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**SUPERAID7**

Stability Under Process Variability for Advanced Interconnects and Devices Beyond 7nm Node

# D1.10: Publishable Version of the Technology Implementation Plan

| | Name | Organisation | Date |
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# Contents

## Abstract

Within the SUPERAID7 project a “Draft Plan for the Dissemination and Exploitation of the projects’ results” was included in the proposal and in the Description of the Action, and was refined in the confidential deliverable D1.2 “Internal Dissemination and Use Plan” prepared shortly after the beginning of the project. This deliverable reports about the implementation of this plan, both regarding exploitation at the partners within the project and dissemination actions which are also essential for the successful exploitation of the project results. The SUPERAID7 Consortium Agreement included regulations which make sure that dissemination is promoted and that exploitation is not negatively affected by publishing of information which needs to be protected.

SUPERAID7 dissemination actions started with the implementation of the project WWW site at www.superaid7.eu, which among others included sections for the general public and for the members of the Industrial and Scientific Advisory Board of SUPERAID7. Papers published in peer review journals and at various important conferences are listed together with workshops which were either organized by SUPERAID7 or where SUPERAID7 took part. The most important exploitation path for results from SUPERAID7 has been via the extension of the commercial offerings of the software house GSS, which is since month 5 of the project part of Synopsys. Furthermore, this document also summarizes the internal exploitation at the four academic partners Fraunhofer, CEA/Leti, Glasgow University, and TU Wien.

At the end of the SUPERAID7 project the Technology Implementation Plan has been prepared both in a public and in a more detailed confidential version. Further information on the dissemination and use of SUPERAID7 results is given in the Final Project Report and in the final confidential deliverables from the workpackages on dissemination and on exploitation, respectively.


## 1. Introduction

Dissemination and exploitation of the project results is a key activity of any research project. Whereas both have their own importance and their own requirements, it is also critical that exploitation of the project results is not endangered or hindered by too early or otherwise inappropriate publication. In SUPERAID7 both exploitation and dissemination were first promoted by appropriate information and approval procedures agreed upon and laid down in the SUPERAID7 Consortium Agreement. The next step was the definition of an initial plan for the dissemination and use of the project results already in the SUPERAID7 proposal and Description of the Action, and the refinement of this plan in a confidential deliverable shortly after the beginning of the project. Dissemination actions planned included among others the project WWW site, publications in journals, conference presentations, workshops, interactions with other projects, and links to teaching. Software results from the project should be used at all partners for internal research and partly for external research projects, and moreover extend the commercial offer of the software house GSS (since month 5 of the project part of Synopsys) which is one of the key partners in SUPERAID7. This document gives an overview of the successful implementation of these plans.

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# 2. SUPERAID7 Use and Dissemination Actions

## 2.1 Dissemination Actions Carried out in SUPERAID7

Successful, broad and well targeted dissemination is an essential contribution to the exploitation of the project results. On the other hand it is important to make sure that open dissemination is not negatively affecting commercialization. As mentioned above, this has been achieved by following the procedures laid down in the Consortium Agreement concerning advance information and approval of dissemination actions.

In the following the dissemination actions carried out in SUPERAID7 are summarized, referring to the detailed internal plans described in deliverable D1.2. An important additional channel for dissemination, not mentioned in D1.2, has been the SUPERAID7 WWW, www.superaid7.eu: Whereas its public section has been used for broad distribution of selected information to the open public, via a dedicated protected section additionally all documents were made available to the members of the Industrial and Scientific Advisory Board of SUPERAID7. Further exchanges with members of the SUPERAID7 ISAB were made via dedicated communications on specific topics, such as specifications and availability of data, and partly via direct involvement in and presentations at two SUPERAID7 workshops. The final content if the SUPERAID7 WWW is summarized in the public deliverable D6.4 “Final version of SUPERAID7 WWW including restricted section and including material from the SUPERAID7 Workshop”.

### Scientific Publications and Conference Participations

Considerable research activities and high-level scientific results have been necessary to achieve the objectives of the SUPERAID7 project. This has automatically also included close interactions with the scientific communities in various fields of TCAD, in order to best consider, use, and compare with developments being made elsewhere. In consequence, it has been vital for the SUPERAID7 project to publish its results at the conferences most important in the field (e.g. SISPAD) and to discuss at these events with the other leading experts in the field. Moreover, publications in leading scientific journals have been mandatory to attract attention for the results of the project, in this way also supporting the other dissemination activities outlined below.

Partners driving the publication and conference participation actions in SUPERAID7 have been the research institutes and universities CEA/Leti, Fraunhofer IISB, Univ. Glasgow, and TU Vienna.

The overall requirement to make publications from SUPERAID7 available via Open Access channels has needed special care because key conferences and journals relevant to the area of SUPERAID7 do not necessarily support Open Access, and the individual contributor has no chance to change the business strategy of the conference or journal. SUPERAID7 has responded to this challenge mainly in two ways: First, to prefer high-level scientific conferences and journal which provide Gold Open Access, potentially with some lag time. This refers especially to SISPAD as the worldwide most important dedicated simulation conference. In cases where Gold Open Access was not possible, papers were made available via Green Open Access.

**Conference Contributions**

Due to the topics covered by SUPERAID7, different scientific areas are relevant in terms of participation in conferences. This includes for instance technology-oriented conferences such as IEDM or EUROSOI-ULIS, device simulation-oriented conferences such as the SISPAD,

but also conferences on nanotechnology such as NMCD and on optics and photonics such as SPIE. Results of SUPERAID7 have been presented at 13 conferences and workshops with a total of 27 conference papers. A complete list of the conferences and the SUPERAID7 papers at these conferences is given in the public deliverable D6.3.

**Peer-Reviewed Publications**

Within SUPERAID7 13 peer-reviewed papers have been published in renowned journals with a high visibility in the scientific community. The list of the peer-reviewed publications is given in the public deliverable D6.3.

### Workshops

An essential part of the SUPERAID7 dissemination strategy has been the organization or the participation in workshops:

- In the Description of the Actions and in deliverable D1.2 it was foreseen that SUPERAID7 would organize as deliverable D1.8 a “Public Workshop on Variability”. This workshop as held on September 3, 2018, linked to the ESSDERC / ESSCIRC conferences held Dresden, Germany, from September 4 to 6, 2018. The workshop organized by SUPERAID7 was named “SUPERAID7 - Process variations from equipment effects to circuit and design impact“, which reflected well the scope of the project. It consisted of eight presentations from SUPERAID7 and one external industrial keynote presentation which linked to the ECSEL project Way2GoFast. In total it was attended by about 20 people. Further information is given in deliverable D1.8 and at the SUPERAID7 homepage.
- Beyond its original plans SUPERAID7 also co-organized two workshops on September 5, 2016, linked to the SISPAD 2016 conference held from Sept. 6 to 8 in Nuremberg, Germany: Workshop 1 “Simulation of Advanced Interconnects” and Workshop 3 “Variability-Aware Design Technology Co-Optimization”. Further information has been provided at the SUPERAID7 homepage.
- SUPERAID7 participated in the 3rd European Nanoelectronics Forum 2016 held from November 23-24 in Rome, Italy, via a SUPERAID7 poster presented by J. Lorenz, Fraunhofer IISB.
- SUPERAID7 participated in the 2018 European Forum on Electronics Components and Systems (EFECS) held from November 20-22 in Lisbon, Portugal, via two SUPERAID7 posters presented by J. Lorenz, Fraunhofer IISB.
- The SUPERAID7 project was also presented at the PATMOS/VARI Conference, September 21-23, 2016, Bremen, Germany: Presentation “Project SUPERAID7: Stability Under Process Variability for Advanced Interconnects and Devices Beyond 7 nm node” given by J. Lorenz, Fraunhofer IISB.

### Training of Scientists and Development of Skills in Europe

Another important aspect has been the dissemination via development of skills in Europe. SUPERAID7 has contributed to this in various respects:

- The research partners in the project (Fraunhofer IISB including its Linked Third Party University of Erlangen-Nuremberg, CEA/Leti, Univ. Glasgow and TU Wien) employ a considerable share of scientists who join the institutions after their university degrees, gain additional technical and management qualification during their work, under the supervision of senior scientists, and mostly after some years join industry. As far as working on the project, such scientists can in an optimum way transfer knowledge about the application of simulation tools like those developed in SUPERAID7 into the semiconductor industry. In general the regulations in the work contracts with these

staff members make sure that although the training and the transfer of application knowledge is beneficial and promoted the IPR of the project partners is protected.

- Whereas the University of Erlangen-Nuremberg, the University of Glasgow and TU Wien directly educate students, also Fraunhofer IISB (via its close cooperation with the University of Erlangen-Nürnberg) is contributing to the training of graduate and PhD students. Referring to Fraunhofer IISB, three senior members of the simulation department involved give lectures at the University of Erlangen-Nuremberg. Training also includes direct participation of young scientists in the research projects like SUPERAID7. IPR is protected in a similar way as with other staff members.
- The statistics collected for the Final Report of SUPERAID7 indicate that besides various levels of experienced researchers also several PhD students or other junior scientist were involved in SUPERAID7.

## 2.2 Status of SUPERAID7 Exploitation

In D1.2 three tasks were outlined for the exploitation within SUPERAID7: The use of enhanced semiconductor simulation programs for own process and device development, the use of enhanced semiconductor simulation programs for research projects, and finally commercialization. In the following the status at the end of SUPERAID7 is compared with the plans outlined in D1.2.

### Use of Enhanced Semiconductor Simulation Models and Programs for own Process and Device Development

Within the SUPERAID7 work package 5 “Software Integration and Variation-Aware Compact Models”, relevant background software from the partners and the software modules developed in SUPERAID7 were integrated with each other and with relevant commercial software like GARAND, Sentaurus Process and Sentaurus Device. Compared with the initial plans at the beginning of SUPERAID7, the acquisition of GSS by Synopsys enabled a much closer integration especially regarding interconnect and device simulation on one side, and compact model extraction on the other side. This enabled both the conduction of the benchmark simulations planned in the project and the provision of a much better software environment for Design-Technology Co-Optimization (DTCO). The benchmark simulations carried out led to an assessment of the impact of process variations for a nanowire process highly relevant for the SUPERAID7 partner CEA/Leti. This has also provided a good starting point for subsequent further internal use and exploitation at LETI. Beyond this, the novel advanced compact model LETI-NSP, developed at CEA/Leti, has not only been integrated with the SUPERAID7 software system but also been included in the standardization activities of the Compact Model Coalition CMC.

### Use of Enhanced Semiconductor Simulation Models and Programs for Research Projects

The physical models, the various software modules and the overall software system developed provide an excellent technical and scientific starting point for subsequent use and exploitation in further research projects:

- The physical models developed for etching and deposition provide a very good basis for use and extension in subsequent modeling, technology or device architecture projects.
- The physical models developed for device simulation provide a very good basis for use and extension in subsequent modeling or device architecture projects.
- The advanced topography simulator developed in SUPERAID7 further enhances the capability of Fraunhofer IISB to contribute to the development of leading-edge lithography equipment and processes, which has already been successfully supported by IISB lithography simulation in several ECSEL projects.

- The novel compact model LETI-NSP and the related compact model extraction methodology from Synopsys are essential to bridge the gap between future device architecture and design projects.
- The overall SUPERAID7 simulation system provides an excellent basis for Design-Technology Co-Optimization optimization of CMOS-based semiconductor technologies, devices and systems, especially regarding the minimization of the impact of variability. Furthermore, is also provides a very good basis for its extension to *More-than-Moore* and *Beyond CMOS* architectures.

### Commercialization

The DTCO flow based on Sentaurus Workbench has been made available to Synopsys customers, starting from the December 2016 release of the GSS tools. Between then and the end of the SUPERAID7 project, several significant improvements to the integration and capabilities of the tools and flows have been made, and been released to Synopsys' customers. In addition, some of the developments obtained within SUPERAID7 on self-consistent multi-subband Monte-Carlo simulation have been useful for the enhancement of the Synopsys QTX framework.

## 3. Conclusions

SUPERAID7 has been very active and successful in the dissemination of its results via the SUPERAID7 WWW site, peer-reviewed publications, conference presentations, workshops, the interaction with the SUPERAID7 Industrial and Scientific Advisory Board, and contributions to teaching. Use of the project has already led to important benefits for the project partners. Commercialization of software results from SUPERAID7 has strongly contributed to the further strengthening of the market position of the software house GSS and since May 2016 Synopsys, which is the primary partner for exploitation towards the outside world.