

October 6, 2005

**Evaluation of the Competence Centre for  
Circuit Design, CCCD  
at  
Lund University, Lund**

**1. Preface, Methodology, and Acknowledgement**

On Wednesday, October 5, 2005 the Centre Director, Jiren Yuan, the Chairman of the Board, Peter Olanders, project leaders, industrial representatives and graduate students of the Competence Centre for Circuit Design, CCCD, briefed the scientific experts of the evaluation team, Erik Bruun and Marc Engels, on the scientific progress and range of projects within the Centre. In the morning of October 6 the entire review committee received information on the research and general issues concerning CCCD by the Director, the Chairman, the Dean of Lund Institute of Technology, LTH, Gunilla Jönson, the head of the Department of Electrosience, Clas Agnvall, project leaders and industrial partners. In addition to these hearings, this evaluation is based on the written report to the international evaluation team, including reprints and manuscripts.

All presentations were very clear and excellently presented. The presenters answered fluently to the questions. The industrial representatives participated actively in the discussion. We were very pleased by the openness and frankness shown in discussing technical as well as strategy issues with us.

We would like to thank the whole CCCD team for the efforts they made in preparing these two days of briefings. We also thank Anders Hedin and Staffan Hjorth of VINNOVA for the invitation and their assistance in all aspects of the review.

**2. Technical and Scientific Outcomes**

The major achievements can be divided according to the three research groups involved in CCCD. For the analog RF group the reduction of the supply voltage down to 0.7 V and the use of RF CMOS up to 10 GHz (aiming at 60 GHz later on) are remarkable achievements. The mixed signal group has been a pioneer with regard to charge sampling as well as to novel ADC and DAC structures (floating point ADC, interpolating DAC and Configurable pipelined ADC). The digital ASIC group has focused on a systematic design approach from algorithm through architecture down to circuits. Various projects (pace maker, image processing, MIMO processing, and flexible coding) can be considered as test cases for this approach. In addition they presented some new architectural ideas, such as the multi-mode operation, and started to work on low leakage techniques.

For all of these topics the research groups actually build practical implementations. This is considered a major advantage over more theoretically oriented research groups.

The results during this period proved that the research groups of CCCD are able to produce a consistent flow of high quality technical achievements.

During stage 3, CCCD published 16 journal papers and 68 international conference papers. The quality of the journals is high. CCCD was also represented at most of the important conferences in the field. However, especially for the digital group, it should be a point of attention to increase the ratio of journal papers to conference publications. Moreover, CCCD could improve in comparing its work to the worldwide state-of-the-art, by preference in a quantitative way. It would also be an improvement if the centre would monitor its citation index. The active patenting policy, resulting in 8 patents up till now, is considered a positive sign of industrial interest in the results.

We particularly appreciated the distribution of research tools (e.g. Indentro) via the web, in view of the public relations of the Centre and as an interesting approach to foster cooperation.

Based on its scientific and technical productivity, CCCD can be considered as a top group in Sweden with a good European reputation. The involvement in several European projects and networks is a proof of this status.

Little evidence was found that CCCD paid attention towards institutionalizing its know-how. For instance, analog and digital design methodologies could be described more explicitly. This could also be a valuable teaching asset.

Following the recommendations of the international review three years ago, the Centre made an effort to focus the activities. Later on, some projects and work packages were added, which were unrelated single PhD student project. This has resulted in a similar situation as before with respect to the research focus of the Centre. A better approach would be to group PhD projects together around common themes, an example of which is the work on image processing. In effect, this work should be considered as a separate project. It is recommended that the Centre put forward a clear strategy and selection criteria for projects (for instance, it was not clear why specifically some blocks were studied in the flexible radio and others not). Focus should be a major concern. It is also suggested to change the way of working of the scientific advisory board and to ask them more specific strategic questions (such as project selection criteria).

The Centre could not show a consistent follow up of key performance indicators. The reviewers found here an opportunity for the development of improved management tools.

CCCD could grow towards more cross-disciplinary research, where topics on the edge of two groups are tackled (not to be confused with making large integrated demonstrators). Several presenters showed a lack of system-level insight (especially in analog and mixed-signal). The researchers should also have a system view into which their specific research topic fits. In this way the Centre could become more than the sum of three groups.

It is considered very positive that cooperation was starting with the groups on antennas and mathematical imaging. The intensity of cooperation should be further increased.

### Conclusions and recommendations

In conclusion, CCCD has consolidated its reputation and standing during the third stage. Both research results and teaching results show good progress. There has been a shift from analog and RF as the main focus towards more system-oriented design with a stronger emphasis on SoC and digital systems and this shift is considered to be in line with the interest of the industrial partners in the centre.

We would like to offer the following recommendations:

- Give more attention to the management of the Centre, using tools such as key performance indicators to set the targets for the future development of activities. This could further improve the effectiveness of the CCCD activities.
- Increase the ratio of journal papers to conference publications.
- Put forward a clear strategy and selection criteria for projects.
- Emphasise more cross-disciplinary research, where topics on the edge of two groups are tackled.

### **3. Industrial Benefits. Impact on Industrial Partners.**

#### Industrial Interaction and Involvement in Centre Activities

CCCD has developed an organizational infrastructure and environment inducing close and productive collaboration between academic researchers and industry personnel, as evidenced by the enthusiastic and very supportive evidence and testimony given by several of its industry partner representatives during the site visit and review. CCCD has also succeeded in fostering a broader cross-disciplinary research in circuit design and, more recently, beyond circuit design by including additional areas such as algorithms and mathematics in its competence profile. This cross-disciplinary knowledge base is very attractive to its industry partners because they can find in one place the collective knowledge and technologies they need. CCCD has also been a catalyst for some collaboration between its industry partners.

Eight industry partners are currently actively engaged in the CCCD programme. They represent an appropriate mix of large, medium, small and start-up companies with diverse interests in circuit design technologies, including hardware and device manufacturers, CAD tool providers, telecommunication service providers, users of system-on-the-chip designs, users of fast processing chips and leaders in Internet surveillance technology. There are international company partners and a promising spin-off company based on technology invented, developed and prototyped at CCCD.

The financial support from the industry partners is quite strong and they also support CCCD through collaboration of industry scientists and engineers in projects, industry funded PhD student, participation in planning, strategy formulation, meetings and

workshops, and through dissemination of new knowledge. All industry partners were very supportive of the Competence Centre model as a cost efficient way of conducting industrially relevant high quality multi-disciplinary research.

The CCCD Board and leadership are to be commended for responding to a recommendation of the Stage 2 review team by systematically implementing policies and operational principles that encourage active partner participation in CCCD projects. In response to a recommendation by the Stage 2 review team, early on during Stage 3, the Board decided to increase the visibility of the system level aspects of research, held a strategy meeting dedicated to this decision and introduced the new project “Flexible terminal for Wireless Systems” into the research program. Furthermore the 2003 CCCD annual workshop had as theme “System Level Implications of Circuit Design”.

Responding to a recommendation of the Stage 2 review three years ago, the Board established annual strategy meetings and introduced “mini-workshops” at partner companies in order to improve the dissemination of results. Many successful such mini-workshops have been held, and they were highly appreciated by the industry partners. Following another recommendation of the Stage 2 review, the Board and the CCCD leadership successfully broadened the research programme into focus areas outside telecommunications.

The review showed that substantial progress has been achieved in sharing the strategic plan and vision of CCCD between its industry partners. Strategy sessions of the Board and good cooperation between the Board and the CCCD Director have played a key role in this progress. The Board is well integrated and appears to be functioning well, as evidenced by the fact that CCCD has continued to fulfil fundamental industry needs, despite the substantial changes in these needs that have taken place over the period since CCCD creation.

There has been good personnel mobility between industry and academia in CCCD. Personnel from companies (four adjunct professors and eight researchers) have worked full or part time at CCCD, and CCCD researchers have worked at industry sites (one faculty member partially employed by a CCCD partner company). Industry partners have hired several PhD graduates from CCCD (5 of 8 graduating PhD students in Stage 3 went to industry, 3 of them to CCCD partner companies).

At the review, all industry partners expressed their satisfaction with their participation in the CCCD programme, with their benefits often exceeding their expectations. Benefits of CCCD cited were: integrated knowledge on circuit design and system level developments, competitiveness, function as an “external R&D Lab”, encounters and new partnerships, frequent and informal access to facilities and technology experts, access to regular and short courses and other training programmes, availability of well educated students as potential employees.

#### Implementation of Results: Technology Transfer, Commercialization, Success Stories

Extensive evidence was presented during the review of the value to industry partners of CCCD research results, which have met fundamental product needs of its industry

partners and provided competitive advantages, conception of new products and new business opportunities. Transfer of knowledge between industry and university occurs frequently and is critically dependent on the CCCD environment. Some examples of successful technology transfer that were presented to us are:

- Ericsson AB has developed for use in products CCCD designs of linear front-ends, linear power amplifiers and chip inductors, and uses for developments in terminals and infrastructure the CCCD designs of FFT algorithms and ADC.
- Axis Communications has benefited from the use of different algorithms from CCCD research in future intelligent cameras. Technology transfer has occurred in identifying circuit designs for speed and low power for the same market area.
- A spin-off company (Phi AB) has been launched based on the unique and patented CCCD digital holography technology.

The Centre provides continuing education, both in the form of specific courses and in the form of mini-workshops. The mini-workshops, with a large number of industrial participants, are considered a very good step forward. Also the distribution of research results by means of a CD and the successful international master on System-on-Chip are highly appreciated.

The successful collaboration between industry and university partners has also created many new funding opportunities, as evidenced by the participation (of both industry and academic partners) in several new EU projects.

### Conclusions and Recommendations

CCCD is clearly a well-recognized centre of excellence in circuit design and has taken important steps to achieve the same prominence in system level design and integration of wireless devices and networks in the future. CCCD has established a successful industry-university collaborative research environment and technology transfer in a technical area critical to Swedish industry and Swedish society. The CCCD programme has led to a variety of benefits to industry including new product development and enhancement of existing products.

We would like to offer the following recommendations:

- Further strengthening of the system aspects of the research programme of the CCCD would be highly beneficial.
- Broadening the applications to new and emerging markets such as health care monitoring and delivery, security and monitoring, should bring in new industry partners and strengthen the overall CCCD programme.
- It would be of importance to give attention to security aspects of wireless devices and networks, especially as it is related to the physical layer, where CCCD has unique and strong expertise.

#### **4. Present Standing of the Centre**

##### International Ranking and Attractiveness

CCCD has built up a solid international network and, together with the Department of Electrosience, has created a well-recognized centre of research excellence in circuit design. This is evidenced by technical advances, a solid publication record in distinguished journals and conferences, collaboration in European research networks, frequent visits by leading international companies and invitations of Centre research scientists to lecture at companies and universities world-wide.

The International Advisory Board of the Centre has met annually in connection with centre workshops to give views on centre research. In all, the international status of the Centre appears to be satisfactory.

##### The Centre as a National Asset

In the opinion of all the industrial representatives, CCCD has become a research group in wireless communication that is not available elsewhere in Sweden, with the capacity to deliver significant research results as well as research scientists and engineers with a competence that is in demand in the important Swedish telecommunications industry. Although internationally oriented, the industry finds it very valuable to have access to this competence specifically in Sweden.

The Centre is experienced as a platform for open and rewarding discussions on new developments in wireless communication research. Thus, the Centre is not only an asset for education in wireless communication and industry/university relationships but also instrumental in promoting contacts and networking on an informal level between participating industries.

##### Role and Impact of the Centre as a Part of the University

The Dean emphasized that IT is an area of priority of LTH, which has endeavoured to create more open and cross-disciplinary contacts within this area with all of Lund University. In particular, contacts between the Department of Electrosience and the Faculty of Medicine is an important development, that is also reflected in the future research plans for the groups of researchers within CCCD.

CCCD has contributed very strongly to education within the Department of Electrosience, on the undergraduate as well as the graduate level. Specifically, staff members from the Centre teach about six courses in circuit design and supervise projects in IC design. During recent years, the number of students has decreased (a general trend within the IT area). The Department of Electrosience has responded by undertaking a major revision of the undergraduate programme in electrosience, in which CCCD participated very actively. Thus, education in IC design has been changed from courses in either analog or digital design into a common project course, making it possible to emphasize a system-on-chip approach and mixed analog-digital designs.

The education is closely linked to the research in the Centre and the selection of courses seems to cover most of the relevant aspects for ASIC and SoC design. It seems that about half of the undergraduate programme is now directly influenced by CCCD activity and results, which is very satisfactory.

Contacts between CCCD and other researchers in the Department of Electrosience have been extensive, but cross-disciplinary contacts with other departments within LTH or LU apparently have been rather limited. In particular, the ambition of CCCD to broaden research on applications in health care and medicine would probably benefit from broader contacts with appropriate departments in the Faculty of Medicine.

### Conclusions and Recommendations

CCCD has developed into an internationally recognized research group and a national asset within the area of wireless communications research. The impact of CCCD on education in the Department of Electrosience has been substantial, but interdisciplinary contacts appear to be more limited. We submit the following recommendation

- CCCD should endeavour to broaden interdisciplinary contacts, for example with respect to research with applications in health and medicine.

## **5. Future Prospects and Strategies**

### Technological-Scientific Prospects of Research Area. Focus of Future Research.

CCCD was originally created due to the strong demand by Swedish industries for increasing university-based research on application-specific integrated circuits (ASIC) and designers of such circuits. While the requirements on the Centre set by these demands have been well fulfilled, it is clear that the rapid development of wireless communication technologies implies that new areas of research need to be opened. The Centre has addressed this issue systematically and it is now evident that the research platform in wireless communication created by the Centre concerns areas in which the technological and scientific prospects of continued research are bright and of great importance to Swedish industry and society. The focus of future research has been discussed extensively with the Centre and the Department of Electrosience and a strategy for the future is emerging.

### Interests and Priorities of Centre Partners

Industry partners in the Centre have concluded that the technical area of wireless systems and its application to new markets such as monitoring and health care is critical for the competence of Swedish industry. Industry partners have expressed their strong commitment to development of research and education in this area.

Both the Department of Electrosience and the industries that support CCCD find it important to sustain the research and educational activities that have been created by the Centre. It was clear from the statements by the industry representatives that the demand

for ASIC designers is now much less than at the time when CCCD was initiated. However, at the same time there are many new technology areas of wireless communications in which demands on research and personnel for industry are rising rapidly. As mentioned above, IT is one of the priority areas of LTH, with emphasis on the need for more cross-disciplinary research involving departments at Lund University outside LTH.

Thus, we found that research and education in wireless communication continues to be an area of priority for both the industries that have supported CCCD and Lund University.

#### Strategies for Stage 4 and beyond

The strategy for stage 4 of research at CCCD implies that initiation of new projects will be limited. The Centre will endeavour to finish the ongoing PhD research and mainly hire post-doctoral students to run projects.

A strategy for continuation of the research beyond stage 4 has also been developed. Indeed, the fact that VINNOVA and the Swedish Foundation for Strategic Research, SSF, have recently opened new programmes aiming at the creation of new competence centres has forced CCCD to already plan in detail for new developments. The strategy is based partially on continuing short-term smaller projects with industrial support, but above all it is based on two major applications for new research centres:

- Next Generation High-Speed Wireless Communication (fundamentally oriented research, in collaboration with other departments at Lund University and Chalmers; application to SSF)
- Wireless Intelligent System Technologies (research directed towards applications; application to the VINN Excellence Center Programme of VINNOVA)

The strategies for stage 4 and the continuation after stage 4 both seem to define commendable ways of proceeding, in view both of the present economically somewhat uncertain future of the Centre and in view of the long-term interests of Lund University, the Department of Electrosience and the industries that now support CCCD.

#### Conclusions and Recommendations

CCCD research is of strategic importance for the participating industries and the technical and scientific prospects within its area are good. The Centre has formulated a clear strategy for sustained development beyond the 10-year period of funding from VINNOVA.

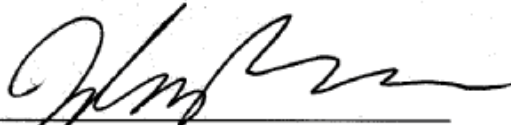
## 6. General Conclusions and Recommendations

CCCD is a well-recognized centre of excellence in circuit design and has taken important steps to achieve the same prominence in system level design and integration of wireless devices and networks in the future. The Centre has established a successful industry-university collaborative research environment and technology transfer in a technical area critical to Swedish industry and Swedish society. The CCCD programme has led to a variety of benefits to industry including new product development, enhancement of existing products and transfer of competencies. The Centre has also had a strong impact on the teaching curriculum at the Department of Electrosience at LTH.

We wish to make the following recommendations

- More attention should be given to the management of the Centre, using tools such as key performance indicators to set the targets for the future development of activities.
- Further strengthening of the system aspects of the research programme of CCCD would be highly beneficial.
- CCCD should endeavour to broaden interdisciplinary contacts, for example with respect to research on applications in health and medicine.

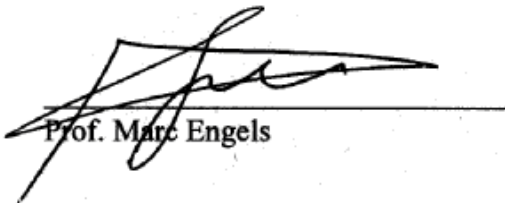
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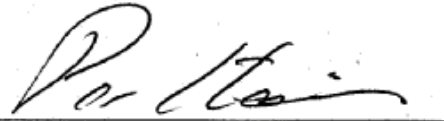
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