Prospective For Nuclear Thermal Hydraulic Created By Ongoing And New Networks

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ABSTRACT

This paper introduces the FONESYS, SILENCE and CONUSAF projects run by some of the leading organizations working in the nuclear sector.
The FONESYS members are developers of some of the major System Thermal-Hydraulic (SYS-TH) codes adopted worldwide, whereas the SILENCE members own and operate important thermal-hydraulic experimental facilities. The two networks work in a cooperative manner and have at least one meeting per year where top-level experts in the areas of thermal-hydraulic code development and experimentation are gathered.
The FONESYS members address various topics such as hyperbolicity and numerics in SYS-TH codes, 3-field modeling, transport of interfacial area, 3D modeling, scaling of thermal-hydraulic phenomena, two-phase critical flow (TPCF), critical heat flux (CHF), and others. As part of the working modalities, some numerical benchmarks were proposed and successfully conducted by the network, addressing some of the most relevant topics selected by the FONESYS members.
On the other hand, SILENCE addresses topics such as identification of current measurement needs and main gaps for further SYS-TH and CFD codes development and validation, definition of similar tests and counterpart tests in Integral Tests Facilities (including containment thermal-hydraulics) to be possibly conducted on Members' test facilities, scaling issue, and other subjects. Furthermore, SILENCE organized a "Specialists Workshop on Advanced Instrumentation and Measurement Techniques for Nuclear Reactor Thermal-Hydraulics (SWINTH)" which was held in Italy on June 2016. A second edition of the Workshop, namely SWINTH-2019, will be held in Italy in 2019 under the umbrella of the OECD/NEA/CSNI/WGAMA.
Recently a new initiative is being taken by launching an international consortium of nuclear thermal-hydraulics code users, the CONUSAF. The main idea is to enhance the interactions between the users of computational tools in nuclear TH, noticeably including SYS-TH and CFD codes, the code developers and the experimentalists. The proposed initiative is expected to have a positive impact on the entire ecosystem by pursuing the assessment of the current code limitations and capabilities, analyzing and addressing issues raised by the users and promoting common R&D efforts on topics of high relevance.

KEYWORDS

THEARMAL-HYDRAULICS, INTERNATIONAL COOPERATION, FONESYS, SILENCE, CONUSAF.

1. INTRODUCTION

The development of the SYS-TH Codes began at the end of the 1960's as a response to the requirements, or knowledge targets, put by the Regulatory Body in the United States, US Atomic Energy Commission (US AEC), now US Nuclear Regulatory Commission (US NRC). The huge amount of investments in the nuclear reactor safety research and developments, including V&V, brought to the nuclear community the availability of the mature computational tools towards the end of 1990's, when those codes were classified as Best Estimate (BE) due to their advanced two-fluid modeling and their extensive validation.

The design of reactor coolant systems and ability to predict their performance and assess their safety depends on the availability of experimental data and models which can be used to describe various multiphase flow processes and phenomena with a sufficient degree of accuracy. From a scientific, as well as from a practical point of view, it is essential that the various mathematical models should be clearly formulated based on the physical understanding of multiphase flow processes and supported by experimental data. For this purpose, specially designed instrumentation and experiments are required which must be conducted together with, and in support of, model development efforts.

Since the resources and capability for new experiments are limited, good planning and international cooperation between experimentalist, code developers, and code analysts are necessary. In view of this, two projects namely FONESYS [1-3] and SILENCE [3,4] were launched aiming respectively at establishing a forum and a network among the code developers and promoting cooperation among teams of experimentalists that are managing or are involved in significant experimental projects in nuclear reactor thermal-hydraulics.

Following the success of FONESYS and SILENCE Networks it appeared appropriate to launch a Consortium specifically dedicated to nuclear TH code users (CONUSAF). The scope of the activities will span from identification of the code limitations to the analyses of the issues raised by user(s), as well as finding possible way to addressing them.

2. THE FONESYS NETWORK

2.1. Founding Motivation and Main Objectives of the Project

The main motivation for starting the FONESYS project was to bring technical argumentation answering possible disbelief in SYS-TH codes or over-criticism against them (see for instance the disbelief in codes as from the Zuber or Wulff papers [5,6]). and to strengthen the current technology. The effort for SYS-TH codes development is decreasing and may even stop but its application cannot be avoided even if new tools such as CFD or CMFD appeared at the beginning of the 2000s The motivation is to bring arguments against over-criticism and at the same time to improve the codes simulation capabilities, and to clearly identify the future roles of SYS-TH codes and CFD codes in reactor thermalhydraulic studies. While doing that, FONESYS should avoid what can be called the “Annapolis-1996 syndrome”, i.e. “deleting number of codes and starting the development of a ‘new-similar’ code on the basis of an ‘old’ one”. Another principal motivation was to form a network of top level experts and code developers that can challenge future problems that can possibly rise during the development and use of the SYS-TH codes.

FONESYS objectives are to keep the code limitations 'under control' and to provide guidance for code improvements. Strategy and activities were planned and decided by top-level experts within a framework consistent with the standards of international Institutions. The main objecti ves are summarized and listed below:

- to create a common ground for discussing envisaged improvements in various areas of System Thermal-Hydraulics, promoting a cooperation aimed at the improvement of the SYS-TH Codes and their application in the licensing process and safety analysis;
- to identify the area of improvement and share experience on the graphical user interface (GUI), SYS-TH code coupling with other numerical tools, such as 3-D neutron kinetics, fuel pin mechanics, CFD, CMFD, etc.;
- to share the experience on code inadequacies and cooperate in identifying experiments and/or code to code benchmarks for resolving the deficiencies;
- to share the user experience on code scalability, applicability, and uncertainty studies;
- to establish the acceptable and recognized procedures and thresholds for Verification and Validation processes;
- to maintain and improve the user expertise and the documented user guidelines for applying the code.

2.2. The FONESYS Members and Reference SYS-TH Codes

Six International Organizations are currently involved in the FONESYS Network, namely Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA) and Framatome (former AREVA NP SAS) from France, Gruppo di Ricerca Nucleare San Piero a Grado / Università di Pisa (GRSNPG/UNIPI) from Italy, Korea Atomic Energy Research Institute (KAERI) from South Korea, State Power Investment Corporation Research Institute (SPICRI) from China, and VTT Technical Research Centre of Finland. The Host Institution is GRNSPG/UNIPI and acts as Secretariat. Institutions involved in FONESYS project use or are developers of the following SYS-TH codes (in alphabetical order): APROS, CATHARE, COSINE, MARS, RELAP5, SPACE, and TRACE.

2.3. Capabilities and Limitations of Current SYS-TH Codes

The evaluation of the Nuclear Power Plants (NPP) performances during accident conditions has been the main issue of the research in nuclear fields during the last 40 years. Therefore, several complex system thermal-hydraulic codes have been developed for simulating the transient behavior of water-cooled reactors.
The system thermal-hydraulic codes are based upon the solution of balance equations for liquid and steam (and in some cases for several fields such as separating droplets and films) that are supplemented by a suitable set of constitutive equations. The balance equations are coupled with conduction heat transfer equations and with neutron kinetics equations, hence the need for coupling with multi-D core physics codes when necessary (typically, for asymmetric overcooling transients, and Main Steam Line Break for PWRs in particular). The two-phase flow field is organized in a number of lumped volumes connected with junctions. Thermal-hydraulic components such as valves, pumps, separators, annulus, accumulators, etc. can be defined to represent the overall system configuration. The limitations and capabilities seen from the code users point of view may differ from the one by the code developers [7].

The main aspects from the code users point of view are summarized below:

- System nodalization – the user develops a detailed nodalization diagram of the whole system. This approach provides large flexibility but also implies a full responsibility of the user in developing an adequate nodalization scheme which makes the best use of the various modules and prediction capabilities of the selected code. The development of a nodalization is always a compromise between the desired accuracy and computational effort due to the code and economic limitations;
- Physical model parameters – various possibilities of how a code can physically model specific

phenomena. Due to the lack of directly measured data, in many cases, the specification of those parameters is left to the engineering judgment of the user;

- Input parameters related to the specific system characteristics – experimental data from the integral effect test (IET) or separate effect test (SET) facilities are the basis for assessment of SYS-TH codes. An importance of the relatively small specific effects which occur in scaled facilities is often underestimated, this could lead to misinterpretation of the results based on incomplete representation of a small-scale test facility;
- Input parameters needed for the specific system components – although system behavior in SYS-TH codes is described by the basic discretization items (nodes and junctions) based on the formulation of the mass, momentum and energy equations, some components (e.g. pumps, separators, etc.) cannot be described without additional models. The data for those models are largely scale-dependent, therefore user has to extrapolate data from the different sources. As a result, this introduces additional uncertainties to the SYS-TH codes prediction;
- Specification of initial and boundary conditions – the initial steady state condition has to be obtained using artificial control systems and the specified boundary conditions. Although user errors are handled by QA procedures, possibility of error in specification of the initial and boundary conditions exists and may introduce small imbalances in the initial data which may overwrite the simulated transient. Therefore, the specification needs to be done in a very detailed and precise manner;
- Selection of parameters determining time step sizes – automatic procedures are used by all existing codes for the selection of time step sizes. However, the code users sometimes need to limit a maximum size of the time step to achieve stable numerical results;
- Code input errors – probability of code input errors is high because of a large number of data (e.g. boundary conditions, model selection, etc.) which need to be provided by the user.

From the point of view of the developers, the main aspects of the current SYS-TH codes capabilities and limitations are the following:

- Simulated phenomena and range of transients/accidents;
- Physical origin – problem with limited knowledge and understanding of physical processes involved. This leads to a certain degree of empiricism of the models and may affect the quality and scalability of the closure laws.
- Macroscopic modelling - There is a possibility that the detailed physical nature of some processes is not fully reflected (or even omitted) in a macroscopic description.
- Mathematical modeling limitations of the code (e.g., does hyperbolicity provide the sufficient condition for obtaining stable converged solutions?);
- Numerical limitations of the code – problem with defining and controlling the level of numerical errors (e.g. due to numerical diffusion and dissipation) and numerical instabilities.

2.4. The Key Items of FONESYS

The following ten topics were identified by the Members of FONESYS as the ones of the highest importance to the code developers:

- Virtual mass and pi terms in the frame of hyperbolicity;
- CHF benchmark;
- Comparison “drift flux – 6 equations – multi-field”;
- Two Phase Critical Flow benchmark;
- Transport of interfacial area and turbulence models - experiments and development;
- Three-field equations: experimental basis and theory;
- Extension of system codes capabilities for super-critical water, gas sodium and lead-bismuth reactors;
- Codes portability and “mesh convergence” issues;
- Coupling between CFD and SYS-TH codes;
- Scalability of closure laws.

Along with the above-mentioned FONESYS topics, seventeen subtopics of interest were defined and are summarized below:

- Use of the Best-estimate SYS-TH codes for licensing;
- Acceptability of errors in code predictions;
- Loop seal clearance;
- Radiation heat transfer;
- Droplet field impact on results of the code calculations;
- Difference between the dispersion and diffusion in physics and numerics;
- To clarify the meaning of convergence in time and in space;
- Relevance of 3-field modeling in system codes' prediction;
- Jacobian;
- Scaling of Thermal-hydraulic Phenomena;
- Reflood;
- 3-D modeling capabilities of SYS-TH codes (e.g. for thermal-mixing studies);
- Natural Convection;
- Natural Circulation;
- Dry-out;
- Critical flow, sonic velocity, effect of sharp edge cavitation;
- CCFL.

Detailed information on each of the aforementioned items and related point of view of the FONESYS Members are reported in [2]. A recently-published paper on hyperbolicity and numerics in SYS-TH codes [8] can be considered as one of the outcomes of the FONESYS technical activities.

2.5. The FONESYS Benchmarks

One of the key topics of FONESYS project is to perform various benchmarks in order to share code experience and to cooperate in resolving codes' deficiencies. The Benchmark activities within the FONESYS can be considered as unique in the sense that they are proposed, agreed and conducted mainly by SYS-TH code developers, thus minimizing the possible the User Effect.

The first of many benchmarks, conducted by the Members of FONESYS, was dedicated to the critical heat flux study (five organizations participated with six SYS-TH codes). Another important benchmark activity is aimed at study of the TPCF phenomenon and is going to be completed within 2018. Seven different SETFs covering more than 110 experimental tests were considered for this activity and seven organizations are involved with eight SYS-TH codes in total. Furthermore, a comparative study on the scalability of different closure laws (e.g. flow regime transitions, wall friction, wall heat transfer, Interfacial friction and heat transfer, etc.) for both 1D and 3D modules considering different flow geometries (e.g. annulus, rod bundle, etc.) was launched in early 2017. Six different SYS-TH codes are considered in the last activity.

2.5. The FONESYS Road Map and Working Modalities

The following working modalities of FONESYS Network were proposed and accepted by all Members:

- Developing a common understanding (e.g. by collecting different opinions and achieving a consensus document) about: SYS-TH codes (the definitions, the requirements, the capabilities, the current status), and limitations for SYS-TH codes (balance equations, numerical solution, user effect, from applications);
- Identification of specific code limitations not covered in the validation process in order to address the areas of investigations;
- Establishment of validation procedures for 3D SYS-TH codes for assigned phenomenon based complementary experiments performed in integral test facilities and 3D separate test facilities;

- Running and collecting results from ‘specific additional’ V&V: specific additional V&V activities performed will involve basic, separate and integral test facilities as well as full scale NPP;
- Attending regular workshops (e.g. 1/year), eventually creating ‘ad-hoc’ groups for special topics;
- Addressing the (possible) skepticism from international community & answering questions;
- Providing recommendations to prioritize code improvements.

FONESYS expert meetings is one of the most important parts of the accepted working modalities of the project. They are organized as workshops where participants discuss one-three of the selected key topics and subtopics, but also show and discuss the results of the benchmark activities.

From the beginning of the FONESYS project in early 2010, eleven workshops, listed in Table I, were organized. The next FONESYS meeting will he hosted by KAERI (South Korea) on October 9-10, 2018, in conjunction with the SILENCE meeting (October 11-12, 2018).

Table 1. FONESYS workshops.

Workshop No.	Data	Host Organization	Country
1	13-14 May 2010	GRNSPG/UNIPI	Italy
2	1-4 February 2011	CEA	France
3	12-14 December 2011	GRNSPG/UNIPI	Italy
4	12-14 September 2012	KAERI	Korea
5	25-26 June 2013	VTT	Finland
6	17-18 February 2014	GRNSPG/UNIPI	Italy
7	3-4 February 2015	AREVA-NP	France
8	3-4 December 2015	CEA	France
9	28-29 September 2016	Becker Technologies	Germany
10	28-29 June 2017	GRNSPG/UNIPI	Italy
11	28 Feb. - 1 Mar. 2018	Texas A&M University	USA

3. THE SILENCE NETWORK

SILENCE is a Network [3,4] for cooperation among teams of experimentalists managing significant experimental projects in nuclear reactor thermal-hydraulics. Established in 2012 by GRNSPG/UNIPI, SILENCE Network connects Institutions and Organizations that are involved in the development and exploitation of thermal-hydraulic experiments as a support to the safety assessment and the design of water-cooled nuclear reactor, of both current and future generations.

3.1. Founding Motivation and Objectives of the Project

There is a risk to lose expertise and “vision” in the area of thermal-hydraulic experimental investigations, therefore a presidium should be established and maintained so to oppose this risk. It is important that the experimentalists join and constitute a “system”, while large budgets available in the past cannot be replicated. Thus, SILENCE Network promotes and fosters the establishment of a common ground for cooperation and discussion, so to drive the prioritization and decision-making processes related to the development of new experiments as well as to optimize utilization of the existing data.

The main objectives of the project are summarized below:

- To optimize the funding available worldwide for experiments, recognizing their vital role for the design and the safety of existing and coming NPP, including connecting with past and recent initiatives like CERTA-TN (former EC-Project) and STRESA-database;

- To coordinate the efforts of teams of experimentalists in order to provide a support for international institutions, like OECD/NEA and IAEA, namely for launching and possibly organizing International Standard Problems;
- To address the scaling issue and providing an agreed view from the side of experimentalists, also including the design and the execution of Counterpart Tests;
- To set up a Center of Expertise for supporting experimental programs in "Embarking Countries" (i.e. new Countries having Nuclear Programs) having interests in the area of large thermal-hydraulic experiments;
- To maintain, expand and use the database of experiments already available from various parts of the world, possibly in cooperation with the international institutions (particularly OECD/NEA, where NEA Data Bank is available);
- To identify margins for possible improvement of the existing measurement techniques.

3.2. The SILENCE Members and the Main Test Facilities Represented

There are seven signatory Institutions currently participating in the SILENCE Network, namely Commissariat à l'Énergie Atomique et aux Énergies Alternatives (CEA) from France, Becker Technologies GmbH (BT), Framatome GmbH and Helmholtz Zentrum Dresden-Rossendorf (HZDR) from Germany, Korea Atomic Energy Research Institute (KAERI) from South Korea, Gruppo di Ricerca Nucleare San Piero a Grado/ Universita di Pisa (GRSNPG/UNIPI) from Italy, Lappeenranta University of Technology (LUT) from Finland, State Power Investment Corporation Research Institute (SPICRI) from China. The Scientific Secretariat is provided by the GRNSPG/UNIPI with the administrative support of Nuclear and INdustrial Engineering (NINE), Italy. Table II summarizes some of the key facility owned by the SILENCE Members.

Table 2. Key facilities owned by the SILENCE Members.

Member	Key Facilities	Country
Framatome	PKL, etc.	Germany
HZRD	ROCOM, TOPFLOW, etc.	Germany
KAERI	ATLAS, etc.	South Korea
LUT	PACTEL, etc.	Finland
Becker Technologies	THAI, MISTRA, etc.	Germany
CEA	OMEGA, DEBORA, METERO, etc.	France
SPICRI	ACME, CERT, etc.	China

3.4. The SILENCE Working Modalities and on-going activities

SILENCE network adopts a form of cooperation based the on exchange of information by means of technical reports, experimental data, correspondence, newsletters, visits, joint meetings, etc. and the execution of joint programs and projects.

The working modalities of the SILENCE network includes but not limited to:

- Developing a common understanding (e.g. by collecting different opinions and achieving a consensus document) about selected topics;
- Attending regular workshops (e.g. one per year), possibly creating ad-hoc groups for special topics;
- Addressing remarks from international community in relation to the needs of new experiments;
- Providing recommendations, primarily to the SILENCE Members but also to the other stakeholders of the International Community, on how-to prioritize budget allocation when planning new experiments.

The main on-going activities are the summarized below:

- The organization of SWINTH-2019 (see Section 3.5.2) in cooperation with OECD/NEA/CSNI/WGAMA;
- Preparation of a Technical Report on the definition of requirements for validation experiments addressing SYS-TH, CFD, and containment codes;
- Preparation of a Technical Report on the definition of possible counterpart tests and similar tests on a set of test facilities operated by the SILENCE Members;
- Mapping of the information related to the existing test facilities operated by the SILENCE Members.

From the beginning of the SILENCE project in 2012, eight meetings, listed in Table III, were organized.

Table 3. SILENCE Workshops.

Workshop No.	Data	Host Organization	Country
1	5-6 July 2012	GRNSPG/UNIPI	Italy
2	27-28 June 2013	VTT	Finland
3	19-20 February 2014	GRNSPG/UNIPI	Italy
4	11-12 September 2015	PSI	Switzerland
5	1-2 December 2015	CEA	France
6	26-27 September 2016	Becker Technologies	Germany
7	26-27 June 2017	GRNSPG/UNIPI	Italy
8	26-27 February 2018	Texas A&M University	USA

3.5. A SILENCE Initiative: SWINTH International Workshop on Instrumentation and Measurement Techniques

The idea for organizing a “Specialists Workshop on Advanced Instrumentation and Measurement Techniques for Nuclear Reactor Thermal Hydraulics” (SWINTH) has been emerged during the first SILENCE meetings. It was suggested by the observation that significant advances have been achieved in the instrumentation and investigation techniques for nuclear TH systems since the OECD/NEA/CSNI Specialists Meeting on Advanced Instrumentation and Measurement Techniques held in Santa-Barbara, California, US, on March 17-20, 1997 [9,10].

The motivation for starting SWINTH workshops is consistent with both the “vision” and the “mission” of SILENCE Network, which promotes and stimulates the establishment of a common ground for cooperation and discussion on thermal-hydraulic experiments, and wants to bolster new experiments, including improvements of the existing measurement techniques.

The purpose of SWINTH workshops is to bring together international experts on instrumentation, experiments and modelling in order to:

- Review the recent instrumentation and experiment techniques developments;
- Identify the specific experimental needs that arose from the development of modern simulation tools including system codes, component codes, and computational multi-fluid dynamics (CMFD) codes provided with advanced models such as dynamic interfacial area modelling, poly-dispersion modelling of bubbly and droplet flow, multi-field models and two-phase turbulence models;
- Discuss future directions for instrumentation developments, modelling and experiments.

The subject is wide and complex and deserves “dedicated” discussion; therefore, specialized workshops such as the present one would be complementary to other events on code development and validation & verification (V&V), and initiatives in which the experimental area is not covered with sufficient detail and focus.

SWINTH workshops also aim at addressing aspects such as:

- Code validation requirements;
- Test design requirements for code validation (e.g. scaling issues);
- Specific requirements for CMFD-grade experiments and related measurements for single- and multi-phase flows;
- Criteria for quality of data (e.g. measurement uncertainty assessment);
- Experimental data handling issues.

The Workshops should also help to identify the current gaps between the modelling and code qualification needs and the available technology as well as the margins for future advancements.

3.5.1. SWINTH-2016: facts and outlook

SWINTH-2016 [11,12] was held on June 15-17, 2016 in Livorno, Italy. Fifty papers were submitted to the workshop and underwent a scrupulous review process by the Scientific Committee, mostly composed by SILENCE representatives, and revised by their Authors according to the reviewers' recommendations. Thirty-eight papers were accepted for oral presentation and subdivided into eight technical sessions. No parallel sessions were organized, so giving every participant the possibility to attend all the presentations. Table 4 and Figure 1 report the number of papers included in the various sessions, and their distribution by organization of origin.

Table 4. SWINTH-2016 technical sessions.

Session title	No. of papers
Thermal Anemometry and Anemo-Thermometry, including hot-wire and hot-film sensors	3
Local Single- and Multi-Sensor Probes (optical probes, conductance probes), including optical fiber probes for phase detection and temperature measurement	3
Special or Combined Experimental Techniques	8
Conductivity Methods – Wire Mesh Sensors	7
Fluid Structure Interaction	3
Flow Visualization Methods (including high-speed cameras and Infrared methods, for liquid film thickness and temperature measurement)	3
Radiographic and Tomographic Methods, including X-rays, gamma-rays, neutrons, and electrical impedance tomography	6
PIV - LDA and LIF	3

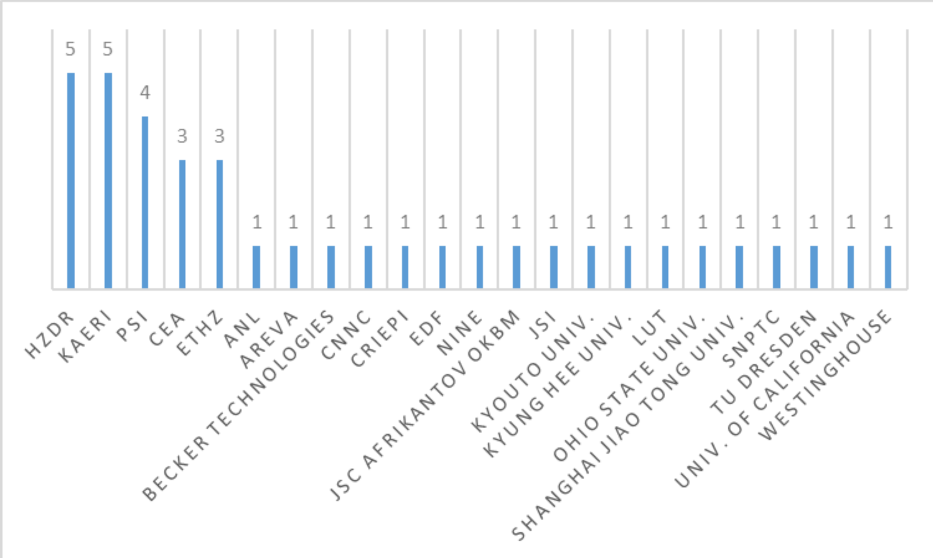

Fig. 1 Number of papers contributed by each participating Organization.

Four internationally recognized experts from important research institutions were invited as keynote lecturers and four sponsors (instrumentation suppliers and research institutes) supported the workshop.

As a collateral activity, SILENCE collected information on the existing gaps in the code validation bases through a questionnaire distributed during the workshop. The same questionnaire was distributed also among the other experts. The answers were then collected and processed, and the extracted insights were thoroughly discussed in the SILENCE meetings. Furthermore, some of the best quality papers were selected for publication in dedicated special issue of Journal Nuclear Engineering and Design, which is currently being published [13].

3.5.2. SWINTH-2019 workshop

Following the success of SWINTH-2016 and the positive feedback expressed by the participants, it was decided to organize a new edition of the workshop in Fall 2019.
The new SWINTH-2019 will be under the OECD/NEA/CSNI umbrella, the WGAMA having a leading role, along with SILENCE, in the organization. The NEA framework constitutes an important reference from the scientific and technological point of view, and a support to proper dissemination of the workshop announcement. Moreover, the scope of SWINTH-2019 is extended to instrumentation and measurement techniques for Thermal-Hydraulics experimentations in the Severe Accident (SA) area. The idea is to provide an opportunity for the TH and SA communities to meet and interact on topics of common interest.

The topics included in the scope of SWINTH-2019 are the following [14]:

- Concerning scale and complexity of test facilities: Integral, Multiple and Separate Effect Test facilities are included;
- Concerning reference reactor technologies: water cooled nuclear reactors, for the phenomena corresponding to defense-in-depth level one through four.
- Concerning the purpose of the experimentation: understanding of phenomena and processes for an accident and its analysis; support to model development and code validation; safety demonstration (licensing);
- Concerning the types of instrumentation: measurement of local and/or average time-dependent - possibly space-dependent - quantities characterizing both single-phase and multi-phase/multi-component flows, fields and structures/materials, with sufficiently fine resolution and uncertainty quantification; e.g. different visualization techniques and optical, radiographic and tomographic methods to measure temperature, pressure, velocity, void, chemical and phase composition, detection of radiation/FPs and fissile materials;

- Any new measurement technique or method;
- Possible use of simulant fluids with well-established similarity laws;
- Concerning types of computer codes which are object of validation: system thermal-hydraulics; sub-channel analysis; computational fluid dynamics; containment thermal-hydraulics; severe accident analysis;
- Fluid-structure interaction, molten-core-coolant interaction and molten-core-structure interaction;
- Scaling related issues;
- Gaps between current model/code validation needs and existing technology; definition of requirements for new experiments and instrumentation, also in terms of "quality" of data;
- Issues related to the handling and preservation of experimental data.

The first meeting of the Organizing Committee was held at NEA offices, Paris, on 21 February 2018. The Workshop Announcement and the Call for Abstract will be issued by April 2018.

4. THE CONUSAF CONSORTIUM

CONUSAF is a consortium of users of thermal-hydraulics computational tools for nuclear reactor safety and design. Established in February 2018 by GRNSPG/UNIPI and Texas A&M University, the CONUSAF aims at connecting International Institutions and Companies performing R&D activities and/or frontier-type of applications in the field of nuclear engineering like Research Centers, Industries, Universities, Technical Support Organizations, Consultancies, etc. The focus of the consortium is to bring solutions to the possible issues identified by the nuclear industry through research, training and education.

4.1. Founding Motivation and objectives of the consortium

The founding motivations for CONUSAF arose from the lessons learned by the founding members from the past activities. The following key items should be outlined:

- Some weaknesses of system codes were not solved in the last 20 to 30 years (e.g. Two-Phase Critical Flow, Critical Heat Flux, etc.) and the feedback from the code users may be relevant in identifying a roadmap for the improvement;
- New issues for nuclear TH codes applications may come from the development of the Nuclear Technology (e.g. Reactor Design, Safety Requirements, etc.);
- The knowledge of the code limitations is steadily decreasing in the TH community and the User Effect could rebound after having fallen;
- New experimental techniques allow revisiting of old issues with more in-depth analysis (e.g. multi-scale analysis). The involvement of code users in the process can be beneficial;
- To benefit from increasing computer power in system codes by using a 3D modelling (so to improve simulation accuracy of various phenomena occurring in reactor core, downcomer, etc.), one need to have new experimental data for model improvement and code validation.

The main objectives of the CONUSAF can be summarized as follows:

- To solve problems faced by the members of CONUSAF through research, development and training;
- To share ideas on how to improve education in nuclear engineering;
- To play a leading role to elevate the nuclear engineering profession with main reference to the area of nuclear thermal-hydraulics.

4.1. The CONUSAF Working Modalities

CONUSAF expert meetings are one of the most important parts of accepted working modalities of the project. They are organized as workshops where participants discuss upon topics in the areas identified with respect to their needs. Meetings are expected to be held at least once a year (tentatively every nine months, in alternating locations in USA, Europe and East Asia). The list of areas proposed for the CONUSAF operations is outlined below:

1. SYSTEM THERMAL-HYDRAULICS
   1.1. The role of phenomena identification
   1.2. The role of scaling
   1.3. The role of system codes
   1.4. New system TH issues related to new systems (passive systems, SMR, generation 4, etc.) and to new safety requirements
   1.5. Prioritization of the research
   1.6. Non-fully developed flow (impact of modelling with correlations developed for F-D flow conditions)
   1.7. Fragmented core cooling

2. TH PHENOMENA
   2.1. How to identify phenomena.
   2.2. A multi-scale approach of phenomena: microscale, meso-scale, macroscale, component scale, system scale, etc.
   2.3. How to rank phenomena in a PIRT
   2.4. TH Phenomena in Non-Water cooled Reactors (e.g. sodium, lead, etc.)

3. SCALING
   3.1. Sharing experience on scaling IET experiments
   3.2. Sharing experience on scaling SET experiments
   3.3. The role of codes in scaling experiments
   3.4. Scalability of system codes: scalability of closure laws, comparing codes on scale dependence
   3.5. Optimum facility scaling (and needs)

4. SYS TH CODES
   4.1. State of the art, benchmarking, sharing experience on validation, on application
   4.2. Advanced modelling, new approaches: 3-field, transport of interfacial area, turbulence, 2-pressure models...
   4.3. New needs related to new systems (passive systems, SMR, generation 4, etc.) and/or to new safety requirements
   4.4. Numerics, new methods, verification
   4.5. Possible areas for model improvements (critical flow, CHF, etc.)
   4.6. Nodalization techniques (e.g. Pressure drops at discontinuities, etc.)
   4.7. Acceptability criteria, accuracy quantification (nodalization and code)
   4.8. User effect

5. UNCERTAINTY/SENSITIVITY (of a calculation), AND RELIABILITY (of passive systems)
   5.1. State of the Art, analysis of different Uncertainty Quantification Methods,
   5.2. How to determine sys-code model uncertainties. Sharing experience on methods
   5.3. How to account for experimental uncertainty
   5.4. How to treat non-modelled phenomena. Scaling uncertainty.
   5.5. Validating model uncertainties on SETs and IETs

5.6. Reliability of passive systems

6. CFD IN POROUS MEDIUM approach
   6.1. State of the art
   6.2. Modelling turbulent diffusion and dispersion in porous medium
   6.3. Validation for core, downcomer, lower plenum, upper plenum, heat exchangers, etc.

7. CFD IN OPEN MEDIUM approach
   7.1. State of the art in 1-phase and in 2 phases
   7.2. Support of CFD for modelling and validating system codes and component codes:
      7.2.1. Core mixing of temperature and boron
      7.2.2. Boiling flow in a core
      7.2.3. Mixing in a downcomer
      7.2.4. SG inlet headers

8. VALIDATION AND EXPERIMENT
   8.1. Identifying new needs
   8.2. Requirements for experiments
   8.3. Multi-scale validation: e.g. using CFD for validating system codes
   8.4. Defining common experimental programs and sharing data
   8.5. New ideas for validation strategies (e.g. V&V&C [15,16])

9. VERIFICATION

10. SAFETY ANALYSES
   10.1. State of the art
   10.2. (New) BEPU methodologies, risk informed, PSA-DSA
   10.3. New safety barriers
   10.4. Sharing experiences, applications, "chains of adopted codes"

11. COUPLING
   11.1. State of the art
   11.2. Coupling between different codes (SYS-TH, fuel performance, CFD, 3DNK, containment, structural mechanics, I&C, etc.)
      11.2.1. Numerical aspects and physical aspects
   11.3. Coupling interfaces (e.g. in-house tools, PVM, etc.)
   11.4. Coupling verification and validation

Containment and subchannel codes are included in CFD or SYS-TH code areas.

The list of areas is supposed to be a "living document" constantly updated considering the needs and the feedback received from the Participants.

4.2. Summary of the Kick-off Meeting

The first announcement of the CONUSAF Kick-off meeting was released on November 2017. Twenty-three international Organization expressed their interest toward the project. The Kick-Off Meeting was held in Texas A&M University, College Station, USA on March 2, 2018 and was attended by eighteen Organizations coming from Europe, United States of America, Canada and Asia. A specific session was devoted to collecting topics of main interest, current issues as well as suggestions from the Participants so as to help CONUSAF activity better meet their needs. The list of CONUSAF areas presented in the previous sub-section reflects the current state of the participants interests.

The first meeting of the CONUSAF project is planned on July 25-27, 2018 in Pisa, Italy.

4. CONCLUSIONS

The present paper provides a brief overview of the three projects named FONESYS, SILENCE, and CONUSAF, outlining their objectives, motivations and working modalities. Examples of the main achievements of the first two projects were discussed.

The FONESYS initiative was started with the goal of promoting the use of SYS-TH Codes and the application of BEPU approaches, to establish acceptable and recognized procedures and criteria for V&V and to create a common ground for discussing envisaged improvements in various areas, including user-interface, and the connection with other numerical tools, including CFD and CMFD Codes.

Established in 2012, SILENCE network replicates for the TH experimental domain the role that FONESYS plays in the code-development domain. The Network connects Institutions and Organizations that are involved in the development and exploitation of thermal-hydraulic experiments as a support to safety assessment and design of water-cooled nuclear reactors, of both current and future generations. The Network organized the SWINTH-2016 Workshop, and is currently organizing, in cooperation with the OECD/NEA/CSNI/WGAMA, a new edition of the workshop (SWINTH-2019).

A new initiative, named CONUSAF, is also presented, putting the focus on the beneficial involvement of code users in addressing relevant topics dealing with the Nuclear Thermal-Hydraulics. New problems raised by code users have first to be discussed among code users, codes developers and experimentalists in view of building a solution which may include new methodologies, new developments in codes, and/or new experiments.

NOMENCLATURE

3DNK	Three-Dimensional Neutron Kinetic
BE	Best Estimate
BEPU	Best Estimate Plus Uncertainty
BT	Becker Technologies
CCFL	Counter Current Flow Limitation
CEA	Commissariat à l'Énergie Atomique et aux Énergies Alternatives
CFD	Computational Fluid Dynamics
CHF	Critical Heat Flux
CMFD	Computational Multi Fluid Dynamics
CONUSAF	Consortium of Users of Thermal-Hydraulics Computational Tools for Nuclear Reactor Safety and Design
CSNI	Committee on the Safety of Nuclear Installations
DSA	Deterministic Safety Assessment
F-D	Fully Developed
FONESYS	Forum & Network of System Thermal-Hydraulics Codes in Nuclear Reactor Thermal-Hydraulics
GRNSPG	San Piero a Grado Nuclear Research Group
GUI	Graphic User Interface
HZDR	Helmholtz Zentrum Dresden-Rossendorf

IAEA	International Atomic Energy Agency
IET	Integral Effect Test
KAERI	Korea Atomic Energy Research Institute
LDA	Laser Doppler Anemometry
LIF	Laser-Induced Fluorescence
LUT	Lappeenranta University of Technology
NEA	Nuclear Energy Agency
NINE	Nuclear and Industrial Engineering
NPP	Nuclear Power Plant
NTH	Nuclear Thermal-Hydraulics
OECD	Organization for Economic Co-operation and Development
PIRT	Phenomena Identification and Ranking Table
PIV	Particle Image Velocimetry
PSA	Probabilistic Safety Assessment
PSI	Paul Scherrer Institute
PVM	Private Virtual Machine
PWR	Pressurized Water Reactor
QA	Quality Assurance
R&D	Research and Development
SA	Severe Accident
SET	Separate Effect Test
SETF	Separate Effect Test Facility
SG	Steam Generator
SILENCE	Significant Light and Heavy Water Reactor Thermal Hydraulic Experiments Network for the Consistent Exploitation of the Data
SMR	Small Modular Reactor
SPICRI	State Power Investment Corporation Research Institute
SWINTH	Specialists Workshop on Advanced Instrumentation and Measurement Techniques for Nuclear Reactor Thermal-Hydraulics Experimentation
SYS-TH	System Thermal-Hydraulics
TH	Thermal-Hydraulics
TPCF	Two Phase Critical Flow
UNIPI	Pisa University
US AEC	United States Atomic Energy Commission
US NRC	United States Nuclear reactor committee
V&V	Verification and Validation
V&V&C	Verification, Validation and Consistency
WGAMA	Working Group on Analysis and Management of Accidents

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