**Project Title:**

Zero-defect manufacturing strategies towards on-line production management for European FACTORies

FOF-03-2016 - Zero-defect strategies at system level for multi-stage manufacturing in production lines

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<td>Z-Fact0r Use Cases</td>
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<td>Submission month of deliverable</td>
<td>M28</td>
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<td>Issuing partner</td>
<td>NECO</td>
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<td>Contributing partners</td>
<td>SIR, DURIT, DATAPIXEL, ATLANTIS, CERTH, HOLONIX</td>
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<td>Dissemination Level (PU/PP/RE/CO):</td>
<td>PU</td>
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“This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 723906”
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Document Information

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<td>Quality check</td>
<td>ATLANTIS, CERTH, SIR</td>
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Revision History

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<td>Z-Fact0r system update</td>
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<td>SIR, CERTH</td>
<td>Internal Review</td>
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<td>3.0</td>
<td>ATLANTIS, CERTH</td>
<td>Final review and release</td>
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</tr>
</tbody>
</table>
Contents

1 Summary .................................................................................................................. 1
2 Introduction .............................................................................................................. 3
   2.1 Content and scope of this deliverable ............................................................... 4
3 End users' shopfloors (AS IS) ................................................................................ 5
   3.1 Microsemi ........................................................................................................... 5
   3.2 Durit .................................................................................................................. 6
   3.3 NECO ............................................................................................................... 7
   3.4 Interseals ......................................................................................................... 9
4 Strategy and Methodology (TO BE) ..................................................................... 12
   4.1 Microsemi Scenario ......................................................................................... 15
      4.1.1 UC–M–01 ............................................................................................... 16
      4.1.2 UC–M–02 ............................................................................................... 18
   4.2 Durit Scenario .................................................................................................. 21
      4.2.1 UC–D–01 ............................................................................................... 21
      4.2.2 UC–D–02 ............................................................................................... 23
      4.2.3 UC–D–03 ............................................................................................... 25
   4.3 NECO Scenario ............................................................................................... 27
      4.3.1 UC–N–01 ............................................................................................... 29
      4.3.2 UC–N–02 ............................................................................................... 32
   4.4 Interseals Scenario ......................................................................................... 34
      4.4.1 UC–I–01 ............................................................................................... 35
      4.4.2 UC–I–02 ............................................................................................... 38
5 Scenario Interpretation and Requirements ............................................................. 41
   5.1 Microsemi ........................................................................................................... 41
   5.2 Durit .................................................................................................................. 42
   5.3 NECO ............................................................................................................... 43
   5.4 Interseals ......................................................................................................... 43
6 Conclusions ............................................................................................................. 45
7 List of Figures ......................................................................................................... 46
8 List of Tables .......................................................................................................... 47
9 References .............................................................................................................. 48
## Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>UK</td>
<td>United Kingdom</td>
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<tr>
<td>PCB</td>
<td>Printed Circuit Board</td>
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<td>KPI</td>
<td>Key Process Indicator</td>
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<td>UC</td>
<td>Use Case</td>
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<td>ROI</td>
<td>Return on Investment</td>
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<td>CPK</td>
<td>Process Capability Index</td>
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<td>LCP</td>
<td>Liquid Crystal Polymer</td>
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<td>M</td>
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<td>D</td>
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<td>SCADA</td>
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<td>Early Stage Decision Support System</td>
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<td>DSS</td>
<td>Decision Support System</td>
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<td>HMI</td>
<td>Human Machine Interface</td>
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<td>KMDSS</td>
<td>Knowledge Management and Decision Support System</td>
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<td>RSC</td>
<td>Reverse Supply Chain</td>
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<td>GDP</td>
<td>Gross Domestic Product</td>
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<td>Small and Medium Enterprises</td>
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<td>ISO</td>
<td>International Standards Organization</td>
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<tr>
<td>AEM</td>
<td>Ethylene Acrylic Rubber</td>
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<td>ACM</td>
<td>Polyacrylate Acrylic Rubber</td>
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<tr>
<td>GUI</td>
<td>Graphical User Interface</td>
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<td>PC</td>
<td>Personal Computer</td>
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<td>HSS</td>
<td>High-Speed Steel</td>
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<td>Outside Diameter</td>
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1 Summary

The Z-Fact0r project has the goal to minimise defects and maximise quality and performance within manufacturing industries. This report focuses on the three end users Microsemi, Durit and NECO and also their use cases described in Chapters 4.1, 4.2 and 4.4 respectively, and implementation of 5 strategies, namely Z-PREDICT, Z-PREVENT, Z-DETECT, Z-REPAIR and Z-MANAGE to demonstrate and implement Z-Fact0r in the existing manufacturing plan with minimum interventions.

The three end users on engrossing 5 strategies:

- **Microsemi Semiconductor Limited, UK (Microsemi)**
  Microsemi is a multinational semiconductor company with a strong UK manufacturing base in Caldicot. This division has extensive micro-packaging capabilities for medical, wireless, telecommunications and security customers. With experience in micro-electronics modules, focusing on miniaturisation, Microsemi understands the potential for new innovative product. Z-Fact0r, will raise the production line of Microsemi on a higher level by solving the errors and minimising the defects that occurs during the process of die placement and gluing onto a mother panel. For instance, the estimated scrap cost of one assembled Printed Circuit Board (PCB) is in the order of $100 to $150 which represents a significant value at even high yields. In other words, 75% produce at 60k per year results a scrap cost of $1.5M, whereas 95% yield represents a scrap cost of $300,000.

- **Durit Metalurgia Portuguesa do Tungstenio LDA, Portugal (Durit)**
  Durit, as a modern family company has been developing and producing standard or custom-made precision tools, and engineering components for large-scale or individual production, made of tungsten carbide for more than 30 years. Focusing on partnership and current customers’ demands, Durit’s experience and expertise, pursue the goal to create sustainable relationship and to embrace trends in today’s production. Z-Fact0r will enable the reduction of the overall product rejections (70%) registered by Durit by implementing 5 strategies of the project.

- **Nueva Herramienta de Corte, Spain (NECO)**
  NECO as part of the TIVOLY Group delivers a diverse portfolio of tools and services around the world. Each time the demands are greater and it’s not always easy to determine the best tool for each application, manufacture and send it to the customer facilities in a short delivery time. Also, the performance of the tool has to be uniform to achieve a reliability in the product. To ensure the right performance of the tool, a lot of characteristics and parameters of the taps have to be checked and controlled. Z-Fact0r will enable the reduction of the quantity of parts (35%) that are produced wrongly by NECO (and therefore, they will have a bad performance) introducing Z-Fact0r strategies inside the production process.

- **Interseals**
  Interseals manufactures elastomeric sealing solution for industrial application, in particular about the 50% of the market is for Automotive. Since the middle of the last year, the company has been implementing the Lean Manufacturing Concept, which allowed them to identify different Product Families. The more important of them in term of production volume (about 50% of the total), is the Family named “All in One” and it will be the Interseals use case for the Z-Fact0r project. The process and quality data gathered for years, show that the most of the defects occur during the moulding phase in which it develops an under controlled relation between the raw material
characteristics and the process parameters. The “unknown” relation is the source of potential defects. This assumption pushed Interseals to change its organization and plant layout from a Department Production, to a Cell Production, welcoming the Lean Manufacturing Concepts. Thanks to this choice, we can easily DETECT the defects on the part after moulding, setting up the machines manually in order to eliminate defects at the next shot. However, until now they can neither PREDICT the defect, nor PREVENT it. So, Interseals really needs a system as Z-Fact0r that will be able to help them reach the zero defects goal.

The detailed description of end users and their shop floors can be found in deliverable D1.1 Z-Fact0r User Requirements.

Scenarios of these end users were conducted in order to identify where Z-Fact0r’s manufacturing strategies can be applied in order to achieve zero defect in the production process for each company. Each use case was developed in detail, integrating the consolidated requirements (D1.1 Z-Fact0r User Requirements), customizing the architecture (D1.3 Z-Fact0r System Architecture) and developing a proper set of Key Performance Indicators (KPI) to evaluate the performance achieved. Each use case will be defined during its whole lifecycle identifying which performance can be measured with the demonstrators.

**Microsemi Scenario**
- UC-M-01 Insufficient Glue
- UC-M-02 Excess Glue

**Durit Scenario**
- UC-D-01 Green Machining
- UC-D-02 Sintering and Finishing
- UC-D-03 Finishing

**NECO Scenario**
- UC-N-01 Wrong cutting angle
- UC-N-02 Wrong flute form

**Interseals**
- UC-I-01 Lack of material
- UC-I-02 Breakages

The TO BE Use Cases are assessed based on the Methodology reported in the Section 4. The template at Table 1 was presented during the online workshop held by ATLANTIS Engineering and provided to all end users as guideline to follow and define use cases. Each end user has reported the defects that are occurring during their own production processes and how those defects can be predicted and prevented, with the possibility to use additive and subtractive manufacturing techniques including also monitoring and real-time decision support.

**NOTE:** Even though Interseals is terminated beneficiary since June 2018 and replaced by NECO, this section provides the information collected during the M01-M04 of the project when Interseals was still the Z-Fact0r consortium partner at the time.
2 Introduction

The Z-Fact0r project is addressing the need for zero-defect manufacturing, but never the less there is still a huge business opportunity for innovative, high-ROI (Return on Investment) solutions to ensure, better quality and higher productivity in the European manufacturing industries.

Manufacturing represents approximately 21 % of the EU’s GDP and 20 % of its employment, providing more than 30 million jobs in 230,000 enterprises, mostly SMEs. Moreover, each job in industry is considered to be linked to two more in related services. European manufacturing is also a dominant element in international trade, leading the world in areas such as automotive, machinery and agricultural engineering. Already threatened by both the lower-wage economies and other high-tech rivals, the situation of EU companies was even made more difficult by the downturn.

Thanks to the 5 intertwined zero-defect strategies the overall solution is expected to contribute to a spectacular improvement in the overall performance and reliability of the targeted multi-stage manufacturing systems and in the production agility (response to continuous adjustments in production targets). It will thus facilitate the adoption of risk-based thinking (in line with ISO 9001:2015) at enterprise level by supporting faster and better decision making at shop floor. The Z-Fact0r solution presented in Figure 1, comprises the introduction of five (5) multi-stage production-based strategies targeting:

- early defect detection (Z-DETECT),
- defect generation prediction (Z-PREDICT),
- defect generation prevention at the production line as well as defect propagation in later stages of the production (Z-PREVENT),
- product reworking/remanufacturing (Z-REPAIR) and
- monitoring and real-time decision support (Z-MANAGE).

Some details of these 5 strategies can be found at Section 4 and their implementation was already presented in deliverable D1.5 Report on Z-Fact0r Strategy Implementation and Risk Analysis.

Figure 1. Synergies and interactions between the five Z-Fact0r strategies.
2.1 Content and scope of this deliverable

This deliverable is the end users’ document that presents the current shop floor statuses (AS IS) as well as defines TO BE scenarios of three end users Microsemi, Durit and NECO. The use cases have derived from a scenario thinking process which involved dedicated workshop held by ATLANTIS Engineering with each end user individually together with other project partners as well. The objective of activity in this task (T1.4 Use case design) has been to identify specific defect of every end user and their needs and goals at production lines and processes as well as to propose the solution for achieving the zero-defect production. Analyses have been carried out based on use case description methodology (Table 1) in Section 4, in order to obtain a list of involved actors, stakeholders, workflows, minimal guarantees, etc.

Some basic background information about the three Z-Fact0r end users and AS IS scenarios are provided in Section 3 in order to provide an understanding of their present state of play, needs and challenges.

The scenarios and use cases have been developed in close cooperation with the Z-Fact0r end users in order to ensure that the scenarios and use cases reflect the needs and challenges which are envisioned by the project. Hence, dedicated workshops working with the scenarios were conducted and the methodology and approach to these is described in Section 4.

In sub-sections 4.1, 4.2 and 4.3, the TO BE scenarios and the future use cases for three end users, Microsemi, Durit and NECO are presented and discussed in details.

Section 5 presents interpretation of the scenarios together with the related requirements of Z-Fact0r partners, followed by conclusion and references, respectively.
3  End users’ shopfloors (AS IS)

The following sub-section 3.1 Microsemi, 3.2 Durit and 3.4 NECO provide general and brief background description of the three end users in Z-Fact0r project which consist of seven use cases that also present their connection with user requirements. The Z-Fact0r system will be addressing in details three different industry types, conductors, metal and plastic proving its applicability and the achievement of the approach for zero-defects in multistage productions of various types of industries.

NOTE: Even though Interseals is terminated beneficiary since June 2018 and replaced by NECO, in Section 3.4 Interseals provides the information collected during the M01-M04 of the project when Interseals was still the Z-Fact0r consortium partner at the time.

3.1  Microsemi

Microsemi Semiconductor Ltd is manufactures miniature electronic modules for medical, security and communication industries. During the glue dot placement process, silicon dies and other wire bondable components are attached to an LCP substrate by means of a conductive glue dispensed via the dispense system. Once the glue dots have been placed on the substrate, the bond head picks up the silicon die from a waffle tray and places it into the glue to a controlled height. Two different types of malfunction can happen during the dispense of the conductive glue. The quantity of glue can either be insufficient or there can be an excess of the dispensed glue. Both malfunctions cause damages to the part and result to discard such parts. At Figure 2 the glue fillet acceptabilities are presented.

![Figure 2. Glue fillet acceptability.](image)

The current failure rate is very high which can only be tolerated in preproduction runs but with target volumes are in the order of 60kPa unacceptable. There is a need to be able to improve this process and ideally control the amount of glue being dispensed in to the cavity. Optical inspection would help along with process trend monitoring, together with prediction of the usability of the glue. The objective is to raise the yield into the high bigger than 95% with a process capability index (CPK) in the order of 2.

The assembly is a multistage process that starts with visual inspection of the base PCB, glue dot dispenses, placement of the die/component, glue cure, wirebond die, etc.
During the Microsemi scenario and its use cases, all Z-Fact0r strategies will be employed, i.e. the Z-REPAIR strategy will be assessed using Additive Manufacturing techniques to rework the product (e.g. remove excess glue, add glue in cases of adhesion problems). This assessment will take place offline using the robotic cell during the product process monitoring, defect life-cycle management and remanufacturing (WP2) of the project.

At the moment, quality control process presented at Figure 3 at the production line is done manually by the operators. They are checking the defects prior placing the part and if the defect occurs, notification is created according to the spotted malfunction, since there is no possibility for automated response. For the part that has the defect - insufficient glue (UC-M-01), the operator is manually applying the rest of the glue using the glue gun correcting the defect and the part is re-entering the process line. However, if the defect is categorised as excess glue defect (UC-M-02), the operator will discard the malfunctioning board. Re-entering the process line is not possible at this stage of the process, but recycling of such part can be possible.

![Diagram](image-url)

Figure 3. Microsemi Scenario, AS IS Workflow.

### 3.2 Durit

Durit is an intensive user of precision grinding, milling and turning operations particularly for the final stages of hard metals (WC-Co) wear tooling for numerous industrial applications. In this field are usual very tight surface finishing, including surface roughness, dimensional tolerances and structural integrity that must meet precise standards, which demands intensive measuring and quality control. The quality control is done manually by operator and there is a possibility to automate this process. The production strategy is for custom order, so instead a production line, there are production cells and there is a specific cell for quality assessment divided in 3 areas:
During check control operations at geometric tolerance quality control, the part could be found with defects. If the defect is detected, the part is excluded from the production, analysed and either send to remanufacturing (if the tolerance is not crossed over) or taken for scrap (if part is in the second phase of sintering since this kind of part is difficult to recycle).

The pore defects quality control is made always by an operator (Figure 4). Some parts only by a visual inspection of an operator and his naked eyes, otherwise for some other parts the operator use magnifying glass or microscope as well as the 3D machines.

Moreover, micro-cracks can occur during the extraction of the die. It is familiar that the pressuring press as well as different angle punching are the problems causing the defect of the part.

In this manufacturing equipment, the quality control is monitored essentially by operator measurement, with no sensor technology. During this scenario use case, the Z-REPAIR strategy will also be assessed in cases of deburring, but also Additive Manufacturing using laser sintering.

3.3 **NECO**

In the current manufacturing process, the first step is the arrival of the raw material (HSS bars). Then, they are cut-off and turned, to be heated and treated to finalised with a process of OD & square grinding that ends the semi-finished blanks stocks (Figure 5). This step has conventional operations and except for the heat treat process, the rest don’t have a critical know how. The lead time are 3-4 weeks for this step, so the critical point is the big batch size needed.
The second step of the manufacturing process starts with the semi-finished blanks stocks when they are sent to the flute grinding and it is show in the Figure 6. After that, they passed through the chamfer grinding and the thread grinding to finish as bulk stock. This step contains critical operations and is the one that brings added value. Its lead time is 2-3 weeks. In this case, the changeover time and the repeatability are the critical points of the process.

This second step is the core of the production process. In it, the tap is given the active part that will cut the material of the piece to work. Inside the second step we will focus on the flute grinding operation.

The flute grinding of special taps is made in WALTER HELITRONIC machines with manual loading. The machine develops 10 % in units of flute grinding operation and has more than 30 % of the value. 2,000 Manufacturing Orders (MO) are manufactured per year and the average batch size is 30 units.

The requirements to control the taps produced in this operation are:

**Functional Requirements**

NECO would use Z-Fact0r to detect the taps defects and monitor dimensional tolerances comparing the produced taps to the original CAD (Computer-Aided Design) file. The system must be able to collect data from the tooling, the process and the machines, detect defects and return an alert or trigger a response action.

**Non-Functional Requirements**

- Ensure a safe workplace for the operator.
- User friendly system.

The current quality control process, which is done manually by the operators, is presented in the Figure 7.
The production of a gasket is made in a single area (“All in One”), composed by raw material, moulding injection machine, tool, human operator, and finishing and checking bench. The process and quality data gathered for years, show that the most of the defects occur during the moulding phase in which it develops an under controlled relation between the raw material characteristics and the process parameters. The “unknown” relation is the source of potential defects. For use case scenarios, Interseals will consider the poly acrylic (AEM) and poly acrylate (ACM) materials that are very modern and very difficult to produce.

Z-Fact0r project will support the building of an Objective Lesson Learnt Data Base that will help Interseals to set up and reconfiguring the parameters in a consistent and repeatable way. It will be possible adding new sensors to the moulding machines level and sensor into the tool, gathering and working on the information collected.

The quality of the goods is constant traced and Interseals ensures to the Customers a quality level, less than 50 ppm. Because of the competitiveness in the market this is not enough. Z-Fact0r system will continuously check the raw material providing advanced monitoring data for better analysis and re-configuration.
Figure 8. Interseals cause-effect process diagram.
Raw material incoming, small specimen check by laboratory

Material carried to the selected molding machine by shift leader

The shift leader checks (visual inspection) and mounts the tool into the clamping side

The shift leader selects manually the set of molding parameters from the display

Warm up and process freeze

Start the production

After 3-5 minutes the clamping side opens and the operator extracts the shot

Flash removal

Operator visual inspection following printed instructions

If inspection ok, operator places the part in ok space

If inspection not ok, operator places the part in not ok space and calls the shift leader

The shift leader changes manually some moulding parameters or call the Laboratory for support

Figure 9. Interseals Scenario, AS IS Workflow.
4 Strategy and Methodology (TO BE)

Each of the developed strategies will be triggered based on detecting and assessing the impact of system level events that cause lower quality, generate defects, and increase the costs. The holistic approach of Z-Fact0r utilizes all the acquired data from which a prediction is made with confidence levels above 95%.

Z-PREDICT

The events detected from the physical layer of the system are engineered into high value data high that will stipulate new and more accurate process models. Such an unbiased systems behaviour monitoring and analysis provides the basis for enriching the existing knowledge of the system (experience) learning new patterns, raising attention towards behaviour that cause operational and functional discrepancies (e.g. alarms) and the general trends in the shop floor. The more the data pool is being increased the more precise (repeatability) and accurate the predictions will be. The estimations for the future states involve the whole production line, e.g. machine status after x number of operations and/or quality of the products for given set of parameters. The system will predict with high confidence the expected quality and customer satisfaction, allowing modifications to the parameters before the production of the products. In addition, Z-Fact0r can operate in the reverse mode, i.e. insert a Customer Satisfaction Goal and control the parameters accordingly to achieve this target. The ability of Z-Fact0r to optimise the manufacturing processes according to certain/target quality levels and/or customer satisfaction is the key innovation to fulfil the industrial requirements.

Z-PREVENT

The prevention of defects strategy is based on the quality control and the inspection tools realised across the shopfloor for condition monitoring of machinery and respective produced quality. The Z-PREDICT is predecessor of Z-PREVENT. The initial estimation of the future states and expected outcomes are taken into account and based on the simulation and modelling of the parameters. For each predicted defect, the responsible parameters are identified and flagged. The system adapts these parameters based on an initial estimation, which after the simulation these are corrected recursively. The result of this process is to avoid the generation of defects based on each recorded event (defect, no-defect, low quality, high-quality) both from previous and current states. The system will demonstrate reduced false alarms by combining the future predictions.

Z-DETECT

This strategy is invoked when a defect is being generated after the adaptation of the parameters. In such a scenario, an alarm is being triggered to flag the parameters that resulted in a defect. By mapping the true reasons, the system will be able to avoid having more generated defects by weighting the system model. Apart from the inspection of the product (from which the defect is being observed), the strategy involves more actions and processes to deal both with the generation of the detected defect, and its propagation to the next stages. Depending on the station that the defect was generated, the system will adapt its parameters to the previous successful state and plan to send the defected product either to downstream or upstream stage. The final decision on the actions is based on the Z-MANAGE strategy.
Z-MANAGE

The overall supervision and optimisation of the system are achieved after the execution of Z-MANAGE strategy. The defects are processes with Decision support system (DSS) tools and are interfaced with Manufacturing Execution Systems (MES). False positives and false negatives are clustered after the Z-DETECT strategy, which results into a good filtering of these false alarms. To achieve so, the previous acquired knowledge and incidents are also processed to fine tune the system's operation. Additionally, the production is optimised by better scheduling, taking into account the environmental impact of each process. The optimised scheduling and adaptability of the manufacturing improves the overall flexibility, placing a premium on the production rates, satisfying the demand, while preserve increased machinery availability. Since, the Knowledge management system will tune the whole production according to certain quality levels and customer satisfaction, it is highly anticipated that the overall performance of the system will suffice the increased needs of the customers. The strategy involves also the decision making in the event of a defect. The defect will be analysed via the Inspection system, from which the defect can be classified and categorised on its severity. In case of “repairable” defects, the system will decide for the following: (i) rework on spot, (ii) removal from the production line for further inspection and rework. If the defect is classified as “non-repairable” then the system will decide whether (a) the product will be forwarded to upstream stages, or (b) considered as total failure where it will be recycled.

Z-REPAIR

Once a “repairable” defect is detected, a proper and customized repairing action must be deployed with the minimum time and effort, assuring the best productivity and production flow. In fact, a major challenge for an effective ZD manufacturing is related with the capability to automatically repair the occurred defects without perturbing the overall production flow. Z-Fact0r will develop a model-based, supervisory control solution that will be able to interpret the interstage quality control measurements together with the monitoring of the process itself, in order to identify the defect sources and generate a proper and customized repairing action. Additive manufacturing in the form of inkjet or paste printing of various materials (metal, ceramic, polymer resins) can successfully be used to fill a missing spot or correct a damaged part. Upon detection of the defected area, the printing head will deliver the patch material in solution or paste form. In the case of inkjet printing, defect as small as 20 μm can be patched. Post printing treatment of the delivered material include solvent evaporation (e.g. in the case of polymer patches), UV curing (e.g. in the case of epoxy resins) and low temperature laser sintering in the case of metal or ceramic nanoparticles, thermal curable resins or paste where a local reflow process is required.

Then, starting from the current shopfloor statuses (AS IS) descriptions and corresponding workflows in the sub-sections 3.1, 3.2 and 3.3, the TO BE scenarios of three end users are developed. Scenarios of these end users were conducted in order to identify where Z-Fact0r’s manufacturing strategies can be applied in order to achieve zero defect in the production process for each company and to set up priorities for implementation. Specifically, this section has identified and presented six use cases from three end users: Microsemi (UC-M-01 and UC-M-02), Durit (UC-D-01, UC-D-02 and UC-D-03) and NECO (UC-N-01 and UC-N-02) summarised in subsections 4.1, 4.2 and 4.3. This information was obtained based on the template (Table 1) presented on the online workshops for each end user held by ATLANTIS Engineering. Each end user has reported the defects that are occurring during within their production processes and how they can be predicted and prevented, with the possibility to use additive and subtractive manufacturing techniques including as well monitoring and real-time decision support. The use cases have derived a scenario composed of a list of involved actors, stakeholders, workflows, minimal guaranties, etc.
The scenarios and use cases have been developed in close cooperation with the Z-Fact0r end users in order to ensure that reflect the needs and challenges, which are envisioned by the project. The five zero-defect strategies and their software components are all intertwined and they work together each step of the process. The basic entry point of Z-Fact0r's solution, is the data collection from the shop floor (from automation systems, machine controllers, Human Machine Interface (HMI), sensors, IoT devices, laser scanners and so on). This set of data will be the first input of data of the iterative process.
Each software component is a knowledge source and it is responsible for storing current states and producing new knowledge solving specific problems. The components run autonomously but push any common knowledge to the middleware. The middleware’s purpose is to manage data sets from the shop floor and knowledge produced by components, guaranteeing an effective communication among the various modules and layers, in order to estimate the five Key Performance Indicators (i.e. Productivity, Efficiency, Quality, Environmental Impact and Inventory Control), point out defect alarms and prediction notes, suggest machine setting adjustment and provide to the green schedule solutions respecting production constraints.

The middleware supports both pull and push logic. Using the pull logic with a time interval, the component(s) retrieve new knowledge. On the other hand, with the push logic as soon as the new knowledge is shared by any other component(s), the middleware informs the related component(s) that need that knowledge. The dataflow starts from the shop floor, moves to the measuring and detection components. Then the prediction, prevention and management components keep producing new knowledge, and the flow ends to the repair related components.

During each production stage, the production process is be kept under control. Z-Fact0r solution support different software systems to evaluate the production status (industrial machine monitoring, production performances, processes monitoring). Furthermore, the two Decision Support System (DSS) components and the Reverse Supply Chain (RSC) component supervise and evaluate performance parameters and responding to defects, keeping historical data. They provide feedback to the decision makers, regarding immediate actions needed in response to shop floor incidents, together with changes to manufacturing operations and processes.

4.1 Microsemi Scenario

Microsemi TO BE scenario and idea to connect the multistage process with Z-Fact0r data gathering and Z-Fact0r five strategies is presented at Figure 10. It is familiar that two different types of defects can happen during the glue dot placement process. The quantity of dispensed glue via the dispense system can either be insufficient, or there can be an excess of the glue onto the LCP substrate. Both defects cause damage to the part and result to discard such a part. This scenario leads to two use cases presented in details in sub-sub-sections 4.1.1 and 4.1.2, respectively. Table 2 UC-M-01 Insufficient Glue and Table 3 UC-M-02 Excess Glue display the use cases details, specifying goals, scopes, actors, etc. followed by respective workflows in Figure 11 and Figure 12.
Figure 10. Microsemi Z-Fact0r data gathering overview.

### 4.1.1 UC–M–01

<table>
<thead>
<tr>
<th><strong>Goal</strong></th>
<th>Detect and address the issue of insufficient glue prior to placement of die in order to avoid this defect or repair the defective part with additive manufacturing actions when possible.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scope</strong></td>
<td>Improvement of Microsemi’s control line in an automatic way and minimize parts/dies with insufficient glue</td>
</tr>
<tr>
<td><strong>Actors</strong></td>
<td>&lt;Control operator&gt; The worker who supervises the machine, visually checks the glue level at the part and decides whether the part should continue on the production line, if there is the right amount of glue or if it should be removed from the production line.</td>
</tr>
<tr>
<td></td>
<td>&lt;Glue workers&gt; They manually apply glue to parts with insufficient glue</td>
</tr>
<tr>
<td><strong>Stakeholders</strong></td>
<td>&lt;Procurement Officers&gt; They should know the rate of failure and order new raw material.</td>
</tr>
</tbody>
</table>
**<Logistics Department>** They need to acknowledge the costs of the production (orders of new raw materials, disposal of scrap, etc.), the possible improvements cost–wise and the efficiency of the machine.

**<Technical Department>** They are monitoring the Company's working system, checking the requisitions for glue and other lubricants, spare parts/ supplies and maintains files/records.

<table>
<thead>
<tr>
<th>Preconditions</th>
<th>The system (algorithms and operators?) has undergone an initial training on detecting insufficient glue type of defects.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trigger</td>
<td>Insufficient glue placement is automatically recognized (by camera/laser) and sends message/warning/notification to the system/operator to add more glue to the specific die.</td>
</tr>
<tr>
<td>Minimal Guarantees</td>
<td>The system is ready to scan the next module on the panel during the process of production.</td>
</tr>
</tbody>
</table>
| Succeed Guarantees | The system should detect and decide precisely which parts need to be reworked and be temporarily excluded during die placement and those that will continue in the production process.  
The objective is to raise the yield into the high >95% with a process capability index (CPK) in the order of 2. |
| Workflow      | 1. The die with insufficient volume of glue is registered in an automatic way.  
2. System automatically sends notification regarding the defect of insufficient glue volume.  
3. The specific part/die is temporary excluded from the production.  
4. Automatically more glue is added on the specific part/die that has a recorded problem.  
5. After adding more glue, the die is returned in the production.  
6. Second automatic inspection recognises that the volume of glue is according to the specifications.  
7. The module is ready and it is released to the next step of the production. |
| Extension     | The system is recalibrated, in order to prevent the production of defective components.  
Data analytics can predict defective parts. |
| Related Information | Semantic context manager, HMI & Sensor network, Data acquisition and processing, Middleware, Real-time quality control, Production management, Integrated KMDSS, Reverse supply chain, Z-Fact0r Repository, Additive Manufacturing repair |
Automatically more glue is added on the specific part/die that has a recorded problem

After adding more glue, the die is returned in the production

Second automatic inspection recognises that the high layer of glue is according to the specifications

Die is placed and it is released to the next step of the production.

The die with insufficient high/layer of glue is registered in an automatic way

System automatically sends notification regarding the defect of insufficient glue layer

The specific part/die is temporarily excluded from the production

Figure 11. UC-M-01 workflow diagram.

4.1.2 UC–M–02

Table 3. UC-M-02 Excess Glue.

<table>
<thead>
<tr>
<th>Goal</th>
<th>Detect and address the issue of excess glue prior to placement of die in order to avoid this defect or repair the defective part with additional manufacturing actions when possible.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>Improvement of Microsemi’s control line in an automatic way and minimize parts/dies with excess glue.</td>
</tr>
<tr>
<td>Actors</td>
<td>&lt;Control operator&gt; The worker who supervises the machine, visually checks the glue level at the part and decides whether the part should continue on the production line, if there is the right amount of glue or if it should be removed from the production line.&lt;Glue workers&gt; They adjust the machine program to not place die to modules with excess glue</td>
</tr>
<tr>
<td>Stakeholders</td>
<td>&lt;Procurement Officers&gt; They should know the rate of failure and order new raw material.&lt;Logistics Department&gt; They need to acknowledge the costs of the production (orders of new raw materials, disposal of scrap, etc.), the possible improvements cost–wise and the efficiency of the machine.</td>
</tr>
</tbody>
</table>
<Technical Department> They are monitoring the Company's working system, checking the requisitions for glue and other lubricants, spare parts/ supplies and maintains files/records.

<table>
<thead>
<tr>
<th>Preconditions</th>
<th>The system (algorithms and operators?) has undergone an initial training on detecting excess glue type of defects.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trigger</td>
<td>Excess glue placement is automatically recognized (by camera/laser) and sends message/warning/notification to the system/operator to reduce glue-dispensing volume to the specific die.</td>
</tr>
<tr>
<td>Minimal Guarantees</td>
<td>The system is ready to scan the next module on the panel during the process of production.</td>
</tr>
</tbody>
</table>
| Succeed Guarantees     | The system should detect and decide precisely which parts need to be excluded from further manufacturing and those that will continue in the production process.  
                          | The objective is to raise the yield into the high >95% with a process capability index (CPK) in the order of 2. |
| Workflow               | 1. The die with excess volume of glue is registered in an automatic way.  
                          | 2. System automatically sends notification regarding the defect of excess glue volume.  
                          | 3. In the case of a gross defect the specific module/die is temporary excluded from the production.  
                          | 4. After being recorded and notification given modules with a smaller excess of epoxy volume are returned to production.  
                          | 5. Module is ready and it is released to the next step of the production. |
| Extension              | The system is recalibrated, in order to prevent the production of defective components. Data analytics can predict defective parts. Data analytics can predict defective parts. Z-repair can attempt removal of excess glue. |
| Related Information    | Semantic context manager, HMI & Sensor network, Data acquisition and processing, Middleware, Real-time quality control, Production management, Integrated KMDSS, Reverse supply chain, Z-Fact0r Repository, Laser Manufacturing repair |
Automatically the system would identify modules with excess glue.

If a module has a small excess of glue it is identified but allowed to continue through the normal production flow.

Modules identified for small excess volumes of glue are checked for glue shorting to wire bond locations.

Acceptable parts are allowed to progress through the normal production flow.

Parts found to have excess glue are put through the Z-repair system (laser ablation).

Step 5: Repaired modules are re-inspected for glue shorts.

Acceptable parts from the rework process are allowed to rejoin the normal process flow.

Figure 12. UC-M-02 workflow diagram.
4.2 Durit Scenario

Durit TO BE scenario introduced at Figure 13, presents Z-Fact0r strategies that will be adopted and implemented as a predictive system to monitor inline the quality of the parts, particularly, the dimensional tolerances and surface defects, register the data and predict quality deviations resulting from systematic errors and improper machine operation. This system is based on a series of sensors coupled to different production stages and include optical sensors, for comparing the true dimensional geometry and tolerances with the specified ones. These scenarios lead to three use cases summarised in Table 4, Table 5 and Table 6, respectively that describe in details Green Machining, Sintering and Finishing, and Finishing TO BE solutions.

![Durit TO BE Scenario](image)

**Figure 13.** Durit TO BE Scenario.

### 4.2.1 UC-D–01

<table>
<thead>
<tr>
<th><strong>Goal</strong></th>
<th>Detect the appearance of dimensional, and surface defects such as large voids or cracks during green stage machining, improving product quality, avoiding adding value on non-compliant parts and develop a predictive algorithm that detects trends in parts quality that may indicate the future presence of the mentioned defects. The strategy is to try correlating the machining conditions, as detected by a set of sensors, and defects such as cracks or dimensional out-of-specification values using automatic 3D optical measurements.</th>
</tr>
</thead>
</table>

Table 4. UC-D-01 Green Machining.
### Scope

| Improvement of DURIT control line in an automatic way and minimize parts/dies with quality defects. |

### Actors

| **<Control operators>** | The worker who supervises the machine or the quality supervisor, visually checks the parts and decides whether the part should continue on the production line, if the quality is sound or analyse the possibility to rework it or even scrap it in case it is not compliant. |
| **<Quality manager>** | Report the non-quality and develop a research on the cause factors and preventive actions to follow. |

### Stakeholders

| **<Metallurgy Manager>** | They should know the rate of failure to prepare workflow and workload. They need to acknowledge the costs of the production (orders of new raw materials, disposal of scrap, etc.), the possible improvements cost – wise and the efficiency of the machine. |
| **<Finishing Manager>** | They should know the rate of failure to prepare workflow and workload. They need to acknowledge the costs of the production (orders of new raw materials, disposal of scrap, etc.), the possible improvements cost – wise and the efficiency of the machine. |
| **<Technical Department>** | They are monitoring the Company's working system, production orders and reworking orders. |

### Preconditions

| The system (algorithms and operators) has undergone an initial training on detecting the different type of defects. |

### Trigger

| Surface defects are automatically recognized when placing the parts in the quality check apparatus (by camera/laser) and sends message/warning/notification. |

### Minimal Guarantees

| The system is ready to scan the next component at panel at process production. The system must be able to recognize different types of geometries. |

### Succeed Guarantees

| The objective is to reduce the rejected parts by 0.8% to less than 0.5% overall, allowing a reduction of 200K€/year. |

### Workflow

| 1. The part is produced. |
| 2. Operator performs Z-Fact0r set-up according to the part, and proceeds to automatic quality check. |
| 3. Inspection of the part, with the Z-Fact0r apparatus. |
| 4. A quality report is performed and presented to the operator. Data is stored in server. |
| 5. Information of non-compliant parts is sent to the different shareholders. |
| 6. Data enters an algorithm that predicts the appearance of future defects based on quality report trends identified earlier. |
| 7. The inspected part proceeds to the next production step, if OK, or is analyzed by quality manager for possible reworking. |

### Extension

| The system is recalibrated to prevent the production of defective components. Data analytics can predict defective parts. |

### Related Information

| Semantic context manager, HMI & Sensor network, Data acquisition and processing, Middleware, Real-time quality control, Production management, Reverse supply chain, Z-Fact0r Repository |

---
Figure 14. UC-D-01 workflow diagram.

4.2.2 UC–D–02

Table 5. UC-D-02 Sintering and Finishing.

<table>
<thead>
<tr>
<th>Goal</th>
<th>Detect the appearance of surface defects such as pores, voids and cracks after sintering and during finishing, improving product quality, avoiding adding value on non-compliant parts and develop a predicative algorithm that detects trends in parts quality that may indicate the future presence of the mentioned defects. The scope of this Use Case includes a correlation with the powder preparation stages (milling, spray drying, sintering) as well as with the finishing operations of the sintered products.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>Improvement of DURIT control line in an automatic way and minimize parts with quality defects.</td>
</tr>
</tbody>
</table>
| Actors | <Control operators> The worker who supervises the machine or the quality supervisor, visually checks the parts and decides whether the part should continue on the production line, if the quality is sound or analyse the possibility to rework it or even scrap it in case it is not compliant.  
<Quality manager> Report the non-quality and develop a research on the cause factors and preventive actions to follow. |
| Stakeholders | <Raw Materials Preparation Manager> They should know the rate of failure to prepare workflow and workload. They need to acknowledge the costs of the production due to deficiencies in the stage of powder preparation and that |
propagate throughout the subsequent production stages, and act accordingly to improve efficiency and thus productivity.

<**Metallurgy Manager**> They should know the rate of failure to prepare workflow and workload. They need to acknowledge the costs of the production (orders of new raw materials, disposal of scrap, etc.), the possible improvements cost – wise and the efficiency of the machine.

<**Finishing Manager**> They should know the rate of failure to prepare workflow and workload. They need to acknowledge the costs of the production (orders of new raw materials, disposal of scrap, etc.), the possible improvements cost – wise and the efficiency of the machine.

<**Technical Department**> They are monitoring the Company's working system, production orders and reworking orders.

<table>
<thead>
<tr>
<th><strong>Preconditions</strong></th>
<th>The system (algorithms and operators?) has undergone an initial training on detecting the different type of defects.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Trigger</strong></td>
<td>Surface defects are automatically recognized when placing the parts in the quality check apparatus (by camera/laser) and sends message/warning/notification.</td>
</tr>
<tr>
<td><strong>Minimal Guarantees</strong></td>
<td>The system is ready to scan the next component at panel at process production. The system must be able to recognize different types of geometries.</td>
</tr>
<tr>
<td><strong>Succeed Guarantees</strong></td>
<td>The objective is to reduce the rejected parts by 0.8% to less than 0.5% overall, allowing a reduction of 200K€/year.</td>
</tr>
<tr>
<td><strong>Workflow</strong></td>
<td>1. The part is produced. 2. Operator performs Z-Fact0r set-up according to the part, and proceeds to automatic quality check. 3. Inspection of the part, with the Z-Fact0r apparatus. 4. A quality report is performed and presented to the operator. Data is stored in server. 5. Information of non-compliant parts is sent to the different shareholders. 6. Data enters an algorithm that predicts the appearance of future defects based on quality report trends identified earlier. 7. The inspected part proceeds to the next production step, if OK, or is analyzed by quality manager for possible reworking.</td>
</tr>
<tr>
<td><strong>Extension</strong></td>
<td>The system is recalibrated to prevent the production of defective components. Data analytics can predict defective parts.</td>
</tr>
<tr>
<td><strong>Related Information</strong></td>
<td>Semantic context manager, HMI &amp; Sensor network, Data acquisition and processing, Middleware, Real-time quality control, Production management, Reverse supply chain, Z-Fact0r Repository</td>
</tr>
</tbody>
</table>
Goal | Detect the appearance of dimensional defects and surface defects such as pores, voids, cracks or excess roughness during finishing stage, improving product quality, avoiding adding value on non-compliant parts and develop a predictive algorithm that detects trends in parts quality that may indicate the future presence of the mentioned defects. In this use case scenario, the system should also be able to monitor some dimensions and geometric tolerances of the parts. In this Use Case the raw materials are sintered hard metal bars acquired from a third party.

Scope | Improvement of DURIT control line in an automatic way and minimize parts with quality defects, including out of tolerance dimensions.

Actors | <Control operators> The worker who supervises the machine or the quality supervisor, visually checks the parts and decides whether the part should continue on the production line, if the quality is sound or analyse the possibility to rework it or even scrap it in case it is not compliant.

<Quality manager> Reports the non-quality and develops a research of the cause factors and preventive actions to follow.

Stakeholders | <Finishing Manager> They should know the rate of failure to prepare workflow and workload. They need to acknowledge the costs of the production (orders of new raw materials, disposal of scrap, etc.), the possible improvements cost wise and the efficiency of the machine.
**<Technical Department>** They are monitoring the Company's working system, production orders and reworking orders.

<table>
<thead>
<tr>
<th>Preconditions</th>
<th>The system (algorithms and operators?) has undergone an initial training on detecting the different type of defects.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trigger</td>
<td>Surface defects are automatically recognized when placing the parts in the quality check apparatus (by camera/laser) and sends message/warning/notification. Dimensional tolerances are measured for specific areas of the part, and compared with the input placed by the operator. A measurement that is out of specification immediately sends message/warning/notification to the operator.</td>
</tr>
<tr>
<td>Minimal Guarantees</td>
<td>The system is ready to scan the next component at panel at process production. The system must be able to recognize different types of geometries, according to the operator input information.</td>
</tr>
<tr>
<td>Succeed Guarantees</td>
<td>The objective is to reduce the rejected parts by 0.8% to less than 0.5% overall, allowing a reduction of losses of 200K€/year.</td>
</tr>
</tbody>
</table>
| Workflow | 8. The part is produced.  
9. Operator performs Z-Fact0r set-up according to the part, and proceeds to automatic quality check.  
10. Inspection of the part, with the Z-Fact0r apparatus.  
11. A quality report is performed and presented to the operator. Data is stored in the server.  
12. Information of non-compliant parts is sent to the different shareholders.  
13. Data enters an algorithm that predicts the appearance of future defects based on quality report trends identified earlier.  
14. The inspected part proceeds to the next production step, if OK, or is analyzed by quality manager for possible reworking. |
| Extension | The system is recalibrated to prevent the production of defective components. Data analytics can predict defective parts. |
| Related Information | Semantic context manager, HMI & Sensor network, Data acquisition and processing, Middleware, Real-time quality control, Production management, Reverse supply chain, Z-Fact0r Repository |
4.3 NECO Scenario

The flute grinding operation presented in AS IS scenario (Section 3.3) is the one with more rejections. A 35% of the quantity of taps manufactured in this operation is wrong (Figure 17).

Figure 16. UC-D-03 workflow diagram.

Figure 17. % of rejections in each operation
In the Figure 18 and Figure 19, it can be seen that the flute grinding operation is a very critical operation. It gives the tap the cutting angle to cut the material and generates the way through the chip generated in the process, with different strategies, will be evacuated from the threaded hole.

![Figure 18. Cutting angle rejection or approval](image)

As there are a lot of different kinds of manufactured geometries for the taps in the NECO Use Case two types of tap geometries (shown in Figure 20) will be checked as they are the most produced ones.

<table>
<thead>
<tr>
<th>GEOMETRY 01</th>
<th>GEOMETRY 02</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUN ENTRY</td>
<td>HELICOIDAL / SPIRAL</td>
</tr>
</tbody>
</table>

![Figure 20. Geometries for the use case](image)

These two geometries have been selected because they are the most commercialized products and the most interested to be controlled. Both geometries have the same defects that’s why in both of them the cutting angle and the flute form will be checked. With Z-DETECT strategy some parameters will be specified such as values of certain radios that should fit in with the obtained piece. In the Figure 21, both types of defects can be observed with different magnitudes of error.

![Figure 21. Different cutting angles and flute forms.](image)
At the moment the quality control process is carried out as is showed in the Figure 7 (Section 3.3). Both defects are addressed in the same way: the operator decides to reject or to rework the wrong tap.

During the NECO use cases, some of the Z-Fact0r strategies will be deployed (in example, Z-DETECT with the scanning of the pieces for detecting the defects of the taps). The two Use Cases are summarized in Table 7 and Table 8 and describe the TO BE Solutions for the Wrong Cutting Angle and the Wrong Flute Form for both geometries.

So, the scheme of the NECO use case is presented in the following Figure 22:

![Figure 22. NECO Use Case scheme.](image)

### 4.3.1 UC-N-01

Table 7. UC-N-01 Wrong cutting angle

<table>
<thead>
<tr>
<th><strong>Goal</strong></th>
<th>Detect the issue of a tap with the wrong cutting angle to avoid that it continues on the production line.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scope</strong></td>
<td>More control and knowledge of the NECO manufacturing process and decrease the number of wrong taps.</td>
</tr>
<tr>
<td><strong>Actors</strong></td>
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<tr>
<td><strong>&lt;Control operator&gt;</strong></td>
<td>The worker who supervises the machine, visually checks the cutting angle of the tap and decides whether the part should continue on the production line, if it has the right angle or it should be removed from the production line.</td>
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</tr>
<tr>
<td><strong>&lt;Production manager&gt;</strong></td>
<td>Report the non-quality and follow the process to see the causes and decide preventive actions to follow.</td>
</tr>
<tr>
<td><strong>Stakeholders</strong></td>
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<tr>
<td><strong>&lt;Logistics Department&gt;</strong></td>
<td>They need to know the latest information on production costs to order new raw materials, etc.</td>
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<tr>
<td><strong>&lt;Technical Department&gt;</strong></td>
<td>They control the whole process, checking the geometry and the process parameters and also maintaining the files.</td>
</tr>
<tr>
<td><strong>Preconditions</strong></td>
<td>The system (machines and workers) has a knowledge of the errors of the taps cutting angle.</td>
</tr>
<tr>
<td>-----------------------</td>
<td>------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Trigger</strong></td>
<td>The wrong angle in the cutting angle is automatically recognized (by the 3d scanning sensor) and sends message/warning/notification to the system/operator to continue through the production line or to remove that part from the production line.</td>
</tr>
<tr>
<td><strong>Minimal Guarantees</strong></td>
<td>The system is prepared to scan the next tap during the manufacturing process.</td>
</tr>
<tr>
<td><strong>Succeed Guarantees</strong></td>
<td>The system should detect the defective parts and exclude them of the production line. It must be able to decide which of the taps can be reworked and the ones that can go through the manufacturing process.</td>
</tr>
</tbody>
</table>
| **Workflow**          | 1. The wrong cutting angle of the tap is detected  
                           2. The system automatically sends a notification  
                           3. The wrong tap is excluded from the production  
                           4. The production and the tap parameters  
                           5. The tap is reworked  
                           6. Second scanning recognizes that the cutting angle is inside tolerances.  
                           7. The tap is ready and it is sent to the following step of the production process. |
| **Extensions**        | The system is controlled in order to prevent the errors in the production line and also an analysis of the data is done to predict future deviations. |
| **Related Information**| Semantic context manager, HMI & Sensor network, Data acquisition and processing, Middleware, Real-time quality control, Production management |
The semifinished tap is registered after the OD & Square Grinding.

The tap goes through the Z-Fact0r apparatus to make a quality check.

A quality report is generated and the data is saved.

Information about the wrong tap is sent to the different workers.

Data follows the algorithms that predict the future deviations.

If the checked tap is OK, it continues in the production process. If not, it will be recycled.

After the Flute Grinding process the tap goes through the Z-Fact0r apparatus again.

Another quality report is created and the new data from the tap is stored.

If the checked tap is OK, it continues to the Chamfer Grinding.

If not the defect will be identified and the corresponding responsible will be informed. The grinding parameters will be adjusted and the tap will be reworked in the Flute Grinding.

Figure 23. UC-N-01 Workflow diagram.
4.3.2 UC-N-02

Table 8. UC-N-02 Wrong flute form

<table>
<thead>
<tr>
<th>Goal</th>
<th>Detect the issue of a tap with the wrong flute form to avoid that it continues on the production line.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope</td>
<td>More control and knowledge of the process and decrease the number of wrong taps.</td>
</tr>
<tr>
<td>Actors</td>
<td>&lt;Control operator&gt; The worker who supervises the machine, visually checks the flute form of the tap and decides whether the part should continue on the production line, if it has the right flute form or it should be removed from the production line. &lt;Production Manager&gt; Report the non-quality and follow the process to see the causes and decide prevention actions to follow.</td>
</tr>
<tr>
<td>Stakeholders</td>
<td>&lt;Logistics Department&gt; They need to know the latest information on production costs to order new raw materials, etc. &lt;Technical Department&gt; They control the whole process, checking the geometry and the process parameters and also maintaining the files.</td>
</tr>
<tr>
<td>Preconditions</td>
<td>The system (machines and workers) has a knowledge of the errors of the taps flute form.</td>
</tr>
<tr>
<td>Trigger</td>
<td>The wrong flute form is automatically recognized (by the 3d scanning sensor) and sends message/warning/notification to the system/operator to continue through the production line or to remove that part from the production line.</td>
</tr>
<tr>
<td>Minimal Guarantees</td>
<td>The system is prepared to scan the next tap during the manufacturing process.</td>
</tr>
<tr>
<td>Succeed Guarantees</td>
<td>The system should detect the defective parts and exclude them of the production line. It must be able to decide which of the taps can be reworked and the ones that can go through the manufacturing process.</td>
</tr>
<tr>
<td>Workflow</td>
<td>1. The wrong flute form of the tap is detected 2. The system automatically sends a notification 3. The wrong tap is excluded from the production 4. The production and the tap parameters 5. The tap is reworked 6. Second scanning recognizes that the flute form is inside tolerances. 7. The tap is ready and it is sent to the following step of the production process.</td>
</tr>
<tr>
<td>Extensions</td>
<td>The system is controlled in order to prevent the errors in the production line and also an analysis of the data is done to predict future deviations.</td>
</tr>
<tr>
<td>Related Information</td>
<td>Semantic context manager, HMI &amp; Sensor network, Data acquisition and processing, Middleware, Real-time quality control, Production management</td>
</tr>
</tbody>
</table>
The semifinished tap is registered after the OD & Square Grinding.

The tap goes through the Z-Fact0r apparatus to make a quality check.

A quality report is generated and the data is saved.

Information about the wrong tap is sent to the different workers.

Data follows the algorithms that predict the future deviations.

If the checked tap is OK, it continues in the production process. If not, it will be recycled.

After the Flute Grinding process the tap goes through the Z-Fact0r apparatus again.

Another quality report is created and the new data from the tap is stored.

If the checked tap is OK, it continues to the Chamfer Grinding.

If not the defect will be identified and the corresponding responsible will be informed. The grinding parameters will be adjusted and the tap will be reworked in the Flute Grinding.

Figure 24. UC-N-02 Workflow diagram.
4.4 Interseals Scenario

NOTE: Even though Interseals is terminated beneficiary since June 2018 and replaced by NECO, this section provides the information collected during the M01-M04 of the project when Interseals was still the Z-Fact0r consortium partner at the time.

The root cause of the defects is the injection molding phase and it depends on many process parameters, status of the tool as well as adequate instructions for the operator for shot extraction and flash removal. At the moment, tool cavity pressure, is identified as the leading parameter to be addressed to. The following Figure 25 represents Z-Fact0r solution and conceptual map of the production cell with sensors measuring the conditions during the filling production phase detecting the defect. Furthermore, two use cases at sub-sections 4.4.1 and 4.4.2 are summarising this scenario and respectful workflows at Figure 26 and Figure 27 with details are presented. Table 9 and Table 10, consist of defined goals, scopes, stakeholders, triggers, minimal guarantees, etc. recognised within these two use cases.

Figure 25. Interseals TO BE Scenario.
### 4.4.1 UC–I–01

Table 9. UC-I-01 Lack of material defect.

| **Goal** | Identify the out of tolerance of those process parameters set that influence the Lack of Material happening (mainly the changing of the raw material properties).  
Detect the lack of material during the visual inspection.  
Address the issue to the system for recalibration or alarm.  
Try to repair the failed parts with additive manufacturing. |
| **Scope** | The scope of the project is to enrich the Production Cell with new equipment, sensors, visual machine, so that the process variables and quality information can be collected, analyzed to give a better feedback to the Middle Management for taking decisions and set up the Production Cell. |
| **Actors** | **<Control operator>:** the worker who checks, according to a quality control plan, the first production trials and gives the green card to start. During the production he can decide about criticism of a defect according to the book of defects.  
**<Shift leader>:** the worker who is responsible for the good functioning of the Production Cell / cells. He carries the right approved raw material to the machine, mounts the tool on the clamping machine unit, start the production and he has got the authority to change the process parameters during the running production.  
**<Operator>:** the worker who feeds the machine with the raw material, extracts the complete shot out of the tool, separates the single gasket from the complete shot, eliminates the extra material (flash or burr) around the single parts and visually checks the gaskets. He takes care of the cleaning of the area and makes also a soft maintenance. He calls the shift leader for every malfunction of the Production Cell or defective parts detected. |
| **Stakeholders** | The **<Market>** and in particular the Automotive market, that represent for Interseals about 70%. To be a benchmark company in this field the scrap rate has to be closed to 2% in total parts.  
The **<Ownership>** because they need to take the Ebita rate greater than a target of 15% and this is possible even with a scrap reduction.  
The **<Management>**, because it owns different KPI influenced either by the scrap percentage or the not quality cost. |
<p>| <strong>Preconditions</strong> | The core of the Production Cell is the molding phase, here defects can be created. In particular these are mostly related with state of the raw material before injection (it will be represented into the system by a spectroscopy curve or a section of it), cavity pressure (it will be represented into the system by a curve pressure – time), dimensional stability of the tool features. |</p>
<table>
<thead>
<tr>
<th>Trigger</th>
<th>The Use Case starts when the quality control gives the ok to begin the series production (normally after a 30-45min of warm up and 5 - 10 trial shots).</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal Guarantees</td>
<td>The system has to be able to record the parameter set at every production cycle (between 3 and 5 minutes) and recognize the out of tolerance for the process parameter and the defects types (lack of material and breakages). The system has to be easy to set up for a new production.</td>
</tr>
<tr>
<td>Succeed Guarantees</td>
<td>The system has to detect the process parameter trends and in automatic or semiautomatic give back information: this can be as recalibrating of the parameters or as visual alarm. Furthermore, the system has to be able to select the ok part from the not ok part.</td>
</tr>
<tr>
<td>Workflow</td>
<td>See the Workflow layout.</td>
</tr>
<tr>
<td>Extension</td>
<td>The system is recalibrated, in order to prevent the production of defective components. Data analytics can predict defective parts.</td>
</tr>
<tr>
<td>Related Information</td>
<td>Semantic context manager, Molding machine and Sensors network, Data acquisition and processing, Middleware, Real-time quality control, Production management, Integrated KMDSS, Reverse supply chain, Z-Fact0r Repository, Additive Manufacturing repair.</td>
</tr>
</tbody>
</table>
Figure 26. UC-I-01 workflow diagram.

1. Raw material properties check
2. Tool check and mount
3. Warm up and process freeze
4. Start the production
5. Tool cavity pressure monitoring - ok
6. Green alarm: ok demolding
7. Flash removal
8. Automatic visual inspection
   - inspection ok, place the part in ok space, save molding parameters
   - If inspection not ok, alarm and go to "A"
9. Tool cavity pressure monitoring - not ok
10. "A" Identify the deviations
11. Red alarm to the shift leader and recalibrated the Production Cell
12. Red alarm to operator: demold the shot and place it in the not ok space
13. Try to repair the failed parts with additive manufacturing
## 4.4.2 UC–I–02

Table 10. UC-I-02 Breakage defect.

| **Goal** | Identify the out of tolerance of those process parameters set that influence the Breakages happening (mainly the changing in the opening of the tool or its status before put it in production. 
Detect the breakages during the visual inspection.
Address the issue to the system for recalibration or alarm.
Try to repair the failed parts with additive manufacturing. |
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Scope</strong></td>
<td>The scope of the project is to enrich the Production Cell with new equipment, sensors, visual machine, so that the process variables and quality information can be collected, analyzed to give a better feedback to the Middle Management for taking decisions and re set up the Production Cell.</td>
</tr>
</tbody>
</table>
| **Actors** | <Control operator>: the worker who checks, according to a quality control plan, the first production trials and gives the green card to start. During the production he can decide about criticism of a defect according to the book of defects.
<Shift leader>: the worker who is responsible for the good functioning of the Production Cell / cells. He carries the right approved raw material to the machine, mounts the tool on the clamping machine unit, start the production and he has got the authority to change the process parameters during the running production.
<Tool operator>: the worker who releases the tool for the incoming production and takes care of it at the end of the production. Currently he works with poor equipment and instructions. He can carefully clean the tool at the end of the production using an automatic washing machine, but he cannot make accurate measurements or maintenance (this activity is related to the User Requirements IN04 and IN08NF).
<Operator>: the worker who feeds the machine with the raw material, extracts the complete shot out of the tool, separates the single gasket from the complete shot, eliminates the extra material (flash or burr) around the single parts and visually checks the gaskets. He takes care of the cleaning of the area and makes also a soft maintenance. He calls the shift leader for every malfunction of the Production Cell or defective parts detected. |
| **Stakeholders** | The <Market> and in particular the Automotive market, that represent for Interseals about 70%. To be a benchmark company in this field the scrap rate has to be closed to 2% in total parts.
The <Ownership> because they need to take the Ebita rate greater than a target of 15% and this is possible even with a scrap reduction.
The <Management>, because it owns different KPI influenced either by the scrap percentage or the not quality cost. |
Preconditions

The core of the Production Cell is the molding phase, here defects can be created. In particular these are mostly related with state of the raw material before injection (it will be represented into the system by a spectroscopy curve or a section of it), cavity pressure (it will be represented into the system by a curve pressure – time), dimensional stability of the tool features.

After the production is freeze, these parameters with their tolerance, become the reference precondition.

Trigger

The Use Case starts when the quality control gives the ok to begin the series production (normally after a 30-45 min of warm up and 5 - 10 trial shots).

Minimal Guarantees

The system has to able to record the parameter set at every production cycle (between 3 and 5 minutes) and recognize the out of tolerance for the process parameter and the defects types (lack of material and breakages). The system has to be easy to set up for a new production.

Succeed Guarantees

The system has to detect the process parameter trends and in automatic or semiautomatic give back information: this can be as recalibrating of the parameters or as visual alarm.

Furthermore, the system has to be able to select the ok part from the not ok part.

Workflow

See the Workflow layout.

Extension

The system is recalibrated, in order to prevent the production of defective components.

Data analytics can predict defective parts.

Related Information

Semantic context manager, Molding machine and Sensors network, Data acquisition and processing, Middleware, Real-time quality control, Production management, Integrated KMDSS, Reverse supply chain, Z-Fact0r Repository, Additive Manufacturing repair.
Figure 27. UC-I-02 workflow diagram.
5 Scenario Interpretation and Requirements

In the first part of this deliverable, scenarios of the end users were conducted in order to identify where Z-Fact0r's manufacturing strategies can be applied in order to achieve zero defect in the production process for each company and to set up priorities for implementation. These scenarios derive from the user requirements and are closely linked to them.

The complete set of functional and non-functional system requirements has been designed in the D1.1 User Requirement according to the Volere methodology (http://www.volere.co.uk/) analysing the current situation of the end users and the main issues and areas to be improved. Based on the perceived areas of improvement, Microsemi, Interseals and Durit together with the complete Z-Fact0r consortium have elaborated a list of technical requirements that will be used to develop the Z-Fact0r system. Functional requirements define specific behaviour or functions of the systems while non-functional requirements specify criteria that can be used to judge the operation of a system, rather than specific behaviours (examples of non-functional requirements are Look and Feel, Usability Performance Maintainability, Security, Legal requirements). Moreover, the Volere Requirements methodology has been adopted to formalize them through a more structured approach.

User requirements serve as primary input to the Z-Fact0r Use Cases Design and aim to improve the production, exclude totally or minimise defect in production by including optical inspection in an automatic way, together with learning control system, training for workers, embracing predictive and preventive maintenance, monitor and provide real-time decision support for Z-Fact0r strategies. Next sub-sections 5.1, 5.2, 5.3 and 5.4 will describe in more details the connections between user requirements and scenarios.

5.1 Microsemi

According to the AS IS Scenario of Microsemi described in section 3.1, it is observed that the production machine has no optical inspection and no method to automatically correct for glue being dispensed into the cavity neither a rework approach to recover rejected products. Actually, visual inspection of the assemblies and manual adjustment of the amount of glue deposited has to take place. Furthermore, it is important to control the shape and volume of the dot dispensed in order to reduce serious problems and failures.

Microsemi would like to use the Z-Fact0r system to reduce the defected products improving the glue inspection and reworking processes.

It is desirable that the solution provides a dedicated GUI (external solution with a PC as Z-Fact0r platform or complete integrate solution on the Tresky computer) in order to facilitate the interaction between workers and the system (non-functional requirements presented in deliverable D1.1).

Microsemi needs to have:

- An external system for providing measurement of glue dispense volume data and acting as a GUI for the Z-Fact0r system which could:
  - give operator instruction for adjustment of the Tresky dispense parameters,
  - automatically adjust dispense times for achieving target dispense volumes,
  - identify the module/s and component/s affected by either excess or insufficient glue,
  - allow defected parts to either be reworked,
  - scan/measure glue dispense dots over an area of no smaller than 160mm x 55mm,
  - work on Windows 7.
The main goal is to detect and address the issue of insufficient/excess glue prior to placement of die in order to avoid this defect or repair the defective part with additional/subtractive manufacturing actions when possible.

Z-Fact0r system will automatically recognized by camera/laser technology insufficient/excess glue placement with online or semi-offline inspection technique (Z-DETECT). Meanwhile the system should detect and decide real-time which parts need to be reworked and be temporarily excluded during die placement and those that will continue in the production process (Z-MANAGE). The system will be constantly recalibrated (Z-PREVENT), in order to prevent the production of defective components and data analytics can predict defective parts (Z-PREDICT). Z-Fact0r system will also automatically add more glue on the specific part/die that has a recorded problem and, as a plus, decide when and how try to remove the excess of glue (Z-REPAIR).

5.2 Durit

The objective of Z-Fact0r project for Durit will be to adopt and implement a predictive system to monitor inline the quality of the parts, particularly, the dimensional tolerances, register the data and predict quality deviations resulting from systematic errors and improper machine operation. This system is based on optical sensors, comparing the true dimensional geometry and tolerances with the specified ones.

Therefore, Durit aims at a system able to:

- detect surface defects and fractures,
- compare dimensional sizes and tolerances of the real parts, as compared to a reference drawing introduced in the system,
- record data and detect quality fluctuations from process, triggering an alert message for imminent non-quality events displayed via a PC monitor at site,
- interact with workers in the shopfloor,
- detect surface defects such as cracks and voids, with sizes from 0.1 to 1mm. The output should be a message alarm and printed report with visual information of the defect,
- indicates the most common type of defects as well as a prevention based on historical data about the probability of the appearance of non-quality and defects.

The main goal is to improve the Durit control line in an automatic way, minimise parts with defects and develop a predicative algorithm that detects trends in parts quality that may indicate the future presence of the mentioned defects.

Z-Fact0r system will work in two different stages of the production (Green Machining and Finishing), but in the same way. The system should automatically recognise the defects by camera/laser technology, with online or semi-offline inspection technique (Z-DETECT). Meanwhile, the system should detect and decide which parts need to be reworked and be temporarily excluded and those that will continue in the production process (Z-MANAGE). The system will be constantly recalibrated (Z-PREVENT), in order to prevent the production of defective components and data analytics can predict defective parts based on historical data (Z-PREDICT). Z-Fact0r system will also perform a quality report that will be presented to the operator. Information of non-compliant parts will be sent to the different stakeholders and data should be stored in a server. The defective part will be analysed by quality manager for possible reworking (Z-REPAIR).
5.3 NECO

The AS IS Scenario of NECO described in section 3.3, it is clear that the process and quality data compiled for years, show that most of the defects occur during the flute grinding operation. Nowadays, the control of this step of the production process is done by visual inspection of the taps or with Go/No Go tests. NECO would like to use the Z-Fact0r strategies to reduce the defected taps improving the quality inspection and reworking less parts.

NECO wants to achieve with Z-Fact0r:

- Give operators instructions and interact with them in the shop-floor
- Scan/measure the cutting angle and flute form
- Compare dimensional sizes and tolerances of the real taps comparing them to a reference drawing introduced in the system
- Allow defected parts to be reworked
- Record data and detect deviations from process, launching an advice or an alarm message for future imminent wrong events

The main goal is to improve the NECO Quality Control in an automatic way identifying the parameters out of tolerance and developing a predictive algorithm that detects trends in parts quality that may indicate the future presence of the mentioned defects. The system will be recalibrated and also an alarm could be generated to inform about the deviation.

Z-Fact0r system will work in the Flute Grinding Operation and it should recognised by camera/ laser technology the defects, with an inspection technique (Z-DETECT). Meanwhile the system should compare production parameters and product defects to decide which parts need to be reworked and be temporarily excluded and those that will continue in the production process (Z-MANAGE). The system will be constantly recalibrated (Z-PREVENT), in order to prevent the production of defective components and data analytics can predict defective parts based on historical data (Z-PREDICT). Z-Fact0r system will also prepare a quality report that will be upload on a server and also show to the corresponding responsible.

5.4 Interseals

*NOTE: Even though Interseals is terminated beneficiary since June 2018 and replaced by NECO, this section provides the information collected during the M01-M04 of the project when Interseals was still the Z-Fact0r consortium partner at the time.*

The process and quality data gathered for years, show that the most of the defects occur during the moulding phase, in which the raw material characteristics and the process parameters develop a relation under controlled conditions. The “unknown” relation is the source of potential defects. The problem is that Interseals cannot continuously check the raw material characteristics, while it is fed into the injection-moulding machine. The equipment is all in the same production layout (or production cell), they can be transfer information via Ethernet or Wi-Fi and these lines are already accessible in the shopfloor.

The Z-Fact0r system should:
• collect data during every production cycle (that lasts from 3 to 4 minutes),
• measure the intrinsic process parameters (temperature, pressure, speed, raw material composition, etc.),
• check the feasibility to control the extrinsic parameters (environmental temperature and humidity),
• perform automatic or semi-automatic visual inspection and dimensional checking of the pieces just after the production,
• augmented reality to support the transfer of information from and to the human operator,
• be easy to use facilitating the job of the workers through simple, intuitive and customized user interfaces,
• be scalable enough to be used on different moulding machines and to receive big amount of data,
• not require too much effort to be maintained and used within the company.

The main goal is to identify the out of tolerance of those process parameters set that influence lack of material/breakages happening (mainly the changing of the raw material properties), detect the defect’s entity during the visual inspection, address the issue to the system for recalibration or alarm and then try to repair the failed parts with additive manufacturing.

Z-Fact0r system will work both online/real-time in the moulding machine and offline in the quality department. The system should continuous check raw material and environment conditions saving data on the server (Z-DETECT and Z-MANAGE). Moreover, the system should be recognised by camera/laser technology the defects, with online/offline inspection technique (Z-DETECT). Meanwhile the system should compare production parameters, environment conditions and product defects to decide which parts need to be reworked and be temporarily excluded and those that will continue in the production process (Z-MANAGE). The system will be constantly recalibrated (Z-PREVENT), in order to prevent the production of defective components and data analytics can predict defective parts based on data set (Z-PREDICT). Z-Fact0r system will also perform a quality report that will be upload on a server. Information of defective parts will be sent to the different stakeholders and data should be stored in a server. The defective part will be analysed by quality department for possible reworking (Z-REPAIR).
6 Conclusions

The deliverable D1.6 Z-Fact0r Use Cases Updated shows the scenario of the new end user NECO. It contains the results of Task 1.4 that, according to Z-Fact0r DoA, reports a detailed development of each use case integrating the consolidated user requirements (D1.1), customizing the Z-Fact0r System architecture (D1.3) and developing a proper set of Key Performance Indicators to evaluate the performance achieved. Each use case has been defined during its whole lifecycle identifying which performance can be measured with the demonstrators.

The current shopfloor statuses (AS IS scenarios) have been presented providing some basic background information about the three Z-Fact0r end users. Then, also customising the Z-Fact0r System architecture (D1.3) and implementing the methodology and strategy defined in section 4, previously presented in dedicated workshops with each end user individually, the TO BE scenarios of Microsemi, Durit, NECO and Interseals have been described in details in sub-sections 4.1, 4.2, 4.3 and 4.4, respectively. The Durit TO BE Scenarios have been updated since during the execution of the project it was observed the need to incorporate a third use case.

Finally, the interpretation of the scenarios, tightly correlated to the defined requirements of the deliverable D1.1 User Requirement, has been presented, followed by this section.

The main achieved goal of the present work is the integration and customization of Z-Fact0r system strategies and architecture in the use cases scenario. This work will be an input for all the activities involved in the Z-Fact0r tools and strategies development (WP2, WP3, WP4, WP5) and then they will flow together in the WP6 Demonstration activities.
7 List of Figures

Figure 1. Synergies and interactions between the five Z-Fact0r strategies ........................................... 3
Figure 2. Glue fillet acceptability .............................................................................................................. 5
Figure 3. Microsemi Scenario, AS IS Workflow ....................................................................................... 6
Figure 4. Durit Scenario, AS IS Workflow ............................................................................................... 7
Figure 5. Taps Manufacturing first step .................................................................................................. 8
Figure 6. Taps Manufacturing second step ............................................................................................. 8
Figure 7. NECO Scenario, AS IS Workflow ............................................................................................ 9
Figure 8. Interseals cause-effect process diagram ................................................................................. 10
Figure 9. Interseals Scenario, AS IS Workflow ....................................................................................... 11
Figure 10. Microsemi Z-Fact0r data gathering overview ...................................................................... 16
Figure 11. UC-M-01 workflow diagram .................................................................................................. 18
Figure 12. UC-M-02 workflow diagram .................................................................................................. 20
Figure 13. Durit TO BE Scenario ......................................................................................................... 21
Figure 14. UC-D-01 workflow diagram .................................................................................................. 23
Figure 15. UC-D-02 workflow diagram .................................................................................................. 25
Figure 16. UC-D-03 workflow diagram .................................................................................................. 27
Figure 17. % of rejections in each operation .......................................................................................... 27
Figure 18. Cutting angle rejection or approval ....................................................................................... 28
Figure 19. Taps’ different geometries .................................................................................................... 28
Figure 20. Geometries for the use case .................................................................................................. 28
Figure 21. Different cutting angles and flute forms .................................................................................. 28
Figure 22. NECO Use Case scheme ....................................................................................................... 29
Figure 23. UC-N-01 Workflow diagram .................................................................................................. 31
Figure 24. UC-N-02 Workflow diagram .................................................................................................. 33
Figure 25. Interseals TO BE Scenario .................................................................................................... 34
Figure 26. UC-I-01 workflow diagram ................................................................................................... 37
Figure 27. UC-I-02 workflow diagram ................................................................................................... 40
8 List of Tables

Table 1. Use Case template ........................................................................................................14
Table 2. UC-M-01 Insufficient Glue............................................................................................16
Table 3. UC-M-02 Excess Glue.....................................................................................................18
Table 4. UC-D-01 Green Machining.............................................................................................21
Table 5. UC-D-02 Sintering and Finishing....................................................................................23
Table 6. UC-D-03 Finishing..........................................................................................................25
Table 7. UC-N-01 Wrong cutting angle.........................................................................................29
Table 8. UC-N-02 Wrong flute form.............................................................................................32
Table 9. UC-I-01 Lack of material defect....................................................................................35
Table 10. UC-I-02 Breakage defect..............................................................................................38
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- D1.1 User Requirement
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