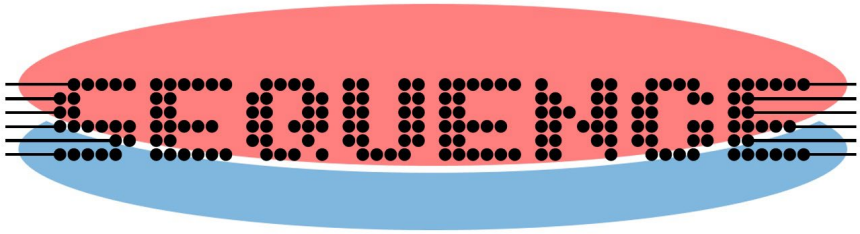
Deliverable – D5.4 Final Dissemination plan



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Authors	Adrien Morel (LETI), Didier Belot (LETI), Stéphanie Robinet (Leti)
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1 Introduction

1.1 Purpose of the document

The initial D5.3 *Dissemination plan* goal was to present the strategy of disseminating project progress and results to the relevant industrial and scientific communities.

In this final dissemination plan, the objectives are

- to summarize the dissemination actions throughout SEQUENCE project
- to evaluate the impact of this dissemination
- to ensure long project sustainability in dissemination efforts beyond the project's completion

1.2 Document Organisation

The deliverable is separated in 6 sections. Sections 1 and 2 introduce the communication strategies of the SEQUENCE project to the reader. Sections 3, 4 and 5 are dedicated to the three different targeted groups of the SEQUENCE project: non-technical audience (Section 3), industries (Section 4), and scientific communities (Section 5). Each of these three sections will describe the dissemination objectives, the messages, as well as the envisioned communication channels. Finally, Section 6 completes this deliverable with a summary of the dissemination actions.

1.3 Methodology

The initial dissemination plan focused on answering the following questions along the following steps:

Table 1 – Methodology for the SEQUENCE dissemination plan

To whom?	Target groups of dissemination (Sections 3, 4 and 5)
What?	What the consortium should disseminate in order to maximize the impacts of the project.
How?	The tools and the communication channels that will be used to propagate the consortium messages to the widest audience.
Why?	The reason behind each target group and the aim the consortium would like to achieve through the results' dissemination.
When?	The timeline and planification of the dissemination.
By whom and with whom?	The person or team responsible for a specific part of SEQUENCE dissemination plan, keeping in mind each partner's skills and contacts.

1.4 Application Area

This document has served as a management (Work Package 6) tool to define the dissemination and communication framework and guidelines for the project consortium, as well as project partners. It was used as a reference document to refer to during the project duration, including for regular monitoring and evaluation. Depending on project progresses and external factors, the dissemination plan was updated and adapted to fit to the needs and to deliver the best possible dissemination for SEQUENCE. The first version of the initial dissemination plan was due for M18, the final version of the dissemination plan was due for M36.

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2 Executive Summary

The *SEQUENCE* Project dissemination activities aim to make visible the project's outcomes and findings, in a plain language, to both scientific and non-specialist audience.

The dissemination of knowledge and expertise between the partners is built into the work package structure and project management. Face-to-face meetings as well as regular web-based consortium meetings were used to share information between the partners in a timely and efficient manner. The dissemination and communication work package was focused on the channels for communication of the project aims and research achievements to groups outside the consortium. All partners have excellent track-records in the dissemination of results in leading scientific journals and at esteemed international conferences. Publicly-funded research bodies have an obligation to disseminate, while for the industrial partners and SME's, publication of state-of-the-art results maintains their profile and high- tech reputation. Some partners were already active as conference chairs/organizers. (IEDM, WODIM/INFOS, ESSDERC/ESSCIRC, WOLTE, IRDS) as well as program committee members in the materials, device/circuit, and millimeter-wave and THz community, for example at DRC, IEDM, IPRM/ISCS, IMS, WODIM/INFOS, EUROSOI-ULIS, ESSDERC/ESSCIRC, WOLTE.

The overall aim of the management committee in relation to project dissemination was to ensure the maximum visibility of the project through innovation and impact, to ensure the intellectual property is secured, and to ensure different target communities are aware of the work and accomplishments of SEQUENCE as a project supported by the European Commission. All abstracts for conferences and manuscripts for journal publication were submitted via web portal in a timely manner to the management committee for this type of dissemination clearance and approval.

Dissemination strategies were differentiated according to specific targets, guaranteeing the initiative also after the end of the project. Multiple communication channels were used to reach the audiences, including presentations at international congresses, publications in scientific journals, existing social networks (twitter) and social-web based tools, etc.

3 Dissemination actions

3.1 Dissemination to a non-technical audience

This activity is central to the dissemination as it plays a critical role in explaining the importance of Nanoelectronics and Quantum Technologies to a broad range of applications, which have a big impact on the everyday lives of people in Europe, spanning the use of advanced semiconductor technologies in communications, health care, and the environment both now and into the future. This area of dissemination is also important to explain and justify to the broader public why it is essential for the European Union to invest in research into the next generation of technologies. Also, sustainable innovation in the field of micro/nano technologies is dependent on encouraging and attracting talented young people into the field.

3.1.1 Video communications

We worked with dedicated personnel at Lund University to make videos to communicate our research work and its significance to the broader public. A video titled "**The coolest hot topic of our age**" has been uploaded to YouTube, and could be used as short clips on "EuroNews", presentation at the EuroNanoForum and many more. It will also serve as a very good introduction during the Industrial Road Show. The video is also available for use by the European Commission, for outreach to schools and for communicating the significance and achievements of the work to local and national politicians.

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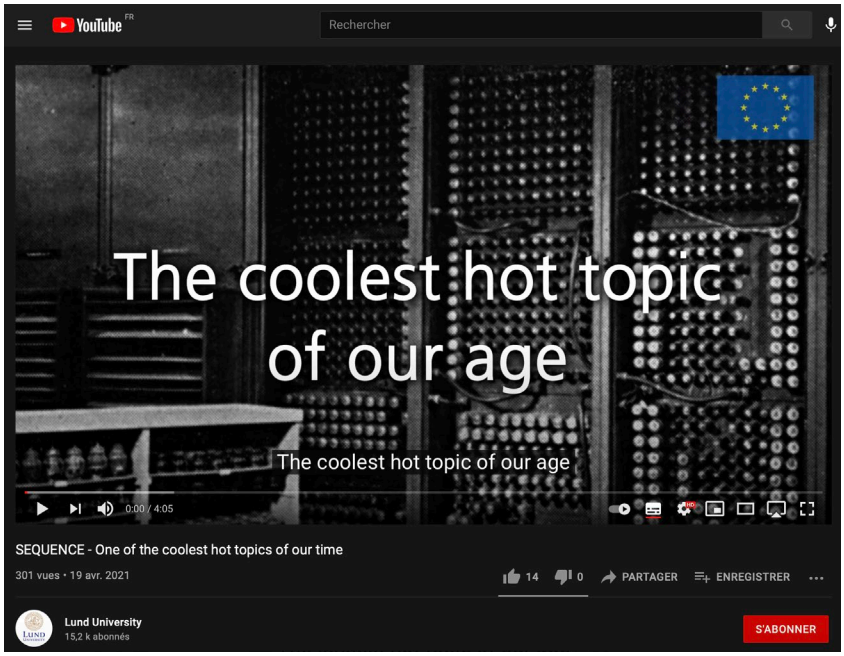

Figure 1 – YouTube video of the SEQUENCE consortium: The coolest hot topic of our age.

3.1.2 Social Media

We engaged social media to deliver to the widest audience a simplified and attractive message on the benefits of EU-funded research. Some of the partners (IBM, T-UCC, IAF) already have in place an active policy to advertise the activities of researchers through direct links to social media platforms (Facebook, LinkedIn, Twitter, Flickr, YouTube, and blogging platforms).

3.2 Outreach events

SEQUENCE members have actively participated in outreach events targeted towards students and secondary school students. Some examples include that in 20230330, participants from ULUND involved in SEQUENCE organized a visit from Her Tech Future with about 30 women from high-school to attract them to the science/engineering subject and spark interest in science and technology. Also, on 2020-06-23, we organized a tutorial - webinar on quantum technologies with two distinguished external invited speakers: Andreas Fuhrer (IBM) and Maud Vinet (CEA-LETI). All these medias were used for the project dissemination.

3.3 Transfer knowledges in universities

Several members of the consortium are regular professors and lecturers at universities. Those channels were used to communicate and raise awareness of the SEQUENCE technologies, transfer knowledge to advanced courses, and attract master and PhD students for research in this field. One example is the course in Nanoelectronics at Lund University, where dedicated lectures about cryogenic electronics have been added to the course program. Also, presentations on qubits are now included for the students visiting ULUND from the 1st year engineering nanoscience program.

Short courses were also given, based on Sequence outcomes.

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Franck Badets (CEA) and Christian Enz (EPFL), participated to IEEE workshop gm/Id organized by CNRS TIMA lab in Grenoble (Sylvain Bourdel). They presented gm/Id approaches for cryoCMOS/ quantum. A second short course was also given to GDR (Group of Research) SOC 10-12 of June 2023 in Lyon.

The SEQUENCE project has been a framework for students internships. Some of them were even organized within the consortium partners. As an example, a student from Grenoble Alpes University working on cryogenic design in CEA was welcome in EPFL working on the cryogenic characterization topic.

4 Dissemination to Industry

The SEQUENCE consortium attended appropriate Conferences/Exhibitions to disseminate the project outcomes and trigger interest for new stakeholders especially in Cryogenic electronics, space applications as well as future communication systems. SEQUENCE prepared a press release, which coincided with the web site launch.

SEQUENCE press release: *https://www.eurekalert.org/pub_releases/2020-09/lu-epa090420.php*
SEQUENCE website: http://www.sequence-h2020.eu/index.php?gpuid=4&L=1

The SEQUENCE consortium also attended brokerage events organized within the framework of EU Ecsel projects (https://www.ecsel.eu).

An industrial roadshow was organized with two specific goals: first to disseminate the knowledge towards specific industrial actors, second to collect inputs from them, identify new needs and maximize the project outcomes.

For this industrial roadshow a common presentation of all the results was produced.

The following table describes the industrial roadshow:

Visited industrials	Date/place	Attendees	Outcome and reactions
STMicroelectronics	July 2022, Grenoble	Reduced committee of experts (about 10) in STM	Interest toward the double usage Quantum/Aerospace target and FDSOI28 performance at cryogenic temperature. Possible outcome: involvement of STM in KDT ARCTIC consortium
Global Foundries	November 2022, Dresden	#40 attendees from GF in Dresden and >100 of attendees in remote connection from all GF sites	Questions were raised on the behavior of GF technology at cryogenic temperature, specifically on dispersion. Collaboration between GF and CEA was reinforced after this meeting.
European Space Agency	October 2022	About 20	Further interaction with ESA and SEQUENCE key partners has been established

5 Dissemination to the Scientific Community

For dissemination to the research community active in nanoelectronics, we utilize the traditional channel of publications and conferences. The SEQUENCE project aligned efforts within the EU Quantum Flagship for instance by inviting speakers to our winter school, in addition to contributions from all

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project partners. The consortium arranged an International Workshop on cryogenic electronics at IMS 2022.

5.1 Publications and conferences

Results related to SEQUENCE have been published in leading journals and presented in leading conferences in the fields of nanoelectronics, solid-state physics and circuit design. Table 2 presents the initial publications target of SEQUENCE as well as the current publications status (at M42) and below is the full list of publications.

Table 2 – Initial publications targets in journals and conferences and publications that have already been published by the consortium (M18 and M42)

Publications	Targeted	M18	M42
IEEE EDL/TED	8	4	14
Nature Elec.	3	1	1
Nano Letters	2	1	1
APL/JAP	2	1	4
IEEE JSSC/TMTT	2	3	4
Journal Low temperature physics / cryogenics	2	1	1
Solid State Electronics	2	2	14
Other journals	0	2	7
IEDM	5	1	3
VLSI	1	0	0
ISCS/IPRM	2	2	2
WOLTE	1	1	2
ESSDERC/DRC	6	0	6
INFOS/EMRS	1	0	0
EUROSOI-ULIS	2	2	5
IMS	2	1	4
Book	0	1	1

Cryogenic MOSFET Subthreshold Current: From Resistive Networks to Percolation Transport in 1-D Systems
Catapano, E., M. Casse and G. Ghibaudo IEEE Transactions on Electron Devices. 70, 8, 4049-4054 (2023)

On the Zero Temperature Coefficient in Cryogenic FD-SOI MOSFETs
Catapano, E., T. M. Frutuoso, M. Casse and G. Ghibaudo IEEE Transactions on Electron Devices. 70, 3, 845-849 (2023)

On the Fluctuation-Dissipation of the Oxide Trapped Charge in a MOSFET Operated Down to Deep Cryogenic Temperatures
Ghibaudo, G. Fluctuation and Noise Letters. (2023)

The Effect of Cryogenic Temperatures on the Lateral Heat Spreading in InGaAs/InP HEMTs

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Graziano, G., A. Ferraris, E. J. Cha and C. B. Zota IEEE Transactions on Electron Devices. 70, 8, 4087-4092 (2023)

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Modeling and simulations of FDSOI five-gate qubit MOS devices down to deep cryogenic temperatures

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In-depth Cryogenic Characterization of 22 nm FDSOI Technology for Quantum Computation

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Casse, M., B. C. Paz, G. Ghibaudo, T. Poiroux, E. Vincent, P. Galy, A. Juge, F. Gaillard, S. de Franceschi, T. Meunier and M. Vinet Applied Physics Letters. 116, 24 (2020)

Ultra-Low Power Scaled III-V-on-Si 1T-DRAMs With Quantum Well Heterostructures
Convertino, C., L. Vergano, L. Czornomaz, C. B. Zota, S. Karg and Ieee. Joint International EUROSOI Workshop / International Conference on Ultimate Integration on Silicon (EUROSOI-ULIS), Caen, FRANCE.(2020)

Cryo-CMOS Compact Modeling
Enz, C., A. Beckers, F. Jazaeri and Ieee. IEEE International Electron Devices Meeting (IEDM), Electr Network.(2020)

On the modelling of temperature dependence of subthreshold swing in MOSFETs down to cryogenic temperature
Ghibaudo, G., M. Aouad, M. Casse, S. Martinie, T. Poiroux and F. Balestra Solid-State Electronics. 170, (2020)

Tuning of Source Material for InAs/InGaAsSb/GaSb ApplicationSpecific Vertical Nanowire Tunnel FETs
Krishnaraja, A., J. Svensson, E. Memisevic, Z. Y. S. Zhu, A. R. Persson, E. Lind, L. R. Wallenberg and L. E. Wernersson ACS Applied Electronic Materials. 2, 9, 2882-2887 (2020)

Vertical InAs/InGaAsSb/GaSb Nanowire Tunnel FETs on Si with Drain Field-Plate and EOT=1 nm Achieving S-min=32 mV/dec and g(m)/I-D=100 V-1
Krishnaraja, A., J. Svensson, L. E. Wernersson and Ieee. IEEE Silicon Nanoelectronics Workshop (SNW), Electr Network.(2020)

Simulation of low-noise amplifier with quantized ballistic nanowire channel
Marty, C., C. Convertino and C. Zota Semiconductor Science and Technology. 35, 11 (2020)

Performance and Low-Frequency Noise of 22-nm FDSOI Down to 4.2 K for Cryogenic Applications
Paz, B. C., M. Casse, C. Theodorou, G. Ghibaudo, T. Kammler, L. Pirro, M. Vinet, S. de Franceschi, T. Meunier and F. Gaillard IEEE Transactions on Electron Devices. 67, 11, 4563-4567 (2020)

Mobility of near surface MOVPE grown InGaAs/InP quantum wells
Soedergren, L., N. S. Garigapati, M. Borg and E. Lind Applied Physics Letters. 117, 1 (2020)

InGaAs MOSHEMT W-Band LNAs on Silicon and Gallium Arsenide Substrates

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Thome, F., F. Heinz and A. Leuther IEEE Microwave and Wireless Components Letters. 30, 11, 1089-1092 (2020)

III-V Nanowire MOSFETs: RF-Properties and Applications
Wernersson, L. E. and Ieee. IEEE BiCMOS and Compound Semiconductor Integrated Circuits and Technology Symposium (BCICTS), Electr Network.(2020)

An up to date list of publications can be found at https://tinyurl.com/2m9brnmf

The initially targeted number of publications, which was 25, is achieved by a large margin with a total of 46 publications in peer-reviewed journals. For conferences the final result is 22, beyond the target of 20.

5.2 International Workshop and Winter/summer school

As planned initially, two dedicated workshops were organized by the SEQUENCE consortium during the project to highlight the technology platform which was being developed by the SEQUENCE consortium and how it could be of benefit to European Industry. In particular, the workshops emphasized the benefits of the SEQUENCE technology platform, which are:

- Cryogenic electronics for quantum computing
- Cryogenic electronics for high-performance computing
- Space communication and sensing
- Future communication systems.

5.2.1 International Microwave Symposium (IMS)

The first workshop happened virtually (originally planned in Atlanta) during the IEEE conference the International Microwave Symposium (IMS) the 20th June 2021.

An international workshop titled “Cryogenic RF and mmW Technology and Circuit Platforms: A Path Toward Quantum-Computing” was organized during the conference IMS (International Microwave Symposium) 2021, the 20th June 2021. IMS is a major IEEE conference and one of the largest event dedicated to the radio frequency and microwave industry in the world (9500 attendees in 2019, 650 exhibiting companies in 2019). The workshop abstract is shown in Figure 4.

	WORKSHOP TITLE	WORKSHOP ABSTRACT
WMC	**Cryogenic RF and mmW Technology and Circuit Platforms: A Path Toward Quantum-Computing** **Sponsor:** IMS; RFIC Organizers: Adrien Morel, CEA-LETI; Didier Belot, CEA-LETI; Michael Schroeter, TU Dresden	Cryogenic electronics will have a strong impact on our society through applications as Quantum Computing but also, space communication, and high performance computing. Quantum computers, for instance, have the potential to radically advance our computational capability and are predicted to strongly impact fields such as medicine, chemistry, science and finance by allowing to solve computational problems that cannot readily be solved by classical computers. The hardware implementations of quantum computers rely on various quantum bit (qubit) technologies, such as superconducting qubits, spin qubits and Majorana fermions. All of these Qubits require cryogenic temperatures (<4K) to operate efficiently, and need, and restitute Analog-RF signals for their manipulation, and results respectively. Thus, there is a need for cryogenic electronics with a large array of functionalities, operating under extremely low noise conditions with limited power budgets. Achieving this will require enhanced understanding of existing transistor technologies, 3D integrated systems and novel nanoelectronic devices employing unique low-temperature effects. With these new devices, new ultra-low noise, ultra-low power, and wide-band circuits and systems are emerging, preparing the next computing revolution. In this Workshop we will explore state of art status of Quantum computing applications and their associated technology and circuits analog-RF platforms.

Figure 4 – International workshop abstract

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The workshop gathers nine talks from experts on qubit technology, devices at cryogenic temperatures and circuits for quantum computing. The planning of the workshop is shown in Table 5. The talks subjects are closely related to SEQUENCE workpackages on cryogenic devices and cryogenic circuits.

Table 5 – Workshop speakers and talks on qubit technology, devices at cryogenic temperatures and circuits for quantum computing

Talks titles	Speakers
Spin Qubit Quantum Computing overview	Tristan Meunier, CNRS, France
Overview of high-frequency electronics for superconducting quantum computing	Cezar Zota, IBM, Switzerland
Cryogenic circuits and systems for Qubits readout	Mathilde Ouvrier-Buffer, CEA, France
Characterization and modelling of FDSOI devices for cryo CMOS applications	Francis Balestra, CNRS, France
Cryogenic behavior of InGaAs Nanowires for RF and mmW, and associated circuits for Quantum computing and other cryogenic applications	Lars-Erik Wernersson, U.Lund, Sweden
Cryogenic InGaAs mHEMT and MOSHEMT for RF and mmW and associated circuits and systems for Quantum computing and other cryogenic applications	Fabian Thome, Fraunhofer IAF, Germany
Horse Ridge: a Cryogenic SoC for Spin Qubit Control Implemented in Intel FinFET Technology to Enable Scalable Quantum Computers	Stefano Pellerano, Intel, USA
Cryogenic SiGe HBT device operation for Quantum Computing	Michael Schröter, TU Dresden, Germany
Cryogenic SiGe Analog-RF circuits for Quantum Computing	Joe Bardin, U.Mass. & Google, USA

This international workshop is a good opportunity to present the consortium works and visions to the RF community and to international companies that might be interested in quantum computing.

5.2.2 Winter School

A Winter school was organized in March 2022 once COVID crisis started to calm down. The booking of the hotel as well as the practical organization was led by LETI, while the scientific organization of the winter school was led by EPFL.

The school covered advanced topics in quantum computing and cryogenic devices, circuits and systems. It targeted at upper-level undergraduates and graduate students who have some prior knowledge of linear algebra, semiconductor physics, and quantum physics. This winter school also targeted at PhD candidates and researchers that work in closely-related fields and are interested in knowing more on quantum computing and cryogenic nanoelectronics.

This workshop was organized in Flaine, French Alps, to facilitate attendees access from Genova airport.

The speakers were invited among consortium partners but also outside the consortium boundaries, such as Stefano Pellerano (Intel), Pascal Chevalier (STMicroelectronics), and Jo Bardin (University of Massachusetts and Amherst & Google Quantum AI).

There were 30 attendees on-site with an additional 30 attendees online (varying over time), with a total of 60 registered for online access.

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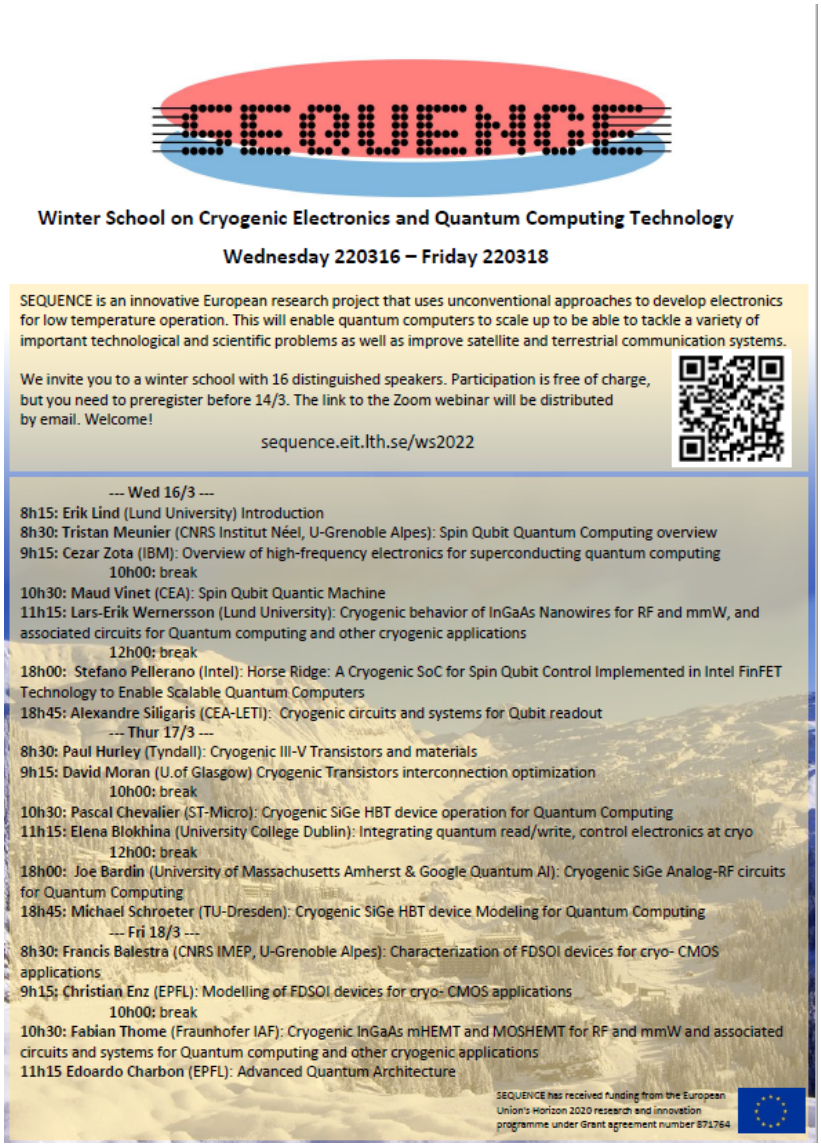

5.3 Contributions to IRDS roadmaps

We contribute to the Quantum computing IRDS (cryogenic electronics and quantum information processing) CEQIP. IBM is already a member of CEQIP and contributed to the IRDS roadmaps to define the processes and performance of transistors for future technology nodes.

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6 Dissemination Summary

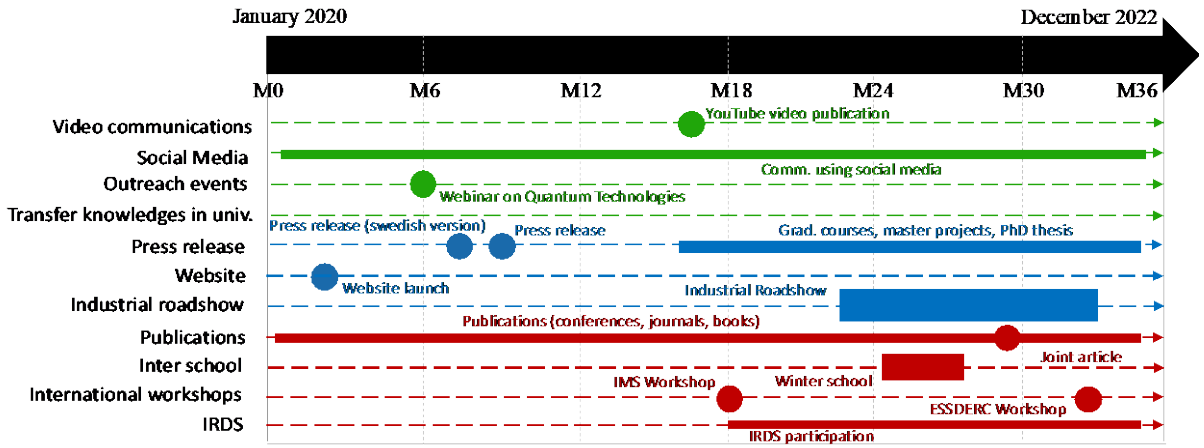

Figure 5 – Dissemination planning

We have to a large extent followed the dissemination plan from D5.3 and have by far reached the goals in terms of targeted journals and number of publications. In conclusion, the SEQUENCE project continues to generate high impact publications in both cryogenic device fabrication, modeling and circuits.

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