HORIZON WIDERA Twinning

Grant agreement nº: 101079473

Call topic identifier: HORIZON-WIDERA-2021-ACCESS-03-01

Organ-on-a-Chip Focused Strategic Partnership (OrChESTRA)

Deliverable D1.1

Gaps and needs analysis report

Work Package 1

Enhancing S&T excellence capacity of ODTÜ MEMS

Document type	:	R — Document, report
Version	:	1.0
Date of issue	:	M10 (13.06.2023)
Dissemination level	:	PU - Public
Lead beneficiary	:	1 – ODTÜ MEMS
Partners contribution	:	All partners

This project has received funding from the European Union's Horizon Europe Programme HORIZON-WIDERA action under grant agreement No 101079473. The dissemination of results herein reflects only the author's view, and the European Commission is not responsible for any use that may be made of the information it contains.

Table of Contents

0 INTRODUCTION

OrChESTRA is a twinning action that links four research organisations that are active in the microfluidics field. The project builds productive and sustainable collaboration links between ODTÜ MEMS and its internationally-leading counterparts TU/e, IMEC, and UFR. With the three twinning partners in place, ODTÜ MEMS aims to acquire the expertise needed not only to fill the identified gaps regarding knowledge, capacity, and networking, but also to join leading networks of excellence in microfluidic-based research areas.

This deliverable corresponds to "Task 1.1 Evaluation and revision of S&T policy and strategies" under "Work Package 1 - Enhancing S&T excellence capacity of ODTÜ MEMS". It presents the results of the gap analysis conducted in the first 6 months of the OrChESTRA project and summarizes recommendations identifying tailored solutions for the underlying gaps and needs. It serves as foundation for the work, aligned across all work packages to be conducted in scope of the project over the coming months.

The report is structured in five chapters. The first chapter is introductory and provides brief overview of the objectives and rationale behind the report. The second chapter outlines the scope and methodology of the analysis study. In the third chapter, findings of the analysis study are presented, bringing to light conclusions on the main gaps and needs at ODTÜ MEMS. The fourth chapter outlines the preliminary recommendations and strategies. Lastly, in the fifth chapter the initial plans regarding the mobility and training activities are presented to address the identified gaps and needs.

1 OBJECTIVES AND RATIONALE BEHIND THE STUDY

1.1 Concept of the project

The overall strategic plan of OrChESTRA is based on local conditions and key priorities of ODTÜ MEMS. As a twinning action, OrChESTRA will follow a series of well-formulated and interlinked coordination and support measures like strategic planning, mobility, training, summer/winter schools, best practice sharing, communication, and networking in order to attain expected impacts at institutional, consortium, national and European level. The main goals of the project will be achieved through dedicated activities and events to be conducted by the twinning partners, accomplished in 36 months. The concept is presented in Figure 1.

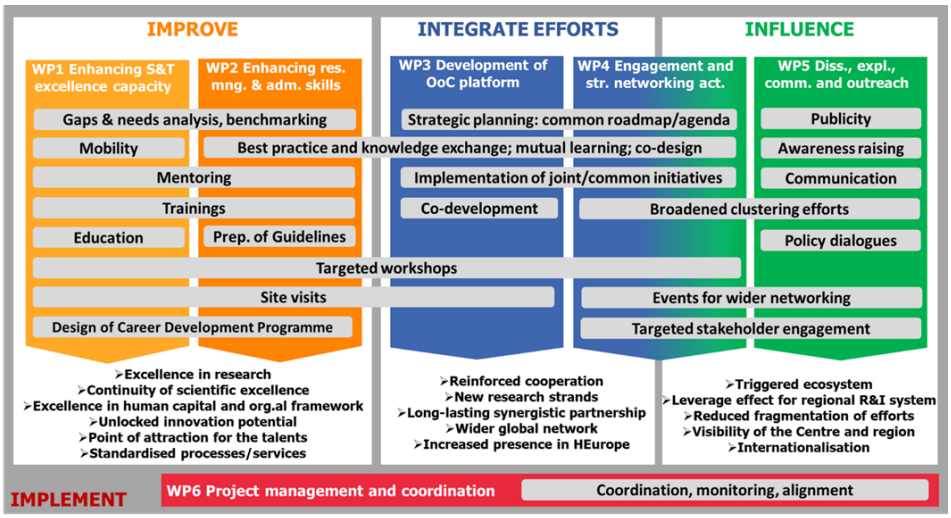

Figure 1: OrChESTRA's overall concept and the dedicated coordination and support measures.

As a result of the comprehensive set of measures planned, ODTÜ MEMS will naturally become a long-term collaborator in the interdisciplinary European research networks surrounding the microfluidics field. This is a win-win approach, which addresses strategic scientific and technological development interests of TU/e, IMEC, and UFR in their quest for further extension and ultimate exploitation of their research and technology development activities in which they currently are in a leading position. Therefore, TU/e, IMEC, and UFR, together with ODTÜ MEMS, expect to expand their R&D capabilities, to attract and provide scientific personnel to focus on microfluidic and organ-on-a-chip systems, creating an innovation ecosystem for the widespread application of such promising systems. The consortium also aims at going beyond the main stream markets served by the stronger economies, accessing the emerging economies and building on the jointly gained expertise for novel applications and innovations, opening opportunities for economic growth and scientific excellence. Therefore, the consortium is strongly committed to further develop this partnership with a long-term sustainable horizon of cooperation beyond the project.

1.2 Internationally-leading partners

The OrChESTRA consortium brings together the worldwide known European research organisations with synergistic scientific and innovative expertise, establishing a long-term, strategic and productive partnership. It builds upon the existing strong research and innovation base of ODTÜ MEMS, TU/e, IMEC and UFR, who develop state-of-the-art approaches in complementary specialisation areas around microfluidics, including organ-on-a-chip, lab-on-a-chip, biosensors, microfabrication, BioMEMS, and tissue engineering.

1.2.1 TU/e – TECHNISCHE UNIVERSITEIT EINDHOVEN

TU/e, particularly the Microsystems Research Group in the Department of Mechanical Engineering, develops innovative technological concepts and fabrication methods for microsystems for a wide range of applications ranging from organ-on-a-chip systems, point-of-care diagnostics, wearable health sensors, water and air quality monitoring and purification, lithography machines, displays, and brain-inspired computing, to soft microrobotics. TU/e will contribute to OrChESTRA with its experience in microfabrication, microfluidics, organ-on-a-chip systems, and soft materials – particularly biological materials and gels, which are commonly utilised as structural matrix material in which cells are grown spatially in three dimensions in organ-on-a-chip systems.

1.2.2 IMEC – INTERUNIVERSITAIR MICRO-ELECTRONICA CENTRUM

IMEC is the leading research hub in Europe in nano- and digital technologies. It brings together more than 5.000 researchers from all over the world, with an expertise in various fields including CMOS, sensing and actuation, photonics, energy technologies and life sciences. It has access to a unique infrastructure, including 12.000 m^2 of cleanrooms with the most advanced equipment for research. IMEC has been a partner in the European ORCHID CSA project drawing up a roadmap for organ-on-chip R&D in Europe. IMEC will contribute to OrChESTRA particularly with its expert practises in microfabrication & integration (microfluidics, sensors) for life sciences applications as well as on non-technical processes (cleanroom management, business, venturing, IPR, RRI, etc.).

1.2.3 UFR – ALBERT-LUDWIGS-UNIVERSITAET FREIBURG

UFR, one of the world's largest academic institutions dedicated to microsystems engineering with strong industrial collaborations, covers a broad spectrum of bioanalytical microsystems and sensors applications, for lab-on-a-chip-based miniaturisation, integration, parallelisation, and automation of biochemical tests into portable (point-of-need) systems for diagnostics, food analysis and environmental monitoring. UFR will contribute to OrChESTRA with its experience in microfabrication, biosensors, microfluidics and system integration.

1.3 Objectives of the analysis study

Gap analysis is a process of examining and evaluating the current situation to identify and compare the differences between the current performance situation and where the organization should be in the future. It is a quality improvement tool that helps organizations achieve their performance and process improvement goals and objectives. It is most commonly used to benchmark current organizational performance against the requirements of a desired performance level. In this regard, the primary objective of the analysis study, presented in this deliverable, is to assess and fully understand the scientific and technological as well as institutional gaps and needs of ODTÜ MEMS. The analysis report is expected to present the assessment results of the analysis study conducted to identify gaps and needs and the initial recommendations about the most appropriate mechanisms to be adopted including the knowledge transfer and training needs.

The outcomes of this task will form the baseline for formulating and developing plans to address the identified gaps and needs and for tailoring the project activities accordingly. Therefore, the study will provide input for a framework of training activities and an agenda of the capacity building activities. Considering the gaps and needs analysis report, the mobility and training activities will be planned annually in order to ensure flexibility and to integrate the plans to the project activities according to the needs specified during the project.

The specific objectives of the gaps and needs analysis study are as follows:

- Identify and assess the differences between the current performance situation and where ODTÜ MEMS should be in the future
- Compare the solution options to overcome the key gaps
- Stimulate best-practice sharing of the twinning partners
- Develop recommendations and substantial approaches
- Define knowledge transfer and training events

2 SCOPE AND METHODOLOGY OF THE STUDY

2.1 Scope

In scope of this study, a complete analysis of the gaps and needs of ODTÜ MEMS has been conducted addressing the organisational framework, business mechanisms (cleanroom management system, standard service procedures, contracting and technology transfer mechanisms, spin-off instruments, ethics management, gender/diversity issues etc.) and R&I management.

After analysing the landscape of the existing situation and carrying out the SWOT analysis, the gap analysis has provided answer to ODTÜ MEMS for the following five questions:

- Where are we now?
- Where do we wish to be in the future?
- What are the gaps and what our needs with priority?
- What are the best practices and suggestions of our twinning partners?
- How are we going to close the gap?

2.2 Methodology

With the goal of identifying the gaps and needs, peer-to-peer collaboration approach has been utilised, promoting the parties (partnering institutions and individuals working together) to share and compare the problems they face and the solutions they create, and contributing to their long-term mutual mentoring and collaboration. The analysis study has been conducted by the experts assigned and matched through a series of tools including review meetings, interviews/consultations, and workshops.

This deliverable has been prepared based on analysis study, interlinked with an iterative process of discussions, interviews and workshops. A series of workshops and consultation meetings were held in cooperation with the twinning partners during the review process and focused on different areas of gaps and needs. The findings are detailed in the third section, comprising the analysis study results.

The findings of the analysis study were synthesized and then validated through the workshops and consultation meetings. The first draft of the report has been prepared, incorporating the findings as well as the feedback and comments received from the twinning partners during the meetings and workshops. The final version has been prepared with additional expert comments and inputs received through the final gaps and needs analysis workshop.

Analysis of the current and targeted situation

The analysis study was started with an introductory meeting organised internally within the Center about the scope and objectives of the gaps and needs analysis. Following this meeting, a series of brainstorming sessions were organised bringing together the research team leaders and executive staff to discuss the internal and external factors affecting the Center's performance and its current and future potential. Based on the results of these meetings, the elaborated draft of the SWOT analysis was prepared.

Consultation

Based on the initial institutional level analysis, ODTÜ MEMS contacted with key stakeholders from private sector, academia, government entities and NGOs. Data collection through sectoral and national level multi-stakeholder consultations were based on discussions with the stakeholders and inputs on the present status of ODTÜ MEMS. The targeted stakeholders are grouped as follows:

- **Business community:** Companies directly/indirectly active in the areas related with microfluidics, biosensors and organ-on-a-chip
- **Academia, research community:** Universities, RTOs, hospitals/healthcare institutions, academics, consortia funded on complementary research topics, senior/young researchers, students interested in microfluidics and organ-on-a-chip and prominent scientific networks

- **Policy and decision makers:** Ministries, grant agencies, standardisation entities, professional associations, etc.
- **General Public:** Civil society, citizens etc. and professionals from other technological domains (e.g., diagnostics, therapeutics and drug development, device manufacturing)

Review meetings and workshops

Synthesis of the research findings: The preliminary findings have been aligned and integrated via consultation and review meetings and workshops organised with participation of all partners. During the workshops, state-of-the-art and best-practices of the partners were shared and discussed to gain insights for improvement in ODTÜ MEMS and to diagnose the gaps between ODTÜ MEMS and its experienced counterparts. Based on the findings synthesised to identify gaps and needs of focus, the initial draft of the analysis study was prepared.

Validation of findings: Following the drafting of the paper, the findings were presented internally to the relevant research and administrative personnel during a two half-day workshop where inputs were gathered for the reviewing and refining the findings. The final version of the analysis study was completed based on the inputs and comments received in group discussions, and additional input sought through online interviews from identified advisory board members.

3 FINDINGS

3.1 Current state-of-play in science and technology

The scientific and technological as well as institutional gaps and needs of ODTÜ MEMS relative to targeted future state as well as relative to its internationally-leading counterparts have been assessed during the analysis process. It is concluded that, the main gaps at ODTÜ MEMS compared to its internationally-leading counterparts have been encountered on the institutional S&T governance capability and related working models on specified issues (such as cleanroom management models, standard service offering approaches, and technology transfer) that have impact on the quality of the S&T activities.

All three leading counterparts (TU/e, IMEC, and UFR) have established cleanroom management systems. Additionally, IMEC has developed technology platforms with standard technology modules and a range of fabrication service procedures for MEMS. In addition to these management competences, IMEC, UFR and TU/e have competence in standardisation of microfluidics as a technical expertise. Additionally, all leading counterparts are experienced in biosensors and organ-on-a-chip systems. ODTÜ MEMS will benefit from these technological and business/non-technological expertise of the leading counterparts.
ODTÜ MEMS has expertise on biomedical micro-electromechanical systems (BioMEMS) and integration of these systems with polymer-based (mostly thermoplastics) microfluidic devices. Additionally, ODTÜ MEMS aims at establishing an infrastructure, particularly for fabrication of these polymer-based microfluidic devices. These competences feature the feasibility of commercialisation of microfluidic devices and particularly the organ-on-a-chip, which will be benefited by all participants in the middle to long-term.

3.2 Institutional framework of ODTÜ MEMS

ODTÜ MEMS Center has entered an organizational restructuring process, in line with its second five-year strategic plan within the scope of the Research Infrastructures law. The envisaged new organizational structure of ODTÜ MEMS Center is presented in Figure 2.

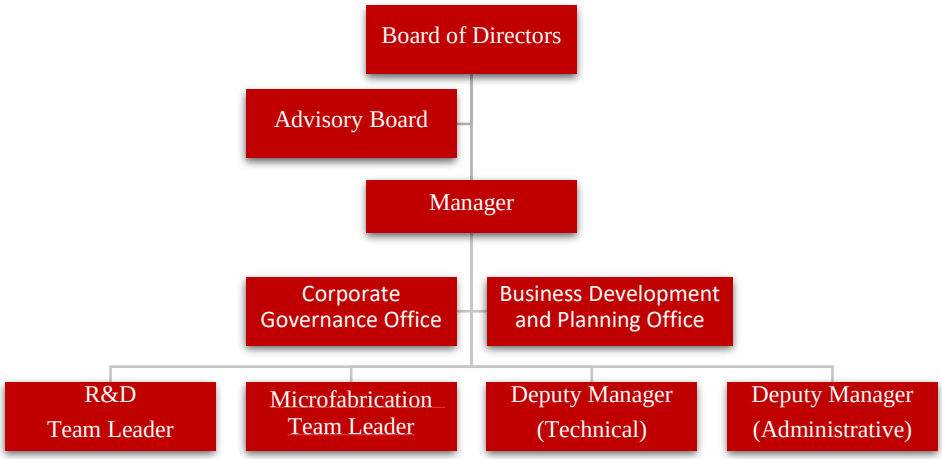

Figure 2: Organisational structure of ODTÜ MEMS.

The microelectronic cleanroom infrastructure of the ODTÜ MEMS Center was established in the early 1990s. Since then, a considerable amount of knowledge and experience has been gained, and the first MEMS research and application center in Türkiye was established in 2008. The available infrastructure supported with projects and investments accelerated the studies on MEMS and pioneered the establishment of today's research center. The total amount of continuing investment is over 60 M€ from public and private sector R&D projects as well as funds from Ministry of Development, Ministry of Science, Industry and Technology, TÜBİTAK, FP6, FP7, and H2020. In 2009, ODTÜ MEMS was awarded by the EC (FP7 REGPOT) additional resources, which aimed to upgrade the RTD capacity and capability of the Center, in addition to improving its integration with the European Research Area. In 2017, the Center was qualified as a national research infrastructure by the government, becoming one of the first National Research Infrastructures in Türkiye and gaining its scientific, budgetary, and managerial autonomy with a significant budget allocated.

ODTÜ MEMS Center's competences in microfluidics, biosensors, and BioMEMS have been proven by several national and international funded projects and international publications. ODTÜ MEMS is also experienced in microfabrication methods with its extensive cleanroom capabilities. Additionally, ODTÜ MEMS plans to establish polymer-based microfabrication facility, which is highly aligned with the development and fabrication needs of organ-on-a-chip technology. However, although the researchers at ODTÜ MEMS have individually worked on organ-on-a-chip systems, currently there is no established foreground research on OoC. OrChESTRA will enable ODTÜ MEMS to attain the necessary environment for research on organ-on-a-chip systems and expand its experience and competencies in microfabrication, microfluidics, biosensors, and BioMEMS.

3.3 SWOT Analysis

The SWOT analysis of ODTÜ MEMS has been elaborated and discussed with the partners during a series of meetings.

SWOT Analysis of ODTÜ MEMS
Strengths
• Micro-manufacturing capability to meet the needs of different sectors in Türkiye • In lined activity fields with Türkiye's and the EU's priorities • Capability to develop advanced technologies compatible with scientific developments worldwide • Being in the position of contributing to the identification of Türkiye's strategic products and research topics in the field of MEMS • International visibility and competitiveness in MEMS and microfluidics • More than 25 years of know-how and capability gained in the design, production and testing processes in the field of MEMS and microfluidics • Experience in project management with private sector and public institutions/organizations • Experience in coordinating international projects • Strong competency in the field of microfluidics • MEMS cleanroom infrastructure and large equipment inventory • Experienced and qualified personnel • Qualified academic staff (by appointment) • Attractive environment for graduate studies • Promotion of the academic staff
Weaknesses

• Weakness in public-univ.-industry relationship
• Low success rate in benefiting from funding sources such as Horizon Europe
• Lack of structured systems in innovation studies
• Lack of knowledge on methods of protecting IP and innovation such as patents and utility models
• Lack of experience/knowledge in global marketing
• Failure to commercialize significant part of the results of the R&D and innovation studies
• Long durations for building basic knowledge and gaining experience in the field of MEMS
• High operating costs for cleanroom
• High circulation of the personnel (esp. research staff), brain drain
• The aging of the equipment inventory and the high maintenance and repair costs
• Lack of polymer processing equipment needed for microfluidics and particularly OoC (organ-on-a-chip) in cleanroom
• Continuation of institutionalisation, problems in
  ◦ Cleanroom management
  ◦ Performance and career management
  ◦ IPR and technology transfer
  ◦ Preventive maintenance
  ◦ MPW (multi-project wafer)-standard process development
  ◦ Spin-off mechanisms
  ◦ Dissemination, communication, and exploitation

Opportunities
• Being active in high value-added sector; micro medical technologies • Clustering mechanisms in the medical technologies in the major provinces (Ankara, Istanbul, Izmir, Samsun) • Competence of researchers in universities and research infrastructures in sub-technology areas (micromanufacturing, microfluidic systems, biosensors) • Increasing investments in advanced technology in recent years • Cooperation and export opportunities with geographically close regions (such as Eastern Europe, Middle East) where micro medical technologies are not sufficiently developed • Presence of technoparks and research centers in the regional ecosystem that will enable product research, development and commercialisation in the field of OoC • MEMS technology's wide range of use from consumer electronics and security to biomedicine • No similar infrastructure open to the use of all stakeholders in the field of MEMS in our country • The need for studies at medium technology readiness levels by the biomedical industry • Advantages based on research infrastructures legislation (exemption from public procurement law, autonomy and independent legal personality, priority in public support, etc.) • Availability of qualified workforce needed in the sector thanks to the potential in the regional universities • Existence of a constantly growing national and international market
Threats
• High risk, high gain and time-consuming certification and productization processes for biomedical technologies outputs • Long durations for costly clinical studies • Fluctuations in exchange rates, local economic instability, foreign currency rates are unpredictable • Brain drain of qualified personnel • Global economic instability after Covid - High input costs (energy, raw material, process) • Weak participation of medical faculties in innovation processes, being focused only on health services • Lack of senior researchers and PhD researchers in MEMS • Failure of critical devices and the repair process to be dependent on abroad and subject to export permits/restrictions

3.4 Identified gaps

In order to improve and upgrade ODTÜ MEMS as a globally recognised organisation, the organisational framework, business mechanisms (cleanroom management system, standard service procedures, contracting and technology transfer mechanisms, spin-off instruments, ethics management, gender/diversity issues etc.) and R&I management will be addressed via best practice sharing and mentoring provided by the advanced partners for institutional and systemic reforms. Particular attention is paid to the following gaps:

- Gap 1: Weakness in public-univ.-industry relationship
- Gap 2: Low share of international funding sources in the overall research budget
- Gap 3: Lack of structured systems in innovation studies (from idea to IP)
- Gap 4: Lack of procedures for protecting intellectual property
- Gap 5: Lack of experience/knowledge in global marketing and technology transfer
- Gap 6: Long durations for building basic knowledge and gaining experience in the field of MEMS
- Gap 7: High operating/maintenance/repair costs for cleanroom and the aging of the equipment inventory
- Gap 8: High circulation of the personnel (esp. research staff), brain drain
- Gap 9: Lack of infrastructure needed for microfluidics and particularly OoC in cleanroom

4 RECOMMENDATIONS

The preliminary findings and related recommendations have been aligned and integrated via consultation and review meetings organised with participation of all partners to develop knowledge sharing mechanisms to address the identified technical and knowledge gaps.

Gap 1: Weakness in public-univ.-industry relationship

Current state

Since its establishment, several research projects have been carried out by ODTÜ MEMS for the development of critical technologies with leading industry organisations, SMEs as well as universities and public institutions/bodies. Focusing on optical sensors, inertial sensors, BioMEMS and RF MEMS, the R&D studies carried out at the Center are mostly between TRL 2 and 5. The Center collaborates with component/subsystem manufacturers starting from TRL 4 and with system manufacturers starting from TRL 6. Economic gain is mostly achieved through the development of subsystems/components of products at the final system level.

Although strategy for access to infrastructure (external use service) has been established, its implementation is not at a sufficient level. External users can benefit from the cleanroom area and device infrastructure mostly in the form of service procurement, other than direct use. 50% of the external users served by ODTÜ MEMS Center are private sector organisations, while the remaining 50% are universities and public research institutions.

As of the beginning of 2023, ODTÜ MEMS Center has been awarded with grant under "High Technology Platforms", one of TÜBİTAK's most significant research support programmes in Türkiye, as the coordinator of "MAESTRO - Micro medical technologies platform". In scope of this Research Programme, namely MAESTRO, 10 different R&D projects in the fields of in-vitro diagnostics, organ-on-a-chip platforms, and monitoring systems will be performed with 25 partners including companies, national research centers, universities, and research organisations. Therefore, ODTÜ MEMS is already in close collaboration with the important actors of organ-on-a-chip area in Türkiye.

Targeted future state

- Widely established local ecosystem on microfluidic devices, biosensors and particularly OoC systems
- Improved competence of ODTÜ MEMS in innovative business mechanisms
- Increased access to ODTÜ MEMS' infrastructure by external stakeholders
- Offering MPW (multi-project-wafer) runs

Recommended actions to close the gap

Knowledge sharing topic	Tool	Involved partner(s), timing
Collaboration models, ways to maintain relations	Best-practice sharing workshop	All (M12)
Providing access to external users	Short term visits	All (M11, M23, M35)
Meetings and interviews with stakeholders	One-to-one meetings/ communication	ODTÜ MEMS, continuous
Opportunities offered by ODTÜ MEMS	Outreach events	ODTÜ MEMS, continuous
Offering MPW runs	Best practice sharing workshop	IMEC (tbd)

Gap 2: Low number of proposal submissions to international grant programmes
Current state
The technologies developed at ODTÜ MEMS are concentrated on BioMEMS (physical and biological sensors), image sensors (infrared, high-performance, low-cost sensors), inertial sensors (gyroscopes and accelerometer), and RF MEMS (RF switch, capacitor, adjustable circuit components). ODTÜ MEMS Center's MEMS and micro production infrastructure has been developed with investments from R&D projects originating from private sector, as well as public funds. In the last 15 years, 34 projects with a total fund amount of 45 million Euro have been or are being carried out at the ODTÜ MEMS Center, and 4 of these projects were financed from international sources. Currently, a total of 12 projects are carried out at the Center, two of which are international projects supported under the Horizon Europe Program (one of them is OrChESTRA). The Center has not realised yet its full potential in terms of international visibility and grant success at the European level. Although project management approaches have been established, project initiation, planning, execution, monitoring, and closing processes have not been defined, yet.
Targeted future state
• Upgrading the newly established "Research Management Unit" under the Business Development and Planning Office • Improved competence of ODTÜ MEMS in proposal preparation • Enhanced project management/administration • Project consortium gathering and leading for joint proposal submissions • Higher number of proposal applications to international grant programmes
Recommended actions to close the gap

Knowledge sharing topic	Tool	Involved partner(s), timing
Strategy development and research management	Best practice sharing workshop (WP2)	IMEC (M13)
What makes a successful project proposal? / Grant success at the European level	Seminar	UFR (M17)
Project management: project initiation, planning, execution, monitoring, and closing processes	Best practice sharing workshop (WP2)	UFR (M15)
Project/consortium development	JAP workshops (WP4)	All (M10, 16, 22, 28, 34)

Gap 3: Lack of structured systems in innovation studies (from idea to IP)
Current state
Today, accelerating technological developments make "strategic technology management" vital for correct use of resources and sustainability. At ODTÜ MEMS there is a lack of structured systems in strategic management approaches which are the set of processes including the planning, management, control, and coordination of the technological competencies. In order to achieve its strategic goals, ODTÜ MEMS needs to define and implement procedures to: - follow the latest technological developments closely in the main fields of activity, - estimate its possible future positions in the targeted areas, - ensure the continuity of technology, - identify relevant science and technology policies.

Targeted future state
• Strengthened strategic technology planning: Innovation Board • Active involvement of Advisory Board to technology planning of the Center • Organisational procedures and processes that will stimulate and inspire creative thinking resulting in new research strands • Dedicated actions for ensuring researchers' enthusiasm about research and innovation

Recommended actions to close the gap

Knowledge sharing topic	Tool	Involved partner(s), timing
Strategic planning (how to decide on the research topics?)	Best practice sharing workshop	All (tbd)
Innovation/technology management (from idea to research, funding mechanisms, promotion mechanisms etc.)	Best practice sharing workshop	IMEC (tbd)
Possible new research directions	Internal seminars	ODTÜ MEMS, continuous
Strategic research topics	Internal brainstorming sessions	ODTÜ MEMS, semi-annually
Ongoing internal projects	Internal briefings/presentations	ODTÜ MEMS, continuous

Gap 4: Lack of procedures for protecting intellectual property

Current state

Since it was qualified a "national research institute" by the state in 2017, no patent application has been made by ODTÜ MEMS yet. The advanced technology development studies carried out by the Center require a detailed study and time to mature and become patentable. Another important point is that industrial companies demand and insist on the ownership of project-based IPRs arising from center-industry cooperation projects carried out at the Center. In such cases, even if the project-based IPR belongs to the industrial company, the Center's approach is to ensure that the industrial company grants ODTÜ MEMS a non-commercial license on the IPR.

As the researcher potential within the Center develops and R&D studies are diversified, it is expected that new applications will increase and income will be generated from these patents. One point that should be emphasised here is that although the Center has not yet obtained a direct income from IPR, it generates income by selling services with the know-how obtained. In addition, it is considered that the know-how of the Center can be sold to companies abroad that have a production infrastructure.

The legislation on IPR and possible rights sharing issues (especially with the assignment from universities) have not been solved yet for different scenarios. Also, there is a lack of knowledge on methods of protecting IP among the researchers as well as the administration.

Targeted future state

- Definition and implementation of IPR protection strategies: IP Commission which includes assigned researchers and administrative staff working at the Center, legal counsel and patent office representative
- Strengthened legislation framework on IPR
- Well-functioning organisational procedures and processes on management of IPR

Recommended actions to close the gap		
Knowledge sharing topic	**Tool**	**Involved partner(s), timing**
IPR protection strategies / IPR management	Best practice sharing workshop	IMEC (tbd)
	Seminars	External experts (tbd)
IP Valuation and Portfolio Management	Best practices	IMEC (tbd)

Gap 5: Lack of experience/knowledge in global marketing and technology transfer

Current state

Competence in global marketing and technology transfer is crucial for turning the IP portfolio into a commercial value, therefore for the sustainability of the Center. Although the Center has not yet obtained a direct income from IPR, income is generated by selling services with the know-how obtained from the R&D projects. As the researcher potential within the Center develops and R&D studies are diversified, it is expected that new applications and therefore related income will increase. Different models are on the agenda to increase visibility of the Center and cooperation in national and international platforms. For example, multiple shared production (Multi Project Wafer – MPW) technology is a model the Center is currently working on. The Center needs more start-ups and spin-off companies to increase the current TRL of the products and compete in the global market.

Targeted future state

- Systematic approach on global marketing
- The Business Development and Planning Office

Recommended actions to close the gap		
Knowledge sharing topic	**Tool**	**Involved partner(s), timing**
Power of social media	Seminar	UFR (M10)
Art of Networking	Seminar	UFR (M10)
Microfluidic platforms and commercialisation strategies at UFR and Hahn-Schickard	Seminar (in scope of BioMEMS and Microfluidics Technologies workshop, 2023)	UFR (M7)
Meet a founder	Workshop	Advisory Board (tbd)
Spin-off mechanisms	Best practice workshop	IMEC, UFR (tbd)
MPW-standard process development	Best practice workshop	IMEC (tbd)
International business development	Seminar	Advisory Board (tbd)
Licensing agreements and royalty management	Seminar	External expert (tbd)

Gap 6: Long durations for building basic knowledge and gaining experience in the field of MEMS

Current state

Currently, it takes more than a year for a new researcher to be checked out from processing equipment to conduct their own process. Moreover, it should be noted that it takes at least 1-1.5 years, for a new researcher to reach the point of making publications on MEMS.

Targeted future state
• Well-functioning organisational procedures and processes regarding check-out process for new researchers • Tools to speed up the check-out process such as coaching, lab buddies etc. • A separate section within the cleanroom for newcomers to carry out their process for gaining experience.

Recommended actions to close the gap

Knowledge sharing topic	Tool	Involved partner(s), timing
Standardised training programmes and tools for newcomers	Best practice workshop	All (tbd)
Employee onboarding processes	Best practice workshop	All (tbd)

Gap 7: High operating/maintenance/repair costs for cleanroom and the aging of the equipment inventory

Current state

The facility of ODTÜ MEMS Center, was established by a company named TESTAŞ A.Ş. with an investment of 40 million USD in the 1980s. The facility was later transferred to METU in 1998. Since then, ODTÜ MEMS Center's MEMS and micro production infrastructure has been developed with investments from R&D projects originating from private sector, as well as public funds. The infrastructure is at a level that can compete with similar centers and research institutions in the world today. The facility has a closed area of 4.500 m^2, of which around 1.000 m^2 is the cleanroom area, defined as 100 Class and 1000 Class in terms of cleanliness criteria. The remaining areas consist of a 300 m^2 special test area with 10.000 class cleanliness and 3.200 m^2 auxiliary facilities.

In order to ensure the management and traceability of the devices, an automation system, namely TOSP in which the devices in the clean area and the operations that the device could perform were defined, was established in the cleanroom. With this system, parameters such as device usage hours and works started/completed on devices can be measured. The capacity usage performance measurement of the devices is calculated only on the number of processes defined for the devices, and this performance value is directly proportional to the workload (batch production) received by the Center. In addition, since the cleanroom in the Center is not a mass production facility by nature, the high-precision devices are not always in operation. “Device capacity utilisation rate”, which is calculated by proportioning the total number of transactions defined to the devices by the number of actual transactions on the devices, is around 40% annually.

Since the processes are performed sequentially in most processes defined in the clean area, when a device fails, the process stops until the malfunction is resolved. The Microfabrication team leader is responsible for keeping the Center's high-cost device infrastructure operational, providing microfabrication services for internal and external stakeholders, and equipment inventory and process organisation of project activities.

Targeted future state

- Mechanisms for prioritisation and outsourcing for maintenance procedures
- Effective tools to extend capacity

Recommended actions to close the gap		
Knowledge sharing topic	**Tool**	**Involved partner(s), timing**
Best practices on preventive maintenance	Best-practice sharing workshop	All (tbd)
	Visits	
Best practices on cleanroom management	Best-practice sharing workshop	All (tbd)
	Visits	
In-house maintenance	Workshop	All (tbd)

Gap 8: High staff turnover rate (esp. research staff), brain drain

Current state

The experience of the research staff of ODTÜ MEMS Center, which carries out interdisciplinary studies, is concentrated in the fields of image sensors, inertial sensors, BioMEMS and RF MEMS. There is a total of 64 permanent staff (researchers, administrative staff and technical staff) working full- or part-time in the Center. In addition, 13 faculty members from different universities have been assigned by their universities as part-time researchers within the Center. Currently, 39 researchers are working as permanent staff at the Center, 8 of which have PhD degrees and 19 of which have M.Sc. degrees. 10 of the master's graduate researchers are currently enrolled in PhD programs.

The most important problem in human resources has been the high staff turnover rate. High turnover negatively affects the performance in advanced research subjects that require experience. It has been observed that the research team needed in the projects carried out by the leading researchers has not yet settled due to staff turnover. The most important reasons that have been observed are uncompetitive salary levels, the lack of a reward system for performance and the lack of career development opportunities. It is concluded that the opportunities offered by ODTÜ MEMS – beyond the wage levels – still do not create the expected attraction for qualified researchers.

Although several steps towards institutionalisation have been taken and human resources management policy development studies have started as of 2021, it has been determined that there are deficiencies in some human resources processes. For example, no concrete approach has been observed for “back-up of critical personnel”, “orientation” and “performance management” processes.

Targeted future state

The main pillars for becoming a point of attraction for senior/young researchers and experts:

- Well-functioning human resources management policy:
  - Performance management system, incl. incentive mechanisms
  - Competency management system
  - Orientation processes etc.
- Definition of organisational procedures/processes and legislation framework on spin-off mechanisms
- Taking advantage of brain drain: keeping connections and statistics

Recommended actions to close the gap

Knowledge sharing topic	Tool	Involved partner(s), timing
Performance and career management	Seminar	TU/e (tbd)
Attracting and keeping talented staff	Best practice sharing	All (tbd)

Gap 9: Lack of infrastructure needed for microfluidics and particularly OoC in cleanroom		
Current state		
ODTÜ MEMS' cleanroom is equipped with a parylene coater, which is primarily used for fabrication of microfluidic chips. However, the Center is lacking thermoplastic polymer processing equipment needed for microfluidics and particularly OoC. A grant for acquiring an injection moulding device and stereolithography (SLA) 3D printer was secured. However, there is no allocated space yet for setting the infrastructure.		
Targeted future state		
An infrastructure that can serve for the fabrication of polymer-based microfluidics at different scales. Alternative technological solutions for polymer microfluidic fabrication with lower investment needs.		
Recommended actions to close the gap		
Knowledge sharing topic	**Tool**	**Involved partner(s), timing**
Integration of polymer microfluidics and MEMS sensors/actuators	Seminar (in scope of BioMEMS and Microfluidics Technologies workshop, 2023)	IMEC (M7)
Best practices in fabrication of polymer microfluidics	Workshop	All (M18)

5 CONCLUSION

According to findings of the analysis study, the process of exchanging knowledge, skills, experience, and understanding among the partners has been elaborated. In this regard, the knowledge sharing strategy has been defined involving the clear definition of the activities and tools which will be implemented in order to support effective knowledge sharing and transfer from the twinning partners TU/e, IMEC and UFR to ODTÜ MEMS. Focusing on S&T gaps and needs of ODTÜ MEMS in strategic research priorities in the field of microfluidics, the following well-formulated mix of activities will be performed in close collaboration among the partners to enable the achievement of the goals:

- Online and/or face-to-face **seminars and training sessions** that involve specific content shared by experts assigned by the partners, advisory board members, third party experts etc.
- **Best practice sharing workshops** organised to facilitate sharing of best-practices and experiences among the partners on a particular scope of activity or practice.
- **Summer/winter schools** organised with contributions of the partners.
- **Short-term (one week-long) exchanges of staff** who work in research-related positions, to increase and foster collaboration opportunities and knowledge/experience exchange with another team through action-based learning.
- **Short-term visits** by ODTÜ MEMS researchers to the partner organisations for 2-3 days to gain new perspectives and to strengthen their knowledge and partnerships.
- Provision of **peer coaching** by the partner organisations via a guidance strategy established for preparing guidance documents including work flows and procedures.