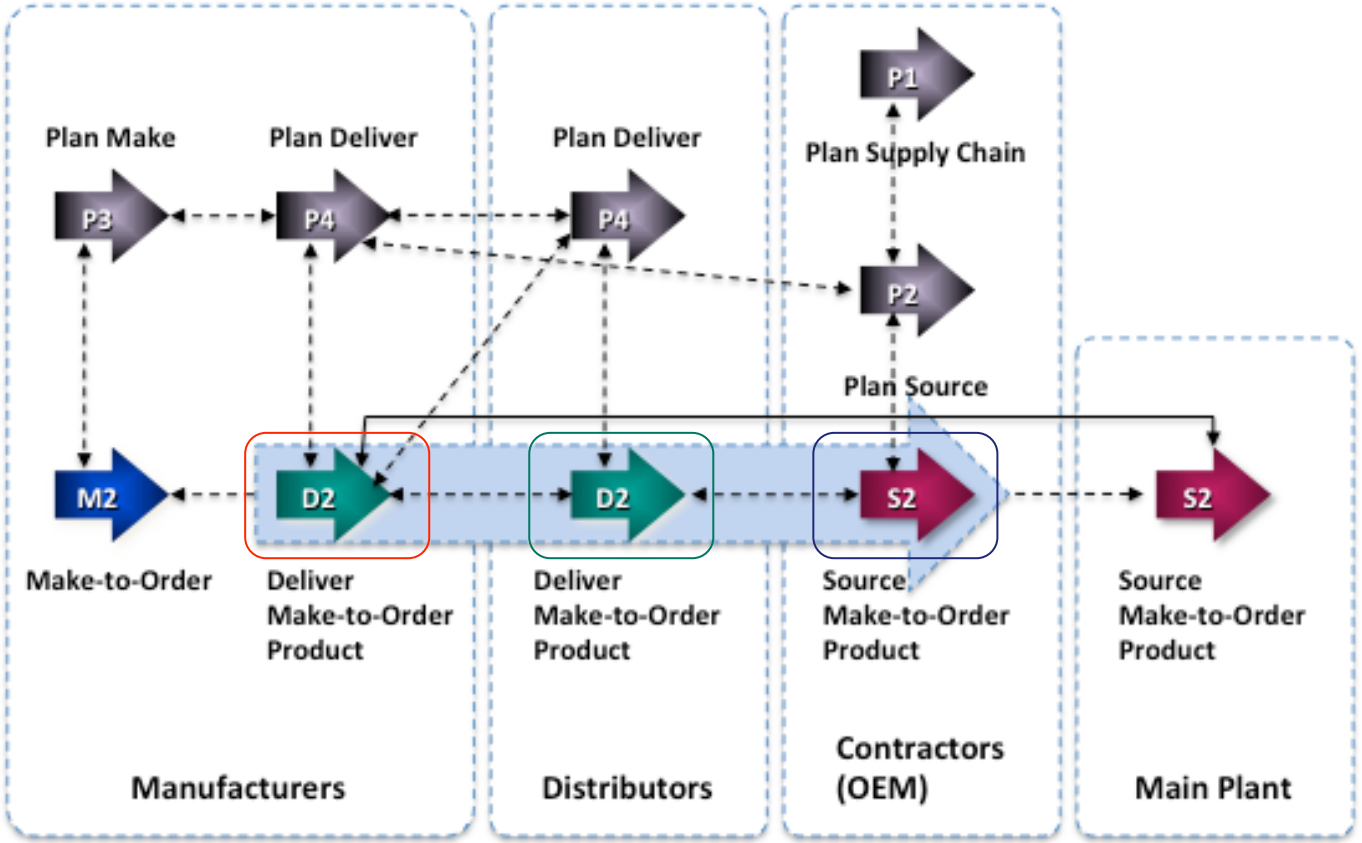
End2end Blueprint

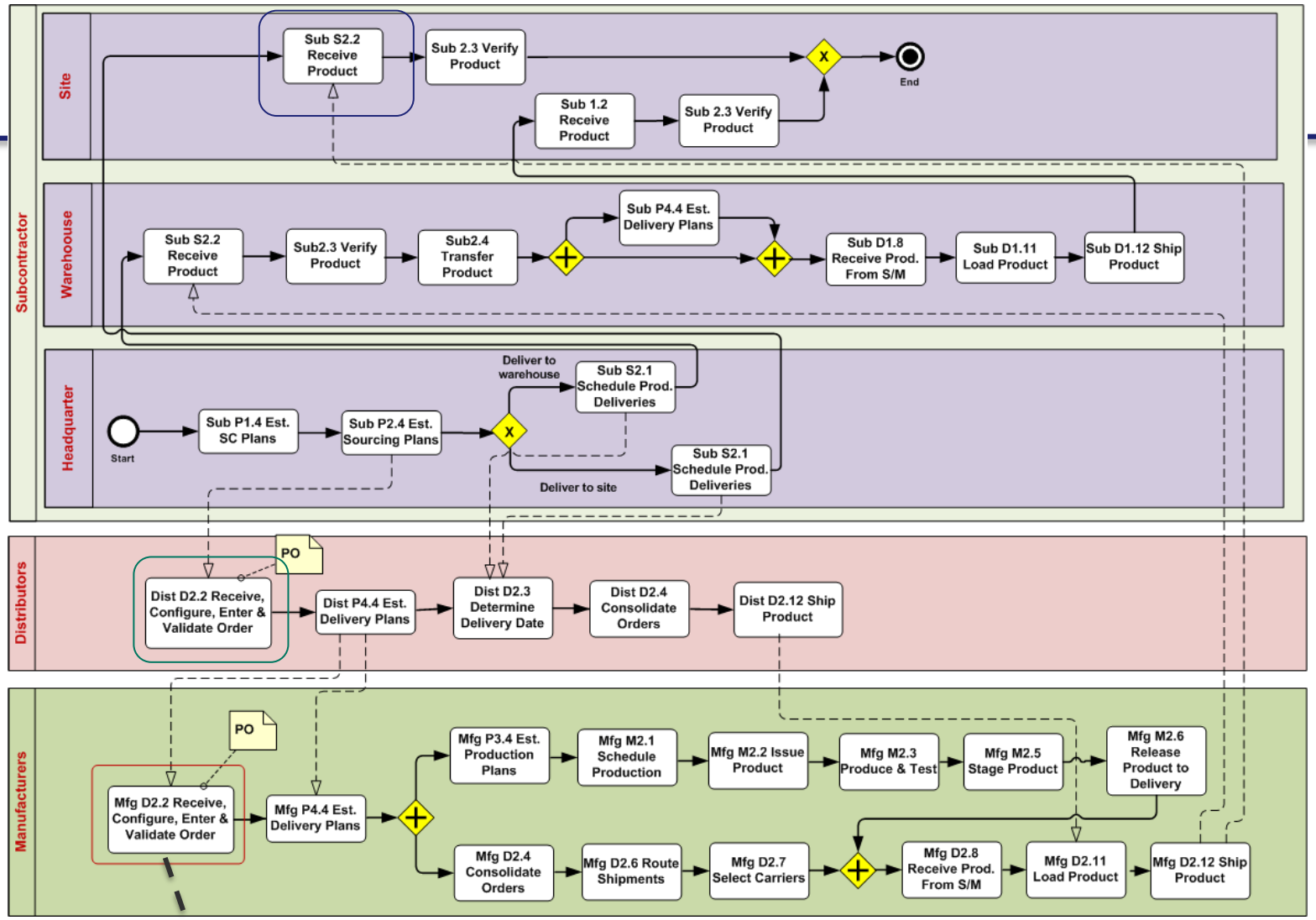
- Identifies core processes that manage business rules, supply chain performance, data collection, inventory, mfg assets, transportation, planning configuration, on the basis of a vendor neutral PLM product generation data.

Typical manufacturing network comprising a "make-to-order" (MTO) SCOR Level 2 products.

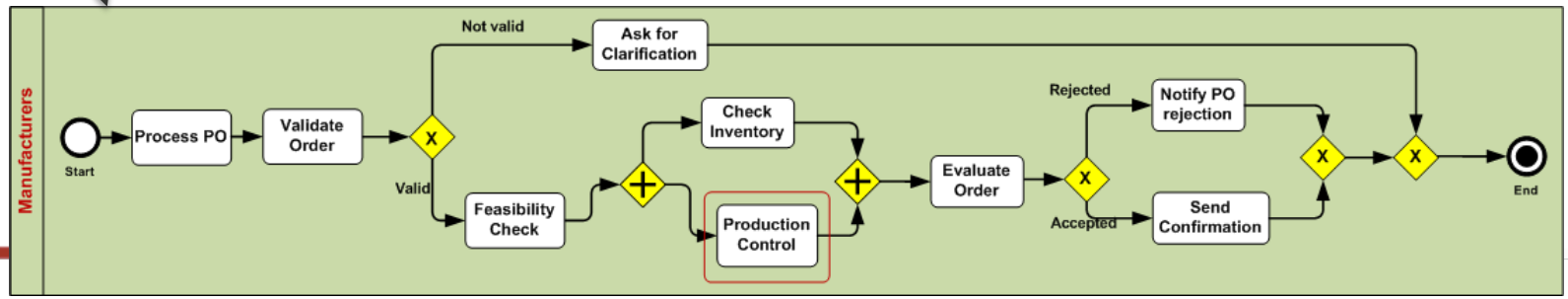
MTO processes signify a production environment where the product is made after receipt of the order by a consumer.

Products of this type are built to a specific design and are products manufactured, assembled, or configured from standard parts or subassemblies





SCOR Level 3 & 4 Process Orchestration



Quality Assurance Blueprint

Quality Assurance Blueprint

- Structures a collection of metrics for operations analytics (MESA). Forms the foundation for activity-based metrics for mfg operations, logistics, & costing:
  - Production Schedule Information – what products are to be made. It contains start or completion times, and it defines the resources (personnel, equipment, and material) to be used in production.
  - Production Performance KPIs – defined in terms of equipment, and material used per production segment, per product or scheduled item.
  - Environmental KPIs.
  - Manufacturing Metrics include
    - Manufacturing Lead Time
    - Rate of Production
    - Production Capacity
    - Work in Progress
    - Design Times
    - Utilisation/Availability

Level 1 Metrics	Performance Attributes				
	Customer-Facing			Internal-Facing	
	Reliability	Responsiveness	Flexibility	Costs	Assets
Perfect Order Fulfillment	X				
Order Fulfillment Cycle Time		X			
Upside Supply Chain Flexibility			X		
Upside Supply Chain Adaptability			X		
Downside Supply Chain Adaptability			X		
Supply Chain Management Cost				X	
Cost of Goods Sold				X	
Cash-To-Cash Cycle Time					X
Return on Supply Chain Fixed Assets					X
Return on Working Capital					X

Putting Things into Motion

Product & QA Master Blueprint for Car Mfg

Production Request & Associated Production Data & Schedule

Partner #1 Partner #2 Partner #3 ... Partner #N

Partner, Product, & QA Participant-Blueprints


Body Shop


Paint Shop


Powertrain


Body Assembly

Preliminary Production Schedule

Master (Network) SLA

Product Definition (quantity, deadlines, skills)

Master Product Blueprint

Master Quality Assurance Blueprint & KPIs

Identification of manufacturing end-to-end process (choreography) & potential resources

Bill of potential Equipment, Personnel & Materials

Master end-to-end process Blueprint

Decomposition of choreographed into orchestrated processes & associated resources

Participant Process Blueprint

Participant Quality Assurance Blueprint & KPIs

Participant SLA

Decomposition & simulation of orchestrated processes into process activities & associated production schedule & operations

Selected Equipment, Personnel & Materials

Master Product Blueprint

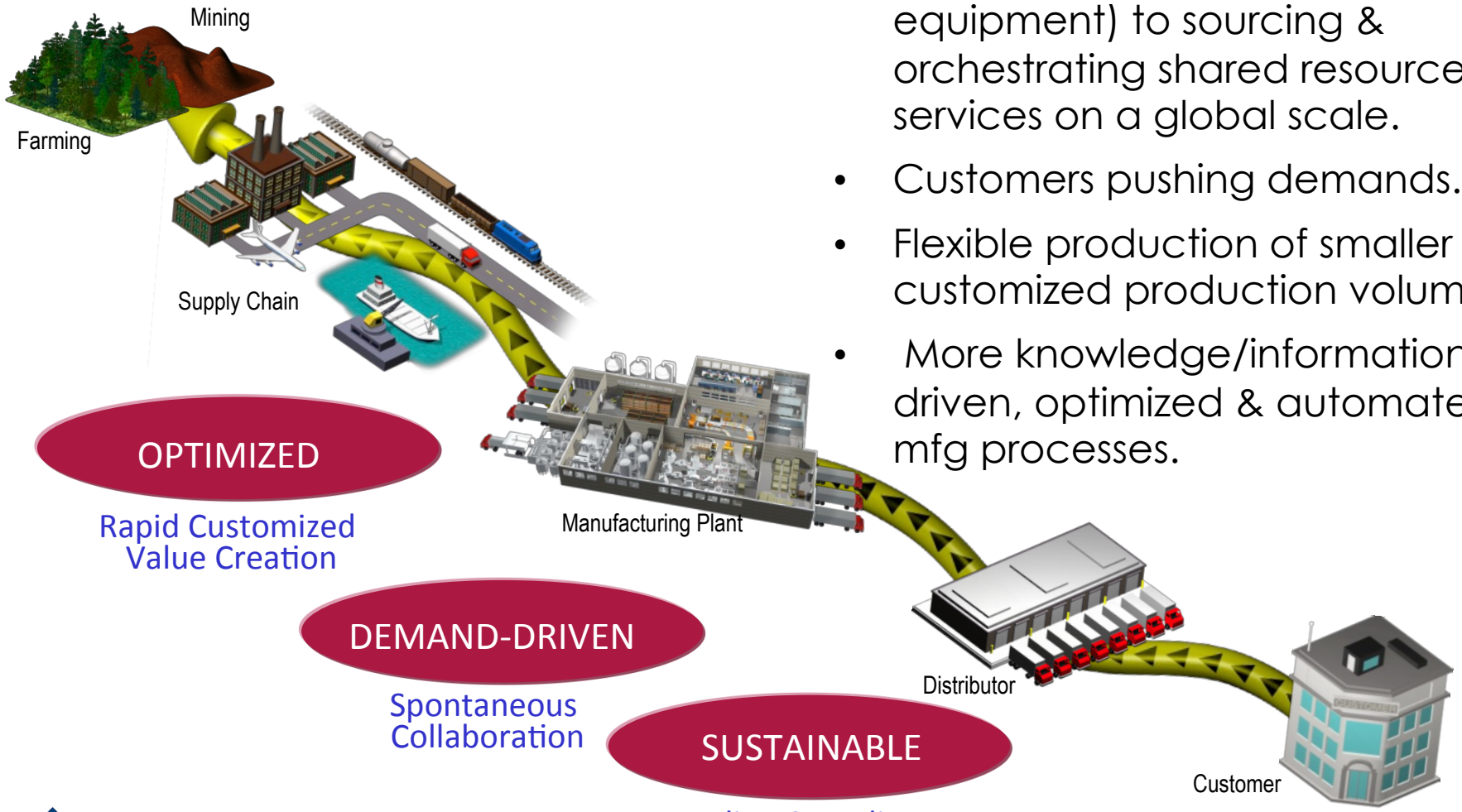
Product parts (segments) produced by processes

Production Response - Assembly of sub-products into final product

Closing Remarks

Concluding Remarks: What's Different about Smart Manufacturing?

- Transitions from "owning & operating" dedicated assets (including people, expertise & equipment) to sourcing & orchestrating shared resources & services on a global scale.
- Customers pushing demands.
- Flexible production of smaller customized production volumes.
- More knowledge/information driven, optimized & automated mfg processes.




THANK
YOU