



KONGSBERG

Smart Chain

Experiences from the SmartChain project at Kongsberg Maritime Subsea

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Outline



- Kongsberg Maritime Subsea (KMS)
- Strategic initiatives of KMS
- SmartChain project
- Supply Chain Execution System (Supply chain MES)
- Wrapping up and key lessons learned from the SmartChain project



EXTREME PERFORMANCE UNDER EXTREME CONDITIONS

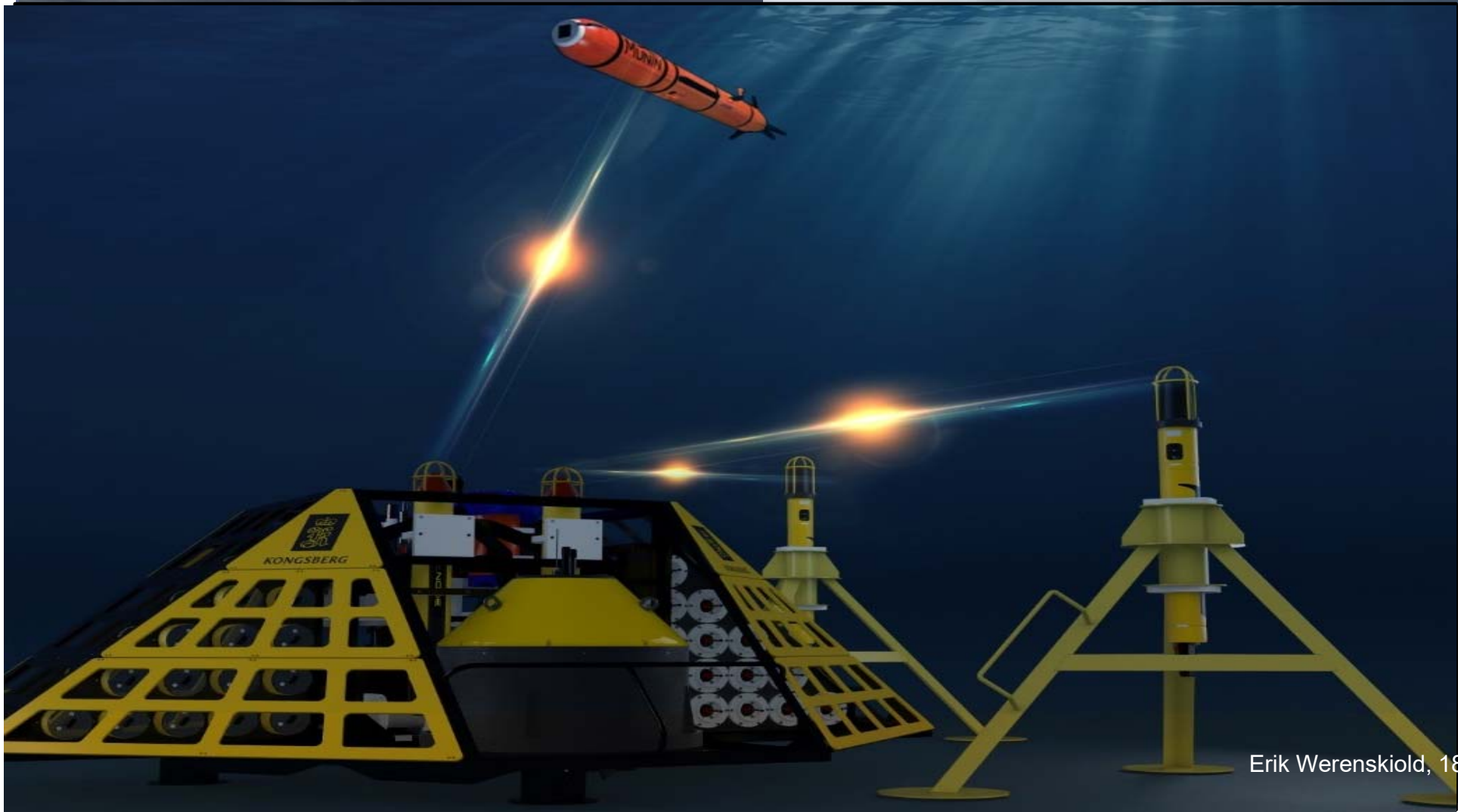
Strong Culture for Product and Technology Innovation



KM Subsea - Strong in Technology & Product Innovations

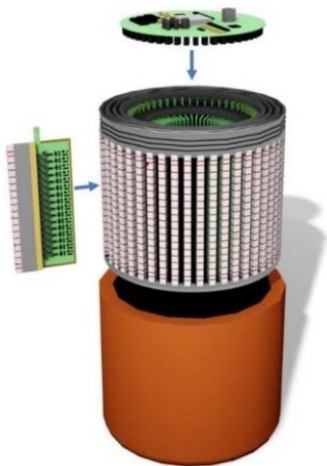


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Erik Werenskiold, 18

Strategy



Product Disruption

- Software defined products
- Standard platforms
- Lower weight, size, power consumption
- Lower price

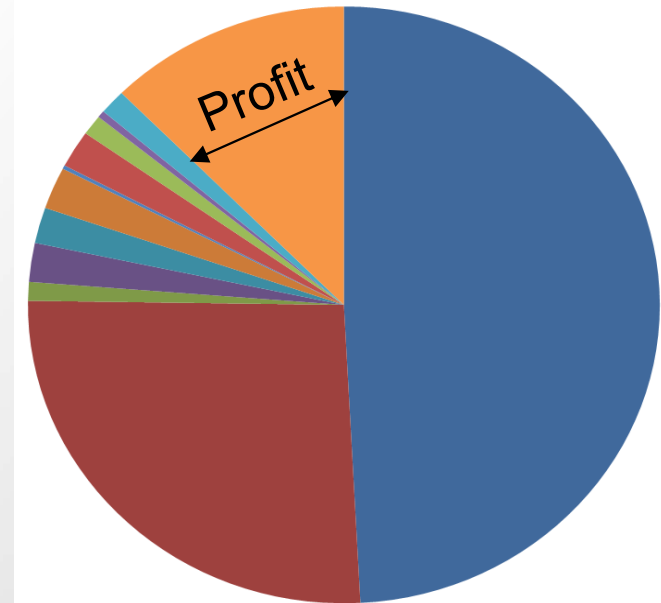
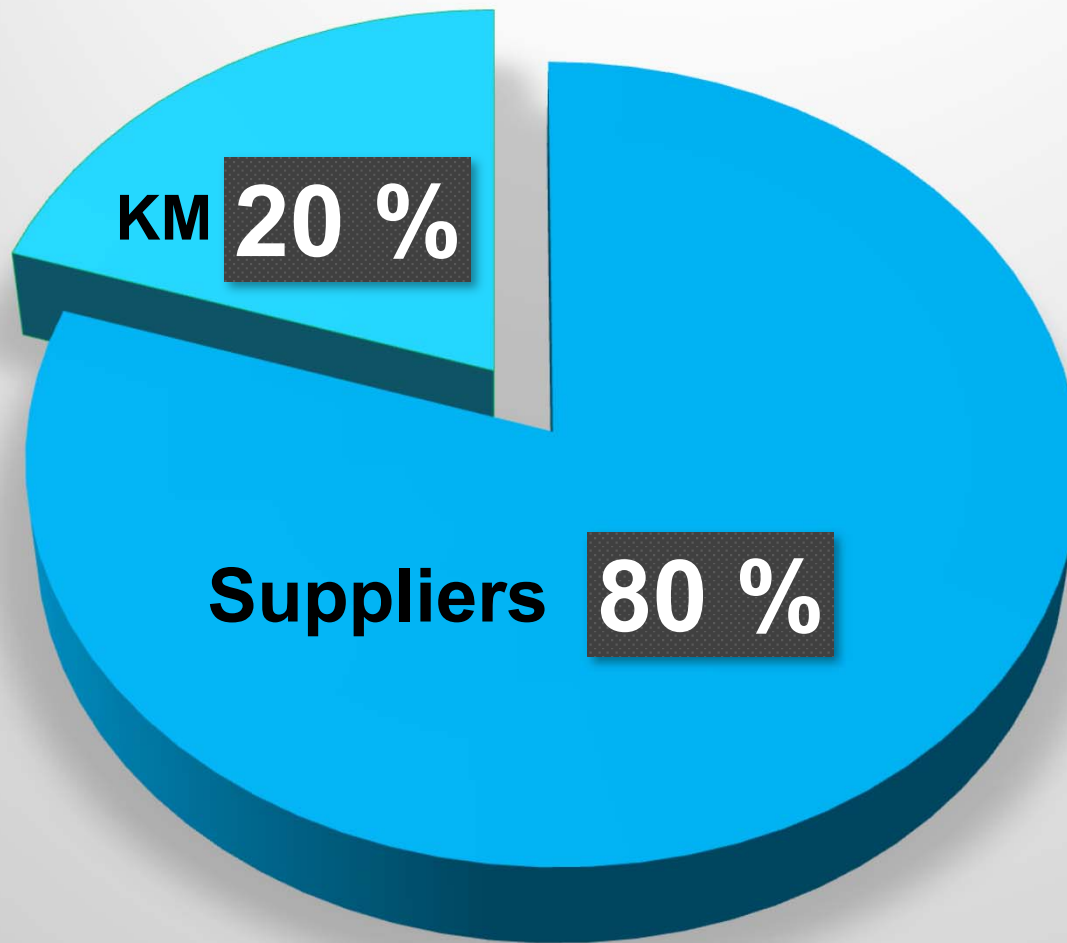
Industry 4.0

- Lean
- Digitization, automation
- Modern supply chain

Solutions and Digital Disruption

- New Services, business models, customers and partnerships.
- Internet of things. Open ecosystems.

Supply Chain Energy



45 000 components

**13 000 components
at KM Subsea
warehouse**

600 Suppliers

KMS Supply Chain Strategy Goal: **Operational Excellence / Execute on Q - C - D - S**



Operational Excellence

- 1 Digital Supply Chain**
- 2 The KONGSBERG Way**
- 3 Strategic Sourcing**
- 4 Innovation Culture**
- 5 Learning Organization**

The KONGSBERG Way: Corporate Lean Programme at KM Subsea



"Continuous improvement is of the utmost importance; in three years we will be recognised as a leading lean organisation"

Bjørn Jalving, October 2014

Building culture for continuous improvements

Supply Chain – KM Subsea



1 Supply Chain Development Program

- 1.1 Lean Implementation – Supply Chain 
- 1.2 Sourcing The Kongsberg Way 
- 1.3 Product & Process Improvement Team 
- 1.4 Hoshin Kanri (Target Break Down - Goals) 

2 Kaizen Program (Lean Boards)

- 2.1 Employee Kaizen (L1) 
- 2.2 Department Kaizen (L2) 
- 2.3 Supply Chain Kaizen (L3) 

3 Problems & Improvements (P&I System)

- 3.1 CAPA Team Suppliers (8D A3) 
- 3.2 CAPA Team Subsea Horten (8D A3) 

4 Research Innovation Projects

- 4.1 SoundChain & SmartChain (NFR) 
- 4.2 Supplier Development Program (IN) 
- 4.3 Lean Mgmt & EuroLEAN+ (NTNU/Sintef) 

Network for Supplier Innovation

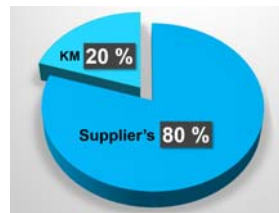
Supplier's



Financial supported by



Research Institute - Communication consultants - Lean consultants



Network for Supplier Innovation



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**Implementation
of the lean
philosophy**

**Integrated
Product
Development**

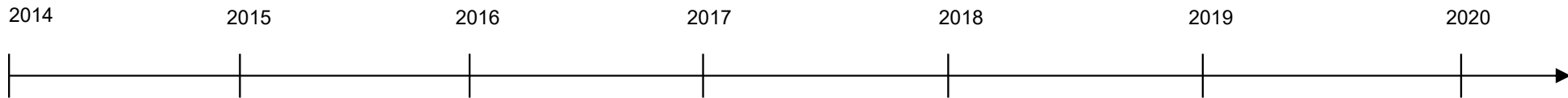
**Implementation
KM - Supplier
Quality Manual**

**Learning
Culture**

Best practice site visit

SINTEF Raufoss
manufacturing

Innovation & Learning for KM Subsea Supply Chain



Lean Implementation

Process Technology & Stability

Digitalization & Automation

Product Standardization





Low



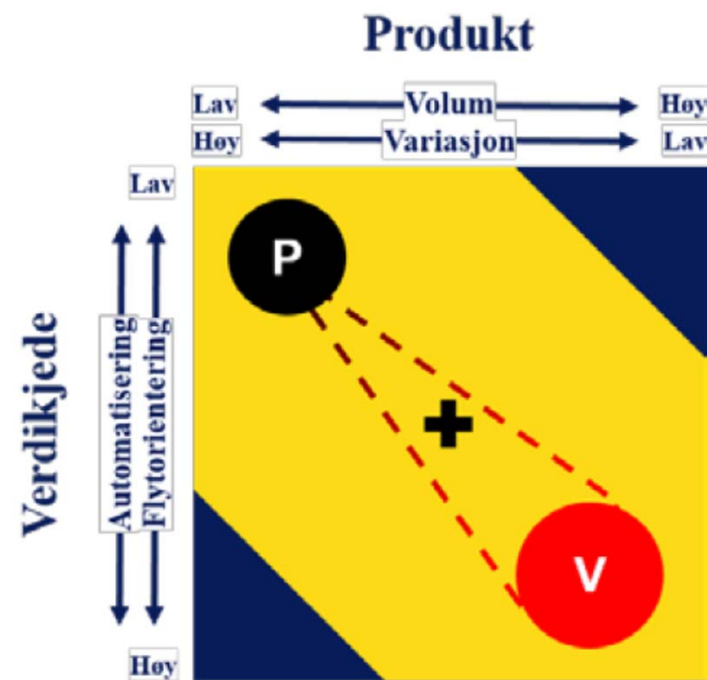
High

Medium



SmartChain Goal

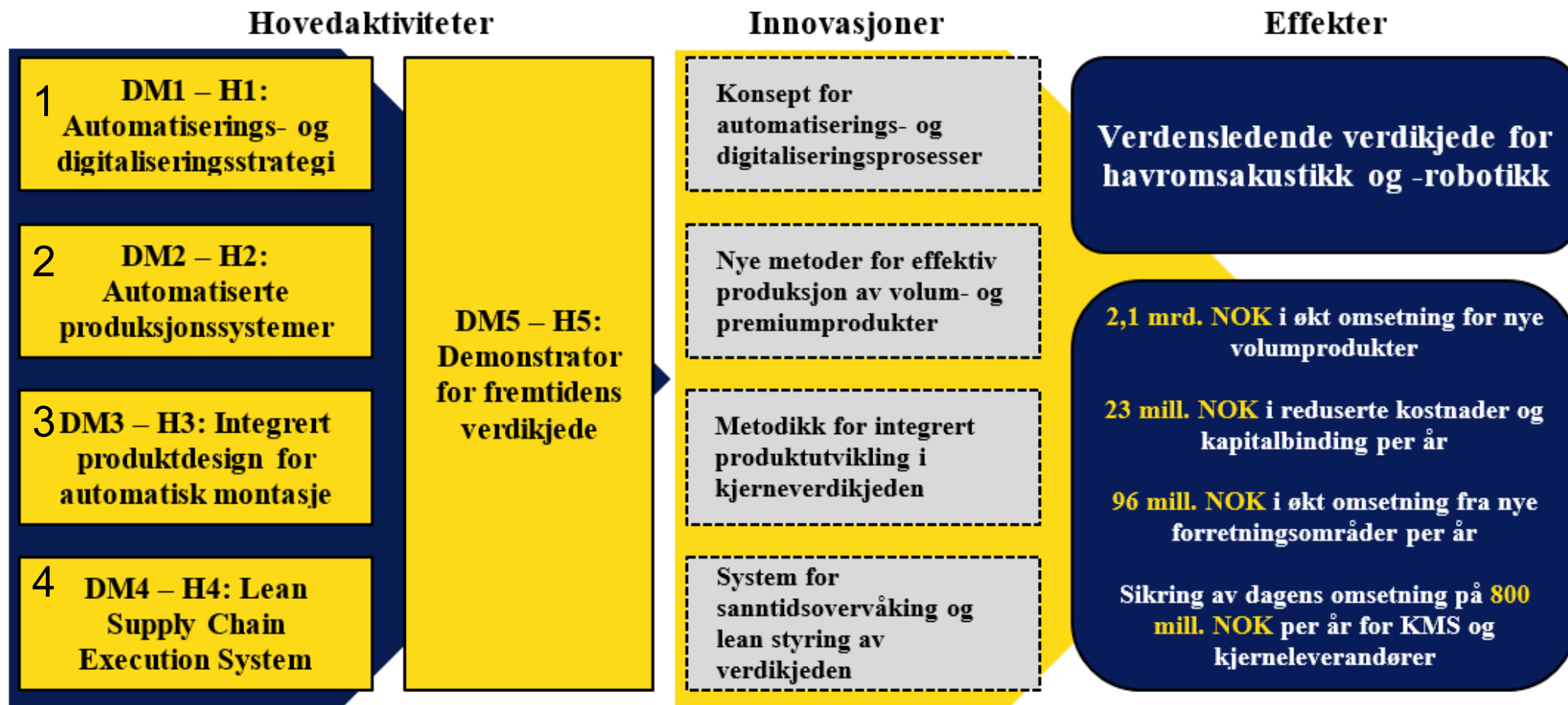
Increase Market Share in medium segment and support a high gross margin in both segments.



Smart Chain

- NFR/BIA project
- Total project cost 38 mill. NOK
 - KM Subsea
 - Norautron
 - Oswo
 - Virinco
 - Sintef Teknologi og Samfunn
 - Sintef Raufoss Manufacturing
- Financial funding from The Research Concil of Norway: **13,3 mill. NOK.**
- Timeframe 2017 - 2020

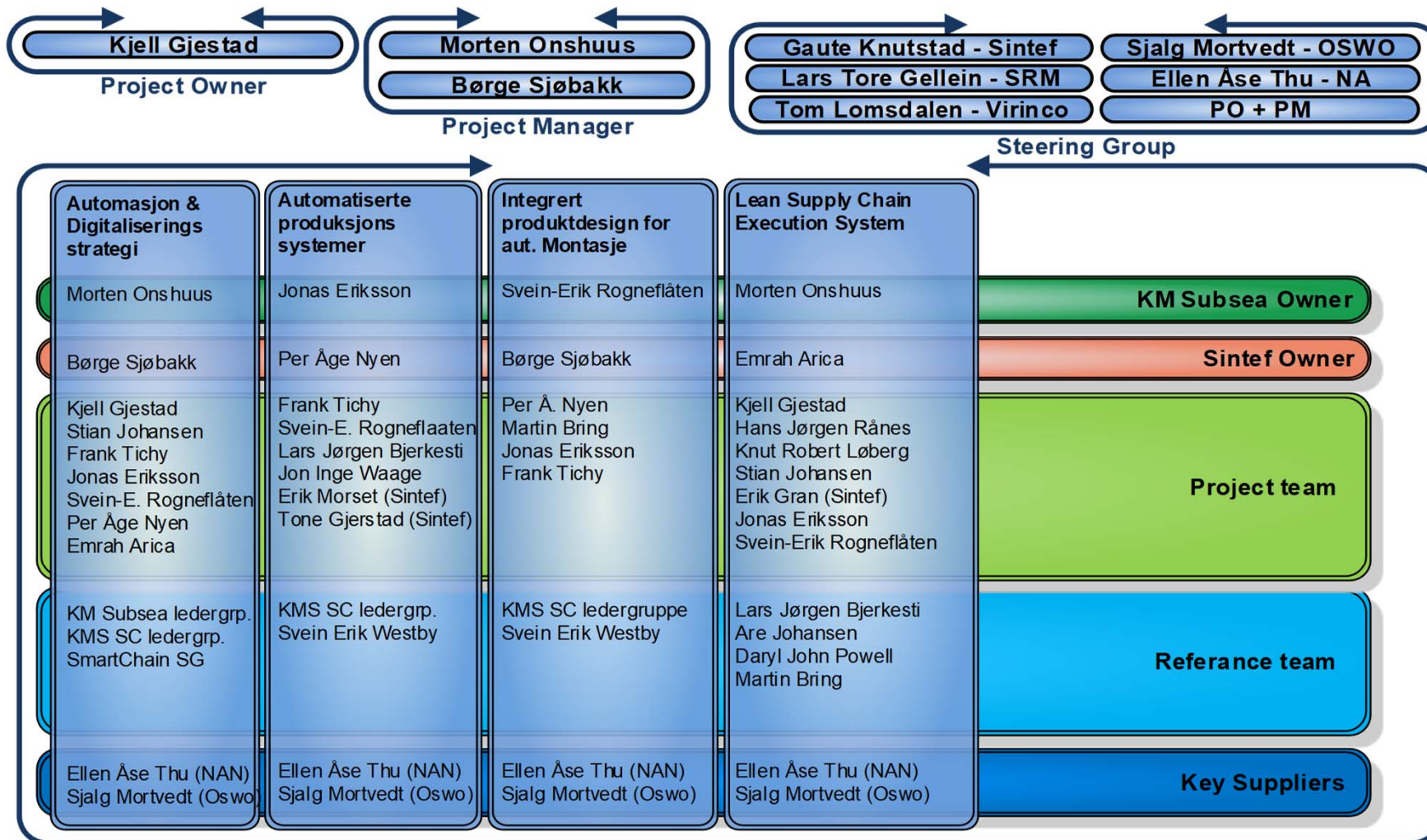
SmartChain - WP1, WP2, WP3 and WP4





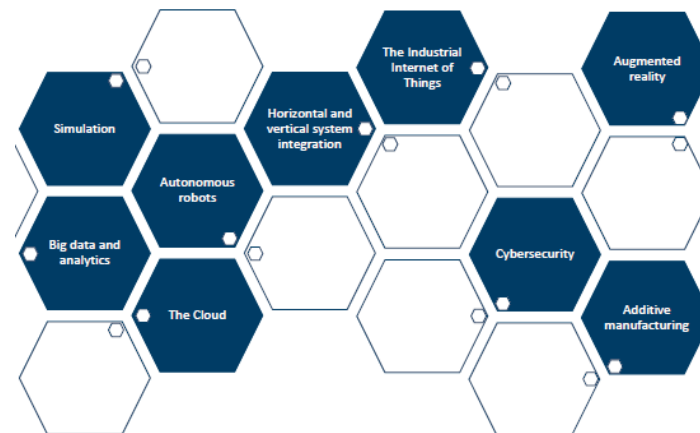
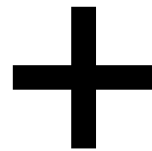
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Project Structure: Project Organization



WP1 – Automation and Digitalization Strategy

Strategy Building Blocks: Lean & Industry 4.0 are not mutually exclusive. They can be seamlessly integrated with each other for a successful production management.

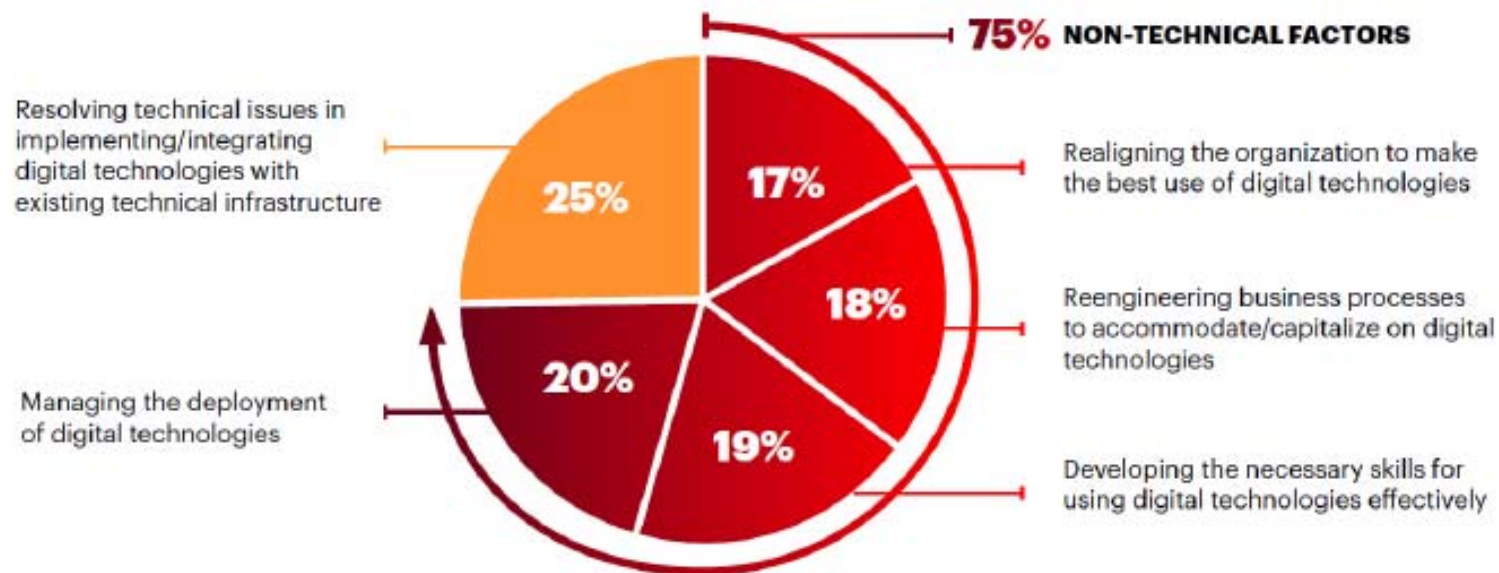


First Lean then Digitize



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- Research found that **non-technical factors** collectively far **overshadowed** **technology issues** as the biggest challenges in digital transformation.¹



The Lean-MES framework

17 main challenges in 6 main areas

Continuous improvement (kaizen)
Lack of communication and share
Limited resources and knowledge
Flow efficiency
Tracking of product
Errors in inventory counting
Waste identification
Complex production scheduling
SMED
Setup time reduction
Operation identification and standardization
Total Productive Maintenance (TPM)
Control of machines breakdown
Management of maintenance activities
Education and training
Total Quality Management (TQM)
Monitoring of process parameters
Monitoring of testing tools
Support operator in defect identification
Automatic stop in case of defect / early detection
Customer focus
Standardize and customised services
Checking of customers' order status

Continuous improvement

Flow efficiency

SMED

Total Productive Maintenance (TPM)

Total Quality Management (TQM)

Customer focus

MES: 13 main functionalities for LM

MES functionalities
Real time data collection
PDCA Analysis
Real-time product monitoring
Inventory tracking
Real-time process monitoring
Advanced production planning
Setup planning
Automatic machine setup
KPIs calculation and analysis
Autonomous maintenance
Process control
Quality data collection & analysis
Defect traceability



UNIVERSITÀ
DEGLI STUDI
DI BERGAMO

Dipartimento
di Ingegneria Gestionale,
dell'Informazione e della Produzione

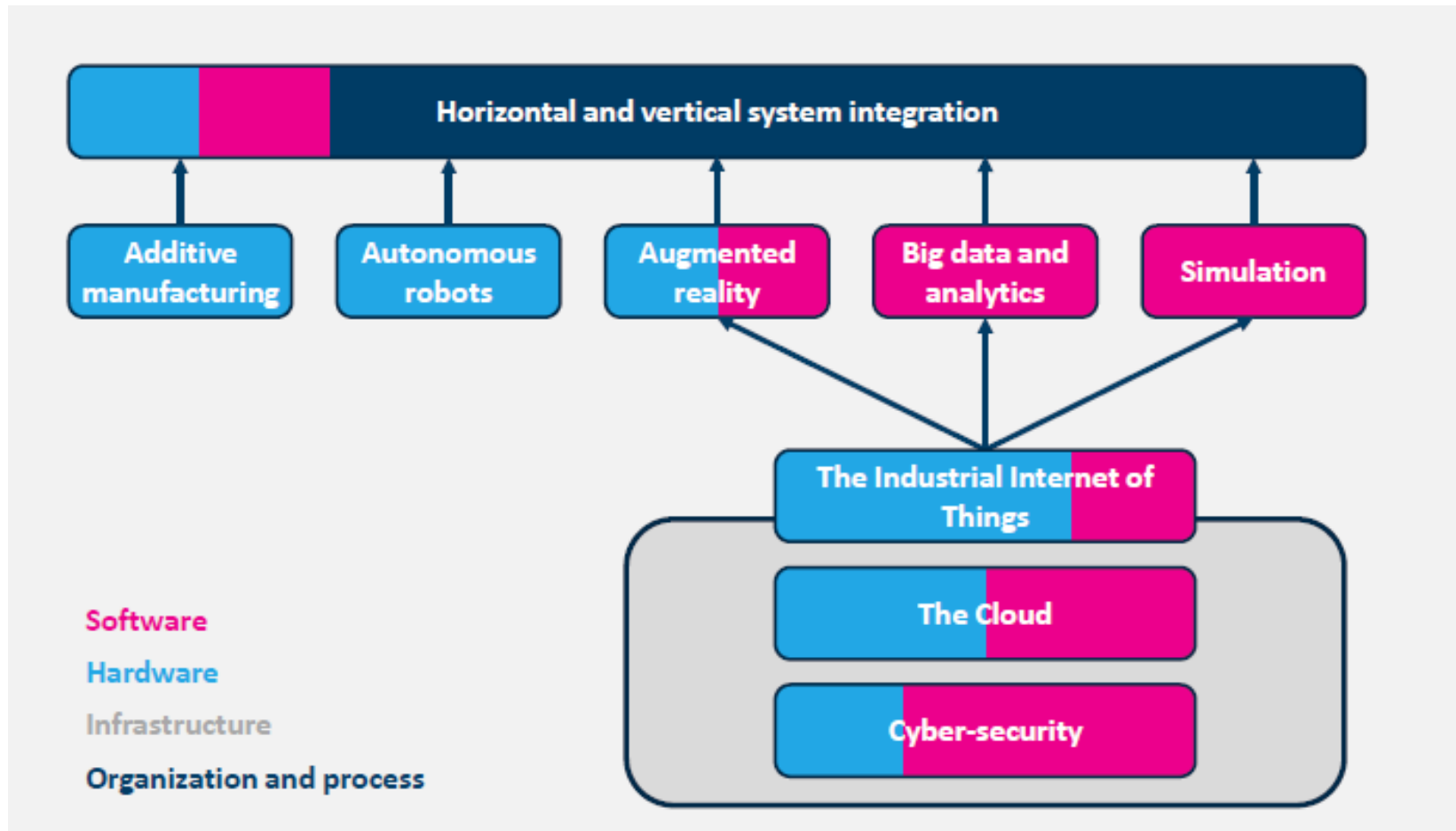
(Perico, Arica, Powell, Gaiardelli, 2019)



14.0 Automatisations & Digitalization strategy components



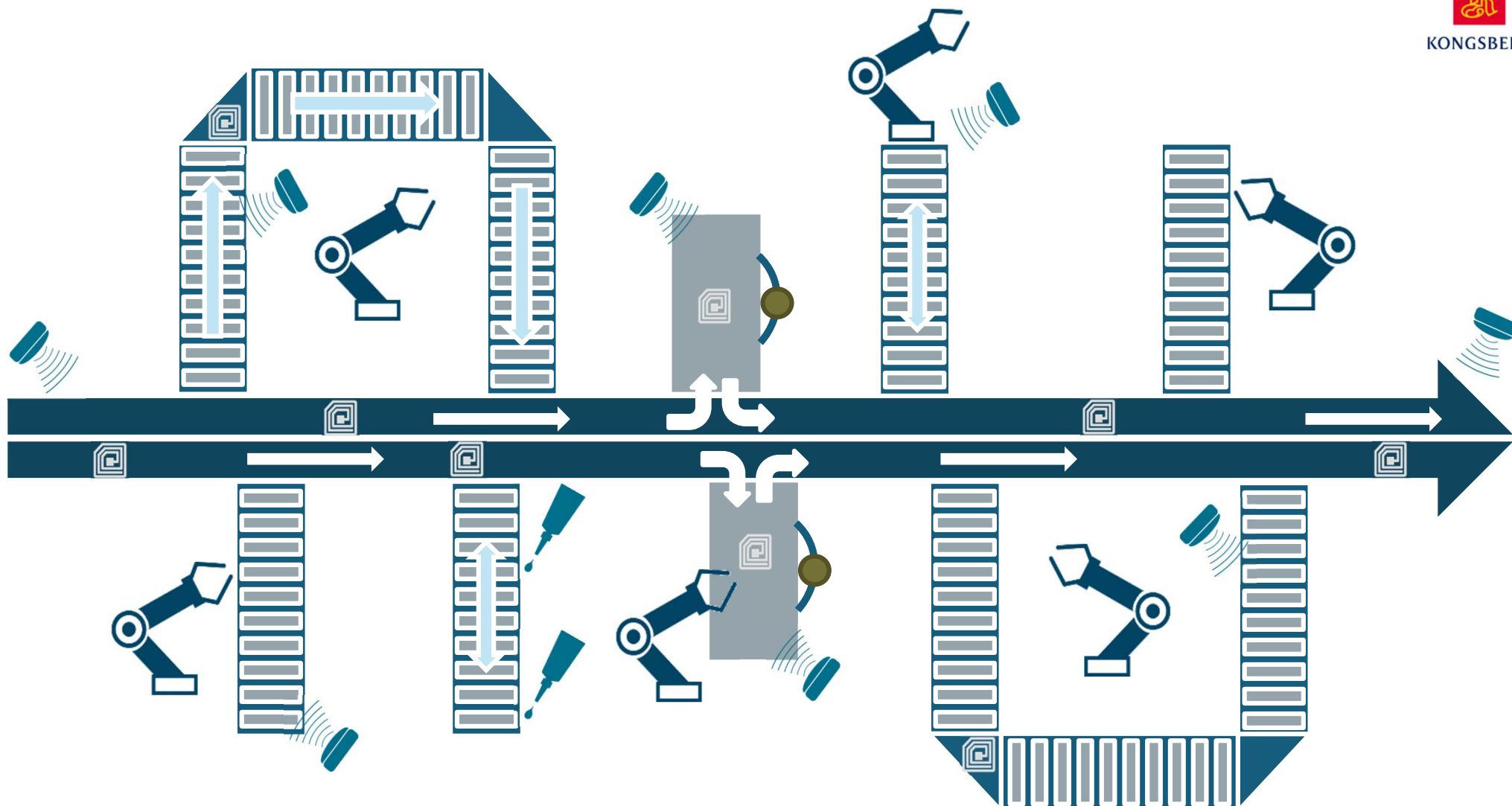
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WP2 – Automated and flexible production systems



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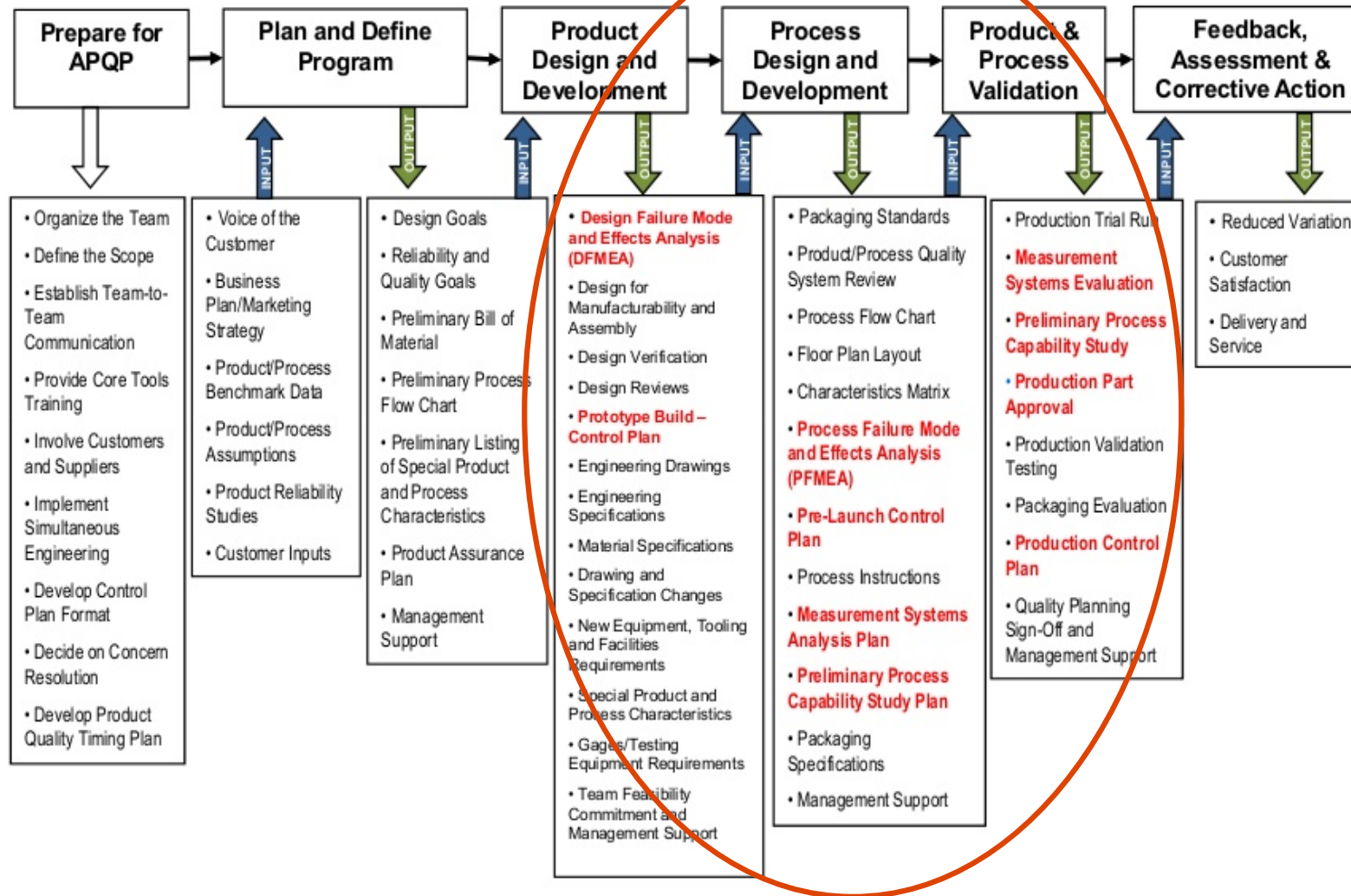


WP3- Integrated product design for automated production line



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Process Flow for APQP



SmartChain - WP1, WP2, WP3 and WP4

Hovedaktiviteter

Innovasjoner

Effekter

1 **DM1 – H1:**
Automatiserings- og digitaliseringsstrategi

2 **DM2 – H2:**
Automatiserte produksjonssystemer

3 **DM3 – H3:** Integrert produktdesign for automatisk montasje

4 **DM4 – H4:** Lean Supply Chain Execution System

DM5 – H5:
Demonstrator for fremtidens verdikjede

Konsept for automatiserings- og digitaliseringsprosesser

Nye metoder for effektiv produksjon av volum- og premiumprodukter

Metodikk for integrert produktutvikling i kjerneverdikjeden

System for sanntidsovervåking og lean styring av verdikjeden

Verdensledende verdikjede for havromsakustikk og -robotikk

2,1 mrd. NOK i økt omsetning for nye volumprodukter

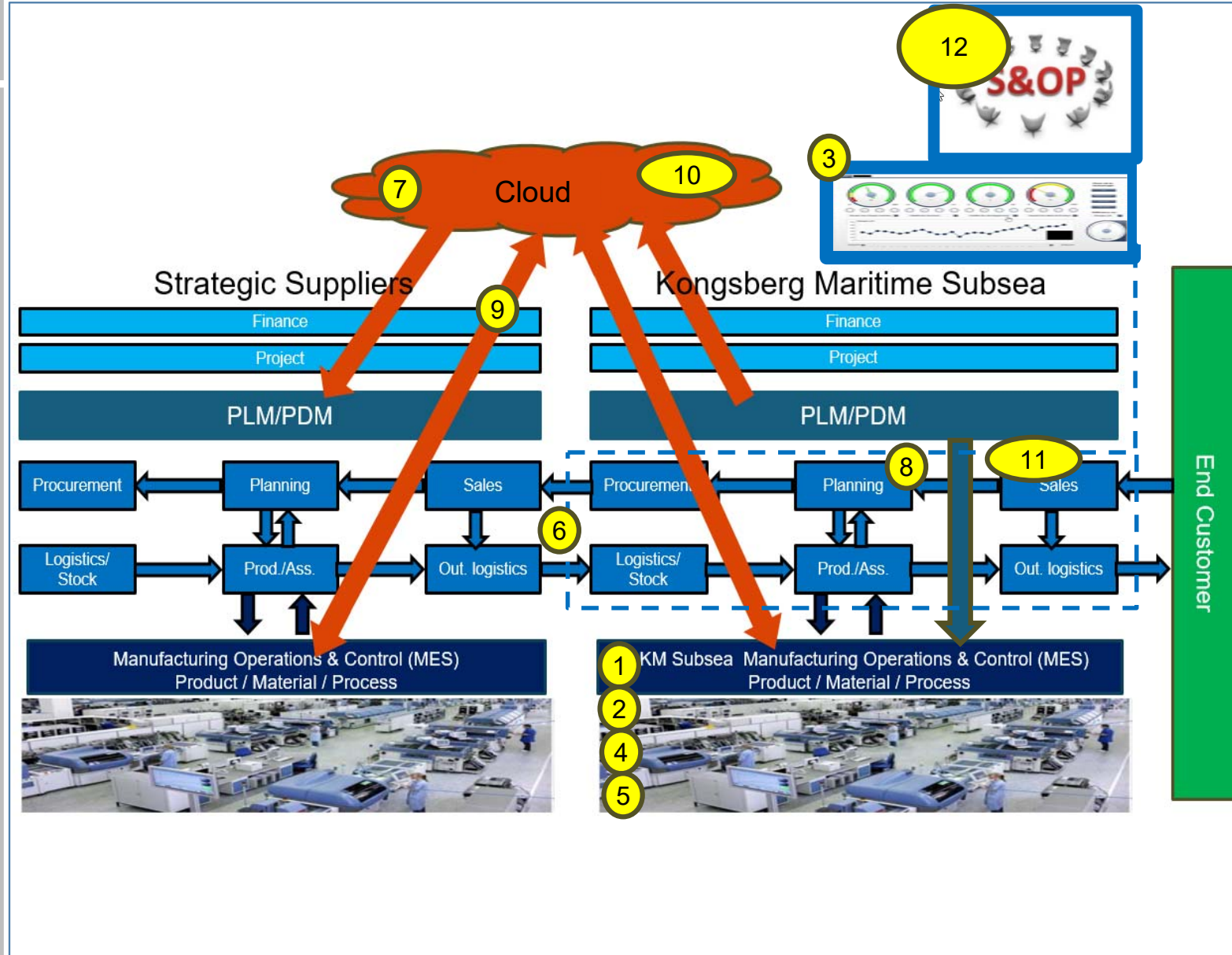
23 mill. NOK i reduserte kostnader og kapitalbinding per år

96 mill. NOK i økt omsetning fra nye forretningsområder per år

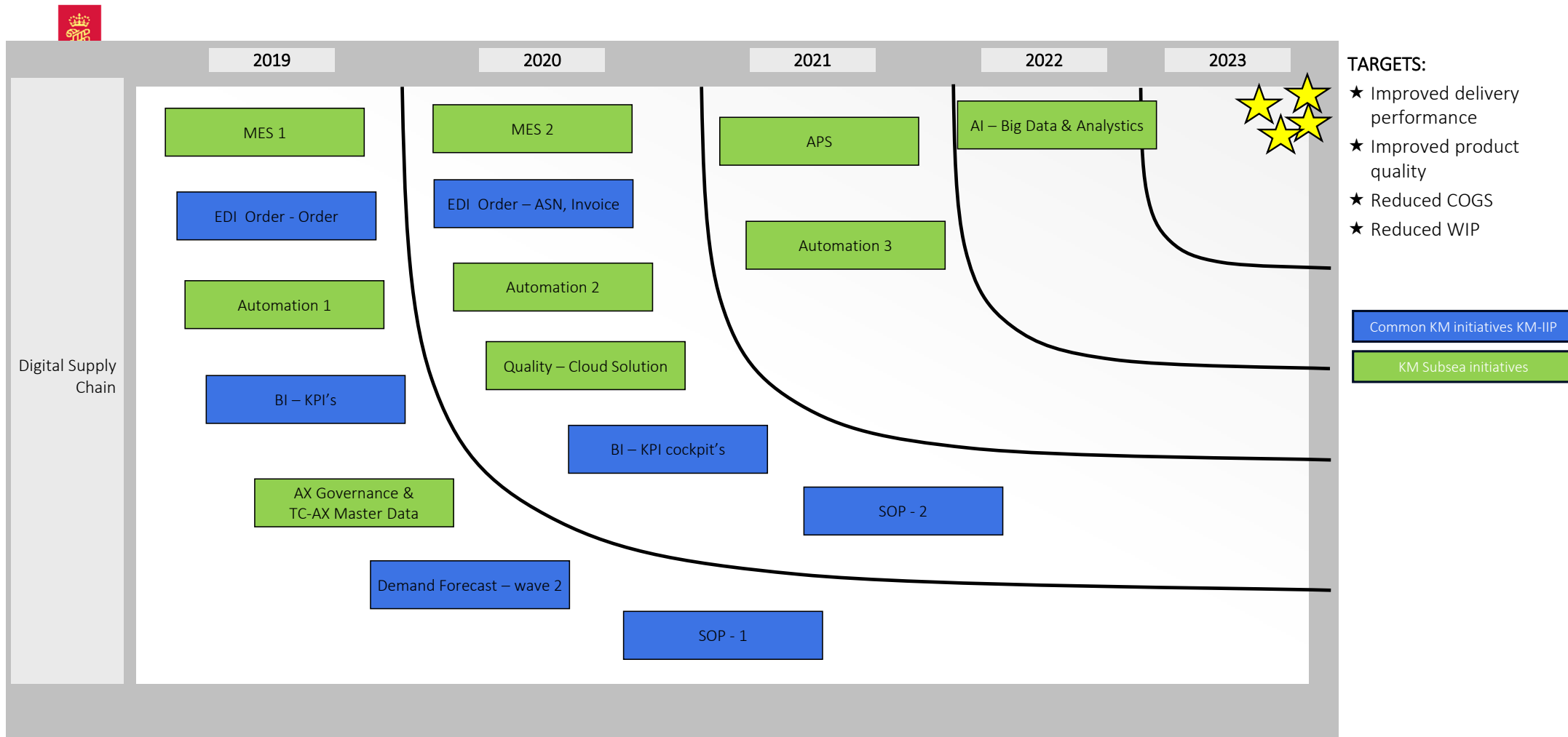
Sikring av dagens omsetning på **800 mill. NOK** per år for KMS og kjerneleverandører

Digital Supply Chain – Full picture

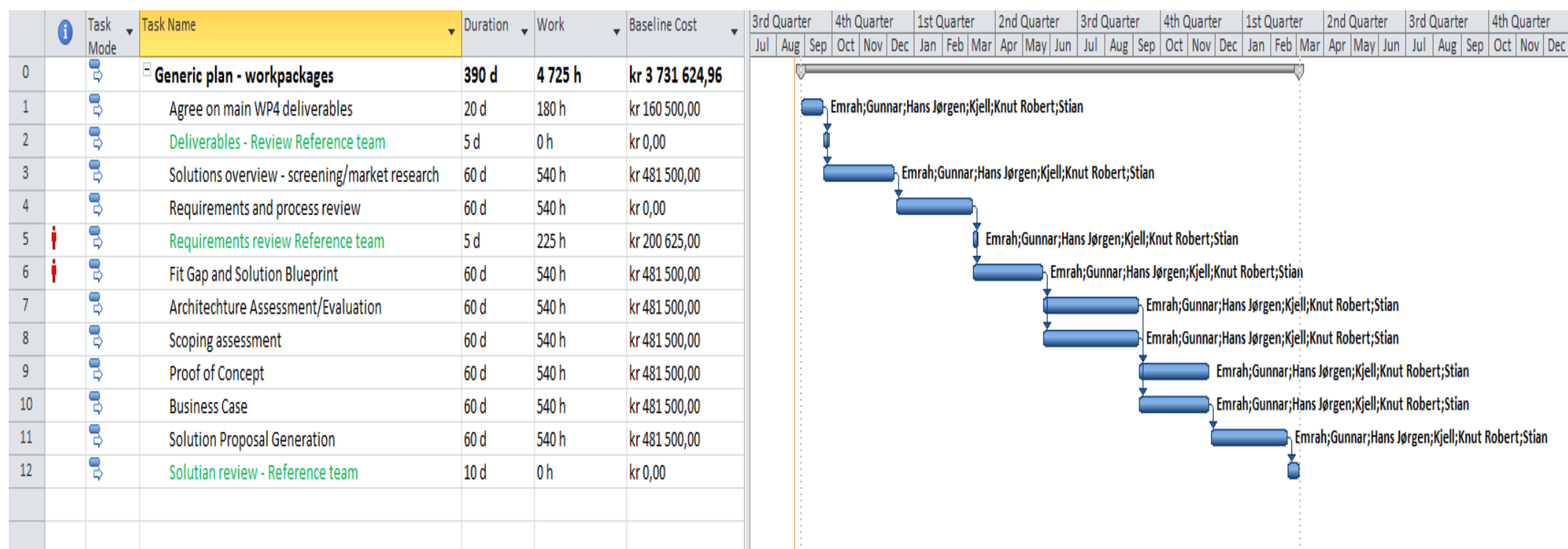
- MES.** Improved online status for Production-, Material- & Process status master data. Improved Planning & Control.
- Quality monitoring & Traceability (As Built)** . Traceability to all test results for complete networks. A Digital Twin .
- Supply Chain KPI Cockpit.** Online KPI's , targets, and history record for Planning, Procurement, Logistics & Production
- MES-Machine integration.** Machine communication for automatic machine setup and process monitoring (OT)
- Machine & Transport automation.** Automation to handle increased volume- & cost targets
Improved OEE – Availability, Quality, Performance
- EDI- Orders.** Automated order & Shipment process.
- Cloud Supplier Portal. Product Specification & Supplier Comm.** EDI supplier order will trigger availability to critical production programs & documentation in a safe way by an integrated cloud service.
- MES-APS.** An integrated MES-APS system will optimize scheduling by taking care of both Flow efficiency, Customer Demands, Capacity, Material & Online Status
- Supplier Quality monitoring + Service traceability.** A Cloud interface will secure full traceability & interface to agreed as built structures & test results. Increased use of WATS
- AI Quality support.** As built structures & test results imported to Cloud Solution will realize advanced big data & AI analyzes for internal quality improvement.
- Forecast – Wave 2.** Implement model to use historical data to automate Forecasts to reduce time and improve forecast.
- IBP/SOP.** Integration & Simulations of several functions in a business or government entity to maximize financial value



Digital Supply Chain – Full picture



Overall project plan for WP4 and MES





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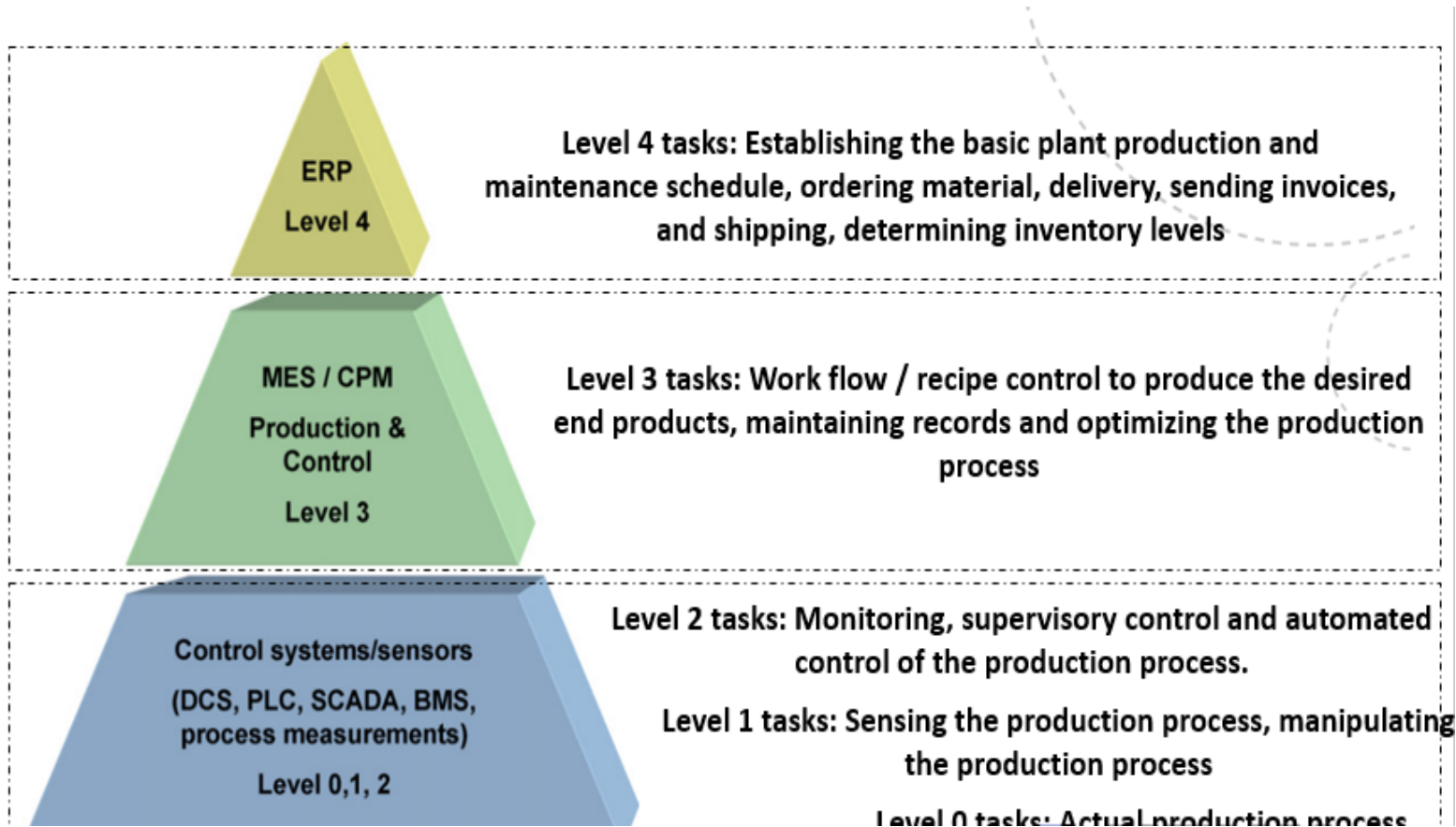
MES - History

- Initial scope identification and market screening (2017)
- SMARTCHAIN - KM Subsea MES MES Mandate & Detailed Demand Specification (2017)
- Standard MES solution evaluation - 10 MES suppliers (2017)
- Shortlisted 3 MES suppliers (2018)
- Extended MES demand specification together with KDA, Arsenale, several CM factories (2019)
- Contract negotiations with 2 MES suppliers (2019)
- Signed Contract with one MES supplier (2019)
- POC in agreement (2019/2020)

Initial screening of the MES market - Relevant MES products for discrete manufacturing

- Aegis FactoryLogix
- Delphi planner
- AquWEB Suite
- FactoryTalk
- DIAMES
- Mv2
- ATS CM4D and ATS Inspect
- ITAC.MES.Suite
- Flexnet
- Hydra MES
- InFrame Synapse
- Operator
- edinn M2
- MEScontrol.net
- cpmPlus (ABB)
- ProMANAGE
- Camstar Manufacturing
- Quartis Optima
- Qubes
- Shopfloor-Online
- SIMATIC IT
- Wonderware MES Software
- SAP ME
- Oracle MES

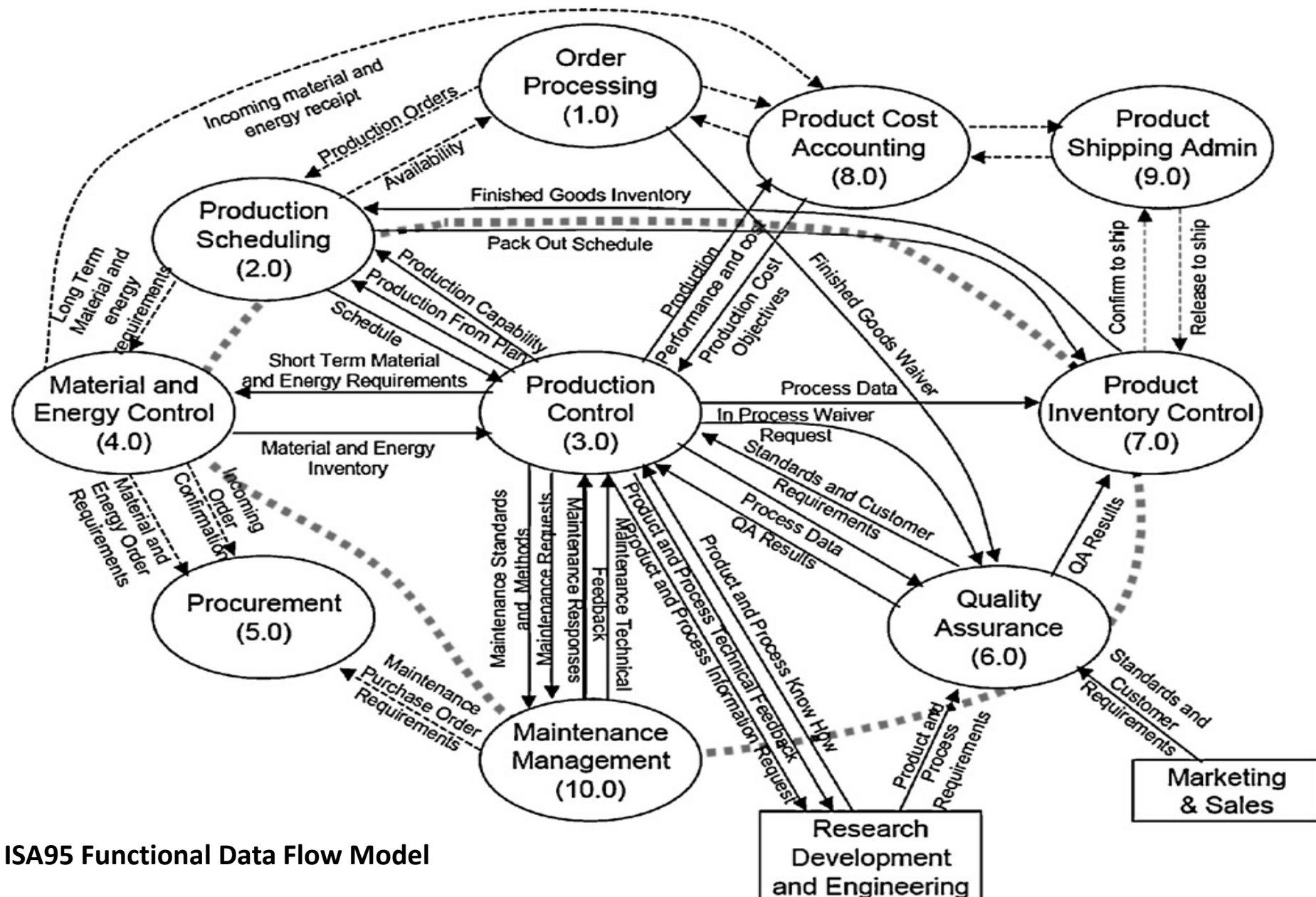
MES – Manufacturing Execution Systems



- MES provides a data management system with the ability to map a company's value stream in real time. Moving beyond the capability of the ERP systems.
- A MES is considered as an essential element of any industry 4.0 strategy (Almada-Lobo, 2017).
- It concerns the activities that take place within a manufacturing department, such as data collection, reporting, analysis and detailed production scheduling.



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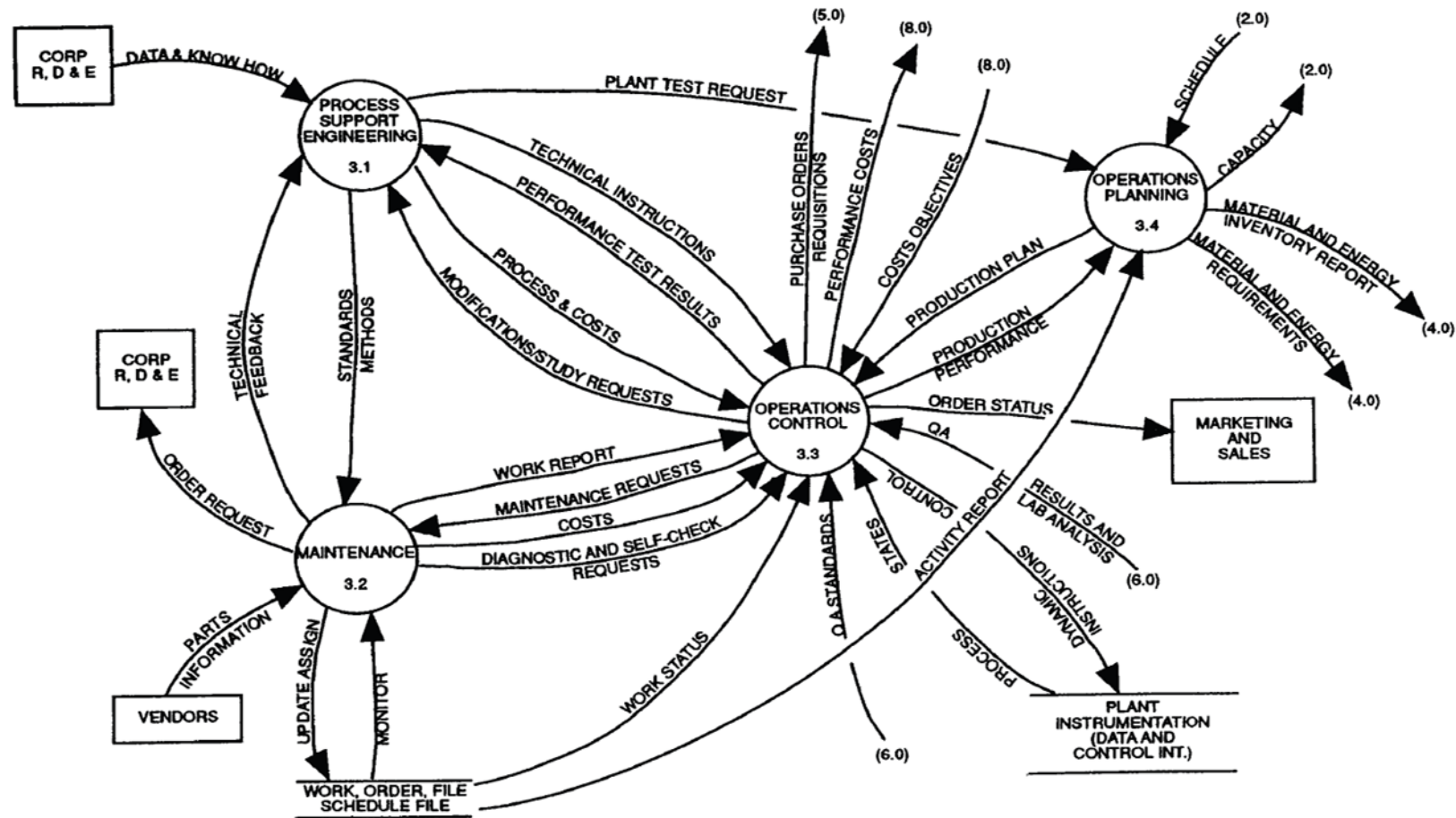


ISA95 Functional Data Flow Model

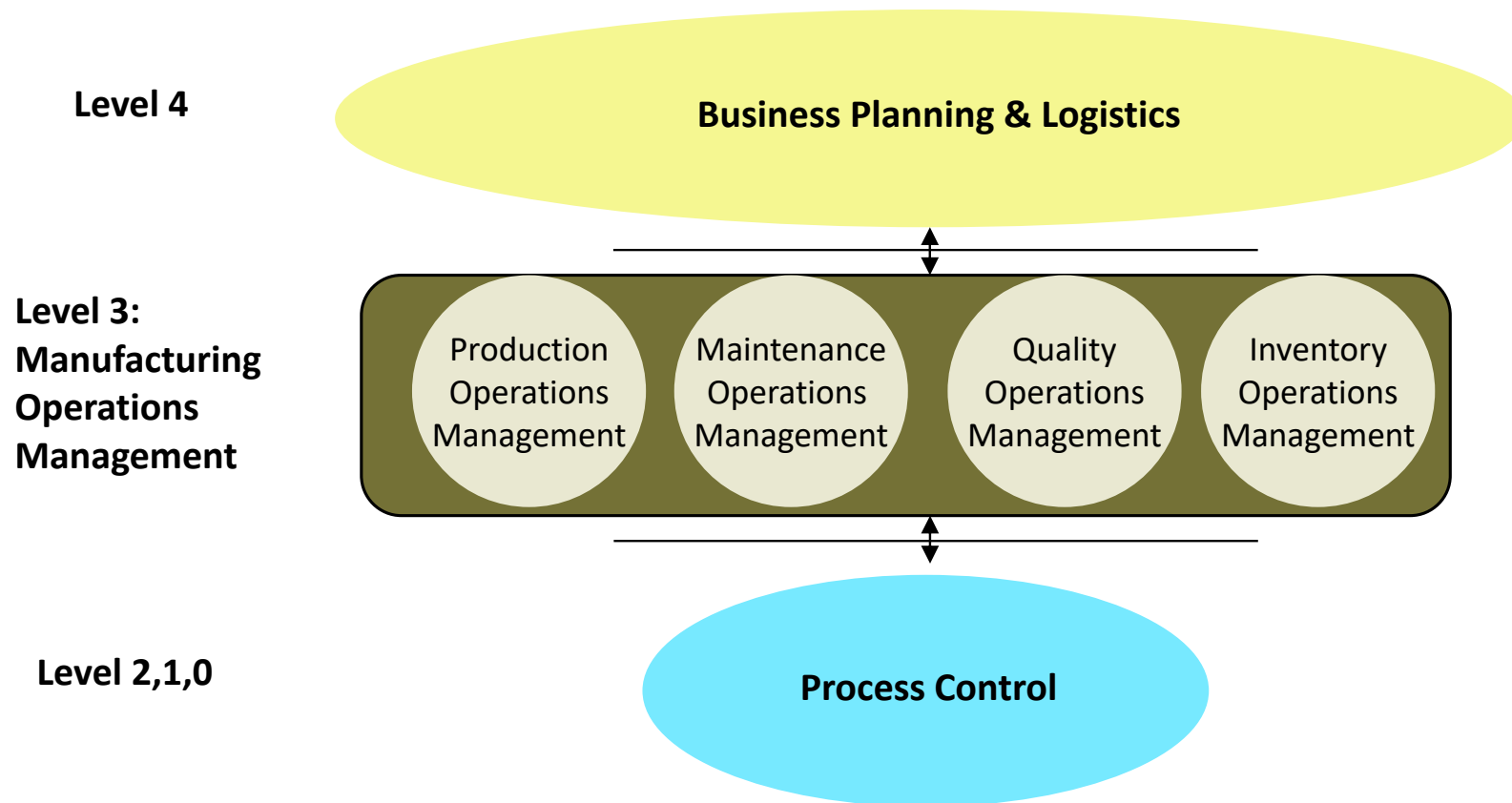
Functional Data Flow Model in Production Control



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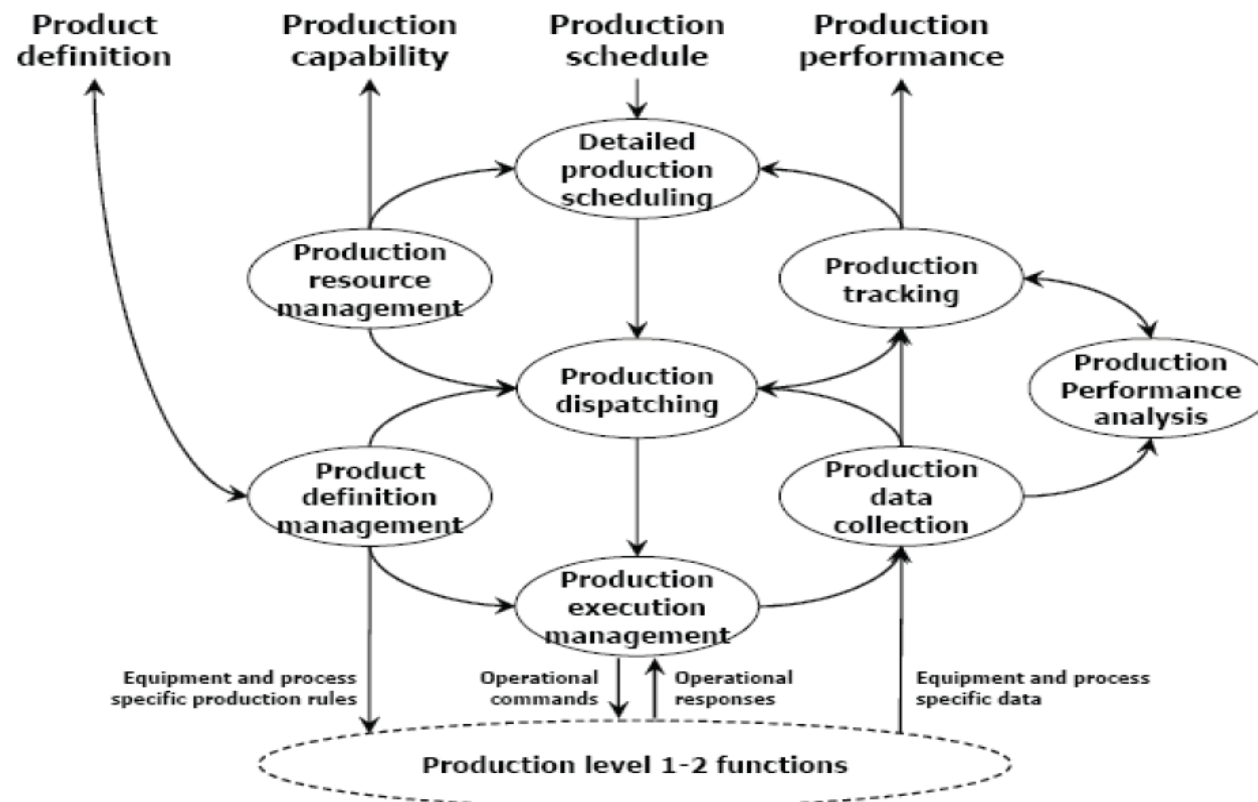
What activities should be supported by MES?



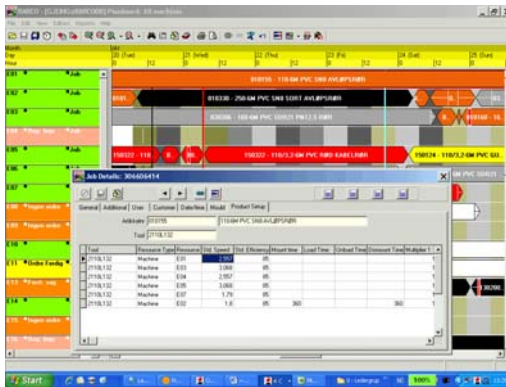
ISA 95 - Activity model for production operations



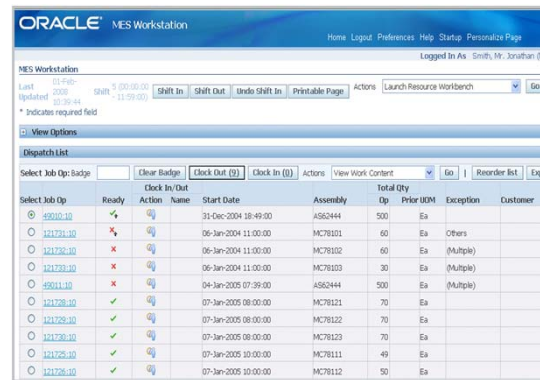
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MES – KMS Prioritized functional areas



Detailed Scheduling

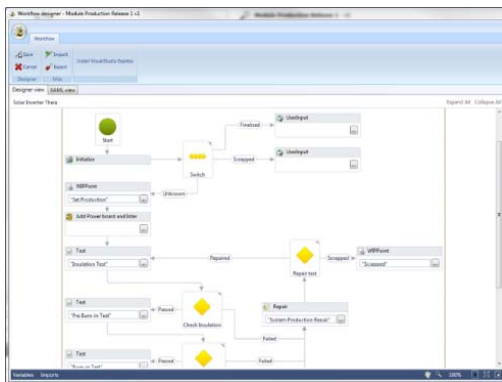


Job ID	Status	Action	Name	Start Date	Assembly	Total Qty	Prior UOM	Exception	Customer
45010.10	Ready			31-Dec-2004 18:49:00	AS62444	500	Ea		
121732.10	Ready			06-Jan-2004 11:00:00	MC78101	60	Ea	Others	
121732.10	Ready			06-Jan-2004 11:00:00	MC78102	60	Ea	(Multiple)	
121732.10	Ready			06-Jan-2004 11:00:00	MC78103	30	Ea	(Multiple)	
45011.10	Ready			04-Jan-2005 07:39:00	AS62444	500	Ea		
121728.10	Ready			07-Jan-2005 08:00:00	MC78121	70	Ea		
121729.10	Ready			07-Jan-2005 08:00:00	MC78122	70	Ea		
121730.10	Ready			07-Jan-2005 08:00:00	MC78123	70	Ea		
121728.10	Ready			07-Jan-2005 10:00:00	MC78111	49	Ea		
121728.10	Ready			07-Jan-2005 10:00:00	MC78112	50	Ea		

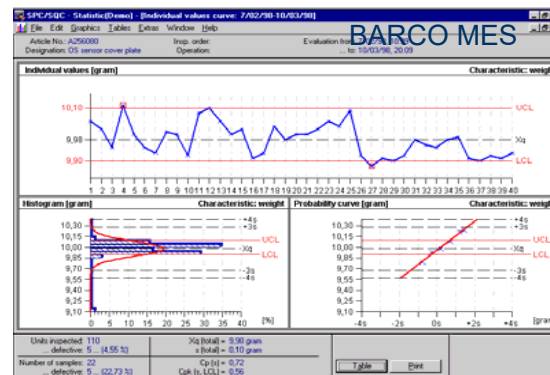
Dispatching



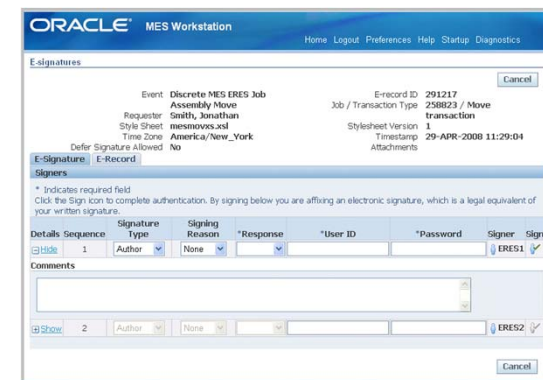
Performance Analysis



Execution management













Quality control



Document control

MES – functional demands – based on ISA 95

Order	Work Item Type	Title
1	Feature	>  1. Detailed Production Scheduling
2	Feature	>  2. Production Dispatching
3	Feature	>  3. Production Execution Management
4	Feature	>  4. Production Resource Management
5	Feature	>  5. Production Definition Management
6	Feature	>  6. Production Tracking
7	Feature	>  7. Production Data Collection
8	Feature	>  8. Production Performance Analysis
9	Feature	>  9. Quality Operation Management
10	Feature	>  10 Maintenance Operation Management

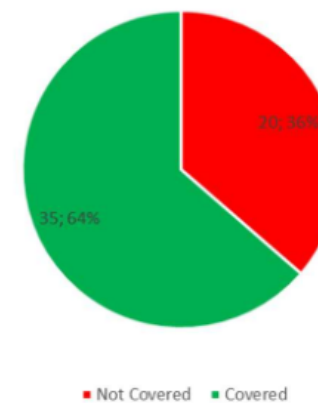
POC – Requirement Coverage

An overall view

	M	S	C	W
Detailed Production Scheduling	10	0	0	0
Production Dispatching	1	0	0	1
Production Execution Management	5	3	2	1
Production Resource Management	2	0	1	0
Product Definition Management	5	1	0	2
Production Data Collection	4	0	0	0
Production Tracking	9	0	1	0
Production Performance Analysis	8	0	0	1
	44	4	4	5
	M	S	C	W
Quality Test Execution Management	4	3	0	2
Quality Data Collection	1	2	0	1
Quality Test Tracking	2	1	0	0
Quality Performance Analysis	0	1	1	0
	7	7	1	3
	M	S	C	W
Maintenance Scheduling	0	1	0	0
Maintenance Execution Management	2	0	0	0
Maintenance Data Collection	0	0	0	0
Maintenance Tracking	1	0	0	0
Maintenance Analysis	1	0	0	0
	4	1	0	0

Purpose of the Proof-of-Concept was to cover the largest set possible of “must” requirements

PoC - Overall Requirements Coverage



MES – System Evaluation

MES SYSTEM EVALUATION	2. round		2. round		2. round		2. round	
	Dynamics AX - MES	Novotek / GE	Operator	Prediktor	ATS + Siemens Camstar	Factory Logics / Aegis	ITAC	Critical Manufacturing
Functionality	2,2	4,8	3,4	3,8	4,8	4,4	4,2	4,5
1. Detailed Production Scheduling	1	5	3	3	5	2	5	1
2. Production Dispatching	2	5	3	3	5	5	4	5
3. Production Execution Management	3	5	3	5	5	5	5	5
4. Production Resource Management	1	5	4	4	5	5	5	5
5. Production Definition Management	3	4	3	4	5	5	5	5
6. Production Tracking	2	4	5	4	5	5	5	5
7. Production Data Collection	3	5	4	5	5	5	5	5
8. Production Performance Analysis	3	5	3	5	5	5	5	5
9. Quality Operation Management	2	5	3	3	5	5	5	5
10 Maintenance Operation Management	1	5	2	2	3	2	3	5
MES Application / System	2,9	5	3,3	3,3	5,0	4,6	4,6	4,2
Documentation of domain knowledge, relevant for type of business / business function								
Supports web services for full bi-directional integration								
Documentation of a marked share of minimum 10%								
Has local presence (Scandinavia, Europe)								
Product development is ahead of customer needs								
Documentation of solution maturity								
Can provide at least 2 relevant reference customers								
Documentation of solid historic financial economy								
No KONGSBERG/KM specific adaptations are required to meet the provided functional specification								
Contains a complete and protected audit trail of user and administrative actions								
Supports running on the most common client device types and platforms								
Supports the most common web browsers								
Vendor	2,2	4,4	3,9	3,9	5,0	4,4	4,4	4,4
Documentation of relevant formal solution competence								
Documentation of relevant competence capacity								
Documentation of relevant solution experience								
Can offer 24x7 support services on installed solution								
Can offer on-site support services on installed solution								
Has local presence and competence								
Documentation of solid historic financial economy								
Can provide documentation of capacity and experience for relevant system and domain knowledge								
Vendor is available for audit by KM and/or third party								
	2,4	4,7	3,5	3,7	4,9	4,5	4,6	4,4

Short list evaluation - 3 days workshop

SmartChain MES - Detailed Production Scheduling										
Number	Business Objective	Use Case	Purpose	Test Steps	Expected Resu	Auth	Achieved Result	Tested	Pass/f	Achieved Resu
01.01.00	Delivery, Cost	Smart Scheduling	<p>Demonstrate ability to make Quick & optimal production plans & prioritize different planning parameters</p> <ul style="list-style-type: none"> - Flow efficiency priority - Machine efficiency (Bottle necks) priority - High priority orders - Be able to control schedule with respect to BOM item availability <p>User story: 10997, 11099, 10799, 11100</p>	<p>1. Schedule some production orders for maximum flow efficiency with limited Capacity (FIFO)</p> <p>2. Optimize one resource group/machine for maximum output (Setup time minimalization)</p> <p>3. Choose one customer order as a rush order, and reschedule</p> <p>4. See material shortages according to schedule, and take one of the shortages into account and replan orders dependent of this ingoing BOM material.</p> <p>NB! All bullets should update Work Centre dispatch lists online</p>						
01.02.00	Delivery, Cost	Simulation	<p>Demonstrate ability to simulate and present optional schedule scenarios (Capacity, Material availability, Order Priority)</p> <p>User Story 11175, 11177</p>	<p>1. Simulate mashine crash on one resooource/Machine and reschedule</p> <p>2. See capacity requirements with and without limited capacity</p> <p>2. Add in extra shift, and reschedule</p>						
01.03.00	Delivery, Cost	Dynamic schedules	<p>Demonstrate or present ability to dynamic schedules based on online status input from MES</p> <p>User Story 11178</p>	<p>1. See how actual start of a not scheduled order rearranges scheduling</p> <p>2. See how a reported number of finished parts (delay) reported on an operation affects rescheduling</p>						

Summary

Detailed Production Scheduling

Production Dispatching

Prod Execution Management

Prod. Resource Management

Prod. Definition ... (+)

What is the benefit from digitalizing the processes? ROI analysis



How often is the process performed?



How expensive is the implementation?

IT readiness (KLM)

Which suppliers are integrated?



What is the maintenance cost?



What are the savings every time the process is performed?



What are the savings from quality improvements?

MES Business Benefits (ROI)



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1. Cost reductions

- Reduce team leader & planner workload by getting online automatic production order status
(As is: Yearly > 2000 po's with avg. 6 months lead time without online progress reporting)
- Reduced time for work order scheduling
- Reduced time to for administrative work at the shop floor
- Reduced time for Quality root cause analysis & Process performance KPI's

2. Quality & Traceability

- Register online "as built" structures: Project Y demand + KMS CM "Must win battle"
- Improved product quality by early detection of defects
- Improved product quality by improved root cause analysis for complete "as built" structures
- Increased control for planned maintenance, machines & tools
- Increased Quality by improved process stability

3. Working Capital

- Reduced WIP by improved Scheduling & *improved overview (Increased flow eff.)*
- Eliminate too early buy signals due to not be able to link materials to operations

4. Delivery performance

- Online order status & stock's
- Planned machine- & maintenance status
- Improved scheduling
- Increased Delivery Performance by improved process stability

Results Summary (5 years)

Total project cost savings/income	Kr'000	14720
Total project expenditures	Kr'000	-10150
Net project savings / income	Kr'000	4570
ROI (return on investment - after 5 years)		45,0%
NPV (net present value)	Kr' 000	2844
at a discount rate of:		7,5%
IRR (internal rate of return)		29,1%
Payback year		Year 3


First step – Agree on a frame contract

Task Information

General | Predecessors | Resources | Advanced | Notes | Custom Fields

Name: Sign Frame Contract Duration: 3 d ☐ Estimated

Notes:



- KM Standardavtale vilkår
- Kongsberg SW utrullingsavtale (Ramme for alle KM og RRCM produksjonssiter)
- Software licences
- Specification of Software
- Maintenance Agreement
- Service fees
- Proof of concept vilkår inkludert escape
- Konsulent profiler

Help OK Cancel

Second step – Analyses Objective, Activities and outcome



Phase Objective

- Detail the scope of the overall project
- Solution Big Picture
- Define Business Case
- Finalize Program Setup and Solution Design
- Ramp-up of the project organization
- Confirm deployment roadmap, required effort and implementation costs

Key activities



Key outcome



Architecture and Design



Value and Risk Assessment



Engagement Model & Roles Definition



Governance & Delivery Model and Cost for next phases

Second step - Analysis Phase activities



Structure & Governance



- Governance
- Engagement model
- Delivery Model
- Risk management
- Change control
- Issue resolution
- Quality control
- Business operations

Business Process



- MES scope definition
- Process definitions (new / refinements)
- Strategic MES roadmap
- Assess process maturity

Requirements & Fit



- Business process based requirements & use cases
- Solution alignment and fit assessment
- Capability gap closure

System Architecture



- Infrastructure / Environments
- System interface / integrations
- Global deployment strategy
- Security
- Performance & scalability
- System monitoring and health

Value



- Business improvement definitions
- MES value definition & business alignment
- Validation of delivered value

Solution Enablement



- Prototyping
- Solution spec & design
- Enable solution implementation & physical deployment
- Enable test planning & execution

User & Organizational Change



- User needs, involvement & acceptance
- Stakeholder management
- Communications
- MES solution team care & feed

Learning



- Learning strategies & tools
- Content development
- Learning delivery plan
- Engage community

Release & Support



- Transition & upgrade
- Deployment plan
- Schedule & cost
- Support & maintenance

Critical Factors in MES Project Implementation

HUMAN

- Project Team
- User Involvement
- Education and Training

TECHNOLOGY

- MES selection
- Technological Infrastructure
- Data Management

ORGANIZATION

- Top management
- Implementation strategy
- Acceptance Control

2014 2015 2016 2017

SoundChain

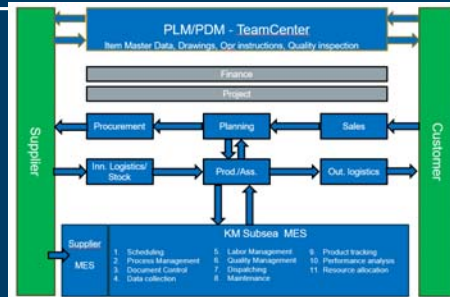
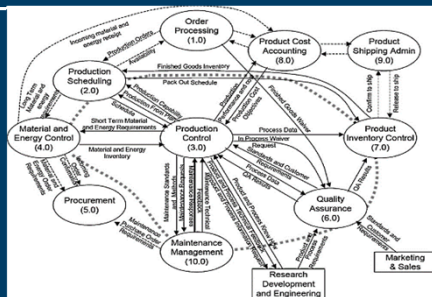
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103 User stories

	Prototype	Later	Out of Sc.
• 11 Production	5	6	0
• 16 Planning	5	11	0
• 12 Scheduling	6	6	0
• 4 Maintenance	1	4	0
• 37 Quality	19	12	8
• 7 Traceability	4	2	0
• 4 Inventory	0	4	0
• 6 IT infrastructure	4	1	0
• 6 Other	1	4	2
	45	50	10

T

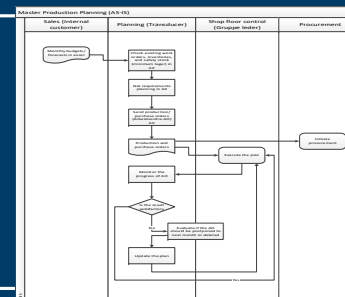


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SC manager

Task	Duration	Work	Resource cost
Generic plan - workpackages	390 d	4 725 h	kr 9 753 624,96
Agree on main MRP deliverables	20 d	240 h	kr 385 500,00
Solution overview - business reference team	5 d	60 h	kr 45 000,00
Solution overview - marketing/market research	40 d	540 h	kr 483 500,00
Requirements and process review	40 d	540 h	kr 0,00
Requirements review - reference team	5 d	225 h	kr 204 425,00
Fit Gap and Solution Blueprint	40 d	540 h	kr 483 500,00
Architecture Assessment/Evaluation	40 d	540 h	kr 483 500,00
Mapping assessment	40 d	540 h	kr 483 500,00
Proof of Concept	40 d	540 h	kr 483 500,00
Business Case	40 d	540 h	kr 483 500,00
Solution Proposal Generation	40 d	540 h	kr 483 500,00
Solution review - reference team	10 d	60 h	kr 0,00



2017

2018

2019

2020

SmartChain

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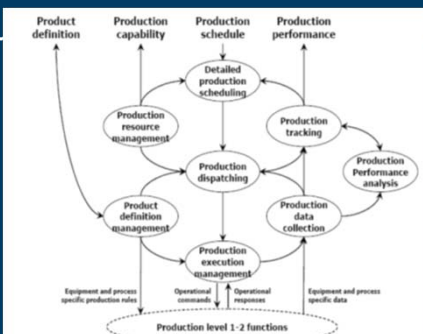


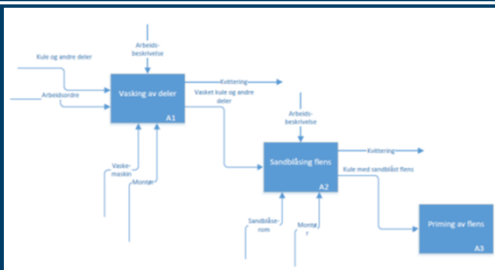
Figure 1.3.3 Production Operations Management activity model



Order ID	Order Date	Order Qty	Order Status	Order Description	Order Location	Order Contact	Order Notes
1000000001	2017-01-01	100	Open	Order for 100 units of Product A	US - New York	John Doe	Standard order
1000000002	2017-01-05	200	Open	Order for 200 units of Product B	US - New York	Jane Smith	Standard order
1000000003	2017-01-10	50	Open	Order for 50 units of Product C	US - New York	Mike Johnson	Standard order
1000000004	2017-01-15	150	Open	Order for 150 units of Product D	US - New York	Sarah Lee	Standard order
1000000005	2017-01-20	75	Open	Order for 75 units of Product E	US - New York	David Kim	Standard order
1000000006	2017-01-25	120	Open	Order for 120 units of Product F	US - New York	Emily White	Standard order
1000000007	2017-02-01	90	Open	Order for 90 units of Product G	US - New York	Chris Brown	Standard order
1000000008	2017-02-05	110	Open	Order for 110 units of Product H	US - New York	Alex Green	Standard order
1000000009	2017-02-10	80	Open	Order for 80 units of Product I	US - New York	Olivia Black	Standard order
1000000010	2017-02-15	130	Open	Order for 130 units of Product J	US - New York	Noah Grey	Standard order

Execution

O



ICT project manager



Key takeaways

- Legacy systems, functional overlaps and system integration
- Creating a business case and obtaining top management support is critical
- The background and position of the project champion
- Potential threat – Lack of operator involvement
 - Not in the core team, nor in the workshops
 - Unclear reaction during the process mapping phase
 - Awareness, education and training
- Process alignment - Considerable time and budget in the execution phase

