

# ZERO DEFECT MANUFACTURING

| FR004



# FOCUS

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**Contributing a strategic approach to EU  
research and innovation policy**

## ZERO DEFECT MANUFACTURING

Robotics  
Clean Manufacturing  
High Precision Manufacturing  
Maintenance and Support

## FR004

FR001  
FR002  
FR003  
FR005

## *Roadmap*

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# STATE OF THE ART

## 01

### Increasing Demand for Mass Customization, Personalization and Small Batch

- Knowledge-based engineering and manufacturing.
- Quality control, planning and design tools.
- Six sigma approaches, based on a large sample of data for defining and monitoring out-of-control process conditions in mass production.



## 02

### Pressure on Efficiency in Delivering Complex, Multi-material Products

- Learning technologies and cognitive computing methods oriented to manufacturing.
- Product traceability technologies.
- Production monitoring technologies.
- Multi-sensor product inspection and data fusion technologies.
- Off-line material characterization technologies.



## 03

### Pressure to Deliver Zero Waste and Improve the Social and Environmental Performance of EU Industries

- Human-robot co-operation and adaptable automation.
- Remanufacturing processes for product repair towards zero-waste production.
- ICT and augmented reality systems for assisting manual assembly processes.
- Recycling technologies and material reuse strategies.



## 04

### New Service-oriented Businesses and Globally Efficient Manufacturing Ecosystems

- Servitization of manufacturing and production systems.
- Software as a service (SaaS) oriented innovative business models.
- Supply chain and logistics management technologies.



## 05

### Integrated Approach to Quality Control, Production Logistics and Maintenance Policies

- Digital products & factories and virtual/augmented reality technologies.
- E-maintenance technologies.
- Cyber-physical systems (CPSs) and system of systems.
- Big data and advanced prognostics.
- Internet of Things (IoT) and cloud-based manufacturing.
- Self-adapting processes and adaptive process control systems.
- Error avoidance & compensation systems for clamping, fixturing, handling, manipulation.
- Error compensating systems at machine-process levels (tool wear, thermal dilatations, volumetric accuracy, vibration avoidance).
- Simulation, modeling & forecasting for component-machine-process levels.



# GAP

## Increasing Demand for Mass Customization, Personalization and Small Batch

- Mass customization and one-of-a-kind production.
- Zero defect manufacturing solutions for complex, dynamic and changeable manufacturing contexts.
- Quality assurance in the presence of alternative process plans.



## Pressure on Efficiency in Delivering Complex, Multi-material Products

- Integrated multi-stage and single-process level analysis.
- Understanding complex inter-stage quality correlations.
- Advanced material modeling to capture complex process-product interactions.
- New inspection technologies for in-line geometric product characterization.



## Pressure to Deliver Zero Waste and Improve the Social and Environmental Performance of EU Industries

- Manufacturing processes that achieve zero defect targets while being resilient to recycled input materials.
- Zero defect remanufacturing and repair solutions.
- Decision support systems for assembly and disassembly.



## New Service-oriented Businesses and Globally Efficient Manufacturing Ecosystems

- New services for quality planning and on-demand inspection capability provision for short system ramp-ups.
- Methods to capture customers' perceived quality in emerging regional markets.
- New methods for root cause analysis and diagnostics in multi-supplier contexts.



## Integrated Approach to Quality Control, Production Logistics and Maintenance Policies

- On-line inspection tools for understanding, monitoring, analysis and real-time fault diagnosis of machine operations and product quality.
- Methodologies and strategies for integrating maintenance, production and quality systems into the multi-stage manufacturing processes.
- Enhancement of current production systems by means of smart manufacturing technologies for collecting, storing and analyzing heterogeneous data on resource conditions, product quality and production logistics key performance indicators.



# CHALLENGE TO FILL THE GAP

## Increasing Demand for Mass Customization, Personalization and Small Batch

- Zero defect manufacturing systems able to prevent the generation of defects based on integration of process, product and context data, applicable to small batch productions.
- Development of dynamic quality control systems, operating under adaptable thresholds and alarm triggering mechanisms.
- Capability of adjusting target quality-productivity trade-offs depending on the market conditions. Zero defect manufacturing during system ramp-ups in the transition to new production.



## Pressure on Efficiency in Delivering Complex, Multi-material Products

- Robust design approaches for non-conventional processes and systems taking into account non-ideal parts, able to anticipate and compensate for product variations already in the design phase.
- Integrated and data-driven product process, and system modeling and analysis tools, able to facilitate understanding of quality bottlenecks and quantitatively predict the effect of quality improvement actions on the service level of defect-free parts. System engineering and control tools for optimized quality and logistics control solutions, at system level.



## Pressure to Deliver Zero Waste and Improve the Social and Environmental Performance of EU Industries

- Solutions for remanufacturing, repairing and reworking defects in-line, thus avoiding non-value-adding energy-intensive processes on already defective parts.
- Quality assurance plans for manufacturing systems that are tolerant to the reuse of recovered materials and components as secondary raw materials, from a circular economy perspective.
- New robotics and ICT solutions in support of accelerated human learning and of robot-assisted manual operations.



## New Service-oriented Businesses and Globally Efficient Manufacturing Ecosystems

- New generation of service-oriented plug-and-inspect sensors, to be selected and integrated into production lines based on their capability to perform the required inspection tasks.
- New quality assurance methods to capture implicit product requirements in emerging region-dependent markets, supporting the delivery of the needed product functionalities at the required quality levels.
- New cross-plant quality information systems to support product traceability and planning coordination in adaptive and multi-stakeholder value chains.



## Integrated Approach to Quality Control, Production Logistics and Maintenance Policies

- Improved condition-based and opportunistic maintenance methods, correlating the machine degradation states to the workpiece quality able to reduce the impact of maintenance actions on the achievement of production targets.
- In line, 100% product, process and resource inspection and data-gathering systems.
- New modular control system architectures for intelligent machining and adaptation of process plans for dynamic workload allocation to compensate for machine degradation.



# RESEARCH PRIORITIES

## Increasing Demand for Mass Customization, Personalization and Small Batch

- Cyber-physical systems able to adapt process plans, parameters and production routings to reduce defects.
- Profile monitoring tools, supporting zero defect manufacturing in small batch productions.
- Defect monitoring in complex manufacturing systems.
- Dynamic control of quality targets during production.



## Pressure on Efficiency in Delivering Complex, Multi-material Products

- Tolerance-oriented assembly methods enabled by on-line optimal part matching algorithms.
- Part variation modeling methods and tools to predict the output quality.
- Learning and diagnosis methods for complex multi-material products.
- Predictive quality planning methods to anticipate quality issues during the system design stage.
- Development of cost-effective in-line geometric product inspection technologies.
- New multi-level, multi-scale, integrated process/system modeling and analytics.



## Pressure to Deliver Zero Waste and Improve the Social and Environmental Performance of EU Industries

- Combining additive & subtractive processes and surface treatments for in-line product repair and remanufacturing.
- Development of manufacturing processes and systems for the reuse of secondary raw materials.
- Development of highly automated demanufacturing and remanufacturing technologies.
- Development of robotics and ICT solutions to support operatives in complex manufacturing tasks.



## New Service-oriented Businesses and Globally Efficient Manufacturing Ecosystems

- Design and implementation of plug-and-inspect sensors for on-demand inspection.
- Cloud-based quality information systems for traceability and planning coordination in the value chains.
- Quality assurance strategies and solutions for supporting frugal innovation in emerging strategic markets with region-dependent requirements.
- Manufacturing strategies and business models for zero defect and zero waste manufacturing systems.



## Integrated Approach to Quality Control, Production Logistics and Maintenance Policies

- Model-based, opportunistic maintenance solutions, integrating maintenance, quality and inventory control decisions.
- Protocols and standards for data collection and integration – including product quality, process conditions and part logistics.
- Development of next-generation machine control systems for adapting process plans according to shop-floor resources.
- Integrated machine, fixture, tool and workpiece models for quality and resource deterioration prediction.
- Integration capabilities in production equipment of intelligent, autonomous, and self-adaptive devices for process degradation monitoring.
- In-process sensors for machine footprint diagnostics supporting decision making in both quality control and maintenance planning.
- Formalized data structures and interaction mechanisms between maintenance, quality and production logistics departments.



# FUTURE TRENDS

## Increasing Demand for Mass Customization, Personalization and Small Batch

- Shorter product lifecycles.
- Increasing product variants and decreasing lot sizes.
- High customization of products, moving towards mass customization.
- Frequent system reconfigurations and ramp-ups.



## Pressure on Efficiency in Delivering Complex, Multi-material Products

- Continuous pressure on quality, due-time performance and cost reduction.
- New advanced materials and disruptive manufacturing processes.
- Complex and hybrid multi-material joining technologies.
- Robustness of zero defect manufacturing solutions.



## Pressure to Deliver Zero Waste and Improve the Social and Environmental Performance of EU Industries

- Emphasis on sustainable and energy-efficient manufacturing.
- Circular economy opportunities and new business models.
- Worker-oriented production and assembly solutions.



## New Service-oriented Businesses and Globally Efficient Manufacturing Ecosystems

- Integration of product and service systems.
- Complex and distributed production networks.
- Region-dependent product features.
- Opportunities for frugal innovation\* for emerging markets.



\* Frugal innovation (also called frugal engineering) is the process of reducing the complexity and cost of goods and their means of production.

## Integrated Approach to Quality Control, Production Logistics and Maintenance Policies

- Progressing in quality costs and performance at operative levels (fixturing/ clamping, machine, process) and system levels (manufacturing cell, workshop).
- Transformation of current value chains into interconnected plants (embracing suppliers, providers, customers).
- Maintenance as new business model with value contribution (past evolution from corrective -> preventive -> predictive).



# Project Partners



**POLITECNICO  
DI MILANO**



**PHILIPS**



**Advanced Manufacturing Research Centre**



**UNIVERSITÀ  
DEGLI STUDI  
DI PADOVA**

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