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Certus-An Organizational Effort Towards Research-based Innovation in Software Verification & Validation

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Abstract What is gratifying to a software engineering researcher? Three of many possible answers to this question are (a) the intellectual exercise in developing/disseminating approaches that address emerging and existing challenges (b) recognition from impact in a community of researchers (c) widespread use of novel ideas, including software, in the society at large leading to enhancement of human ability and job creation. A *culmination* of these sources requires an *organizational effort*. This article presents a detailed account of a research-based innovation centre, Certus, to facilitate such a culmination for software engineering researchers. Certus has established a body of knowledge, methods and tools for the validation and verification (V&V) of software systems in the Norwegian private and public sector. Certus works in close cooperation with five founding *user partners* and is hosted by the Simula Research Laboratory. We present the organizational structure of Certus and describe how Certus's life and health is planned and evaluated on a regular basis as a research-based innovation centre. We hope that this document will serve as a basis to encourage national/international funding schemes to create *call for proposals* for long-term research-based innovation centres. This, we believe, is one way to justify use of tax payers resources in creating a win-win situation for the triple helix: government, researchers and industry.

Keywords organization, Certus, software V&V, annual work plan, evaluation

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1 Introduction

The well-known american author Henry Jackson van Dyke once said, "In the progress of personality, first comes a declaration of independence, then a recognition of interdependence.". From a software engineering researcher's perspective this entails making the transition from being satisfied by results known to his/her research community to widespread impact in the software industry and the society at large. This is a non-substantial effort and often has several barriers such as attitudes and communication between researchers and practitioners, strain from the quintessential drive of publish-or-perish, technique and tools not very well deployed to be useful in industry, and lack of an organizational structure for serious commitment and dialogue between industry and academia. In this article, we present an organizational structure to facilitate fruitful industry-academia research in a specific and important area of software engineering: software verification and validation.

Why Software V&V? Software is everywhere in our modern technological society. It is not just on our computers, but also in our mobile phones, in (most) cars, ATMs, ticket vending machines, airplanes, hospitals, financial and business systems, and national defense systems. As a result, complex software systems have become an increasingly critical component in the functioning of our daily lives, cutting across almost every aspect of global, national, social, and economic function. E.g., a typical cell-phone or modern television contains several (2-5) million lines of source code, an amount which is estimated to increase roughly by a factor 10 over the next four years. Norways software-intensive industry is expanding, with estimated annual revenues of 75 billion NOK. The Norwegian ICT sector as a whole has annual revenues of 236 billion NOK and employed almost 100,000 people in 2010.2 This makes up for approximately 40% of Norwegian industrial R&D, second only to the oil sector. Due to its infrastructural role, innovation in software engineering practices will lead directly to innovation in other business areas and the public sector. However, if software systems have low quality, are unreliable, insecure or useless, the immense potential economic and social benefits can not be realized. Despite impressive technological advances, the existing approaches to developing and maintaining software are stretched to the max due to exponentially increasing demands, complexity, and scale. Consequently, software is often built with techniques for which we have insufficient evidence to confirm their suitability, quality, costs, and inherent risks. A recent review of existing software project surveys shows that about 60% of software projects are completed late and that the average cost overrun is 30-40%. A proportion of the late and underbudgeted projects are outright failures. The results of these software failures have a huge economic and social impact. For example, the US National Institute for Standards and Technologies estimated that software failures cost the American economy nearly $60 Billion annually [1]. Many critical failures are regularly reported in many countries, for example in the

[1] `https://www.rti.org/pubs/software_testing.pdf`

financial and automotive industries, and are well documented. In order to improve software quality and gain a sufficient level of confidence in its reliability, one must engineer and evolve software systems in a cost-effective manner. Effective impact analysis and recommendation technology to guide the evolution process, as investigated in this project, is paramount to achieve these goals, and will benefit society by helping to increase the quality and reliability of all those software systems that have become so important in the functioning of our daily life.

An organizational effort towards Software V&V We present the model of a centre for software verification&validation research called Certus [2] hosted by the Simula Research Laboratory [3] (in greater detail than the article in [Sen(2014)]) . The Certus Centre has established a body of methods and tools for the validation and verification (V&V) of software-intensive systems. Working in close cooperation with Certus's five founding user partners (software companies), the centre's researchers have analyzed and produced innovative methods to validate the following types of systems: (a) real-time embedded software systems (b) highly-configurable software systems and (c) data-intensive software systems. Certus aims to achieve a win-win situation for the triple helix of government, industry and academia. Industry does not have to invest in their own research lab but gets access to high quality research that helps them improve or even develop their Software V&V and testing framework. Investment from industry is often in-kind, i.e., time and effort. Academics are funded by the government to address industrial challenges as research problems instead of blue sky research. This entails converting very domains-specific software V&V tasks to generalized hard problems in computer science and software engineering. The government benefits by justifying use of tax payers money to help create jobs that greatly improves the quality of software in the Norwegian industry. We present Certus as an example to motivate the creation of similar centres in conducive environments. We envisage a huge potential for such centres in city areas with universities and a large number of software companies. A centre such as Certus can help train both undergraduate and graduate students better for both the workforce of the local software industry and effective industry-academia research.

The article is organized as follows. In Section 2, we present how Certus is funded under a governmental scheme called SFI. We present the architectural overview of Certus in Section 3. We briefly describe the evaluation of the centre's health in Section 4. In Section 5, we present some related work on the subject of research-based innovation. We conclude in Section 6, with future perspectives.

[2] `http://certus-sfi.no`
[3] `http://simula.no`

2 Funding the Centre

A legally binding agreement among the *triple helix* [Henry Etzkowitz(1998)]: government, academia, and industry is a key requirement to fund and establish centers such as Certus. Some of the text in this section is a re-production of content from the Norwegian research council's website that provides several options for sharing the same information.

In 2006, the Minister of Education and Research announced the creation of fourteen centers for research-based innovation or in Norwegian Senter for forskningsdrevet innovasjon (SFI) [4]. These SFIs were appointed by the Executive Board of the Research Council and started in the spring 2007 and will be financed by the Research Council for eight years until the spring 2015. The centers include CAST for Stem-cell based Innovation, SIMLAB or Structural Impact Laboratory, MABCENT-Marine bioactives&drug discovery, and MI Lab-Medical Imaging Laboratory, NTNU and so on.

The call for proposals of such centers is renewed every four years similar to the model of the olympic games. Seven new centres were appointed by the Research Council Board on 16th December 2010. They have started their activities in the autumn 2011 and are expected to operate until 2019. The Certus Center is one of them. It was established by Prof. Lionel Briand (who was also the first centre leader, while Arnaud Gotlieb is the current leader) in collaboration with Simula Research Laboratory. The centre leader plays an important role in attracting funding owing to his/her outstanding scientific credentials.

The SFI scheme aims to :

- Encourage companies to innovate through a greater focus on long-term research, and make it attractive for international companies, to establish their operations in Norway.
- Facilitate active cooperation between innovative companies and prominent research groups.
- Promote the development of industry-oriented research that is in the forefront of international research and included in dynamic international network.
- Stimulate research in areas that are important for industry and research-based knowledge and technology.

SFI scheme has higher goals, greater longevity and a more concentrated effort than other means of innovation. The initiative is aimed specifically at the R&D active part of the Norwegian sector. SFI scheme provides companies with the opportunity for greater persistence, continuity and risk reduction in funding for research. For the research opens the SFI opportunity for long-term human resources development through research of high scientific level in close cooperation with companies.

SFI has two overarching criteria that form the basis for selection of centers:

[4] `http://www.forskningsradet.no/prognett-sfi/About_the_SFI_scheme`

– Potential for innovation and value creation
– Scientific quality

The SFI is related to a research institution or company that is responsible as the host institution for business. Host Institutions for the centers could be universities, colleges, research institutes, R&D-performing companies and research performing public service which is well placed to realize SFI concept. The host institution and a number of partners constitute Centre (CRI consortium). Partners can be enterprises, public enterprises and research institutions. The SFI is a time-limited research that is not regarded as a separate legal entity.

SFI centers shall have a duration of eight years, but extension beyond five years is dependent on a positive result of the evaluation will be conducted after 3.5 years. Indicative financial framework for Research Council funding of an SFI are 9.12 million per. year for up to eight years. At least 50 percent of the agency's annual budget is funded by SFI consortium. It is expected that the business partners in the consortium alone should cover at least 25 percent of the agency's annual budget. This means that a center would normally have an annual budget of 20-30 million. *A large part of this contribution from business partners of Certus is accomplished by involvement in person-weeks by employees on the business partner company sites.*

3 Architectural Overview

The Certus centre for research-based innovation (Certus SFI) is a 5-8 year research centre within the area of software validation and verification established in October 2011. The centre engages Simula Research Laboratory (Simula or SRL) as host institution and primary research partner, and several *user partners* forming a *consortium* that sign a joint *consortium agreement*. An user partner is involved in various projects prescribed in collaboratively developed *annual work plans* as described in Section 3.3. The current user partners of Certus include Kongsberg Maritime, Cancer Registry of Norway, Norwegian Customs and Excise, Cisco and Esito, and ABB Robotics. The role of the centre in this architectural setup is to test and transfer research results from software verification and validation into the workflow of its user partners.

3.1 Scope of the Certus Center

In response to the continually increasing demand for dependable systems and ways to bring software Verification & Validation costs under control, the Partners intend to create a research and innovation centre on software V&V. In this centre, hosted by Simula Research Laboratory, research-intensive enterprises and world-leading research groups will join forces and develop new, industrystrength technology for V&V. Building a centre where the software industry

collaboratively develops and exchanges state-of-the-art knowledge and technology within V&V is to the shared benefit of the Norwegian softwareintensive industry and society since: (1) most organizations cannot afford to build comprehensive V&V competence on their own, (2) the centre's partners include major players whose objective is to improve the efficiency of the public sector or to develop technology that minimize mans footprint on the environment.

3.2 Consortium Agreement

This Consortium Agreement governs the relationship between the Partners in the Certus Centre where, on behalf of the Consortium, the Host Institution has received financial support from the Research Council to carry out the implementation of the Certus Centre. The Consortium Agreement governs the organization and implementation of the Certus Centre, as well as rights and obligations between the Partners.

3.3 Annual Work Plan

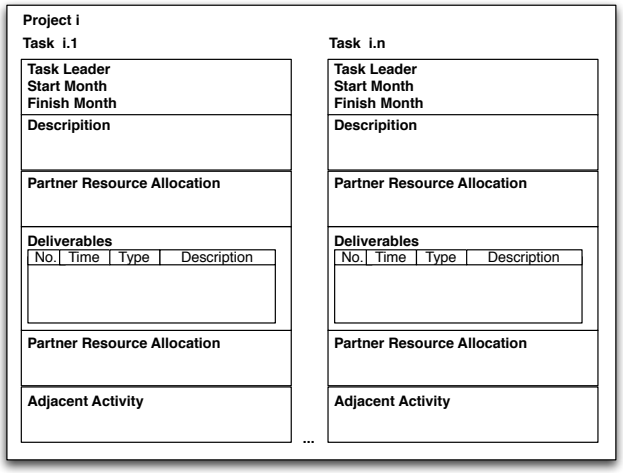

Fig. 1 Annual Work Plan Structure

The Annual Work Plan (AWP) refines and develops the Research and Innovation actions of the centre. It is an agreement between the Certus centre, its user partners, and the primary funding body (The Norwegian Research Council) about the actions to be taken in the current year. The AWP is organized in Projects and Tasks which correspond respectively to long-term scientific areas and short-terms dedicated actions. Each task has one or more deliverables.

The template for the projects in the AWP is presented in Figure 1. For instance, the plan for 2014 contains 8 active Projects and 24 active Tasks. The production of the Centre is expected to be of 68 deliverables, for a total effort of 173 Person Months. The deliverables in each task are produced in four categories:

1. **Administrative documents.** These deliverables correspond to documents used for the administration of the centre. This includes plans, progress reports, minutes, lists of participants, budgets, and so on.
2. **Technical reports.** These deliverables correspond to technical documents containing scientific results, results of experimental evaluation, domain and state-of-the-art analysis, partner's specific case study, and so on.
3. **Presentations.** These deliverables correspond to technical presentations made by or for the user partners of the Centre.
4. **Software.** These deliverables correspond to both administrative soft. designed for the needs of the centre administration and scientific software designed for implementing and evaluating scientific results.

Projects define the various activities of the centre. A project is managed by a responsible, and has a research type: industrial or fundamental. Each project has several tasks. Each task has a leader and he/she must ensure that deliverables are submitted within the timeline. The different activities in projects include:

1. **Management.** actions involves tasks such as planning and reporting (deliverables include budget, and reporting to the research council, and the annual work plan), governance (deliverables include minutes from meetings, updated online repository of deliverables), mid-way evaluation (deliverables include mandate for self-evaluation process, self-evaluation report, document outlining improvements suggested).
2. **Industrial Exploitation.** aims to develop research results (a) into best practices guidelines in a form specifically adapted to the needs of the individual user partners (b) in the form of software prototypes into software tools with stability and functionality adapted to the needs of the individual user partners (c) in the form of software prototypes into software tools with stability and functionality suitable for general distribution without any form of warranties (d) To support and maintain the developed best practices guidelines and software tools for the benefit of the consortium throughout the term of the centre. The tasks in the project include development of an exploitation policy, exploitation case studies consisting of legal issues and an exploitation plan, and exploitation of specific projects such as our tool Depict to test data quality in the Norwegian Customs and Excise department.
3. **Training and Knowledge Transfer.** This project aims to train industry professional with the state of the art in software V&V.
4. **Dissemination and Communication.** The Certus dissemination and communication activities are on-going efforts throughout the term of the SFI. In accordance to the listed objectives, the SFI aims to disseminate

information in popularized, scientific and industrialized form. Certus produces an annual report with text, facts and figures summarizing the activities and achievements of the centre during the year. Certus also maintains a website [5] that publishes the deliverables and news updates. Research scientists in Certus are also closely involved in supervising masters students from the University of Oslo.

5. **Scientific theme-specific projects.** Certus researchers lead projects with a scientific theme, which also involve extensive interaction with user partners. These themes include model-based testing, testing data-intensive system, smart testing of evolving systems, and model-based requirements engineering. Scientific projects are led by postdocs and permanent researchers. They actively undertake PhD student supervision under their respective themes.

The lifetime of projects will span the entire duration of the existence of Certus. New projects can be added to the AWP depending on addition of a new form of competence in the centre. However, the tasks and their deliverables are bounded by time. They are preserved in the AWP, and additional tasks or deliverable are added each year. The new tasks and deliverables are added based on a workshop held with user partners (Section 3.6).

3.4 Governance and Administration

The Certus center is governed by a board and led by a center director.
Certus Board: The board of the SFI centre is to consist of representatives of the consortium participants, i.e. the host institution, the cooperating user partners and any other partners. To ensure the centre retains a strong, lasting focus on the users, the representatives of the centres user partners are to have a majority on the board. The Certus Board shall be entitled to instruct all Partners to document the resources contributed to the Project in relation to agreed plans and budgets. Further, the Certus Board shall be entitled to receive and approve the scientific qualifications for all researchers working at the Research Partners. The Certus Board shall develop guidelines for the Centre Leader that defines the Centre Leaders role, obligations and powers of attorney.
Center Director: The centre is headed by a director alone or by a director supported by a management group. The centre director is to serve as project manager pursuant to the contract between the Research Council of Norway and the host institution. Centre directors must have experience in research and proven ability in research management and team-building. The director is to have considerable independence in relation to scientific contexts as well as on questions involving the recruitment of staff to the centre. The director and members of the management group, if any, will be appointed by the host institution in consultation with the other partners in the SFI consortium.

[5] `www.certus-sfi.no`

The Centre Leader shall attend all board meetings and is responsible for the preparations of the board meetings in collaboration with the chairperson of the Certus Board.

3.5 Web and Internet

The operational website Certus is offers a much easier platform for communication. Having a website that is regularly updated with news and other interesting items is of great importance in the dissemination architecture of Certus. Items for the news-section will by created by Certus with input from all user partners. Each yeart this task covers activities relating to dissemination of research results internally in the centre. This is reflected in two separate deliverables: The creation of an internal e-mail service to be used for spreading information about activities and results in the centre. This has been requested by many of the partners and is important to ensure a steady flow of information about Certus. This again is important for keeping Certus on the radar internally. A new set up to list the deliverables will be produced. Certus plans to create a wiki-like setup to enable distributed flow of information from user partners. Certus also uses Bitbucket repositories to share code and other software artifacts.

3.6 User Partner Workshops

Certus organizes User Partner Workshops (UPW) to bring all user partners together. We realize two workshops, one in the spring and one in the fall. These workshops provide a platform for (a) Researchers to eliminate jargon and communicate their scientific ideas to our industry partners in the most conducive manner (b) Encourage our partners to express their problems with complete trust in Certus SFI. Trust with regard to aligning our research activities to solve these problems to the very end (c) Identify commonalities across problems in various user-partners (d) Find a middle path to foster effective innovation and state-of-the-art research for the current year. We achieve these goals by organizing the workshop as a combination of lectures, group work and plenum discussions to foster effective interaction between Certus and our partners. Each workshop will be arranged as a 1.5 day overnight event at a conference hotel.

4 Evaluating Certus's Health

The center is evaluated based on a number of factors. Some factors include number of publications, innovation index (spin-offs and tools successfully transferred to the industry), international cooperation, gender equality to name a few. The research council and external evaluators (in a mid-way evaluation) evaluate Certus on these factors. We describe some of the factors below.

4.1 Publications

Scientific publications is the primary factor to evaluate the health of Certus. Publication quality is evaluated based on rankings of conferences and journals in software engineering. Conference venues where Certus members normally publish include MODELs, ICSE, ICST, ICSM, ICTSS, SPLC, CAISE, CP, QSIC to name a few. The journal venues include SoSym, IEEE Trans. of Software Engineering, IEEE Software, IST, ACM TOSEM, and so on. A number of publications in Certus are co-authored with industry partners.

4.2 Industrial Exploitation

Objectives

- To further develop research results into best practices guidelines in a form specifically adapted to the needs of the individual SFI user partners.
- To further develop research results into best practices guidelines in a form suitable for broad industrial exploitation.
- To further develop research results in the form of software prototypes into software tools with stability and functionality adapted to the needs of the individual SFI user partners.
- To further develop research results in the form of software prototypes into software tools with stability and functionality suitable for general distribution without any form of warranties.
- To support and maintain the developed best practices guidelines and software tools for the benefit of the consortium throughout the term of the SFI

The Exploitation Policy outlines the scope, format and ambitions of industrialized results (knowledge and technology - best practice guidelines and industry strength tools) to be delivered from the SFI, as well as partners competencies, interests and budgets to contribute to the development and maintenance of industrialized results. It clarifies the consortiums needs to work with third parties, such as consulting companies or software developers, to be able to develop and maintain the industrialized results. The policy specifies metrics for evaluating the potential of knowledge for exploitation and metrics for evaluating the performance and success of exploitation. It details mechanisms for knowledge protection as well as mechanisms for increasing the visibility of exploitation activities and results.

4.3 Postgraduate Education

One of the objectives of the Certus Centre is to educate at least 20 M.Sc. students with in-depth knowledge of industrial V&V challenges. There is also a high demand for this expertise among the user partners. We develop simple guidelines for the recruitment of master students who are willing to write theses

on topics that are of interest for Certus (either general or more specific). Certus involves tasks in its projects to streamline and integrate activities that are currently being undertaken with master students. This includes recruitment, supervision and inclusion into ongoing research-activities in Certus. Another part of this task relates to the summer interns that are recruited by Simula and integrated into Certus. The final part of this task relates to the setting up of scholarships for master students who pursue and complete a thesis in relation to Certus's activities

4.4 Open Industrial Courses

Certus is involved in several dissemination activities. Giving courses to industry professionals is an important form of dissemination to greatly improve communication between researchers and industry professionals. These courses are held one or two times a year over the period of two full days. It is offered to employees of user partners and also opens doors to new professionals. The low frequency of the courses is due to conflicting commitments of full-time employees. The courses are tailored to suit the needs of the industry professionals. For instance, the training program in 2014 will disseminate scientific elements in Software V&V that is relevant to challenges identified after the 2013 collaboration with our user partners. The program is designed for the specific needs of our user partners. However, it is assumed that the program will be of interest to external organisations. The program will be open and advertised to a broader network of contacts. External participants will not be charged except for direct seminar costs if they become substantial. The goal is to deliver 20 user-weeks of training during 2013 (about 750 user hours), where 50 % is internal to the SFI and 50 % is external.

4.5 International Cooperation and Standardization

International cooperation with researchers in software engineering and other domains is also of paramount importance to evaluate the health of the centre. Certus officially collaborates with partners from China, Italy, Luxembourg, Canada, and France and is always looking to extend its reach. Certus also contributes to standardization efforts such as UML MARTE, and UML Testing Profile. Certus also actively participates in European projects such as Opencoss for safety certification. As a results of its collaboration with partners in EU, Certus actively seeks external funding in European call for proposals.

4.6 Gender Equality

Certus's host institution Simula is committed to promoting and increasing the visibility of women in science and engineering and has signed signed the European Code of Best Practices for Women in ICT. In particular, Simula has

developed a gender action plan that states that by December 2015, Simula should have at least 25% female employees in both the scientific and support staff. When recruiting personnel, the centre is required to incorporate gender equality perspectives and actively strive to attract outstanding national and international researchers. In particular, the centre is to facilitate the exchange of staff members between consortium participants and international partners.

5 Related Work

Capitatlization of knowledge is gaining importance in countries to spawn innovation and create jobs. The triple helix of government, industry, and academia have made several efforts to enable effective research-based innovation [Carayannis et al(2000)Carayannis, Alexander, and Ioannidis,Etzkowitz(1998), Leydesdorff and Etzkowitz(1996),Etzkowitz(2008),Etzkowitz(2003)]. Industry-academia collaborations [Beckman et al(1997)Beckman, Coulter, Khajenoori, and Mead] have shown to be governed by several success factors[Wohlin(2012)] and challenges [ME et al(2003)ME, M, and PS]. Creating science-based industries from academic research is a common theme of industrial policy, whether made explicit as in France, China [Cai and Liu(2014)], Gulf states [Akili(2005)] and Mexico [Rivera Vargas(2010)] or implicit such as in the USA [Block and Keller(2009)] [Henry Etzkowitz(1998)] [Etzkowitz(1998)]. When it comes to research in software engineering just before the turn of the 20th century Robert Glass wrote an influential article [Glass(1994)] . He pointed out that software research was too *narrow* and *arrogant* to address practical problems. There were several analytical approaches in controlled setups but a lack of empirical evaluation of large systems. Industry-academia collaborations also involved provision of CASE tools for software engineering education [Werth(1991)] to better prepare a generation of engineers. On the other hand [Potts(1993)], wrote about the emergence of the modern trend in software engeering to adhere to the *industry-as-laboratory model* leading to empirical definition of problems. Similarly, there has been an emphasis on more agile collaborative research between industry and academia [Sandberg et al(2011)Sandberg, Pareto, and Arts]. This burgeoning of ideas is now leading to the culmination of organizational efforts such as Certus. There are several industry-led research labs in software engineering such as Google research [Steiber and Alnge(2013)] Microsft research, Nokia Research, Ercisson research, IBM research to name a few. However, centres such as Certus accomplish a close collaboration within the triple helix of government, industry and academia as idealized in editors Henry Etzkowitz et. al. [Henry Etzkowitz(1998)]. Examples of well-established centres for research-based innovation in software engineering include SnT, Interdisciplinary Centre for Security, Reliability and Trust [6], the Fraunhofer Centre for experimental software engineering, Maryland to name a few.

[6] `http://www.securityandtrust.lu`

6 Conclusion

In this paper, we present a detailed overview of the Certus center for research-based innovation. Certus is a center for software verification and validation research that is driven by challenges in the local Norwegian software industry. The architecture of Certus is based on an annual work plan that consists of projects, tasks and deliverables. It is an agreement between Certus and its user partners for the tasks to be achieved over an year. The health of Certus is evaluated based on several criteria including publications, international co-operation, standardization efforts, innovation index, and gender equality. We believe that the paper presents some elements of the Certus organizational model that can help play a role in motivating funding schemes and university research groups in countries with a flourishing software industry.

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